Roosevelt Elk of the Hoh Valley, Olympic National Park

Final Report,
Contract # CX 9000-7-0085

By Kurt Jenkins and Edward Starkey
National Park Service
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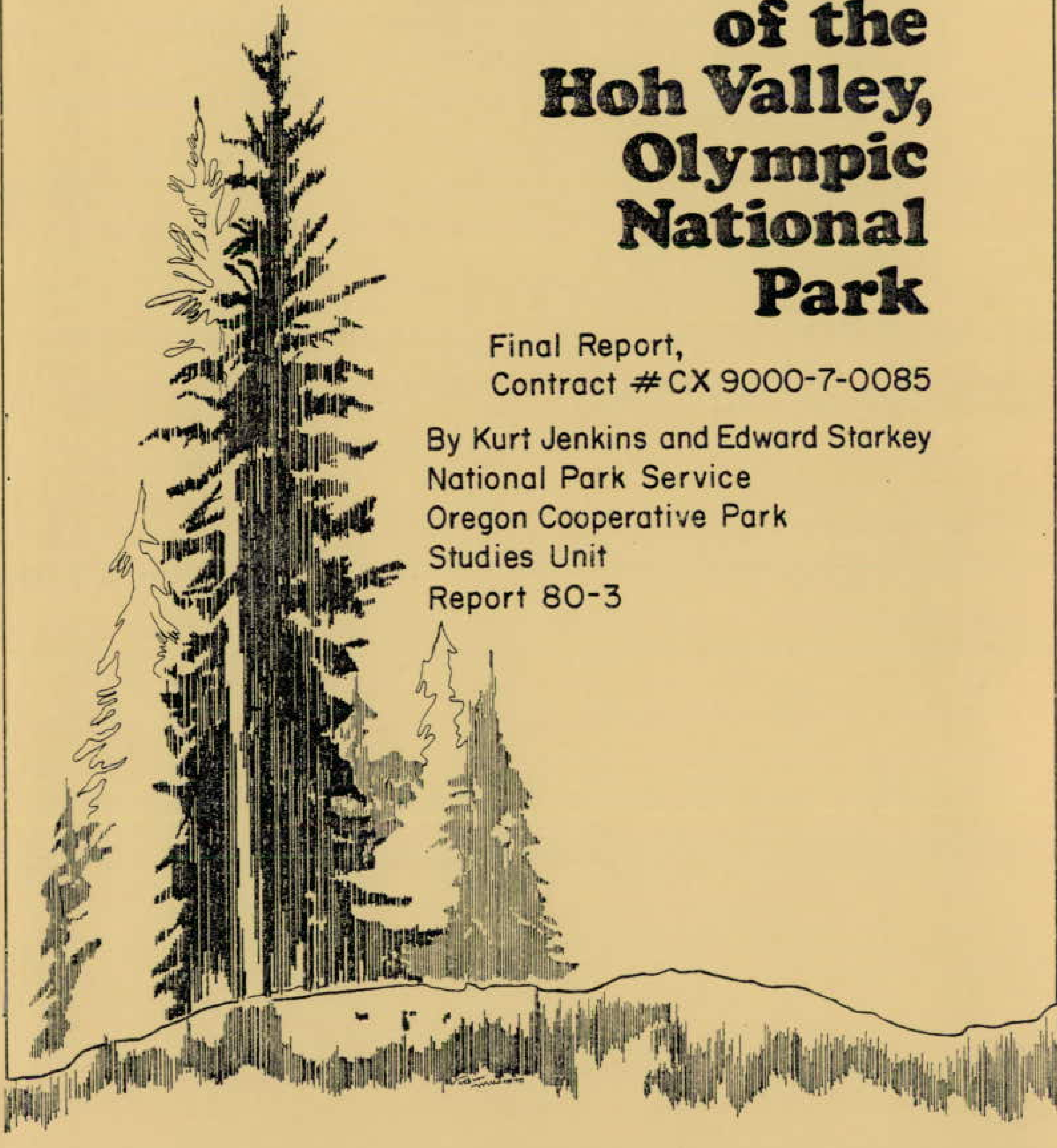
Report 80-3



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OLYMPIC NATIONAL PARK

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SYNOPSIS

Research on the movements and habitat use of cow elk in the Hoh Valley assessed the influence of land management practices outside Olympic National Park on "park" elk and provided baseline information on the behavior of undisturbed elk in old growth forests.

Approximately 250 elk occupied 1764 ha of winter range which occurred in the study area. Eleven elk monitored in this study were non-migratory. Generally, movements of those elk were restricted to home ranges which averaged 1112 ha. No elk more than 5.0 km within the park was ever observed outside the park. Movements of elk were less localized during late summer; 2 elk traveled independently to the Bogachiel drainage to the north, which suggested that some intermingling of populations may occur in that season.

The valley floor was important year around habitat for cow elk. Annual home ranges of elk were oriented to the axis of the valley floor. Additionally, elk selected the valley floor over other physiographic zones during all seasons. Elk selected areas north of the river during late winter and south of the river during summer probably in response to changing phenological and thermal conditions. Lower south-facing slopes were also favored in winter apparently because of their thermal characteristics. The valley floor was probably the most important physiographic zone because forest clearings there provided environmental heterogeneity and abundant forage for elk.

There were seasonal variations in the preferences of habitat units on the valley floor. During summer and winter, elk preferred spruce-hemlock and the maple habitats. During late winter, a nutritionally important time of year, cow elk were highly selective of alder flat habitat units. Thus, management alternatives that protect elk from disturbance in those habitats should be favored.

Elk formed relatively stable associations of adult females and their offspring. Elk within a group were highly associated and there was no lasting interchange of marked individuals between groups. Those findings support the suggestion that social organization is more stable in elk that inhabit undisturbed environments. (Franklin and Lieb 1979).

This study indicated that non-migratory cow elk in the Hoh Valley are influenced little by forest and wildlife management practices which occur outside the park. Although five of the radio-collared elk made use of non-park land, they did not preferentially seek out areas outside the park. It was concluded that elk greater than 5.0 km within the park were not influenced by hunting and land management outside the park. Thus, the behavior and ecology of elk in the Hoh Valley represents the most primeval condition of elk on the Olympic Peninsula and provide unique opportunities for research.

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INTRODUCTION

This research is part of a long term investigation of the behavior and ecology of Roosevelt elk (*Cervus elaphus roosevelti*) in Olympic National Park. The objective of this, the first phase of the research, was to describe the distribution and movements of cow elk in a representative watershed near the boundary of the park. A primary purpose was to determine the extent to which elk within Olympic National Park made use of non-park land. That information was needed to assess effects of hunting and forest management outside the park on park elk. A second goal was to provide baseline information so that changes in the distribution and behavior of elk within the park can be identified.

To attain those objectives, radio-telemetry was used to monitor the movements of adult cow elk in the Hoh Valley for seven months during 1978 and 1979. Systematic locations of monitored elk were used to obtain information on home range and movement, habitat use and social group interactions by elk. That approach provided information to appraise the degree of movement by elk across the national park boundary and to establish initial understanding of the behavior of elk in an undisturbed old-growth forest. As more information becomes available, it will provide a means to assess the overall influence of forest management and human activity on the behavior of Roosevelt elk.

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 red cedar (*Thuja plicata*) and Douglas-fir (*Pseudotsuga 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 in 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 Heulsdonk, 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. 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. No elk were legally hunted until 1933.

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 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, Sumner (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" (Sumner 1951:2). Seven years later, Newman (1958:2) 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: 217). The 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, sub-populations on the adjacent forest lands may have increased in response to increased forage production following logging (Parsons 1976). If migratory elk from 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 1938, 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 90% 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

Olympic National Park occupies the central mountainous portion of the Olympic Peninsula in northwest Washington (Fig. 1). The study area is located in the valley of the Main Fork of the Hoh River and extends from Canyon Creek, 3 km west of the National Park boundary, upriver approximately 15 km. A single paved road extends the length of the study area along the north side of the Hoh River. The area west of the National Park boundary is managed for timber production by the Washington Department of Natural Resources.

