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The Starkey Project: History, Facilities, and Data Collection Methods for Ungulate Research

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Abstract

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In the 1980s, resource managers were increasingly concerned about effects of timber harvest on ungulates in National Forests. Land and resource management plans incorporated restrictions on timber harvest to maintain cover for Rocky Mountain elk *(Cervus elaphus nelsoni* V. Bailey) and mule deer *(Odocoileus* hemionus hemionus Rafinesque), and habitat models were used to predict effectiveness of various habitat components for these ungulates. Many of the assumptions on which these models were based were untested, however. The Starkey Project, in northeastern Oregon, was begun to address some of these issues through manipulative experiments in a landscape representative of inland National Forests in the West. A 25,000-acre (10 125-ha) area was surrounded with game-proof fencing to support studies on elk, mule deer, and cattle *(Bos taurus)*. A newly developed telemetry system, using loran-C (long range navigation-C) signals, tracks distribution of the three species in relation to common land management activities and habitat variables. Four primary research projects are underway: animal-unit equivalencies, intensive timber management, effects of roads and traffic, and breeding efficiency of bull elk. Activities at Starkey include trapping, feeding, and handling of deer and elk, radio-telemetry data collection, road and traffic monitoring, hunting, timber harvest, cattle grazing, and vegetation monitoring. An intensive technology transfer program is also an integral part of the Starkey Project. The physical site, including handling facilities and telemetry-related structures, and chronology of events related to the Starkey Project are described. A bibliography of project publications also is included.

Keywords: Cattle, deer, elk, forest management, ungulates, Blue Mountains, Oregon, radio telemetry, habitat, Starkey Project, technology transfer, wildlife research.

Contents

Introduction

Land-use planning for National Forests (NFs) in the 1980s illustrated the growing conflict over public lands management. In land and resource management plans (Forest plans) for the NFs of the Blue Mountains in Washington and Oregon, interactions of livestock with wildlife, especially deer[1] and elk, were identified as a major concern, as was the relation of wildlife to timber production. Constraints on timber harvest and road construction were incorporated in several Forest plans to meet objectives for deer and elk populations and habitats. These constraints may result in restricted timber harvest (Riggs and others 1993) and thus lower revenues for NFs, local governments, and timber companies, as well as road closures that potentially reduce opportunities for recreation and are costly to establish and maintain. During the 1980s, models for predicting habitat effectiveness for deer and elk were being developed and implemented that promoted closing roads or maintaining certain cover:forage ratios for wildlife (Lyon 1983, Thomas and others 1979, Wisdom and others 1986).

National Forests support, during some part of the year, more than 90 percent of the elk population in the United States and thus provide habitat essential for the welfare of elk populations. With increasing pressure on National Forests to provide timber, wildlife habitat, livestock grazing, and other potentially conflicting resources, better research was needed to predict outcomes of forest management on deer and elk. Thus was born the Starkey Project, a long-term research collaboration between the Oregon Department of Fish and Wildlife (ODFW) and the U.S. Department of Agriculture (USDA), Forest Service (FS). Oregon State University (OSU), the National Council of the Paper Industry for Air and Stream Improvement (NCASI), Boise Cascade Corporation, and the Rocky Mountain Elk Foundation also have supported various aspects of the research. Launching the project included fencing 25,000 acres (10 125 ha) of the Starkey Experimental Forest and Range (SEFR) and adjacent FS lands to create a closed population of deer and elk in a large, natural setting (see appendix 1 for statistics on Starkey in both English and metric units).

Origins of the Starkey Project

The idea of fencing land in the Blue Mountains for ungulate research was first broached in 1982 (see appendix 2). A report by Vavra (1980), commissioned by the Pacific Northwest Research Station (PNW), emphasized the need for forage allocation and elk and livestock research in the Blue Mountains. Thomas (1983) concluded that the primary topics to investigate were forage allocation between domestic and wild ungulates and impacts of roads and traffic on big game habitat effectiveness. Thomas and others (1979) had previously compiled a landmark work about wildlife and forest management in the Blue Mountains; models and prescriptions for forage and cover areas from this document were widely used in forest planning in the 1980s. Yet Thomas and other authors of this work conceded that better information was needed to reliably prescribe habitat management for deer and elk in National Forests.

A natural collaboration arose between ODFW and the FS in proposing the Starkey Project. The two agencies had cooperated on wildlife and forest research for many years at the La Grande Forestry and Range Sciences Laboratory (FRSL). An ODFW biologist (Donavin Leckenby) was already housed in the FRSL and had just completed several years of study on elk habitat relations. Warren Aney, Northeast Region supervisor for ODFW, also supported the Starkey proposal. As ideas about the research coalesced, the Starkey Project was proposed to address four major problems identified by ODFW and PNW staff in La Grande: (1) lack of information on site-specific forage

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[1] See appendix 5 for scientific names of all species mentioned

allocation among elk, mule deer, and cattle in National Forests; (2) insufficient information on effects of intensive timber management on populations of mule deer and elk; (3) declining elk calf recruitment, perhaps caused by a high proportion of immature bull elk in the breeding population; and (4) the need for better information on effects of traffic levels on deer and elk (USDA Forest Service 1985).

Research to address these problems would require fencing to create a "closed system," thus eliminating movements of deer and elk into or out of the area; a telemetry system to locate animals continuously, with resolution to better than 10 acres (4 ha); and a site where hypotheses about summer range conditions could be tested without the confounding effects of winter weather and forage. The SEFR west of La Grande was proposed as the best site for the new research. Nearly 30 meetings with private and governmental groups were held from 1983 to 1985 to discuss the project. Major concerns identified in these meetings were disruptions of elk migration patterns by erecting the fence, replacement of previously permitted cattle with cattle owned by OSU, water quality and fisheries, and effects of proposed timber harvest in the intensive timber management area. Some hunters also anticipated a "shooting gallery" effect, whereby elk would be easily killed along the fenceline. Others were concerned that elk inside the fence would become tamed, or be subjected to inhumane treatment for research.

Approval of the multimillion dollar proposal would dictate several changes in the SEFR area and its operation. More than 1,000 acres (405 ha) in Half Moon pasture, usually grazed by domestic sheep, would be enclosed by game-proof fencing and thus no longer be available for sheep. One hundred and fifty cattle, grazing under permits to the Starkey Cattle and Horse Association, would be replaced with cattle owned by OSU. This exchange would ensure genetic consistency of the cattle used in research and make available fistulated cattle, if necessary, for dietary studies. Hunting seasons also would be altered, with only limited-entry hunting and fewer hunter recreation days.

Following the scoping meetings, the environmental assessment for the project (USDA Forest Service 1985) was completed in December 1985 and signed in early 1986 (appendix 2). Forest Service Chief Max Peterson approved the project in July 1986 and denied appeals filed to prevent it. Funding was received in early 1987 to begin construction of the fence, with additional money procured to assemble the radio-telemetry system and begin the research.

The fence was erected around a large portion of the SEFR and some adjacent FS land (Wallowa-Whitman NF) to contain the deer and elk herds present when the research began (Bryant and others 1993). Construction of this fence, encompassing 25,000 acres (10 125 ha) of summer range, allowed researchers to trap animals on a winter feed ground, provide them with controlled winter diets, attach radio collars, and collect data (fig. 1). Concomitantly, the fenced area was large enough to encompass the typical summer movements of both species in the Blue Mountains (Leckenby 1984, Pedersen 1985), so that hypotheses tested about activities on summer range would be applicable to free-ranging ungulates. Completion of the fence created one of the largest known research enclosures for wildlife in the world.

Figure 1 -Construction of the game-proof fence at the Starkey Experimental Forest and Range enclosed the native herds of mule deer and elk, which became the experimental population.

A combination of certain features makes the Starkey Project exceptional in the realm of wildlife research:

- The control of winter foraging conditions for ungulates that are free-ranging in summer (that is, the ability to offer controlled diets to many of the research animals, all subjected to the same winter weather conditions)
- The attempt to simulate the effect of future habitat conditions, resulting from forest management, on wildlife in a “closed system”
- The scale of operation, which makes the study site one of the largest wildlife research enclosures in the world
- The first use of loran-C navigational signals for terrestrial wildlife locations, combined with an unprecedented number of radio locations per animal, all automatically collected and stored in computers
- The continuous collection of hundreds of thousands of wildlife radio-telemetry locations at a resolution of about 6.2 acres (2.5 ha) (80 percent confidence interval)

Techniques used in the Starkey Project, as well as hypotheses to be tested, were developed only after investigating similar operations and research questions around the world. Starkey scientists traveled throughout the United States and to New Zealand and Sweden to explore the best technologies available before embarking on the project.

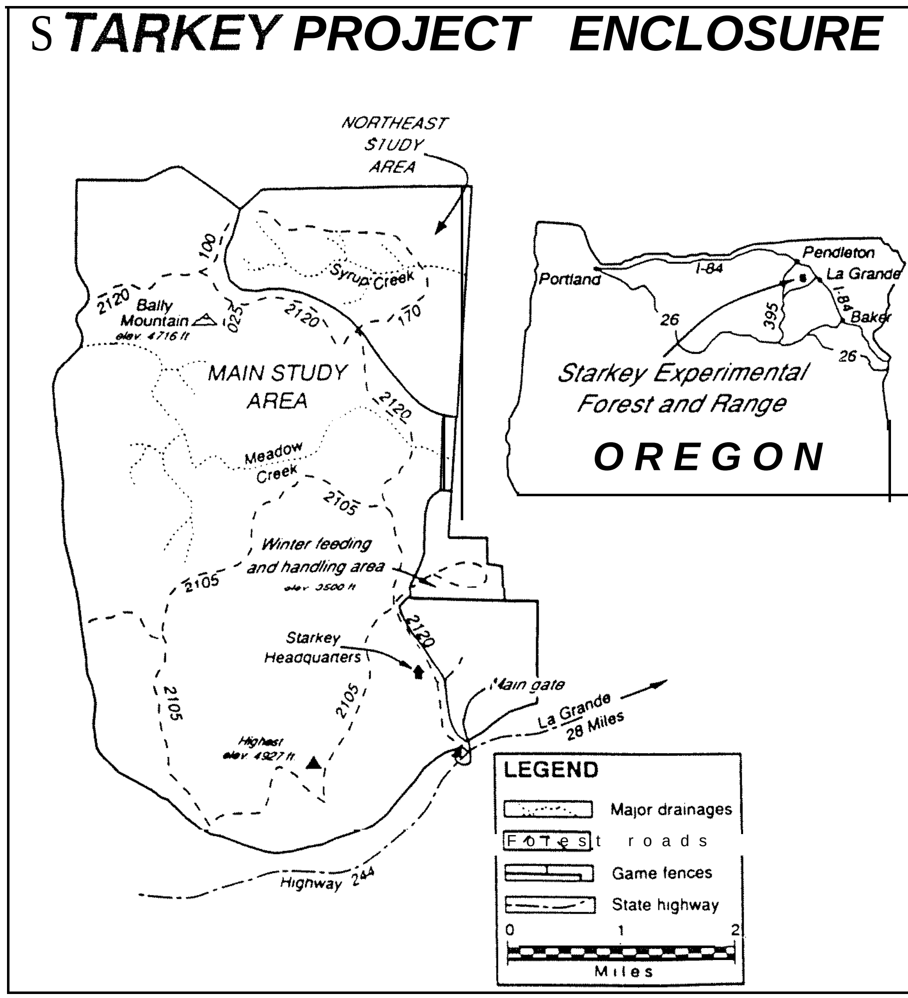

Figure 2—The Starkey Project area, northeast Oregon

The Starkey Environment

As an existing Forest Service research area in the Wallowa-Whitman National Forest, the Starkey Experimental Forest and Range offered an ideal location for conducting the Starkey Project experiments. The site, southwest of La Grande, OR (fig. 2), supports a mosaic of timber and grassland types common in the Blue Mountains of Oregon and Washington. Just as important, it was deemed “neutral ground” for conducting research that could affect timber and hunter management across thousands of acres of public and private land. Other advantages of the site were its public land status, the existence of baseline vegetation data, the long tradition of livestock grazing, terrain suitable for construction of a game-proof fence, an area large enough that ungulates inside the fence would maintain their wild nature, and existing housing and laboratories. It was chosen as an Experimental Forest and Range by the FS in 1940 because “the area reflected the history of resource exploitation typical of the ponderosa pine-bunchgrass forests throughout the West“ (Skovlin 1991: 1). It is, in fact, the only experimental area encompassing both forest and range in the United States today, the others being solely experimental forests (Skovlin 1991). A rich history of research in the SEFR on grazing systems, wildlife, and forest ecology preceded the Starkey Project. Skovlin (1991) thoroughly summarized this work, recounting the history, research, personnel, and resources of the SEFR from its inception in 1940 until 1988.

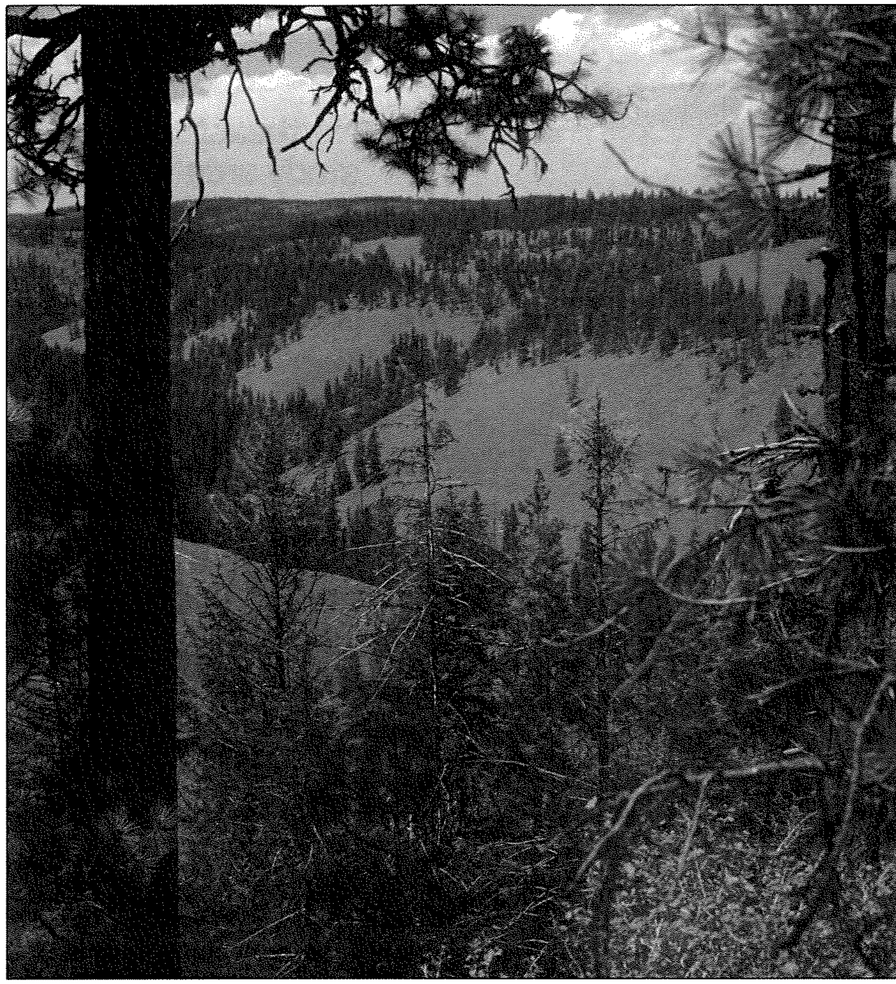

Figure 3—The Starkey landscape is characterized by rolling meadows and moderately steep canyons.

The following description of the Starkey landscape is taken primarily from Skovlin (1991: app. 1); the reader is referred to this publication for further detail. The SEFR is in the Blue Mountains province (Franklin and Dyrness 1973), with major vegetation types of ponderosa pine, pine-Douglas fir, and bunchgrasses such as bearded bluebunch wheatgrass, Sandberg bluegrass, and onespike danthonia. Elevation within the fenced portion ranges from 3,681 feet (1122 m) in Meadow Creek Alley to 4,922 feet (1500 m) in the southern portion, with rolling uplands and several moderately steep canyons (fig. 3). Major drainages are Meadow, Smith, Syrup, Battle, and Bear Creeks. Most of the 20 inches (51 cm) of precipitation each year falls as winter snow. June is the primary month of vegetative growth for herbaceous plants, but fall regrowth often occurs.

The Starkey Project area has been divided by game-proof fencing into four primary sections: the main study area of 19,180 acres (7762 ha), hereafter referred to as "Main"; Campbell Flat pasture (1,537 acres [622 ha]); the intensive timber management area, or northeast study area (Northeast or NE), covering 3,590 acres (1453 ha): and the winter feeding and handling area of 655 acres (265 ha), hereafter referred to as the "winter area" (fig. 4; appendix 1). Road densities in the fenced area are typical of Blue Mountains NFs, averaging 4.2 miles per square mile (2.6 km/km^2) in Main and 5.9 miles per square mile

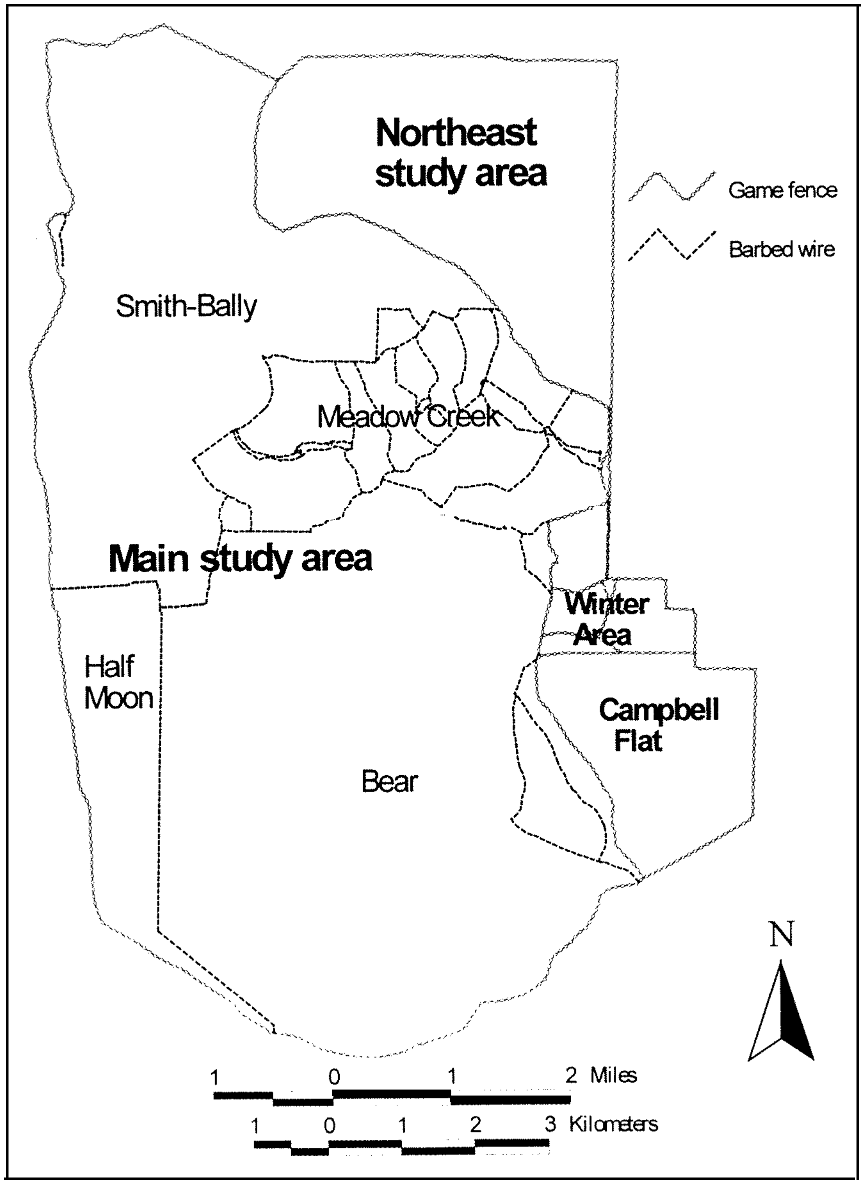

Figure 4-The Starkey Project is separated by game-proof fence into four primary research areas: Main, Northeast, Campbell Flat, and the winter area; cattle pastures also are shown.

