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This research provides information on the distribution of an unexploited Roosevelt elk population in unaltered habitat in Olympic National Park. Radio-telemetry was used to document home range and habitat use by 11 adult cow elk in the Hoh Valley during March 1978, from 10 June-15 September 1978, and from 1 January-20 March 1979. That information provides a baseline for comparison with managed herds adjacent to the park and identification of long term changes in the distribution of elk in the Hoh Valley.

Four groups of cow elk were identified in the study area. Cow groups were stable; elk within a group used a common home range and were highly associated. Home ranges of elk from adjacent groups overlapped but there was no permanent interchange of collared elk between groups during the period of study.

There was no significant difference between mean summer and mean winter home range size; however, summer home range was larger than winter home range in five, of seven, comparisons. Average home range area of collared elk was 1034 ha during summer and 1003 ha during winter.

Daily movement of elk was greater during summer than during winter; minimum daily movement distance averaged 843 m during summer and 676 m during winter. Movement of cow elk with newly born calves in June was considerably less than movement of elk without calves.

The habitat use of radio-equipped elk was studied in relation to 13 habitat units on national park land and 11 units on non-park land. Collared elk were found primarily in habitat units on the valley floor during both seasons, although there was seasonal variation in the use of those units. Elk were least selective of habitat during winter, most selective during late winter and moderately selective during summer. Alder flats were selected by each collared elk during late winter and were identified as important elk habitat in the Hoh Valley because use of such areas was prevalent during a nutritionally important time of year for cow elk. Other patterns of habitat use were discussed in relation to thermal and nutritional characteristics of the watershed.

Home Range and Habitat Use by Roosevelt Elk in Olympic National Park, Washington

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HOME RANGE AND HABITAT USE BY ROOSEVELT ELK IN OLYMPIC NATIONAL PARK, WASHINGTON

INTRODUCTION

Cervus elaphus migrated to North America over the Bering land bridge during the Pleistocene period, and subsequently occupied most of North America (McCullough 1969). Those populations that colonized the humid coastal forests of the Pacific Northwest evolved to the form known as Roosevelt elk (*Cervus elaphus roosevelti* McCullough). Primevally, that form was distributed throughout northwest California, western Oregon and western Washington (Graf 1943, Harper 1971).

During the 1890's and the turn of the century, Roosevelt elk populations declined under pressures of settlement and intensive market hunting, and were eliminated in some regions. Subsequently, populations increased and re-occupied much of their original range. Today, Roosevelt elk populations are scattered from the redwood forests in extreme northwest California throughout the Coast Range of Oregon and Washington (Mace 1956, Kuttel 1975). Additionally, discrete populations exist in the western Cascade Mountains, Vancouver Island, and an introduced population inhabits Afognak Island in Alaska (Troyer 1960). The Olympic Peninsula is considered a major population center of Roosevelt elk as it supports nearly half of the total elk population in Washington (Parsons 1976).

Information on the ecology and behavior of the Roosevelt elk is limited, in part because the subspecies is difficult to observe in their native habitat. The first systematic research on Roosevelt elk was conducted by Schwartz (1939) on the Olympic Peninsula. He described the distribution and abundance of elk in each major watershed on the peninsula in addition to assessing the condition of the range in each. Graf (1943) studied the natural history of Roosevelt elk for four years in the Coast Range of Oregon. Harper *et al*. (1967) summarized existing knowledge of food habits and life history of Roosevelt elk at Prairie Creek Redwoods State Park, California. Additionally, the effects of timber harvest on the distribution and abundance of Roosevelt elk were examined by Lemos and Hines (1973,1974,1975,1976). Lieb (1973) and Franklin et al. (1975) documented the social organization of Roosevelt elk in Prairie Creek Redwoods State Park. Population characteristics and habitat use patterns by elk in Redwood National Park were described by Mandel and Kitchen (1979).

The present research is the first part of a long term investigation of the behavior and ecology of Roosevelt elk in Olympic National Park. Radio-telemetry was used to obtain locations on adult cow elk in the Hoh Valley, Olympic National Park, for seven months during 1978 and 1979. Systematic locations of monitored elk were used to:

a. identify groups of cow elk that occurred in the study area and obtain information on the association of elk within and between groups,

b. identify seasonal characteristics of home range and movements of cow elk, and

c. identify seasonal patterns of habitat use by cow elk.

Specific hypotheses that were tested were:

a. there are no significant seasonal differences in home range size, activity center and minimum daily movement distance of cow elk, and

b. use of habitat units by cow elk is random and independent of season.

The present study describes the distribution of unmanaged Roosevelt elk in habitat which has been essentially unmodified by man. These elk are of interest because they may reflect the condition that existed before habitat alteration and hunting pressure influenced the ecology and behavior of Roosevelt elk elsewhere. Therefore, in the future, findings from this study may be compared to findings on Roosevelt elk elsewhere to provide better understanding of the effects of forest management on Roosevelt elk. Data from this research will also provide baseline information so that long term changes in the distribution of elk in the Hoh Valley may be identified.

HISTORICAL PERSPECTIVE

Pre-settlement Period

Before human settlement, the Olympic Peninsula supported continuous old growth forests that consisted of Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*) and Douglas-fir (*Psuedotsuga menziesii*). Wolves (*Canis lupus*) and cougars (*Felis concolor*) were thought to be abundant throughout those forests (Scheffer 1946). Natural clearings occurred in the valley bottoms and in the high mountains that undoubtedly supported Roosevelt elk. Numerous accounts suggest that elk were plentiful on the Olympic Peninsula before settlement occurred, but numbers are unknown. Morganroth (1909) reported that elk were abundant throughout the Peninsula until about 1895.

Settlement Period

Settlers first occupied river drainages on the west side of the Peninsula in the early 1890's. The upper Hoh River was settled in 1892 by John Huelsdonk, who lived outside of what is now the boundary of Olympic National Park.

Settlement and exploration of the Olympic Peninsula in the 1890's led to the proliferation of sport and commercial hunting. From that time until the early 1900's there was severe hunting pressure on elk for meat, hides and upper canine teeth. The canine teeth were worn as watch fobs by members of the Protective Order of the Elks (Johnson 1923). As a result, elk populations were depleted and extirpated from the eastern and northern portions of the Peninsula (Morganroth 1909). Even in the remote Hoh Valley, Huelsdonk complained of elk scarcity and was forced to travel 20 miles upriver from his homestead to hunt elk (Murie 1935). By 1905, the Peninsula population was reduced to an estimated 2,000 elk (Morganroth 1909).

Residents of the Olympic Peninsula were outraged over the depletion of elk. Local politicians established a bounty on cougars; concurrently, settlers depleted wolf populations to protect the diminishing elk herds and to protect livestock. In 1905, the state legislature initiated a ten year moratorium on elk hunting throughout the Peninsula. However, no elk were legally hunted until 1933. Aware of the elk situation, President Theodore Roosevelt set aside 615,000 acres as Mt. Olympus National Monument in 1909 for the expressed purpose of providing a reserve for Roosevelt elk.

The Elk-range Interrelationship

As a result of protection and predator control, elk populations on the Peninsula apparently increased rapidly after 1905. In 1915, there were reports of "overbrowsing" in some drainages on the west side of the Peninsula. During the severe winter of 1916-1917, large numbers of elk died in the Hoh watershed and other west side drainages (Schwartz 1939).

For four decades after the die-off in 1916-1917, there was concern about elk "overpopulation" and range "deterioration" on the western drainages, especially in the Hoh Valley. Bailey (1918) and Riley (1918) both recognized localized overbrowsing in the Hoh watershed and recommended regulated hunting to distribute elk onto under-utilized portions of the valley. Despite calls for regulated hunting, seasons remained closed until 1933 when 157 antlered bulls were harvested from the most heavily populated drainages (Skinner 1933).

Because of widespread disapproval of the reopened elk hunting season, the state again enacted legislation which prohibited elk hunting on the Olympic Peninsula. Concern over elk hunting and apparent overbrowsing prompted more investigation. Olaus Murie (1934) and Adolf Murie (1935) both described portions of the Hoh Valley as being overbrowsed. Schwartz (1939:85) noted that at the beginning of his study in 1935, "range deterioration had progressed further on portions of the Hoh than on any other elk range" indicated by poor condition of deer fern (*Blechnum spicant*), huckleberry (*Vaccinium spp.*) and vine maple (*Acer circinatum*).

In an effort to alleviate those conditions, elk hunting on the Olympic Peninsula was allowed again in 1936, 1937, and 1938. In 1937, hunting of either sex was allowed whereas in 1936 and 1938, legal harvest was restricted to bulls. Schwartz (1939) reported that due to the removal of 511 elk from the Hoh Valley during those three years, the situation had improved, although over-utilization was still prevalent. In 1938, Mt. Olympus National Monument was expanded and became Olympic National Park. Consequently, there has been no legal hunting in the Olympic interior since 1938.

Investigations conducted by National Park biologists indicated that range conditions improved during the 1940's and 1950's. In the first investigation conducted by the Park Service, Summer (1938) reported that range deterioration was still very evident in the Hoh Valley. However, in 1951 he reported that elk forage "appeared adequate and the animals seemed in balance with their range, indicating an improvement over conditions twelve years ago" (Summer 1939:2). Seven years later, Newman (1958:27) noted that the range was not severely overused and that the elk population was stable because of the "rapid and regular seasonal growth of forage plants, even pressure from predators and natural die-offs".

Thus, it appears that elk populations on the Olympic Peninsula may have undergone an irruptive phase of rapid growth followed by a decline and the establishment of a stable herbivore-vegetation equilibrium. That pattern is characteristic of ungulate populations when the balance between the population and the available forage is disrupted (Caughley 1976). When populations on the Peninsula were reduced at the turn of the century, the availability of forage probably increased, which conceivably induced a high rate of increase of the newly protected populations. The expanding populations may have overshot the food resource by 1917 which may have contributed to the extensive elk die-off of that winter. Additional elk die-offs were reported for the early spring of 1933 (Murie 1935), 1937 (Schwartz 1939), 1949 (Newman 1955), 1956 (Newman 1958), and 1964 (Brent 1967). Such die-offs seem to occur regularly and undoubtedly are important in regulating elk populations within the park.

Caughley (1976) described the reciprocal relationship between plant and herbivore density during irruptive phases of ungulate population growth; when ungulate populations increase, vegetation decreases in density, concomitantly. As the ungulate population approaches equilibrium, the vegetation also attains stable density and productivity, although the composition of vegetation may be changed from its original state; presumably that condition has been attained within Olympic National Park. Therefore, elk in the park appear to be at ecological carrying capacity as defined by Caughley (1976). The population for the entire park has apparently stabilized at approximately 5,000 elk (Schwartz 1939, Newman, 1958). The Hoh Valley population apparently declined from 2,000 elk during the peak of the irruption (Bailey 1918) to around 700-800 elk for the two forks of the Hoh River (Schwartz 1939, Newman 1958).

Although the national park elk population may be stable, subpopulations on the adjacent forest lands may have increased in response to increased forage production following logging (Parsons 1976). If migratory elk from within Olympic National Park make use of non-park land during winter, park populations may also be increasing in response to greater forage production outside the park. Such an event would alter the equilibrium that presumably exists between vegetation and elk within the park.

Historical Distribution of Hoh Valley Elk

Early investigators reported that both resident and migratory elk existed in the Hoh Valley (Skinner 1933, Schwartz 1939). Resident elk were believed to stay in restricted home ranges on the lower slopes and valley bottoms and not intermingle with elk from other watersheds (Skinner 1933). Conversely, migratory elk were thought to remain at higher elevations and intermingle with elk from adjacent drainages (Skinner 1933). The contention that resident elk stayed in a restricted home range was supported by Newman (1958). He tagged 27 elk calves on river bottoms in the Hoh Valley and noted that none were located more than three miles from the point of capture. Those investigators suggested that resident and migratory elk occur together during severe winters and may change migratory habits between years (Schwartz 1939, Newman 1958). However, those suggestions were not substantiated by observing marked individuals.

Distribution of elk in the Hoh Valley during winter was reported to depend on the severity of the winter. Schwartz (1939) described the winter range as extending upriver 16 km from the present Hoh Ranger Station and upslope approximately 500 m from the valley floor, although he believed the range was reduced during the severe winters. Newman (1954) delimited a smaller winter range which extended upriver 16 km from the Hoh Ranger Station and 75 vertical meters from the valley floor. Using that boundary, he calculated 2,841 ha (=6,950 acres) of winter range. That range supported approximately 600 elk or one elk per 4.6 ha (=11.5 acres) on winter range. During periods of deep snow, the lower elevation areas of the valley wall were reported to be important winter range (Newman 1956). At such times, snow accumulation was greater on the valley floor causing elk to spend more time on the adjacent hillsides.

Schwartz's (1939) observations on feeding habits provided limited indirect information on elk distribution. During early spring, Schwartz (1939) determined from direct observation that 75% to 95% of the diet of cow elk consisted of grasses and weeds. This suggests that elk used river bottoms where grasses are abundant. During summer and winter the diet was mostly browse, which suggests that grassy alder flats were no longer important at that time of year. However, during early fall, grasses again comprised the majority of the elk diet, indicating that elk returned to riparian areas.

THE STUDY AREA

Location

Olympic National Park occupies 3600 km^2 in the central mountainous portion of the Olympic Peninsula in Northwest Washington (Fig. 1). This study was conducted in the valley of the north fork of the Hoh River from Canyon Creek, 3.0 km west of the national park boundary, to 2.0 km east of the Hoh Ranger Station (Fig. 2). The area west of the national park boundary is managed for timber production by the Washington Department of Natural Resources.

Physiography and Vegetation

The Hoh Valley has a broad U-shaped configuration which is characteristic of a glaciated watershed. Elevations range from 150 m on the valley floor to 910 m on adjacent ridgetops. The valley floor is generally 1.0-1.5 km wide, and consists of gravel bars and at least four river terraces. The three younger terraces are alluvial deposits dated by Fonda (1974) as 80-100 years old (Terrace 1), 400 years old (Terrace 2), and 750 years old (Terrace 3), respectively. The oldest terrace (Terrace 4) is a glacial deposit from the Pleistocene ice sheet (Fonda 1974). Additionally, a valley bench, also glacially derived, occurs near the park boundary and is approximately 70 m above the river level.

Vegetation in the Hoh Valley was classified by Fonda (1974) and Henderson et al. (1979). Fonda (1974) recognized six vegetation cover types on the valley floor, which represents a successional sequence from bare gravel, adjacent to the river, to mature Sitka spruce-western hemlock communities on the oldest river terrace. Henderson et al. (1979) classified the vegetation by describing eight plant communities on the valley floor. The relationship of the cover types of Fonda (1974) to the plant communities of Henderson et al. (1979) is shown in Table 2 (page 23).