Climate in the Hoh Valley is maritime, with mild, wet winters and cool, dry summers. Average annual precipitation is 345 cm. Areas below 600 m receive mostly rain during winter, although approximately 25 cm of snow falls in valley bottoms each winter (Phillips 1963).

The Hoh Valley has the broad U-shaped configuration characteristic of glaciated watersheds. Elevations range from 150 m on the valley floor to 910 m on adjacent ridgetops. The valley floor is 1.0 - 2.0 km wide, and consists of gravel bars, at least 4 river terraces, and various glacial deposits. The vegetation has been described by Fonda (1974) and represents a sequence of primary succession from bare gravel adjacent to the river, to mature Sitka spruce-western hemlock forests on older terraces (Fig. 2, Table 1). Gravel bars, periodically flooded by the Hoh River, support pioneer communities of young red alder (*Alnus rubra*) and willow (*Salix spp.*). The youngest river terrace is an alluvial deposit 80-100 years old and supports

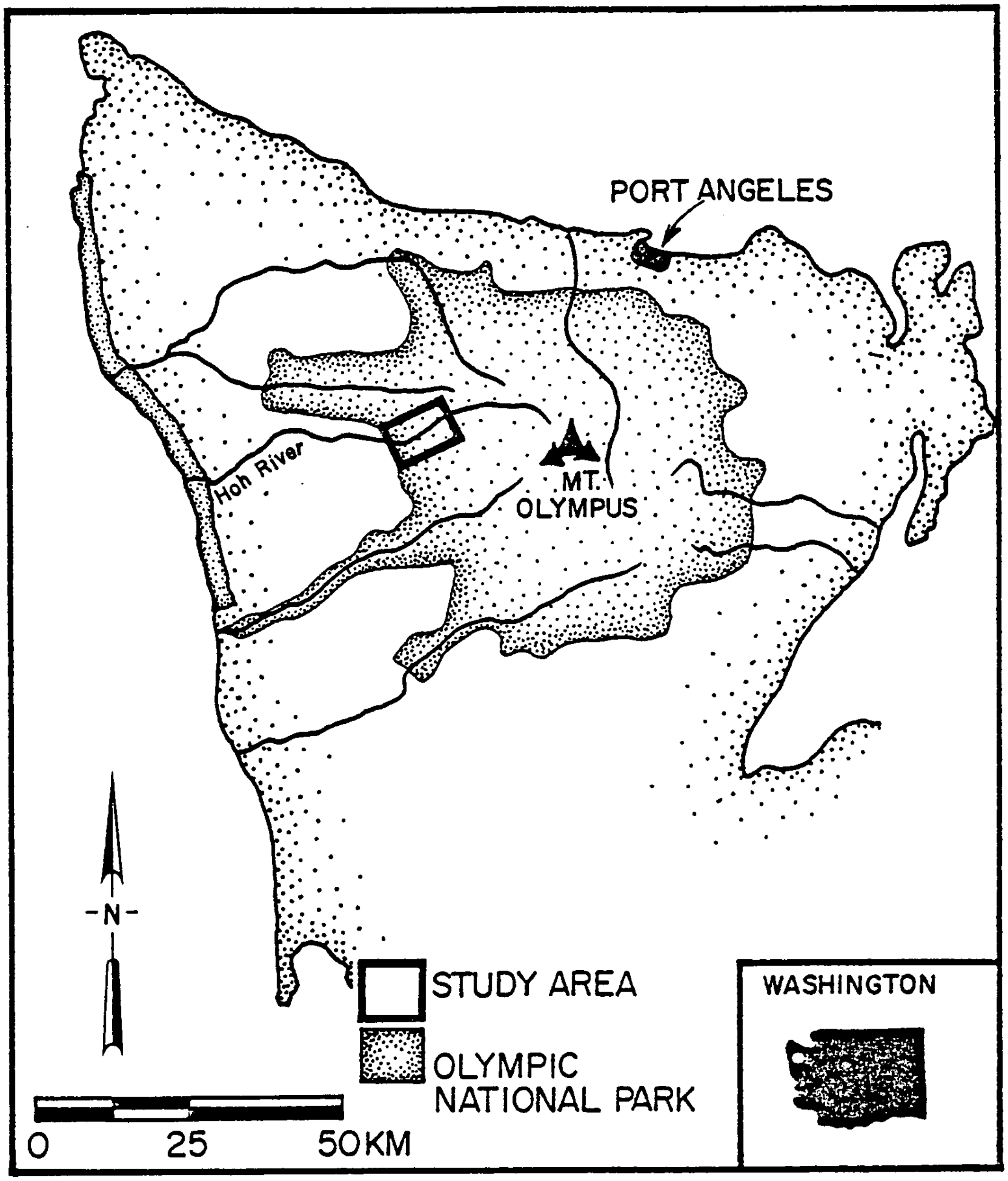

Fig. 1 Geographical location of Olympic National Park and the Hoh Valley study area.