(3.7 km/km*) in Northeast. (Road densities in the managed portion of the Wallowa-Whitman NF are 4 to 6 miles per square mile and less than 3 miles per square mile in the Umatilla NF.) There are about 165 miles (266 km) of roads in Main, Campbell Flat, and Northeast, with an additional 4 miles (7 km) in the winter area. Public traffic is allowed only in Main, on 27 miles (44 km) of roads posted with green dots.

The Starkey landscape is traditional summer range for mule deer and elk, with an average midsummer adult population of about 614 elk (85—Northeast, 475—Main, and 54—Campbell) and 300 deer (70—Northeast, 230-Main). Native mule deer and elk, like game populations elsewhere, were overharvested at Starkey by early settlers, so that by the late 1800s, game was scarce. Passage of game laws and bounties brought recovery of herds until they were again self-sustaining and capable of supporting hunting seasons (Skovlin 1991). Other large mammals in the Starkey area include black bears, cougars, and coyotes. Bull and Wisdom (1992) list the fauna of the SEFR.

Research Focus

Four main studies are underway inside the Starkey enclosure: animal-unit-equivalencies (AUE), intensive timber management, effects of roads and traffic, and breeding efficiency of bull elk. All but the bull elk study rely heavily on animal locations determined by the AATS (automated animal telemetry system, further described below in "Radio-Telemetry Data Collection"). As mentioned previously, these studies are relevant only to summer range use and behavior,with winter foraging conditions relatively consistent for all animals each year.

Animal-Unit-Equivalencies Study

Increasing interest in and conflict over forage allocation among domestic and wild ungulates in the Blue Mountains province are summarized in a report (Vavra 1980) commissioned by PNW. This account served as a catalyst for many of the objectives formalized in the AUE study at Starkey. Following this summary, Thomas (1983) prioritized wildlife research for the next 5 years at the La Grande laboratory. He stated, in response to the elk-livestock problem, that "development and testing of a practical and affordable procedure for judging site-specific animal equivalency between big game (primarily elk) and livestock is the most important contribution research can make at the moment ." (Thomas 1983).

Managers of public lands have long recognized the need for better techniques to allocate forage among ungulates, including cattle, than the traditional use of animal-unit-equivalencies. The AUE standard, as reported in the 1940s, equates forage removal by a 1 ,000-pound (454-kg) cow-calf pair with that of two elk or six deer (Stoddart and Smith 1943). This equivalency, based solely on relative body weights, offers no adjustment for habitat preferences or dietary, spatial, or temporal overlap among the species. A simple division of available forage among estimated numbers of cattle, deer, and elk is unrealistic at best and assumes complete overlap in diets and distribution of animals. Better management of forested rangelands required the development of a more realistic model equating effects of these herbivores on forage removal. The AUE study at Starkey was designed to provide such a model and test other hypotheses about forage use by ungulates and cattle on Blue Mountains rangelands (Johnson and others 1994).

The AUE study has three phases. In the first phase, a model will be developed that predicts distributions of elk, deer, and cattle in relation to a suite of landscape variables, such as distance to water or roads, slope, or percentage of cover. In the second phase, dietary overlap will be determined for the three species in a variety of habitats at Starkey, by using a combination of tamed animals and previously published information. Intake rates also will be measured for cattle, deer, and elk. These data will be combined with animal weights and the distribution model to predict AUEs for various habitats.

In the final phase, project scientists will develop an expert system combining data on animal distribution and preference, diets, and estimates of forage production to allocate forage among deer, elk, and cattle. A prototype forage allocation model recently has been developed for Starkey (Johnson and others 1996).

Intensive Timber Management Study

Better understanding of the role of forest cover in deer and elk energetics, distribution, and population demographics is a primary goal of the Starkey Project. Changes in timber harvest strategies to meet cover guidelines for elk and deer were implemented in Forest plans for the Blue Mountains, yet the role of cover had not been thoroughly investigated. Although it was well documented that elk move away from timber harvest activities (Hieb 1976, Lyon and others 1985), it was unknown whether this movement affected animal welfare and, ultimately, population performance. When initially conceived, the Starkey Project was intended to create conditions mimicking the “managed forest of the future,” compressing the changes of more than 30 years of forest management into 10 years. By monitoring a “closed” population of deer and elk and changing coverquantity and other habitat features, researchers could test effects of these changes on population performance and animal distribution. The animals could not disperse to other, perhaps more preferred, habitats as a result of the changes being effected. “Intensive timber management” was one of four harvest strategies identified in forest plans for the Blue Mountains in the 1980s. In the Starkey Project, responses of deer, elk, and cattle to such management could be studied under relatively controlled conditions (Anon. 1987a).

A portion of the Starkey Project (Northeast) was fenced specifically to accommodate research on effects of timber harvest on deer, elk, and cattle. (The elk and deer in this part of Starkey are kept separate from elk and deer in Main or Campbell Flat). Of the 3,590 acres (1453 ha) in Northeast, about 2,800 (1134 ha) were forested, primarily with ponderosa pine and grand fir. Logging was planned for the Syrup Creek drainage and was to include a series of thinnings and overstory removals, leaving the existing understory to mimic plantation conditions of the future. However, drought and insect infestations (primarily western spruce budworm) in the area did not abate as predicted but worsened after the sale was designed in 1987. By 1989 it was apparent that the amount of timber available for harvest was less than originally planned. Bought by Boise Cascade Corporation, the sale totaled 6 million board feet (Mbf), down from the proposed harvest of 12 Mbf. Timber removal began in fall 1991 and was completed by the end of 1992 (fig. 5; appendix 2).

A variety of harvest and postharvest alternatives were incorporated to restore vigor of stands in this drainage, with 63 cut units ranging from 3 to 55 acres (1 to 22 ha). Cover requirements for deer and elk were intentionally ignored in planning the sale. The combined harvest of 1,207 acres (489 ha) entailed mainly seed tree cuts (871 acres or 353 ha); the remainder was in shelterwood cuts, thinning, no cut, and individual tree selection. Postharvest prescriptions included broadcast burning, grapple-piling, precommercial thinning and stand cleaning, and planting. Seedlings, primarily of ponderosa pine and western larch, were planted on more than 830 acres (336 ha) in 1994 and 1995, in accordance with goals of restoring these two species to their former dominance at Starkey. Other species planted were Douglas-fir, lodgepole pine, and Engelmann spruce. Seeds were collected from these species before the harvest to provide seedlings for regeneration.

About 24 miles (38 km) of new roads were built and 4 miles (6.4 km) reconstructed in Northeast for the timber sale, which tripled the road mileage there. Road traffic was monitored by collecting data from traffic counters and a camera in Northeast; additional counters were placed in Northeast in 1992 to closely monitor postsale traffic. Since the construction of the Starkey Project fence, travel in Northeast has been restricted to administrative use by La Grande Ranger District (RD) and Starkey personnel, with the following exceptions: elk hunters in Northeast are allowed to drive in to retrieve animals killed there, and on occasion, hunters have been allowed to drive into Northeast for hunts there.

Figure 5—The timber sale in Syrup Creek removed over 6 million board feet from the Starkey Project area.

Responses of deer, elk, and cattle to the harvest and associated activities, such as road construction, were recorded with radio telemetry. Baseline data on elk and cattle locations were collected for three summers (1989-91) before the sale. During the harvesting period, 4 to 6 deer, 6 to 13 elk, and 12 to 13 cattle were tracked. Postharvest data are being collected on similar numbers of animals until 1997.

Initially, researchers planned to use cow elk harvested in Northeast to provide data on pregnancy rates, conception dates, and condition, as is done in Main. The required sample sizes were not attainable, however, with this smaller herd. Cow hunts, consequently, have been discontinued in Northeast. Animal data collected in Northeast include calf:cow and fawn:doe ratios, pregnancy rates of cow elk (determined from blood samples), weights of trapped elk and deer, and estimates of yearling recruitment.

Effects of Roads and Traffic

Road closures and restrictions on new road construction were incorporated in Forest plans in the 1980s to accommodate perceived needs of deer and elk for relatively undisturbed areas. If effects of roads on deer and elk are less adverse than predicted, these restrictions may have led to unnecessary road closures and the ensuing decrease in recreational use and associated expense of maintaining the closures. Conversely, effects of traffic on deer and elk may be more widespread and deleterious than previously believed. Impacts of roads and traffic on deer and elk have been incorporated into several habitat effectiveness models (for example, Lyon 1983; Thomas and others 1979, 1988; Wisdom and others 1986). In these models, no adjustment is made for traffic frequency or type of road. All roads are simply considered “open” if there is any vehicle traffic. Effects of traffic on ungulates are likely confounded by such factors as amount and type of adjacent cover, level of traffic, season, type of vehicle, type of road, and time of day. The Starkey Project addresses these effects on deer and elk distribution in a controlled environment.

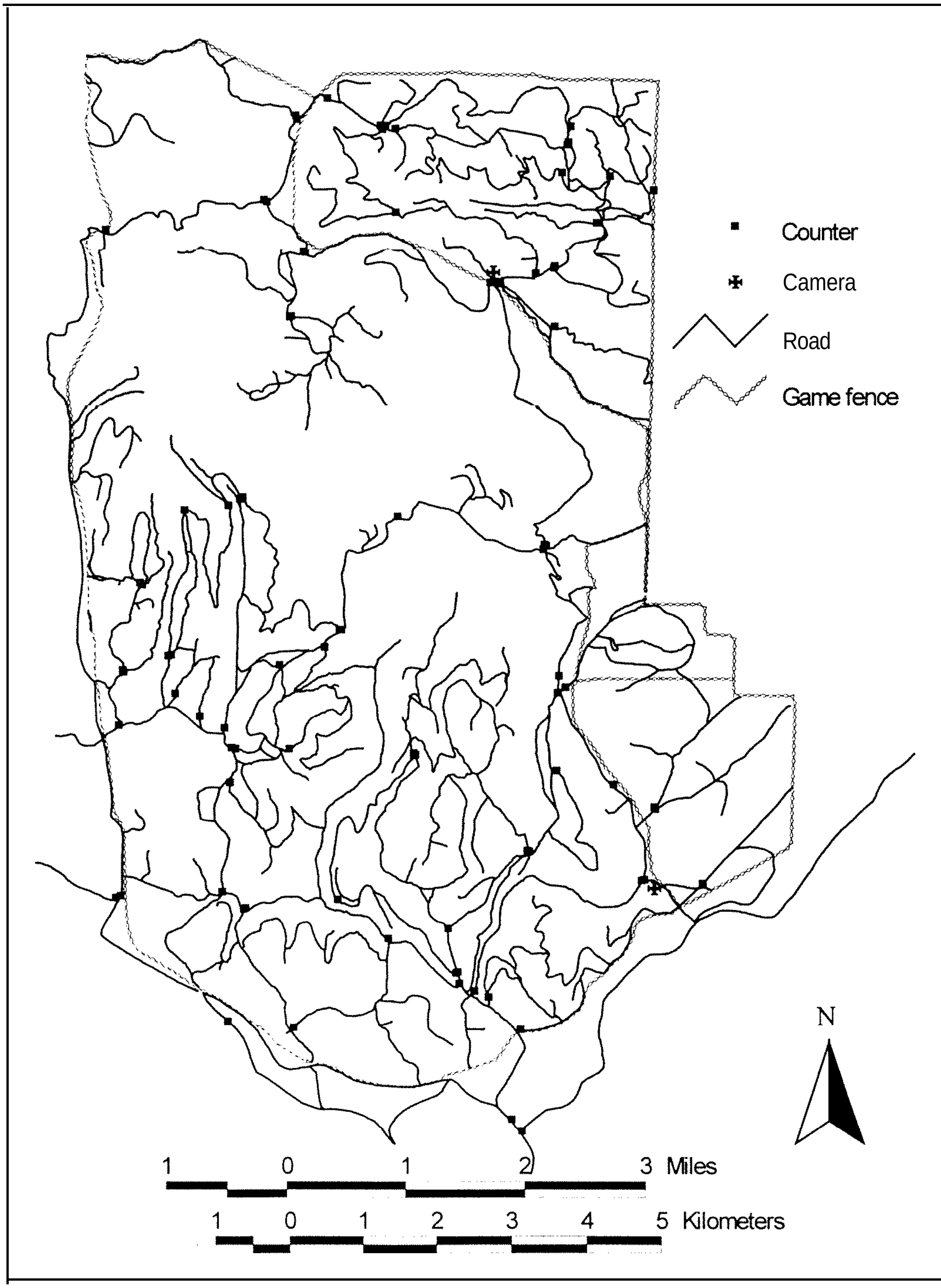

Figure 6—More than 70 traffic counters are placed at road intersections throughout Starkey to monitor frequency of vehicle traffic.

The initial objective of the roads study was to investigate effects of traffic frequency and road density on distributions of deer, elk, and cattle (Anon. 1987b). Since 1988, 75 traffic counters have been established at Starkey (Main, NE, and Campbell Flat) along primary roads, closed roads, and at road junctions (fig. 6). In addition, an extensive habitat database has been compiled, with data on more than 100 variables entered for more than 112,000 98- by 98-foot (30- by 30-m) pixels in the Starkey Project area (Rowland and others, in prep.). Patterns of habitat selection and use are being analyzed for 20 to 60 radio-collared females of each of the three species for summers from 1991 to 1995 (Wisdom and others, in prep., a and b).

To test effects of traffic frequency, roads were stratified into four frequency classes: high, medium, low, and zero. Each cell (pixel) in the Starkey Project area was characterized for a variety of continuous variables, including distance to each of the four traffic frequency classes. Probability of use in each cell, habitat availability, and selection indices were calculated. A linear model of use and selection index as a function of traffic frequency is being developed (Wisdom and others, in prep. b).

Distribution of wild and domestic ungulates also is influenced by road density. To analyze this effect, Starkey was stratified by density of open roads, with three replicates of each of three open-road density levels: low (less than 0.5 mile per square mile [0.3 km/km*]); moderate (0.5 to 2.1 miles per square mile [0.3 to 1.3 km/km*]); and high (more than 2.1 miles per square mile [1.3 km/km^2]). Hypotheses being tested include whether (1) elk select habitats with low densities of open roads, (2) deer select habitats independent of road density, and (3) cattle select areas with a high density of roads (Wisdom and others, in prep. a).

Open road densities and levels and types of traffic in Starkey also will be altered experimentally. Data will be gathered simultaneously on habitats occupied by radio-collared deer, elk, and cattle. Following development of a draft model based on these tests, the model will be validated through further experimentation.

Breeding Bull Elk Study

During the 1980s, when the scope of the Starkey Project was being defined, wildlife and public land managers were increasingly concerned about low productivity of elk populations in the Blue Mountains. Declining calf:cow ratios had been observed in many herds (Schommer 1991), concomitant with low bull:cow ratios-especially mature bulls. Increased hunter access, removal of hiding cover, and increased hunter pressure were seen as possible causes for the low numbers of bull elk (Leckenby and others 1991).

The lack of mature bulls was a potential problem in part because younger bulls tend to breed later in the season than do older bulls (Hines and Lemos 1979, Prothero and others 1979). Younger bulls also extend the breeding season over a relatively longer period. Such delayed breeding leads to later birth dates for calves and thus potentially smaller calves when winter begins. The enclosed elk population at Starkey, where hunting seasons could be tailored to control elk numbers and herd composition, provided an opportunity to examine effects of age of bulls on conception dates and pregnancy rates (Noyes and others 1992).

In 1988 two hunts were held to remove all antlered elk from Main (table 1). Bulls not harvested were released outside the fence after trapping (table 2), were culled, or were darted from helicopters, so that an estimated 98 percent of the antlered bulls were removed before the turnout of elk back into Main in the spring. A similar hunt was held in Northeast in 1988 to remove antlered bulls (table 1). A single cohort of bull elk in Main, the male calves born in 1988, was allowed to mature to 5 years (through 1993). About 70 bulls were in this group, with an average of 350 cows, for a bull:cow ratio of 20:100. Bull calves born in subsequent years were released each spring outside the fenced winter area. Additional hunts were held in later years to eliminate yearling elk not

Table I-Summary of harvest statistics for elk in the Starkey Project area from 1988 to 1995, in chronological order[a]

Hunt type	Hunt area	Year	Dates	Number of hunters[b]	Estimated animals available	Harvest	Hunter success rate
Antlered	Main,[c] NE[d]	1988	10/26 - IO-30	***169***	**51**	0.53	
Antlered	Main, NE	1988	11-5 - 11-12	***99***	118	48	.48
Antlered[e]	NE	***1989***	9/2 - 9/10	***10***	6	3	.30
Antlerless	Main	***1989***	12/9 - 12/15	***59***	565	32	.54
Antlerless’	Main	***1989-90***	12/30 - 1/7	28	533	9	.32
Spike	Main	***1990***	8/18 - 8/26	141	65	46	.33
Antlered[e]	NE	***1990***	8/18 - 8/26	23	10	5	.22
Antlerless	NE	***1990***	12/1 - 12/7	12	91	10	.a3
Antlerless	Main	***1990***	12/1 - 12/7	82	623	51[g]	.62
Spike	Main	***1991***	8/17 - 8/25	138	72	43	.31
Antlered[e]	NE	***1991***	8/17 - 8/25	14	8	2	.14
Antlerless	Main	***1991***	11/30 - 12/6	118	511	55	.47
Antlerless	NE	***1991***	11/30 - 12/6	14	111	9	.64
Antlered	NE	***1991***	11/30 - 12/6	10	15	3	.30
Spike	Main	***1992***	8/15 - 8/23	177	53	33	.19
Antlered[e]	NE	***1992***	8/15 - 8/23	26	13	9	.35
Antlerless	Main	***1992***	12/5 - 12/11	130	522	35	.32
Antlerless[h]	NE	***1992***	12/5 - 12/11	14	4	0	.00
Spike	Main	***1993***	8/14 - 8/22	131	61	31	.24
Antlered[e]	NE	***1993***	8/14 - 8/22	15	10	3	.20
Antlerless	Main	***1993***	12/4 - 12/10	122	413	49	.40
Antlered[e]	NE	1994	8/13 - 8/21	22	12	5	.23
Any elk’	Main	1994	8/27 9/25	78	631	14	.18
Spike	Main	1994	10/26 - 10/30	130	30	11	.08
Antlered	Main	1994	11/5 11/13	140	79	65	.46
Antlered	Main	1994	11/19 - 11/27	75	12	5	.07
Antlerless	Main	1994	1213 - 12/9	84	453	27[g]	.32
Antlered[e]	NE	1995	8/19 - 8/27	25	12	a	.32
Antlerless	Main	1995	12/2 - 12/8	103	490	58	.56

[a] Additional harvest statistics, such as daily harvest and percentage of hunters on opening day, are available from ODFW Starkey personnel.
[b] Number of hunters afield, not number of tags issued.
[c] Main study area, which included Campbell Flat prior to 1992.
[d] Northeast study area.
[e] Only branch-antlered bulls with 3 or more points, including the brow tine, on at least 1 antler.
[f] Included an option to harvest any branch-antlered bull seen.
[g] Project staff harvested additional cows to obtain an adequate sample of reproductive tracts.
[h] Hunters offered option to switch to antlerless elk hunt in Main; 20 made this change, harvesting 6 elk. These 20 hunters and 6 elk are included in the harvest statistics for the 1992 antlerless elk hunt in Main.
[i] Special archery-only hunt to simulate season structures and dates outside the Starkey enclosure.