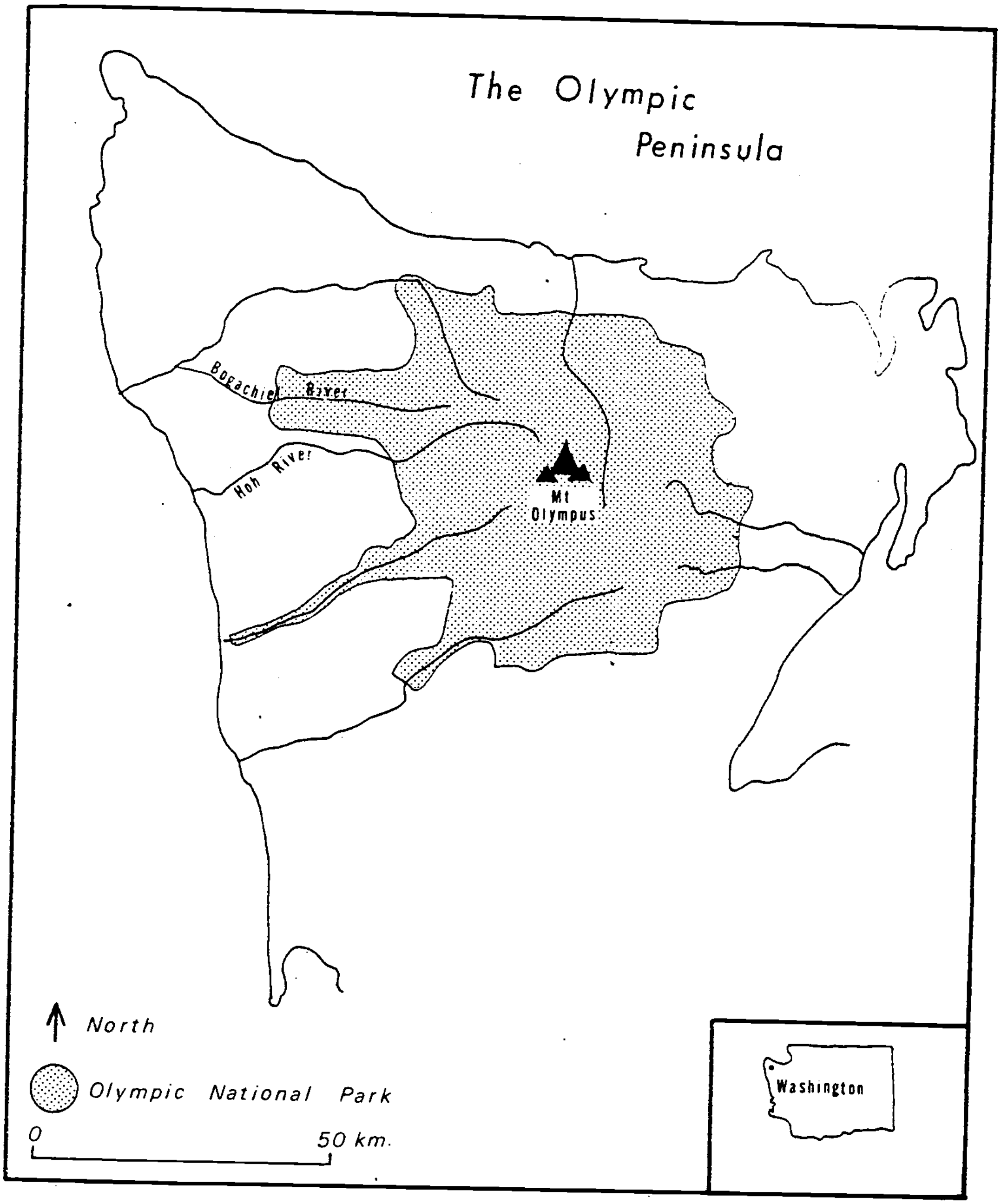
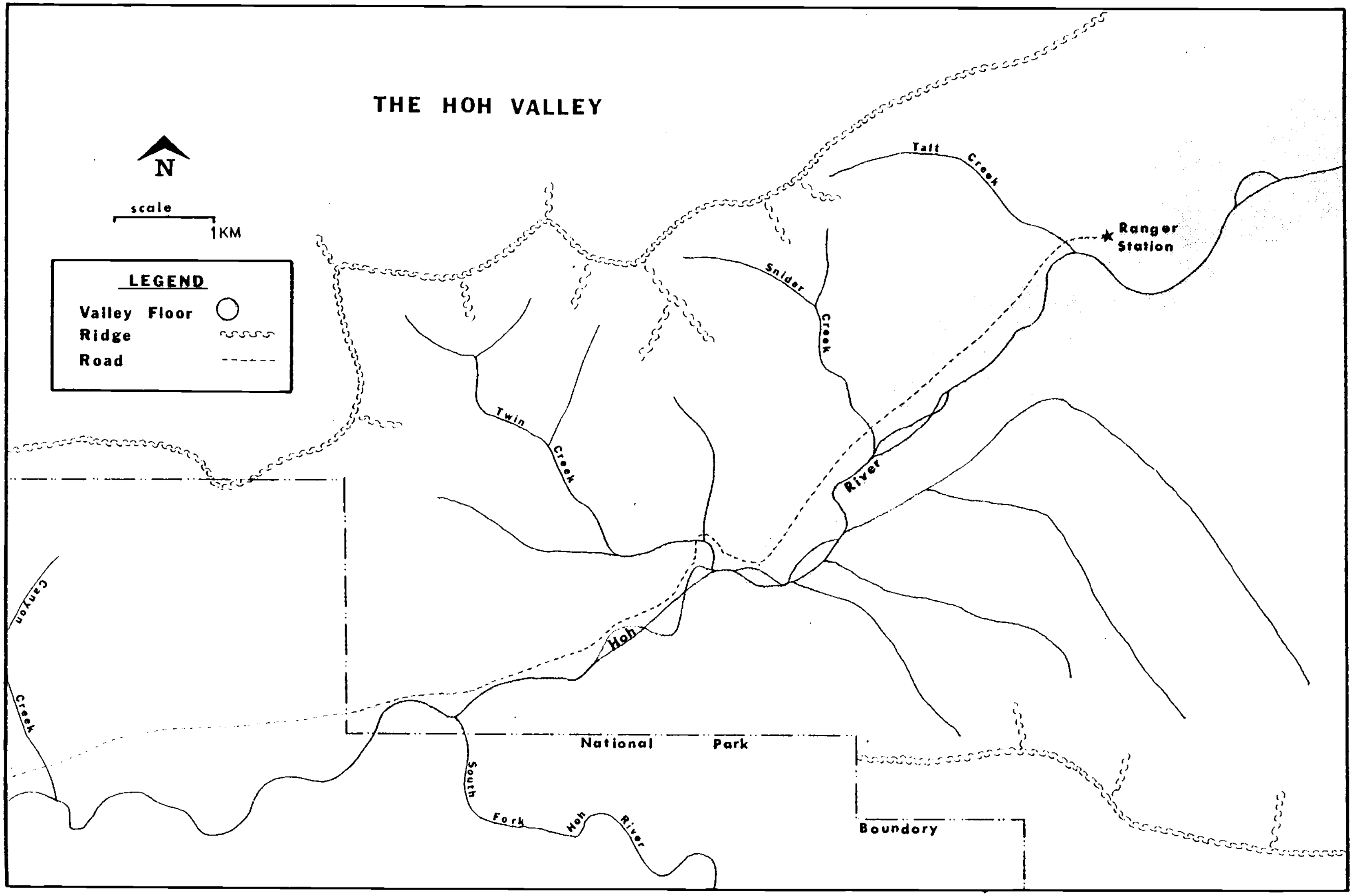


Figure 1. Location of Olympic National Park and the Hoh Valley.

Figure 2. Map of study area in the Hoh Valley


THE HOH VALLEY
N
scale
1KM
LEGEND
Valley Floor
Ridge
Road
Taft Creek
Ranger Station
Snider Creek
Twin Creek
Hoh River
Canyon Creek
National Park Boundary
South Fork Hoh River

The early successional community on gravel bars is dominated by red alder (*Alnus rubra*) saplings and Scouler's willow (*Salix scouleriana*). Herbaceous cover is low and dominated by grass species (Fonda 1974, Henderson *et al*. 1979) (Table 2).

A red alder community occurs on the next older and more stable land surface (Terrace 1). That community is dominated by mature red alder that originally became established on gravel bars. Shrub density is sparse; however, herbaceous cover is high and dominated by grass species (Fonda 1974, Henderson *et al*. 1979) (Table 2).

A sitka spruce-black cottonwood (*Populus trichocarpa*) community occurs on the second terrace. The canopy is dominated by Sitka spruce, big leaf maple (*Acer macrophyllum*) and black cottonwood. The shrub layer, dominated by vine maple (*Acer circinatum*), is more developed than in the younger red alder community. The herbaceous layer is dominated by both grass and forb species (Fonda 1974) (Table 2).

Sitka spruce-western hemlock communities occur on the third and fourth river terraces. Those communities are characterized by the presence of massive Sitka spruce (230-330 cm dbh), an open canopy, low tree density and a conspicuous moss-forb layer on the forest floor. The shrub layer is more developed than in younger successional communities and usually is dominated by vine maple, huckleberry (*Vaccinium parvifolium*, *V. alaskense*) and salmonberry (*Rubus spectabilis*) (Fonda 1974, Franklin and Dyrness 1973) (Table 2).

A bigleaf maple community occurs on shallow, rocky soils, usually at the base of the valley wall. The canopy is dominated by bigleaf maple whereas vine maple dominates the shrub layer. The herbaceous layer is similar to that of younger successional communities; forbs and grasses are prevalent and mosses have low coverage (Fonda 1974) (Table 2).

Vine maple communities occur in forest clearings on the third and fourth terraces. They have high coverage of vine maple and forbs dominate the ground layer (Henderson *et al*. (1979) (Table 2).

Forests on the valley wall are dominated by western redcedar, western hemlock and Douglas-fir (*Psuedotsuga menziesii*) (Fonda 1974). The shrub layer is dominated by red huckleberry (*V. parvifolium*) and salal (*Gaultheria shallon*) on warm aspects and blue huckleberry (*V. ovalifolium*) and salmonberry on moister, cool slopes. The herb layer is generally sparse and dominated by wood sorrel (*Oxalis oregana*), coolwort (*Tiarella trifoliata*) and moss species (Fonda 1974).

Mammals

The study area provides habitat for 44 species of mammals (Franklin *et al*. 1972). Of those, the Columbian black-tailed deer (*Odocoileus hemionus columbianus*) is the only other large herbivore. Extant predators include cougar, coyote (*Canis latrans*), bobcat (*Lynx rufus* and black bear (*Ursus americanus*). The density of those populations is unknown.

Climate

Climate in the Hoh Valley is maritime, with mild, wet winters and cool dry summers (Appendix A). The Hoh Ranger Station receives an average of 345.4 cm of precipitation each year. Areas below 600 m receive mostly rain during the winter, although approximately 25 cm of snow falls in the valley bottoms each winter (Phillips 1963).

The winter study periods of 1978 and 1979 were relatively mild. About 77.5 cm and 103.7 cm of precipitation occurred during those respective periods. There was a trace of snow present on the valley floor for three days during winter 1978. Measurable snow was present for 16 days during the winter of 1979, and ranged in depth from <1.0-10.0 cm.

MATERIALS AND METHODS

Field Procedures

The adult cow elk were equipped with radio-transmitter collars during the winter of 1978. Radio-collared elk were located one to three times daily during March 1978, from 10 June-15 September 1978 and from 1 January-20 March 1979. Seasonal observations on some elk were not possible due to transmitter difficulties. An additional cow elk was radio-collared in January 1979. A total of 2565 locations were obtained on the 11 collared elk (Table 1).

Capture and Immobilization

Adult cow elk were immobilized through injection of either liquid or powdered succinylcholine chloride (SCC) into the hip. Liquid SCC was administered using a 1.0 cc projectile syringe that was fired from a powder charge Palmer "Cap-chur" rifle. Powdered SCC was administered using pre-loaded Pnue darts (Liscinsky et al. 1969), delivered from the same rifle.

Drug dosages that were administered to cow elk (Appendix B) were higher than reported elsewhere (Flook et al. 1962, Harper 1965, Logsdon 1965). Average reaction time was ten minutes; average immobilization period was approximately 61 minutes (Appendix B). One drug-related fatality of 14 immobilizations, occurred using 26 mg SCC. An adult cow, that was probably weakened from malnourishment during late winter, was unable to regain coordination after immobilization and was found drowned. No other obvious physiological complications were observed for other elk during immobilization.

Table 1. Number of telemetry locations for each elk and season

Elk No.	Season March 1978	 Summer 1978	 Winter 1979	Total
1	29	112	115	296
6	29	114	112	255
9	31	114	142	287
10	30	121	154	305
11	27	122	153	302
88	--	---	127	127
4	31	111	153	295
7	30	107	---	137
12	--	---	138	138
3	19	115	156	301
8	19	103	---	122
Totals	256	1019	1290	2565

Radio-telemetry Equipment and Procedures

Radio-transmitters used in this study were SBII pulsing transmitters manufactured by AVM Company, Champaign Illinois (AVM 1979). The transmitters operated in the 164 MHz range (164.425-164.725 MHz) and had a pulse rate that ranged from 71-124 per minute. Two 2.8 volt lithium batteries powered each transmitter. The theoretical life expectancy of the package was 30 months.

The transmitter-battery package was constructed according to directions from AVM Company. The package was potted in Perm dental acrylic. Collars also were modeled after the AVM design (AVM 1979) and were constructed using nylon-rubber conveyor belting.

A 12-channel portable receiver (AVM LA-12) and a three or four element hand held yagi antenna were used to locate instrumented elk. The working range of the system on level topography was nearly 2.0 km.

Forty telemetry receiving stations were established on gravel bars along the Hoh River and in open areas along the Hoh River road. While locating elk, generally three telemetry stations were chosen for azimuth determinations. To minimize error, stations were chosen such that the intersection of the outermost azimuths was approximately 90° (Heezen and Tester 1967). A station for obtaining the third azimuth was located midway between the outermost stations, such that the angle of intersection of that azimuth with the others was nearly 45°. If the collared elk was very close to the receiving stations, only two azimuths were used to determine its location; on other rare occasions, four azimuths were used.

At each station, the general direction to the elk was determined first by rotating the antenna 360° until the strongest signal was received. The receiver gain was then reduced, and the signal null on either side of the peak was determined. The midpoint of the arc between the two nulls was used as the estimated direction. A Silva Ranger compass was used to determine the azimuth of that direction.

Elk locations were estimated by plotting the azimuths on a base map of the study area after they were obtained for each elk. The base map was an orthographically corrected aerial photograph of the study area (scale = 1:24,000) which was referenced using Universal Transverse Mercator (UTM) grid coordinates. After three azimuths were plotted, a circle was inscribed within the triangle formed by the intersection of the three lines. The center of the circle was used as the estimated location of the elk. UTM coordinates of that location and the habitat unit occupied by the elk also were recorded.

An elk location was rejected if it did not conform to the following standards:

1. each of the azimuths intersected,
2. the circle which was inscribed within the triangle was within the boundary of one habitat unit, and
3. the estimated elk location was within the same general region as predicted by the investigator.

Predictions were based on the investigators subjective interpretation of the radio signal. For example, the signal of a collared elk on the valley wall was discernable from that of an elk on the valley floor. If the elk was known to be in one of those broad areas, and the plotted location indicated otherwise, that location was rejected. If a telemetry location was rejected, the equipment was used to find the elk and determine its location either visually or aurally.