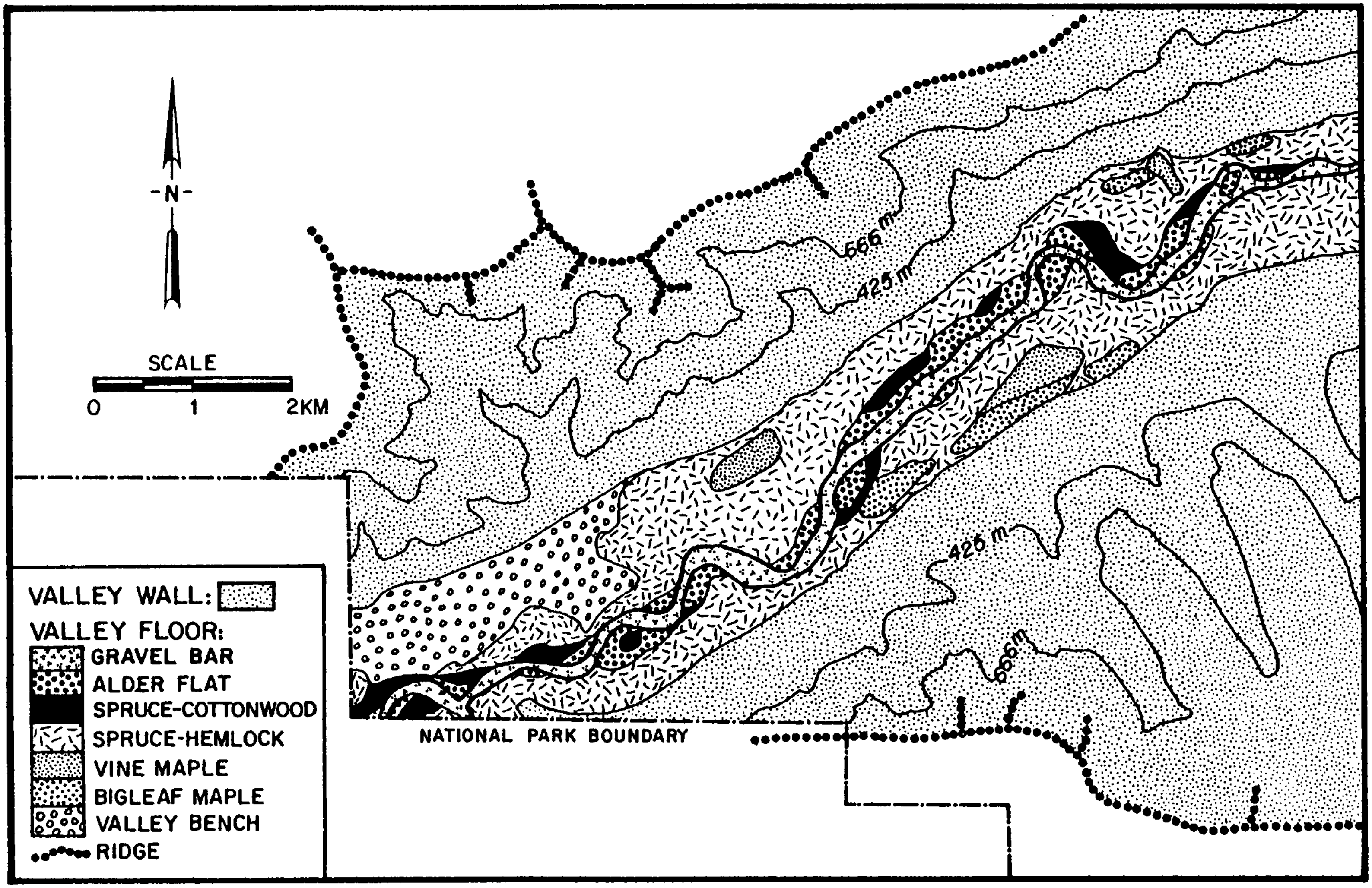

Fig. 2 Physiographic zones and habitat units within Olympic National Park in the Hoh Valley.

Table 1. Characteristic plant species[a] in habitat units on the floodplain of the Hoh Valley.

HABITAT[b] UNIT	TREE LAYER	SHRUB LAYER	HERB LAYER
Gravel Bar	Alnus rubra Salix spp.	Alnus rubra Salix spp.	Agrostis spp. Holcus lanatus Rumex acetosella Hypochaeris radicala
Alder Flat	Alnus rubra Picea sitchensis	Rubus ursinus Rubus spectabilis	Agrostis spp. Elymus glaucus Poa trivialis Oxalis oregana
Spruce-Cottonwood	Picea sitchensis Populus trichocarpa Acer macrophyllum Alnus rubra	Acer circinatum	Oxalis oregana Poa trivalis Agrostis spp. Polystichum munitum Bryophytes
Spruce-Hemlock	Picea sitchensis Tsuga heterophylla	Acer circinatum Vaccinium spp. Rubus spectabilis	Bryophytes Oxalis oregana Polysticum munitum Tiarella unifoliata
Bigleaf Maple	Acer macrophyllum Picea sitchensis	Acer circinatum	Polysticum munitum Oxalis oregana Melica subulata Agrostis spp.
Vine Maple		Acer circinatum	Oxalis oregana Tolmiea menziesii
Valley Bench	Tsuga heterophylla	Vaccinium spp.	Bryophytes Oxalis oregana Tiarella unifoliata

[a]Nomenclature after Hitchcock and Cronquist (1973)

[b]All habitat units are after Fonda (1974), except Vine Maple and Valley Bench which were previously undescribed.

a mature red alder community. The next older terraces, 400 and 700 years of age, are also alluvial deposits and support seral Sitka spruce-black cottonwood (Populus trichocarpa) and mature Sitka-spruce-western hemlock communities, respectively. The oldest, most extensive terrace is a pleistocene glacial deposit and also supports the climax Sitka spruce-western hemlock forest. The valley bench, also a pleistocene deposit, supports an additional climax forest characterized by a dense canopy of western hemlock.

The extensive spruce-hemlock forests of the Hoh Valley, commonly referred to as rain forest (Kirk 1966) or moist coniferous temperate forest (Fonda 1974) is a variation of the Picea sitchensis vegetation zone, which occurs in coastal areas of Oregon and Washington. Several distinctive features include: an abundance of bigleaf maple (Acer macrophyllum), vine maple, dead and down trees, and a conspicuous coverage of cryptogams and bryophytes on the ground and on nurse logs, and club mosses on limbs of live trees (Franklin and Dyrness 1973). Forests are comprised of massive Sitka spruce and western hemlock and have variable canopy coverage which results in a complex mosaic of understory vegetation. Small forest clearings are numerous and are dominated by salmonberry (Rubus spectabilis), vine maple and grasses. The shrub layers of denser forest stands are dominated by huckleberry (Vaccinium parvifolium, V. alaskaense), vine maple and sword fern (Polysticum munitum). Overall, heterogeneity is an important characteristic of the spruce-hemlock climax forest.

Two additional plant communities on the valley floor appear to edaphically controlled. Bigleaf maple communities occur on shallow, rocky soils of alluvial fans formed by tributaries of the Hoh River or of colluvial deposits at the base of the valley wall. Vine maple communities occur on alluvial outwashes as well as in areas that are seasonally flooded by winter rains.

Forests on the valley wall are dominated by western red cedar, western hemlock, and Douglas-fir. A prominent shrub layer is comprised of 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), cryptogams, and bryophytes.

Eleven habitat units occurred on managed forest land adjacent to the park. Three habitat units, gravel bar, alder flat, and spruce-cottonwood, corresponded to communities on the valley floor within the park. The remaining eight coincided mostly with stages of forest regeneration after logging (Fig. 3, Table 2).

METHODS AND MATERIALS

Ten adult cow elk were immobilized and radio-collared between January and March 1978. An additional cow was radio-collared in January 1979. They were immobilized by injecting liquid or powdered succinylcholine chloride into the hip of the animal (Harper 1965, Liscinsky et al. 1969) using a powder charged Capchur TM rifle. Transmission frequencies of radio-collars were approximately 164 MHz. Nine of the eleven collars were distributed