Table 2-Number of elk released from Starkey Project site to adjacent areas outside the fence, 1989-95

	Females			Males				
Year[a]	Calves	Yearlings	Adults	Calves	Yearlings	Adults	Unknown[b]	Total
1988-89	7	2	17	1	16	6	6	55
1989-90	3			2	2	3		10
1990-91	20	9	80[c]	35	15			159
1991-92	2	1	4	8	3			18
1992-93	7	7	10	9	6	3		42
1993-94	1		1	8	17	14		41
1994-95				22	11	21		54
Total	40	19	112	85	70	47	6	379

[a] Trapping season runs from about November until April.
[b] Either yearlings or adults.
[c] Large number due to inclusion of some elk originally from outside the SEFR, but being held in South pasture to obtain elk calves for thermal cover research.

captured in the winter area (table I), so that the original cohort of bulls was the primary breeders of cows in Main from 1989 to 1993. (Yearling bulls that escaped hunters were released from Starkey after being trapped in the winter area.) Hunts also helped to maintain bull:cow ratios at similar levels among years of the study. The initial cohort of bulls was harvested in fall 1994 as 6 year olds, after the completion of the first 5 years of study (table 1). Antlered bulls that eluded this harvest were removed by trapping, culling, and helicopter darting and release. The study is being repeated with a second cohort of bull calves born in 1994; these will be allowed to mature for 5 years, as in the first study.

Antlerless elk have been hunted in Main since 1989 to collect data on reproduction, condition, age, and other variables. Conception dates and pregnancy rates were estimated for each year of the study with these data. Recruitment into the population was measured with helicopter classification counts and records from the winter area (Noyes and others 1992). Results of comparisons of reproductive parameters with age of breeding bull elk have been summarized by Noyes and others (1996).

A second phase of the study was begun in 1993 in Campbell Flat (fig. 4), which was fenced in 1992 to create a separate, game-proof pasture for the experiment (Johnson and others 1993). (Before 1992 this area was part of Main.) The enclosure totals 1,537 acres (622 ha) and also is grazed by cattle on a deferred-rotation system (see "Cattle Grazing," below). Researchers will examine effects of bull numbers and age and three specific bull:cow ratios on birth dates of calves and pregnancy rates (Johnson and others 1993). Paternity of calves will be determined through DNA fingerprinting, so that ages of sires will be known. Forty cow elk are held in the pasture each spring, summer, and fall, along with eight yearling bull elk and varying numbers of branch-antlered bulls. Supplemental feed is offered each year from August 1 to September 15 to offset potential declines in diet quality in this relatively dry site. The Campbell Flat elk are baited to move to the winter area and are fed there during winter, as are elk from Main and Northeast (see "Handling and Feeding of Deer and Elk," below). Calves from the Campbell cows are

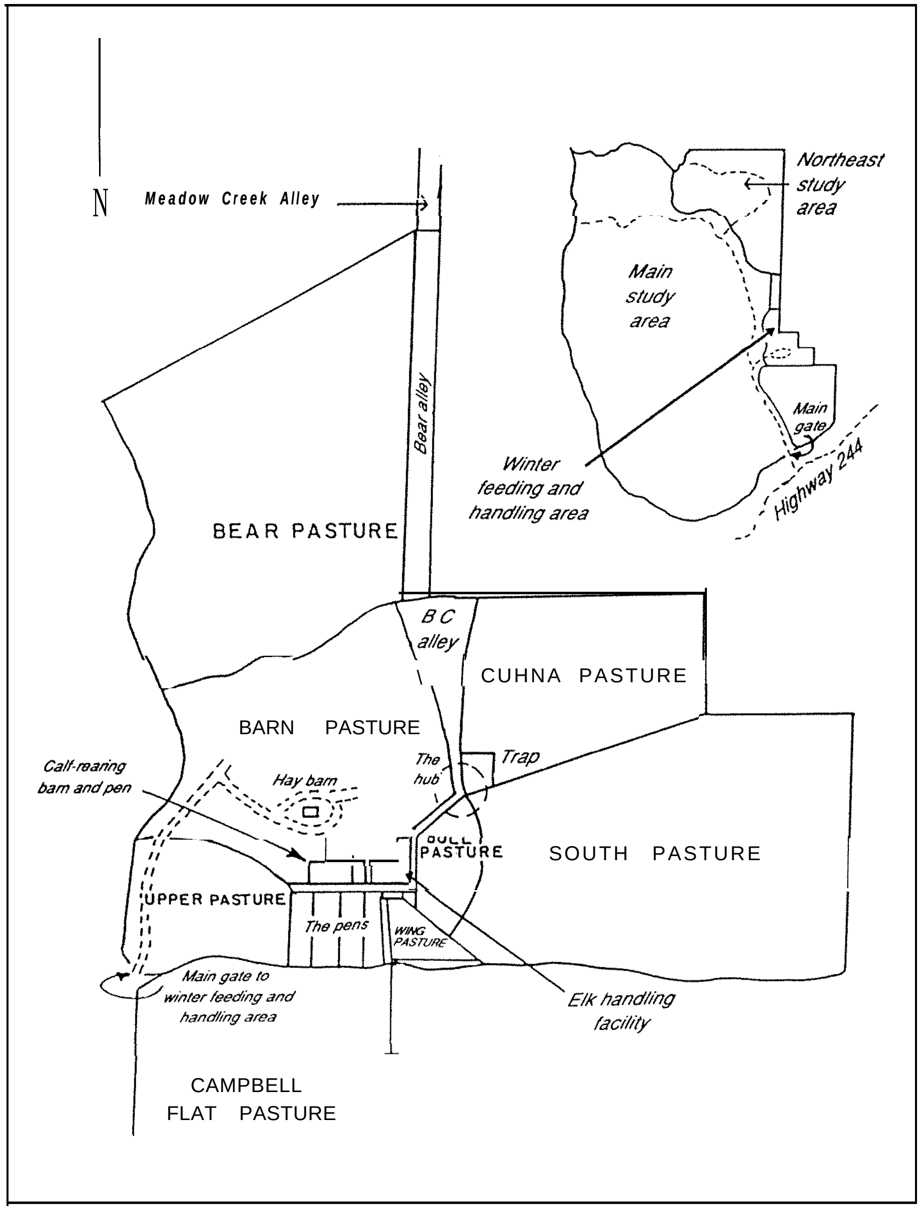

Figure 7-Pastures and facilities within the 655-acre (265-ha) winter area.

born in South pasture (fig. 7), where biological data are collected and radio collars are attached to monitor survival. Results of this research, to be completed in 2000, will be used to suggest specific **ages** and numbers of adult bulls needed for early and synchronous breeding of cow elk. The research will thus help managers design hunting seasons that continue to offer recreational opportunity, while improving bull ratios, increasing numbers of mature bulls, and improving productivity of herds.

Related Research

The Starkey Project has supported research on ungulates beyond the original four studies. For example, more than 100 elk calves were captured in South pasture from 1991 to 1993 and used to assess birth weights and dates and neonatal diseases (Cook and others 1994). About 75 female calves were subsequently tamed for use in a thermal cover study sponsored by NCASI and the FS (Cook and others 1994). These calves

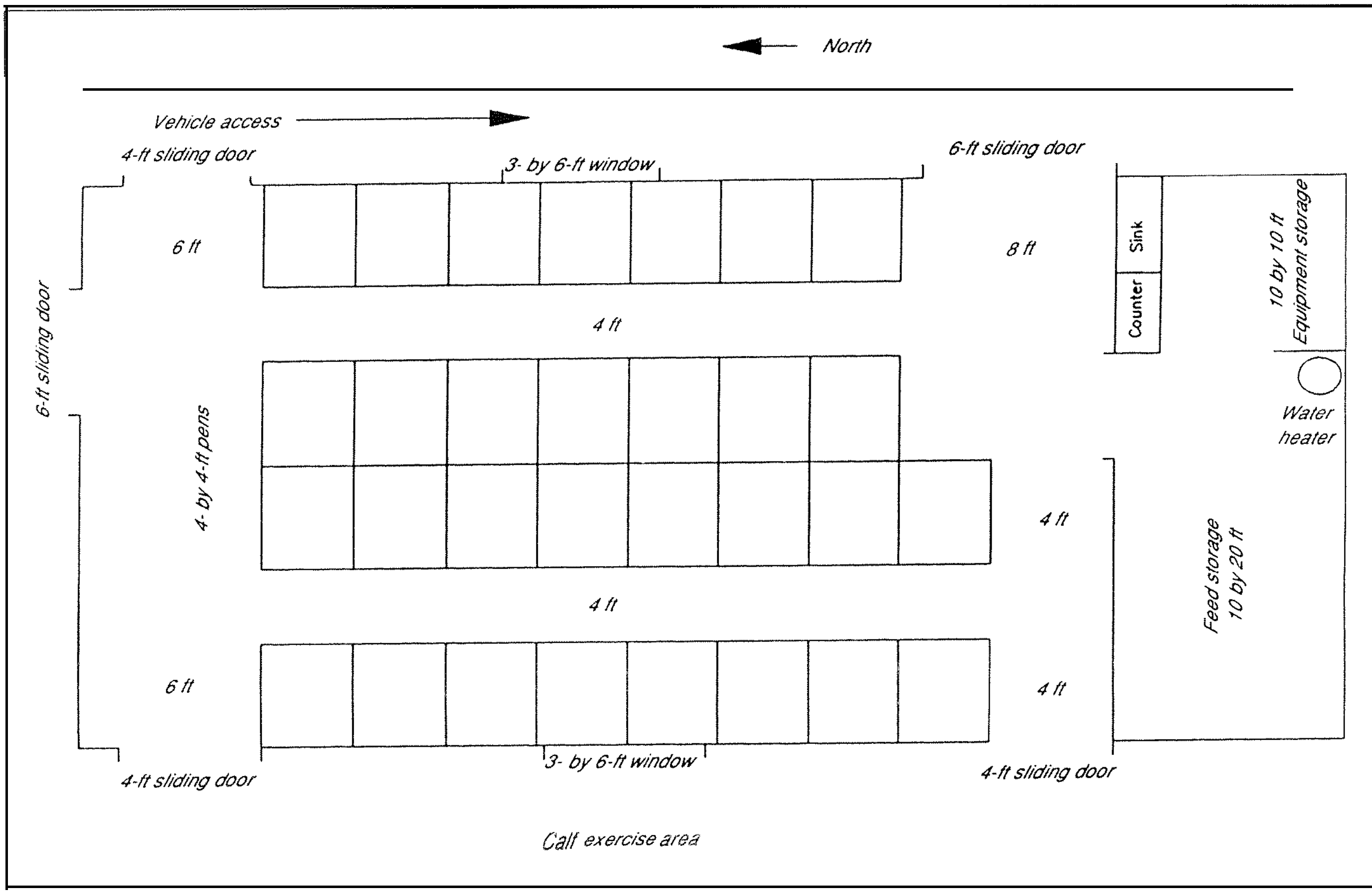

Figure &--Floor plan of barn for rearing tame mule deer and elk in the winter feeding and handling area. (Meters = feet x 0.305.)

were raised in the calf-rearing facilities at the winter area in Starkey (fig. 8), and later moved to a study area near Kamela, OR. The thermal cover experiment ended in 1995, but many of these tamed elk are now being used in research at Kamela to investigate effects of birth date and nutrition on calf growth and subsequent reproduction in cow elk (Cook and others 1995). This study will directly complement the breeding bull elk research underway at Starkey. Other research has recently been completed on effects of preconditioning forage for elk with domestic sheep south of the Starkey Project area (Clark and others 1996). The AATS was used to track radio-collared elk on winter range adjacent to the SEFR, but outside the fence.

Biodiversity and forest health are current emphases in forest management in the Blue Mountains; these issues may bear on the ungulate studies of the Starkey Project in the future. Several recently completed or ongoing studies in the SEFR are pertinent. Forest health has been addressed in research on interactions of dwarf mistletoe with western spruce budworm in affecting growth and mortality of Douglas-fir (Filip and Parks 1987). Plots established for this study continue to be read every 3 years. Long-term monitoring of western spruce budworm populations, and associated tree mortality, is ongoing at Bally Mountain.[2] Other work has focused on the creation of wildlife trees by inoculating

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[2] Personal communication, 1996. Richard R. Mason, principal insect ecologist, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande,. OR 97850.

Figure 9—Tightlock game-proof fence surrounds 25,000 acres (10 125 ha) of the Starkey Experimental Forest and Range and adjacent FS lands.

live trees such as western larch with decay-causing fungi (Parks and others 1995). A wealth of avian research has also been conducted wholly or in part in the SEFR. Recent studies have focused on pileated woodpeckers (Bull and Holthausen 1993), Vaux's swifts (Bull and Beckwith 1993, Bull and Collins 1993), and forest owls (Bull and others 1989, 1990). Finally, long-term studies on relative abundance of larval amphibians in stock ponds at Starkey were conducted from 1981 through 1 992.[3]

Facilities

The Starkey Fence

One of the most prominent features of the Starkey Project is the game-proof fence (fig. 9). A safe, long-lasting, and virtually impermeable fence was needed, not only to contain the valuable research animals but also to keep deer and elk outside the fence from entering. Construction of the high-tensile woven wire fence, which cost $585,000 for labor and materials, was completed in 6 months in 1987 (Bryant and others 1993). The fencing was developed originally in New Zealand to contain commercially farmed red deer. The Starkey fence was the first large-scale use of Tightlock deer fence for wild ungulates in the United States.[4] Tightlock fencing was chosen because of its durability, safety to large animals, cost-effectiveness, and strength. The Starkey fence is 8 feet (2.4 m) high and is surveyed regularly in its entirety; injuries to deer and elk have been minimal (Bryant and others 1 993). Designed to last 30 years, the fence requires little maintenance. Details of fence construction, costs, and performance are given in Bryant and others (1993).

[3] Personal communication. 1996. Evelyn Bull, research wildlife biologist, Pacific Northwest Research Station, Forestry and Range Sciences Laboratory, 1401 Gekeler Lane, La Grande, OR 97850.

[4] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

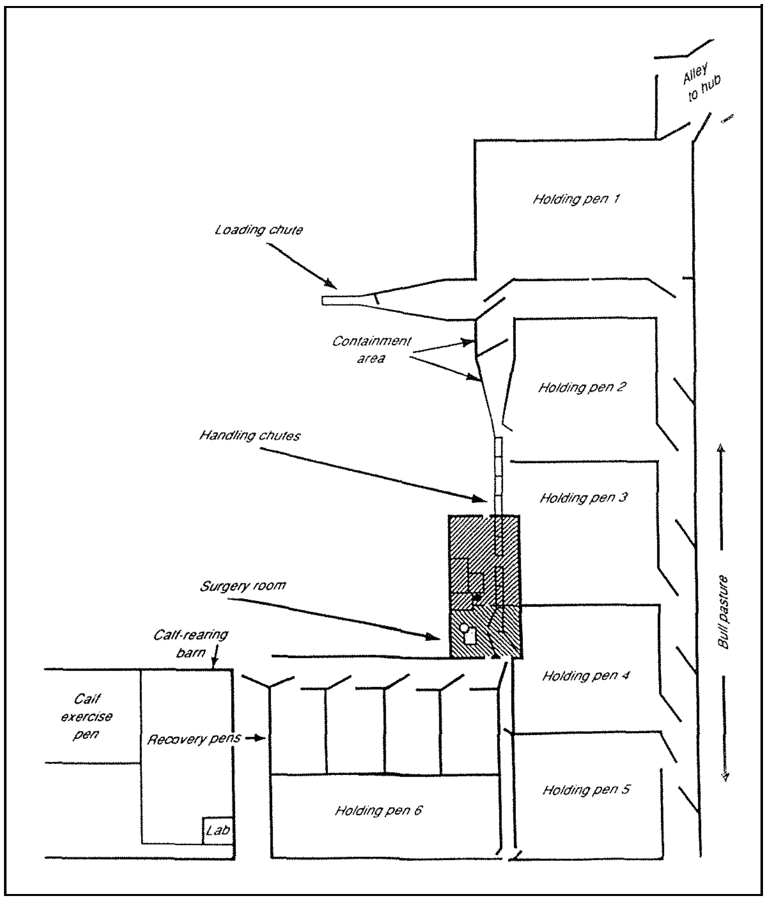

Figure 1 O-Holding pens and chutes at the elk handling facility allow efficient capture and movement of animals.

Most of the current fence was constructed in 1987, including 27 miles (44 km) of perimeter fence and 9 miles (14 km) of interior pasture fence (fig. 4). After the first trapping season (1987-88) the Starkey crew realized that additional pastures were needed in the winter area to separate deer and elk and to streamline elk handling. Consequently, the winter area was further divided in 1988 with the addition of 3 miles (5 km) of elk fence. Seven pastures, along with smaller catch pens and alleys, now divide the winter area (fig. 7). Another 2 miles (3 km) of elk fence were added in 1992 when Campbell Flat (originally part of Main) was enclosed to hold elk apart from the rest of Main (fig. 4).

In addition to the game-proof fencing, there are over 35 miles (56 km) of cattle fence in the Main study area of Starkey, mostly four-strand barbed wire (fig. 4). Cattle pastures in Main (Smith-Bally, Bear, and Half Moon) and Campbell Flat are grazed on a deferred rest-rotation system (see “Cattle Grazing,” below).