During summer 1978, the accuracy of the telemetry procedure was tested by having one investigator locate a radio-equipped elk by direct observation, while another located the same elk remotely using the above procedure. The elk was located by both parties and the criteria for accuracy were met for the remote location in 41 tests. Locations were obtained from a total of 135 azimuth determinations. The 41 tests and the 135 azimuth determinations were used to analyze location error and azimuth error. Location error was defined as the distance between the actual location of the elk and the estimated location. Azimuth error was defined as the number of degrees between the azimuth to the actual location and the telemetry derived azimuth. Additionally, the habitat unit actually occupied by a collared elk in each test was compared to the habitat unit assigned using the telemetry procedure. Those comparisons were used to determine the frequency of incorrect habitat determinations that were made using radio-telemetry in this study.

Habitat Units

Thirteen habitat units were identified and mapped on national park land in the study area (Fig. 3). Eight additional units were identified and mapped on non-park land (Fig. 4). Habitat units were defined as mappable, distinctive land areas with vegetation and thermal characteristics that were believed to be ecologically significant to elk. The term habitat "unit" was used to avoid confusion with other terms with more specific ecological meaning. For example, habitat "type" refers to a land area that is capable of supporting a particular climax plant community (Daubenmire 1968); the term cover type implies units with disjunct canopy characteristics. Habitat units on the valley floor within the park coincided largely with vegetation types identified by Fonda (1974) and Henderson et al. (1979) (Table 2). The valley wall within the park was divided into six habitat units corresponding to three elevational bands on the north and south valley walls (Table 3). Habitat units on non-park land were based on past forest harvest and land modification practices (Table 4). Gravel bar, alder flat and spruce-cottonwood habitat units were recognized on both park and non-park land.

Analytic Procedures

Delineation of Home Range

An elliptical home range model (Koepple et al. 1975) was used to delineate the home ranges and activity centers of radio-collared elk. Home range has been defined as "the area over which an animal

Figure 3. Map of habitat units on national park land.

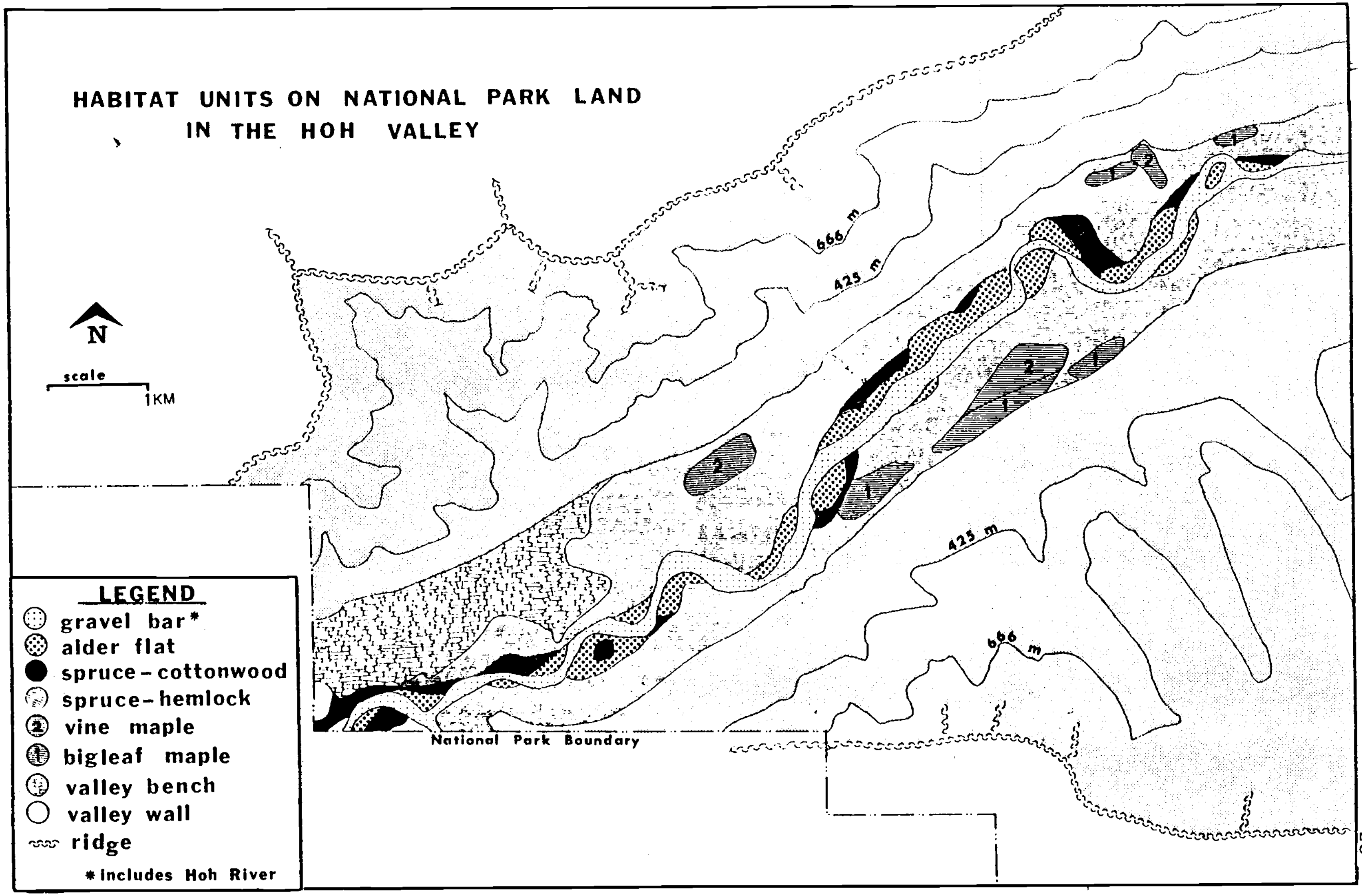
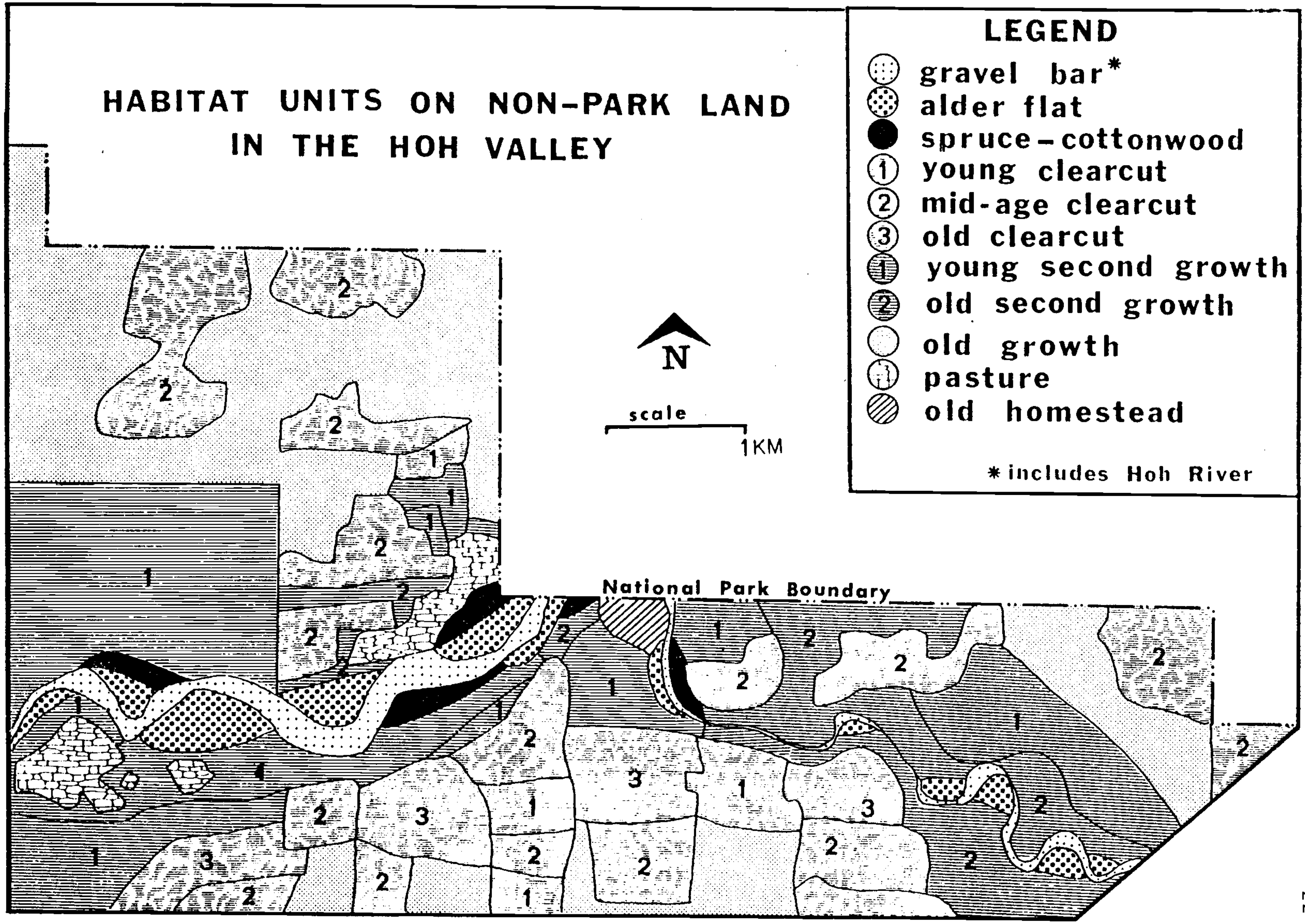

HABITAT UNITS ON NATIONAL PARK LAND
IN THE HOH VALLEY
N
scale
1KM
666 m
425 m
425 m
666 m
National Park Boundary
LEGEND
gravel bar*
alder flat
spruce-cottonwood
spruce-hemlock
vine maple
bigleaf maple
valley bench
valley wall
ridge
*includes Hoh River

Figure 4. Map of habitat units on non-park land.



HABITAT UNITS ON NON-PARK LAND IN THE HOH VALLEY

Table 2. Description of habitat units on the valley floor in the Hoh Valley study area and their relationship to previously described cover types [a] and community types. [b]

Habitat Unit	Corresponding Cover Types [a]	Corresponding Community Types [b]	Characteristic Species	Location
Gravel bar (GB)	Gravel bar	*Alnus Rubra*- *Salix scouleriana*/ grass	red alder Scouler's willow blue wildrye velvet grass	Adjacent to river
Alder Flat (AF)	*Alnus rubra*	*A. rubra*/grass	red alder colonial bentgrass blue wildrye rough bluegrass	1st terrace
Spruce-Cottonwood (SpCo)	*Picea sitchensis*- *Acer macrophyllum*- *Populus trichocarpa*	no description	sitka spruce black cottonwood bigleaf maple colonial bentgrass wood sorrel sword fern	2nd terrace
Spruce-Hemlock (Sp He)	*P. sitchensis*- *Tsuga heterophylla* plus *T. heterophylla*	*P. sitchensis*- *T. heterophylla* *Acer circinatum*/ *Achlys triphylla* plus *P. sitchensis*- *T. heterophylla*/ *A. Circinatum*/ *Polystichum munitum*- *Oxalis oregana*	Sitka spruce western hemlock vine maple salmonberry huckleberry sword fern	3rd terrace plus 4th terrace

Table 2. (continued)

Habitat Unit	Corresponding Cover Types a/	Corresponding Community Types b/	Characteristic Species	Location
Spruce-Hemlock (continued)		P. sitchensis- T. heterophylla/ Vaccinium alaskense plus P. sitchensis- T. heterophylla/ P. munitum- O. oregana		
Vine Maple (ViMa)	no description	A. circinatum/forb	vine maple	no description
Bigleaf Maple (BLMa)	A. macrophyllum	A. macrophyllum/ A. circinatum/ O. oregana	bigleaf maple vine maple wood sorrel sword fern colonial bentgrass	colluvial deposits
Valley Bench (VB)	no description	P. sitchensis- T. heterophylla/ V. alaskense	western hemlock Alaskan huckleberry wood sorrel mosses	no description

a/ Cover types described and named by Fonda (1974)

b/ Community types described and named by Henderson *et al*. (1979)

Table 3. Description of Habitat Units on the Valley Wall in the Hoh Valley Study Area.

Habitat Unit	Description
Valley Wall -N,L	Northern valley wall, lower slopes Elevation = 150 m - 425 m Predominately southern aspect
Valley Wall -S,L	Southern valley wall, lower slopes Elevation = 150 m - 425 m Predominately northern aspect
Valley Wall -N,M	Northern valley wall, middle slopes Elevation = 425 m - 666 m Predominately southern aspect
Valley Wall -S,M	Southern valley wall, middle slopes Elevation = 425 m - 666 m Predominately northern aspect
Valley Wall -N,H	Northern valley wall, higher slopes Elevation = 666 m - 910 m Predominately southern aspect Winter snow
Valley Wall -S,H	Southern valley wall, higher slopes Elevation = 666 m - 910 m Predominately northern aspect Winter snow

Table 4. Description of habitat units on non-park land.

Habitat Unit	Description
Gravel Bar (GB)	Same as Gravel Bar community (Fonda 1974)
Alder Flat (AF)	Same as *Alnus rubra* community (Fonda 1974)
Spruce-Cottonwood (SpCo)	Same as *Picea sitchensis*-*Acer macrophyllum*-*Populus trichocarpa* community (Fonda 1974)
Young Clearcut (CC,Yng)	0-4 years since harvest Bare soil and slash conspicuous Dominated by forbs, blackberry, young conifer seedlings
Mid-age Clearcut (CC,Mid)	4-12 years since harvest Dominated by grasses, blackberry and spruce and hemlock reproduction
Old Clearcut (CC,Old)	12-20 years since harvest Dominated by dense spruce-hemlock reproduction
Young Second Growth (SG,Yng)	Approximately 20-50 years since harvest Dense stand of pole sized (10-30 cm dbh) spruce, hemlock or Douglas-fir Red alder groves and grassy clearings present Poor understory development
Old Second Growth (SG,Old)	Approximately 50 or more years old Dominated by spruce, hemlock or Douglas-fir (>30 cm dbh)
Old Homestead (OH)	Old grassy fields with spruce reproduction invading edges
Pasture (P)	Pasture land, fenced and generally not available to elk
Old Growth (OG)	Found on valley walls in study area Same as valley wall habitat units within the National Park

normally travels in pursuit of its routine activities" (Jewell 1966). On two occasions, journeys by elk beyond their normal range were excluded from the analysis of home range. Using that approach, home ranges were delimited by probability ellipses that include 95% of each animals utilization of habitat. An ellipse was also used to indicate the activity center of each elk. Those ellipses are a statistical expression of the geometric mean of the location data on each collared elk. In this study, they represent a 95% confidence interval for the true mean of an infinite number of location fixes.

The elliptical model is based on the assumption that location data have a bivariate normal distribution. The location data from this study approximated a normal distribution along the major and minor axes of each ellipse. Additionally, examination of scatter plots of the location data showed the distribution of the data was generally elliptical; therefore, the method appears to be suited for use in this study.

Home Range Groups

Home range groups of cow elk were identified by mapping the annual home range of each of the collared elk. Home range group was defined by Hunter (1964) as a group of animals which share a common home range. Differences in the location data of each pair of collared elk within a home range group were statistically tested using activity center confidence ellipses. The null hypothesis, that there was no significant difference in the activity center of that pair, was rejected if the elliptical confidence intervals for activity centers did not overlap.