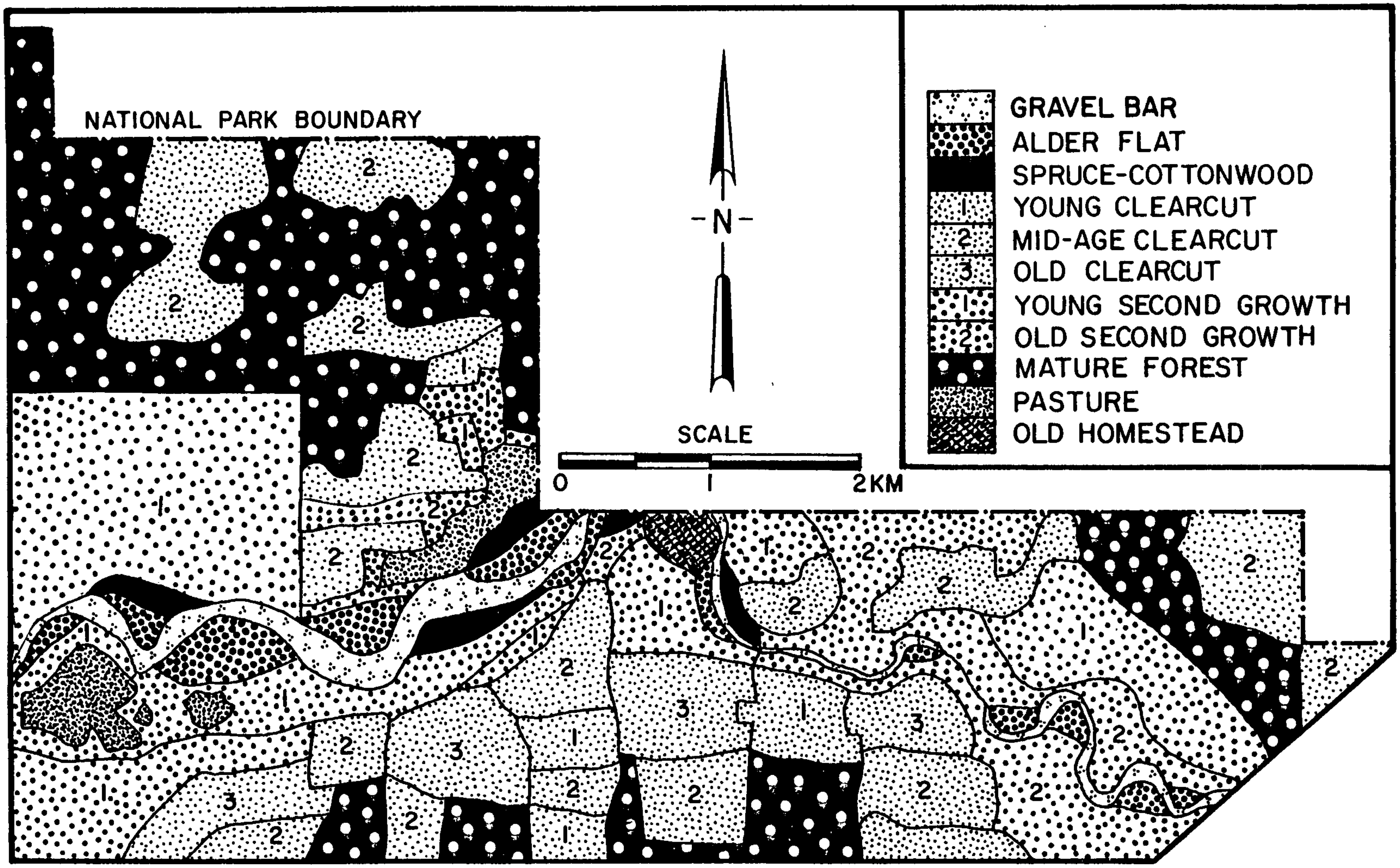

Fig. 3 Habitat units adjacent to Olympic National Park in the Hoh Valley.

Table 2. Description of Habitat units on non-park land

Habitat Unit	Description
Gravel Bar	Same as Gravel Bar habitat unit within park
Alder Flat	Same as Alder Flat habitat unit within park
Spruce-Cottonwood	Same as Spruce-Cottonwood habitat unit within park
Young Clearcut	0-4 years since harvest Bare soil and slash conspicuous Dominated by forbs, blackberry, young conifer seedlings
Mid-age Clearcut	4-12 years since harvest Dominated by grasses, blackberry and spruce and hemlock reproduction
Old Clearcut	12-20 years since harvest Dominated by dense spruce-hemlock reproduction
Young Second Growth	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	Approximately 50 or more years old Dominated by spruce, hemlock, or Douglas-fir (>30 cm dbh)
Old Homestead	Old grassy fields with spruce reproduction invading edges
Pasture	Pasture land, fenced and generally not available to elk
Mature Forest	Found on valley walls in study areas Same as valley wall habitat units within the National Park

evenly between 3 cow groups within the park; the remaining were placed on elk adjacent to the park.

Collared elk were located during March 1978, from 1 June - 15 September 1978, and from 1 January - 20 March 1979, by triangulating from the ground using an AVM LA-12 receiver and hand held yagi antenna and by direct observation. The location of a collared elk was established by determining the direction of the strongest radio-signal from 3 receiving stations and by plotting azimuths on an orthographically corrected aerial photograph (scale= 1:24,000). To minimize error, triangulation stations were located on open gravel bars where reflection of radio-signals was minimal and were chosen so that the intersection of the outermost azimuths was approximately 90^{o} (Singer 1979). If 3 bearings intersected, a circle was inscribed within the resulting triangle. The center of the circle was used as the estimated elk location and assigned coordinate values. If bearings did not intersect or if the accuracy of the location was doubtful, telemetry equipment was used to locate the elk visually or aurally. Each elk was located 1 to 3 times daily usually at different times each day.

Home range was defined as "the area over which an animal normally travels in pursuit of its routine activities" (Jewell 1966:103). Therefore, infrequent journeys by elk beyond their normal range were excluded from analyses. An elliptical home range model (Koepple et al. 1975) was used to delineate annual home ranges of collared elk. Home ranges lacked definite boundaries by that method and were expressed as elliptical areas that included 95% of the animals' activity.

Daily movements were estimated during each season by measuring the line distance between the first location of a collared elk one morning and the first location the following morning. Undoubtedly the actual distance moved each day was greater than the distance calculated; however, the index was useful in examining seasonal changes in daily movements.

Habitat selection by 9 elk within the park was analysed in two phases. Initially, the study area in the park was divided into 8 physiographic zones. These zones were the valley floor on either side of the river, and 3 elevational belts on the north and south valley wall (Fig. 2). Secondly, the valley floor was further divided into 7 habitat units corresponding largely to vegetation types identified by Fonda (1974) on the river terraces (Fig. 2, Table 1).

Use of physiographic zones and habitat units was examined by comparing availability of each to its utilization by elk (Neu et al. 1974). In the first analysis, availability was defined as the percent of the watershed covered by each physiographic zone and utilization as the percent of radio-locations within each zone. In the second, availability was measured as the percent of area within elk home ranges covered by each habitat unit. Elk selected a zone or habitat unit if utilization was significantly greater ($p<0.05$) than availability or avoided it if utilization was significantly less than availability ($p<0.05$). In both analyses, use of zones and habitat units was described during summer (10 June - 31 August 1978), winter (1 January - 28 February 1979) and late winter (1 March - 20 March 1978, 1979).

Late winter was delimited because there was a noticeable shift in habitat use at the beginning of March.

Use of non-park land was studied by comparing utilization of areas outside the park to their availability within home ranges of 5 elk. Additionally, habitat use by 2 elk that used non-park land extensively was studied in relation to 11 habitat units. Use of habitat units by elk outside the park was described by comparing utilization of habitats to their availability within the home range of each elk.

Interactions between elk groups were described by examining spatial overlap of home ranges and association of collared elk within each group. Association referred to the percent of time a collared elk was located in the presence of each other collared elk. Coefficients of association were calculated according to the procedure described by Cole (1949) and applied to elk by Knight (1970) and Schoen (1977). Values range linearly from 0.0 to 1.0, indicating no association to perfect association, respectively. Inferences concerning stability of elk groups were made by comparing association of elk within a group to association of elk between groups.

RESULTS AND DISCUSSION

Approximately 250 elk inhabited the study area. Four groups of elk occupied the area and approximately 60 elk associated with each group. Using Newman's (1954) delineation of winter range, the study area provided 1764 ha of winter range or 7 ha per elk. That estimate of density is lower than Newman's (1954) estimate of 4.7 ha per elk. The discrepancy largely is due to lack of precise population estimators in these studies; however, the figures indicate that elk populations have probably remained constant or decreased. That pattern is expected of ungulate populations as equilibrium with the food resource is attained (Caughley 1976). Ongoing quantitative data is needed to accurately assess population trends in the Hoh Valley.

Home Range and Movements

Radio-collared elk were non-migratory. None of those elk dispersed from the lowlands to use a discrete summer range at higher elevations; nor was there an observable seasonal movement of elk across the national park boundary. No collared elk observed in Olympic National Park was ever located more than 2.0 km outside of the park. Additionally, no elk from greater than 5.0 km within the park was ever observed on land adjacent to the park.

Skinner (1933) and Schwartz (1939) suggested that a migratory portion of the population remained in the upper Hoh River watershed unless deep snow caused them to move down river. Under such conditions, migratory elk may 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, elk would probably occupy densely 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.

Seasonal movement of elk up and down valley was minimal; however, two elk traveled independently to the Bogachiel Valley to the north on 14 August 1978 and 17 August 1978. Each traveled 4.8 km from its last confirmed location in the Hoh Valley and was absent from its home range for 12 to 18 days before returning. The cause of the movements was unknown, but 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 their group and wandered prior to the onset of the rut. Hormonal changes during estrus probably contribute to the restlessness of cow elk (Lieb 1973). Movement of cow elk between watersheds indicated that intermingling of populations from adjacent drainages may occur; however interchanges of non-migratory elk between watersheds is probably uncommon. Only 2 elk moved extensively during this study, and in both cases they returned to their normal range.

