1982

Distribution Habitat Use and Movements of Elk in Relation to Roads and Human Disturbances in Western Montana

W. Daniel Edge
The University of Montana

DISTRIBUTION, HABITAT USE AND MOVEMENTS OF ELK IN RELATION TO ROADS AND HUMAN DISTURBANCES IN WESTERN MONTANA

BY

W. Daniel Edge

B. S., University of Montana, 1979

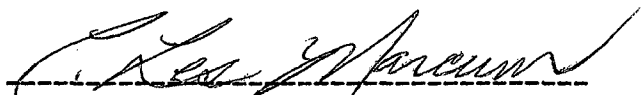
Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1982

Approved by:



Chairman, Board of Examiners

Dean, Graduate School

Date

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

7-1-82

ABSTRACT

Edge, W. D. , M. S. 1982 Wildlife Biology

Distribution, Habitat Use and Movements of Elk in Relation to Roads and Human Disturbances in Western Montana (98 pp.)

Director: C. Les Marcum

Elk movements and habitat use in relation to roads and human disturbances were studied in the Chamberlain Creek area between May and December during 1980 and 1981. Twenty-seven cow elk, equipped with radio transmitters, were located from airplanes a total of 846 times. An additional 61 locations were made by ground tracking 9 elk between 12 August and 30 September, 1981. Elk response to open roads varied with season, traffic volume , and vegetative and topographic cover. Elk were displaced from heavily traveled roads to a greater extent than lightly traveled roads, from calving through rutting season. Topographic barriers between the elk and the nearest open road or disturbance aided in reducing the amount of displacement. Elk use was depressed within 750 m of roads and 1,000 to 1,500 m of human activities. Use of preferred habitats was greatly reduced within 500 m of human activity. The proximity of roads to water was not a factor in elk avoidance of areas near water. Elk movements were modified by logging activity; movements were greater when elk moved away from logging than when moving towards it. Elk were significantly closer to logging units on weekends than on weekdays. Elk maintained a buffer zone of at least 500 m from logging activity. This buffer zone effectively reduced the availability of habitats to elk. Elk response to roads and human activity during the hunting season was of 2 types: general displacement within 2,000 m and an associated use of topographic barriers, and use of safety zones closed to hunting in close proximity to human habitation. Roads designed to avoid natural openings and to take advantage of topographic barriers will benefit elk habitat effectiveness. Human activity will greatly impact habitat use by elk in areas with little topographic relief, large drainages without secondary ridge systems and in areas without a high percentage of tree cover.

ACKNOWLEDGMENTS

I owe thanks to many people for making this project and my tenure in the wildlife program a most enjoyable experience. Committee members, Drs. C. L. Marcum, W. L. Pengelly and B. W. O'Gara were helpful in providing guidance and inspiration. Special thanks go to Les Marcum, my major advisor and project director, for continual encouragement, support, concern, problem discussion, as well as financial wizardry.

Three sources have provided financial support throughout my study. I am most grateful for this continual funding from the Bureau of Land Management, the McIntire-Stennis Federal Forestry Program administered by the Montana Forest and Conservation Experiment Station, and the Timber and Lands Department of the Burlington Northern Company.

Field and laboratory assistance was provided by numerous people. Bob Baxter was a most competent and amiable field assistant. Jina Mariani was a reliable lab assistant, contributing a great deal to data and manuscript preparation. Tom Morrare was especially helpful and knowledgeable in use of the DEC-system computer. Three pilots from Hamilton Aviation, Bill Tubbs, Fred Hasskamps, and Dave Rosenkranz, flew me on the numerous, safe and successful flights. I wish to thank my fellow graduate students who provided assistance in trapping and acted as a forum for many interesting discussions. Bud Clinch and Steve Diehl gave hours of their time in checking traps and also provided dinner on occasion. Chris Orr invested a great deal of time in all the typing required by a project of this scale. Special thanks are due Sally Olson

for a secluded place to write, and editing the original manuscript.

Finally I wish to acknowledge two groups of people who deserve all the thanks I can give. My parents have given me more support, encouragement and blessings than one child deserves. Last, but not least, my friends, who provided me with hours of fun and distraction, without which I would not have been able to persevere.

TABLE OF CONTENTS

Page

ABSTRACT ii

ACKNOWLEDGMENTS iii

LIST OF TABLES vi

LIST OF FIGURES vii

CHAPTER

I. INTRODUCTION 1

II. ELK DISTRIBUTION AND HABITAT USE IN RELATION TO ROADS . . 4
Study Area 5
Methods 8
Results 9
Discussion 26

III. DISTRIBUTION OF ELK AND USE OF COVER IN RELATION TO HUMAN DISTURBANCES IN WESTERN MONTANA 37
Study Area 38
Methods 41
Results 42
Discussion 51

IV. MOVEMENTS AND DISTRIBUTION OF ELK IN RELATION TO TO LOGGING DISTURBANCES 58
Study Area 59
Methods 62
Results 63
Discussion 66

V. SUMMARY AND CONCLUSIONS 71

REFERENCES CITED 74

APPENDICES

A. PERCENTAGES OF AVAILABILITY AND ELK USE FOR EACH VARIABLE CROSS-CLASSIFIED WITH DISTANCE TO OPEN ROADS . . 81

B. PERCENTAGES OF AVAILABILITY AND ELK USE FOR EACH VARIABLE CROSS-CLASSIFIED WITH DISTANCE TO HUMAN DISTURBANCE 92

LIST OF TABLES

Table | Page

1. Percentages of availability and elk use by distance to open roads during 1980 and 1981 11

2. Percentages of availability and elk use by distance to human disturbances during 1980 and 1981 43

3. P-values associated with test of hypotheses on distance to logging units, and movements for individual elk, summer 1981 65

4. Total and net movements of 9 cow elk between successive locations, by direction of movement and day of week, summer 1981 67

LIST OF FIGURES

Figure		Page
1.	The Chamberlain Creek Study Area	6
2.	Deviation from percent availability, and percent elk use by distance to open roads and traffic volume during the calving season of 1980 and 1981	12
3.	Deviation from percent availability, and percent elk use by distance to open roads and traffic volume during the summer season of 1980 and 1981	13
4.	Deviation from percent availability, and percent elk use by distance to open roads and traffic volume during the rutting season of 1980 and 1981	14
5.	Deviation from percent availability, and percent elk use by distance to open roads and traffic volume during the hunting season of 1980 and 1981	15
6.	Deviation from percent availability, and percent elk use by distance to open roads and topographic barriers during the calving season of 1980 and 1981	17
7.	Deviation from percent availability, and percent elk use by distance to open roads and topographic barriers during the summer season of 1980 and 1981	18
8.	Deviation from percent availability, and percent elk use by distance to open roads and topographic barriers during the rutting season of 1980 and 1981	19
9.	Deviation from percent availability, and percent elk use by distance to open roads and topographic barriers during the hunting season of 1980 and 1981	20

Figure Page

10. Deviation from percent availability, and percent elk use by distance to open roads and overstory canopy coverage during the summer season of 1980 and 1981 22

11. Deviation from percent availability, and percent elk use by distance to open roads and overstory canopy coverage during the rutting season of 1980 and 1981 23

12. Deviation from percent availability, and percent elk use by distance to open roads and successional stage during the summer season of 1980 and 1981 24

13. Deviation from percent availability, and percent elk use by distance to open roads and successional stage during the rutting season of 1980 and 1981 25

14. Deviation from percent availability, and percent elk use by distance to open roads and distance to water during the summer season of 1980 and 1981 27

15. Deviation from percent availability, and percent elk use by distance to open roads and distance to water during the rutting season of 1980 and 1981 28

16. The Chamberlain Creek Study Area 39

17. Deviation from percent availability, and percent elk use by distance to human disturbance and topographic barriers during the calving season of 1980 and 1981 44

18. Deviation from percent availability, and percent elk use by distance to human disturbance and topographic barriers during the summer season of 1980 and 1981 45

19. Deviation from percent availability, and percent elk use by distance to human disturbance and topographic barriers during the rutting season of 1980 and 1981 46

Figure Page

20. Deviation from percent availability, and percent elk use by distance to human disturbance and topographic barriers during the hunting season of 1980 and 1981 47

21. Deviation from percent availability, and percent elk use by distance to human disturbance and overstory canopy coverage during the summer season of 1980 and 1981 49

22. Deviation from percent availability, and percent elk use by distance to human disturbance and overstory canopy coverage during the rutting season of 1980 and 1981 50

23. Deviation from percent availability, and percent elk use by distance to human disturbance and successional stage during the summer season of 1980 and 1981 52

24. Deviation from percent availability, and percent elk use by distance to human disturbance and successional stage during the rutting season of 1980 and 1981 53

25. The Chamberlain Creek Study Area 60

26. Movements of cow elk number 1020 relative to logging disturbances, summer 1981 64

CHAPTER I

INTRODUCTION

The Rocky Mountain elk (Cervus elaphus nelsoni) is one of North America's most prized big game animals. From the standpoint of hunter interest, it is Montana's most important game animal (Rognrud and Janson 1971). It holds a similar position of interest in essentially every western state containing a population that sustains hunting (Boyd 1978). This strong interest, coupled with an increasing human population, has placed a high demand on a limited resource. This demand may exceed supply in Montana by 1985 (Mont. Dept. Fish and Game 1978).

Historically, the elk was widespread in the western states during the period of settlement. However, populations reached a low point by the late-1800's, primarily because of excessive hunting. At the turn of the century, many western states severely limited or curtailed hunting. This protection and a series of transplants, principally from Yellowstone National Park, restored most of the decimated populations (Murie 1951). This protection and transplants, as well as large scale environmental changes during the first third of the century, caused by fire, logging, and agricultural development, are cited as the key factors determining present elk populations (Taber 1966, Pedersen et al. 1980).

Demands of increasing human populations on land used by elk, has led to several land-use problems. Cooney (1952) felt that elk depredations on cropland was one of the most serious land-use problems in Montana. However, this problem has been localized, and therefore, is not one of the more pressing problems from the standpoint of elk management. Livestock competition for forage and social incompatibility between elk and livestock have been more serious concerns of game managers (Craighead 1952, Morris 1956, Taber 1966, Mackie 1970). This problem still needs extensive investigation. The major problem facing game managers today is the loss of quantity and quality of habitat (Mont. Dept. Fish and Game 1978). Subdivision of land in elk habitat, especially winter range, is an increasing problem (Picton 1980) that may only be solved by purchase of land or through conservation easements.

Because a common component of elk habitat is forest, a major concern of game managers has been the impact of timber management activities on elk. Prior to 1960, logging was generally assumed to enhance elk habitat by providing more forage. However, by the mid-60's, game biologists were beginning to suspect that logging activities decreased the quality and quantity of elk habitat. Disturbance during active logging, loss of cover, an increase in the number of roads and road use, and an associated increase in hunter access have all been cited as possible problems with timber management activities in elk habitat (Lyon 1971). Early studies were limited in scope, and often not designed to test specific hypotheses (Lyon 1971, Beaufait 1976). Also, wildlife response to logging might vary from area to area (Pengelly

1972, Wallmo and Schoen 1981). These concerns, and the inherent value of the animal prompted most elk-producing states to initiate elk-logging studies. The Montana Cooperative Elk-Logging Study was initiated in 1970 as a cooperative agreement between the University of Montana School of Forestry, the Montana Fish and Game Department, and the Intermountain Forest and Range Experiment Station and Region One of the U. S. Forest Service. The Bureau of Land Management became a cooperator in 1971.

Since 1975, personnel from the University of Montana have been under contract to the Bureau of Land Management to conduct the Chamberlain Creek elk-logging project. This study is part of that project, which in turn is part of the Montana Cooperative Elk-Logging Study. From 1976 through 1977, Scott (1978) surveyed pellet groups along belt transects within the main Chamberlain Creek drainage, to describe elk habitat selection and use on this undisturbed summer range. Between 1977 and 1980, Lehmkuhl (1981) used radio telemetry, and increased the scope of the project to include areas around Chamberlain Creek. Originally, his objectives were to document elk habitat selection and use during the disturbance phase of the study, but because of delays in road construction and the timber sale within Chamberlain Creek, his work was primarily a pre-disturbance study. Since spring 1980 I have continued the telemetry study. The major objective of which was to document short term changes in elk distributions and habitat use during active logging of this previously undisturbed summer range.

CHAPTER II

ELK DISTRIBUTION AND HABITAT USE IN RELATION TO ROADS

Roads associated with timber management activities have increased in recent years on both private and public lands, especially in previously remote areas. An increasing demand for recreational activities has also led to higher traffic volumes on new and existing roads. Roads within elk (Cervus elaphus) habitat cause both a direct effect through loss of habitat, and an indirect effect by displacing elk from adjacent areas (Pedersen 1979). There is a need for additional information concerning the effect of roads upon elk distribution and habitat use (Rost and Bailey 1979, Pedersen et al. 1980). Temporal or spatial controls (Green 1979) were missing from many of the earlier studies, as well as controls on other factors such as livestock and human access.

Thiessen (1976) reported an increase in elk densities following road closures. Ward et al. (1980) found that elk use was significantly depressed within 400 m of open roads. Traffic volume and speed appear to influence elk. Ward et al. (1973) reported that elk were unconcerned by rapidly moving vehicles, but sought cover when vehicles stopped and people got out. Main roads had more effect than primitive roads on elk use of adjacent habitat (Perry and Overly 1976). Burbridge and Neff (1976) reported that vehicles moving rapidly along good roads were less disturbing than vehicles "clanking " along slowly on primitive roads.

Hershey and Leege (1976) and Lyon and Jensen (1980) found that presence of roads had a major effect on elk use of clearcuts. Morgantini and Hudson (1979) reported that elk preferred to bed down in forested areas farthest from roads during winter. Lyon (1979a) reported an inverse relationship between the distance at which elk were displaced and percent overstory canopy coverage.

The objective of this study was to assess the effect of open roads upon the distribution and habitat use of elk. This study was conducted in conjunction with the Chamberlain Creek elk-logging project, which was designed to describe elk distribution and use of several available environmental factors before, during and after logging in Chamberlain Creek.

Study Area

The Chamberlain Creek study area lies in the northern Garnet Mountains, 56 km east of Missoula, Montana (Fig. 1). Radio-collared elk used approximately 23,300 ha. The core study area (CSA), a previously undisturbed area in which the Chamberlain Creek elk-logging project is focused, is 2,350 ha. Mean monthly temperatures range from -8.4° C in January to 16.8°C in July (Steele 1981). The mean annual precipitation is 44.7 cm, most of which falls December through May.

Forests cover 85% of the study area. Habitat Types (Pfister et at. 1977) are within the Douglas-fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*) series. High elevation cover types are predominantly lodgepole pine (*Pinus contorta*), with a few stands of

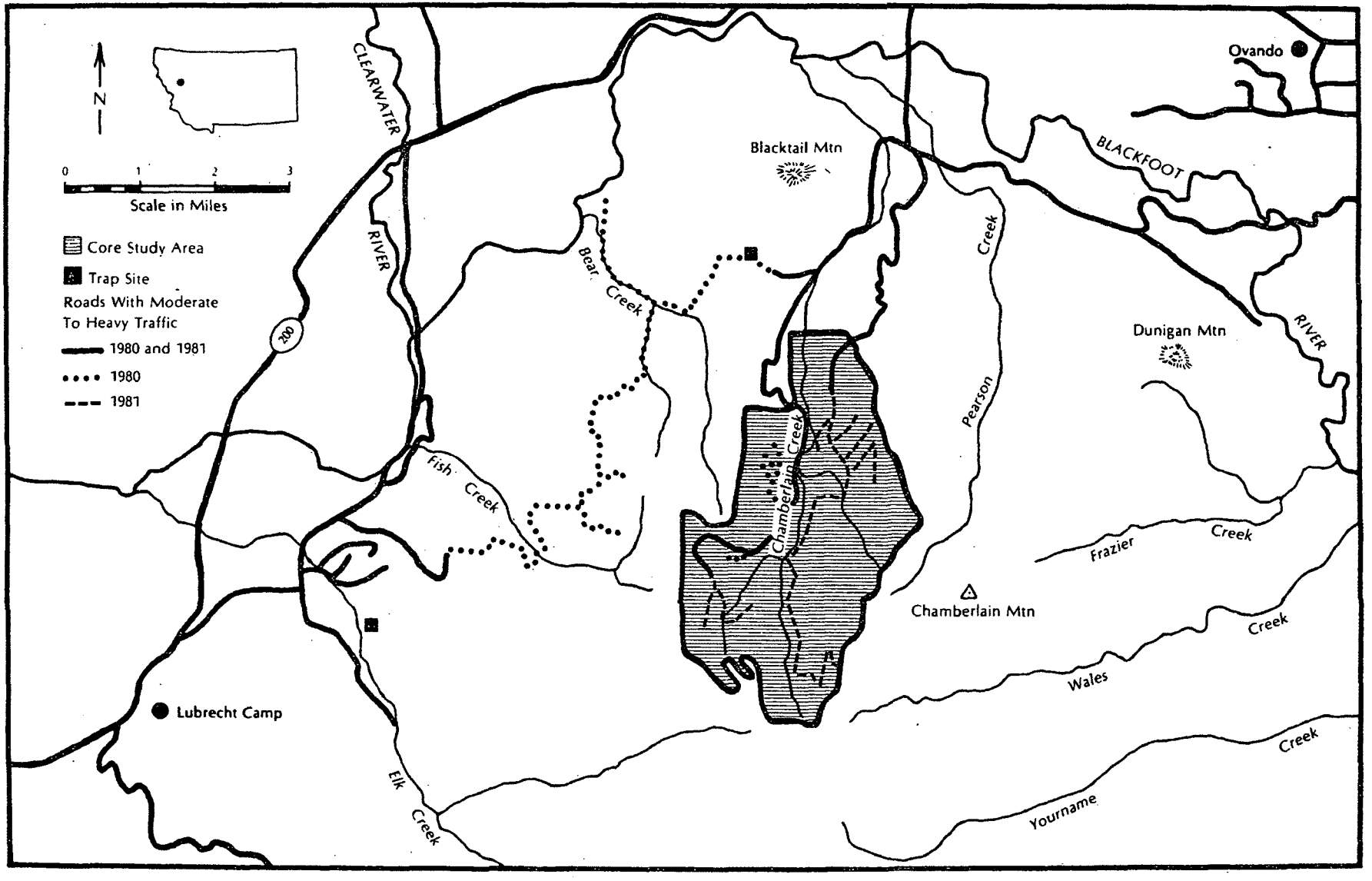


Fig. 1. The Chamberlain Creek Study Area.

Engelmann spruce (Picea engelmanii) and subalpine fir. Mid-elevations are forested with Douglas-fir, or Douglas-fir and western larch (Larix occidentalis) stands. Douglas-fir is the primary cover type on lower elevations, with ponderosa pine (Pinus ponderosa) as a codominant on drier sites. Pastures and hayfields, natural meadows, clearcuts, brushy riparian, water, roads, and scree account for the remainder of the study area habitat components.

Elevations range from 1,160 to 2,090 m. Topography is a series of moderately steep primary and secondary ridges between 9 second and third order stream systems. The Blackfoot River borders the study area to the north and west. Scott (1978) and Lehmkuhl (1981) described the study area in detail.

Timber harvest is the principal land use. The study area has been extensively logged within the last 50 years, with the exception of the CSA, and the upper portions of Pearson, Frazier and Wales Creeks. Partial cuts are the primary silvicultural method. Except for the CSA, much of the area is grazed by cattle or horses from June to October. The main recreational activity is big game hunting in the fall. The study area lies within the Blackfoot Special Management Area, which is closed to vehicle traffic from 1 September to 1 December.

State highway 200, which runs along the north and west edge of the study area, and a county road on the west receive heavy traffic year-round. An extensive logging road network covers the Fish, Little Fish, Bear, West, East and main Chamberlain drainages. During 1980, logging activity and associated road use was widespread. Because of

logging units in Fish and Bear creeks, and on Blacktail Mountain, virtually all roads west, north, and east of the CSA were open from early May to 1 September. From 1 September until the beginning of hunting season, access of these areas was limited to logging traffic, and was confined to the main haul roads. Traffic within the CSA was limited to road construction crews from August through December, with road construction within the CSA continuing through the hunting season. During 1981, logging activities and road use were concentrated in the main and East Chamberlain drainages. From May through June, 2 roads on the southwest side of Blacktail Mountain were used for access to a timber salvage operation. The main haul road within the CSA was extensively used from September through October. Roads in the lower portions of East Chamberlain Creek were extensively used from September through November in conjunction with 2 logging units.

Methods

Elk were trapped in corral traps baited with alfalfa from December through April and salt from March to September. Age was estimated based upon incisor replacement (Quimby and Gaab 1957) and wear. A 150-151 MHz radio inserted in a PVC pipe collar (Pedersen 1977) was placed on each animal. Elk were located using a Piper Super Cub or a Cessna 182 from mid-May to December. Locations were marked on aerial photographs and later transferred to topographic maps. Distances to open roads and water were measured, and topographic barriers were determined using these maps. Overstory canopy coverage and successional stages were

evaluated from the aerial photos. Availability of each variable was estimated from a series of random points (Marcum and Loftsgaarden 1980).

A DECSYSTEM-20 computer and a package of statistical programs (SPSS; Nie et al. 1975) were used to analyze the data. Differences between use and availability of each level of a habitat variable were simultaneously examined using the Bonferroni approach (Miller 1966:67).

Results

During 1980, 29 flights resulted in 438 locations of 19 cow elk. During 1981, 408 locations were obtained of 15 cow elk during 38 flights. Flights were made between 15 May and the end of hunting season each year. Field seasons were divided into 4 periods: calving, 15 May to 15 June; summer, 16 June to 31 August; rut, 1 September to the beginning of the hunting season; and the hunting season. The 1980 hunting season opened on 20 October and closed on 30 November. The 1981 hunting season ran from 25 October through 29 November.

During 1980, open and closed roads comprised 2% of the land area sampled by random points. Elk used roads in excess of their availability during that summer, but use was less than availability during the other seasons. During 1981, all roads accounted for 3% of the land area. Use was greater than availability during the summer and rutting seasons. Elk use of roads was significantly less than availability ($P<0.05$) during the 1981 hunting season.

Areas within 250 m of open roads were used significantly in excess of their availability during the 1980 calving season (Table 1), and used above availability during the 1981 calving season. During the summer of both years and the 1980 rutting season, use approximated availability within 250 m of open roads. Elk use was significantly depressed in areas within 250 m during the rutting and hunting seasons of 1981. Over 50% of elk use occurred in areas greater than 1,000 m from open roads during the rutting and hunting seasons each year, with that distance being significantly above availability during the 1980 rut.

Roads within the study area were classified into 2 groups based upon traffic volume. The large majority of open roads were classified as receiving light traffic. These were light-duty dirt roads, 4-wheel tracks, or logging roads not being used for hauling. Roads with moderate to heavy traffic were those roads used for access to logging units or ranches, or roads on which logs were hauled. Roads with moderate to heavy traffic were used less than availability in 29 out of 40 seasonal distance categories (Figs. 2 through 5); 14 of these were significant deviations. Conversely, 30 out of 40 seasonal distance categories with light traffic roads were used greater than availability, but only 6 of these were significant. Areas within 500 m of moderate to heavily traveled roads were used less than availability from calving through rutting season for both years. Conversely, areas within 500 m of light traffic roads were used in excess of availability during these seasons. Areas within 250 m of moderate-to-heavy traffic roads were used significantly less than availability during the calving through

TABLE 1. Percentages of availability and elk use by distance to open roads during 1980 and 1981.