Handling Facilities

A group of buildings constructed between 1987 and 1990, commonly referred to as the “handling facility,” accommodates hands-on research associated with the Starkey Project (figs. 10 and 11). The facilities, located within the winterfeeding and handling area, consist of a surgery-animal handling building, hay barn and feed storage building, corrals, chutes and pens, calf-rearing barn, and a garage-shop. The surgery-handling building covers

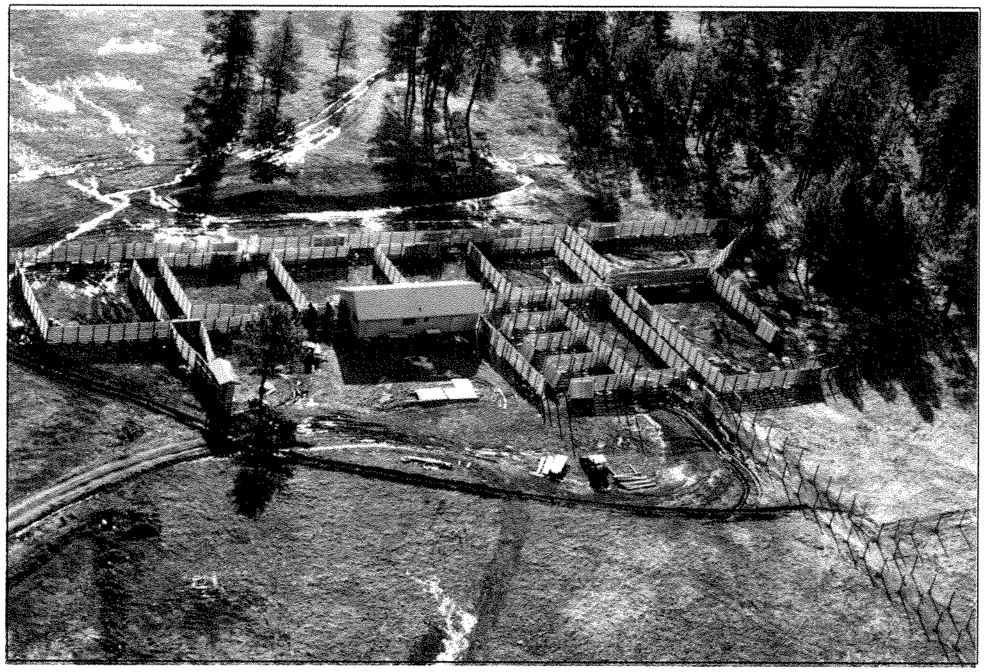

Figure 1 l-The handling facilities were constructed in 1987 and 1988 and include chutes, pens, and an indoor surgery room.

1,620 square feet (151 m^2) and is the primary site for data collection on elk. Single elk are worked through the building via a series of chutes, both inside and outside the building, where they are restrained while blood samples, weights, and other measurements are taken (fig. 12; see Wisdom and others 1993 for further details). A surgery room in the building was incorporated to allow operations such as implants of heart-rate transmitters. Various holding pens and chutes outside the handling building allow for efficient sorting and moving of animals before and after they are processed (fig. 10; see "Trapping and handling," below).

The calf-rearing barn, constructed in 1990, was designed for rearing juvenile elk and deer (fig. 8). It was first used for raising elk calves in the NCASI-sponsored research on thermal cover requirements of elk (Cook and others 1994; see Wisdom and others 1993 for protocols for rearing tame elk). The insulated building is 30 by 60 feet (9 by 18 m), with 32 stalls for housing juveniles separately. A l-acre (0.4-ha) pen, adjacent to the building, is available for exercising tame elk. Four enclosures permit separation of research animals, if necessary (see fig. 10).

Radio-Telemetry System

A superior telemetry system was a critical part of the Starkey Project proposal. Research objectives required data on animal locations with better resolution and in greaterquantities than were traditionally gathered with conventional radio-telemetry systems. Technology to analyze large quantities of location data also was needed. A time-of-arrival radio-telemetry system, used in moose tracking, was examined in Sweden by project personnel. This configuration was rejected because it was more expensive than initially thought, and lengthy delays were likely in procuring the system for Starkey, especially in obtaining international government trade and State Department clearances. Global Positioning Systems (GPS) also were considered but abandoned as being too costly and unreliable for wildlife tracking. Too few satellites were transmitting signals for GPS systems to

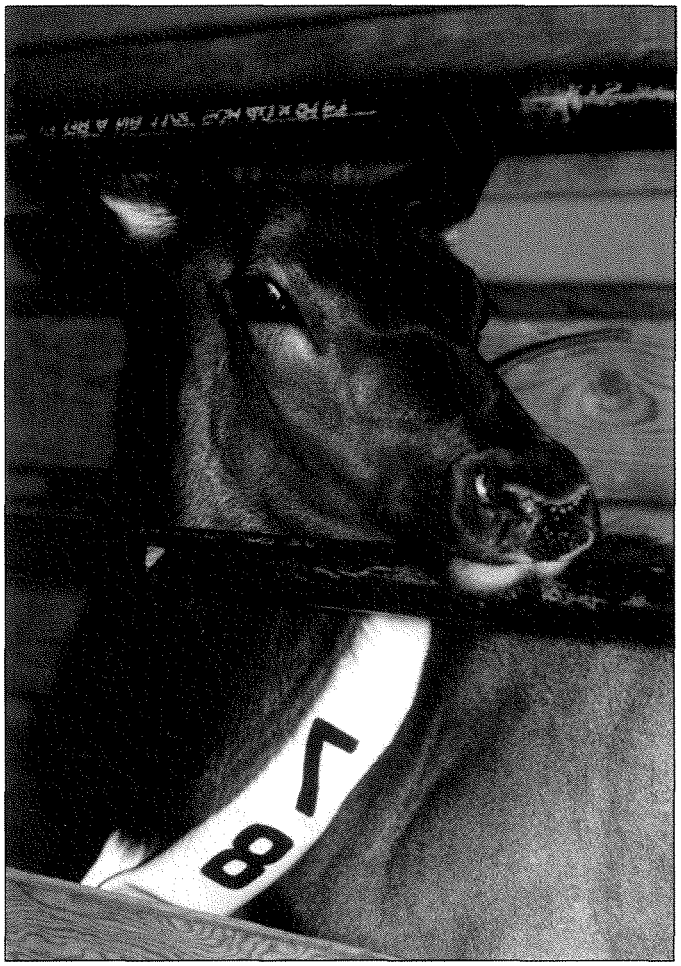

Figure 12—Elk are worked through a series of chutes as physiological data are collected and radio collars removed or attached.

provide constant, 24-hour coverage, and the GPS receivers worked poorly in areas of steep terrain or dense tree cover. Lightweight GPS collars with adequate battery life also were unavailable in the late 1980s.

Preliminary testing of a conventional radio-telemetry system at Starkey in summer 1988 demonstrated that location accuracy was still insufficient to meet project objectives (ODFW 1988; appendix 3). Bryant then consulted with Tracor Aerospace, Inc. (Austin, TX) staff about adapting loran-C navigational technology for use in wildlife telemetry (appendix 3). This technology was developed originally to track maritime vessels and had not yet been applied to wildlife tracking. Potential problems preventing more widespread application of loran-C technology to wildlife telemetry included its use of an external antenna, the band width required, the relatively high initial cost of the system, and the perceived future superiority of GPS.

Collaboration between Bryant and Walt Fowler (Tracor) led to development of a prototype automated animal telemetry system (AATS) that used loran-C to monitor animal movements at Starkey. Initially, 30 collars were built and tested at Starkey on about 20 animals. Following this successful pilot study, the FS contracted with Tracor to complete the

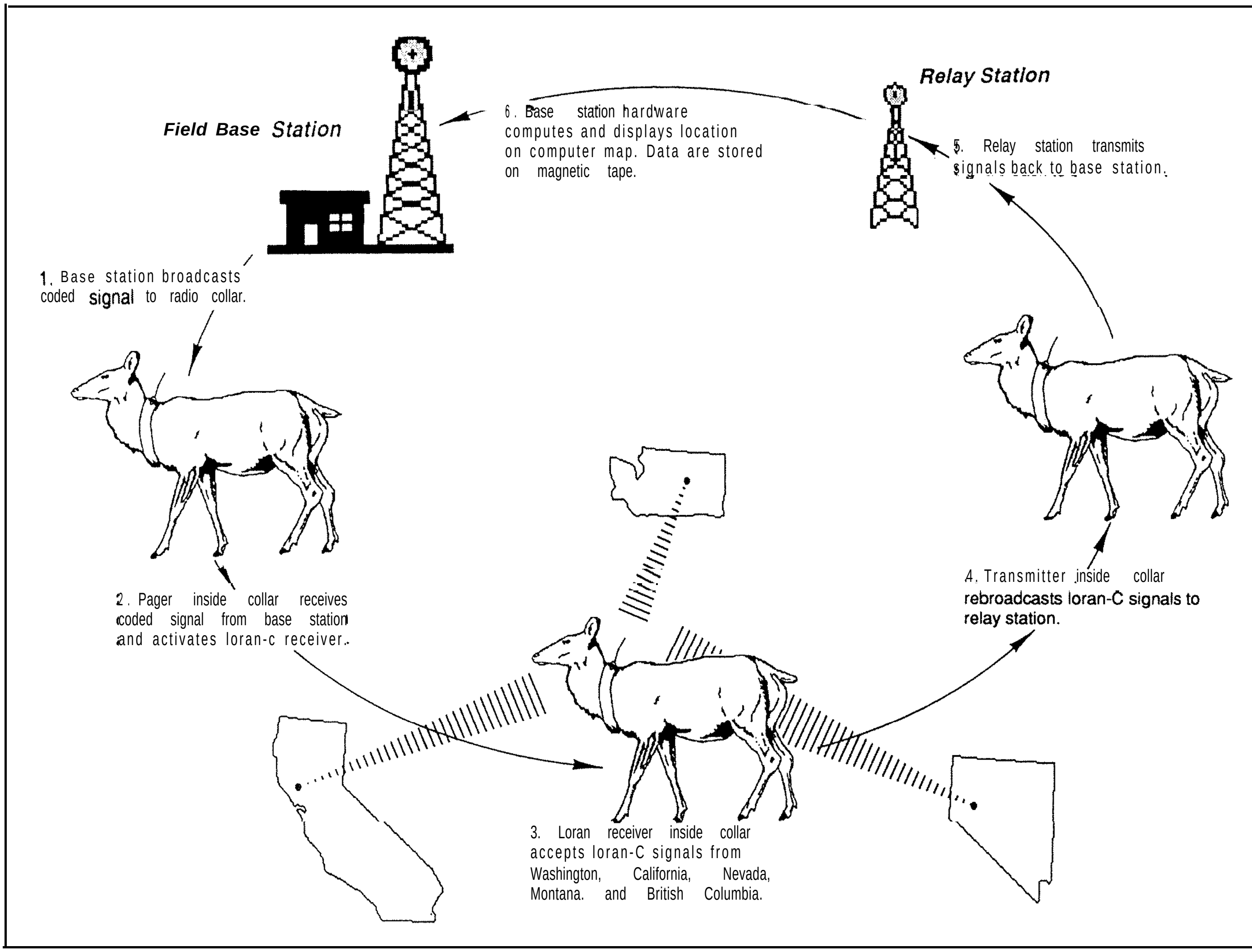

Figure 13—With the automated animal telemetry system (AATS), radio collars on animals at Starkey receive signals from loran stations in several Western states or provinces, then relay these signals through microwave towers (relay stations) to the base station.

system for $993,000, including 200 collars and loran-C hardware and software to analyze signal locations (appendix 3). The FS provided the microwave system, towers, and buildings at the remote tower sites for an additional $300,000.

In loran-based systems, low-frequency (40 MHz) radio pulses are sent by a master station and at least two slave stations; these stations comprise a "chain." The collar receives the loran-C signals, then relays them to the base station on a radio frequency, where the usable loran-C signals are processed (fig. 13). The time differences between the master and slave stations are then used to compute the location of the radio collar. The AATS originally received signals from only the West Coast U.S. chain; however, the system was upgraded in 1992 by adding the North Central U.S. chain. With this improvement, signals from both chains can be used simultaneously to provide better geometry and thus improve the level of resolution.

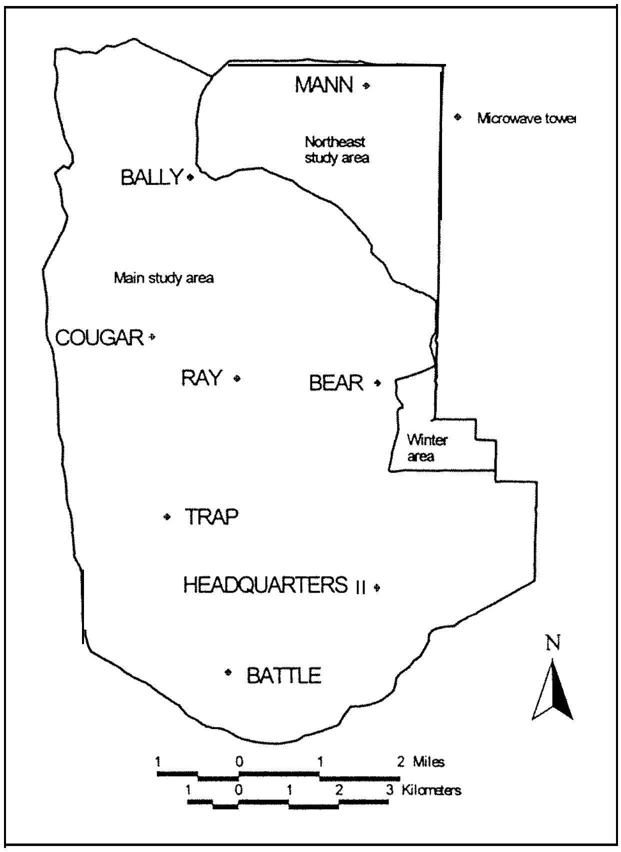

Figure 14—Seven remote microwave towers inside the Starkey Project site relay signals from loran-C radio collars to Headquarters II.

The AATS was first installed in June 1989; two remote microwave relay towers were constructed to serve Northeast (Mann and Bally; fig. 14; appendix 3) and a temporary base station was built at the Starkey compound (location of the housing and weather-monitoring facilities at Starkey). Over 50,000 locations were recorded for nine elk and nine cattle from June through October that year. The AATS now consists of a 195-foot (59-m) base station tower at Headquarters II (fig. 14) and seven remote microwave towers, ranging in height from 150 to 195 feet (46 to 59 m; fig. 15). The solar-powered towers, built in 1989 and 1990 (appendix 3), have high-frequency microwave dishes and telemetry antennas attached to them. A building at each tower houses the microwave transmitters and radio-telemetry receivers. Towers were located to optimize coverage of the entire Starkey area and are generally dispersed around major drainages (fig. 14).

The base station facilities (Headquarters II) include the tower mentioned above, paging and telemetry antennas, and seven microwave dishes. The building houses the microwave telemetry and loran-C receivers, a paging system, and two IBM-compatible computers for data analysis. The paging system operates 24 hours per day, automatically contacting a different radio collar about every 20 seconds by activating the collar pager. The pager turns on a loran-C receiver and telemetry transmitter inside the collar. The receiver then collects signals from loran-C transmitters (six sources, located in British Columbia, California, Montana, Nevada, and Washington) for 16 to 17 seconds. The loran-C signals are then sent by the collar telemetry transmitter to one or more of the microwave towers

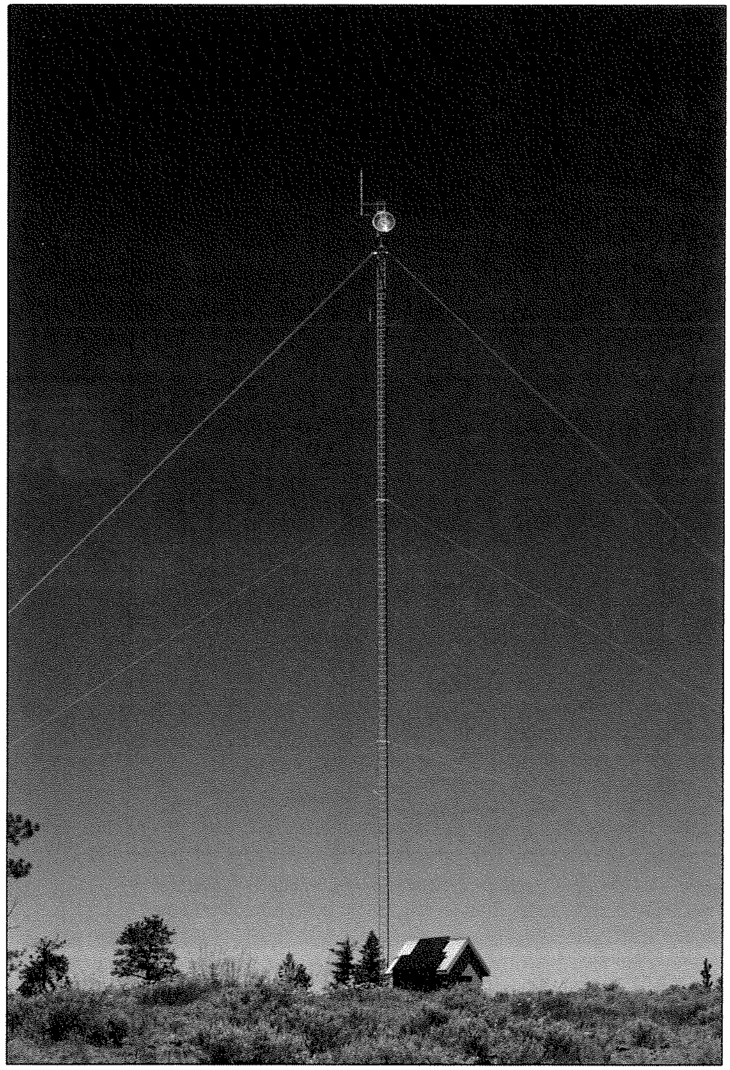

Figure IS---Remote microwave tower sites include microwave dishes and telemetry antennas on the towers; the attached buildings house solar panels, microwave transmitters, and radio-telemetry receivers.

at Starkey. The receiving towers retransmit the signal to Headquarters II, where loran-C hardware selects the strongest signal for processing and then determines the collar location. Computer software allows differential correction of the various signals in real time. Time differences (from the master versus slave stations) are converted with software to UTM (Universal Transverse Mercator) coordinates for the location, and location status is coded. A complete rotation of all collared animals takes from 1 to 2 hours, depending on whether cattle are being paged; however, specific paging sequences can be programmed if necessary.

At Headquarters II, two computers gather and analyze loran-C data for plotting animal locations. The "signal" computer is the workhorse of the operation; it pages the collars and receives the location signals in response to paging. This computer also analyzes data, plots current locations, and tracks information about the collar and quality and quantity of received signals. The second computer (also known as the data or map computer) receives location data from the signal computer. It is used primarily for backup and visual display of location data. Telemetry data from any files on its hard drive can be mapped onscreen and the image enlarged or otherwise manipulated for better visual interpretation of animal locations. The UTM coordinates of each telemetry location are recorded and tagged with the time, status code, and other pertinent signal information. Telemetry data are transferred weekly from the hard drive to magnetic tape (in triplicate) and transported to the La Grande laboratory.