A total of 2565 locations of the radio-equipped elk was obtained (Table 3). Annual home range areas, calculated using locations from the entire study period, averaged 1112 ha (Table 3). Orientation and size of home ranges within the park were influenced by the valley floor. The major axis of each ellipse was aligned closely to the floodplain of the valley (Fig. 4). Additionally, width of home range was related significantly to the breadth of the valley floor measured through the geometric center of the home range ($r^2=0.57$, $p<0.05$); home ranges were broadest near Twin Creek where the valley floor was most extensive (Fig. 4). In southwest Oregon, home ranges of Roosevelt elk also were influenced by topographic features; home range diameters averaged 1.3 mi in steep canyons whereas in valley floodplains they averaged 3.0 mi (Harper 1971).

Home ranges of elk outside the park also were influenced by the location of clearcuts that were used heavily by elk. The home range ellipse of elk No. 8 is poorly aligned with the valley floor (Fig. 5); rather it is oriented to a series of clearcuts south of the park boundary.

Daily movements of cow elk were greater during summer than winter ($p<0.05$). Elk traveled an average minimum distance of 843 m between successive mornings during summer and 688 m during winter. This reduction of activity during winter may conserve energy at a time when weather is typically severe, and forage does not satisfy maintenance requirements. The metabolic rates of black-tailed deer (Odocoileus hemionus columbianus), mule deer (O. h. hemionus), and white-tailed deer (O. virginianus) fluctuate annually with fasting heat production being highest during summer and lowest during winter (Regelin 1979, Silver et al. 1969, Thompson et al. 1973). It seems likely that metabolic rates of elk are reduced similarly during winter, resulting in decreased movement.

Daily movements of cow elk with calves were least in June. Those with calves traveled an average minimum distance of 541 m/day in June whereas those without traveled an average of 1040 m. Movement of cows with calves was restricted in June because frequent nursing required that cows stay close to the less mobile calves.

Darling (1937) emphasized the importance of tradition as a determinant of movement and home range use of red deer (C. e. elaphus). Similarly a high level of traditionality appeared to be associated with home range use by elk in the Hoh Valley. Several heavily used foraging areas and travel corridors existed within home ranges and were used in a sequential, and often predictable

Table 3. Location and home range information on 11 radio-collared elk.

Elk No.	Number of Locations March 1978	Summer 1978	Winter 1979	Home Range Size (Ha)
1	29	112	155	949
6	29	114	112	904
9	31	114	142	1028
10	30	121	154	954
11	27	122	153	951
88	0	0	127	823
4	31	111	153	1472
7	30	107	0	1123
12	0	0	138	1368
3	19	115	156	1445
8	19	103	0	1217

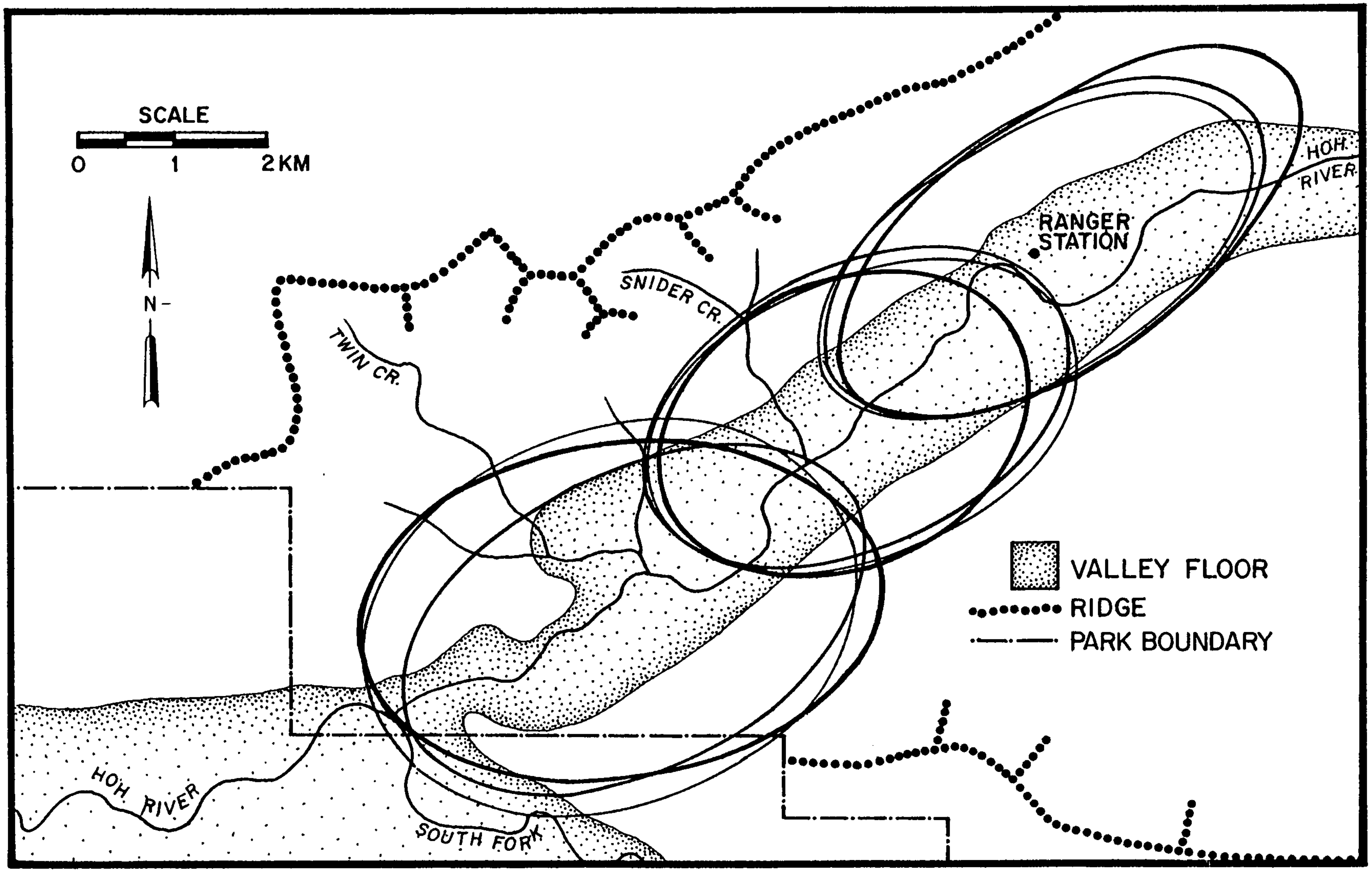

Fig. 4 Home ranges of 9 cow elk in the Hoh Valley.