Distance to open roads (m)	Calving		Summer		Rutting		Hunting	
	Avail.	Use	Avail.	Use	Avail.	Use	Avail.	Use
1980								
<250	39.8	58.1*	45.5	44.2	27.1	23.0	16.4	17.0
251-500	22.1	17.6	23.4	24.5	15.4	11.5	11.4	5.7
501-750	13.4	4.1*	13.7	9.2	11.4	8.8	9.7	15.9
751-1,000	10.4	10.8	8.4	11.7	9.7	5.3	6.4	5.7
>1,000	14.4	9.5	9.0	10.4	36.5	51.3*	56.2	55.7
N	299	74	299	163	299	113	299	88
1981								
<250	24.3	27.9	23.7	18.6	18.3	6.2**	10.0	0.0**
251-500	16.0	14.7	14.7	21.8	12.3	7.8	7.0	11.3
501-750	12.3	8.8	13.3	14.7	11.0	11.6	7.3	4.8
751-1,000	6.3	10.3	6.3	1.9	7.7	11.6	7.0	3.2
>1,000	41.0	38.2	42.0	42.9	50.7	62.8	68.7	80.6
N	300	68	300	156	300	129	300	62

* $P<0.05$
** $P<0.01$

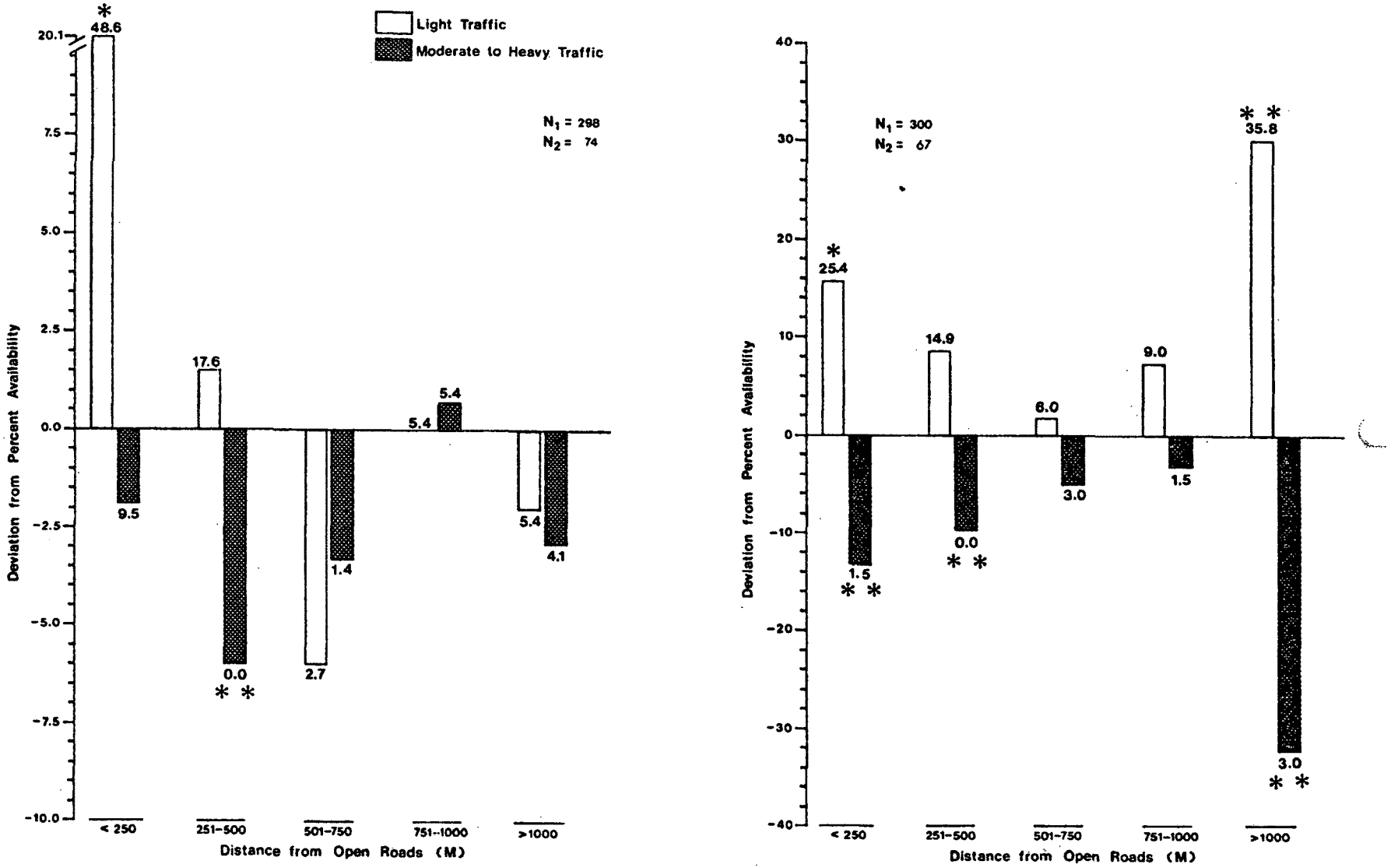


Fig. 2. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and traffic volume during the calving season of 1980 (left) and 1981 (right). * ($P<0.05$) ** ($P<0.01$)

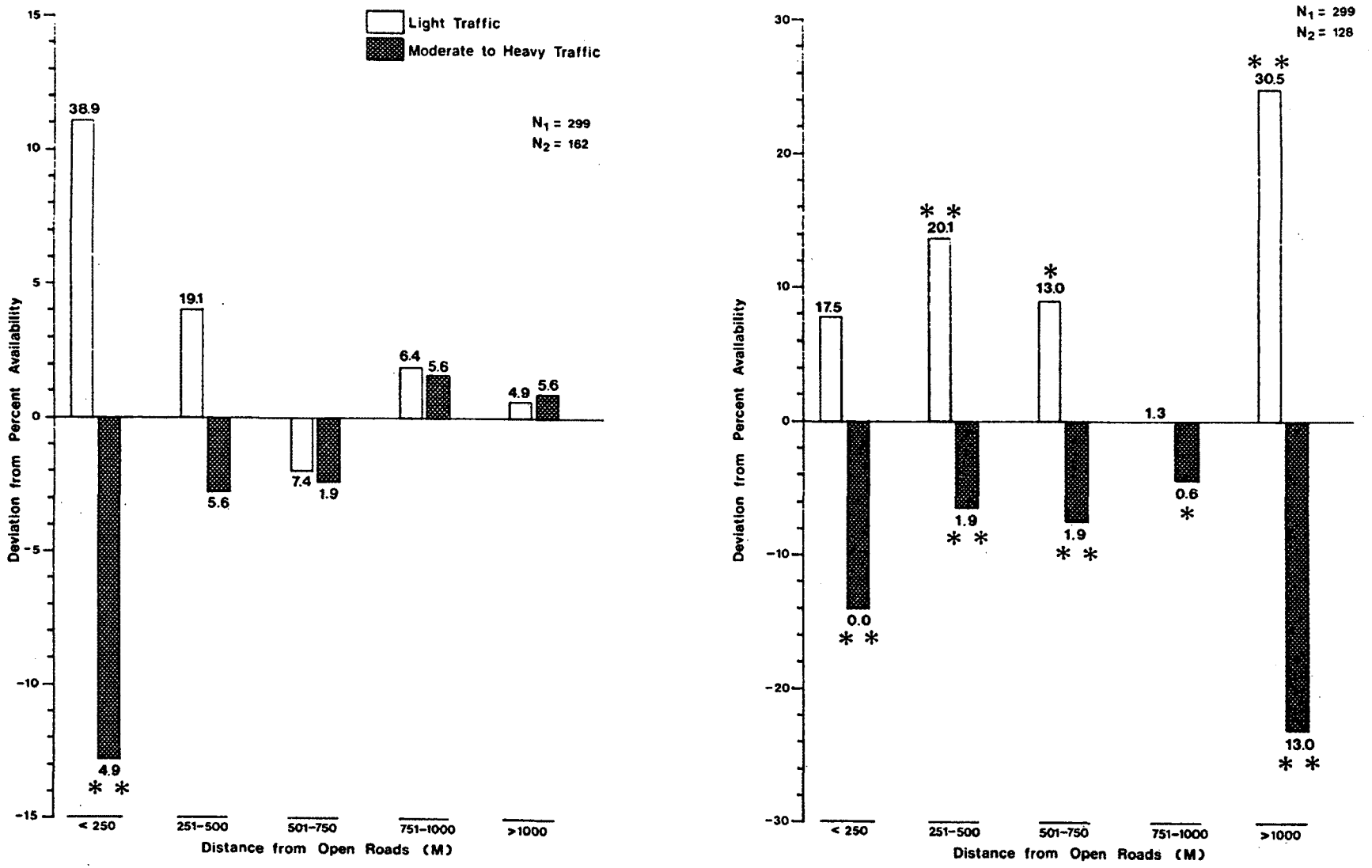


Fig. 3. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and traffic volume during the summer season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

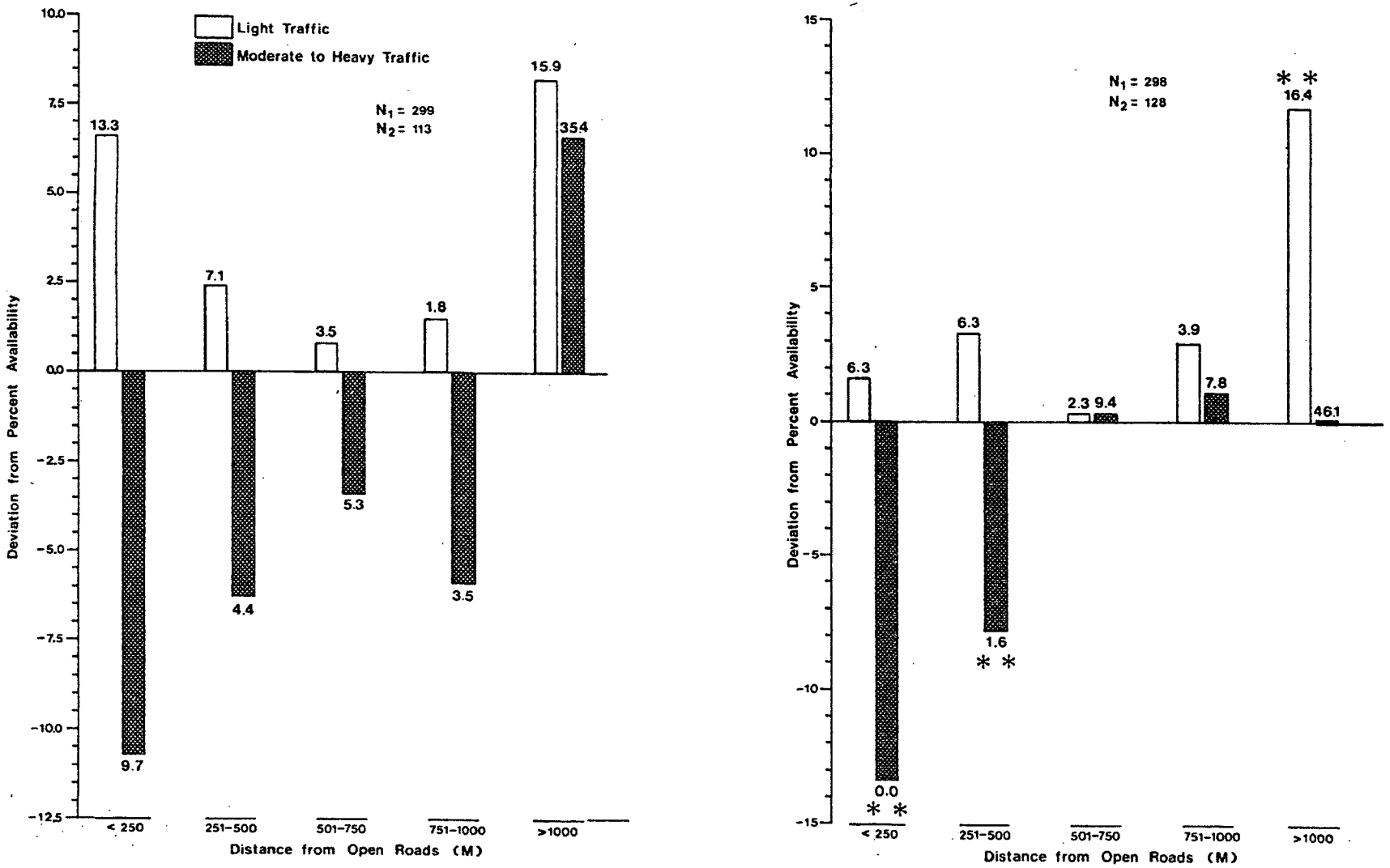


Fig. 4. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and traffic volume during the rutting season of 1980 (left) and 1981 (right. * ($P<0.05$) ** ($P<0.01$)

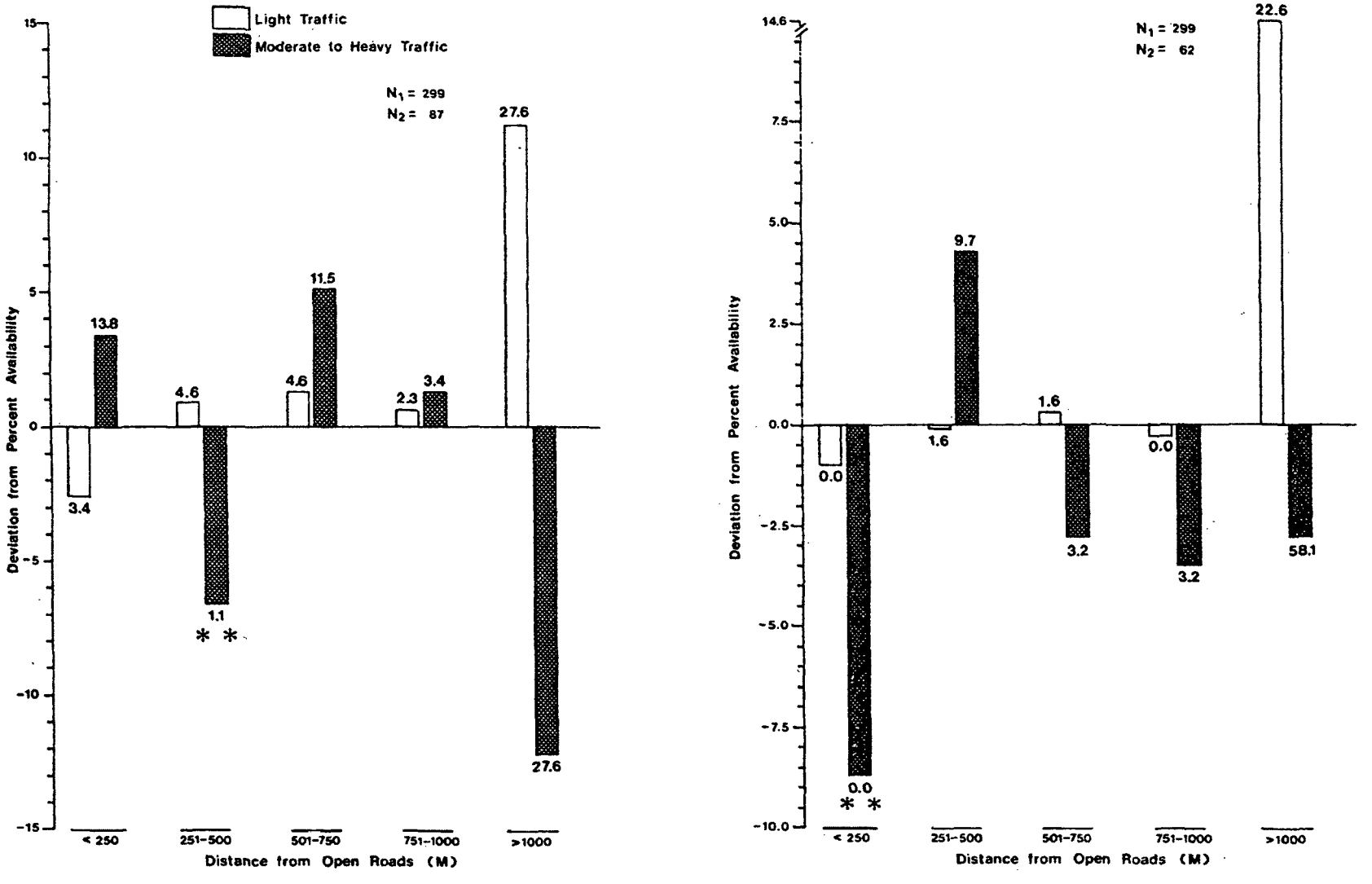


Fig. 5. Deviation from percent availability, and percent elk use (above of below bar) by distance to open roads and traffic volume during the hunting season of 1980 (left) and 1981 (right). * ($P<0.05$) ** ($P<0.01$)

rutting seasons of 1981, and during the summer of 1980. All distance categories for moderate-to-heavily traveled roads were used significantly less than availability during the summer of 1981. Use of areas within 250 m of heavily traveled roads was significantly less than availability during the 1981 hunting season, but used in excess of availability during this season in 1980. Sample size precludes controlling for traffic volume when examining other variables. Appendix A contains the percent availability and percent use for each variable cross-classified with distance to open roads.

Areas between elk locations and open roads were examined on topographic maps and classified as to whether a topographic barrier existed. Elk locations without topographic barriers between them and an open road were used less than availability in 32 out of 40 seasonal distance categories; 9 of these were significantly less (Figs. 6 through 9). Use exceeded availability in 30 out of 40 seasonal distance categories with topographic barriers between them and the nearest road; 3 of these were significant deviations. Use of areas without topographic barriers, that were within 250 m of an open road was less than availability, during all seasons except both calving seasons and the 1980 hunting season. Over 40% of the elk use during the rutting and hunting seasons each year was in areas greater than 1,000 m from an open road with a topographic barrier in between.

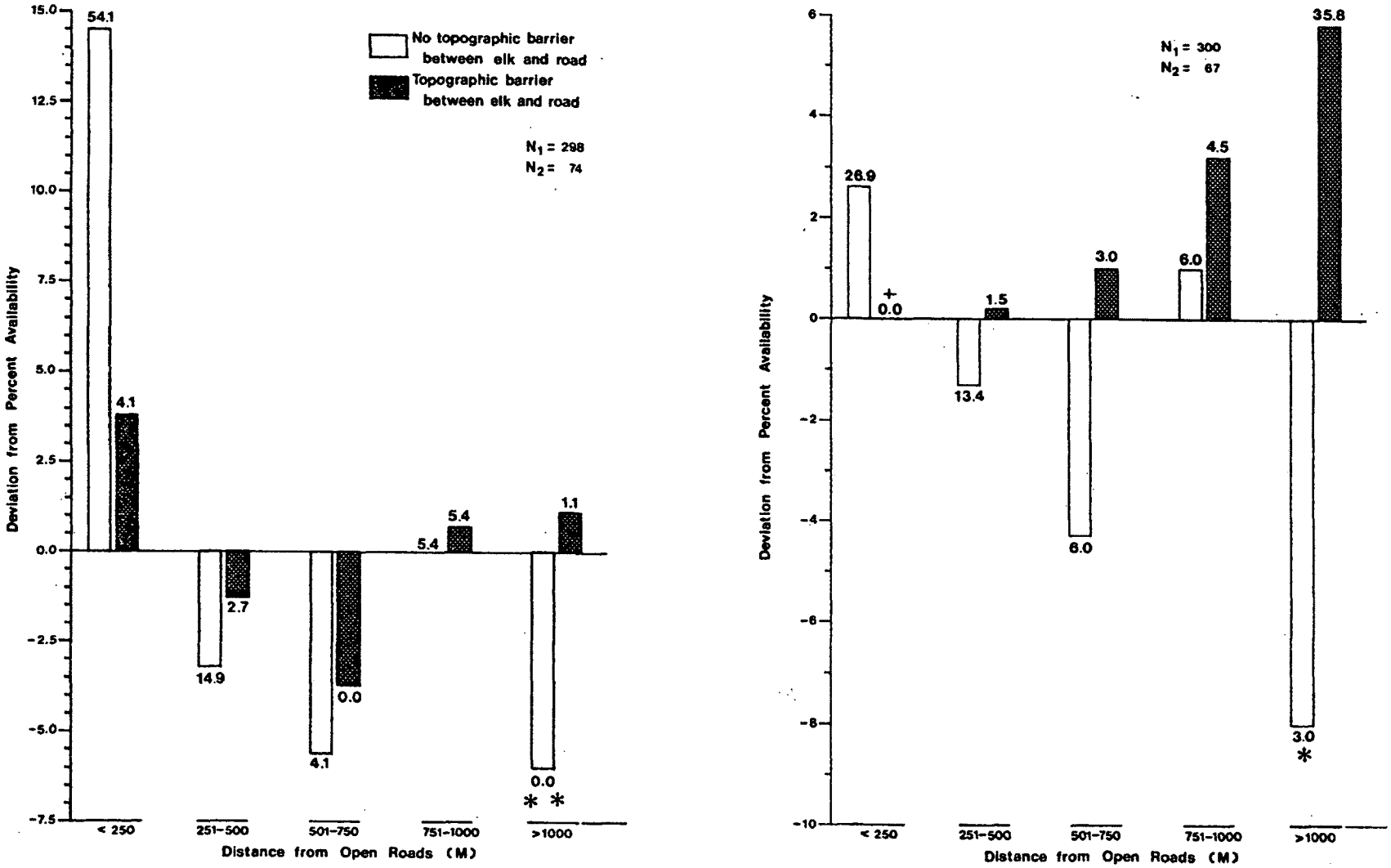


Fig. 6. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and topographic barriers during the calving season of 1980 (left) and 1981 (right).
* ($P<0.05$) ** ($P<0.01$) + Availability < 0.05%

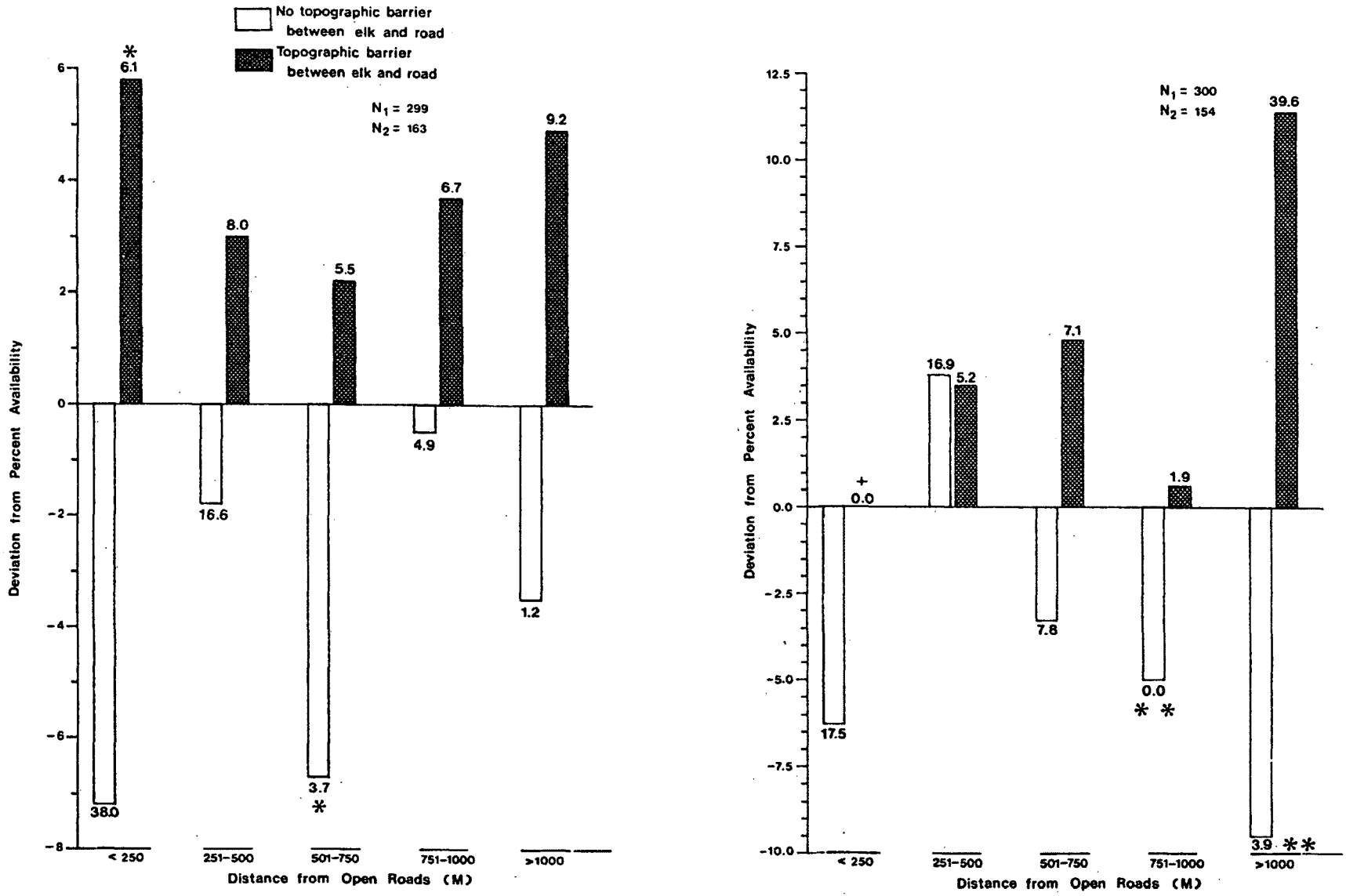


Fig. 7. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and topographic barriers during the summer season of 1980 (left) and 1981 (right).
* ($P<0.05$) ** ($P<0.01$) + Availability < 0.05%

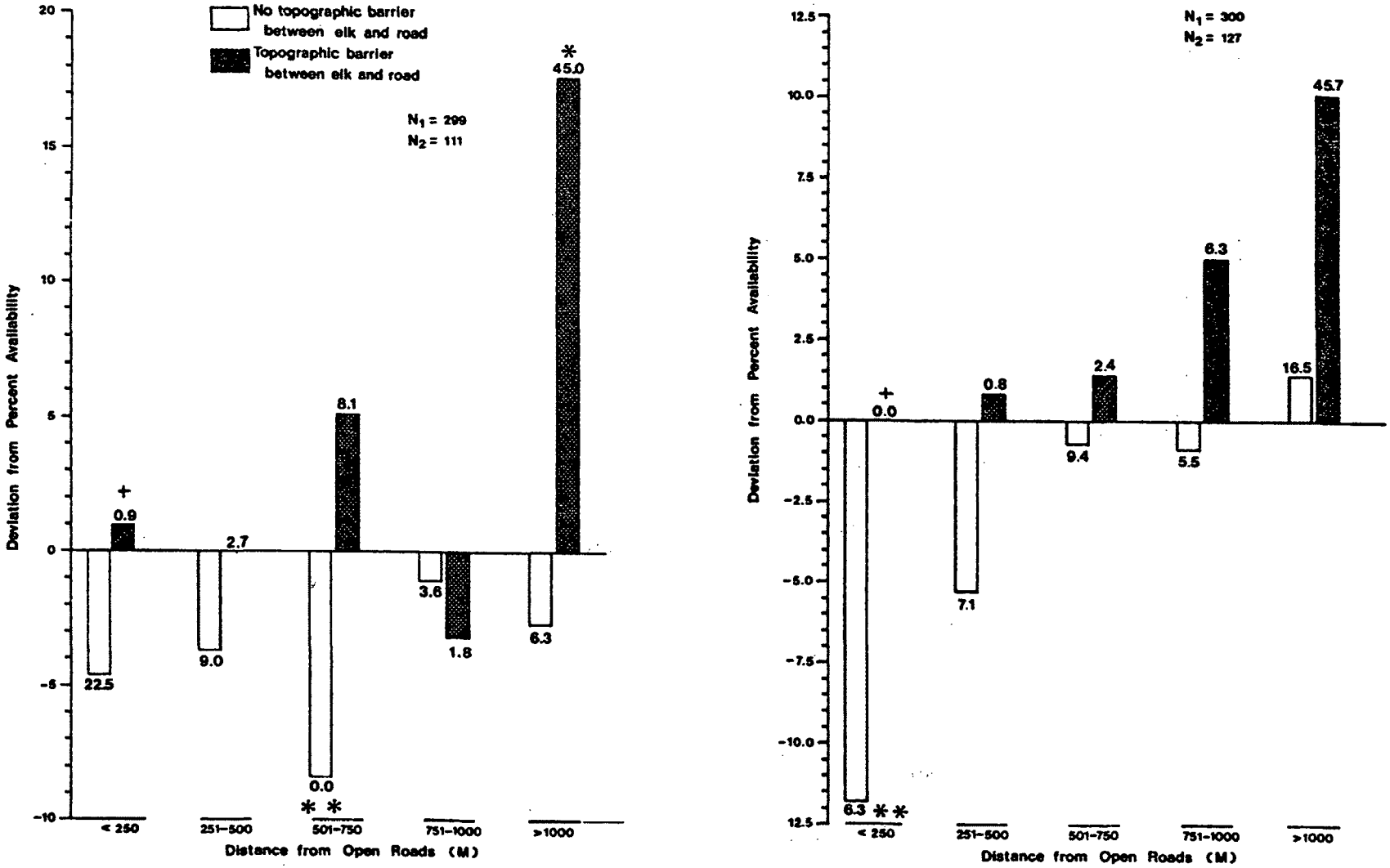


Fig. 8. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and topographic barriers during the rutting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%.