For further discussion of the daily operation of the telemetry system at Starkey, error analysis, and other features, see "Radio-Telemetry Data Collection," below.

Weather Station

Historically, weather data have been collected in the Starkey area since 1910. The original weather station was at the site of the Starkey Post Office, but it was moved to the SEFR in the 1940s. Most of the early records are of temperature and precipitation, although some wind speeds were recorded, along with notes on exceptional weather events. These data are stored at the La Grande laboratory.

One weather station, established in 1984, now operates in the SEFR across the 2120 road from the Starkey compound. The equipment records temperature and precipitation. Ambient temperature is logged every 30 minutes with an Omnidata Digital Recorder and stored in ASCII format on a microchip that is replaced every 21 days. Temperature data are downloaded to a computer at the La Grande laboratory with a datapod-cassette recorder. Precipitation is recorded continuously to the nearest 0.01 inch (0.03 cm) with a wet fall-dry fall sampler supplied by the National Atmospheric Deposition Program (NADP). (Collections in the dry sampler, such as particulates, are not analyzed.) Precipitation data are manually transferred from the recording graph paper to a data form and entered in a spreadsheet. Project staff note the type of precipitation (rain, snow, sleet, or hail). Water in the wet fall sampler, emptied weekly, is used to measure conductivity and pH. These data are sent to an NADP contractor, along with the weekly water samples (up to a liter per sample), for acid rain monitoring. Data summaries and further analysis are completed by the contractor, including identification of anions and cations.

Other Facilities

Housing and administrative buildings have been located at the SEFR since the first cabin was moved there in the 1940s; this area is commonly referred to as the "Starkey compound." Additional residence trailers, office and lab space, and utility sheds have been added over the years. A proposal to upgrade facilities at the compound would allow for better accommodation of the present Starkey staff as well as the many regional and international scientists who have shown interest in sabbaticals or other long-term cooperative research at the Starkey Project (Dick and others 1993).

Activities

Research activities occur year-round at Starkey (fig. 16), whereas the area is open to the public only from May 1 to mid-December. The winter closure is scheduled to facilitate baiting of animals to the winter area and trapping of deer and elk without disruption and interference from humans. Public recreation at Starkey includes camping, hunting, mushroom picking, hiking, photography, and horseback riding. Firewood gathering, fishing, and snowmobiling are not allowed.

Cattle Grazing

Cattle have been grazed continuously in the Starkey basin since the 1840s. Long-term research on cattle grazing began in 1955 at Starkey; riparian research, in particular, was an integral part of early grazing studies at the SEFR (Skovlin 1991). Data on vegetation, stream temperature and flow, and streambank conditions are still collected in the Meadow Creek pastures.

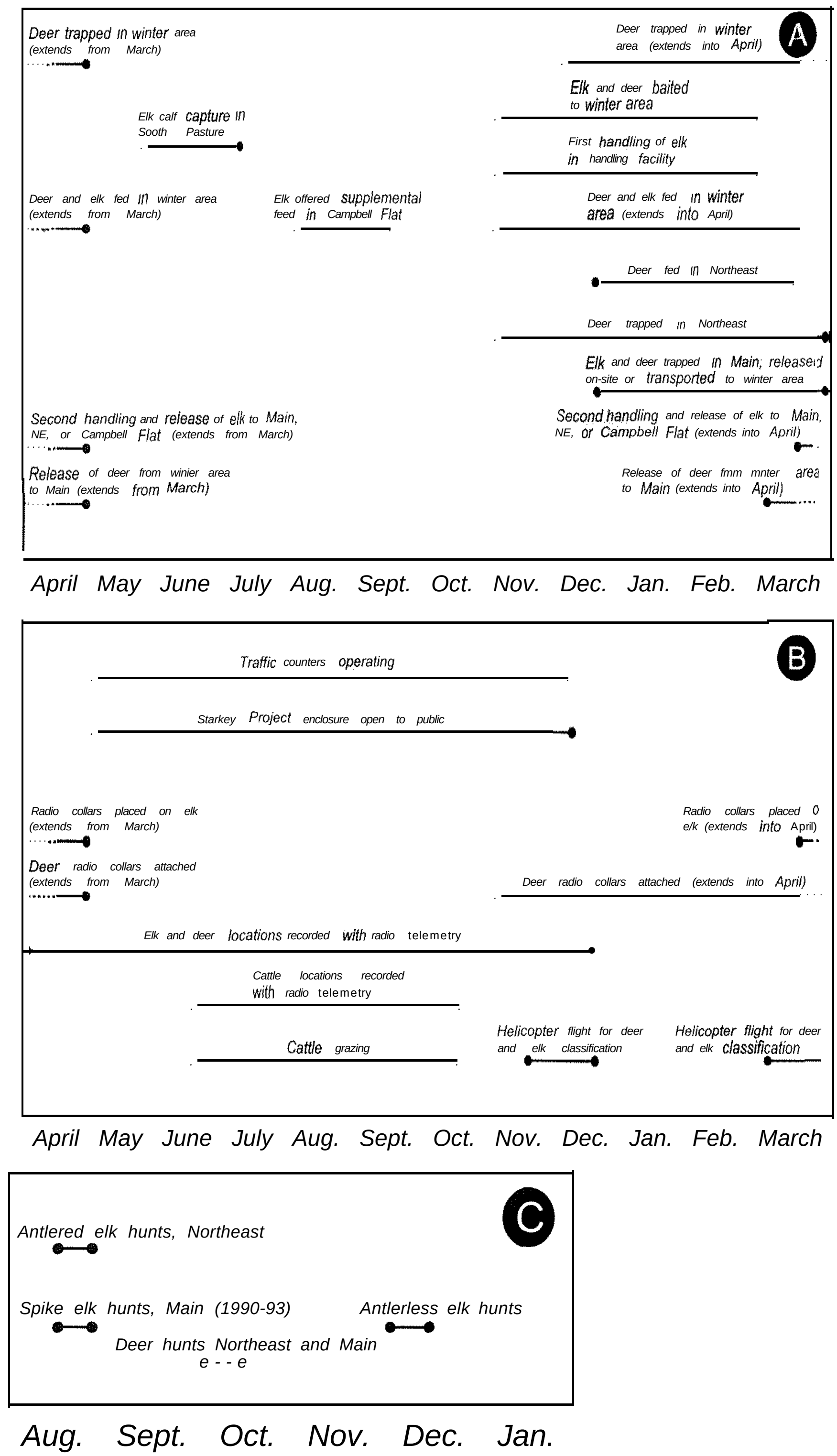

Figure l&--Generalized chronology of major seasonal activities for the Starkey Project related to (A) feeding and handling of deer and elk; (B) radio-telemetry and traffic data collection, livestock, aerial surveys, and public use; and (C) hunting seasons. Dates may differ slightly across years.

Figure 17-Radio-collared cows at Starkey are used in studies of forage allocation and competition.

Cattle grazing at Starkey has continued as the Starkey Cattle and Horse Allotment, formally administered by the La Grande Ranger District of the Wallowa-Whitman National Forest. Allotment monitoring is carried out by Starkey staff. The two permittees are the Starkey Cattle and Horse Association (in Main, Campbell Flat, and the SEFR outside the fence), which formed in the early 1900s, and OSU (in Northeast and Meadow Creek, as well as some cows in Main and Campbell Flat). Currently 590 cow-calf pairs are grazed each summer: 500 in Main (including Campbell Flat), 40 in Meadow Creek, and 50 in Northeast. Cattle are not mixed among these three areas. An additional 90 pairs are grazed at the SEFR, but outside the Starkey perimeter fence. Before being released inside the fence each summer, all cattle are ear-tagged, weighed, and vaccinated against major ungulate diseases. Annually about 60 cows, owned by OSU, wear radio-telemetry collars (fig. 17; see "Radio-Telemetry Data Collection," below). Cattle in Meadow Creek also have worn telemetry collars at times to monitor collar reception and to observe cattle movements in an area also grazed by deer and elk.

Stocking rates are characteristic of the Blue Mountains and range from 5 to 15 acres per AUM (animal-unit-month). Cattle are moved in a deferred-rotation system among Campbell Flat and three pastures in Main: Smith-Bally, Half Moon, and Bear. They are grazed season-long in Northeast, and in the Meadow Creek pastures for 12 weeks on a separate grazing schedule. In most years, introduction of cattle in Starkey is around June 15, with an average 120-day grazing season. Typical dates for the grazing rotation in Main are as follows:

Pasture name	Even years	Odd years
Smith-Bally	8/30 - 10/15	6/16 - 7/30
Half Moon	8/22 - 8/29	7/31 - 8/7
Bear	7/16 - 8/21	8/8 - 9/22
Campbell Flat	6/16 - 7/15	9/23 - 10/15

Cattle in Meadow Creek are weighed monthly for research on weight gains. Location data are recorded for all radio-collared cattle and used primarily in the AUE study and development of the forage allocation model (see "Animal-Unit-Equivalencies Study," above). Collared cattle in Northeast also are being used to monitor effects of road construction and timber harvest on elk, deer, and cattle interactions and habitat use.

Use of shrubs and grasses is measured in key riparian areas and uplands, and in Main, Campbell Flat, Northeast, and Meadow Creek. See "Vegetation Monitoring" (below) for further details on these measurements and other, similar, data collection.

Handling and Feeding of Deer and Elk

All handling, feeding, and care of deer and elk at Starkey are reviewed and guided by an Institutional Animal Care and Use Committee (IACUC). Protocols for these activities are described in detail by Wisdom and others (1993) and have been approved by the USDA Animal and Plant Health Inspection Service (APHIS). The protocols are in full compliance with the Animal Welfare Act of 1966 and provide for the safe, humane treatment of animals with minimal stress. The IACUC meets at least twice a year to review facilities and animal care at Starkey and also prepares an annual report of these activities. See Wisdom and others (1993) for details of handling procedures and immobilization of deer and elk, as well as the functions of the IACUC.

Feeding and handling of deer and elk in winter are requisite for meeting Starkey Project research objectives. Handling is necessary to collect biological data, such as weights and pregnancy status, check for occurrence of diseases, sort animals into correct pastures, and attach and remove radio collars. Feeding is needed to maintain winter diet quality at an adequate level to negate any potentially confounding effects of winter diet on research results. In most winters, native forage at Starkey is inadequate to support the numbers of deer and elk within the enclosure. (Although the winter area is at the lowest elevation in Starkey, it is nonetheless summer range for deer and elk.) The feeding and handling of deer and elk has evolved each year since construction of the Starkey fence, with reduced handling losses and improvements in handling time, feeding regime, and overall efficiency of the operation. The following procedures are those now in use by Starkey staff.

Moving animals to the winter area-Ideally all elk and deer inside Starkey should be transported or baited to the winter area each year, so that they could be fed similarly and handled for data collection and attaching radio collars. After several years of experience, however, Starkey staff realized that this was not always feasible. Procedures used now are as follows: When the cow elk hunt has ended in Main and public access is no longer allowed, typically by mid-December, deer and elk in Main and Campbell Flat are lured to the winter area by baiting with alfalfa hay (fig. 16). Feeders are placed by gates leading into the winter area, with short bait lines, and moved inside the gates when animals begin responding to the bait. Animals in Main that are not responding to bait are occasionally trapped with panel traps (deer) or portable corral traps (elk) and trucked to the handling area. In most winters, however, elk trapped in portable corral traps are moved to the winter area only if needed to meet sample size requirements for a particular pasture, or if weather is severe. Baiting elk from Main and Northeast to the winter area may continue through February if animals are still needed for handling and data collection. The percentage of animals coming to the winter area in any year is highly variable and dependent on weather and its effects on forage availability.

Table 3-Summary of harvest statistics for deer in the Starkey Project area from 1988 to 1995, in chronological order[a]

Hunt type	Year	Dates	Number of hunters[b]	Estimated animals available	Harvest	Success rate
Any deer	1988	10/1 - 10/12	118	571	82	0.69
Any deer	1989	9/30 - 10/11	87	411	61	.70
Buck	1990	9/29 - 10/10[c]	25	50	8	.32
Buck	1991	9/28 - 10/4	24	57	9	.38
Buck	1992	10/3 - 10/9	21	84	6	.29
Buck	1993	10/2 - 1018	22	89	9	.41
Buck	1994	10/1 - 10/12	24	94	9	.38
Buck	1995	9/30 - 10/11	23	92	8	.35

[a] Hunts held in both Main and Northeast study areas combined.
[b] Number of hunters afield, not number of tags issued.
[c] Hunting allowed in Northeast study area for first 3 days of hunt only; this restriction continued in all subsequent years.

In Northeast deer are no longer moved to the winter area but are fed and trapped on site in winter. Elk, however, are baited to the winter area with hay, as in Main, traveling through Meadow Creek and Bear Alleys en route to the handling facility (fig. 7). Bear Alley was added in 1991 as a continuation of Meadow Creek Alley; before Bear Alley was constructed, elk from Northeast were baited into Bear pasture, where they were sometimes impossible to catch and handle. Baiting for deer may begin as early as October in Northeast, because of the relatively short hunting seasons in that area (tables 1 and 3). Baiting ceases before any hunt and resumes afterwards. Elk in Northeast that do not respond to baiting are not trapped or transported to the winter area.

Feeding-Goals of winter feeding include offering feed that does not differ substantially from diet quality available to deer and elk during an “average” winter in the Blue Mountains; providing adequate forage for animals that are being held on traditional summer, not winter, range; controlling winter diets and animal distributions so that winter forage and weather are not experimental variables; and returning animals to test pastures in “like” condition each year. The public is not allowed in the winter area at any time except by permit or during tours.

During the first winter of the Starkey Project (1987-88), elk and deer were baited into one large feeding area, with no separate pastures. Herding elk into pens before they were handled in the chutes was extremely difficult, however, and behavioral conflicts between deer and elk during feeding were apparent. The following summer, more pastures were created in the winter area with the addition of 3 miles (5 km) of Tightlock fence (fig. 7).

Elk now enter the winter area through Upper or Bear pastures (from Main and Campbell Flat) or Meadow Creek Alley (from Northeast) (fig. 7) and, if possible, are moved directly to the handling facility for the first data collection of the season (see “Trapping and handling” [below] for procedures). They are then released into either South or Cuhna pastures to feed through the winter (fig. 7). Deer from Main enter through Upper pasture and are lured into Barn pasture, where they are fed, separate from elk, through the winter. In the winter area, elk and deer are fed *ad libitum*, typically 8 to 12 pounds (4 to 5 kg) of hay/(elk · day) and 4 to 6 pounds (2 to 3 kg)/(deer · day), unless weather is severe (fig.18). Deer also are fed a specialized pelleted supplement in racks. Hay is scattered in long feed lines from a tractor and also placed in racks. Deer and elk that do not come to the winter area are fed in place in Main or Northeast; the amount fed varies, depending on weather and the availability of native forage.

Trapping and handling-Ideally each elk is handled twice during the winter period: once when it enters the winter area, which can occur from November through February, and a second time when it is released in spring (fig. 16). During the first handling, branch-antlered bulls are not worked but are released directly into a pasture for feeding. Adult cow elk are bled, weighed, and checked for ear tags. About 10 percent of the blood samples are tested for a variety of diseases, including brucellosis; more intensive testing is done with samples from the Campbell Flat cow elk. Calves are weighed and eartagged. Any radio collars on these elk are removed for battery replacement, repair, or both.

When elk are handled the second time, in March or April, they are trapped in small groups by baiting them for several days from a selected pasture into a central hub and alleyway leading to the handling chutes (fig. 7). Elk are herded with personnel on all-terrain vehicles down the alleyway toward the handling facility (figs. 7 and 10). There they are held in pens and quickly moved singly into a series of chutes and then into the surgery-handling building (fig. 19). As many as 60 elk can be worked in a single day. If a branch-antlered bull is captured, it is released back into Wing pasture (fig. 7); these bulls are worked at the end of the season, after they shed their antlers. Spikes and bulls that have shed are worked with the cows and calves. Data collection during the second handling is similar to that of the first handling, except that the only cows bled are those with questionable pregnancy tests from the first handling or cow elk to be released into Campbell Flat pasture (for phase II of the bull elk study). Radio collars are attached to the necessary number of adult cows, and the elk are sorted and released into Main, Northeast, or Campbell Flat. Elk from Main and Northeast return to their respective pastures (that is, they are kept as separate herds). Different cow elk are released into Campbell Flat each year to comply with research objectives of the breeding bull study. Cow elk held in Campbell Flat the previous year are turned into South pasture and fed there until native vegetation is sufficient to sustain them. These elk are released into Main by mid-July, after calving and calf searches are completed.

Deer are captured by baiting under a drop net or into individual panel traps and handled according to protocols described by Wisdom and others (1993). As mentioned earlier, deer in Northeast are fed there all winter, where they are captured in panel traps and radio collared as needed to meet sample size objectives. Panel traps also are set in Barn pasture and in Main; the drop net is in Barn pasture only. When deer are captured, sex and age are recorded, and a numbered, aluminum ear tag is attached. A blood sample is drawn from females for pregnancy and disease testing and a plastic identification collar or radio collar is placed around the neck (does only). Any existing wounds or injuries are treated topically, and a mixture of vitamin B and selenium is sometimes administered to reduce effects of capture myopathy. Deer are released where captured or transported by truck in wooden crates to another area inside the fence and released. Deer trapping continues until temperatures are too high for safe handling, or when new forage growth in spring renders baiting ineffective, typically by mid-April.

Figure 18—Elk are fed *ad libitum* with alfalfa hay in the winter area to control winter foraging conditions as much as possible.

Figure 1 9—Large groups of elk are worked quickly through the pens at the handling facility and then released

Table 4-Number of handling events and individual deer and elk handled for the Starkey Project, 1988-96[a]

Winter[b]	Deer		Elk	
	Events	Individuals	Events	Individuals
1988-89	58	58	571	504
1989-90	14	14	113	112
1990-91	39	35	459	418
1991-92	44	44	77	68
1992-93	84	71	885	614”
1993-94	43	43	441	308
1994-95	27	27	946	501
1995-96	60	59	633	322

[a] Includes animals worked in the handling facility and others trapped, darted, or netted elsewhere within Starkey.
[b] Trapping season generally runs from November 1 through April.
[c] Includes 66 cow elk trucked to Starkey from surrounding areas to provide calves the following spring for associated research.

The numbers of animals handled and total handling events since the beginning of the project are summarized in table 4. Handling mortalities have been minimal, ranging from 0 to 6 percent annually for deer and 0.7 to 2.5 percent for elk. Improvements made in handling techniques and structures (such as construction of new pens and adding drainage and base rock to the corrals) have decreased injuries even further. Handling records are stored in database files designed to provide rapid access to all records collected on elk and mule deer at Starkey. Tables are linked by unique identification numbers for each animal; data entered include ear tag numbers, handling dates, weights, blood parameters, pregnancy status, harvest statistics, and fate of animal (for example, harvested, released into study area, or released outside the perimeter fence). Elk are sometimes released outside the Starkey fence when they are not needed as part of the experimental population (that is, numbers are above research objectives; table 2). Since the fence was erected in 1987, Starkey staff have released 379 elk to adjacent SEFR and other FS lands (table 2).