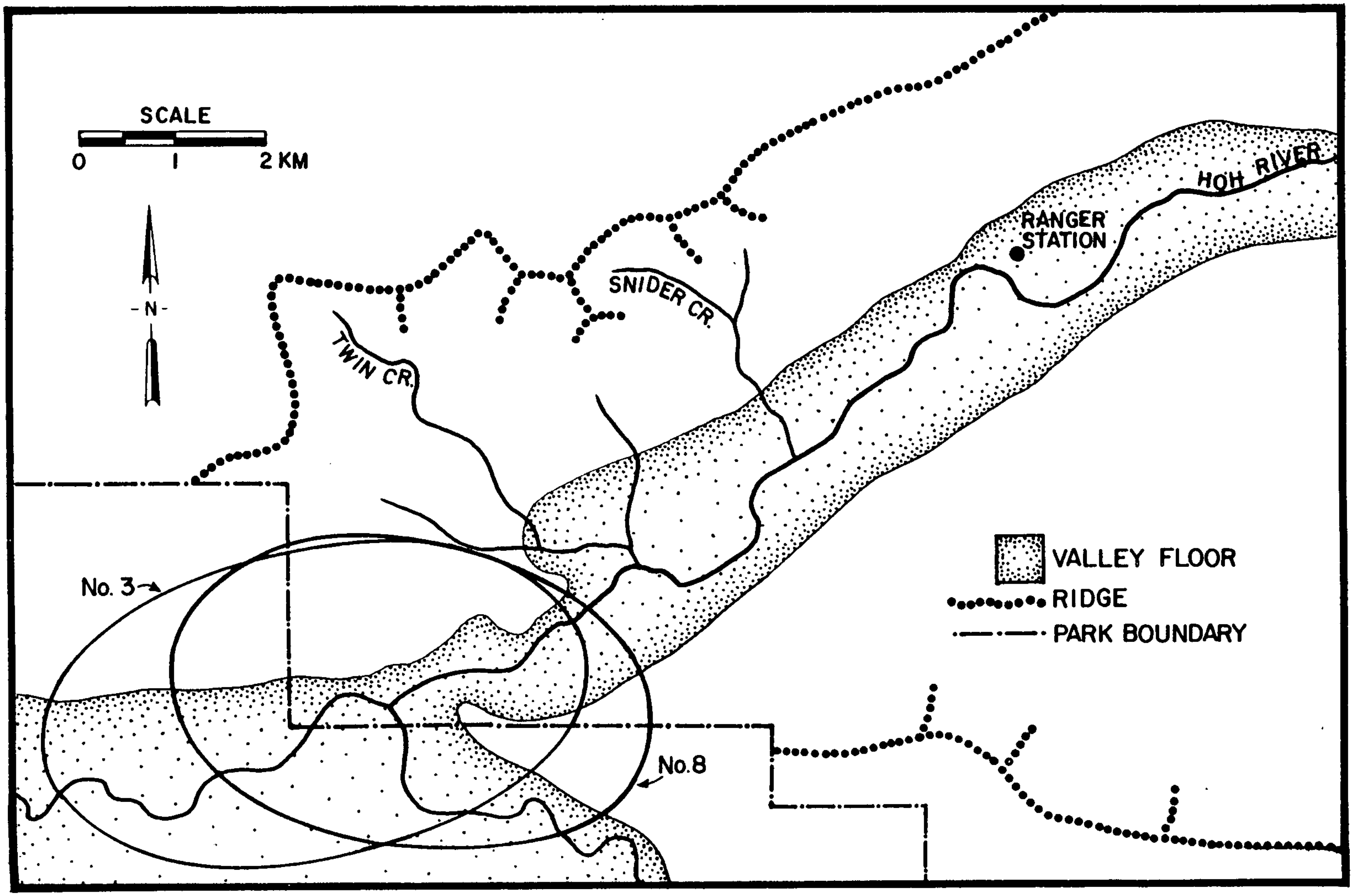

Fig. 5. Home ranges of 2 cow elk adjacent to Olympic National Park in the Hoh Valley.

pattern. Generally, elk remained in a favored foraging area for 1 to 3 days. Although elk often moved through their home ranges in a predictable manner, an overall circuit of travel did not exist.

Patterns of Habitat Use

Use of Physiographic Zones

Elk selected valley floor zones during all seasons and generally avoided valley walls (Fig. 6). The valley floor was probably the most important habitat because the assemblage of plant communities provided the best dispersion of forage and cover. Clearings on the forest floor were used heavily by feeding elk, generally sustained the highest browsing intensity and probably provided more abundant and diverse forage than valley walls.

Although the valley floor was important in all seasons, elk selected lower parts of the valley wall under certain conditions. The lower north valley wall (south-facing) was selected during winter 1978 (Fig. 6) and was frequented by elk during clear, cold periods and when snow cover existed. South facing slopes intercept more solar radiation which results in warmer temperatures and lower snow depths than on the valley floor. The relatively dense canopy on valley walls may intercept more snow and also contribute to reduced snow depths (Jones 1974). At night, significantly more downward infrared energy is radiated from a relatively dense canopy than from either less dense canopies or the clear sky (Moen 1973:83). Temperature inversions probably are common, and together with the above factors may create more moderate thermal conditions on the valley wall than on the valley floor during winter.

Elk generally selected areas north of the Hoh River (south-facing) during late winter and south of the river (north-facing) during summer (Fig. 6). During late winter, elk may have preferred the north side of the river because greater solar radiation initiated early forage production. As summer progressed, vegetation on the north side of the river may have cured and become less nutritious, drawing elk to the south where phenological development was less advanced. Additionally, the south side of the river may have attracted elk because it was cooler. Elk may have selected areas south of the river during summer also to avoid human activity north of the river. However, elk seemed quite undisturbed by humans. In most cases, spruce-hemlock forests provided elk an effective visual screen from the Hoh River road. Elk bedded often in spruce-hemlock stands within audible range of human voices and traffic and appeared to be accustomed to activity on the road. However, we do not dismiss the possible influence of visitor use on the distribution of elk.

Use of Habitat Units

Elk on the valley floor selected spruce-hemlock, vine maple and bigleaf maple habitat units during summer and winter. Gravel bars were avoided during all seasons (Fig. 7); however, use was greatest during summer, especially during hot midday periods in July. Breezes may have provided relief from insects and summer heat. Early successional alder flat and spruce-cottonwood habitats were used in proportion to availability during summer (Fig. 7). Grasses, which were prevalent in those communities, may have cured and become