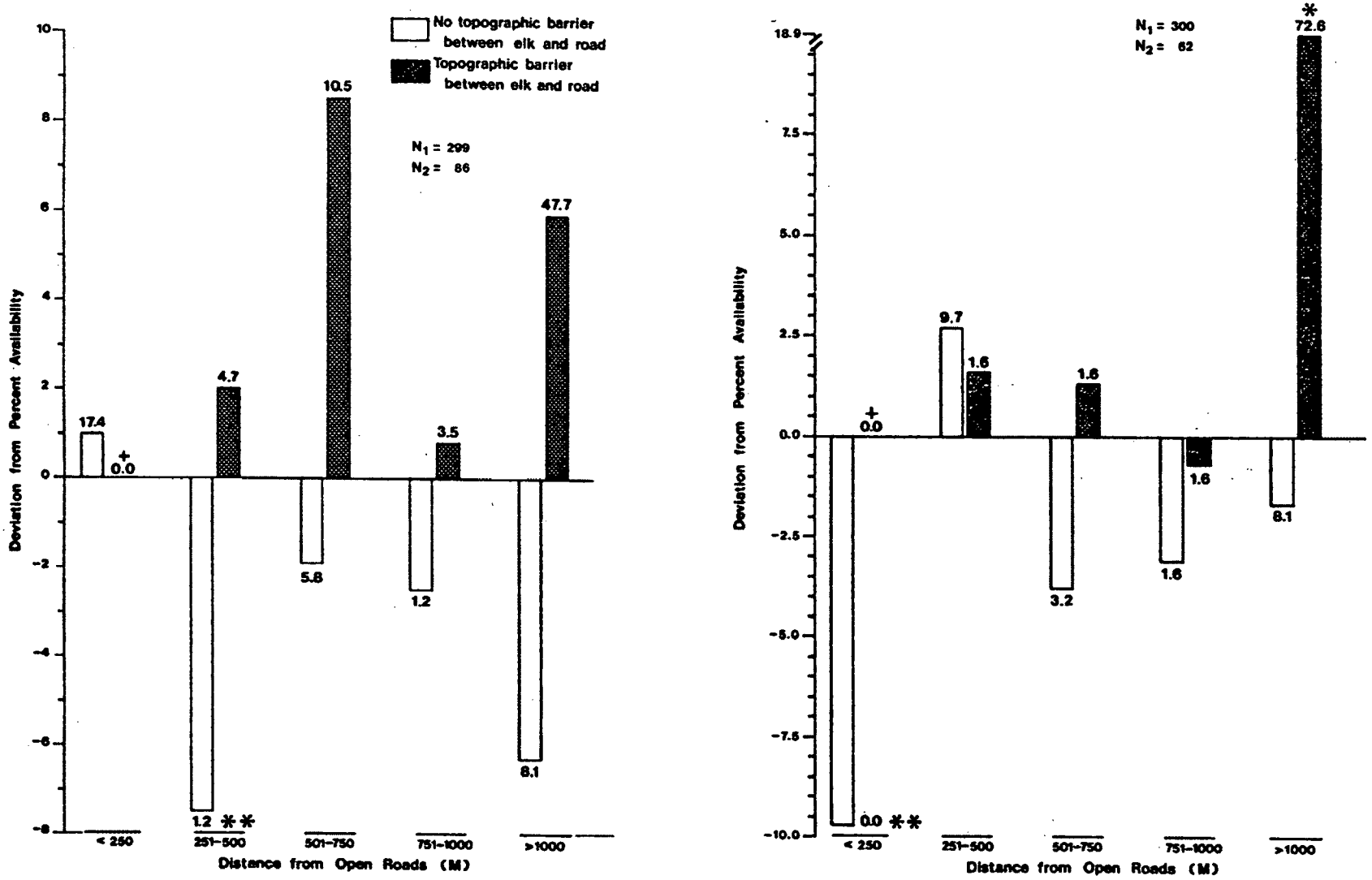


Fig. 9. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and topographic barriers during the hunting season of 1980 (left) and 1981 (right).
* (P<0.05) ** (P<0.01) + Availability < 0.05%

Elk locations were classified into 1 of 5 overstory canopy coverage classes using aerial photographs. A 0.4 ha area was the minimum area of vegetation examined. Sample size was inadequate for cross-classification of data during the calving and hunting seasons. Except for roads, scree, and water, areas with no trees made up 8.7% of the study area and were always used less than availability for the summer and rutting seasons. With the exception of areas less than 250 m from an open road during the 1980 rut, areas with no trees always received less use than their availability, within 750 m of an open road (Figs. 10 and 11). During the summer of 1980, 51.7% of the elk use was in areas of less than 75% canopy coverage, and less than 500 m from an open road. Areas with 75-95% (dense) canopy coverage, within 500 m of an open road, received 28.9% of the use during the 1981 summer season. During both rutting seasons, more than 50% of the elk use was within the dense coverage class. During this period, elk used dense stands greater than 1,000 m from an open road significantly in excess of their availability. Conversely, during the rutting seasons, areas with less than 25% canopy coverage were used less than availability, within 500 m of an open road.

Elk locations were classified into 1 of 5 successional stages using aerial photographs. Sample sizes preclude cross-classification of data during the calving and hunting seasons. As expressed in the overstory canopy coverage results, the grass-forb and the brush-seedling-sapling stages were used less than availability, within 500 m of an open road, except during the 1980 rutting season (Figs. 12 and 13). Young-to-pole

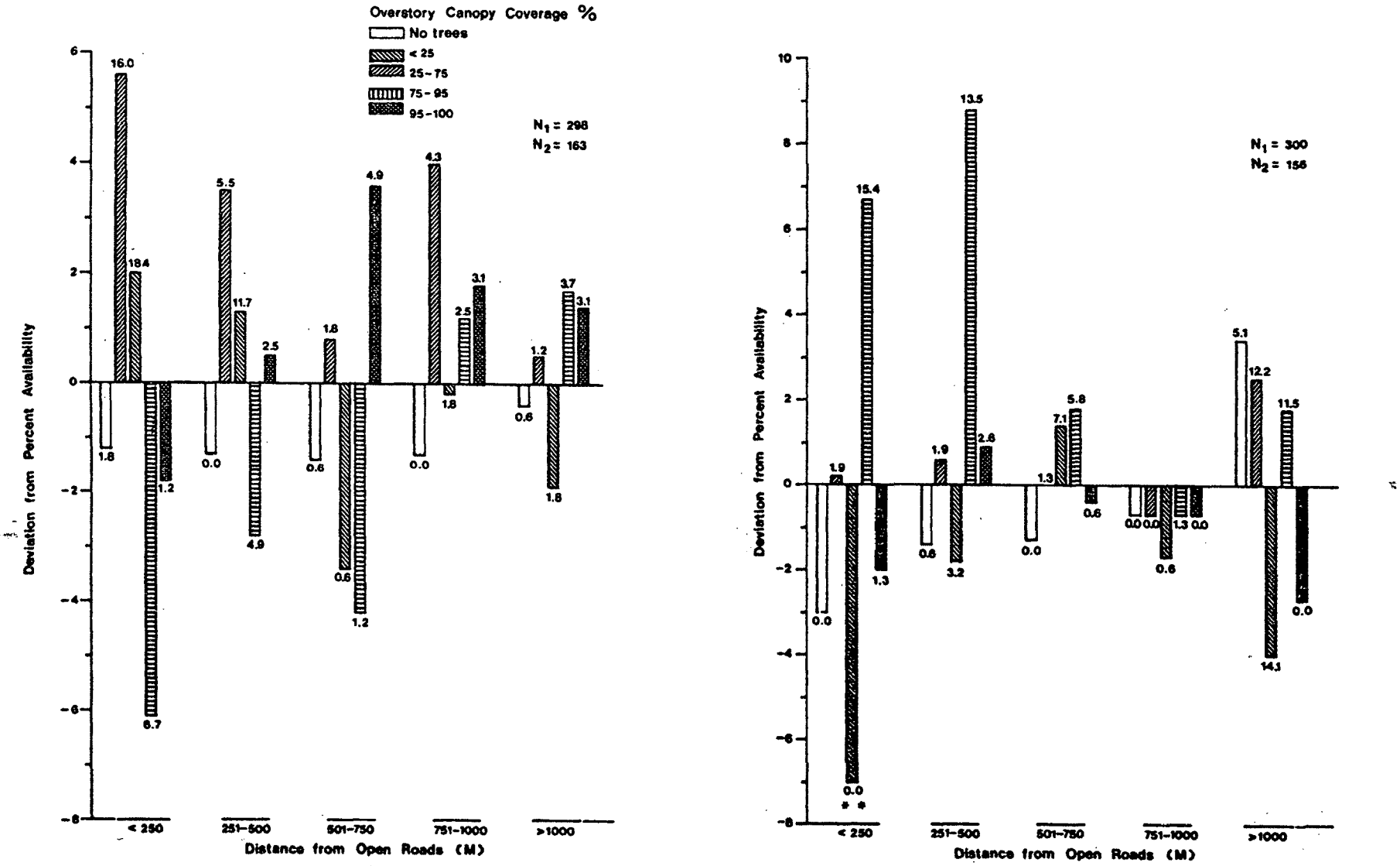


Fig. 10. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and overstory canopy coverage during the summer season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

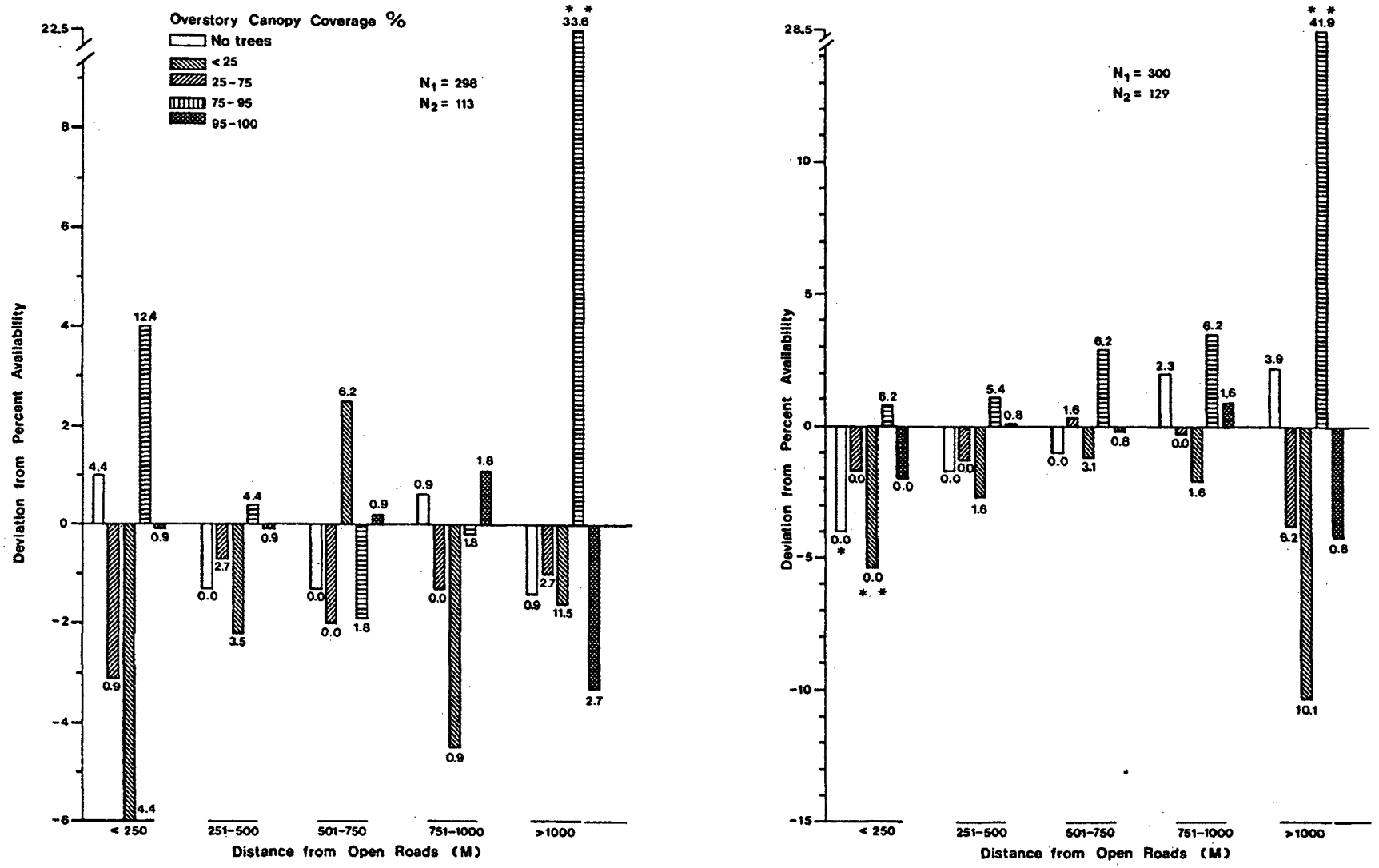


Fig. 11. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and overstory canopy coverage during the rutting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

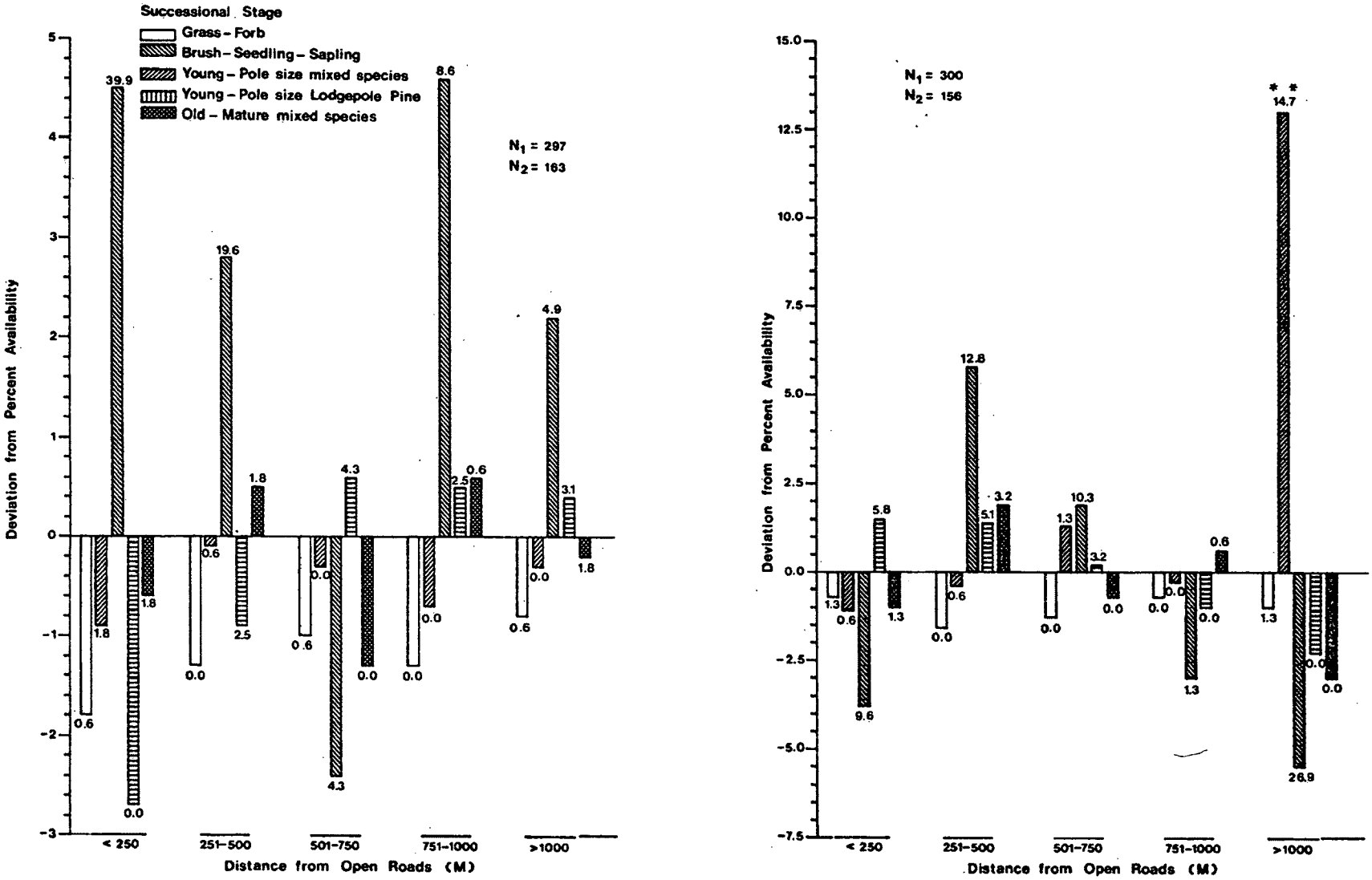


Fig. 12. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and successional stage during the summer season of 1980 (left) and 1981 (right).
* ($P<0.05$) ** ($P<0.01$)

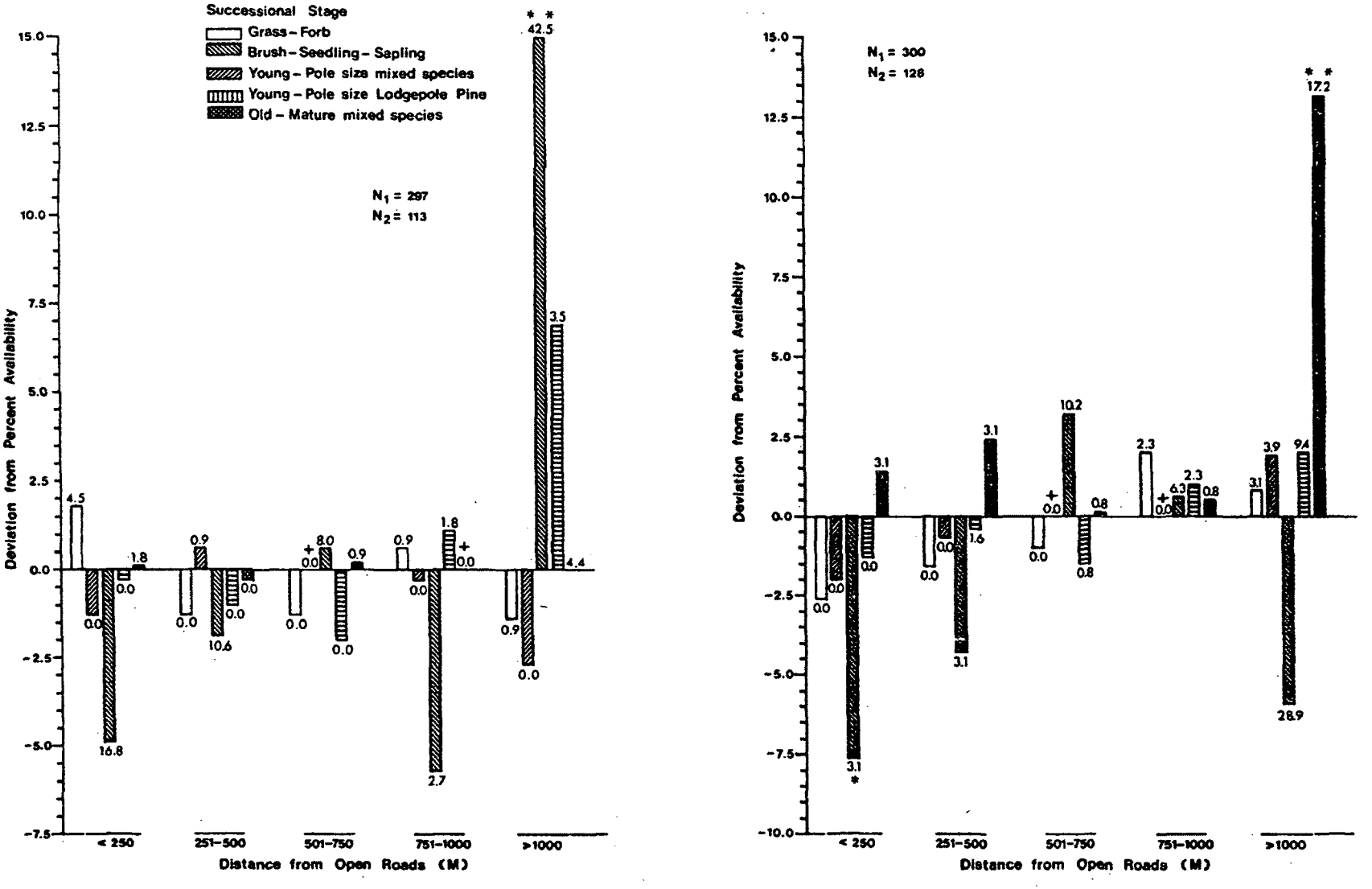


Fig. 13. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and successional stage during the rutting season of 1980 (left) and 1981 (right).
* ($P<0.05$) ** ($P<0.01$) + Availability < 0.05%

size mixed species stands received the majority of use for each distance category during all seasons. During the summer and rut of 1980, use was relatively high in areas within 250 m of an open road, and was concentrated in the young-to-pole size mixed species stands.

Distance to nearest water was measured for each location. Small sample sizes did not allow cross-classification of data during the calving or hunting seasons. Areas within 200 m of water comprise 57.7% of the study area. Although less than availability, these areas received 30 to 50% of the use each season. Use of areas within 100 m of water was less than availability in 16 out of 20 seasonal distance categories. Except for the 1981 summer season, this deviation was greatest within 250 m of an open road (Figs. 14 and 15). With the exception of summer 1980, elk use of areas within 100 m of water was highest when these areas were greater than 1,000 m from an open road.