The association between cow elk within the same home range group was compared to their associations with cow elk from different home range groups. Association refers to the percentage of time that one marked elk was located in the presence of another marked elk. The coefficient of association was calculated as follows:

$$CA = \frac{2AB}{A + B}$$

where AB = number of times elk A and elk B were located together,

A = number of times elk A was located, and

B = number of times elk B was located (Cole 1949).

The coefficient ranges linearly from 0 indicating no association, to 1, indicating perfect association.

Home Range and Movement

Location data collected during summer 1978 and winter 1979 were used to test for seasonal differences in home range activity centers. Student's t-test for paired observations (Dixon and Massey 1969) was used to test the null hypothesis that there was no seasonal difference in the home range sizes of collared elk. Additionally, confidence ellipses for summer and winter activity centers of the collared elk were mapped; seasonal differences in the location of activity centers were inferred if the ellipses were mutually exclusive.

The minimum daily movement distance was used as an index of the actual distance that a collared elk moved in a day. That measure was the line distance between the first location of a collared elk one morning and the first location of that elk the following morning. It was likely that the actual distance moved by the collared elk each day was greater than the distance indicated by the index value; however, the index values were used to examine seasonal changes in the magnitude of daily movement.

Generally, the first location on each collared elk was obtained between 0600 and 1100 each morning; thus, there was variation in the number of hours between location fixes on successive mornings. However, during both winter and summer, the duration of time between those two fixes averaged 24 hours. Additionally, there was no relationship between the number of hours between location fixes and the movement index value ($R^2 = 0.13$, $t = 0.60$, $p > 0.05$). Therefore, no bias was observed that may influence the outcome of seasonal comparisons of daily elk movement.

Seasonal and monthly differences in the daily movement of elk were examined. Student's t-test was used to test the null hypothesis that there was no significant difference in the movement index values during summer and winter. Within the summer and winter season, two factor analysis of variance was used to test the null hypothesis that there were no significant differences in the movement index values obtained during different months. Within each season, Duncan's multiple range test was used to determine which movement indices of pairs of months were significantly different.

Habitat Use

The analyses of habitat use were based on comparisons of utilization of designated habitat units by elk to availability of those units. Habitat selection referred to the cases where the utilization of a habitat unit by an elk was statistically greater than availability of that habitat unit. Habitat avoidance indicated that utilization was significantly less than availability. Unselective use of a habitat unit referred to the cases where there was no statistically significant difference between utilization and availability of that habitat unit.

Patterns of habitat use were analyzed from two perspectives:

1. by comparing the pooled utilization of habitat units by all radio-collared elk to the availability of the habitat units in the entire watershed, and
2. by comparing the utilization of habitat units by individual elk to the availability of the habitat units within each individuals home range.

In both analyses, the selection and avoidance of north and south side of the Hoh River was examined in addition to the selection and avoidance of designated habitat units.

Habitat use was analyzed separately for three seasons:

1. summer (10 June 1978 - 31 August 1978),
2. winter (1 January 1979 - 28 February 1979), and
3. late winter (1 March - 20 March 1978, 1979)

Late winter habitat use was described separately because there was a noticeable shift in habitat use in the beginning of March. Observations from March 1978 and 1979 were pooled to form the late winter data set. For each season, Chi-square analyses (Dixon and Massey 1969) were used to test the hypothesis that habitat use by elk was random.

For each elk and season, selection and avoidance of each habitat unit were tested for statistical significance. In each case, the null hypothesis was that there was no significant difference between utilization and availability of the habitat unit. To test that hypothesis, the Bonferonni Z-statistic was used to establish a confidence interval for utilization of each habitat unit (Nue et al. 1974). If the confidence interval for utilization of a habitat unit did not encompass the value of availability of that habitat, the null hypothesis was rejected.

There were problems with statistical interpretation in cases where there were no locations of elk in a habitat unit; construction of a confidence interval was not possible when utilization equalled zero. Those cases were interpreted as signifying avoidance, although the statistical significance of such comparisons was not testable.

RESULTS

Accuracy of Radio-telemetry Procedure

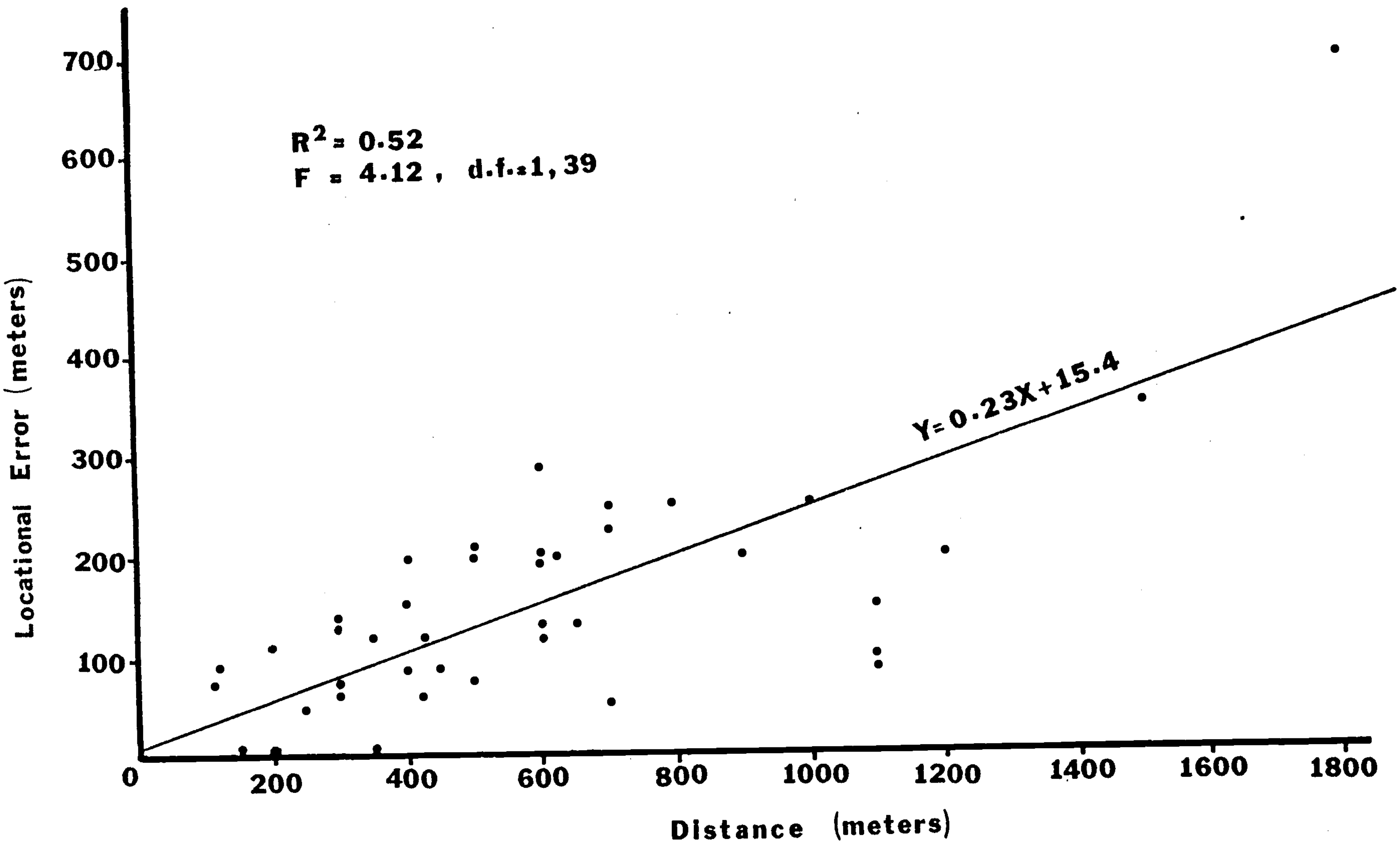
Azimuth error was defined as the number of degrees between the azimuth of the confirmed location of the radio-collared elk and the telemetry derived azimuth. Location error was defined as the distance between the actual location of the elk and the estimated location. The accuracy of azimuths was not related to distance of collared elk from the telemetry station ($R^2 = 0.002$, $F = 0.28$, $p > 0.05$). Azimuth error averaged 6.8° (S.D. = 5.9°, range = 0-22°). However, location error was related linearly to distance ($R^2 = 0.52$, $F = 4.2$, $p < 0.05$) and was generally 23% of the distance (Fig. 5).

Of the 41 tests, four incorrect habitat determinations were made using the remote telemetry procedure (Table 5). Three of those cases were outside the National Park, where a complex pattern of clearcuts occurred. Therefore, the road system which is present there was used to facilitate confirmation of locations in that area. Only one incorrect habitat determination was made in the first three distance classes indicating that determinations of the habitat unit occupied by a radio-collared elk were reliable.

Home Range Groups

Four home range groups, which were comprised of mature females calves and yearlings of both sexes, were identified in the Hoh Valley study area. Although home ranges of elk from adjacent groups overlapped greatly, the four groups were distinct (Figs. 6,7,8,9). Those groups were named the Ranger Station group (Fig. 6), Snyder Creek group (Fig. 7), Twin Creek group (Fig. 8), and park boundary group (Fig. 9). Home ranges of collared elk within most of the home range groups were nearly identical (Figs. 6,7,8). Home ranges of elk No. 3 and No. 8, in the park boundary group, were least similar (Fig. 9).

Figure 5. Relationship of location error to distance of elk from telemetry receiving station.



R2 = 0.52
F = 4.12 , d.f.=1, 39
Y=0.23X+15.4
Locational Error (meters)
700
600
500
400
300
200
100
0
200
400
600
800
1000
1200
1400
1600
1800
Distance (meters)

Table 5. Reliability of determining habitat unit occupied by radio-collared elk using radio-telemetry procedure.

Distance Class (m)	No. of Trials	No.[a] of Errors	% Correct Habitat Determinations
0–300	9	0	100
301–600	19	1	95
601–900	6	0	100
>900	7	3	57

a/ number of cases in which the telemetry derived location occurred in a habitat unit not actually occupied by the radio-collared elk

Figure 6. Annual home range and activity center of radio-collared elk in the Ranger Station group.

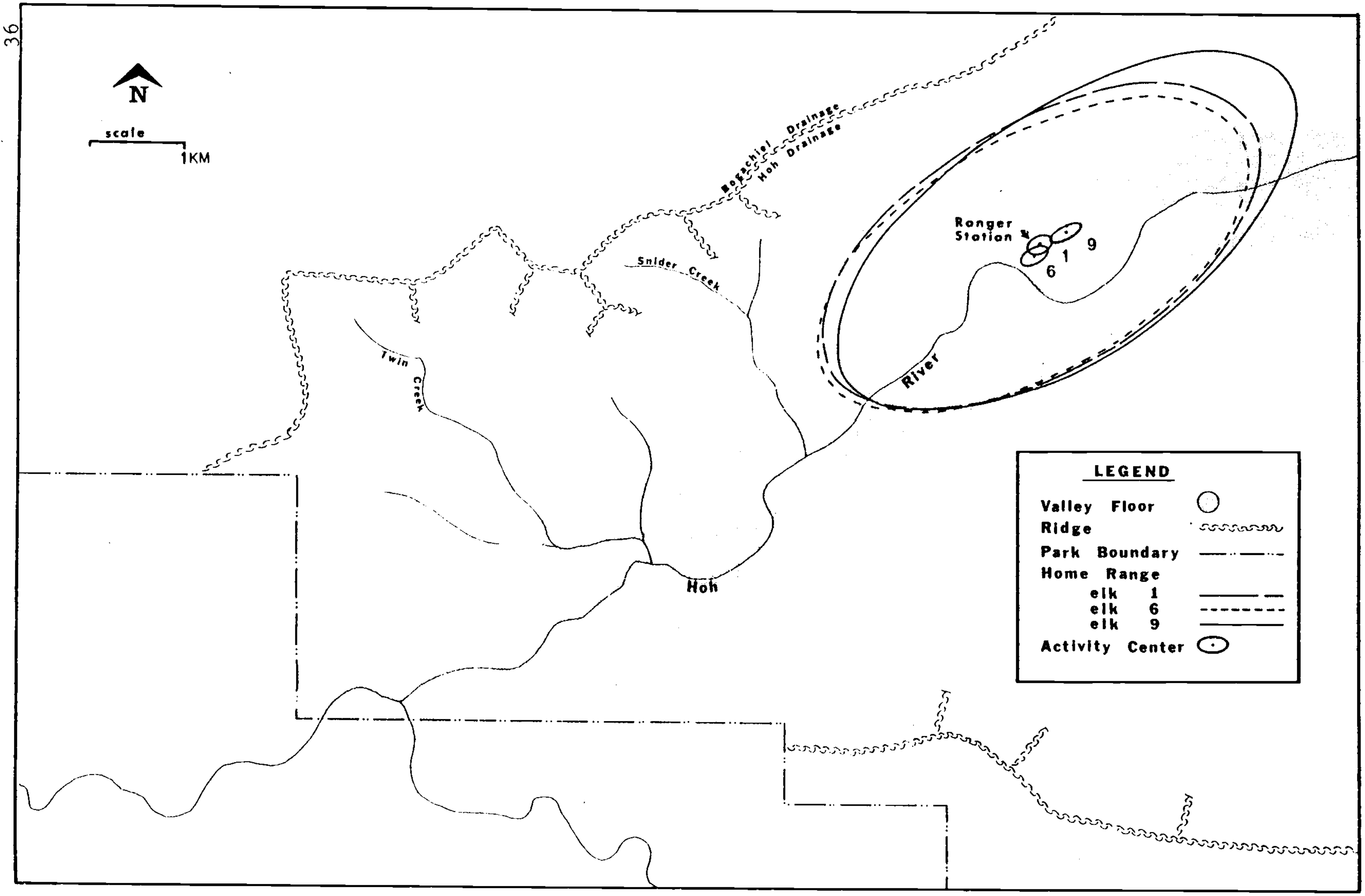

N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
Ronger Station
1
6
9
River
Hoh
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
elk 1
elk 6
elk 9
Activity Center

Figure 7. Annual home ranges and activity centers of radio-collared elk in the Snyder Creek group.