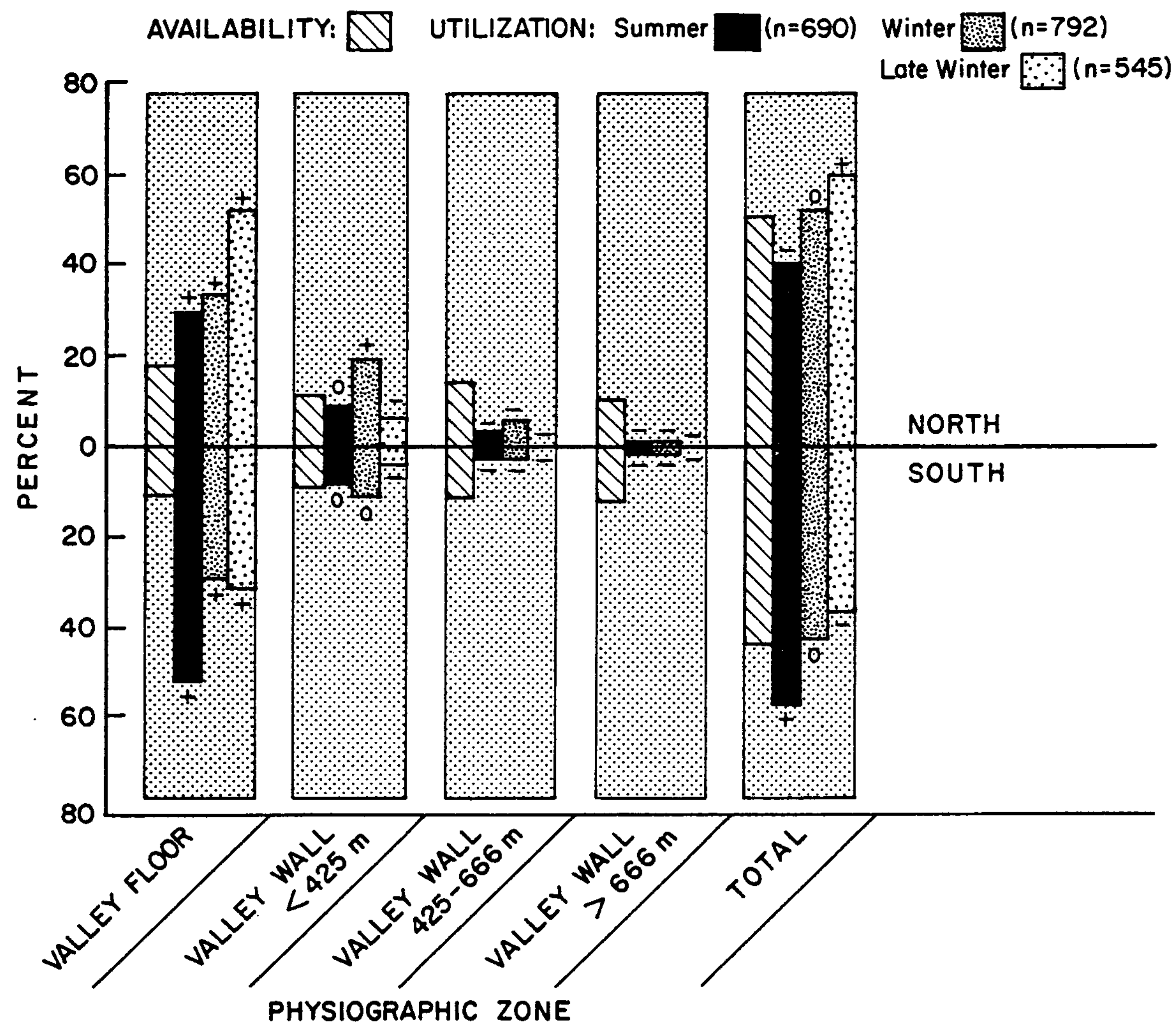

Fig. 6. Utilization of physiographic zones by cow elk in the Hoh Valley.

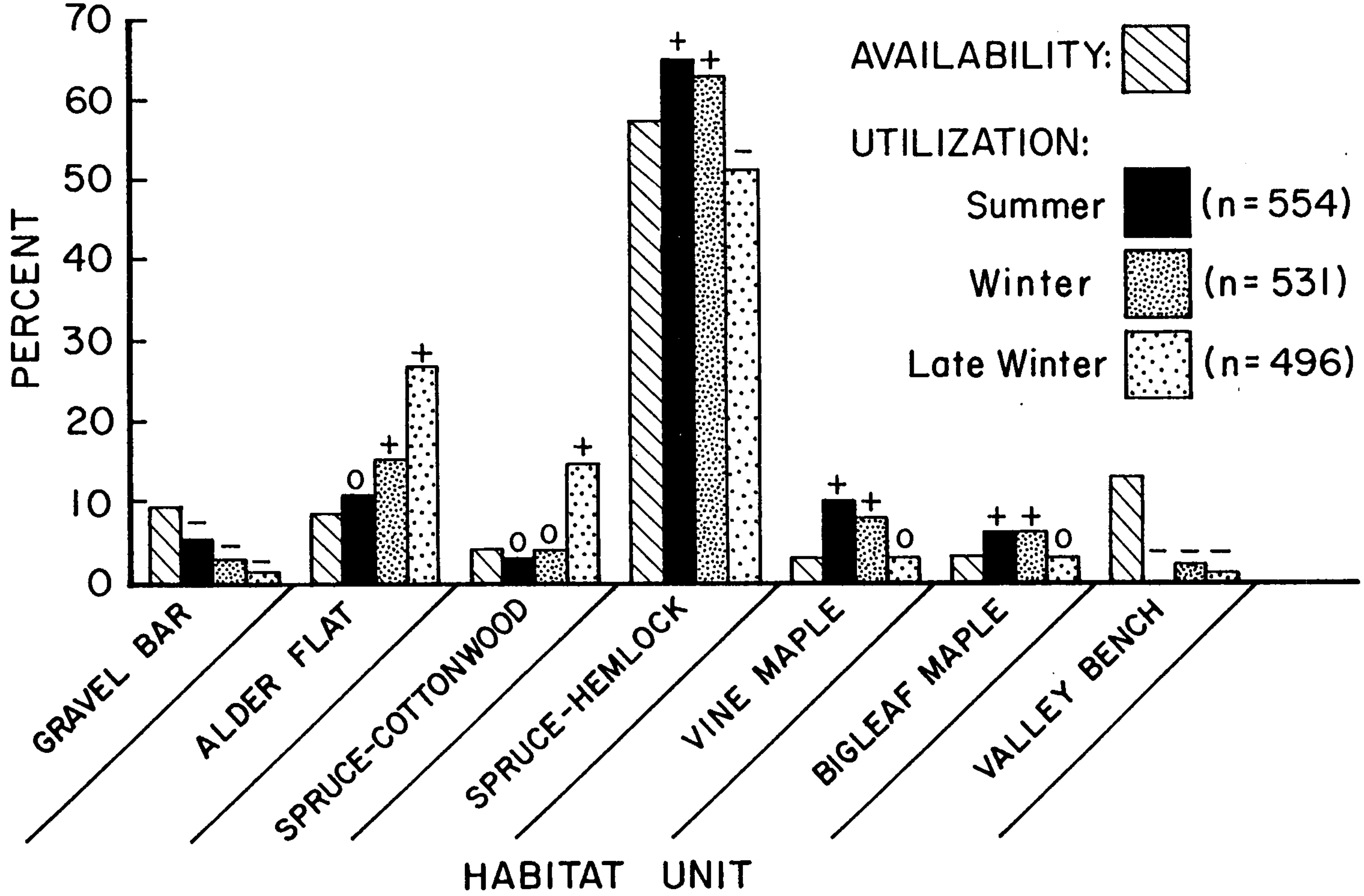

Fig. 7. Utilization of habitat units by cow elk in the Hoh Valley.

less palatable to elk in summer. However, elk selected alder flat habitats during winter (Fig. 7) when grass was also poor in nutritional value. Perhaps elk became less selective feeders in winter when the nutritional value of forage was low and presumably less heterogeneous. Ongoing nutritional research may help explain these seasonal patterns of use.

During late winter, radio-collared elk selected alder flat and spruce-cottonwood habitats (Fig. 7). Production of grass, the dominant component in the riparian ground layer and in the diet of elk during spring (Schwartz and Mitchell 1945) probably influenced habitat selection. Spruce-hemlock habitats were avoided by elk; however they included more than 50% of the radio-locations (Fig. 7) and were important because of their vast coverage. Frequently, spruce-hemlock stands were used for bedding. Elk traveled from alder flats into adjacent spruce-hemlock stands in 62% of 98 occasions to bed during the midday period.

Use of Non-park Land

Home ranges of 5 elk included non-park land. Home ranges of elk near Twin Creek (Elk Nos. 4, 7, 12) included 8-16% non-park land and used that area less than its availability (Table 4). Home ranges of elk near the park boundary (Elk Nos. 3, 8) included 57-68% non-park land and used both sides of the park boundary non-selectively during summer and late winter (Table 4). The only elk that selected areas outside the park was No. 3 during winter (Table 4). Perhaps during winter, the differences in the quality of browse on open, clearcut land and on more densely forested park land is relatively great. That difference may attract elk to non-park land it if exists within the individual's home range; however, elk with little or no non-park land within their home range were not drawn outside the park. These findings support Tabor's (1973) suggestion that probably elk are not attracted to clearcuts beyond the boundary of their traditional home range.

The use of habitat units on non-park land by elk No. 3 and No. 8 was very similar during summer and late winter. During both seasons, mid-age clearcuts were used in proportion to their availability, whereas young and old clearcuts were avoided (Table 5). Mid-age clearcuts were used mostly for feeding during early morning and late evening. Elk using clearcuts for feeding generally moved into young or old second growth stands to bed during mid-day. During both seasons, those elk frequently used an old homestead site and young second growth stands (Table 5) at the confluence of the South Fork and the main fork of the Hoh River. Both areas contained a mosaic of clearings within a dense stand of Douglas-fir and Sitka spruce regeneration.