Discussion

A direct effect on elk habitat was shown by an approximate 1% increase in the area covered by roads, throughout the study area between 1980 and 1981. However, this increase alone did not have a significant effect upon Chamberlain Creek elk. Use was proportional to availability during all seasons except the 1981 hunting season. Marcum (1975) concluded that elk avoid human activity on roads and not the roads themselves. Lehmkuhl (1981) also found use of all roads proportional to availability, but felt that hunters walking on closed roads caused elk to avoid them. My results concur with these 2 studies. Elk showed no

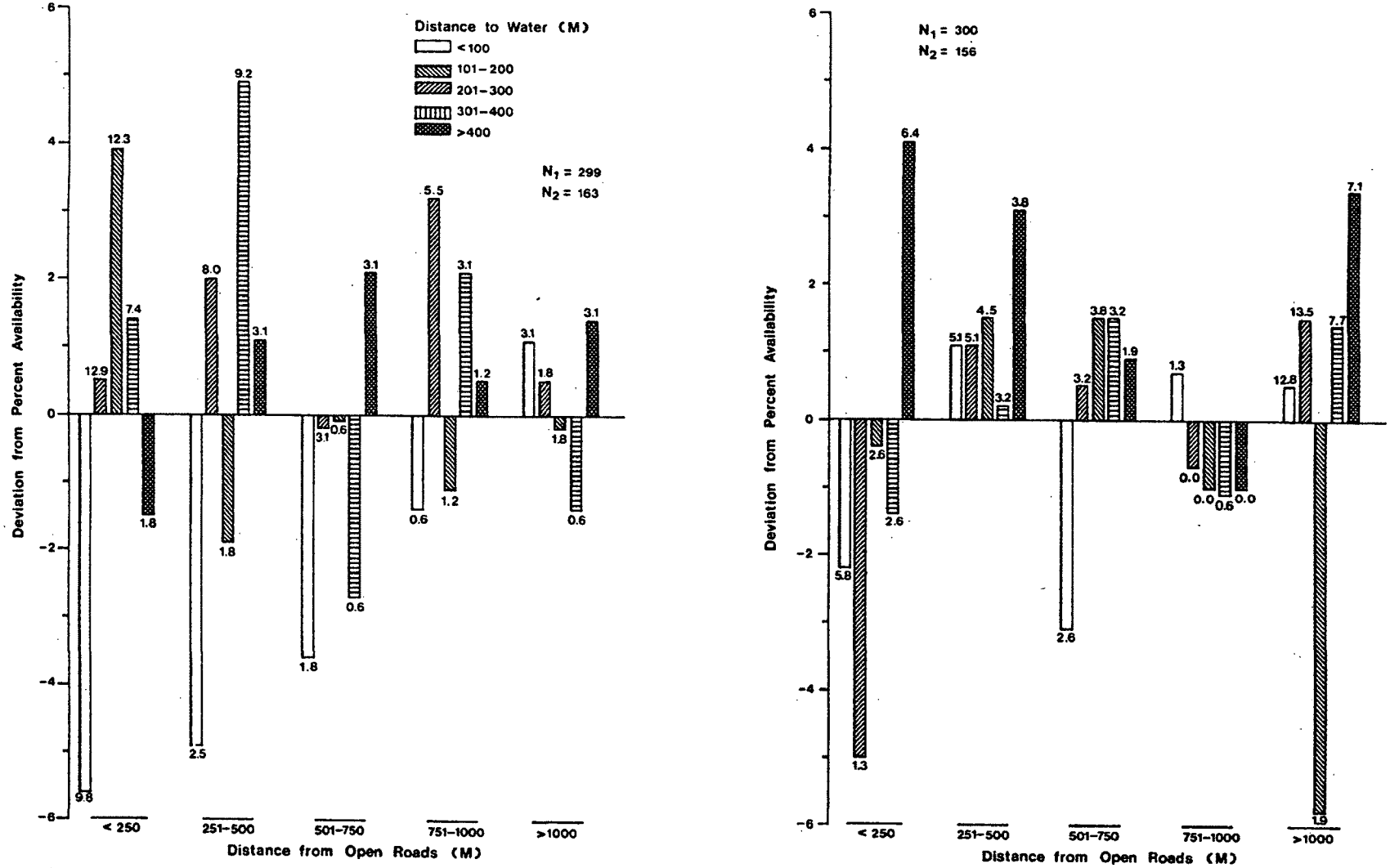


Fig. 14. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and distance to water during the summer season of 1980 (left) and 1981 (right). * ($P<0.05$) ** ($P<0.01$)

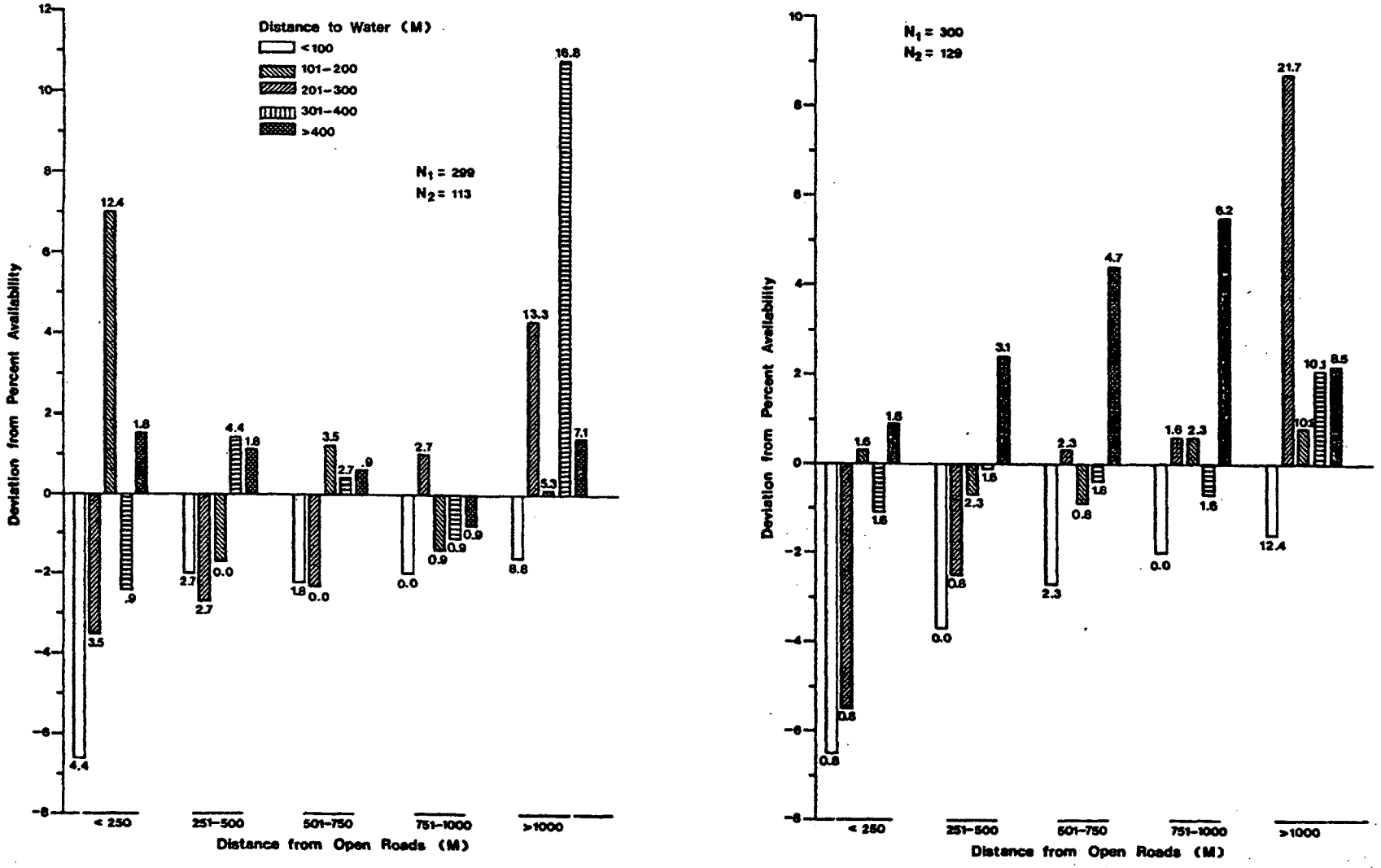


Fig. 15. Deviation from percent availability, and percent elk use (above or below bar) by distance to open roads and distance to water during the rutting season of 1980 (left) and 1981 (right).
* (P<0.05) ** (P<0.01)

actual avoidance of the road structure itself, and often used roads as travel lanes from calving through the rutting season. However, in areas of road closures, hunters may be expected to walk along roads, and thereby reduce elk use of those roads.

Several studies have shown elk use depressed in habitat adjacent to open roads. The distance within which elk use is significantly affected varies from 400 m (Marcum 1975, Perry and Overly 1976, Irwin 1978, and Ward et al. 1980) to over 1,000 m (Lyon 1979a and Pedersen 1979). These effects often vary from area to area depending upon season or habitat. Gruell and Roby (1976) reported that elk avoid roads only during the hunting season. Lehmkuhl (1981) found that elk avoid roads during the rutting season as well as the hunting season. Rocky Mountain National Park elk adapt to human activity along roads and show little avoidance (Schultz and Bailey 1978). Rost and Bailey (1979) reported that elk pellet densities in Colorado increase with distance from roads on the east side of the Continental Divide, but not on the west, and attributed this to the greater availability of winter range on the east side. My data indicate that elk showed no avoidance of open roads during the calving and summer seasons of both years, and the rut of 1980. Chamberlain Creek elk showed a significant avoidance of areas within 250 m of roads during the rut and hunting seasons of 1981. Furthermore, the majority of use during these seasons, for both years, was greater than 1,000 m from an open road. The apparent lack of avoidance of roads during the calving and summer seasons of both years and the 1980 hunting season was probably a function of traffic distribution and elk

behavioral patterns. The majority of open roads during the calving and summer seasons of both years were either lightly traveled, or if heavily traveled, they were primarily at lower elevations or in areas not typically used by Chamberlain elk. A relaxation of the flight response to human stimuli may occur over the winter. In general, only roads peripheral to the study area receive winter use. This road use pattern may also account for the lack of avoidance shown by elk for open roads early in the season. Bergerud (1974) characterized caribou (Rangifer tarandus) response to human disturbance as a learned response requiring occasional reinforcement. Marcum (1975) hypothesized that this apparent habituation to human disturbance on spring range may be caused by "seasonal differences in their susceptibility to human disturbance as a result of seasonal behavioral differences ...". Rost and Bailey (1979) found less avoidance of roads where winter range, and therefore alternative habitat was limited. The lack of avoidance of areas within 250 m of an open road during the 1980 hunting season was a function of elk using safety zones, which are closed to hunting. These zones were established in areas surrounding human habitation and livestock concentration, and were invariably in close proximity to open roads. Lieb (1981) reported that the long-distance flight response of elk to hunters did not occur until there was a hunter/elk encounter. Irwin and Peek (1979) and Lehmkuhl (1981) reported that elk initially displaced at the beginning of the hunting season often return to the area of initial displacement after several days. Irrespective of the use of safety zones, the majority of locations during both hunting seasons were in

areas greater than 1,000 m from an open road. Use of dense stands during the hunting season was high, but did not increase over the levels of use during the rut (Marcum and Edge 1982). Elk response to open roads during the hunting season was generally one of strong avoidance except where safety zones provided "islands of security" in close proximity to open roads.

Avoidance of open roads by Chamberlain elk appears dependent upon traffic volume and cover provided by topography and vegetation. Lyon (1980) felt that the degree to which any roads reduces elk use was dependent upon "location of the road, amount of traffic, and cover availability." My results showed a strong dichotomy between elk use relative to light and moderate-to-heavily traveled roads, especially during the calving through rutting seasons. Lemke (1975) reported a greater number of locations near secondary roads than primary roads, but did not consider the relative availability of the 2 types. Marcum (1975) found that open road systems were selected against, open spurs and 4-wheel drive tracks were used in proportion to their availability, and closed roads were selected for. Hershey and Leege (1976) reported a higher occurrence of elk crossing secondary roads than primary roads. Except during the hunting season, traffic volume had a major effect on elk use of habitat adjacent to open roads. Greater use of areas near heavily traveled roads than lightly traveled roads, during both hunting seasons was again a function of use of safety zones and the heavy traffic over most roads in these zones.

The importance of security cover to elk cannot be overstated (Allen 1977, Thomas et al. 1979a, and Peek et al. 1982). Lonner and Cada (1982) stated that increasingly restrictive hunting restrictions in Montana were a function of loss of habitat security, rather than an increase in the number of hunters. Security cover may be provided by both topography and vegetation (Wallmo and Schoen 1981). My data indicate that elk showed a strong preference for areas with a topographic barrier between them and open roads, regardless of traffic volume. Except for the calving seasons and the 1980 hunting season, areas within 250 m of open roads were preferred if a topographic barrier existed. The lack of selectivity during the calving seasons was probably a function of the behavioral differences discussed earlier. The safety zones again account for the apparent difference during the 1980 hunting season. All safety zones were located on relatively flat land without topographic barriers. The large majority of use greater than 1,000 m from roads, with a topographic barrier between indicates a strong avoidance of open roads during the hunting season. Lyon (1979b) reported that elk disturbed by logging activities moved into the next drainage, effectively placing a topographic barrier between themselves and the disturbance. However, Thomas et al. (1979a) state that "Topography has not been demonstrated to be a substitute for vegetative cover." In forested, mountainous habitat, separating one variable from the other would be virtually impossible, and in general, variables act in tandem to reduce the effect of open roads upon elk.

Several studies have shown that elk use relative to open roads is affected by either overstory canopy cover or the successional stage of the adjacent area. Elk use of clearcuts (Hershey and Leege 1976, Lyon and Jensen 1980) and mountain meadows (Perry and Overly 1976, Morgantini and Hudson 1979) was reduced adjacent to open roads. In areas with no overstory canopy coverage, elk use still increases between 2,400 and 3,200 m from open roads (Lyon 1979a). Ward et al. (1980) found that the highest number of elk crossing per unit of road was in open burned areas, but attributed this to higher quality of habitat and noted that most crossings were at night. Chamberlain Creek elk use of various overstory canopy coverage classes and successional stages was a function of selection for security cover and seasonal habitat preferences. In general, areas with a low amount of cover (no trees, grass-forb, and brush-seedling-sapling successional stages) were avoided within 750 m of an open road. Previous studies in the Chamberlain Creek area (Scott 1978, Lehmkuhl 1981) reported that these vegetative characteristics generally received less use than their availability. Elk use within 500 m of an open road was not significantly reduced in areas with 25 to 95% canopy coverage or in young-to-pole size mixed species stands during the summer and rutting seasons. Lehmkuhl (1981) found that these stands were generally preferred habitat. These sites provided preferred forage as well as adequate security cover, and were more effective in maintaining elk in close proximity to open roads. Selection for dense mixed species stands greater than 1,000 m from an open road during the rut was as much a function of habitat preference during this period as

it was a selection for security cover. Several studies (Knight 1970, Bohne 1974, Baglien and Biggins 1976, and Lehmkuhl 1981) noted an increase in use of denser timber with the inception of the rut. If sample sizes had been adequate to control for traffic volume, the relationship between roads and the vegetative cover of adjacent habitat would have been clearer. Traffic volume undoubtedly has a major effect on elk selection of vegetative cover adjacent to roads.

Lehmkuhl (1981) found no selection for areas in close proximity to water and hypothesized this was because water was widely available in the Chamberlain Creek area. Marcum and Edge (1982) also reported a general avoidance of areas within 140 m of water during all seasons, but felt that the close proximity of roads to water might be a factor. Thomas et al. (1979b) noted that areas along streams were attractive locations for roads. Evidence was not conclusive for acceptance of the hypotheses that close proximity to roads had an effect upon elk use of areas near water. Areas less than 100 m from water were generally avoided regardless of their proximity to roads. However, a large portion of the Chamberlain elk use occurred within 200 m of water. Elk did not select sites in close proximity to water because of its abundance on the study area. Lyon (1980) pointed out that the role of surface water in elk habitat has not been clear. The use of moist areas appears to be a function of their availability. Marcum (1975) and Lemke (1975) found a selection for sites close to water while Ward (1980) did not. Pedersen et al. (1979) felt that the high abundance of water within their study area was the cause for a lack of correlation between

elk use and distance to water. Collins (1979) reported that elk select for the forage plants associated with wet sites and not water itself. In view of these findings, there is potential for concern in areas where water is not abundant, and this potential should be further investigated.

The results of my study indicate that elk response to open roads varies with season, traffic volume, and cover provided by topography and vegetation. Elk respond to heavily traveled roads to a greater extent than lightly traveled roads from calving through rutting seasons. Areas with topographic barriers between elk and the nearest open road were generally preferred over areas without such topographic cover during all seasons except during calving and the 1980 hunting season. Lack of avoidance of open roads during the calving season was attributed to either distribution of traffic, or behavioral differences during that season. Elk response to open roads during hunting season was one of general avoidance, except where no hunting areas provided security in close proximity to roads. Elk use was generally depressed within 750 m of an open road in areas with no tree cover. Conversely, elk use was not significantly reduced within 500 m of open roads, during the summer and rutting seasons, if there was at least 25% canopy coverage. However, traffic volume was not controlled for in this analysis. Elk selection of dense vegetative cover may be expected to be more pronounced adjacent to heavily traveled roads. The proximity of open roads to water was not a factor in elk avoidance of areas near water.

I conclude that elk use will be reduced in areas adjacent to open roads. The extent of this reduction will depend upon traffic volume and the amount of topographic and vegetative cover available. To maintain elk use of logged areas, roads should be designed to avoid natural openings and take advantage of topographic barriers. In areas of low water availability, elk use may be reduced if roads are not routed away from water sources. Road closure following timber sales will increase habitat effectiveness for elk, but probably not to the levels prior to road construction.

CHAPTER III

DISTRIBUTION OF ELK AND USE OF COVER IN RELATION TO HUMAN DISTURBANCES IN WESTERN MONTANA

Elk (Cervus elaphus) response to human activities has been a major concern of land managers. Many of mans' activities have been shown to reduce elk use of proximal habitat. The influence of roads was reviewed in the previous chapter. Non-hunting recreational activities (Ward et al. 1973, Picton 1980, and Ward et al. 1980), seismic exploration (Knight 1980) and timber management activities (Ward 1976, Long et al. 1980, Lehmkuhl 1981 and Lieb 1981) have all been shown to displace elk from areas adjacent to the activity. Peek et al. (1982) state that security cover "appears to be a requirement for elk in the presence of human disturbance." Lyon (1979a) modeled the relationship between overstory canopy cover and road density as it affects habitat effectiveness for elk. Basile and Lonner (1979) reported that in areas where cover was poor (one-third or less of the total area) vehicle restrictions will reduce harassment and emigration of elk during the hunting season.

The objective of this study was to determine the effect of cover on elk use of areas in close proximity to human disturbances, principally logging activities. This study was conducted in conjunction with the Chamberlain Creek elk-logging project, which was designed to describe elk distribution and use of several available environmental factors

before, during, and after logging in Chamberlain Creek.

Study Area

The study area lies 56 km east of Missoula, Montana, in the northern Garnet Mountains (Fig. 16). The area used by all radio-collared elk is approximately 23,300 ha. The core study area (CSA), a previously undisturbed summer range in which the Chamberlain Creek elk-logging project is focused, is 2,350 ha. Mean monthly temperatures range from -8.4° C in January to 16.8°C in July (Steele 1981). The mean annual precipitation is 44.7 cm, the majority of which falls December through May.

Vegetation of the study area is primarily forest (85%). Habitat Types (Pfister et al. 1977) are within the Douglas-fir (Pseudotsuga menziesii) and subalpine fir (Abies lasiocarpa) series. Lodgepole pine (Pinus contorta) and Engelmann spruce (Picea engelmanii) are the higher elevation cover types. Mid-elevations are forested with Douglas-fir or Douglas-fir and western larch (Larix occidentalis) stands. Lower elevations are primarly Douglas-fir with ponderosa pine (Pinus ponderosa) as a codominant on drier sites. Pastures and hayfields, natural meadows, clearcuts , roads, water, and scree account for the remainder of the study area habitat components.

Elevations range from 1,160 m to 2,090 m. Topography is a series of moderately steep primary and secondary ridges between 9 second and third order stream systems. The north and western edges of the study area are bordered by the Blackfoot River. A more thorough description of the study area is provided by Scott (1978) and Lehmukhl (1981).

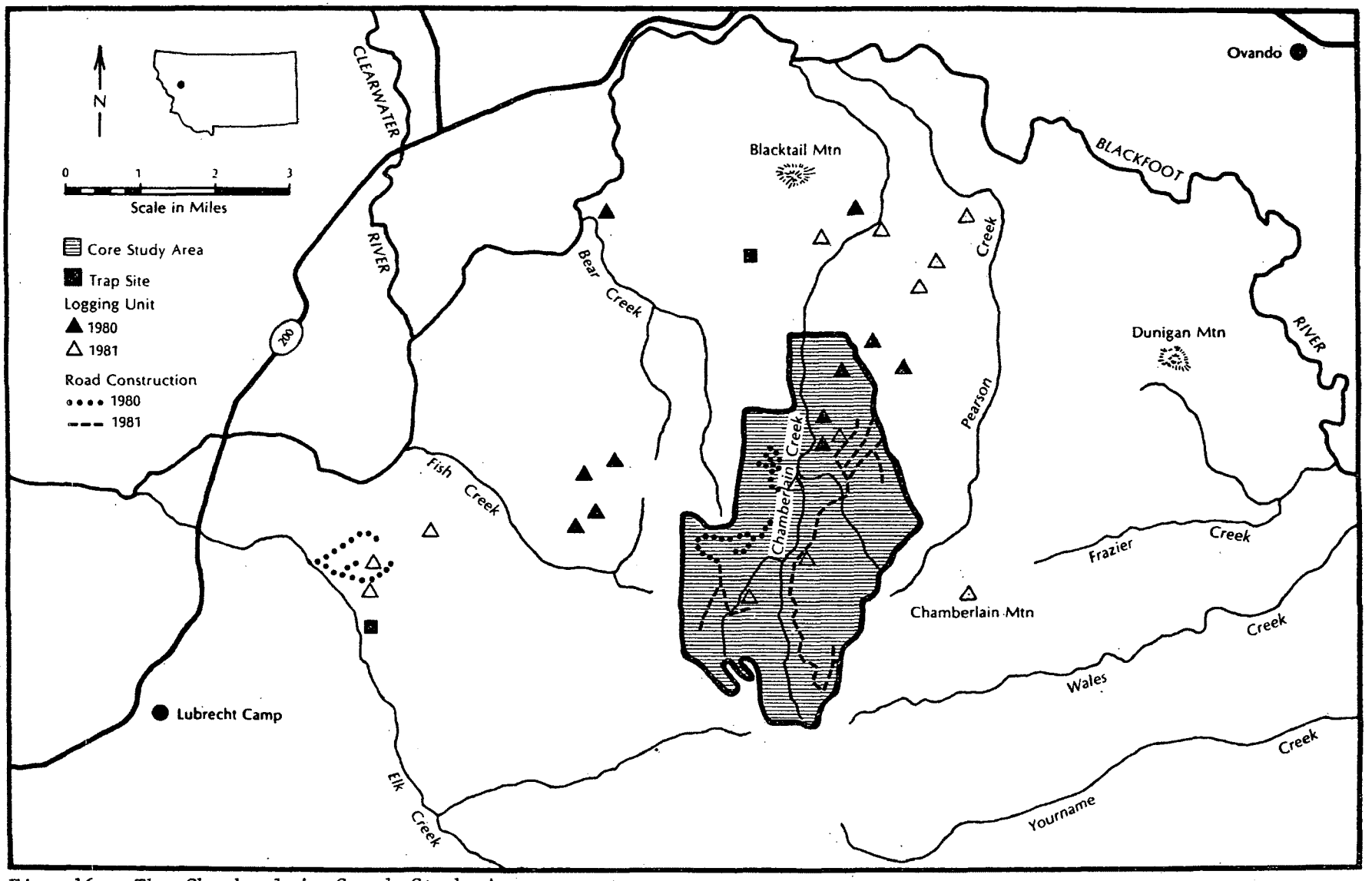


Fig. 16. The Chamberlain Creek Study Area.

Timber harvest is the principal land use. With the exception of the CSA and the upper portions of Pearson, Frazier and Wales creeks, the area has been extensively logged within the last 50 years. Some type of partial cut is the primary silvicultural method. With the exception of the CSA, grazing by cattle or horses occurs from June to October. Big game hunting is the main recreational activity. The study area lies within the Blackfoot Special Management Area and is closed to vehicle traffic from 1 September to 1 December. With the exception of roads used for active logging sales and ranch access, vehicle traffic is generally light the remainder of the year.