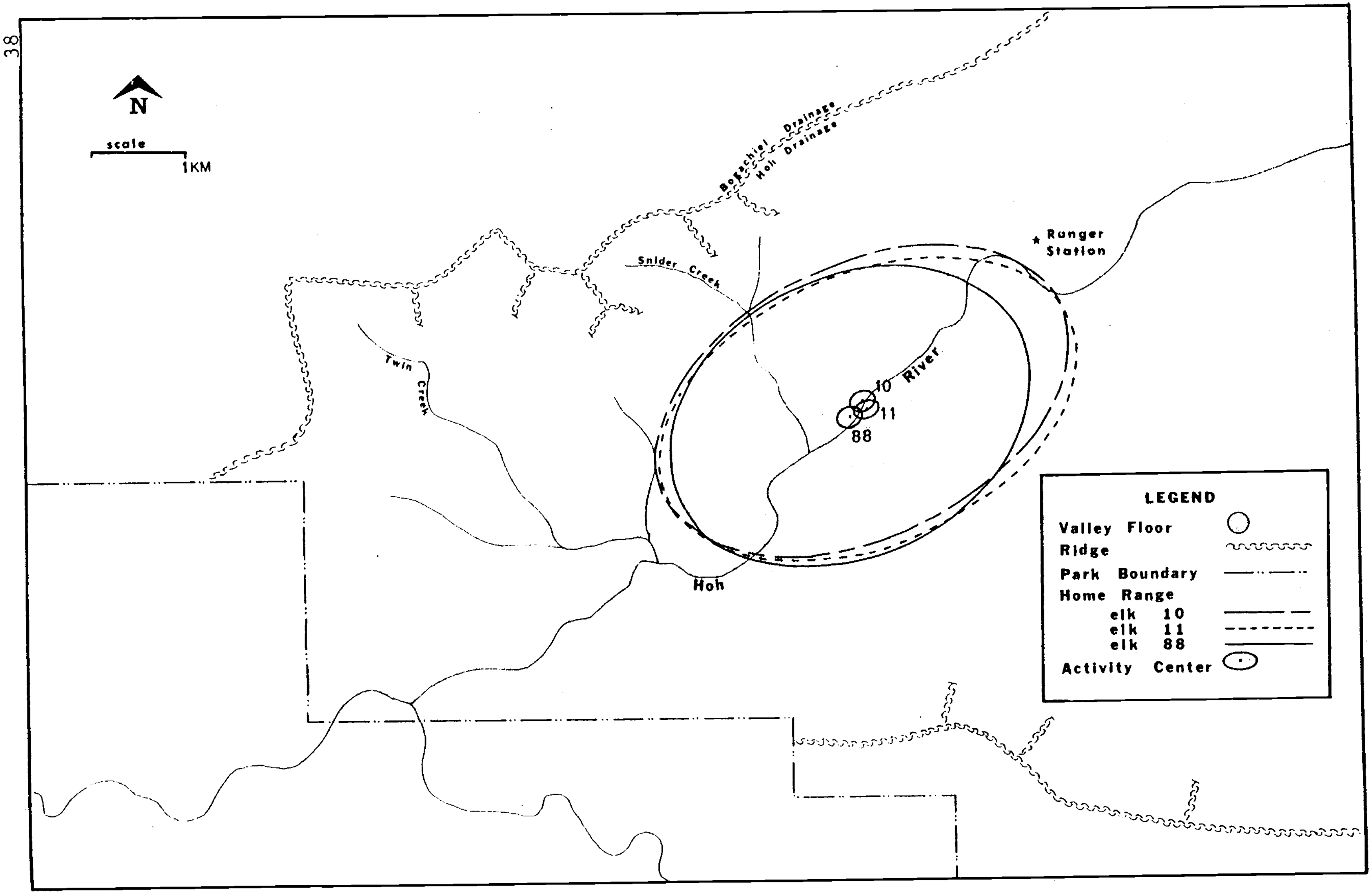

N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
Ranger Station
10
11
88
River
Hoh
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
elk 10
elk 11
elk 88
Activity Center

Figure 8. Annual home ranges and activity centers of radio-collared elk in the Twin Creek group.

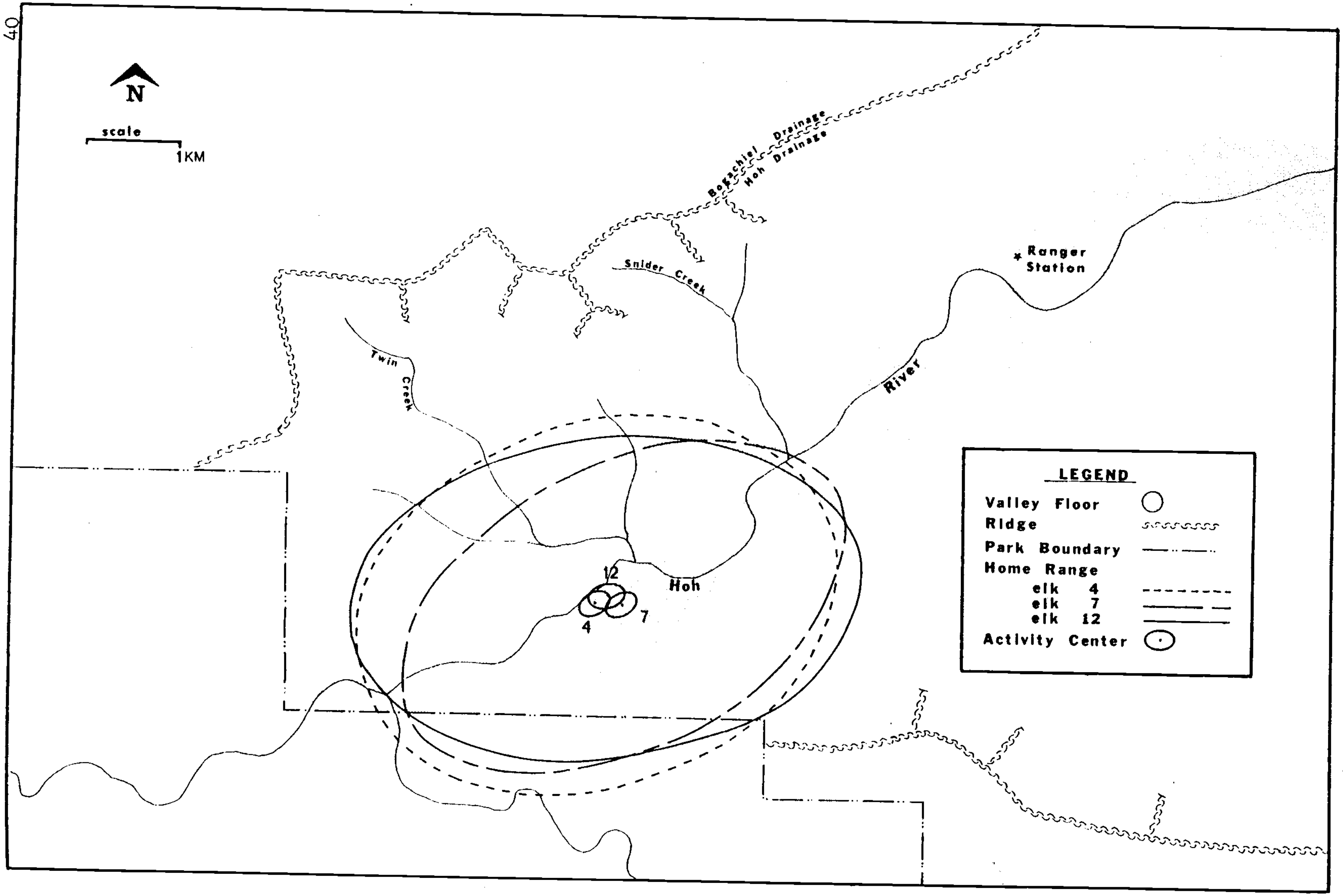
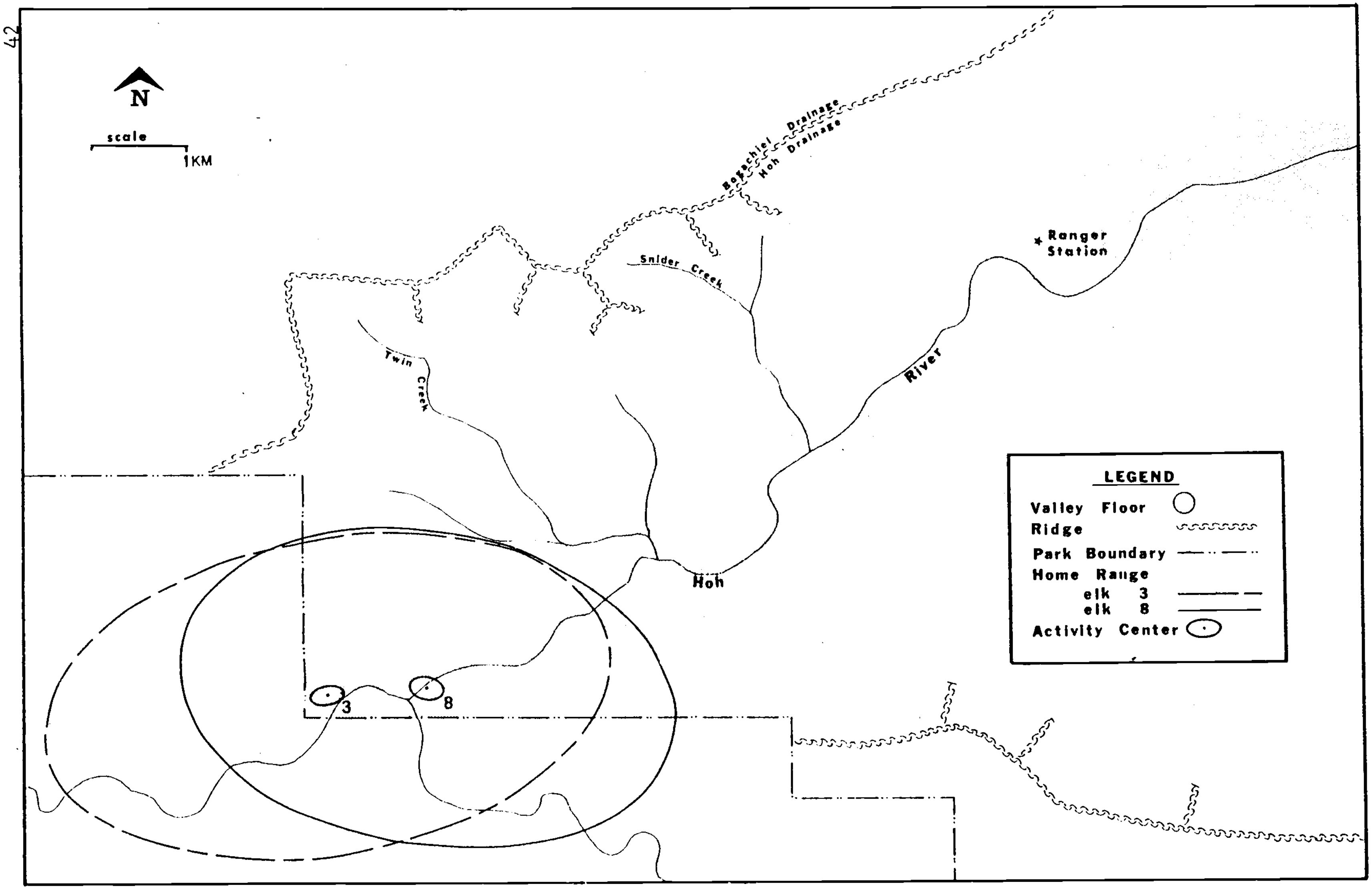

N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
Ranger Station
River
Hoh
12
4
7
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
elk 4
elk 7
elk 12
Activity Center

Figure 9. Annual home ranges and activity centers of radio-collared elk in the park boundary group.


N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
Ranger Station
River
Hoh
3
8
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
elk 3
elk 8
Activity Center

There was no significant difference in the location of activity centers of collared elk within most home range groups. In the Ranger Station group, there was no difference in the location of activity centers of elk No. 1 and No. 6 ($p > 0.05$), and of elk No. 1 and No. 9 ($p > 0.05$), although the activity centers of elk No. 6 and No. 9 were distinct ($p < 0.05$) (Fig. 6). Additionally, there was no difference ($p > 0.05$) in the location of activity centers of collared elk within the Snyder Creek (Fig. 7) and Twin Creek (Fig. 8) groups. However, the activity centers of No. 3 and No. 8 in the park boundary group were distinct ($p < 0.05$) and separated by one kilometer (Fig. 9).

Elk within home range groups were highly associated with each other (Fig. 10A). Coefficients of association for elk within a home range group ($\bar{x}$ = 0.71, range = 0.13-0.94) were greater than those for elk between home range groups ($\bar{x}$ = 0.009, range = 0.00-0.05). The lowest coefficient of association for elk within a home range group (0.13) occurred between No. 3 and No. 8 in the park boundary group (Fig. 10A)

Coefficients of association between elk with calves (No. 3, No. 8, No. 4, No. 7) were lowest in June 1979 (Fig. 10B). Elk No. 10 and No. 11 were not observed with a calf; however, on the basis on the low association between them in June, it is likely that one of those cows was with a calf. Elk No. 1, No. 6 and No. 9 maintained high association with each other and were not observed with young in 1978.

Although collared elk within home range groups were highly associated, collared members of a group separated for short periods of time. The duration of those periods averaged 5.4 days (n =42) whereas collared elk remained together an average of 17.8 days (n =46) (Table 6). The duration of those periods varied considerably between and within elk pairs. Separation between collared members of a group was most frequent during calving.

Collared elk from adjacent groups were rarely seen together. In eight cases in which collared elk from adjacent groups were located together, the association lasted for three days or less ($\bar{x}$ = 1.4 days).

Figure 10. Coefficients of association for pairs of radio-collared elk during the entire study period and during June only. Values in shaded cells are coefficients for pairs of elk within a home range group; values in unshaded cells are coefficients for pairs of elk from adjacent home range groups; empty cells are shown for elk whose home ranges did not overlap and were never located together.

A. ENTIRE STUDY

ELK NO.	1	6	9	10	11	88	4	7	12	3	8
1	1.00										
6	0.94	1.00									
9	0.76	0.71	1.00								
10	0.00	0.00	0.00	1.00							
11	0.01	0.01	0.00	0.75	1.00						
88	0.02	0.02	0.01	0.88	0.88	1.00					
4				0.01	0.01	0.01	1.00				
7				0.01	0.01		0.49	1.00			
12				0.01	0.01	0.01	0.88		1.00		
3							0.01	0.01	0.00	1.00	
8							0.05	0.01	0.00	0.13	1.00

ELK NO.

B. JUNE ONLY

ELK NO.	1	6	9	10	11	4	7	3	8
1	1.00								
6	0.94	1.00							
9	0.85	0.92	1.00						
10	0.00	0.00	0.00	1.00					
11	0.00	0.00	0.00	0.26	1.00				
4				0.00	0.00	1.00			
7				0.00	0.00	0.11	1.00		
3						0.00	0.00	1.00	
8						0.00	0.06	0.00	1.00

ELK NO.

Table 6. Duration of periods that pairs of elk within the same home range group were observed together and apart.

Elk pair	TOGETHER			APART		
	n	$\bar{x}$ (days)	S.D. (days)	n	$\bar{x}$ (days)	S.D. (days)
1,6	5	35.2	21.9	3	6.3	4.04
6,9	8	17.4	17.2	8	6.0	7.4
1,9	9	15.0	13.6	10	3.6	6.2
10,11	5	24.2	25.8	4	6.5	3.9
10,88	1	53.0	--	1	2.0	--
11,88	1	53.0	--	1	2.0	--
4,7	9	4.9	3.4	8	6.8	9.3
4,12	3	19.7	22.3	3	3.0	1.7
3,8	5	7.6	5.5	4	8.2	9.9

In four cases, two groups merged, each with at least two collared elk. The original pairs of collared elk remained together after the brief association. Thus, there was no permanent crossing over of collared elk between home range groups during the study.

Home Range and Movements

The ten elk that were equipped with radio-transmitters during the winter of 1978 were non-migratory. None of those elk dispersed from the lowlands to use a discrete summer range at higher elevations. However, two elk traveled to the Bogachiel River Valley during August 1978. Elk No. 8 was observed in the Hoh Valley on 14 August. Seven days later, she was observed in the Bogachiel Valley, 4.8 km from her location on 14 August. On 17 August, No. 4 traveled to the Bogachiel Valley independent of No. 8. The maximum distance she was observed from her location on 17 August also was 4.8 km. No. 4 was observed in her normal Hoh Valley range on 4 September.