During winter 1979, only the radio-collar of Elk No. 3 functioned. She used most of the habitat units unselectively (Table 5). Young clearcuts and mature forest were used to a greater degree during winter than during other seasons (Table 5). Use of the old homestead site decreased greatly during winter (Table 5). Use of mid-age clearcuts and second growth stands was comparable to other seasons (Table 5).

Table 4. Selection and avoidance of park and non-park land by elk near the boundary of Olympic National Park.[a]

Summer					
Elk No.	4	7	12	3	8
Park Land	+	+		0	0
Non-Park Land	-	-		0	0

Winter					
Elk No.	4	7	12	3	8
Park Land	+		+	-	
Non-park Land	-		-	+	

Late Winter					
Elk No.	4	7	12	3	8
Park Land	+	0	+	0	0
Non-park Land	-	0	-	0	0

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

Table 5. Selection and avoidance of habitat units on non-park land by elk near the boundary of Olympic National Park.[a]

	Summer Elk No.		Winter Elk No.	Late Winter Elk No.	
	3	8	3	3	8
Young Clearcut	-	-	0	-	-
Mid-age Clearcut	0	0	0	0	0
Old Clearcut	-	-	-	-	-
Young Second Growth	0	+	0	0	0
Old Second Growth	0	0	0	0	0
Old Homestead	+	0	-	+	0
Mature Forest	-	-	0	-	0

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

Social Group Interactions

The individual home ranges of 3 collared elk in each of the 3 groups coincided closely (Fig. 4). Although home ranges of elk from adjacent groups overlapped, there was no permanent interchange of collared elk between groups. Elk from adjacent groups were observed together in only 8 cases. Association lasted for 3 days or less ($\bar{x}$=1.4 days), and the original groups of collared elk were preserved after temporary associations. Coefficients of association for pairs of elk within a group ($\bar{x}$=0.71 , range = 0.13 - 0.94) were greater than those between groups ($\bar{x}$=0.01, range = 0.00 - 0.05) (Fig. 8). The lack of perfect association between elk in a group indicated that subgroups were periodically absent from the main group. The duration of those periods averaged 5.4 days (n=42) but was highly variable (S.D.=6.2 days). The coefficients of association between elk No. 4 and No. 7, which were known to have calves, were lowest in June (Fig. 8). This may indicate sub-grouping was more common during calving.

Previous studies suggested that stability of elk groups was variable. Darling (1937) believed that groups of red deer consisted of a dominant female, her mature daughters, and their offspring. The matriarchal concept has been accepted widely (Altmann 1952, McCullough 1969, Franklin et al. 1975). It implied that home range was passed on through generations, a trait known as home range conservatism (Murie 1951), and that elk groups were stable, comprised of a constant membership. In contrast, Knight (1970) found that the mean coefficient of association between female Rocky Mountain elk (C. e. nelsoni) never exceeded 0.47, and felt that elk groups should be considered aggregations rather than social groups. Schoen (1977) reported a mean coefficient of association of 0.20 for 39 female Rocky Mountain elk in western Washington, which also indicated low group stability. Marcum (1975), Mackie (1970) and Shoesmith (1979) reported that Rocky Mountain elk groups changed composition frequently, however, the effect of seasonal migration and human predation on the constancy of those groups in unknown.

Harper (1971) found that non-migratory Roosevelt elk herds on managed forest lands in southwest Oregon continuously changed composition and that marked members of adjacent groups interchanged freely. In contrast, non-migratory and unhunted elk in the unmanaged Prairie Creek Redwoods State Park formed more stable associations of adult females and their immature offspring (Franklin et al. 1975). In that population, small fluctuations in group size occurred as sub-groups entered and left the herd; however,absent individuals always returned. Franklin and Lieb (1979) hypothesized that variations in group stability of non-migratory elk in Prairie Creek Redwoods State Park and in southwest Oregon may be caused by differences in habitat. They suggested that the continual alteration of vegetation due to logging in southwest Oregon created changing habitat conditions which affected the development and maintenance of social organization. They concluded that relatively stable social organizations may be expected in elk populations that inhabit stable, unmanaged environments which permit long term bonding between individuals.

SUMMARY AND CONCLUSIONS

Home ranges of elk were influenced primarily by topographic features of the Hoh Valley. Major axes of each home range were aligned to the floodplain of the valley and widths of home ranges were related to the breadth of the

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

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

Fig. 8. Coefficients of association for all pairs of radio-collared elk in the Hoh Valley. Shaded cells represent pairs of elk within a group and non-shaded cells represent pairs from adjacent groups.

valley floor. Additionally, radio-locations of the collared elk were concentrated on the valley floodplain. It seems likely that the distribution of elk in the unmanaged forest setting is governed largely by the location of suitable foraging areas. Numerous forest clearings on the floodplain provide environmental heterogeneity and abundant forage for elk. Thus, the extent of valley floor may be an important determinant of elk density in unmanaged fluvial forests on the Olympic Peninsula.

Current logging practices are sometimes suggested to be beneficial to elk because the removal of overstory trees creates new foraging areas for elk. However, we found that densely timbered, south-facing walls were favored by elk over the more open valley floor in winter, especially during cold periods with snow cover. Closed canopy forests on south-facing slopes may be extremely important habitat during periodically severe winters, both because they provide a more moderate thermal environment and because lower snow depths may result in greater availability of forage (Jones 1974). The relative value of mature forests and clearings as foraging areas on elk winter range remains poorly understood; however, managers should be aware of the importance of mature forest under certain winter conditions.

Seasonal differences in phenology and thermal regimes appear to have influenced distribution of elk in the Hoh Valley. Additionally, dietary preferences probably influenced selection of habitat units on the valley floor. During summer and winter, older river terraces, where browse and forbs are abundant, were selected. During late winter, cow elk selected riparian alder-flat and spruce-cottonwood habitats where new growth of grasses is available. Late winter is a crucial period for cow elk nutritionally. Protein and energy reserves are low after winter, and demands of rapid fetal growth are high (Moen 1973). Thus alder flat and spruce-cottonwood communities should be considered critical elk range in the fluvial rain forest valleys.

Cow elk formed relatively stable associations of adult females and their offspring and conformed to the model of group behavior of Franklin and Lieb (1979). There was no permanent interchange of collared elk between groups, and elk within groups were more highly associated than reported elsewhere. These findings support the hypothesis that more stable elk groups may form where habitat is constant and not disturbed by logging. Additional comparative research on the behavior of elk groups in managed and unmanaged forest settings is needed to further test the hypothesis.

Apparently, non-migratory cow elk in Olympic National Park are influenced little by forest and wildlife management practices that occur outside the park. Park elk within 5.0 km of the park boundary made use of non-park land and thus, may be hunted and influenced by habitat changes which occur there. Beyond a 5.0 km strip, elk were isolated from events outside the park. Therefore, management practices outside the park do not affect the majority of cow elk within the park and may not be used to manage them. Information on migratory and male segments of the Hoh Valley population is needed before the overall influence of external factors on elk in Olympic National Park can be described completely.

Results of this study also indicate that because the majority of elk in the Hoh Valley are not influenced by events outside the park, the behavior and ecology of elk within the park are the most accurate reflection of the primeval condition of elk on the Olympic Peninsula. They provide a unique opportunity to research natural regulation of herbivore populations and the influence of elk on forest communities. Additionally, comparative research on elk within and outside of Olympic National Park is important to determine the influence of forest management on elk movement, productivity, and social organization.

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APPENDIX A

Appendix A. Record of marked elk in the Hoh Valley

Date	Elk No.	Drug Dosage (mg)	Reaction Time (minutes)	Immobilization Period (minutes)	Heart Girth (inches)	Collar Collar Symbol	Ear Tag
19 Jan. 1978	6	30	38	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