Road construction and logging were the main sources of disturbance during my study. During 1980, logging was widespread. Five units were selectively logged on the east side of main Chamberlain Creek throughout the May to December field season. An 80 ha unit was selectively logged on the south side of Blacktail Mountain from June through mid-October. During May through July, several 40 ha units were selectively logged in Fish and Little Fish Creeks, and an 80 ha unit was selectively cut in the Bear Creek drainage from July through mid-October. A series of spur roads were constructed within the main Chamberlain Creek drainage from August through December.

Disturbances during the 1981 field season were primarly concentrated within the main and East Chamberlain drainages. A 120 ha salvage operation was conducted on the south slope of Blacktail Mountain from May through June. Two 4 ha clearcuts and 4 selective cuts, 4 to 20 ha, were logged in main Chamberlain Creek from August through October.

Two 80 ha units were selectively cut within the East chamberlain Creek drainage from September through November. In addition to these disturbances, several ranches, peripheral to the study area, were considered as causes of disturbances.

Methods

Corral-type traps, baited with alfalfa from December through April and salt from March to September were used to capture elk. Age was estimated based upon incisor replacement (Quimby and Gaab 1957) and wear. A 150-151 MHz radio in a molded PVC pipe collar (Pedersen 1977) was placed on each animal. Elk were located from an airplane on a weekly basis, weather permitting, from mid-May to December. Each location was marked on an aerial photograph and later transferred to USGS 7.5 minute quadrangle maps. Distances to the nearest human disturbance were measured, and the existence of topographic barriers were inferred from these maps. Successional stage and overstory canopy coverage were evaluated from the aerial photos. Availability of each variable was estimated from a series of random points (Marcum and Loftsgaarden 1980).

Data were analyzed using a DECSYSTEM-20 computer and the SPSS statistical programs (Nie et al. 1975). Differences between use and availability of each level of a habitat variable were simultaneously examined using the Bonferroni approach (Miller 1966:67).

Results

During 1980, 29 flights resulted in 438 locations of 19 cow elk. During 1981, 408 locations were made of 15 cow elk during 38 flights. Flights were made between 15 May and the end of hunting season each year. Field seasons were divided into 4 periods: calving, 15 May to 15 June; summer, 16 June to 31 August; rut, 1 September to the beginning of the hunting season; and the hunting season. The 1980 hunting season opened 20 October and closed 30 November. The 1981 hunting season ran from 25 October through 29 November.

In general, elk use increases with distance from human disturbance (Table 2). Elk use was significantly less than availability of areas within 500 m of human disturbances, except during the hunting seasons and the 1980 calving season. Areas greater than 2,000 m received 35 to 76% of the use during each season. Use of these areas was significantly greater than availability during the summer of 1981 and both rutting seasons. Use approximated availability in areas within 500 m of human disturbance during both hunting seasons, but over half the use was in areas farthest from disturbance.

Each location was classified as to the existence of a topographic barrier between that point and the nearest disturbance. Areas without topographic barriers were used less than available in 30 out of 40 seasonal distance categories (Figs. 17 through 20); 14 of these were significantly less than availability.

Table 1
(Edge 1982)

Distance to disturbance (m)	Calving Avail.	Calving Use	Summer Avail.	Summer Use	Rutting Avail.	Rutting Use	Hunting Avail.	Hunting Use
1980								
<500	11.0	8.1	19.4	3.7**	15.0	4.4**	4.0	10.2
501-1,000	11.4	13.5	201.	16.0	17.1	14.2	17.4	10.2
1,001-1,500	13.7	16.2	18.7	17.2	20.7	15.9	11.7	13.6
1,501-2,000	17.1	25.7	16.7	28.2*	16.4	19.5	14.7	14.8
>2,000	46.8	36.5	25.1	35.0	30.8	46.0*	52.2	51.1
N	299	74	299	163	299	113	299	88
1981								
<500	9.3	0.0**	13.7	0.6**	10.0	0.0**	7.0	1.6
501-1,000	18.0	41.2**	19.3	9.0**	19.3	26.4	16.7	21.0
1,001-1,500	10.0	8.8	10.3	10.3	10.0	8.5	10.0	4.8
1,501-2,000	11.7	14.7	10.0	3.8*	8.0	26.4**	9.7	6.5
>2,000	51.0	35.3	46.7	76.3**	52.7	38.8*	56.7	66.1
N	300	68	300	156	300	129	300	62

* P<0.05
** P<0.01

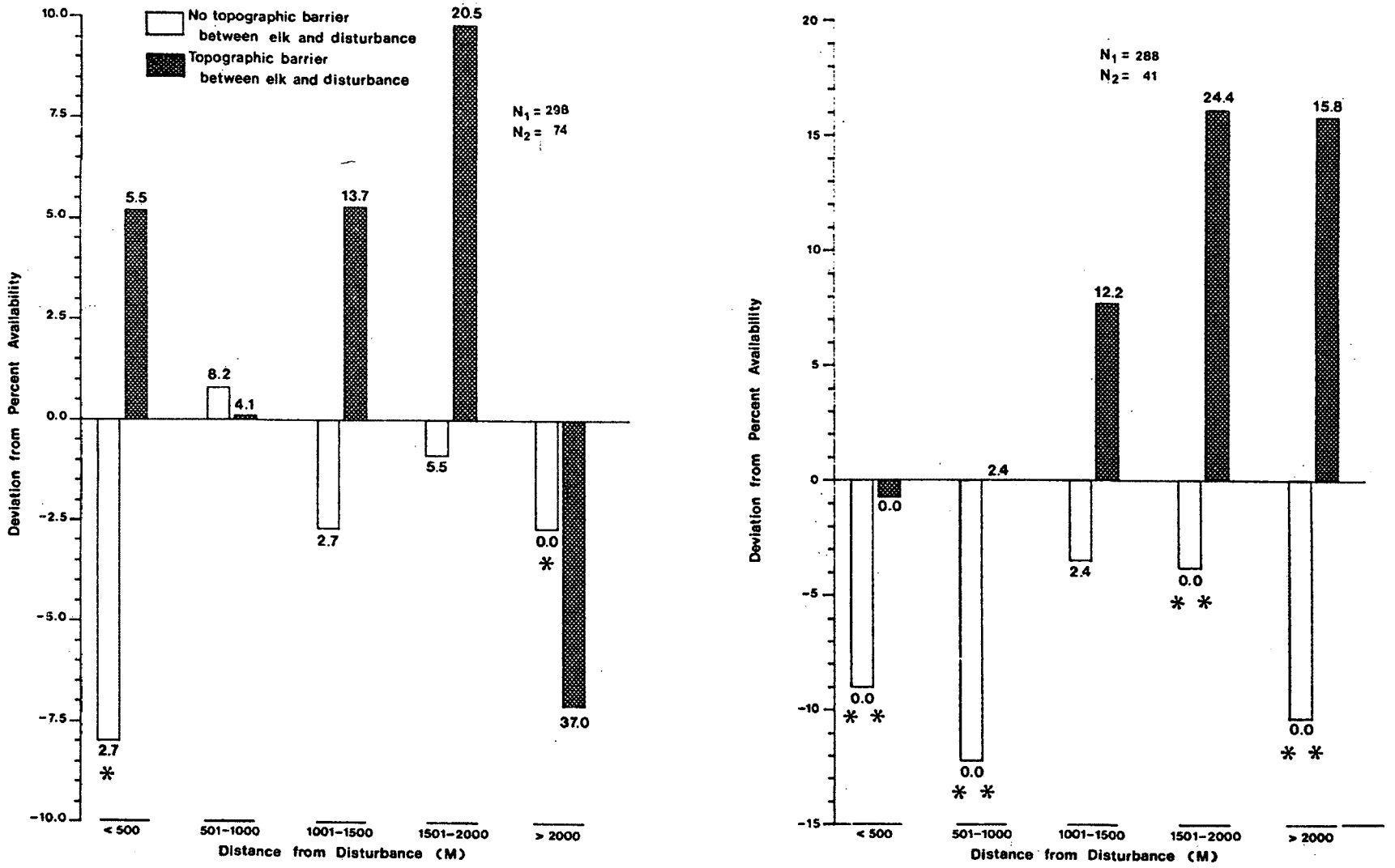


Fig. 17. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and topographic barrier during the calving season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

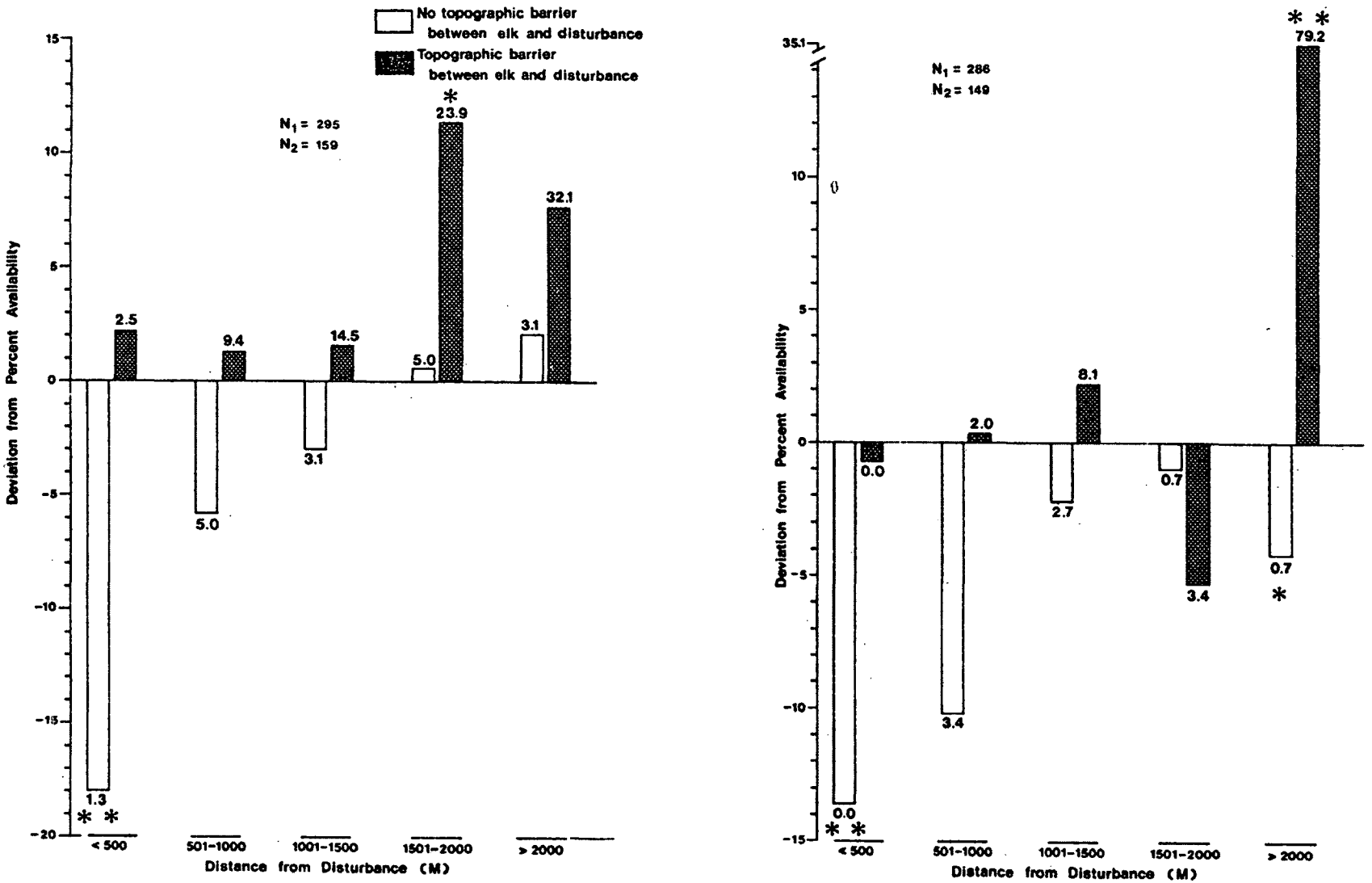


Fig. 18. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and topographic barrier during the summer season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

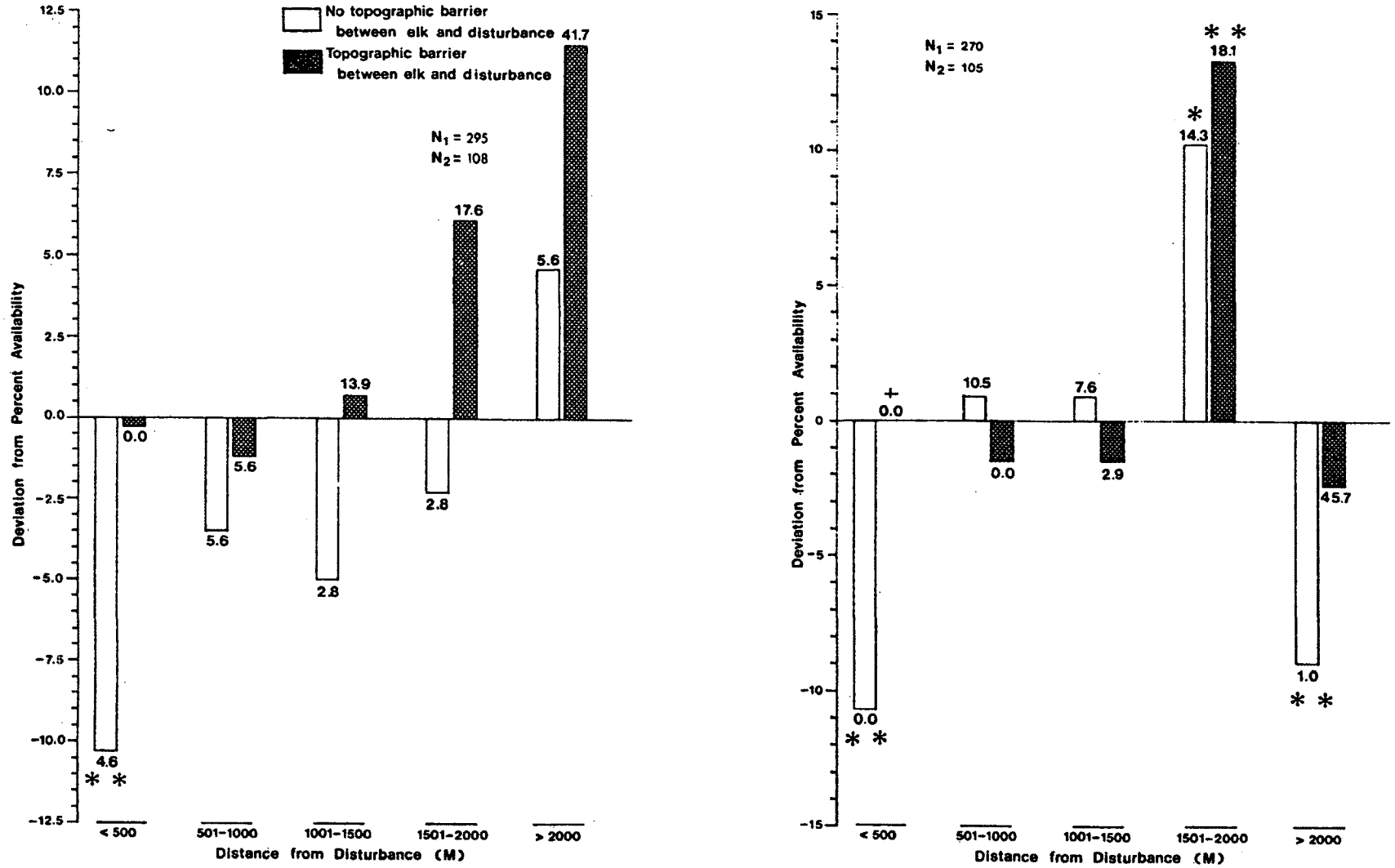


Fig. 19. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and topographic barrier during the rutting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%

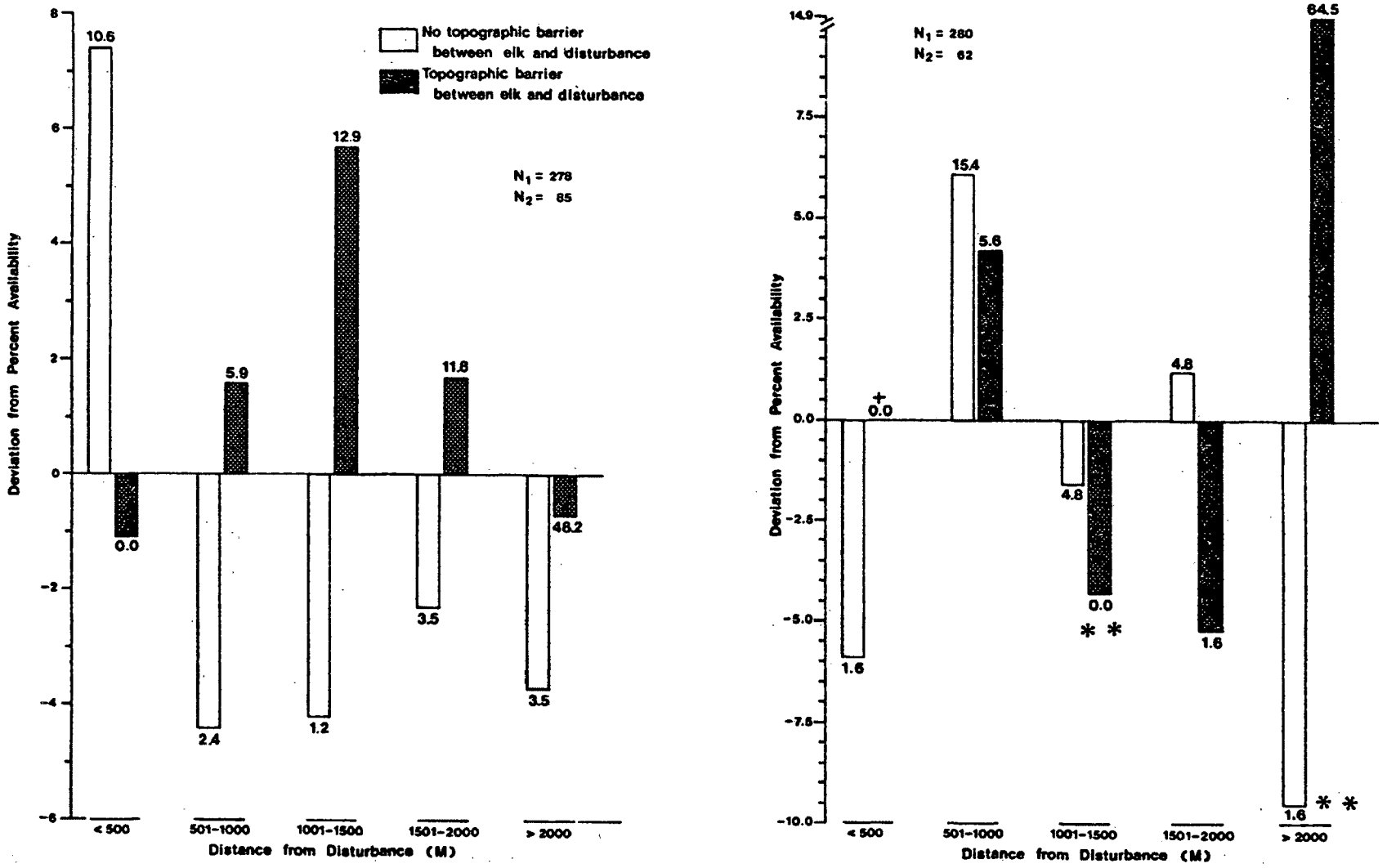


Fig. 20. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and topographic barrier during the hunting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%

Conversely, areas with topographic barriers were used in excess of their availability in 24 out of 40 seasonal distance categories, but only 3 of these were significantly different from availability. With the exception of the hunting seasons, use of areas without topographic barriers, within 500 m of human disturbance was always significantly less than availability. Appendix B contains the percent use and percent availability for each variable cross-classified by distance to nearest human disturbance.

Each location was categorized into one of the following canopy coverage classes: no trees within 0.4 ha, less than 25%, 25 to 75%, 75 to 95%, and 95 to 100%. Cross-classification of this variable by distance to disturbance was only possible during the summer and rutting seasons because of sample size. Use of all cover classes was less than availability, within 500 m of human disturbance (Figs. 21 and 22). Areas without trees within 1,500 m of disturbances were used less than availability, except during the summer of 1980. During that time, use of areas without trees was depressed within 1,000 m. Most use of areas without trees and with less than 25% canopy coverage was greater than 1,500 m from disturbance. Use of the 25 to 100% canopy coverage classes were highly variable beyond 1,000 m. During the rut of both years, areas beyond 500 m with 75-95% canopy coverage received the majority of use.

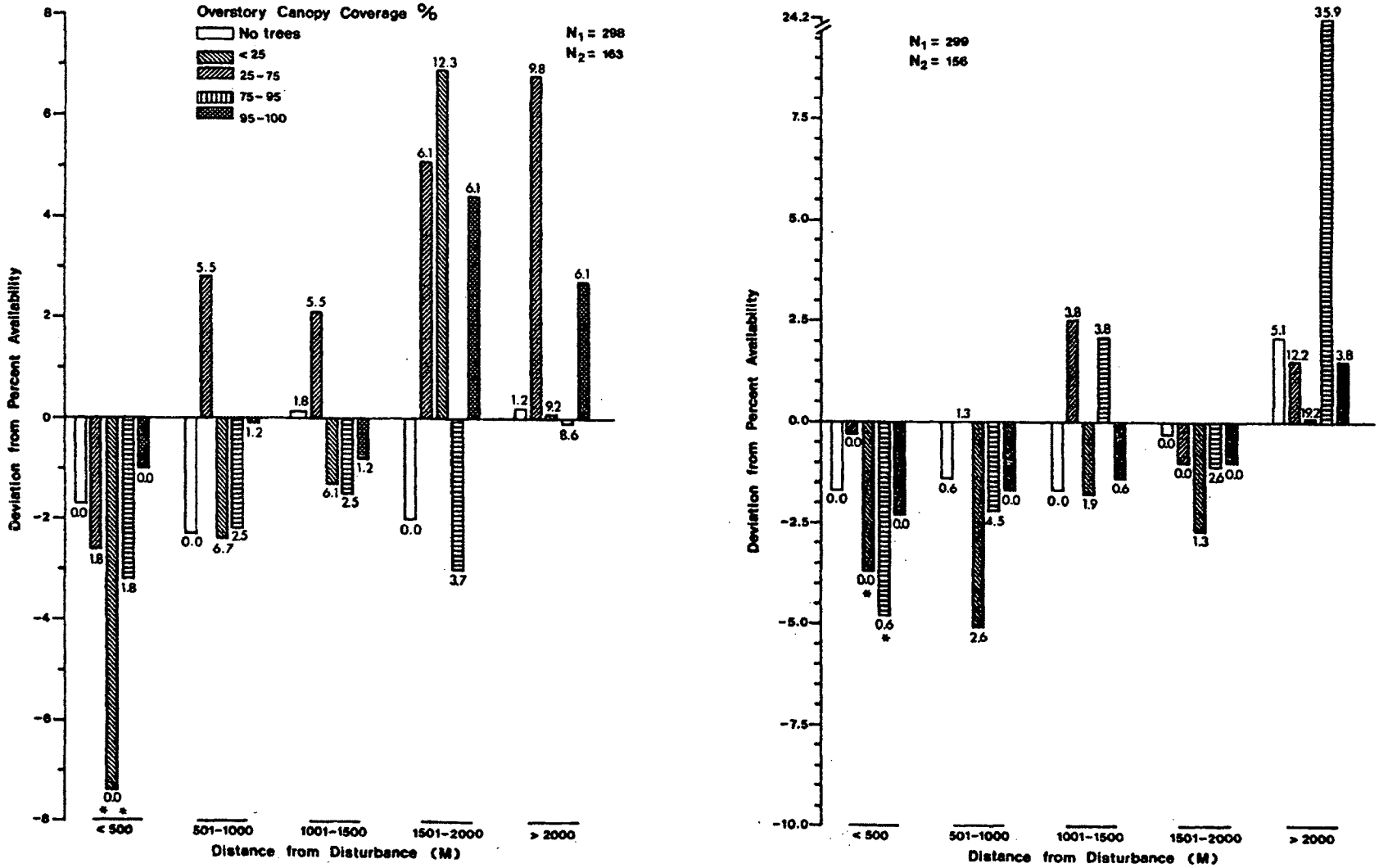


Fig. 21. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and overstory canopy coverage during the summer season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01)