Seasonal comparisons of home range size and activity center were based on locations of seven elk in which both summer and winter observations were obtained. Although summer home range was usually larger, there was no significant difference between summer and winter home range size ($t = 0.92$, $p > 0.05$). Summer home range size averaged 1034 ha whereas winter estimated averaged 1003 ha (Table 7).

Summer and winter activity centers on all collared elk were significantly different ($p < 0.05$). Out of seven comparisons, activity centers of five elk shifted toward the south side of the river during summer; the activity centers of five elk also shifted upriver during summer. Thus the trend was a shift of elk activity toward the south side of the river and upriver during summer. The summer and winter home ranges and activity centers of four representative elk are shown in Figures 11 and 12.

Distances of daily movement of the radio-collared elk were greater during summer than during winter ($t = 5.39$, $p < 0.05$). The

Table 7. Home range size of radio collared elk during summer 1978 and winter 1979

Elk No.	Home Range Size (HA) Summer	Winter
1	1132	883
6	1153	757
9	1129	828
10	1056	878
11	985	924
88	---	823
4	1273	1620
7	971	---
12	---	1368
3	774	972
8	732	---
Mean	1034	1003
S.D.	188	295

Figure 11. Home range and activity center of elk No. 1 and No. 4 during summer, 1978, and winter, 1979.

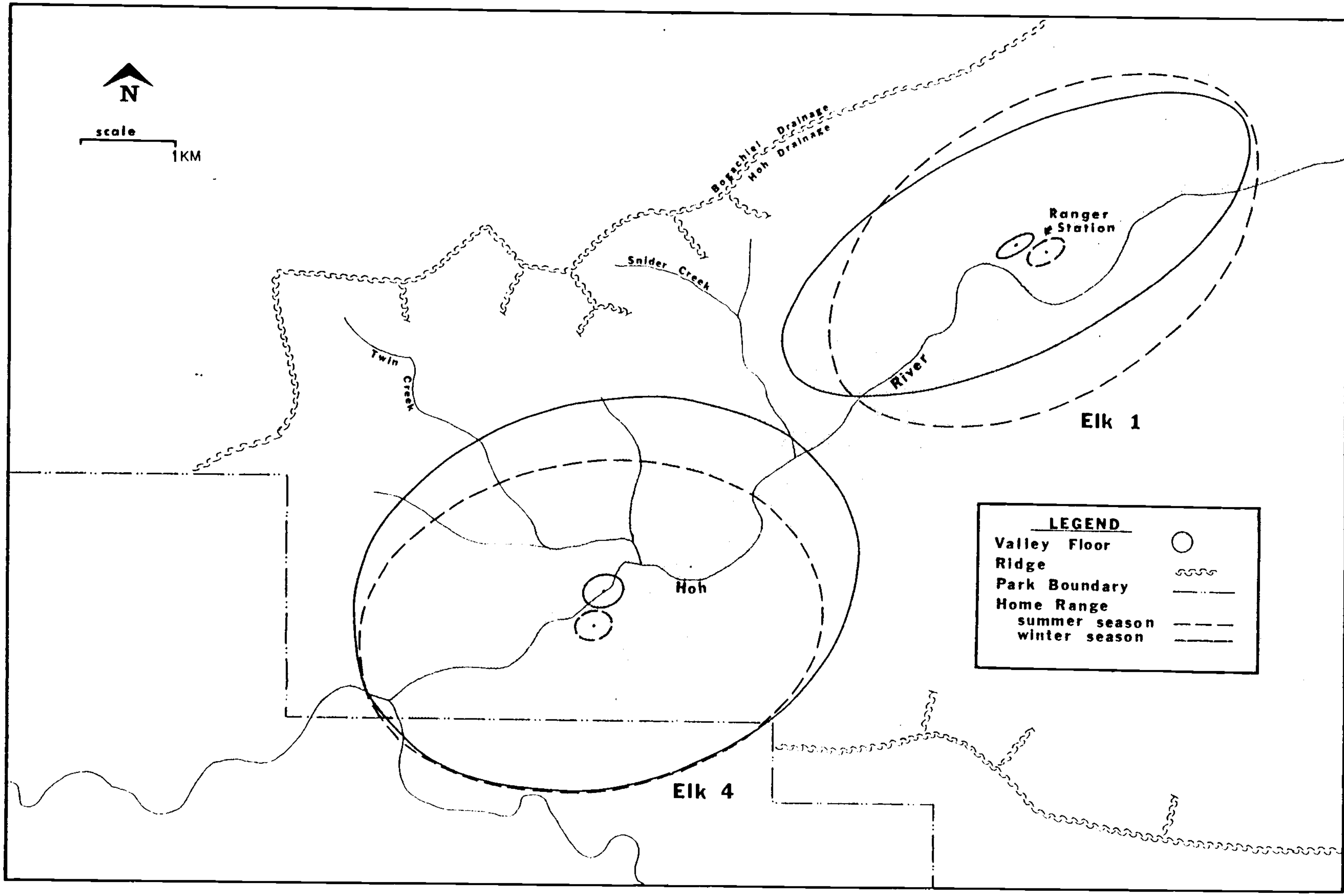
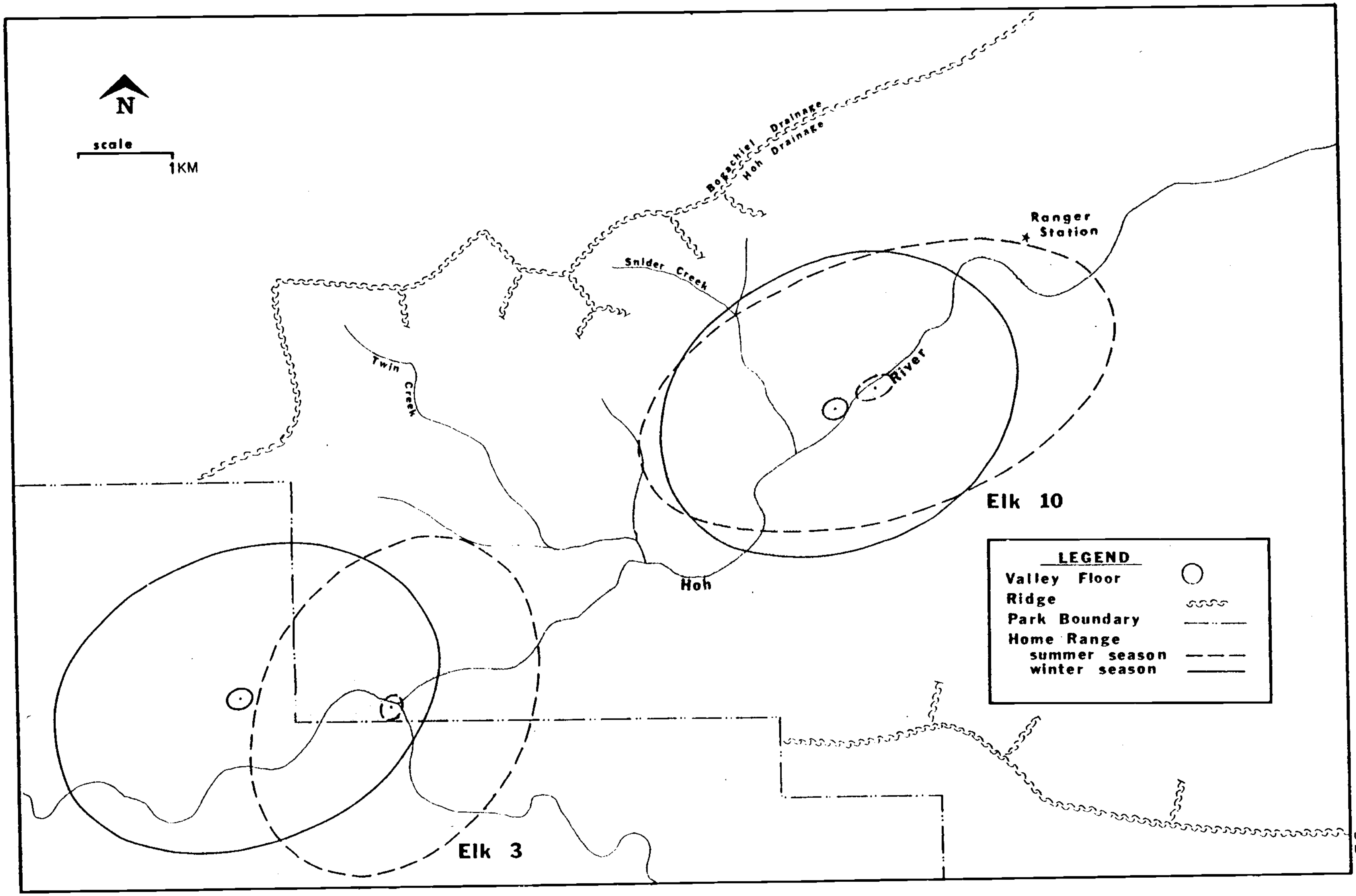

N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
Ranger Station
River
Elk 1
Hoh
Elk 4
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
summer season
winter season

Figure 12. Home range and activity center of elk No. 10 and No. 3 during summer, 1978 and winter, 1979.


N
scale
1KM
Bogachiel Drainage
Hoh Drainage
Snider Creek
Twin Creek
River
Hoh
Ranger Station
Elk 10
Elk 3
LEGEND
Valley Floor
Ridge
Park Boundary
Home Range
summer season
winter season

movement index averaged 843 m during summer (Table 8) and 676 m during winter (Table 9). Within the winter season, movement of collared elk was less during February than during January and March ($F = 10.47$, $p < 0.05$). There was no difference in the distance moved by collared elk during each of the summer months ($F = 3.39$, $p > 0.05$). During June, movements of elk with calves (No. 3, 8, 4, 7) were less than those without calves ($F = 19.92$, $p < 0.05$). The minimum distance moved by cows with calves averaged 541 m whereas those without calves averaged 1040 m (Table 8).

Habitat Use

Overall Pattern on National Park Land

The pooled locations of 11 cow elk were distributed primarily on the lower slopes and valley floor during each season. However, elk use of habitat units within that general area differed significantly between seasons ($X^2 = 306.9$, $p < 0.05$) (Table 10).

During summer, radio-equipped cow elk selected alder flat, spruce-hemlock, vine maple and bigleaf maple habitat units (Table 10). Elk avoided the valley wall and valley bench habitat units, except for the lower third of the north valley wall. Elk selected the south side of the river during summer (Table 10).

During winter, cow elk avoided gravel bars but selected all other floodplain terrace habitat units (alder flat, spruce-cottonwood, spruce-hemlock, vine maple and bigleaf maple habitat units) and the lower south-facing slopes on the north valley wall (Table 10). Lower north-facing slopes were used in proportion to their availability but all of the other valley wall habitat units and the valley bench were avoided Cow elk were unselective of north or south side of the river during winter.

During late winter, cow elk avoided gravel bars, vine maple, and bigleaf maple habitats and selected alder bottoms, spruce-cottonwood, and spruce-hemlock habitats (Table 10). All valley wall and valley bench habitats were avoided. The north side of the river was selected during late winter.

Table 8. Average minimum daily movement distance for each radio collared elk during summer 1978[a/]

Elk No.	Minimum Movement Distance (M) June	July	Aug.	Sept.	Mean	S.D.	N
1	873	924	845	1024	905	529	72
6	1124	912	852	979	943	581	74
9	1201	974	870	1018	990	606	74
10	916	877	942	878	906	479	70
11	994	967	1036	813	968	556	72
4	802	757	730	627	745	480	59
7	435	733	569	912	654	442	62
3	458	609	709	790	643	490	69
8	401	715	933	1037	747	521	52
Mean	817	836	833	906	843		
S.D.	618	520	512	540		538	
N	105	202	200	97			604

a/ Elk No.'s 4, 7, 3, 8 had calves during summer 1978.

Table 9. Average minimum daily movement distance for each radio collared elk during winter 1979

Elk No.	Minimum Movement Distance (M) Jan.	Feb.	March	Mean	S.D.	N
1	630	513	794	660	492	85
6	696	656	794	740	521	61
9	612	520	530	551	416	86
10	654	494	665	610	463	85
11	788	515	807	717	519	83
88	542	493	796	601	495	52
4	805	682	938	822	512	86
12	831	730	1067	854	553	59
3	540	574	610	579	404	91
Mean	679	572	758	676		
S.D.	435	451	542		491	
N	188	224	276			688

Table 10. Selection and avoidance of habitat units and north and south side of Hoh River during summer, winter and late winter, calculated using pooled location data from all radio-collared elk. [a]

Habitat Unit	SEASON		
	Summer	Winter	Late Winter
Gravel Bar	0	-	-
Alder Flat	+	+	+
Spruce-Cottonwood	0	+	+
Spruce-Hemlock	+	+	+
Vine Maple	+	+	0
Bigleaf Maple	+	+	0
Valley Wall-North, Lower	0	+	-
Valley Wall-North, Middle	-	-	-*
Valley Wall-North, Higher	-*	-	-*
Valley Wall-South, Lower	-	0	-
Valley Wall-South, Middle	-*	-*	-
Valley Wall-South, Higher	-*	-*	-*
Valley Bench	-*	-	-
North	-	0	+
South	+	0	-

[a] + = significant selection

- = significant avoidance

0 = used in proportion to availability

-* = elk not observed in that habitat, avoidance not statistically testable

Individual Patterns on National Park Land

The patterns of habitat use of individual elk were also examined to identify individual characteristics of home range utilization. In those analyses, the utilization was compared to the availability of habitat units within the annual home range of each individual. The null hypothesis, that elk used habitat units within their home range randomly, was rejected for all elk and seasons ($p < 0.05$) (Table 11). The hypothesis, that use of habitat units by individual elk was independent of season was also rejected for each elk ($p < 0.05$) (Table 12).

Summer

During summer, most elk on national park land selected spruce-hemlock and vine maple habitat units (Table 13, Fig. 13). Alder flats, spruce-cottonwood and bigleaf maple habitats were used in proportion to their availability by most elk. Additionally, most elk used the lower portion of the south valley wall in proportion to its availability (Table 13, Fig. 13). Other valley wall habitats, the valley bench habitat, and gravel bars were avoided by most elk (Table 13, Fig. 13). Three elk that used gravel bars in proportion to their availability were observed mostly bedded on gravel bars during hot, midday periods in July. All radio-collared elk selected the south side of the river during summer (Table 14).

Winter

Cow elk were less selective of the habitat units during the winter of 1979 than during the summer season (Fig. 13). On the valley floor, alder flat, spruce-cottonwood, spruce-hemlock, vine maple, and bigleaf maple habitat units were used by most elk in proportion to their availability (Table 15, Fig. 13). Most elk were unselective of valley wall habitats or avoided them (Table 15. Fig. 13). The lower,

Figure 13. Summary of habitat selection and avoidance by radio-collared elk during summer 1978, winter 1979, and late winter 1978 and 1979. N equals the number of collared elk with that habitat unit within its home range. Black bars represent the percentage of elk that avoided that habitat unit; white bars represent the percentage of elk that used that habitat unit in proportion to its availability; shaded bars indicate the percentage of those that selected that habitat unit. Key of habitat unit abbreviations same as Table 13.