The following recommendations were provided by Starkey staff after 8 years of trapping and handling elk:

- Use visual barriers, such as burlap, plastic fencing, tarpaulins, or boards, whenever possible to reduce excitability of elk and subsequent mortality or injury in high-pressure areas (catch pens, alleys, or corrals).
- When holding animals prior to handling, release, or loading in a truck, confine them to as small a pen as possible to reduce pacing and stress.
- Increase flexibility in handling and capture by having as many pens, pastures, alleys, and gates as possible.

Capturing elk calves-Elk calves were captured, primarily in South pasture, from 1990 to 1996 (excluding 1992). Before 1994, calves were captured and tamed for thermal cover research taking place nearby or to provide data on neonatal elk weights and diseases (Cook and others 1994). Since phase II of the breeding bull elk study began (1994), cow elk bred in fall in Campbell Flat have been sequestered in South pasture

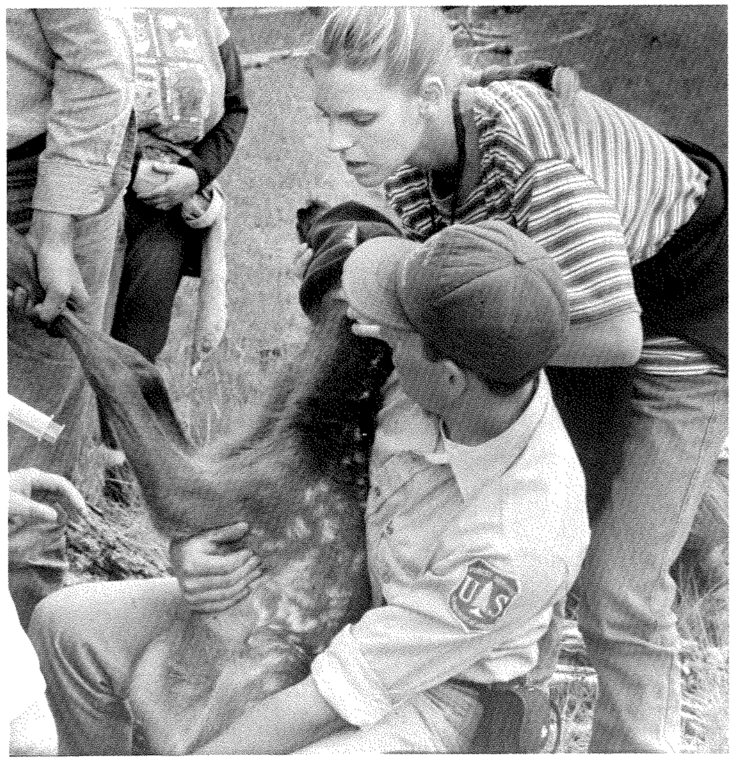

Figure 20-Elk calves are captured each spring for ongoing studies on effects of bull elk numbers and age on calf birth dates and survival.

each spring until after parturition. Calf searches are held from late May until early July in an attempt to capture all calves born to the Campbell Flat cows (fig. 20; see "Breeding Bull Elk Study" (above) for details on the research with Campbell elk). Wisdom and others (1993) provide details on protocols used to capture elk calves.

Hunting Seasons

Hunting seasons for mule deer and elk have been held since the 1930s in the Starkey area. Following construction of the game-proof fence around the Starkey Project, limited-entry hunting seasons continued (fig. 21). (No hunting was allowed in fall 1987 when the fence was being completed, to allow for both establishment of the research herd and worker safety.) The SEFR is part of lands ceded to the Confederated Tribes of the Umatilla Indian Reservation for hunting rights. Tribal members have continued to hunt at Starkey since the fence was constructed and have informally cooperated with Starkey staff to coordinate their hunts.

A primary reason to continue hunts within the enclosure was to maintain deer and elk populations at densities similar to those outside the fence, so that results of the research will be relevant to nearby big game herds in the Blue Mountains, Other reasons for the hunts are biological data collection; to obtain baseline population estimates from harvest statistics; to provide traditional recreational opportunity; to collect data for input in an elk vulnerability model; and to subject research animals to hunting pressure and disturbance similar to that outside the fence. The first bull elk hunts inside the fence (1988) had a more specific objective of removing all antlered bulls from Main for the first phase of the breeding bull study (see "Breeding Bull Elk Study," above). A similar hunt in 1994 was used to remove all antlered elk prior to repeating the breeding bull study in fall 1995 (table 1).

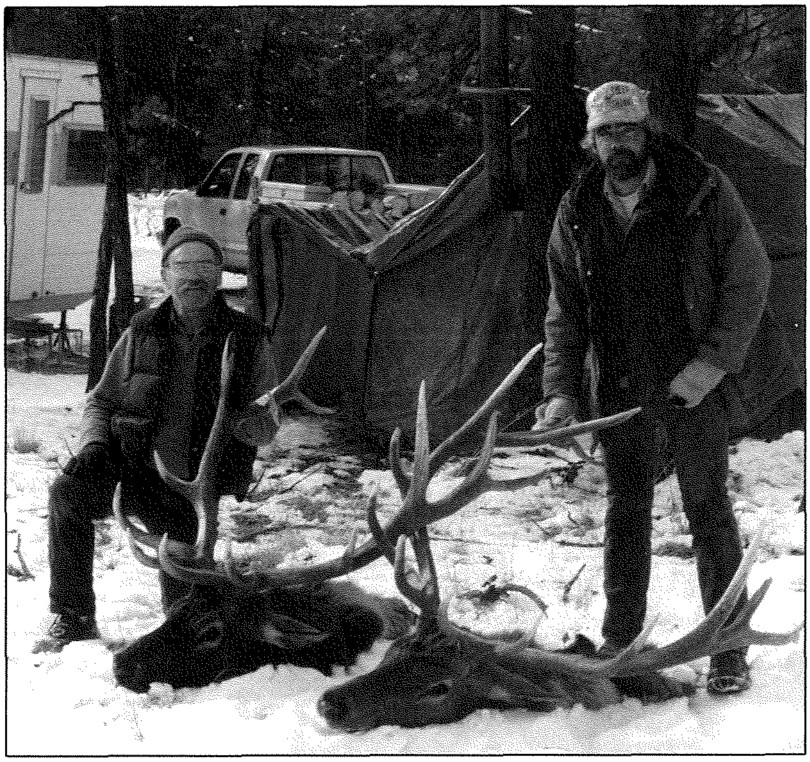

Figure 21-Hunting continues as an important recreational activity at Starkey.

Nearly 400 deer tags and over 2,300 elk tags were issued from the beginning of the Starkey Project through 1995 (see tables 1 and 3). Early fears over animals within the fence becoming tame and thus easy targets for hunters were unfounded. informal comparisons of hunter success rates for elk inside the fence with rates in the adjacent Starkey Game Management Unit show that hunter success has been, in fact, somewhat lower inside the fence. In 1992, for example, harvest rates for antlerless elk were 32 percent inside the Starkey Project area and 34 to 83 percent outside. In 1994, all elk hunts combined yielded 22 percent success inside Starkey, but 30 percent in the Starkey Unit.

Cow elk hunts were held in Main from 1989 through fall 1993 to collect reproductive tracts for the breeding bull elk study and to offer recreational opportunity. Hunts for yearling bull elk also were continued during this period to harvest bulls not of the breeding cohort in Main. Initial plans called for maintaining only yearling bulls in Northeast, as a "control" for the Main study; however, this proved impossible. Trapping and hunts in Northeast have been structured, though, to maintain a relatively young bull population in this area. Either-sex hunts for deer were offered in 1988 and 1989; subsequent deer hunts have been limited to bucks. The number of permits available in recent years has been relatively consistent for both deer and elk.

Hunts are closely monitored by Starkey staff to obtain accurate harvest and hunter density estimates, as well as to collect biological information from animals killed by hunters. Starkey personnel operate a check station, just inside the main gate, during the hunts (fig. 22). The only public access into Starkey is through the main gate from State Highway 244. All hunters in Starkey receive instructions prior to arrival requesting that they sign in at the check station before they begin hunting. If possible, license numbers

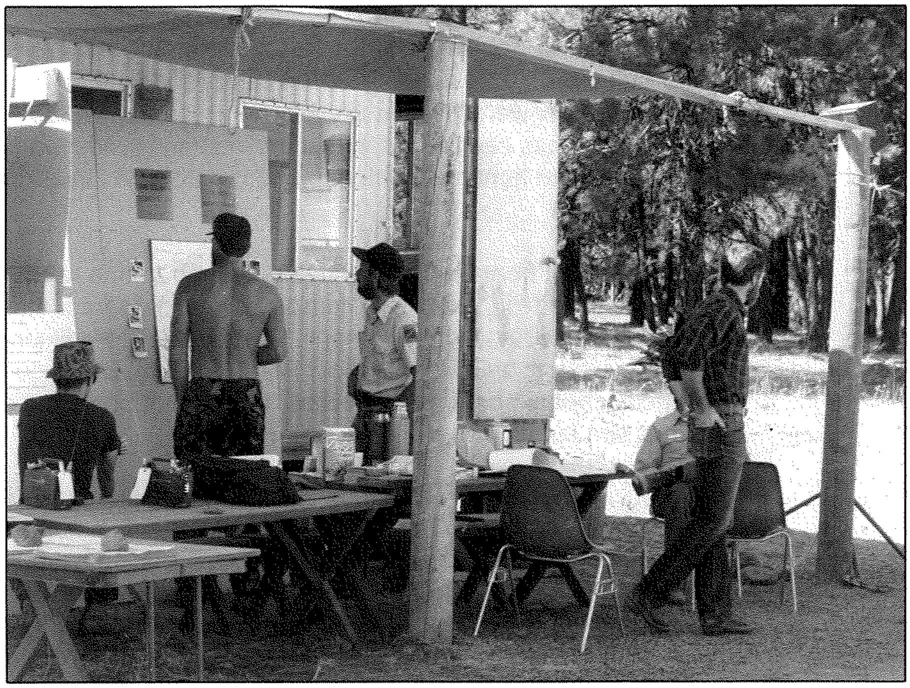

Figure 22-Check stations are operated for all hunts at Starkey; hunters participate in research by providing animal parts and information on kill sites.

and descriptions are recorded for all hunters' vehicles. Staffing and operation of the check station vary somewhat, depending on the particular hunt taking place, as well as how many days have elapsed since opening day. Field checks of hunters also provide information on harvest and areas hunted.

The perimeter fence is patrolled by FS employees on all-terrain vehicles during the hunts for enforcement of regulations and to check for injured animals or broken wires in the fence. A 1/4-mile (0.40-km) buffer adjacent to both sides of the perimeter fence is usually closed to hunting, to prevent hunters from accidentally pushing animals against the fence, as well as to prohibit hunters from intentionally trapping and then killing elk or deer along the fence. No off-road vehicle traffic is allowed in Starkey, including during the hunting seasons, except by project personnel. All motor vehicle traffic is prohibited in Northeast and in Meadow Creek, except by permit.

Data collection-Extensive data are collected from animals killed by hunters inside Starkey, especially from cow elk. Hunters in the cow hunts are provided with a collection bag and diagram of reproductive parts, blood tubes, and instructions. Hunters also must view a short orientation video before they begin hunting. Animal parts requested from hunters include kidneys (for kidney fat measurements), a liver sample (to detect selenium levels), the udder (to see whether the cow raised a calf the previous summer), uterus with ovaries (to determine pregnancy status and date of conception), and the front lower jaw, from which a central incisor is removed to estimate age. Two small tubes of blood are collected by hunters from harvested elk to help validate a technique used to detect pregnancy in elk (Noyes and others, in press). If a bull is killed, the check station staff measure the antlers, remove an incisor, and occasionally collect a kidney or liver sample. Hunters are also requested to turn in any ear tags, identification collars, or radio collars retrieved from harvested animals.

Results of hunting seasons-Eight hunts for deer and 29 for elk were held from 1988 through 1995 (tables 1 and 3). Mean hunter success rates were 0.46 for cow elk, 0.28 for bull elk, 0.70 for either-sex deer hunts, and 0.36 for buck-only hunts. A total of 726 elk and 192 deer were killed in Starkey hunts between 1988 and 1995. Although no formal evaluation has been made, hunting conditions inside the fence (for example, animal densities and hunter:elk ratios) approximate those in areas surrounding the Starkey enclosure.

The data set from the Starkey hunts, though from a relatively small area, is valuable in its completeness, especially compared with data from outside the fence. The elk harvest data have been used in developing a model for elk vulnerability (Vales 1995), and also will be used to validate this model (Vales 1996). Because of the unique opportunity to strictly control open-road densities, hunter numbers, and other factors, Starkey is an ideal site for such validation experiments.

Effects of hunter movement on elk distribution were tested in fall 1990 during two pilot studies in Northeast (Bryant and others 1991). Ten hunters in each of two hunting seasons wore backpack frames with AATS transmitting units attached, identical to the loran-C units worn by ungulates in the study area. Radio-collared cow elk in Northeast and the hunter backpack collars were paged about every 10 minutes during the two hunting seasons. Animal and hunter movements were overlaid with a GIS (geographic information system) program and monitored in real time from a computer screen (Bryant and others 1991). Further research with this technique could explore several aspects of elk vulnerability, including relations between hunter and elk densities, energetic effects on elk from various degrees of hunting pressure, and changes in elk habitat selection during hunting seasons.

Radio-Telemetry Data Collection

The AATS operates from April until early December each year. During winter, animals are fed in or baited to come to the winter area and thus are not tracked. Also, the AATS was not designed to function in low winter temperatures-the batteries on the microwave towers are solar-powered and are difficult to recharge when snow covers the solar panels. Except for special circumstances, all radio-collared deer, elk, and cattle are continuously paged 24 hours per day. Only females are fitted with the AATS collars. Research objectives for numbers of animals collared at any one time are 10 of each species (deer, elk, and cattle) in Northeast and 50 of each in Main (table 5).

The radio collars, molded from PVC pipe (Pedersen 1977), accommodate loran-C receivers, telemetry transmitters, pagers, antennas, and batteries. Collar weights range from about 3.5 pounds (1.6 kg) for deer to 3.7 (1.7 kg) pounds for elk and cattle, and collars cost about $1,100 each. They also contain sensors that record ambient temperature to the nearest degree Celsius whenever a collar is paged. Radio collars were reengineered in 1994 to use three instead of four batteries, decreasing collar weight by about 4 ounces. The new, more powerful batteries, combined with increased collar efficiency from reengineering, have improved collar longevity.

Radio collars are removed from elk when they are first handled in early winter. Batteries are replaced and minor repairs made before collars are repackaged in new PVC pipe and placed on elk in March or April prior to their release back to Main or Northeast. Deer radio collars are removed whenever possible. If available, a new or retrofitted collar is placed on the animal during the same capture event, primarily because individual deer likely will be captured only once during a winter season. Cattle are radio collared in June prior to their release into Starkey; only research cattle owned by OSU wear radio collars.

Table S-Number of functioning loran-C radio collars attached to research animals for the Starkey Project, midsummer, 1989-95

	Year						
Species and area	1989	1990	1991	1992	1993	1994	1995
Deer:							
Main[a]			15	13	14	27	33
NE[b]			4	6	9	7	8
Total, deer			19	19	23	34	41
Elk:							
Main		7"	42	27	37	40	40
NE	9	14	13	6	11	12	13
Total, elk	9	21	55	33	48	52	53
Cattle:							
Main		47	47	49	42	46	36[d]
NE	9	15	13	12	12	13	IO
Total, cattle	9	62	60	61	54	59	46
All animals	18	83	134	113	125	145	140

[a] Main study area, including Campbell Flat.
[b] Northeast study area.
[c] 21 additional collars on elk in Meadow Creek.
[d] 4 additional collars on cattle in Meadow Creek.

Four heart rate transmitters have been implanted in Starkey research animals (two elk and two cattle) to test their compatibility with the existing loran-C telemetry system. To date, two of the transmitters have not functioned consistently, possibly due to faulty electrode contact with muscle tissue in the animals. The interface with the telemetry system has been successful, however. Once this technology is developed further, researchers will be able to monitor heart rate response as vehicle traffic or a hunter approaches an elk or deer, or when cattle move into an area occupied by wild ungulates.

A substantial proportion of time spent in telemetry data collection and analysis is required for postprocessing the thousands of locations. Postprocessing begins with identifying and correcting for cycle slips. These are systematic translocations of signals about 1,750 yards (1600 m) north-south or 7,656 yards (7000 m) east-west. Some cycle slips can be identified mathematically, when four time differences are received; otherwise, the slips must be removed after visual inspection of the data. Data are summarized by month and ordered by date and time for each radio collar. After removal of cycle slips, location data are transferred to Oracle software (FS) for analysis. Animal locations can be displayed at Headquarters II or in the La Grande laboratory on interactive, computerized maps. Linking animal locations with GIS to the habitat database compiled for Starkey (Rowland and others, in prep.) allows the user to simultaneously view animal movements and the cover type, slope, distance to water, or a number of other environmental attributes in those same pixels.

Accuracy and system improvements and failures-The upgrade of the AATS to six loran-C sources (dual chain) in July 1992 resulted in a maximum of four time differences received for each animal location, rather than two (that is, four combinations of master-slave transmitting towers). This upgrade, which cost about $250,000, reduced the area estimate for locations from 8.4 to 7.7 acres (3.4 to 3.1 ha, at 90 percent confidence; Findholt and others 1996). (It is much more likely that the true position of an animal is in the center of the area estimate rather than near the perimeter.) Because mean habitat patch size at Starkey is 36.1 acres (14.6 ha), position estimates from the AATS are sufficiently accurate to assess habitat relations (Findholt and others 1996). The computer system at the base station was improved in 1992 by replacing the old model 286 processors with model 486 computers. The new computers are not only faster but also collect more detailed signal information than did the 286s.

Some gaps have occurred in AATS data collection. A malfunctioning reference collar rendered 2 weeks of data unusable in September 1991 (appendix 3). Lightning strikes in July 1993 also reduced the level of coverage of the AATS by disabling two microwave towers. Further strikes at Headquarters II in June 1994 also disrupted the system (appendix 3). Otherwise, the AATS has recorded data continuously since July 1989, except for short periods when the system has been brought down for maintenance or repairs, or by lightning strikes.