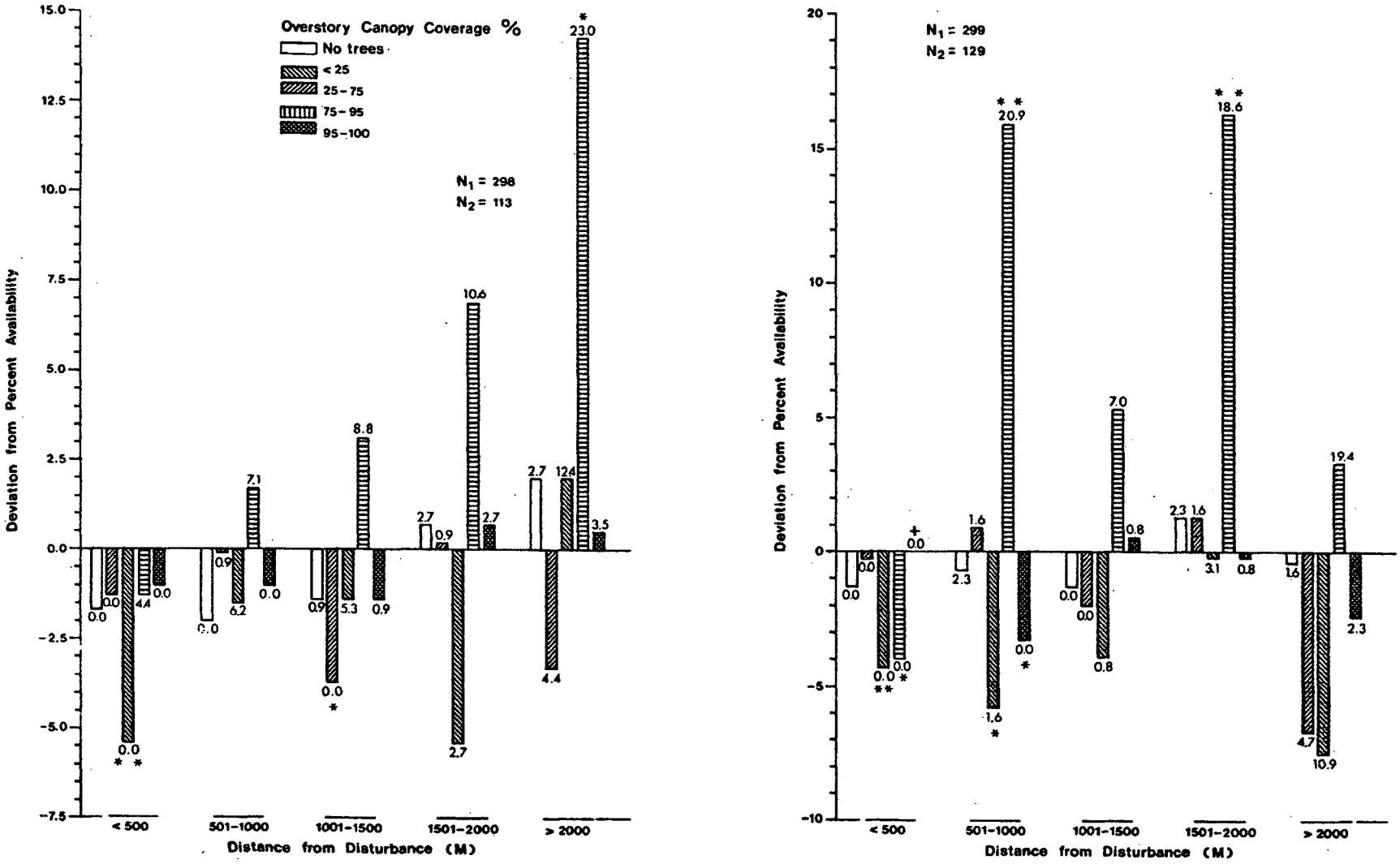


Fig. 22. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and overstory canopy coverage during the rutting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%

Locations were classified into 5 successional stages: grass-forb, brush-seedling-sapling, young-to-pole size mixed species stands, young-to-pole size lodgepole pine stands, and mature-to-old mixed species stands. Sample sizes were inadequate to cross-classify successional stages by distance to disturbance for the calving and hunting seasons. As expressed by the canopy coverage results, all successional stages within 500 m of disturbance were used less than their availability (Figs. 23 and 24). The young-to-pole size mixed species stands within 500 m were used significantly less than availabiility during 3 of 4 seasons. The grass-forb stage was always used less than availability within 1,500 m of disturbance. The majority of use was in young-to-pole size mixed species stands. No successional stages within 1,500 m of disturbance were used significantly in excess of their availability.

Discussion

Human disturbances, principally logging, displaced elk within 500 m regardless of the availability of cover. The 2 exceptions noted during this study were the 1980 calving season and both hunting seasons. Use of areas within 500 m of disturbance during the 1980 calving season was depressed, but not significantly. Two types of responses to human disturbance were noted during the hunting season. The large majority of elk moved more than 2,000 m away from the disturbance, often with a topographic barrier in between. Elk also used safety zones that were closed to hunting within a mile of human habitation or livestock

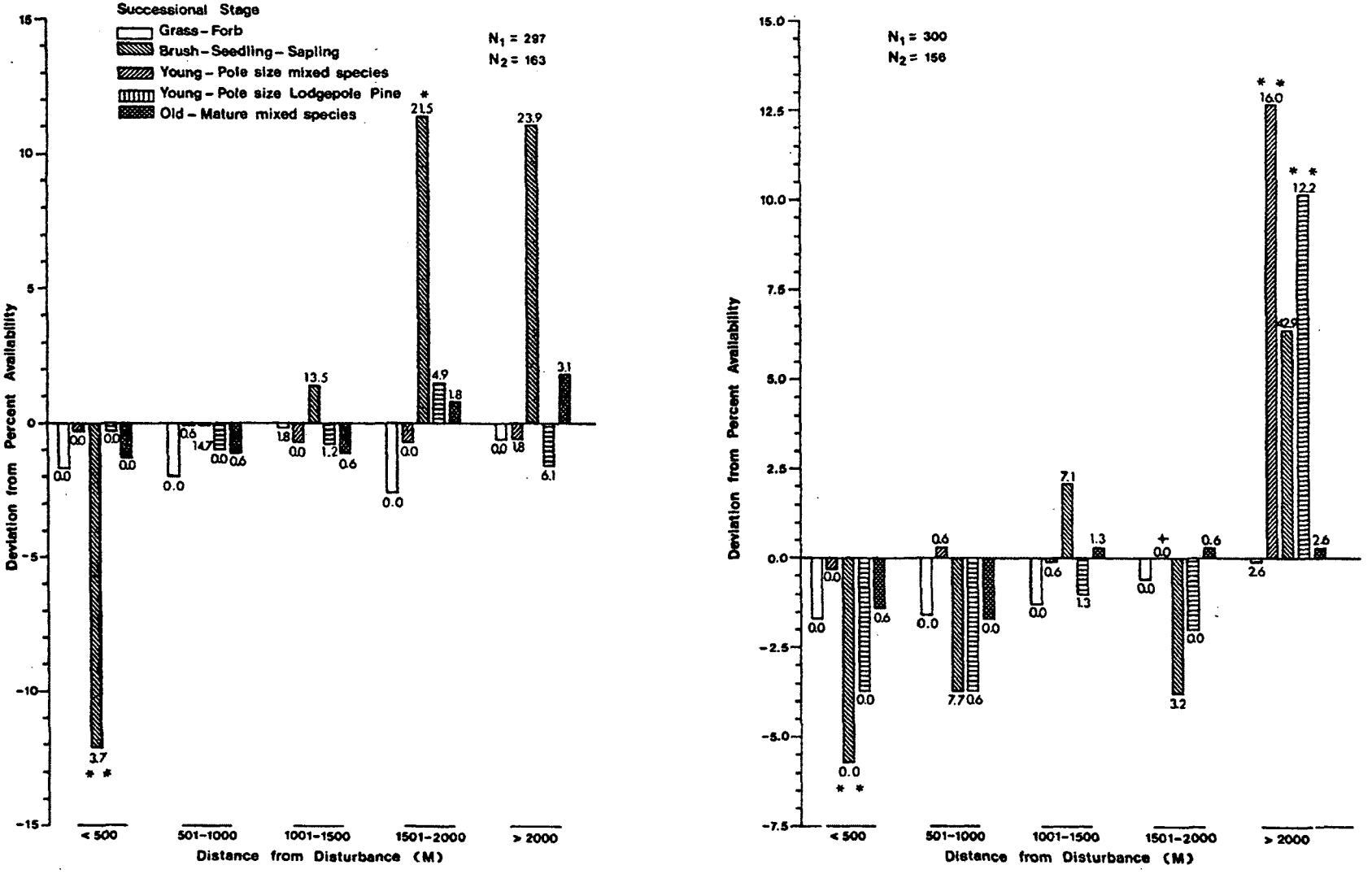


Fig. 23. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and successional stage during the summer season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%

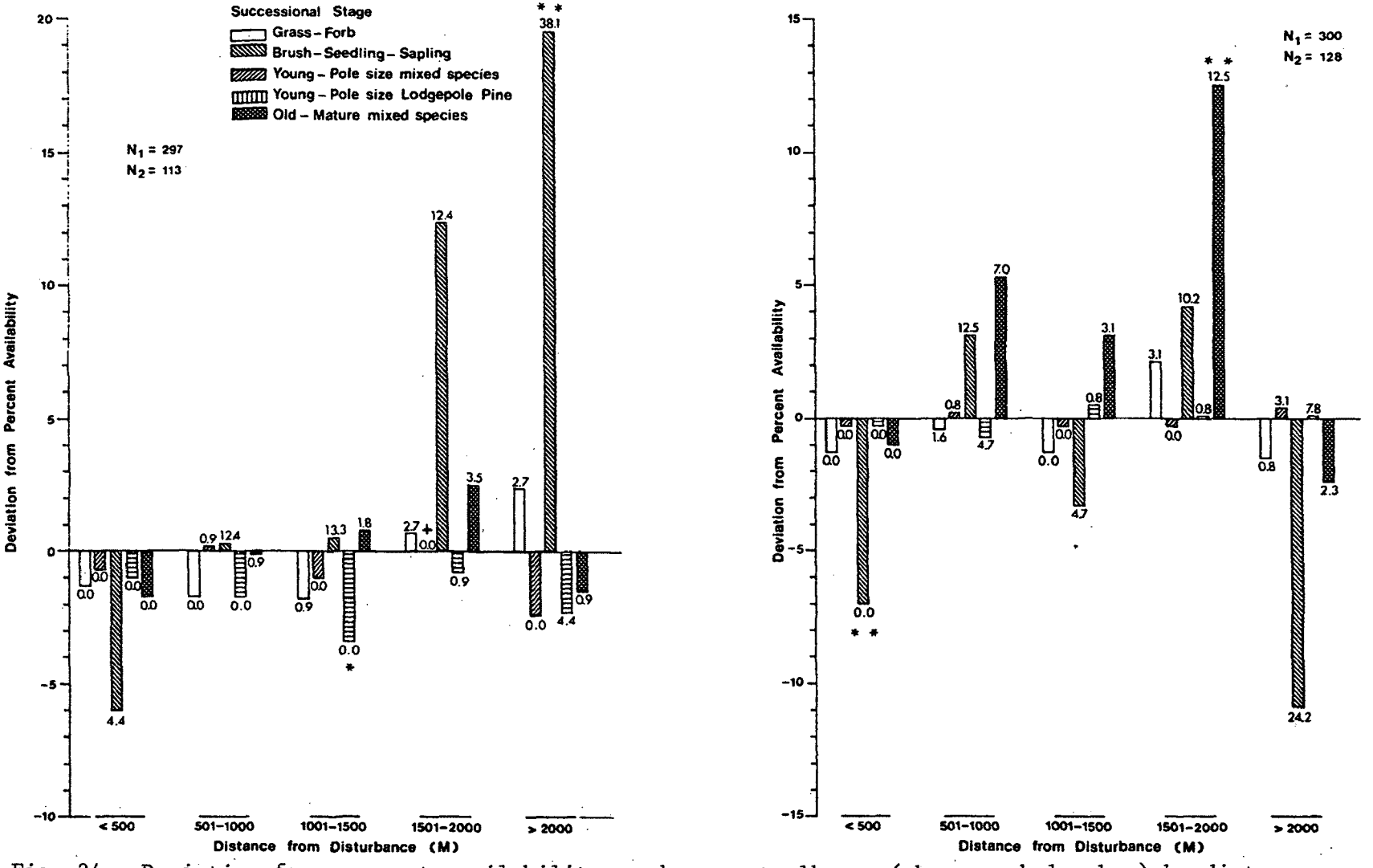


Fig. 24. Deviation from percent availability, and percent elk use (above or below bar) by distance to human disturbance and successional stage during the rutting season of 1980 (left) and 1981 (right). * (P<0.05) ** (P<0.01) + Availability < 0.05%

concentrations. These areas received no hunting pressure. Lieb (1981), also working at Chamberlain Creek, noted that use during the hunting season was primarly restricted to portions of the study area outside the areas of intensive hunter use. During the calving, summer, and rutting seasons, use was not only depressed within 500 m, but also increased with distance from human disturbance.

Reports of elk avoidance of areas near human disturbance are widespread in the literature, and the extent of displacement appears to be dependent upon the type of disturbance. Hayden-Wing (1979) felt that elk distributions on a winter range in southeastern Idaho were primarly influenced by man's activities. Elk in Rocky Mountain National Park exhibit greater flight distances from people than from vehicles (Schultz and Bailey 1978). Ward (1976) reported that elk in Wyoming were seldom found within 400 m of any human activity. Elk use was depressed within 800 m of human activity associated with homes and was more affected by this activity than logging (Ward et al. 1980). Daneke (1980) noted that distance to roads during the hunting season was only one factor in elk security; difficulty of access, as influenced by snow depth, terrain, and cover were also important factors. Logging activities in elk habitat have been shown to significantly reduce elk use from 800 m (Ward 1976, Lehmkuhl 1981) to 1,600 m (Long et al. 1980), and even up to 8,000 m (Lyon 1979b).

My results indicate that topographic barriers were more consistently used as cover than vegetation. However, forests cover approximately 85% of the study area, and therefore, vegetative cover is highly available. Basile and Lonner (1979) noted that security for elk was not significantly enhanced by road closures in areas with greater than 60% cover. All vegetation classes as well as areas without topographic barriers were avoided within 500 m of human disturbance. Only areas with topographic barries were used above availability within 500 m. Areas with topographic barriers consistently received a disproportionate amount of use each season. Conversely, no successional stage or overstory canopy coverage classification was consistently preferred within 1,500 m. Lieb (1981) felt that elk response to human disturbance was modified by habitat factors such as physiography and availability of escape cover. Lyon (1979b) reported that elk moved away from areas that had direct line-of-sight contact with a source of disturbance. Human disturbance, particularly logging will impact elk habitat use to a greater extent in areas of little topographic relief, large drainages without secondary ridge systems, and where the disturbances occur on ridgelines. Lyon(1979b) reported that elk were displaced as much as 5 miles from ridgeline disturbances.

Although less obvious, vegetative cover does appear to reduce the effect of human disturbance upon elk use of adjacent habitat. Schwartz and Mitchell (1945) noted that frequent islands of cover increased elk use of logged areas. Perry and Overly (1976) reported that a minimum reduction in elk use occurred adjacent to roads in dense forest cover.

Lyon (1979a) stated that the "distance [from roads] at which no further increase [in elk use] occurred was substantially reduced by the presence of cover." My results indicate that early successional stages and areas with less than 25% overstory canopy coverage will result in a reduction in elk use from 1,000 to 1,500 m from disturbance. Elk will be displaced from preferred habitats for at least 500 m surrounding disturbance. Lehmkuhl (1981) and Marcum and Edge (1982) reported that the young-to-pole size mixed species stands received a large amount of use during all seasons. This type of stand received the majority of use during this study, but was avoided or selected against within 500 m of disturbance. Approximately 85% of the Chamberlain Creek study area is forested to some extent, and vegetative cover is abundant. This abundance of vegetative cover probably masked the relationship between cover and disturbance. Disturbance in areas with less forest cover can be expected to produce significant reductions in elk use well beyond 500 m.

In summary, human disturbance, principally logging, reduced elk use within 500 m from calving season through rutting season. Elk use generally increased with distance from disturbance. Topographic barriers between elk and disturbances were more consistently used than vegetative cover, especially within 1,000 m, probably because of the abundance of vegetative cover in the study area. Elk use of early successional stages and areas with less than 25% overstory canopy coverage was reduced from between 1,000 and 1,500 m. Use of preferred habitat was greatly reduced within 500 m. Elk response during hunting

was of 2 types: long flight distances and associated use of topographic barriers and use of safety zones closed to hunting in close proximity to human habitation. Human activity will adversely effect elk habitat use in areas with little topographic relief, large drainages without secondary ridge systems, and in areas without high percentages of forest cover.

CHAPTER IV

MOVEMENTS AND DISTRIBUTION OF ELK IN RELATION TO LOGGING DISTURBANCES IN WESTERN MONTANA

Movements have been used to assess short term responses of animals to human disturbance in a number of studies. Mean daily movements were used by Folk and Marchinton (1980) to examine turkey (Meleagris gallopavo) responses to deer hunters, and by Singer et al. (1981) to assess wild boar (Sus scrofa) reactions to hikers. Distance between successive locations for white-tailed deer (Odocoileus virginianus) (Dorrance et al. 1975) and grey squirrels (Sciurus carolinensis) (Nixon et al. 1980) and flight distances of bald eagles (Haliaeetus leucocephalus) (Stalmaster and Newman 1978) have also been used to examine animal responses to human disturbances. Renouf et al. (1981) counted the number of harbor seals (Phoca vitulina) and grey seals (Halichoerus grypus) seabound and inbound to their hauling grounds, before and after human visitation. Several studies (Beall 1976, Knight 1980, Kvale 1980, Long et al. 1980, and Lieb 1981) have examined elk (Cervus elaphus) movements relative to human disturbances. However, with the exception of the study by Renouf et al. (1981), these studies did not analyze data in respect to direction of movement. These studies all concentrated on the magnitude of movement; direction of movements were descriptively examined, if at all.

The objective of this study was to examine the movements and distribution of elk in relation to logging disturbance, with special emphasis on the direction of movements. This study was conducted in conjunction with the Chamberlain Creek elk-logging project.

Study area

The Chamberlain Creek study area is located in the northern Garnet Mountains, 56 km east of Missoula, Montana (Fig. 25). Radio-collared elk use a 23,300 ha area which ranges in elevation from 1,160 to 2,090 m. The core study area (CSA), the area in which the movements were primarily examined is approximately 2,300 ha. Topography is a series of moderate sloping primary and secondary ridges, separated by 9 second and third order stream systems. The Blackfoot River borders the study area on the north and west.

Forests cover approximately 85% of the area. Habitat Types (Pfister et al. 1977) are within the Douglas-fir (Pseudotsuga menziesii) and subalpine fir (Abies lasiocarpa) series. Cover types vary depending upon elevation. Higher elevations are primarly lodgepole pine (Pinus contorta) stands, as a result of burns within the last century, and residual old growth stands of subalpine fir and Engelmann spruce (Picea engelmanii). Mid-elevation sites are characterized by Douglas-fir or Douglas-fir and western larch (Larix occidentalis) stands. Lower elevations are primarly Douglas-fir with ponderosa pine (Pinus ponderosa) as a codominant on drier sites. The remainder of the area is typified by pastures and hayfields at lower elevations, and natural meadows and clearcuts dispersed throughout the study area. Topography

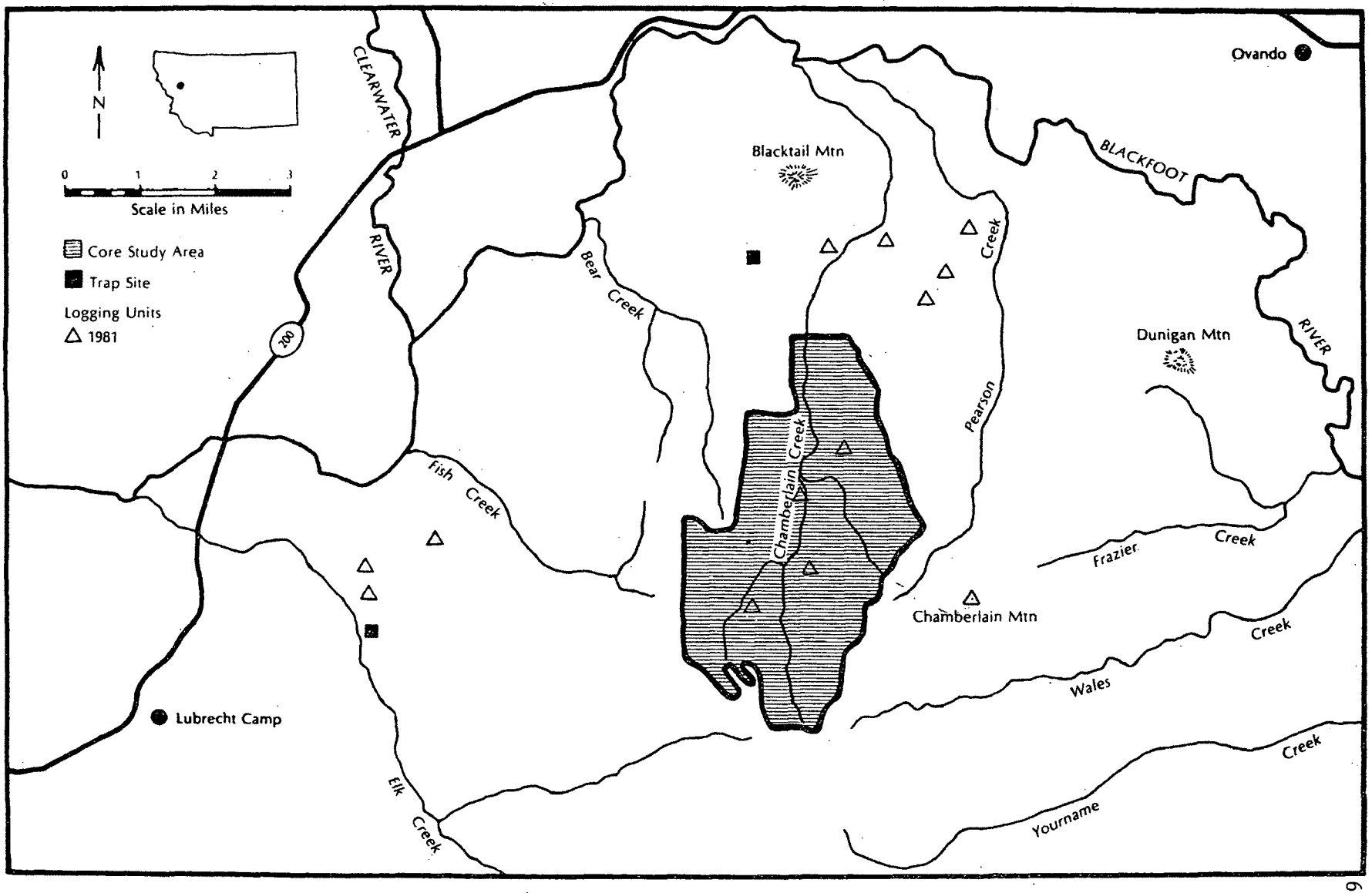


Fig. 25. The Chamberlain Creek Study Area.

and vegetation of the area are throughly described by Scott (1978) and Lehmukhl (1981).

The climate is characterized by cool, moist winters and warm, dry summers. Mean monthly temperatures range from -8.4 °C in January to 16.8° C in July (Steele 1981). The mean annual precipitation is 44.7 cm, the majority of which falls between December and June.

Logging is the principal land use. Approximately 55% of the area has been logged within the past 50 years, with some type of partial cutting as the main silvicultural system. Grazing by cattle or horses occurs between June and October in most of the area except the CSA, which is fenced. The primary recreational activity is big game hunting. The study area lies within the Blackfoot Special Management Area, which is closed to vehicle access from 1 September to 1 December. Vehicle traffic the rest of the year is generally light, with the exception of roads used for active logging sales.

Several sources of disturbance occurred during 1981. A salvage operation was conducted on the south slope of Blacktail Mountain during May and June. Four partial cuts and 2 small clearcuts were logged within the CSA from August through October. Two large areas were selectively logged in the East Fork of Chamberlain Creek from September through November.

Methods

Elk were trapped in corral-type traps baited with alfalfa during January through March, and baited with salt April through August. Elk were aged, based on incisor replacement (Quimby and Gaab 1957) and wear. Polyvinal Chloride encased (Pedersen 1977), 150-151 MHz transmitters were placed on each animal. Elk were located from an airplane on a weekly basis, weather permitting, from 13 May to 30 November, 1981. Animals in close proximity (< 2 km) to active or proposed logging sales were located from the ground using radio triangulation between August and October. Bearings to elk were taken 2 or 3 times a day from high, treeless areas using a hand-held, 2-element yagi antenna system. Usually 3 bearings were used to fix locations. Bearings were generally taken within 30 minutes of each other. Elk movements were assumed to be minimal during the interval between bearings. The accuracy of the tracking system was tested by taking 79 bearings on known-location transmitters. Ninety-five percent error arcs ($\theta = 11.96^{\circ}$) were calculated. Actual movements were separated from equipment error using error polygons derived from these arcs (Springer 1979).