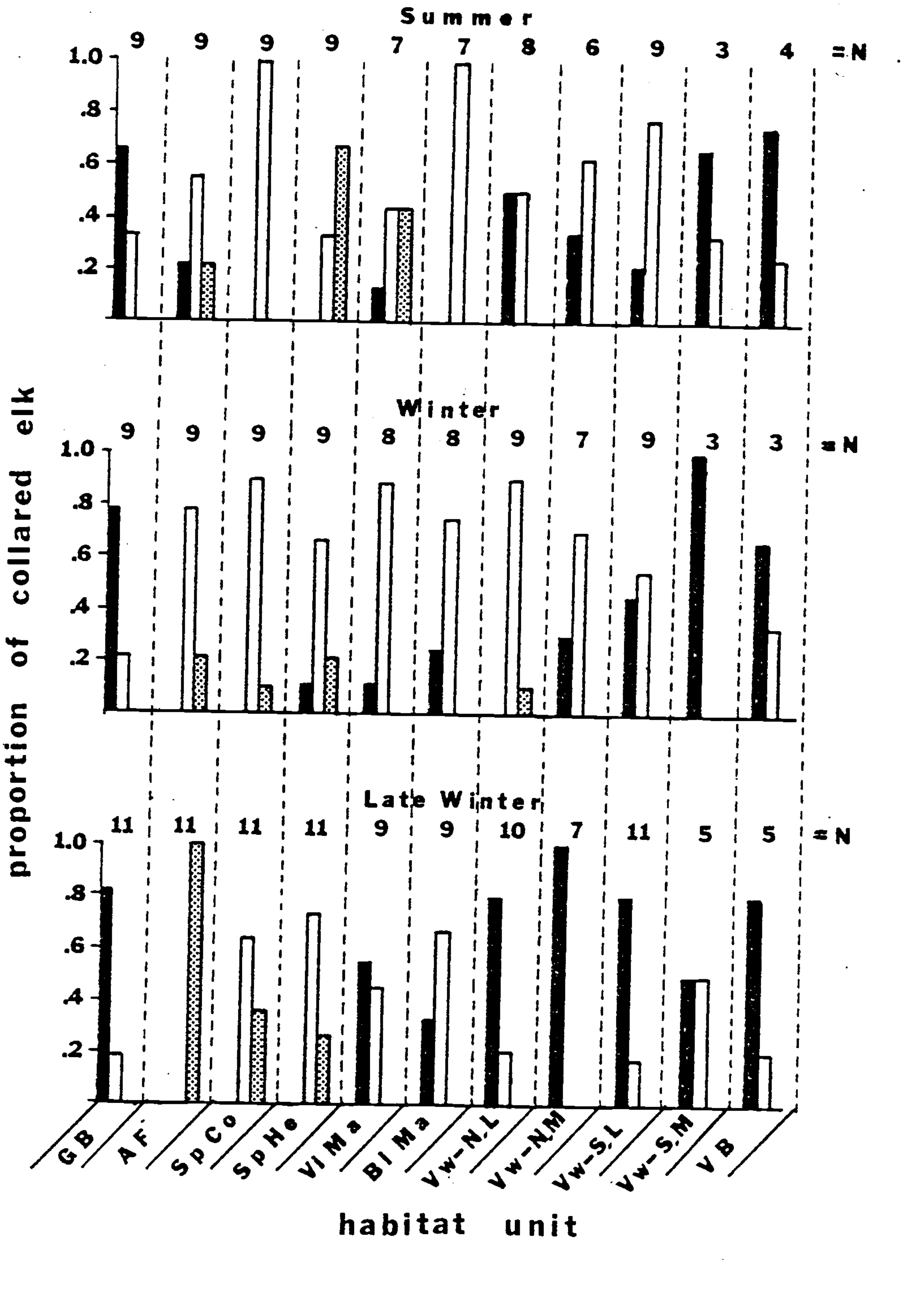

Summer
9 9 9 9 7 7 8 6 9 3 4 =N
Winter
9 9 9 9 8 8 9 7 9 3 3 =N
Late Winter
11 11 11 11 9 9 10 7 11 5 5 =N
1.0
.8
.6
.4
.2
proportion of collared elk
GB
AF
SpCo
SpHe
VlMa
BlMa
Vw-N,L
Vw-N,M
Vw-S,L
Vw-S,M
VB
habitat unit

Table 11. Chi-square values used to test the hypothesis that elk use of habitat units was random. Tabular chi-square values at p = 0.05 are in parentheses.

Elk		SEASON	
	Summer	Winter	Late Winter
1 (15.51)	44.70	21.81	44.46
6 (15.51)	43.21	32.74	44.22
9 (15.51)	63.63	25.63	47.31
10 (15.51)	41.05	17.62	186.82
11 (15.51)	37.73	22.54	197.06
88 (15.51)	--	29.78	148.62
4 (25.00)	89.00	41.27	225.94
7 (19.68)	42.21	--	75.98
12 (23.68)	--	27.78	126.00
3 (25.00)	237.18	84.96	232.80
8 (23.68)	79.48	--	38.75

Table 12. Chi-square values used to test the null hypothesis that elk use of habitat units was independent of season. Tabular chi-square values at p = 0.05 are in parentheses.

Elk No.	Chi-square
1	30.06 (23.68)
6	46.94 (26.30)
9	57.65 (26.30)
10	70.96 (26.30)
11	93.37 (26.30)
88	32.05 (14.07)
4	74.47 (23.68)
7	19.45 (14.07)
12	25.42 (14.07)
3	143.40 (36.42)
8	24.50 (18.31)

Table 13. Selection and avoidance of habitat units on national park and non-park land[a/] during summer 1978, using location data from individual elk[b/]

Habitat Unit				ELK NO.					
	1	6	9	10	11	4	7	3	8
GB	-	-	-	-	-	0	0	-	0
AF	+	0	0	-	-	+	0	0	0
SpCo	0	0	0	0	0	0	0	0	0
SpHe	0	0	+	+	+	+	+	0	+
ViMa	+	+	+	0	0	-*	0		
BLMa	0	0	0	0	0	0	0		
VW-N,L	0	0	-	-	-	-*		0	0
VW-N,M	0	0	-	-*		0			0
VW-S,L	-*	0	0	0	-	0	0	0	0
VW-S,M						-*	-*	0	
VB						-*	-*	0	-
CC,Yng								-*	-*
CC,Mid						-	-	0	0
CC,Old								-*	-*
SG,Yng						0	-*	0	+
SG,Old						0	-*	0	0
OH						-*	-*	+	0
OG						0	-*	-*	-*

a/ Habitat units on national park and non-park land:

GB	Gravel Bar
AF	Alder Flat
SpCo	Spruce-Cottonwood

Habitat units on national park land only:

SpHe	Spruce-Hemlock
ViMa	Vine Maple
BLMa	Bigleaf maple
VW-N,L	Valley Wall-North,Lower elev.
VW-N,M	Valley Wall-North,Middle elev.
VW-N,H	Valley Wall-North,Higher elev.
VW-S,L	Valley Wall-South,Lower elev.

Table 13. (Continued)

Habitat units on national park land only (continued):

VW-S,M	Valley Wall-South,Middle elev.
VW-S,H	Valley Wall-South,Higher elev.
VB	Valley Bench

Habitat units on non-park land only:

CC,Yng	Young Clearcut
CC,Mid	Mid-age Clearcut
CC,Old	Old Clearcut
SG,Yng	Young Second Growth
SG,Old	Old Second Growth
OH	Old Homestead
OG	Old Growth Forest

b/ + = significant selection
- = significant avoidance
0 = used in proportion to availability
-* = elk not observed in that habitat, avoidance not statistically testable

Table 14. Selection and avoidance of north and south side of river during summer 1978, winter 1979, and late winter 1978, 1979, using location data from individual elk[a/]

Habitat Unit	ELK NO. 1	6	9	10	11	88	4	7	12	3	8
SUMMER 1978											
North	–	–	–	–	–		–	0		–	–
South	+	+	+	+	+		+	0		+	+
WINTER 1978											
North	+	+	+	–	–	–	0		0	+	
South	–	–	–	+	+	+	0		0	–	
LATE WINTER 1978,1979											
North	0	0	0	+	+	0	–	0	–	–	0
South	0	0	0	–	–	0	+	0	+	+	0

a/ + = significant selection – = significant avoidance 0 = used in proportion to availability

Table 15. Selection and avoidance of habitat units on national park and non-park land[a/] during winter 1979, using location data from individual elk.[b/]

Habitat Unit	ELK NO. 1	6	9	10	11	88	4	12	3
GB	–	–	–	–	–	–	0	0	–*
AF	+	+	0	0	0	0	0	0	0
SpCo	0	–*	0	0	0	0	0	0	0
SpHe	0	0	0	0	0	0	+	+	–
ViMa	0	–*	0	0	0	0	0	0	
BLMa	–	–*	0	0	0	0	0	0	
VW-N,L	0	0	+	0	0	0	0	0	0
VW-N,M	0	0	0	0		–*	0	–*	
VW-S,L	–*	–*	–*	0	0	0	0	0	–*
VW-S,M							–*	–*	–*
VB							–	0	–
CC,Yng									0
CC,Mid							–*	–*	0
CC,Old									–*
SG,Yng							–*	–*	0
SG,Old							–*	–*	0
OH							–*		–*
OG							–*	–*	0

a/ Key of abbreviations of habitat units same as Table 13.

b/ + = significant selection
– = significant avoidance
0 = used in proportion to availability
–* = elk not observed in that habitat, avoidance not statistically testable

north valley wall was used more frequently than any of the other valley wall habitats. Elk were usually observed using the lower, south facing slopes on clear, cold days in January and February. There was no trend in the selection of north or south side of the river during the winter season (Table 14).

Late Winter

During late winter, elk were attracted to early successional communities. All collared elk selected alder flat habitats during that season (Table 16, Fig. 13). Many radio-collared elk also selected spruce-cottonwood or spruce-hemlock habitats whereas vine maple and bigleaf maple habitats were avoided or used unselectively (Table 16, Fig. 13). Most of the collared elk avoided valley wall habitats and the valley bench habitat (Table 16, Fig. 13). There was no trend in selection or avoidance of the north or south side of the river during that season (Table 14).

The radio-collared elk generally used alder flat and spruce-cottonwood habitats during early morning and late afternoon feeding periods. Usually during mid-morning, elk left those habitats and often spent the midday period bedded in the spruce-hemlock habitat unit. Of 185 morning observations, the collared elk were located in alder flat or spruce-cottonwood habitats on 98 occasions. Of the 98, the elk moved into the spruce-hemlock habitat unit during midday on 61 occasions; on the remaining 37, they spent the entire day in the alder flat or spruce-cottonwood habitat.

Use of Non-Park Land

Elk No. 3 and No. 8 were the only collared elk that spent considerable time on non-park land. During summer 1978, both elk avoided young and old clearcuts (0-4 and 12-20 years since harvest, respectively) and used mid-age clearcuts (4-12 years since harvest) in

Table 16. Selection and avoidance of habitat units on national park and non-park land[a/] during late winter 1978, 1979, using location data from individual elk. [b/]

Habitat Unit	ELK NO.										
	1	6	9	10	11	88	4	7	12	3	8
GB	-*	-*	-*	-*	-	-*	-	0	0	-*	-*
AF	+	+	+	+	+	+	+	+	+	+	+
SpCO	0	0	0	+	+	+	0	0	0	+	0
SpHe	+	+	0	0	0	0	+	0	0	0	0
ViMa	0	0	0	-	-*	-*	-*	-*	0		
BLMa	-*	-*	0	0	0	0	0	0	-*		
VW-N.L	-	-	0	-	-*	-*	-*		-*	-*	0
VW-N,M	-*	-*	-*	-*		-*	-*		-*		
VW-S,L	-*	-*	-*	-	-	-	0	-	-	0	-*
VW-S,M							0	0	-*	-*	0
VB							-	-*	-	-	0
CC,Yng										-*	-*
CC,Mid							0	-*	-*	0	0
CC,Old										-*	-*
SG,Yng							-*	-*	-*	0	0
SG,Old							-*	-*	-*	0	0
OH							0	+		+	0
OG							-*	-*	-*	-*	0

a/ Key of abbreviations of habitat units same as Table 13.

b/ + = significant selection
- = significant avoidance
0 = used in proportion to availability
-* = elk not observed in that habitat, avoidance not statistically testable

proportion to their availability (Table 13). Clearcuts were used mostly during the early morning and late evening for feeding. The most heavily used area was a young second growth stand (20-30 years since harvest) of dense Douglas-fir and Sitka spruce at the confluence of the South fork and main fork of the Hoh River. Many wet meadows were interspersed throughout the stand. Elk No. 3 selected an old homestead site at the confluence of the two rivers, which also had several open meadows within a dense stand of Douglas-fir and Sitka spruce regeneration. Elk No. 3 and No. 8 both avoided old growth stands outside the national park and used older second growth stands (50 years since harvest) in proportion to their availability (Table 13).

Elk No. 3 was the only radio-collared elk using non-park land during the winter season. She used young and mid-age clearcuts, young second growth stands, and old second growth stands in proportion to their availability (Table 15). She selected old growth stands during that season (Table 15), often bedding in such areas which border clearcuts on the north valley wall outside the park. The homestead habitat unit and old clearcuts were avoided (Table 15).

No. 3 and No. 8 selected the alder flat during late winter (Table 16). No. 3 selected the spruce-cottonwood and old homestead habitat units (Table 16). Both elk avoided young and old clearcuts whereas they used mid-age clearcuts and young and old second growth in proportion to their availability (Table 16). Use of old growth declined during late winter.

DISCUSSION AND CONCLUSIONS

Home Range Groups

Previous studies suggest that group constancy or group stability is variable within Roosevelt elk populations and within the conspecific Rocky Mountain elk (*Cervus elaphus nelsoni*) and red deer (*C. e. elaphus*). Darling (1937) considered that elk groups generally consisted of a dominant female, her mature daughters and their offspring. This matriarchal concept has been accepted widely (Graf 1943, Murie 1951, Altmann 1952, McCullough 1969, Franklin *et al*. 1975, Lieb 1973). It implies that home range is passed on through generations, a trait known as home range conservatism (Murie 1951), and that elk groups should be relatively stable. Darling (1937), Altmann (1952), and McCullough (1969) reported that cow groups were stable, although they did not provide quantitative support for their conclusion. With the use of marked Roosevelt elk, Franklin *et al*. (1975) observed that a cow herd formed an "open and semi-stable" association of adult females and their immature offspring. They noted small fluctuations in herd size as "subgroups" entered and left the herd; however, they concluded that the herd was stable since absent individuals always returned to the herd (Franklin *et al*. 1975). Portions of that herd's home range overlapped with other herds but there was no interchange of marked individuals (Franklin *et al*. 1975).