Correcting biases in AATS locations has spanned several years of the Starkey Project. Position bias (related to effects of topography on loran-C signals) was first measured at Starkey during field tests in summers 1991 and 1992 by using portable GPS receivers and loran-C radio collars placed at fixed sites throughout Starkey (Findholt and others 1996). A pilot study in fall 1991 revealed that mean positional errors ranged from 0 to 219 yards (0 to 200 m) and were especially pronounced in the northwest corner of Starkey (Lachapelle and Townsend 1992). In 1992, differentially corrected GPS bearings were collected at 386 systematically located points in Starkey, along with loran-C locations. Geostatistics were used to interpolate these results and develop a time difference correction to apply to loran-C locations throughout Starkey. Finally, 40 loran-C collars were randomly placed in Starkey to compare bias-corrected loran-C positions with uncorrected loran-C data. The corrected data were significantly better than uncorrected data for locations recorded before the AATS was upgraded to the dual chain system. However, locations since July 1992 were not improved by correcting for positional bias. Mean position error of the AATS ranges from 148 to 174 feet (45 to 53 m), which is much less than errors typically reported for loran-C studies (Findholt and others 1996).

An additional complication of the radio-telemetry system was first identified in 1992 when it was discovered that system performance was inconsistent across the Starkey landscape. Specifically, the probability of receiving a good telemetry location of a radio-collared animal differed slightly across areas of Starkey. Analyses to determine the source of this bias did not pinpoint any single, predictable source, but the bias was most closely associated with line-of-sight to a microwave tower, slope position, canopy closures greater than 40 percent, and slopes greater than 35 percent (Johnson and others, in press). Corrections for this bias were made, based on performance of collars placed on animals in 1992 and 1993. The model was further developed and validated with data on animal locations in 1991, 1994, and 1995 (Johnson and others, in press).

Figure 23-Traffic counters record numbers of vehicles in 1 S-minute blocks and operate continuously from May through December.

Road and Traffic Monitoring

Public access is allowed in Starkey from May 1 until about mid-December, after the last hunt of the year (fig.16). Off-road vehicle use is prohibited, except as needed for research, and public vehicle traffic is restricted to roads posted with green dots. The right-of-way along the perimeter fence is also closed to public vehicle traffic. By far the largest influx of people is during hunting seasons each fall. Traffic is monitored intensively to meet objectives of the roads research for the Starkey Project (see "Research Focus," above).

The level of intensity in traffic monitoring for the Starkey Project is likely unparalleled on National Forest lands. Traffic count data have been collected at Starkey since 1988. Counters are strategically placed to monitor traffic on all major road segments not physically blocked to vehicle traffic. At each counter site, an inductive loop was installed several inches below the road surface and connected to the counters. In 1988, counters were established at 69 sites in Starkey; they now total 75 (figs. 6 and 23). Over the years, counter sites have been added or dropped as the road system and research needs have changed. The National Forest System bought the counters, which are maintained by the Grande Ronde Engineering Zone, Wallowa-Whitman National Forest. Counters are set in place each spring before May 1; they operate continuously (that is, all vehicles are recorded when a counter is on-line) until their removal in December for winter storage.

Traffic volume is recorded in 15-minute blocks by each counter, allowing analysis of data in whatever temporal scale is desired (for example, time of day, week, or hunting season; Cimon and others, in prep.). Data are stored on microchips and are collected weekly and downloaded into FS database software (Oracle). Traffic volumes also are monitored outside the fenced area at additional sites; these "bulk" counters do not record data in timed intervals but are read for a total tally of vehicles each week.

A relational database has been constructed in Oracle software for managing and analyzing the Starkey traffic data (Cimon and others, in prep.). Two primary tables make up the database: one, where the operating periods for each site are listed, and the second for the nonzero vehicle counts for all sites since the beginning of the project. Over 215,000 nonzero count records were recorded from 1988 to 1993. Additional information, linked from the Starkey habitat database via GIS, can be incorporated, such as road segment number and road intersection. Simple graphs depicting daily vehicle counts by counter can be easily constructed. Much more sophisticated analysis is also possible, given the level of resolution of the data and the relatively high density of counters at Starkey.

In addition to the counters, two cameras operate at Starkey, one near the main entrance gate and one in Northeast (fig. 6). The cameras are activated by the counters at these locations and thus photograph every passing vehicle. Data are categorized by type of vehicle (all-terrain vehicle, passenger car, pickup truck, bus, single-unit truck, or multiple-unit truck), as well as whether the vehicles are commercial, recreational, or administrative.

Vegetation Monitoring

Scientists have monitored vegetation in the SEFR since the site was established in the 1940s. Ongoing vegetation studies meet a variety of research objectives, summarized below.

Campbell Flat-Cattle are grazed in Campbell Flat, along with the three pastures in Main, in a deferred-rotation grazing system. Cattle grazing is a potentially confounding factor, however, in ODFW research on cow elk condition and pregnancy. Vegetation monitoring therefore was begun in Campbell Flat in 1993 to estimate forage use by elk and cattle, document forage use patterns, and understand effects of forage availability on elk condition. Thirty-three paired (grazed and ungrazed) vegetation plots were established that are clipped four to six times each year, beginning in May before cattle are released in the pasture. Forage usage by elk and cattle combined is measured in riparian, grassland, and forested sites during each clipping period. Production is also estimated for each of these three community types, by clipping period. A separate estimate of use by elk only is made by clipping vegetation before cattle are turned out each year, but after elk have been released into the pasture. Another usage estimate for elk only has been available for the Campbell Creek riparian area since it was fenced to exclude cattle in 1994. Details of this vegetation monitoring are in Cox (n.d.).

Main-Within Bear, Half Moon, and Smith-Bally pastures, key riparian areas are measured for shrub and grass use each year, before livestock are turned out, to estimate forage removal by deer and elk. These measurements are repeated as soon as possible after livestock are removed, and the sites are photographed. Upland sites are measured once each year for usage estimates after cattle leave. If possible, grass regrowth in key areas is assessed in fall by remeasuring stubble height.

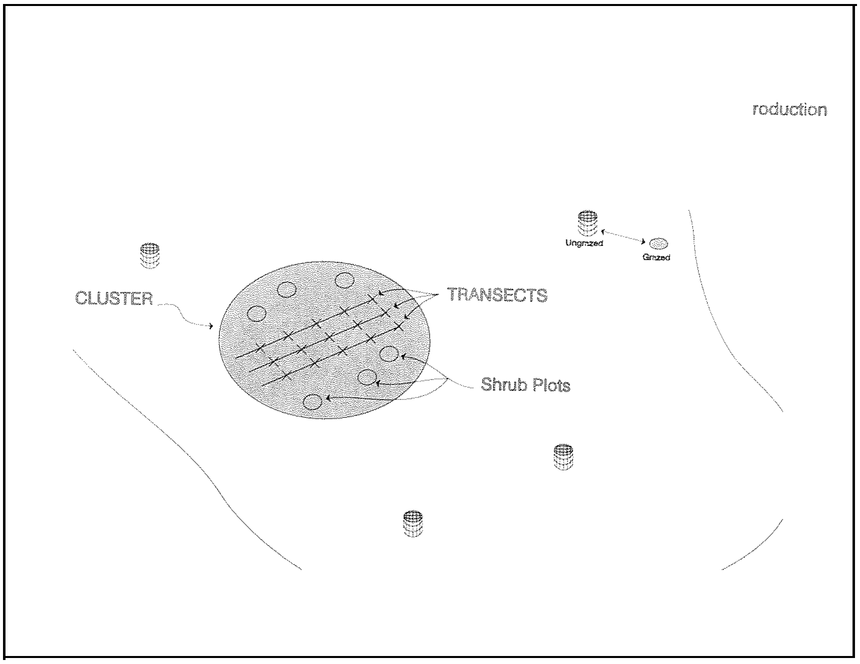

Figure 24—Vegetation is monitored in the Northeast study area by sampling in 48 macroplots.

Northeast-Forty-seven macroplots have been established in Northeast for measuring vegetation in relation to experimental timber harvest and animal response (fig. 24; Coleman and Bobowski 1991). Biomass is clipped, and ground and vegetative cover are recorded along three transects, totaling 109 yards (100 m) in each macroplot. In addition, each macroplot site has five shrub plots, which are clipped for biomass, and a single tree plot, in which all trees are tallied and canopy cover estimated. Macroplots were sampled in 1991 and in 1995. There also are '235 plots (utilization cages) randomly located in Northeast for monitoring vegetation production, percentage of use, and vegetation response to silvicultural treatments. These plots are stratified by habitat type and have been sampled each fall since 1991.

Meadow Creek-Pastures in Meadow Creek were established in the 1970s for long-term riparian research on the SEFR. Ongoing vegetation monitoring and sampling includes the riparian habitat of phase III, where25 paired-plot cages are clipped to estimate herbaceous production and use after cattle leave each year. A shrub use transect, established in summer 1993, is measured before and after cattle use each year. Phase IV, primarily forest and grassland, has 20 paired-plot cages, clipped as in phase III. Before 1991, an additional 60 cages were clipped annually in phases I and II. Cattle have been excluded from phases I and II since 1991.

Phenology measurements-Phenological change in herbaceous and shrub species during the growing season has been monitored at Starkey since 1991 (fig. 25). In June of that year, 11 transects were established to represent grassland, open forest, and closed forest areas at two elevations (table 6). Transects are randomly located within typical sites, and four plots (each 5.4 square feet [0.5 m^2]) are sampled at 32.5-foot (1 O-m) intervals along each transect. Biweekly monitoring usually begins in April and continues through October.

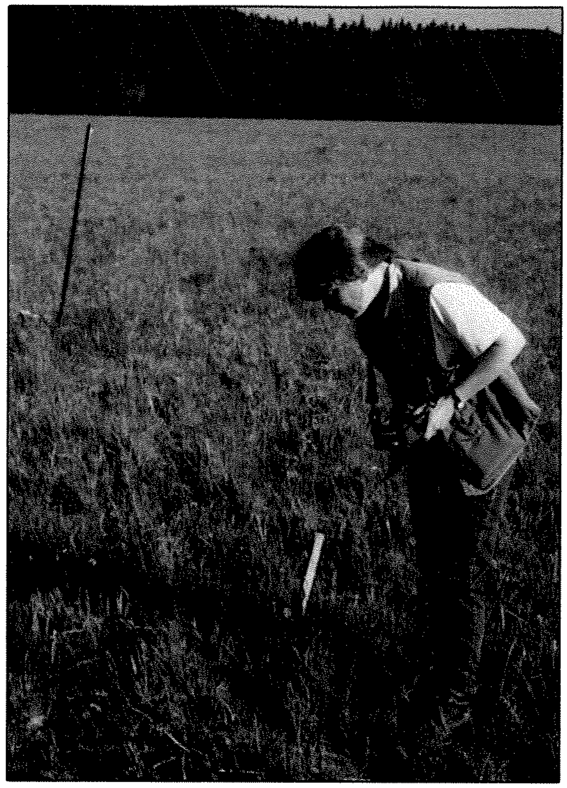

Figure 25—Phenology of vegetation is recorded at selected sites throughout the growing season at Starkey.

Table (i-vegetation phenology transects established for the Starkey Project in 1991

Transect	Name	Type	Elevation	Aspect	Slope
			Feet	Degrees	Percent
1	Campbell	Grassland	4180	39	5
2	Turkey Low	Grassland	4830	210	1
3	Lone Pine	Grassland	4720	30	2
4	Turkey Upper	Open pine	4880	200	6
5	HQII	Open pine	4580	196	22
6	Super Tree	Open pine	4240	72	14
7	Ray	Grassland	4360	166	15
8	Bally North	Dense fir	4600	340	20
9	Bally South	Dense fir	4640	202	10
10	Battle	Dense fir	4500	6	24
11	Meadow	Dense fir	3840	50	25

Table 7-Population estimates of deer and elk inside the Starkey Project area, northeast Oregon, 1989-95[a]

Year	Deer	Elk
1989	287	487
1990	239	568
1991	246	520
1992	280	501
1993	275	452
1994	281	431
1995	254	406

[a] Estimates are for adult populations, prior to parturition, in Main study area only.

The following information is recorded at each visit: percentage of nonvegetated ground or moss or large tree; percentage of grass and grasslike species; percentage of forbs; percentage of shrubs; and percentage of evergreens. Phenological stage is recorded for each type of vegetation in 20-percent increments (for example, 60 to 80 percent). Stages are defined as growing (preflowering and during flowering); vegetative (postflowering and green); and cured (plant completely dried). Dominant species in the plot and number of flowers or flower stalks also are recorded. Hard copies of all phenology data are filed, and the records also are being summarized in a database.

Ungulate Population Estimation

Elk-The Starkey environment provides a unique setting for testing population estimation techniques for elk. Starkey elk are free-ranging in a natural area resembling other landscapes in the Blue Mountains where wildlife managers estimate elk populations, but a large proportion of the Starkey elk are trapped each year. The combination of harvest data, trapping records, and aerial classification counts (since 1988) in a closed population yields an estimate that approaches the true population parameter (μ) and thus can be used to validate population models.

Each year elk are classified by project personnel during two winter helicopter flights. From 1988 through 1996, the same pilot has flown on all flights but one. The first classification is in late November or early December, typically before elk are baited to the winter area. Elk in Main are classified separately from those in Northeast. During the second flight, in March, elk remaining in Main or Northeast for the winter are classified and these totals are added to the number of elk in the winter area for estimates of sex and age ratios. (Elk in Campbell Flat are usually in the winter area during the classifications.)

A population model for Starkey elk was built from a combination of data sources: harvest statistics, including poaching and crippling losses; trapping and handling records; and helicopter classification counts. The population is quite dynamic; animals are born each year and others removed by hunting, natural mortality, and trapping and release to maintain population objectives (tables 2 and 7). Population estimates for cow elk, based on sightings of radio-collared animals, agree closely with modeled population estimates. Model estimates for bulls in fall 1994 were very close to numbers actually killed by hunters during an attempt to remove all antlered elk from Main at the conclusion of the breeding bull study (phase I):

Age class	Model estimate	Number killed
Yearling	34	31
2	13	14
3	4	4
4	3	2
5	4	5
6	46	47
7	1	1

A Lincoln-Petersen index (Lancia and others 1994) also was used in 1991 and 1992 to estimate the elk herd; marked animals were the radio-collared elk observed during helicopter counts. This index became less reliable in subsequent years, however, because the exact number of live, marked (collared) animals was unknown. Older collars sometimes break and fall off, and collared elk may die in the forested areas, where they are not visible. Population estimates for Northeast are more precise than those for Main. In some years, nearly all (more than 95 percent) elk in Northeast are trapped in the winter area, allowing virtually complete enumeration.

The Idaho Department of Fish and Game recently developed a sightability model for estimating populations of elk in Western mountains (Unswor-th and others 1994). The model uses predictor variables (group size and number of groups, vegetation cover, and snow cover) to derive population estimates and confidence intervals. Developed to count elk from helicopters, the Idaho model was first tested at Starkey in 1989. Model estimates were much lower than known numbers of elk from winter trapping. After revision, the sightability model was validated at Starkey during four flights in 1991 and 1992 (Leptich and others 1995). In a further application of the sightability model, a modified version was produced for counts made from helicopters other than the Hiller UH-12E, for which the model was originally developed. This revised model was validated at Starkey in 1994 (Gratson and others, in prep.).

Deer-Deer are classified annually during two helicopter flights, as described above for elk, and on the winter area. The number of deer that come to the winter area and the number trapped are highly variable; thus, helicopter counts are the primary source of population data for deer. When the second flight is made, in March, deer have typically been released back into Main from Barn pasture. As with elk, deer in Main and Northeast are classified separately. The deer population is estimated with a POP-II model (Bartholow 1990) based on harvest data and classification counts. The accuracy of the Starkey deer model is unknown. Mark-recapture estimations have been attempted with this herd, but collared deer are difficult to find in the dense timber, especially in Northeast, and the number of collared deer dying each year is unknown. The population has declined somewhat since the project began in 1987 (table 7).

Technology Transfer

Technology transfer has been an essential part of the Starkey Project since its inception. In 1987, Michael Wisdom was assigned to a full-time position established in La Grande by the National Forest System specifically to coordinate technology transfer for the Starkey Project. The objective of the technology transfer program was to provide scientific information generated by the project to the National Forest System, the public, and other resource agencies. The technology transfer program encompasses functions such as research, development, application, technology transfer, public affairs, and public education. Material about the purpose of the project and its findings has been disseminated through public meetings, radio and television broadcasts, tours of the Starkey facilities for the public and scientists, newspaper articles, fact sheets, scientific publications, popular articles, and videotapes. After 3 years, the technology transfer program and Starkey Project personnel had:

- Conducted 197 tours and presentations for over 5,000 people.
- Distributed 32 news releases.
- Conducted 14 workshops on elk management issues for biologists and managers.
- Provided information to the media, as well as summarized its own information, resulting in publication of 129 articles in newspapers and magazines.
- Distributed 15,000 fact sheets about the project to the public and natural resource agencies.
- Established a photograph and slide collection about the Starkey Project with more than 10,000 entries.

In 1993, the Starkey Project received the technology transfer award of the Pacific Northwest Research Station (FS). In winning this award, the Starkey technology transfer program was eligible for nomination for the Chiefs Award (FS) for Excellence in Technology Transfer, as well as a similar award from the Federal Laboratory Consortium. The Starkey Project won both in 1993. As the recipient of the Chiefs Award, the project was cited for "superlative technology transfer of Starkey research and development products to over 100,000 recipients encompassing local, regional, national and international groups and agencies."

New Technologies

Several technologies used in the Starkey Project were either developed specifically for the project or are unique in their application or scope as related to the project:

- **Tightlock** fence-Prior to the Starkey Project this fencing had never been used in the United States to enclose wildlife. The size of the enclosure also was unprecedented for wildlife research in this country (Bryant and others 1993). Potential applications of this fencing in the United States include protection of agricultural fields and orchards from deer and elk damage, blocking access to highways to prevent cervids from crossing, and holding elk or other ungulates used in captive breeding programs.

- **Telemetry** system-The AATS, with its automated computer entry of radio-telemetry locations, was developed specifically for the Starkey Project. The Starkey AATS has since been adapted by the National Marine Fisheries Service to track sea turtles. Their system, tested in the Gulf of Mexico, differs from the Starkey AA,TS in the antenna used, the lack of a pager, and by containing a microchip to record diving times of turtles. Several other researchers have expressed interest in adapting the AATS for their projects.