The data were analyzed using a DEC-20 computer and a package of statistical programs (SPSS, Nie et al. 1975). The NPAR TESTS subprogram was used to conduct Runs test and Mann-Whitney U tests (Siegel 1956).

Results

Fifty-six aerial and 296 ground locations were made on 9 cow elk between 12 August and 30 September 1981. Only 61 ground locations were retained after error polygons were examined (Springer 1979). With 3 exceptions, no 2 ground locations obtained during 1 day, for any elk, could be separated from equipment error. Usually 2 or 3 days and often as much as a week elapsed between distinct separation of error polygons. For each location, 3 measurements were made on a topographic map: distance to nearest logging disturbance; total distance moved between successive locations; and the net distance moved between successive locations, relative to the nearest logging unit.

The mean distance to logging for all locations was 1,932 m. When examined by day of week, distances were significantly greater ($P=0.0012$) on weekdays ($X=2,065$ m) than on weekends ($\bar{X}=1,202$ m). Four of 7 individual elk, with weekend locations, were closer to logging on the weekend than during the week (Table 3; H1). Three bearings placed elk number 1020 (Fig. 26) within a logging unit during the weekend of 12 September. Error polygons for 3 other locations overlapped logging units on weekends. No weekday locations were close enough for error polygons to overlap logging units.

The mean total distance moved between all successive locations was 1,389 m. Locations were separated into groups based upon direction of movement relative to the nearest logging unit. Total distances moved

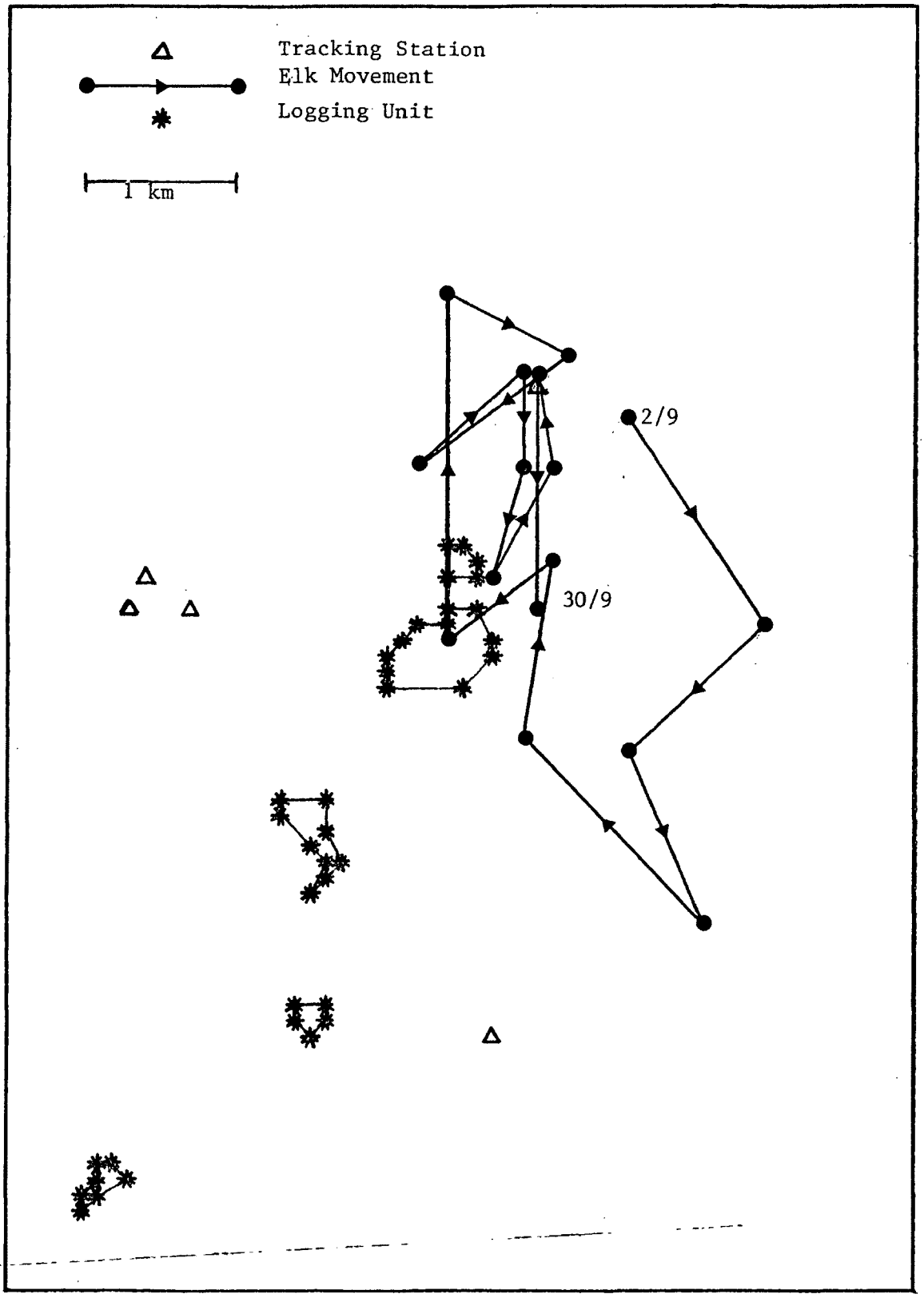


Fig. 26. Movements of cow elk number 1020 relative to logging disturbances, summer 1981.

TABLE 3. P-values associated with test of hypotheses on distance to logging units, and movements for individual elk, summer 1981.

Elk no.	Alternative Hypotheses H1*	H2*	H3*	H4*	H5*	H6**	N
1010	0.1558	0.2088	0.3303	0.4324	0.0640	0.6875	13
1020	0.0131	0.3214	0.1015	0.1009	0.4326	0.2736	15
1050	0.0093	0.2089	0.2603	0.1561	0.3579	0.9857	15
2050	0.2593	0.2919	0.4278	0.3187	0.4068	1.0000	11
2093	+	0.5000	0.4400	+	+	1.0000	8
3030	0.0478	0.0385	0.0787	0.0607	0.0607	1.0000	7
3101	0.0513	0.0111	0.5470	0.1265	0.1265	1.0000	10
3111	0.0160	0.0749	0.0813	0.4470	0.2747	0.3983	19
3120	+	0.5000	0.2818	+	+	0.0562	8

* Mann-Whitney U
** Runs test of randomness
+ No weekend locations
H1 Distance to logging on weekday > weekend.
H2 Total distance moved towards logging < away from logging.
H3 Net distance moved towards logging < away from logging.
H4 Total distance moved on weekday > weekend.
H5 Net distance moved on weekday > weekend.
H6 Movements in relation to logging are not at random.

between successive locations for all elk were significantly greater for movements away from disturbance than for movements toward disturbance (Table 4). Two elk individually showed significantly greater movements away from than toward logging units (Table3; H2).

The net distance moved between locations relative to logging units was 852 m. A significant difference was noted between all net movements away from logging, and those towards logging (Table 4). However, no individual elk showed significant differences between net movements by direction (Table 3; H3). No significant differences were found in total or net movements between successive locations by day of week for individual elk (Table 3; H4 and H5) or for all movements combined (Table 4). A Runs test of randomness was done on each elk to determine whether direction of movement occurred at random. All individual elk moved at random in respect to the logging units (Table 3; H6).

Discussion

Normal summer movements were short in Chamberlain in 1981 and were probably a response to available forage. Chamberlain elk showed a mean movement between successive locations of 1,389 m, and usually 2 or 3 days were required to separate true movements from bearing error. Craighead et al. (1973) and Schoen (1977) reported that elk rarely move more than 1 mile in 24 hours. Irwin (1978) noted that elk move approximately 1,000 m in one day. Schwartz and Mitchell (1945) and Mackie (1970) reported that elk movements were primarly related to

TABLE 4. Total and net movements of 9 cow elk between successive locations, by direction of movement and day of week, summer 1981.

	Direction of Movement				Day of Week			
	Towards		Away		Weekday		Weekend	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
Gross movements								
(m)	58	1134*	50	1686	90	1476	18	956
Net movements								
(m)	58	670*	50	1063	90	892	18	651

* Significant difference between groups (Mann-Whitney U test) ($P<0.05$).

forage availability and preference. Lieb (1981) noted that Chamberlain elk concentrate their activity to "preferred spots" until moving to other preferred areas.

My results indicate that normal movements are modified by disturbances. Both total and net movements were greater when moving away from disturbances than towards. However, movements occurred at random in respect to disturbance. This indicates that elk move in a normal fashion until some stimuli associated with the logging activity causes a flight response, culminating in a movement which is longer than normal. Beall (1976), Lyon (1979b), Long et al. (1980) and Lieb (1981)all reported long flight distances when elk were disturbed by logging activity.

Ward and Cupal (1979) suggested that elk maintain a buffer zone of approximately 800 m from human disturbance. My results show that elk maintain a mean distance of approximately 2,000 m from active logging units, and a buffer zone of at least 500 m and probably 1,000 m. Once this buffer zone is established, elk move in a random fashion, probably in response to forage as discussed earlier.

On the weekends, during which there was no disturbance, elk responded by moving into or near logging units. Chamberlain elk were significantly closer to these units on weekends than during the week, and 4 locations could not be established as being outside the logging units. However, no difference was noted in either total or net movements between weekends and weekdays. Elk apparently respond rapidly to periods of non-disturbance, moving into more preferred areas, and

decreasing buffer zones. Length of movements were not different, indicating that return movements were gradual in nature.

Return movements probably represent elk response to increased availability of some habitat factor, or reoccupation of preferred home range areas, rather than habituation to disturbance because elk rapidly moved away once logging began again. Other studies (Lyon 1979b, and Lieb 1981) have reported that elk moved back into logged areas, but not until the operation shut down completely. Beall (1976) reported a gradual return of elk to the vicinity of an active logging sale, during the early spring when the summer range was unavailable. Sweeney et al. (1971) and Hood and Inglis (1974) noted that white-tailed deer return to approximately the same location within 1 day after being displaced by disturbance.

Habituation may occur depending upon the duration or extent of disturbance. Bergerud (1974) and Schultz and Bailey (1978) felt that habituation by caribou (Rangifer tarandus) and elk respectively, occurs relatively rapidly to frequent stimuli depending upon severity. Dorrance et al. (1975) suspected that white-tailed deer habituated over time to snowmobile disturbance. Beall (1976) and Long et al. (1980) felt that elk may habituate to logging disturbances if logging occurs over a long period of time. Hanson (1981) reported that caribou show some habituation to stationary pipeline facilities. Knight (1980) reported that elk may habituate to stationary oil wells, but not to the irregular disturbance of seismic exploration.

Habituation to logging disturbances may have reduced to some extent the displacement of Chamberlain elk. The Chamberlain Creek study area has a history of extensive logging with the exception of the CSA. This stimulus is regular temporally, but irregular in spatial distribution. Lyon (1979b) suspected that 5 consecutive years of logging may have imposed a learned behavior which contributed to a delayed return to logged areas. The CSA is a primary summer range for Chamberlain elk, and during the summer of 1981 received a disproportionate amount of use (Marcum and Edge 1982). However, logging in this area, for the first time, may have magnified the response to disturbance. Regardless of the extent of habituation, or the amount of use during inactive periods, logging displaces elk within 500 to 1,000 m of the disturbance. This effectively reduces the availability of those habitats, and conversely, may increase elk use of habitat beyond these limits.

In summary, normal elk movements in the Chamberlain Creek area are short and probably a result of forage availability. Movements away from disturbance are longer than those toward disturbance, but all movements are random in respect to the source of disturbance. Elk tend to move back into areas of disturbance on weekends, but the movements are probably a response to increased accessibility of some habitat factor rather than habituation to the disturbance. A buffer zone of at least 500 m and perhaps 1,000 m separates areas of high elk use from areas of disturbance. Habituation may act to decrease this buffer zone. This displacement of elk can cause substantial reductions in habitat availability.

CHAPTER V

SUMMARY AND CONCLUSIONS

Elk movements and habitat use in relation to roads and human disturbances in western Montana were studied between May and December during 1980 and 1981. Twenty-seven radio-collared cow elk were located from an airplane a total of 846 times. An additional 61 locations were made by ground tracking 9 elk between 12 August and 30 September 1981. Habitat variables and distances from roads and human disturbances were classified or measured from aerial photographs and topographic maps. Percentage of use in each level of a habitat variable was compared to its percentage availability as determined by a series of random points.

Elk response to open roads varied with season, traffic volume, and cover provided by topography and vegetation. Elk were displaced more by heavily traveled roads than by lightly traveled roads from calving through rutting seasons. Areas with topographic barriers between the nearest road were generally preferred over areas without topographic barriers. Areas without tree cover had depressed elk use within 750 m of an open road. Conversely, elk use was not significantly reduced within 500 m if overstory canopy coverage exceeded 25%. The proximity of open roads to water was not a factor in elk avoidance of areas near water.

Roads designed to avoid natural openings and take advantage of topographic barriers will have less impact on elk habitat use. Roads should be routed away from water sources in areas of low water availability. Closure of roads following timber sales will benefit habitat effectiveness for elk. In areas where year-round road closures impact other uses, closures during the hunting season will lower elk susceptibility to hunters, and will act to increase habitat effectiveness over levels prior to the closure.

Human disturbances, primarly logging, significantly reduced elk use within 500 m from calving through rutting season. Elk use, in general, increased with distance from disturbance. Areas with topographic barriers between elk and disturbances were more consistently preferred than areas with high vegetative cover, but vegetative cover was abundant in the study area. Areas in early successional stages and areas with less than 25% overstory canopy coverage had reduced elk use within 1,000 to 1,500 m of disturbance. Use of preferred habitats was greatly reduced within 500 m.

Elk response to roads and human disturbances during the hunting season was either long flight distances and associated use of topographic barriers, or use of safety zones closed to hunting in relatively close proximity to human habitation. Human activity will impact elk most in areas with little topographic relief or forest cover, and in large drainages without secondary ridge systems.

Normal elk movements were short and probably related to the availability of forage. Normal movements were modified by logging disturbances. Elk moved greater distances away from logging disturbances than towards them. Elk responded to weekend shutdowns by moving significantly closer to the logging units. Return movements probably represented elk response to an increased availability of a preferred habitat factor, or reoccupation of preferred home range areas. Habituation, if it occurred, may have acted to reduce the buffer zone effect, which was at least 500 m. Regardless of habituation, logging in elk habitat will displace elk from at least the first 500 m surrounding the disturbance, effectively reducing habitat availability.

REFERENCES CITED

Allen, E.O. 1977. A new perspective for elk habitat management. Proc. West. Assoc. State Fish and Game Comms. 57:195-205.

Baglien, J.W. and D.E. Biggins. 1976. A plan for elk management by habitat manipulation. Pages 81-84 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Basile, J.V., and T.N. Lonner. 1979. Vehicle restrictions influence elk and hunter distribution in Montana. J. For. 77:155-159.

Beall, R.C. 1976. Elk habitat selection in relation to thermal radiation. Pages 97-100. in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Beaufait, W. 1976. Integration of wildlife objectives with other forest goals and objectives. Pages 88-90 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Bergerud, A. 1974. The role of the environment in the aggregation, movement and disturbance behavior of caribou. Pages 552-584 in V. Geist and F. Walther, eds. The behavior of ungulates and its relation to management. ICUN Publ. New Series 24.

Bohne, J.R. 1974. Food habits, seasonal distribution, and habitat utilization of elk in the South Fork of Fish Creek, Lolo National Forest, Montana. M.S. Thesis. Univ. Mont., Missoula. 187pp.

Boyd, R.J. 1978. American elk. Pages 11-29 in J.L. Schmidt and D.L. Gilbert, eds. Big game of North America ecology and management. The Stackpole Co., Harrisburg, Penn.

Burbridge, W.R., and D.J. Neff. 1976. Cocoino National Forest-Arizona Game and Fish Department Cooperative roads-wildlife study. Pages 44-57 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Collins, W.B. 1979. Feeding behavior and habitat selection of deer and elk on northern Utah summer range. Ph.D. Thesis, Utah State Univ., Logan. 112pp.

Cooney, R.F. 1952. Elk problems in Montana. J. Range Manage. 5:3-7.

Craighead, J.J. 1952. A biological and economic appraisal of the Jackson Hole elk herd. N. Y. Zool. Soc., and Conserv. Foundation. New York. 32pp.

_____,F.C. Craighead, Jr., R.L. Ruff, and B.W. O'Gara. 1973. Home ranges and activity patterns of nonmigratory elk of the Madison drainage herd as determined by biotelemetry. Wildl. Monogr. 33. 50pp.

Daneke, D.E. 1980. Forage selection and population structure of the Middle Fork elk herd. M.S. Thesis. Univ. Mont., Missoula. 74pp.

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

Folk,III,R.H., and R.L. Marchinton. 1980. Effects of intensive deer hunting on behavior of wild turkeys. J. Wildl. Manage. 44:922-927.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologist. John Wiley and Sons, New York. 257pp.

Gruell, G.E., and G. Roby. 1976. Elk habitat relationships before logging on Bridger-Teton National Forest, Wyoming. Pages 110-121 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Hanson, W.C. 1981. Caribou (Rangifer tarandus) encounters with pipelines in north Alaska. Can. Field Nat. 95:57-62.

Hayden-Wing, L.D. 1979. Distribution of deer, elk and moose on a winter range in south-eastern Idaho. Pages 122-131 in M.S. Boyce, and L.D. Hayden-Wing, eds. North American elk: ecology, behavior and management. Univ. Wyoming, Laramie.

Hershey, T.J., and T.A. Leege. 1976. Influences of logging on elk on summer range in north-central Idaho. Pages 72-80 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Hood, R.E., and J.M. Inglis. 1974. Behavioral responses of white-tailed deer to intensive ranching operations. J. Wildl. Manage. 38:488-498.

Irwin, L.L. 1978. Relationships between intensive timber culture, big game habitats, and elk habitat use patterns in northern Idaho. Ph.D. Thesis. Univ. Idaho, Moscow. 282pp.

_____, and J.M. Peek. 1979. Relationship between road closures and elk behavior in northern Idaho. Pages 199-204 in M.S. Boyce, and L.D. Hayden-Wing, eds. North American elk: ecology, behavior and management. Univ. Wyoming, Laramie.

Knight, J. E., Jr. 1980. Effects of hydrocarbon development on elk movements and distribution in northern Michigan. Ph.D. Thesis. Univ. Mich., Ann Arbor. 79pp.

Knight, R.R. 1970. The Sun River elk herd. Wildl. Monogr. 23. 66pp.

Kvale, C.T. 1980. Preliminary phosphate mining impacts on mule deer, elk and moose in southwestern Idaho. Proc. Annu. Conf. West Assoc. Fish Wildl. Agencies. 60:527-546.

Lehmkuhl, J.F. 1981. Distribution and habitat selection of elk in the north Garnet Mountains of western Montana. M.S. Thesis. Univ. Mont., Missoula. 130pp.

Lemke, T.O. 1975. Movement and seasonal ranges of the Burdette Creek elk herd, and an investigation of sport hunting. M.S. Thesis. Univ. Mont. 127pp.

Lieb, J.W. 1981. Activity, heartrate, and associated energy expenditure of elk in western Montana. Ph.D. Thesis. Univ. Mont. 200pp.

Long, B., M. Hinschberger, G. Roby, and J. Kimbal. 1980. Gros Ventre cooperative elk study final report 1974-1979. Wyo. Fish and Game Dept., and USDA For. Serv. 192pp.

Lonner, T.N., and J.D. Cada. 1982. Some effects of forest management on elk hunting opportunities. West. States Elk Workshop, Mimeo. 15pp.

Lyon, L.J. 1971. A cooperative research program: effects of logging on elk in Montana. Proc. West. Assoc. State Game and Fish Comms. 51:447-457.

_____.1979a. Habitat effectiveness for elk as influenced by roads and cover. J. For. 77:658-660.

_____.1979b. Influences of logging and weather on elk distribution in western Montana. USDA For. Serv. Res. Paper INT-236. Intermountain. For. and Range Exp. Sta., Ogden, Utah. 11pp.

_____.1980. Coordinating forestry and elk management. Trans. No. Amer. Wildl. and Natur. Resour. Conf. 45:278-287.

_____, and C.E. Jensen. 1980. Management implications of elk and deer use of clear-cuts in Montana. J. Wildl. Manage. 44:352-362.

Mackie, R.J. 1970. Range ecology and relations of mule deer, elk and cattle in the Missouri River Breaks, Montana. Wildl. Monogr. 20. 79pp.

Marcum, C.L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Ph.D. Thesis, Univ. Mont., Missoula. 188pp.

_____, and W.D. Edge. 1982. Job II-D, Chamberlain Creek study. in press Ann. Prog. Rept. Mont. Coop. Elk-logging Study. 64pp.

_____, and D.O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. J. Wildl. Manage. 44:963-968.

Miller, R. 1966. Simultaneous statistical inference. McGraw-Hill Book Co., New York. 272pp.

Mont. Dept. Fish and Game. 1978. Design for tomorrow 1977-1990. Mont. Dept. Fish and Game, Helena. 48pp.

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

Morris, M.S. 1956. Elk and livestock competition. J. Range Manage. 9:11-14.

Murie, O.J. 1951. The elk of North America. The Stackpole Co., Harrisburg, Penn. 376pp.

Nie, N.H., C.H. Hull, J.G. Jenkens, K.Steinbrenner, and D.H. Bent. 1975. SPSS:Statistical package for the social sciences. McGraw-Hill Book Co., New York. 675pp.

Nixon, C.M., M.W. McClain, and R.W. Donohoe. 1980. Effects of clear-cutting on grey squirrels. J. Wildl. Manage. 44:403-412.

Pedersen, R.J. 1977. Big game collar-transmitter package. J. Wildl. Manage. 41:578-579.

_____.1979. Management and impacts of roads in relation to elk populations. Pages 169-173 in Proc. Recreational Impacts on Wildlands Symposium. Univ. Wash., Seattle.

_____, A.W. Adams, and J. Skovlin. 1979. Elk management in Blue Mountain habitats. Ore. Dept. Fish and Wildl. Rept. 27pp.

_____,_____, and _____. 1980. Elk habitat use in an unlogged and logged forest environment. Ore. Dept. Fish and Wildl., Wildl. Res. Rept. 9. 121pp.

Peek, J.M., M.D. Scott, L.J. Nelson, and D.J. Pierce. 1982. Role of cover in habitat management for big game in northwestern United States. In press Trans. No. Amer. Wildl. and Natur. Resour. Conf. 47.

Pengelly, W.L. 1972. Clearcutting: detrimental aspects for wildlife resources. J. Soil and Water Conserv. 27:255-258.

Perry, C., and R. Overly. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. Pages 62-68 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Picton, H.D. 1980. Land use impacts on elk in the Gallatin Valley. J. Soil and Water Conserv. 35:93-95.

Pfister, R.D., B.L. Kovalchik, S.F. Arno, and R.C. Presby. 1977. Forest habitat types of Montana. Intermountain For. and Range Exp. Sta. USDA For. Ser. Gen. Tech. Rep. INT-34. 174pp.

Quimby, D.C., and J.E. Gaab. 1957. Mandibular dentition as an age indicator in Rocky Mountain elk. J. Wildl. Manage. 21:435-451.

Renouf, D., L. Gaborko, G. Galway, and R. Finlayson. 1981. The effects of disturbance on the daily movements of harbour seals and grey seals between the sea and their hauling grounds at Miquelon. Appl. Anim. Etho. 7:373-379.

Rognrud, M., and R. Janson. 1971. Elk. Pages 39-51 in T.W. Mussehl, and F.W. Howell, eds. Game management in Montana. Mont. Dept. Fish and Game, Helena.

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

Schoen, J.W. 1977. The ecological distribution and biology of wapiti (Cervus elaphus nelsoni) in the Ceder River watershed, Washington. Ph.D. Thesis. Univ. Wash., Seattle. 405pp.

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

Schwartz, J.E., II, and G.E. Mitchell. 1945. The Roosevelt elk on the Olympic Peninsula, Washington. J. Wildl. Manage. 9:295-319.

Scott, M.D. 1978. Elk habitat selection and use on an undisturbed summer range in western Montana. M.S. Thesis, Univ. Mont., Missoula. 98pp.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., New York. 312pp.

Singer, F.J., D.K. Otto, A.R. Tipton, and C.P. Hable. 1981. Home ranges, movements, and habitat use of European wild boar in Tennessee. J. Wildl. Manage. 45:343-353.

Springer, J.T. 1979. Some sources of bias and sampling error in radio triangulation. J. Wildl. Manage. 43:926-935.