Other studies on marked elk indicated that cow groups were temporary, changing entities. Harper (1964, 1971) found that Roosevelt elk herds in southwestern Oregon continuously changed composition and that marked members of adjacent groups interchanged freely. Knight (1970) and Schoen (1977) used Cole's (1949) coefficient of association to quantify the association between marked elk. Knight (1970) found that the mean coefficient of association between female Rocky Mountain elk in Montana never exceeded 0.47, indicating that those groups should be considered to be aggregations rather than social groups. Shoen

(1977) reported that the mean coefficient of association was 0.20 for 39 female Rocky Mountain elk in western Washington. Marcum (1975), Stehn (1973), and Mackie (1973) also indicated that Rocky Mountain elk groups changed composition frequently. Social groups may be disrupted by seasonal migration in all of those populations.

Franklin and Lieb (1979) hypothesized that variation in group stability between resident Roosevelt elk in Prairie Creek Redwoods State Park and in southwestern Oregon (Harper 1964, 1971) may be caused by differences in the stability of habitat. They suggested that the continual alteration and succession of vegetation due to logging in Southwestern Oregon creates changing habitat conditions which may affect the development and maintenance of social organization. They conclude that relatively stable social organization may be expected in elk populations which inhabit constant environments where the development of long term bonding between individuals may be favored.

In the Hoh Valley, four stable cow groups were identified. Individuals within each group had nearly identical home ranges and activity centers. Additionally, the mean coefficient of association between collared animals within a group ($x = 0.71$) was higher than that reported for elk elsewhere (Knight 1970, Schoen 1977). Although home range groups overlapped broadly, there was no interchange of marked individuals. Separations between marked individuals probably reflected the "subgrouping" phenomenon described by Franklin et al. (1975). The low association between elk with calves in June, indicated that there was a greater frequency of subgrouping as cows left the group to calve. Lieb (1973) and Franklin et al. (1975) also reported that subgrouping was most common during calving. Findings from this study support the hypothesis of Franklin et al. (1975), that more stable elk groups may occur where elk are largely protected from disturbance and habitat alteration.

The concept of herd, or home range group, may not accurately describe the relationship of elk No. 3 to No. 8. Although they occurred together during and after immobilization and used largely the same portion of the watershed, the coefficient of association for that pair was lower than that for any other pair within a group. Additionally, the home ranges and activity centers of those elk were more spatially separated than those of other associated pairs. Although that sample size is too small to allow conclusions, elk groups inhabiting cutover lands adjacent to the park may be less stable than those within the park because of disturbance due to hunting and logging activities. That hypothesis could be tested by comparing the social behavior of elk adjacent to Olympic National Park to that of a nearby population within the park.

Home Range and Movements

Resident elk in the Hoh Valley occupied limited home ranges which mostly included valley bottoms and lower portions of the valley wall. Those findings are in agreement with the early findings of Schwartz (1939) and Newman (1958). However, two resident elk made separate journeys to the adjacent Bogachiel Valley, which indicated that elk are not restricted to lowland areas. Infrequent intermingling among resident populations may occur.

Elk from within Olympic National Park were not drawn to cutover land adjacent to the park. The only radio-collared elk which were influenced by those areas were those whose home ranges included non-park land. No other collared elk migrated or shifted activity down river during winter to make greater use of those areas. Therefore, it appears that the resident elk population in the Hoh Valley is little influenced by land management practices outside the park.

Skinner (1933) and Schwartz (1939) suggested that a migratory portion of the population remains in the upper watershed unless deep snow causes them to move down river. Under such conditions, migratory elk could cross the national park boundary. However, it is unlikely that cutover areas outside the park would be available to elk during severe winters because of snow accumulation; rather, they would probably occupy densly timbered hillsides within the Park, as observed by Newman (1956). Therefore, it seems doubtful that either resident or migratory elk in the Hoh Valley make use of non-park land during winter. However, information on migratory elk in the Hoh Valley is still lacking.

Home range areas of cow elk were usually larger during summer ($\bar{x}$ = 1034 ha) than during winter ($\bar{x}$ = 1003 ha), although the trend was not statistically significant. Home ranges of Roosevelt elk in the Hoh Valley are comparable to those of Roosevelt elk in other areas. In coastal areas of California and Oregon, home ranges of female Roosevelt elk rarely exceeded 2.0 mi^2 (518 ha) (Graf 1943, Franklin et al. 1975). In southwestern Oregon, 97% of each cow elk's movement occurred within 4.0 mi^2 (1035 ha) (Harper 1971). Additionally, home ranges of Rocky Mountain elk in western Washington (Schoen 1977) were similar to those of elk in the Hoh Valley; summer home ranges averaged 1775 ha whereas winter areas averaged 671 ha. Undoubtedly, regional variation in home range size depends on differences in topography, nutritional aspects of vegetation, climate, elevation, hunting and predation.

Daily movements of cow elk were greater during summer than during winter. The only movement of radio-collared elk beyond the Hoh watershed occurred during late summer. The cause of those movements was not known, although they may have been associated with reproductive behavior because they occurred near the onset of the rut. Lieb (1973) reported that cow elk in Prairie Creek Redwoods State Park occasionally left the group prior to onset of the rut and wandered; he suggested that hormonal changes during estrus may contribute to the restlessness of cow elk. Of the winter months, movements of cow elk were greatest in March, which may have reflected a response to production of new green forage.

Movement of cow elk in the Hoh Valley may have been greater during summer than during winter because of climate and seasonal differences in the metabolic rate of cow elk and the nutritive quality of forage. Moen (1973:129) indicated that the metabolic rate of ungulates varies seasonally and is lowest during winter. Silver et al. (1969) demonstrated that fasting metabolism, voluntary food intake and activity of white-tailed deer in New York State were significantly reduced during winter. They suggested that the seasonal changes in metabolism represent a physiological response to weather. Additionally, McEwen et al. (in Behrend 1966:146) suggested that seasonal changes in metabolism and activity of white-tailed deer in the Adirondack Mountains may have evolved in response to poor forage conditions. Reduced movement of elk during winter in the Hoh Valley may also be part of a complex adaptation for energy conservation in response to poor forage and weather conditions.

Habitat Use

During both seasons, the radio-collared elk were distributed primarily on the valley floor. That area is comprised of a successional series of plant communities and may be favored because it is heterogeneous and provides an optimal mosaic of cover and forest clearings which may be used for bedding and feeding, respectively. Additionally, increased solar radiation in forest clearings on the valley floor may enhance the nutritional value of plants which grow there (Klein 1965). Thus, the density of cow elk in other west-facing drainages on the Olympic Peninsula is likely to be related to characteristics of the valley floor, including width of flood plain, extent of alder flats, extent of forest clearings and abundance of browse.

There was seasonal variation in the preference of habitat units within each individuals home range. The collared elk were least selective of habitat during winter, moderately selective during summer, and most selective during late winter. In the Sapphire Mountains, Montana, elk distribution in the summer was influenced by the location of productive feeding sites in close proximity to thermal cover (Marcum 1975). During winter, elk were more influenced by the location of suitable cover than by the location of feeding areas (Beall 1974). In the Hoh Valley, winters are mild and suitable cover is extensive; therefore, cover is probably not limiting and may not have an important influence on the selection of habitat units by elk. High quality forage is probably more limiting to elk in the Hoh Valley and may have more influence on the distribution of those elk. Perhaps as hypothesized in the Cedar River, Washington (Schoen 1977), habitat selection of elk in the Hoh Valley is influenced by seasonal variation in the nutritional heterogenity of the watershed.

Under certain conditions however, elk appeared to select the valley wall habitat because of its thermal features. The lower portion of the north valley wall (south facing) was frequently used by collared elk during clear, cold periods and periods when snow existed on the ground. South facing slopes intercept more solar radiation and are warmer. Additionally, snow depths are lower than on the open valley floor; there may be more available forage in these areas.

Most of the collared elk selected the south side of the river during summer; perhaps because human activity increased on the north side of the river. However, elk appeared to have become conditioned to the sound of automobile traffic and human voices on the Hoh River road. During summer, collared elk often bedded in spruce-hemlock stands, near the road and within the sound of voices and traffic. In most cases, spruce-hemlock stands provided an effective visual screen and the elk largely were undisturbed.

Elk may also have selected the south side of the river during the summer because of nutritional differences in vegetation and thermal differences. Perhaps as spring progresses, new vegetation may be produced first on the north side of the river. That vegetation may cure and become less nutritious earlier than on the south side of the river. Additionally, the south side of the river may be cooler.

Alder flats and spruce-cottonwood stands were important habitats to cow elk during late winter. Elk were observed on the north side of the river more than during other seasons; perhaps because grass became productive on the north side first. Cow elk are nutritionally stressed after winter, and pregnant elk have high protein and energy requirements to support fetal growth. Elk in the Hoh Valley have adapted to those conditions by utilizing productive areas with grassy herbaceous cover during late winter. The influence of new spring growth on elk distribution also was reported in the Sun River drainage, Montana (Brazda 1953, Knight 1970), on the White River Plateau, Colorado (Boyd 1970), and in Yellowstone National Park, Wyoming (Craighead _et al_. 1973).

The recognition of alder flats as important elk habitat has some practical implications. Since alder flats have an open understory, elk are more visible in alder flats than in spruce-hemlock stands and thus, more susceptible to disturbance from human activity. Disturbance may have two adverse affects on ungulates (Geist 1970). First, energy expenditure of an animal increases under disturbance because of an elevated metabolic rate and increased movement in response to the disturbance. Secondly, if disturbance is frequent in an area, the animal may respond by curtailing use of that area, or restrict use to periods when disturbance is infrequent. Because cow elk use alder flats at a nutritionally important time of year, those effects could affect reproduction. A screen of vegetation should be left around any planned human developments to minimize the impact of human activity on elk.

No information was obtained on the distribution of male elk during this study; mature males were not observed with cow groups in the lowlands except during the rut. Male Rocky Mountain elk in Canada were reported to occur at higher elevations and to disperse greater distances than cow elk (Flook 1964). In southwestern Oregon, male Roosevelt elk were reported to occasionally travel several miles in a day (Harper 1971). Therefore, it is likely that male elk in the Hoh Valley occur at higher elevations and travel more extensively than females. Thus, the distribution of males is probably influenced by different factors from those influencing the distribution of females. A study of the movements and habitat use by bull elk would be useful to identify those factors.

Too few collared elk made use of non-park land to allow conclusions concerning the patterns of habitat use on managed land. However, during both seasons, mid-age clearcuts were preferred by two collared elk over clearcuts of other ages, probably because forage was most abundant in that stage. During winter, old growth adjacent to clearcuts was favored as cover. However, during summer, a young second growth stand and an old homestead site were heavily used. Both sites provided good dispersion of meadows within an otherwise dense stand. Uniformly dense second growth stands were avoided by elk. Therefore, it appears that maintenance of proper dispersion of dense cover and small clearings is important to elk on managed land.

The results from this study have provided an initial understanding of the factors which influence the distribution of cow elk and has allowed the formulation of hypotheses to guide additional research. Ongoing research currently is being directed toward understanding nutritional aspects of elk biology. Findings from that and additional research will complement these findings in providing the basic descriptive information on the park's elk resource.

SUMMARY

1. Research on the home range and habitat use by 11 cow Roosevelt elk was conducted to provide basic information on the distribution of an unexploited Roosevelt elk population in unaltered habitat in Olympic National Park.

2. Four home range groups, composed of mature cows, calves and yearlings of both sexes were identified in the study area. The groups were considered stable because home ranges of elk within a home range group were nearly identical, elk within a group were highly associated with each other and there was no permanent interchange of marked individuals between groups. These findings support the contention of Franklin and Lieb (1979) that more stable social organization is found in elk groups which inhabit constant environments. It was hypothesized for future research that elk groups outside the park may be less stable because they inhabit a more temporary, changing habitat.

3. Elk monitored in this study were non-migratory. However, two resident elk made separate journeys during the late summer into the adjacent Bogachiel drainage, suggesting that infrequent intermingling among resident populations from adjacent drainages may occur. Because there was no apparent movement of elk outside of the national park, it was concluded that resident elk in the Hoh Valley are little influenced by land management practices outside the park. However, information on migratory and male segments of the Hoh Valley population is still lacking.

4. Home ranges used by resident cow elk averaged 1034 ha during summer and 1003 ha during winter. However, minimum daily movement of cow elk was significantly greater during summer than during winter; movement indices averaged 843 m during summer and 676 m

during winter. Additionally, during June, movement of cow elk with calves (541 m/day) was significantly less than that of cows without calves (1040 m/day). It was suggested that reduced movement during winter may have evolved as part of a complex adaptation for minimizing energy expenditure in response to poor forage conditions.

5. During both seasons, the radio-collared elk were located primarily on the valley floor. Because the valley floor was identified as important elk habitat in the Hoh drainage, it was suggested for further research that the abundance of elk in other west-facing drainages on the Olympic Peninsula may be related to characteristics of the valley floor.

6. Within each elk's home range there was seasonal variation in the preference of habitat units. The elk were least selective of habitat units during winter, moderately selective during summer, and most selective during late winter. During winter, most valley floor habitat units were used in proportion to their availability. During summer, elk selected the south side of the Hoh River and preferred spruce-hemlock and vine maple habitat units. During late winter, elk were highly selective of alder flat habitat units. Because elk are susceptible to disturbance in alder flat habitats and alder flats were identified as important elk habitat, it was suggested that management alternatives that would protect elk from disturbance in alder flats should be favored. It was hypothesized that nutritional aspects of the environment have an important influence on the distribution of resident cow elk in the Hoh Valley.

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APPENDICES

Appendix A. Monthly means for daily maximum temperature, daily minimum temperature and precipitation at the Hoh Ranger Station.[a]

Month	Daily Maximum Temperature (oC)	Daily Minimum Temperature (oC)	Monthly Precipitation (cm)
January	4.5	-1.2	50.8
February	7.7	-0.1	39.6
March	9.6	0.4	45.0
April	14.2	1.7	18.8
May	17.3	4.6	17.5
June	20.8	6.2	8.6
July	23,8	8.9	7.6
August	23.3	9.7	11.7
September	20.5	7.7	14.2
October	14.1	3.7	28.2
November	7.6	1.0	47.2
December	5.0	-0.1	56.4
	Average Annual Precipitation =		354.4 = 136 inches

a/ Averages were calculated from weather data collected between January 1972 and December 1978.

Appendix B. Summary of Information on Immobilization and Marking of Cow Elk

Date	Elk No.	Drug Dosage (mg)	Reaction Time (minutes)	Immobilization Period (minutes)	Heart Girth (inches)	Collar Symbol	Ear Tag
19 Jan. 1978	6	30	8	65	--	none	none
26 Jan. 1978	1	27	10	54	59.0	1	none
29 Jan. 1978	4	27	20	35	--	4	none
10 Feb. 1978	7	30	10	80	--	7	Orange #7-Rt. ear
11 Feb. 1978	3	30	8	63	63.0	3	Yellow #3-Rt. ear
24 Feb. 1978	88	28	--	65	59.5	8	White #8-Rt. ear
26 Feb. 1978	9	30	--	80	60.0	9	Yellow #9-Lft. ear
27 Feb. 1978	10	28	7	67	59.5	A	none
4 March 1978	11	28	9	40	--	B	Orange #11-Rt. ear
9 March 1978	8	28	--	60	--	X	Orange #24-Lft. ear
14 March 1978	--	28	9	55	61.0	*	Orange #1-Lft. ear
20 March 1978	--	26	8	65	60.5	*	Orange #25-Rt. ear
13 Jan. 1979	12	28	6	50	--	C	Orange #23-Rt. ear

* no radio collar, ear tag only