Stalmaster, M.V., and J.R. Newman. 1978. Behavioral responses of wintering bald eagles to human activity. J. Wildl. Manage. 42:506-513.

Steele, R.W. 1981. Weather data summary 1957 through 1980, Lubrecht Experimental Forest, Greenough, Montana. Mont. For. and Cons. Exp. Sta. Misc. Pap. 13. School of Forestry, Univ. Mont., Missoula.

Sweeney, J.R., R.1. Marchinton, and J.M. Sweeney. 1971. Responses of radio-monitored white-tailed deer chased by hunting dogs. J. Wildl. Manage. 35:707-716.

Taber, R.D. 1966. Land use and native cervid populations in America north of Mexico. Trans. Int. Union of Game Biol. 6:201-225.

Thiessen, J.L. 1976. Some relations of elk to logging, roading and hunting in Idaho's game management unit 39. Pages 3-5 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Thomas, J.W., H. Black, Jr., R.J. Scherzinger, and R.J. Pedersen. 1979a. Deer and elk. Pages 104-127 in J.W. Thomas, ed. Wildlife habitats in managed forest, the Blue Mountains of Oregon and Washington. USDA For. Ser. Agric. Handb. 553.

_____,C. Maser, and J.E. Rodiek. 1979b. Riparian zones. Pages 40-47 in J.W. Thomas, ed. Wildlife habitats in managed forest, the Blue Mountains of Oregon and Washington. USDA For. Ser. Agric. Handb. 553.

Wallmo, O.C., and J.W. Schoen. 1981. Part 2. Forest management for deer. Pages 434-448 in O.C. Wallmo, ed. Mule and blacktailed deer of North America. Univ. Nebraska Press, Lincoln.

Ward, L.A. 1976. Elk behavior in relation to timber harvest operations and traffic on the Medicine Bow Range in south-central Wyoming. Pages 32-43 in Proc. Elk-Logging-Roads Symposium, Univ. of Idaho, Moscow.

Ward, L.A. 1980. Multiple use of timbered areas: Views of a wildlife manager specifically for elk and mule deer. Pages 1-24 in Proc. Rocky Mountain For. Industries Conf. Jackson, Wyoming.

_____, J.J. Cupal, A.L. Lea, C.A. Oakely and R.W. Weeks. 1973. Elk behavior in relation to cattle grazing, forest recreation and traffic. Trans. No. Amer. Wildl. and Natur. Resour. Conf. 38:327-337.

_____, N.E. Fornwalt, S.E. Henry, and R.A. Hodorff. 1980. Effects of highway operation practices and facilities on elk, mule deer and pronghorn antelope. Fed. Highway Admin., Office Res. and Develop. Rept. FHWA-RD-79-143.

_____, and _____. 1979. Telemetry heart rate of three elk as affected by activity and human disturbances. Pages 47-56. in J. Shaw, ed. Proc. Dispersed Recreation and Natur. Resour. Manage. Symposium. Utah State Univ., Logan.

APPENDIX A

PERCENTAGES OF AVAILABILITY AND ELK USE FOR EACH VARIABLE CROSS-CLASSIFIED WITH DISTANCE TO OPEN ROADS

Percentages of availability and elk use by distance to open roads, and traffic volume during the calving season.

Traffic Volume	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
Light	28.5	48.6 *	16.1	17.6	8.7	2.7	5.4	5.4	7.4	5.4
Heavy	11.4	9.5	6.0	0.0 **	4.7	1.4	4.7	5.4	7.0	4.1
1981										
Light	9.7	25.4 *	6.3	14.9	4.3	6.0	1.7	9.0	5.7	35.8 **
Heavy	14.7	1.5 **	9.7	0.0 **	8.0	3.0	4.7	1.5	35.3	3.0 **

Percentages of availability and elk use by distance to open roads, and traffic volume during the summer season.

Traffic Volume	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
Light	27.8	38.9	15.1	19.1	9.4	7.4	4.3	6.2	4.3	4.9
Heavy	17.7	4.9 **	8.4	5.6	4.3	1.9	4.0	5.6	4.7	5.6
1981										
Light	9.7	17.5	6.4	20.1 **	4.0	13.0 *	1.3	1.3	5.7	30.5 **
Heavy	14.0	0.0 **	8.4	1.9 **	9.4	1.9 **	5.0	0.6 *	36.1	13.0 **

* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and traffic volume during the rutting season.

	Traffic Volume	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980											
	Light	6.7	13.3	4.7	7.1	2.7	3.5	0.3	1.8	7.7	15.9
	Heavy	20.4	9.7	10.7	4.4	8.7	5.3	9.4	3.5	28.8	35.4
1981											
	Light	4.7	6.3	3.0	6.3	2.0	2.3	1.0	3.9	4.7	16.4 **
	Heavy	13.4	0.0 **	9.4	1.6 **	9.1	9.4	6.7	7.8	46.0	46.1

Percentages of availability and elk use by distance to open roads, and traffic volume during the hunting season.

	Traffic Volume	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980											
	Light	6.0	3.4	3.7	4.6	3.3	4.6	1.7	2.3	16.4	27.6
	Heavy	10.4	13.8	7.7	1.1 **	6.4	11.5	4.7	3.4	39.8	27.6
1981											
	Light	1.0	0.0	1.7	1.6	1.3	1.6	0.3	0.0	8.0	22.6
	Heavy	8.7	0.0 **	5.4	9.7	6.0	3.2	6.7	3.2	60.9	58.1

* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and topographic barrier during the calving season.

Topographic Barrier	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
No	39.6	54.1	18.1	14.9	9.7	4.1	5.4	5.4	6.0	0.0
Yes	0.3	4.1	4.0	2.7	3.7	0.0 **	4.7	5.4	8.4	9.5 **
1981										
No	24.3	26.9	14.7	13.4	10.3	6.0	5.0	6.0	11.0	3.0
Yes	0.0	0.0	1.3	1.5	2.0	3.0	1.3	4.5	30.0	35.8 *

Percentages of availability and elk use by distance to open roads, and topographic barrier during the summer season.

Topographic Barrier	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
No	45.2	38.0	18.4	16.6	10.4	3.7 *	5.4	4.9	4.7	1.2
Yes	0.3	6.1 *	5.0	8.0	3.3	5.5	3.0	6.7	4.3	9.2
1981										
No	23.8	17.5	13.1	16.9	11.1	7.8	5.0	0.0 **	13.4	3.9 **
Yes	0.0	0.0	1.7	5.2	2.3	7.1	1.3	1.9	28.2	39.6

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to open roads, and topographic barrier during the rutting season.

Topographic Barrier	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
No	27.1	22.5	12.7	9.0	8.4	0.0 **	4.7	3.6	9.0	6.3
Yes	0.0	0.9	2.7	2.7	3.0	8.1	5.0	1.8	27.4	45.0 *
1981										
No	18.1	6.3 **	12.4	7.1	10.1	9.4	6.4	5.5	15.1	16.5
Yes	0.0	0.0	0.0	0.8	1.0	2.4	1.3	6.3	35.6	45.7

Percentages of availability and elk use by distance to open roads, and topographic barrier during the hunting season.

Topographic Barrier	Distance to Open Roads (m) <250 Avail.	Use	251-500 Avail.	Use	501-750 Avail.	Use	751-1,000 Avail.	Use	>1,000 Avail.	Use
1980										
No	16.4	17.4	8.7	1.2 **	7.7	5.8	3.7	1.2	14.4	8.1
Yes	0.0	0.0	2.7	4.7	2.0	10.5	2.7	3.5	41.8	47.7
1981										
No	9.7	0.0 **	7.0	9.7	7.0	3.2	4.7	1.6	15.1	8.1
Yes	0.0	0.0	0.0	1.6	0.3	1.6	2.3	1.6	53.7	72.6 *

* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and overstory canopy coverage during the summer season.

Overstory Canopy Coverage	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
No Trees	3.0	1.8	1.3	0.0	2.0	0.6	1.3	0.0	1.0	0.6
<25%	10.4	16.0	2.0	5.5	1.0	1.8	0.3	4.3	0.7	1.2
26-75%	16.4	18.4	10.4	11.7	4.0	0.6	3.7	1.8	3.7	1.8
76-95%	12.8	6.7	7.7	4.9	5.4	1.2	1.3	2.5	2.0	3.7
96-100%	3.0	1.2	2.0	2.5	1.3	4.9	1.3	3.1	1.7	3.1
1981										
No Trees	3.0	0.0	2.0	0.6	1.3	0.0	0.7	0.0	1.7	5.1
<25%	1.7	1.9	1.3	1.9	1.3	1.3	0.7	0.0	9.7	12.2
26-75%	7.0	0.0 **	5.0	3.2	5.7	7.1	2.3	0.6	18.1	14.1
76-95%	8.7	15.4	4.7	13.5	4.0	5.8	2.0	1.3	9.7	11.5
96-100%	3.3	1.3	1.7	2.6	1.0	0.6	0.7	0.0	2.7	0.0

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to open roads, and overstory canopy coverage during the rutting season.

Overstory Canopy Coverage	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
No Trees	3.4	4.4	1.3	0.0	1.3	0.0	0.3	0.9	2.3	0.9
<25%	4.0	0.9	3.4	2.7	2.0	0.0	1.3	0.0	3.7	2.7
26-75%	10.4	4.4	5.7	3.5	3.7	6.2	5.4	0.9	13.1	11.5
76-95%	8.4	12.4	4.0	4.4	3.7	1.8	2.0	1.8	11.1	33.6 **
96-100%	1.0	0.9	1.0	0.9	0.7	0.9	0.7	1.8	6.0	2.7
1981										
No Trees	4.0	0.0 *	1.7	0.0	1.0	0.0	0.3	2.3	1.7	3.9
<25%	1.7	0.0	1.3	0.0	1.3	1.6	0.3	0.0	10.0	6.2
26-75%	5.4	0.0 **	4.3	1.6	4.3	3.1	3.7	1.6	20.4	10.1
76-95%	5.4	6.2	4.3	5.4	3.3	6.2	2.7	6.2	13.4	41.9 **
96-100%	2.0	0.0	0.7	0.8	1.0	0.8	0.7	1.6	5.0	0.8

* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and successional stage during the summer season.

Successional Stage +	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
1	2.4	0.6	1.3	0.0	1.6	0.6	1.3	0.0	1.4	0.6
2	2.7	1.8	0.7	0.6	0.3	0.0	0.7	0.0	0.3	0.0
3	35.4	39.9	16.8	19.6	6.7	4.3	4.0	8.6	2.7	4.9
4	2.7	0.0	3.4	2.5	3.7	4.3	2.0	2.5	2.7	3.1
5	2.4	1.8	1.3	1.8	1.3	0.0	0.0	0.6	2.0	1.8
1981										
1	2.0	1.3	1.6	0.0	1.3	0.0	0.7	0.0	2.3	1.3
2	1.7	0.6	1.0	0.6	0.0	1.3	0.3	0.0	1.7	14.7 **
3	13.4	9.6	7.0	12.8	8.4	10.3	4.3	1.3	32.4	26.9
4	4.3	5.8	3.7	5.1	3.0	3.2	1.0	0.0	2.3	0.0
5	2.3	1.3	1.3	3.2	0.7	0.0	0.0	0.6	3.0	0.0

+ Successional Stages:
1 Grass-Forb
2 Brush-Seedling-Sapling
3 Young-to-Pole Size Mixed Species
4 Young-to-Pole Size Lodgepole Pine
5 Mature-to-Old Mixed Species
* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and successional stage during the rutting season.

Successional Stage +	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
1	2.7	4.5	1.3	0.0	1.3	0.0	0.3	0.9	2.3	0.9
2	1.3	0.0	0.3	0.9	0.0	0.0	0.3	0.0	2.7	0.0
3	21.7	16.8	12.5	10.6	7.4	8.0	8.4	2.7	16.2	42.5 **
4	0.3	0.0	1.0	0.0	2.0	0.0	0.7	1.8	10.4	3.5
5	1.7	1.8	0.3	0.0	0.7	0.9	0.0	0.0	4.4	4.4
1981										
1	2.6	0.0	1.6	0.0	1.0	0.0	0.3	2.3	2.3	3.1
2	2.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	2.0	3.9
3	10.7	3.1 *	7.4	3.1	7.0	10.2	5.7	6.3	34.8	28.9
4	1.3	0.0	2.0	1.6	2.3	0.8	1.3	2.3	7.4	9.4
5	1.7	3.1	0.7	3.1	0.7	0.8	0.3	0.8	4.0	17.2 **

+ Successional Stages:
1 Grass-Forb
2 Brush-Seedling-Sapling
3 Young-to-Pole Size Mixed Species
4 Young-to-Pole Size Lodgepole Pine
5 Mature-to-Old Mixed Species
* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and distance to water during the summer season.

Distance to Water (m)	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
<100	15.4	9.8	7.4	2.5	5.4	1.8	2.0	0.6	2.0	3.1
101-200	12.4	12.9	6.0	8.0	3.3	3.1	2.3	5.5	1.3	1.8
201-300	8.4	12.3	3.7	1.8	0.7	0.6	2.3	1.2	2.0	1.8
301-400	6.0	7.4	4.3	9.2	3.3	0.6	1.0	3.1	2.0	0.6
>400	3.3	1.8	2.0	3.1	1.0	3.1	0.7	1.2	1.7	3.1
1981										
<100	8.0	5.8	4.0	5.1	5.7	2.6	2.0	1.3	12.3	12.8
101-200	6.3	1.3	4.0	5.1	2.7	3.2	0.7	0.0	12.0	13.5
201-300	3.0	2.6	3.0	4.5	2.3	3.8	1.0	0.0	7.7	1.9
301-400	4.0	2.6	3.0	3.2	1.7	3.2	1.7	0.6	6.3	7.7
>400	2.3	6.4	0.7	3.8	1.0	1.9	1.0	0.0	3.7	7.1

* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to open roads, and distance to water during the rutting season.

Distance to Water (m)	Distance to Open Roads (m) <250 Avail.	<250 Use	251-500 Avail.	251-500 Use	501-750 Avail.	501-750 Use	751-1,000 Avail.	751-1,000 Use	>1,000 Avail.	>1,000 Use
1980										
<100	11.0	4.4	4.7	2.7	4.0	1.8	2.0	0.0	10.4	8.8
101-200	7.0	3.5	5.4	2.7	2.3	0.0	1.7	2.7	9.0	13.3
201-300	5.4	12.4	1.7	0.0	2.3	3.5	2.3	0.9	5.4	5.3
301-400	3.3	0.9	3.0	4.4	2.3	2.7	2.0	0.9	6.0	16.8
>400	0.3	1.8	0.7	1.8	0.3	0.9	1.7	0.9	5.7	7.1
1981										
<100	7.3	0.8	3.7	0.0	5.0	2.3	2.0	0.0	14.0	12.4
101-200	6.3	0.8	3.3	0.8	2.0	2.3	1.0	1.6	13.0	21.7
201-300	1.3	1.6*	3.0	2.3	1.7	0.8	1.7	2.3	9.3	10.1
301-400	2.7	1.6	1.7	1.6	2.0	1.6	2.3	1.6	8.0	10.1
>400	0.7	1.6	0.7	3.1	0.3	4.7	0.7	6.2	6.3	8.5

* P<0.05
** P<0.01

APPENDIX B

PERCENTAGES OF AVAILABILITY AND ELK USE FOR EACH VARIABLE CROSS-CLASSIFIED WITH DISTANCE TO HUMAN DISTURBANCE

Percentages of availability and elk use by distance to human disturbance, and topographic barrier during the calving season.

Topographic Barrier	Distance to Human Disturbance (m) <500 Avail.	Use	501-1,000 Avail.	Use	1,001-1,500 Avail.	Use	1,501-2,000 Avail.	Use	>2,000 Avail.	Use
1980										
No	10.7	2.7 *	7.4	8.2	5.4	2.7	6.4	5.5	2.7 *	0.0
Yes	0.3	5.5	4.0	4.1	8.4	13.7	10.7	20.5	44.1	37.0
1981										
No	9.0	0.0 **	12.2	0.0 **	5.9	2.4	3.8	0.0 **	10.4	0.0 **
Yes	0.7	0.0	2.4	2.4	4.5	12.2	8.3	24.4	42.7	58.5

Percentages of availability and elk use by distance to human disturbance, and topographic barrier during the summer season.

Topographic Barrier	Distance to Human Disturbance (m) <500 Avail.	Use	501-1,000 Avail.	Use	1,001-1,500 Avail.	Use	1,501-2,000 Avail.	Use	>2,000 Avail.	Use
1980										
No	19.3	1.3 **	10.8	5.0	6.1	3.1	4.4	5.0	1.0	3.1
Yes	0.3	2.5	8.1	9.4	12.9	14.5	12.5	23.9 *	24.4	32.1
1981										
No	13.6	0.0 **	13.6	3.4	4.9	2.7	1.7	0.7	4.9 *	0.7
Yes	0.7	0.0	1.7	2.0	5.9	8.1	8.7	3.4	44.1	79.2 **

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to human disturbance, and topographic barrier during the rutting season.

Topographic Barrier	Distance to Human Disturbance (m) <500 Avail.	<500 Use	501-1,000 Avail.	501-1,000 Use	1,001-1,500 Avail.	1,001-1,500 Use	1,501-2,000 Avail.	1,501-2,000 Use	>2,000 Avail.	>2,000 Use
1980										
No	14.9	4.6 **	9.2	5.6	7.8	2.8	5.1	2.8	1.0	5.6
Yes	0.3	0.0	6.8	5.6	13.2	13.9	11.5	17.6	30.2	41.7
1981										
No	10.7	0.0 *	9.6	10.5	6.7	7.6	4.1	14.3 *	10.0	1.0 **
Yes	0.0	0.0	1.5	0.0	4.4	2.9	4.8	18.1 **	48.1	45.7

Percentages of availability and elk use by distance to human disturbance, and topographic barrier during the hunting season.

Topographic Barrier	Distance to Human Disturbance (m) <500 Avail.	<500 Use	501-1,000 Avail.	501-1,000 Use	1,001-1,500 Avail.	1,001-1,500 Use	1,501-2,000 Avail.	1,501-2,000 Use	>2,000 Avail.	>2,000 Use
1980										
No	3.2	10.6	6.8	2.4	5.4	1.2	5.8	3.5	7.2	3.5
Yes	1.1	0.0	4.3	5.9	7.2	12.9	10.1	11.8	48.9	48.2
1981										
No	7.5	1.6	9.3	15.4	6.4	4.8	3.6	4.8	11.1	1.6 **
Yes	0.0	0.0	1.4	5.6	4.3	0.0 **	6.8	1.6	49.6	64.5

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to human disturbance, and overstory canopy coverage during the summer season.

Overstory Canopy Coverage	Distance to Human Disturbance (m) <500 Avail.	<500 Use	501-1,000 Avail.	501-1,000 Use	1,001-1,500 Avail.	1,001-1,500 Use	1,501-2,000 Avail.	1,501-2,000 Use	>2,000 Avail.	>2,000 Use
1980										
No Trees	1.7	0.0	2.3	0.0	1.7	1.8	2.0	0.0	1.0	1.2
<25%	4.4	1.8	2.7	5.5	3.4	5.5	1.0	6.1	3.0	9.8
26-75%	7.4	0.0 **	9.1	6.7	7.4	6.1	5.4	12.3	9.1	9.2
76-95%	5.0	1.8	4.7	2.5	4.0	2.5	6.7	3.7	8.7	8.6
96-100%	1.0	0.0	1.3	1.2	2.0	1.2	1.7	6.1	3.4	6.1
1981										
No Trees	1.7	0.0	2.0	0.6	1.7	0.0	0.3	0.0	3.0	5.1
<25%	0.3	0.0	1.3	1.3	1.3	3.8	1.0	0.0	10.7	12.2
26-75%	3.7	0.0 *	7.7	2.6	3.7	1.9	4.0	1.3	19.1	19.2
76-95%	5.4	0.6 *	6.7	4.5	1.7	3.8	3.7	2.6	11.7	35.9 **
96-100%	2.3	0.0	1.7	0.0	2.0	0.6	1.0	0.0	2.3	3.8

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to human disturbance, and overstory canopy coverage during the rutting season.

Overstory Canopy Coverage	Distance to Human Disturbance (m) <500		501-1,000		1,001-1,500		1,501-2,000		>2,000	
	Avail.	Use	Avail.	Use	Avail.	Use	Avail.	Use	Avail.	Use
1980										
No Trees	1.7	0.0	2.0	0.0	2.3	0.9	2.0	2.7	0.7	2.7
<25%	1.3	0.0	1.0	0.9	3.7	0.0 *	0.7	0.9	7.7	4.4
26-75%	5.4	0.0 **	7.7	6.2	6.7	5.3	8.1	2.7	10.4	12.4
76-95%	5.7	4.4	5.4	7.1	5.7	8.8	3.7	10.6	8.7	23.0 *
96-100%	1.0	0.0	1.0	0.0	2.3	0.9	2.0	2.7	3.0	3.5
1981										
No Trees	1.3	0.0	3.0	2.3	1.3	0.0	1.0	2.3	2.0	1.6
<25%	0.3	0.0	0.7	1.6	2.0	0.0	0.3	1.6	11.4	4.7
26-75%	4.3	0.0 **	7.4	1.6 *	4.7	0.8	3.3	3.1	18.4	10.9
76-95%	4.0	0.0 *	5.0	20.9 **	1.7	7.0	2.3	18.6 **	16.1	19.4
96-100%	0.0	0.0	3.3	0.0 *	0.3	0.8	1.0	0.8	4.7	2.3

* P<0.05
** P<0.01

Percentages of availability and elk use by distance to human disturbance, and successional stage during the summer season.

Successional Stage +	Distance to Human Disturbance (m) <500		501-1,000		1,001-1,500		1,501-2,000		>2,000	
	Avail.	Use	Avail.	Use	Avail.	Use	Avail.	Use	Avail.	Use
1980										
1	1.7	0.0	2.0	0.0	2.0	1.8	2.6	0.0	0.6	0.0
2	0.3	0.0	0.7	0.6	0.7	0.0	0.7	0.0	2.4	1.8
3	15.8	3.7 **	14.8	14.7	12.1	13.5	10.1	21.5 *	12.8	23.9
4	0.3	0.0	1.0	0.0	2.0	1.2	3.4	4.9	7.7	6.1
5	1.3	0.0	1.7	0.6	1.7	0.6	1.0	1.8	1.3	3.1
1981										
1	1.7	0.0	1.6	0.0	1.3	0.0	0.6	0.0	2.7	2.6
2	0.3	0.0	0.3	0.6	0.7	0.6	0.0	0.0	3.3	16.0 **
3	5.7	0.0 **	11.4	7.7	5.0	7.1	7.0	3.2	36.5	42.9
4	3.7	0.0 *	4.3	0.6	2.3	1.3	2.0	0.0	2.0 **	12.2
5	2.0	0.6	1.7	0.0	1.0	1.3	0.3	0.6	2.3	2.6

+ Successional Stages:
1 Grass-Forb
2 Brush-Seedling-Sapling
3 Young-to-Pole Size Mixed Species
4 Young-to-Pole Size Lodgepole Pine
5 Mature-to-Old Mixed Species
* $P<0.05$
** $P<0.01$

Percentages of availability and elk use by distance to human disturbance, and successional stage during the rutting season.

Successional Stage +	Distance to Human Disturbance (m) <500 Avail.	<500 Use	501-1,000 Avail.	501-1,000 Use	1,001-1,500 Avail.	1,001-1,500 Use	1,501-2,000 Avail.	1,501-2,000 Use	>2,000 Avail.	>2,000 Use
1980										
1	1.3	0.0	1.7	0.0	2.7	0.9	2.0	2.7	0.3	2.7
2	0.7	0.0	0.7	0.9	1.0	0.0	0.0	0.0	2.4	0.0
3	10.4	4.4	12.1	12.4	12.8	13.3	11.8	12.4	18.5	38.1 **
4	1.0	0.0	1.7	0.0	3.4	0.0 *	1.7	0.9	6.7	4.4
5	1.7	0.0	1.0	0.9	1.0	1.8	1.0	3.5	2.4	0.9
1981										
1	1.3	0.0	2.0	1.6	1.3	0.0	1.0	3.1	2.3	0.8
2	0.3	0.0	1.0	0.8	0.3	0.0	0.3	0.0	2.7	3.1
3	7.0	0.0 **	9.4	12.5	8.0	4.7	6.0	10.2	35.1	24.2
4	0.3	0.0	5.4	4.7	0.3	0.8	0.7	0.8	7.7	7.8
5	1.0	0.0	1.7	7.0	0.0	3.1	0.0	12.5 **	4.7	2.3

+ Successional Stages:
1 Grass-Forb
2 Brush-Seedling-Sapling
3 Young-to-Pole Size Mixed Species
4 Young-to-Pole Size Lodgepole Pine
5 Mature-to-Old Mixed Species
* $P<0.05$
** $P<0.01$