- Ice racks-Developed specifically for the Starkey Project, ice racks are a series of metal gates that span streams to link the Tightlock fence at these junctions (fig. 26). Six ice racks have been installed over three streams at Starkey. The gates hang from large metal trusses, which in turn are placed on top of steel pylons. The tubular steel gates keep animals from crossing the fenceline at streams, yet swing open to allow ice and debris to pass through, rather than accumulate behind the gates. Such accumulation eventually would knock down the fence and allow research animals to escape or animals outside the fence to enter the research enclosure. Similar gates built for cattle fencing at stream crossings fostered the idea for the Starkey ice racks. The technology

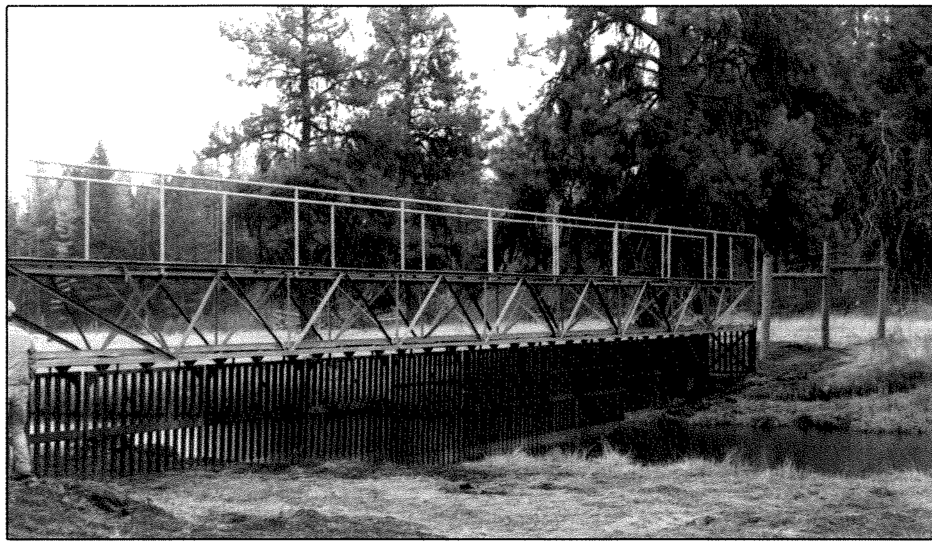

Figure 26—Ice racks were built where the fence spans major streams to allow the passage of ice and debris while barring animal movement into or out of the enclosure.

was developed by engineers working for the Wallowa-Whitman National Forest. Research, development, and construction were completed in only 4 months in 1987, creating an effective stream barrier when the perimeter fence was constructed.

- **Heart rate implants-A** cost-share contract with Starlink, a leader in implanted telemetry systems, led to construction of 13 heart rate transmitters that can be linked with the **AATS** at Starkey (see "Radio-Telemetry Data Collection," above, for furtherdetails).

Although the Starkey Project has no unique technologies for handling and feeding wild elk and deer in winter, the large number of animals handled is unusual (table 4). The data collected are singular in that the animals are essentially wild and are hunted yet, through their capture, yield abundant information on age and sex ratios, weights, condition, pregnancy status, and other physiological parameters.

Tours and Presentations

More than 350 tours and presentations about the Starkey Project were conducted from 1987 to 1992, with more than 5,000 people visiting the study area (fig. 27). Visitors to the Starkey Project have included the Chief of the Forest Service, state legislators, congressional staff members, university research scientists, hunters, high school and college classes, employees of public lands management agencies, state wildlife department personnel, and members of professional organizations (for example, Society of American Foresters and Wildlife Management Institute). Many local public and user groups also have toured the facilities and are generally well acquainted with the project and its scope.

Not only have local and regional audiences observed the Starkey Project but international visitors also have examined the scope and application of Starkey to other areas and research problems. Forexample, a contingent of Soviet scientists, including entomologists and natural resource administrators, visited Starkey in 1989 to learn about the technologies being developed and used for the Starkey Project (fig. 28). Earlier international tours were conducted in 1988 and 1989, with scientists visiting from over 30 nations. Former Acting Project Leader Larry Bryant traveled to New Zealand, Mexico, and Poland to discuss Starkey Project technologies and results with other scientists. A Polish scientist returned to observe the Starkey Project in 1993.

Figure 27-Hundreds of visitors have toured Starkey as part of the ambitious technology transfer program.

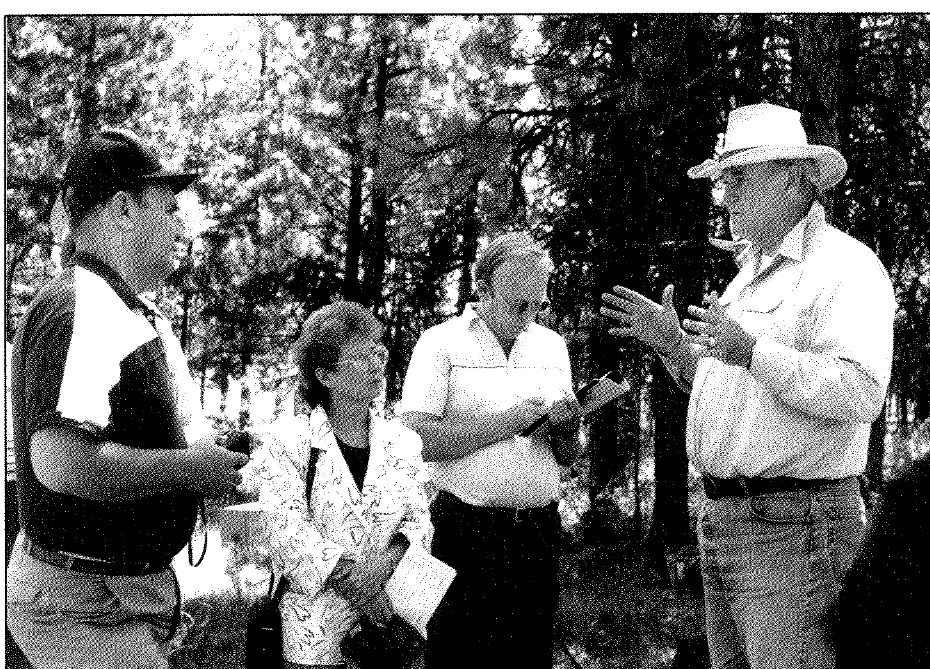

Figure 28—Soviet entomologists are among the many international scientists who have traveled to Starkey.

Publications

Twelve scientific papers about the Starkey Project have been published to date, including three Forest Service publications (appendix 4). An additional 26 articles are in preparation for submission to journals or as Station publications. Several dozen popular articles have appeared in magazines; **a** subset of these is listed in appendix 4. Newspaper coverage has been extensive, especially in the early years of the project. Additional technical articles are being written as the telemetry data are analyzed and new models are developed and validated with data from Starkey. Publication of scientific and popular articles should continue well into the next decade.

Future Research

The facilities and animals within the Starkey Project area offer ample opportunity to continue innovative wildlife research, given adequate funding and personnel. Effects of predators, such as black bears or cougars, on deer and elk could be studied by manipulating either predator or prey populations and monitoring population responses. Another potential area of research is effects of herbivory by wild and domestic ungulates on plant communities in the Blue Mountains (Irwin and others 1994). Grazing trials at Starkey, coupled with long-term grazing exclosures, could be used to test hypotheses related to herbivory.

An especially suitable area of research in the Starkey environment is elk vulnerability. With its closely monitored hunts and reliable population estimates, the Starkey site could host research on effects of hunter harassment on elk behavior and hunter success, effects of hunter density on harvest rates, or a myriad of other facets related to elk vulnerability to harvest by hunters.

Other potential research at Starkey that would complement ongoing studies includes:

- Effects of fire and salvage logging on deer and elk populations.
- Effects of elk on mule deer distribution and population dynamics.
- Effects of domestic and wild ungulates on habitats of Neotropical migratory birds and small mammals.
- Further model validation, such as habitat effectiveness, forage allocation, and population estimation models.
- Manipulating rates of traffic frequency and measuring direct distributional responses of ungulates.

Acknowledgments

Leonard Erickson and Donavin Leckenby of ODFW played primary roles in proposing and implementing the initial phase of the Starkey Project-Erickson on the breeding bull elk study and Leckenby on the animal-unit-equivalencies study-as well as in tests of potential telemetry systems.

Richard Collins, Evelyn Kalb, John Lipscomb, and Randall Nielsen, engineers for the Grande Ronde Engineering Zone, Wallowa-Whitman National Forest, established the traffic monitoring system used at Starkey. Collins, in particular, developed the counter system and reviewed past records for accuracy. Doug Barton (La Grande RD) played a key role as liaison between the National Forest System and Research in coordinating the Starkey Project. He was followed in that role by Pete Etchamendy and Paul Boehne; the latter currently serves as liaison. The ice racks were designed, constructed, and installed by engineers Dave Dahlstrom and Larry Monical, Grande Ronde Engineering Zone.

The timber sale in Syrup Creek (Northeast) was coordinated by a La Grande RD interdisciplinary team, District Silviculturist Jim Barrett, and project scientists Larry Bryant and Jack Ward Thomas. Barrett also wrote the sale prescriptions, laid out the sale, served as harvest inspector, and coordinated the marking with the La Grande RD crew. Tom Burry was sale administrator. Other assistance with the timber harvest (site preparation and planting) was provided by Gary Bruch, John Lipscomb, and Greg Vergari.

Since the project began, permittees with cattle inside Starkey have cooperated by grazing cattle according to research requirements. Current permittees are Oregon State University (OSU) and three members of the Starkey Cattle and Horse Association: Dick Snow, Dave Umbarger, and Dennis Waite. Martin Vavra and Tim DelCurto, through the OSU Agricultural Experiment Station, are responsible for the cattle that are radio collared each year and data associated with them.

A large, interdisciplinary project such as Starkey requires many people and talents. The Starkey field crew has worked to maintain healthy elk and deer on the winter area, trap and radio collar animals, collect data, and keep Starkey operations running smoothly. Brian Dick has served as area manager since 1992. The field crew also has included Ben Bobowski, Cheryl Borum, Dale Borum, Dave Carroll, Brett Coleman, Brian Cox, Scott Feltis, Ryan Kennedy, Paul Kennington, Randy Lewis, Pat Medina, Jack Nothwang, Brian Swearingen, Kathy Jo Westenskow-Wall, Bill Wallhauer, Tim Westfall, and Wayne Williams. Other project personnel have worked primarily with data analysis and computer applications; they include Norm Cimon, Priscilla Coe, Scott Findholt, Catherine Poppenwimer, and Rosemary Stussy. Technology transfer for the Starkey Project was aided by the work of Jan Abeita, Judith Hector, Les Ozawa, and Mark Patterson; Dan White produced a videotape depicting the breeding bull study.

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Appendix 1

Starkey Statistics

Feature	Unit of measure: English	Unit of measure: Metric
Area:		
Main[a]	19,180 acres	7762 ha
Campbell Flat	1,537 acres	622 ha
Northeast	3,590 acres	1453 ha
Winter area	655 acres	265 ha
Total	24,962 acres	10 102 ha
Radio-collar weight:		
Deer	3.2 lb	1.5 kg
Elk	3.7 lb	1.7 kg
Cattle	4.0 lb	1.8 kg
Pixel size	33 x 33 yd	30 x 30 m
Game-proof fence:		
Perimeter	27 mi	44 km
Interior	14 mi	22 km
Total	41 mi	66 km
Resolution of telemetry locations	7.7 acres	3.1 ha[b]
Roads:		
Main—		
Open	27 mi	44 km
Closed	48 mi	77 km
Restricted[c]	50 mi	80 km
Total roads, Main	125 mi	201 km
Campbell Flat—		
Closed	3 mi	5 km
Restricted[c]	4 mi	6 km
Total roads, Campbell Fiat	7 mi	11 km
Northeast[d]—		
Closed	3 mi	5 km
Restricted[c]	30 mi	49 km
Total roads, Northeast	33 mi	54 km
Winter area[d]—		
Closed	1 mi	2 km
Restricted[c]	3 mi	5 km
Total roads, winter area	4 mi	7 km
Total, all roads	169 mi	273 km
Road density:		
Main—		
Open roads	0.90 mi/mi^2	0.57 km/km^2
All roads	4.18 mi/mi^2	2.59 km/km^2
Campbell Flat	2.92 mi/mi^2	1.77 km/km^2
Northeast[d]	5.89 mi/mi^2	3.72 km/km^2
Starkey[e]	4.34 mi/mi^2	2.70 km/km^2
Elevation:		
Minimum	3,681 ft	1122 m
Maximum	4,922 ft	1500 m
Average rainfall	20 in	51 cm
Area harvested in NE	1,207 acres	489 ha

[a] Includes 24 ha of Meadow Creek exclosures.
[b] Area estimate (90-percent confidence interval) of each position from the upgraded telemetry system, after correction for bias.
[c] Includes administrative and other roads closed to the public and rarely used.
[d] All roads in Northeast and the winter area are closed to vehicular traffic except for administrative use or for retrieving elk or deer killed during hunts in Northeast.
[e] All roads in Main, Campbell, and Northeast, open or closed; does not include the winter area.

Appendix 2

Chronology of Major Events in the History of the Starkey Project

Date	Event
1982	initial discussion of research project that would require fencing the SEFR to test habitat use and interactions of deer, elk, and cattle on managed forests. Principal figures were Warren Aney (Northeast Region supervisor for ODFW), Larry Bryant (wildlife biologist at the La Grande Forestry and Range Sciences Laboratory, Pacific Northwest Experiment Station), Fred Ebel (Boise Cascade Corporation), William Farrell (county agent, Grant County), Donavin Leckenby (wildlife biologist, ODFW), John Lowe (Forest supervisor, Umatilla NF), and Jack Ward Thomas (project leader for wildlife research at La Grande).
Dec. 1985	Environmental Assessment (EA) for Starkey Project completed.
Jan. 1986	EA approved: allowed fence construction to enclose most of the SEFR and outlined the four main studies.
July 1986	Forest Service Chief Max Peterson approves Starkey Project; appeals filed by local hunters and an environmental group are rejected.
1987	Initial funding approved for fencing Starkey and conducting research and development. Michael Wisdom assigned to Starkey Project to lead technology transfer program.
Fall 1987	No hunting allowed so that (1) researchers can accurately estimate populations of deer and elk and (2) animals can acclimate to fenced area. Initial perimeter fencing completed, enclosing 25,000 acres (IO 125 ha) of the SEFR and nearby FS lands with high-tensile, woven-wire, game-proof fence.
Winter 1987-88	Elk fed along roads and in the winter area created in the eastern portion of Starkey; deer are fed in Main and Northeast, because it is believed that they will not come into the winter area voluntarily. Mild winter hampers trapping of elk and deer. Handling facilities under construction.
Jan. 1988	Starkey area closed to public for 6 weeks to avoid disruption while animals are baited to winter area.
1988	Sixty-nine traffic counters established in Starkey to monitor traffic frequency for road effects study. Construction begins on microwave towers for telemetry system. Handling facilities completed.
1988-89	Project personnel build interior fences to create separate pastures for deer and elk in the winter area.
Fall 1988	Limited-entry hunting resumes; by end of winter, 98 percent of antlered bulls are removed from Starkey for beginning of breeding bull elk study.

Date	Event
Winter 1988-89	Deer and elk are baited to winter area and are now fed in separate pastures. Heavy snows boost capture to more than 75 percent of deer and elk.
Summer 1989	Automated Animal Telemetry System (AATS) now operational, recording a daily average of 25 locations each for 10 cows and 10 elk in Northeast.
Dec. 1989	Begin collection of reproductive tracts from cow elk killed by hunters in Main, to be used in breeding bull elk study. Collection to continue through 1993.
Feb. 1990	Timber in Northeast marked for green sale.
Summer 1990	Forest Service accepts bid from Boise Cascade Corporation to harvest 6 million board feet in Northeast by November 1992.
Sept. 1990	Last microwave relay tower installed, making AATS fully operational across the entire Starkey Project area.
Oct. 1990	250,000 radio-telemetry locations recorded to date for ungulates in Starkey.
1991	Formation of IACUC, a committee that oversees handling and care of animals fenced within Starkey.
Summer 1991	Road construction begins in Northeast, including 24 miles (39 km) of new roads and reconstruction of 4 miles (6 km) of roads.
Oct. 1991	Logging begins in Northeast.
Winter 1991-92	Mild winter results in low numbers of deer and elk arriving at the winter area.
Summer 1992	Construction of new game-proof fence creates 1,537-acre (622-ha) Campbell Flat pasture for phase II of the breeding bull elk study.
July 1992	Improved AATS installed and tested. New dual-chain system uses six loran-C transmitter sites, thereby improving accuracy of location data.
Nov. 1992	Logging completed in Northeast, with over 7 million board feet harvested.
Winter 1992-93	Preliminary results from breeding bull elk study show that older bulls impregnate cows earlier and over a shorter breeding period.
Summer 1993	Improvements made in handling facilities to reduce stress and improve footing for animals in catch pens. Cleanup and burning of logging residue and site preparation in Northeast.

Date	Event
Spring 1994	More burning of logging residue and site preparation in Northeast; planting of cut units begins.
Summer 1994	Prototype forage allocation model developed for deer, elk, and cattle.
Fall 1994	Six-year-old bulls in Main available for hunting following completion of phase I of breeding bull elk study; male calves born this year will be used to repeat study for 5 more years.
Spring 1995	Planting of cut units in Northeast completed.
Fall 1995	Initial analysis of Starkey data for traffic and AUE studies.
Summer 1996	Corrections of performance bias of telemetry system finalized; results submitted for publication.

Appendix 3

Chronology of Development and Operation of the Automated Animal Telemetry System

Date	Event
Oct. 1987	Donavin Leckenby, Larry Bryant, and Glenn McLaughlin travel to Sweden to investigate time-arrival telemetry system at the Grismo Research Center near Stockholm; further pursuit abandoned when costs and probable delay in construction for Starkey are realized.
Fall 1987	Bryant travels to Texas to investigate "advanced" conventional telemetry system (designed by SW Research); discovers that Starkey would need 30 or 40 towers for 164- to 230-foot (50- to 70-m) resolution. Also visits Tracor Aerospace, Inc., to discuss possible loran-6 navigational system application for radio telemetry at Starkey.
March 1988	Bryant writes $50,000 contract for feasibility study of a loran-C system at Starkey.
Summer 1988	Newer, more compact loran-C receivers tested at Starkey. Conventional telemetry system also tested at Starkey but found inadequate for resolution needed. Construction begins on first three microwave towers for radio-telemetry system (at Mann, Bally, and Starkey compound; fig. 14).
Fall 1988	Request for proposals issued for automated telemetry system for the Starkey Project; Tracor Aerospace, Inc., awarded contract in September.
Spring 1989	Thirty prototype loran-C collars constructed by Tracor Aerospace, placed on elk and cattle. Completion of first three microwave towers for loran-C signal reception.
Summer 1989	Automated Animal Telemetry System (AATS) tested and first phase

Date	Event
	of AATS completed. Nine elk and nine cattle collared in Northeast; receiving signals from three loran-C sources (Middleton, CA; Fallon, NV; George, WA).
1990	Navigation section of Tracor Aerospace bought out by Trimble Navigation, which fulfills remainder of original AATS contract. Several former Tracor employees, including Walt Fowler, form Starlink, Inc., a navigation hardware company. Starlink supplies and maintains all future loran-C radio collars for the Starkey Project. Trimble will service loran-C hardware and software; project receives first 200 collars from Trimble.
Sept. 1990	Construction completed on five additional microwave towers and a permanent base station at Headquarters II, making AATS fully operational over Starkey. Fourteen elk and 15 cattle with radio collars in Northeast; 7 elk and 47 cattle collared in Main.
Fall 1990	Over 250,000 animal locations recorded to date. Ten hunters in each of two hunts outfitted with radio-telemetry backpacks to track their movements, and responses of elk, during hunting seasons. Pilot study deemed successful for future use in elk vulnerability experiments.
Summer 1991	Field testing to assess accuracy of telemetry system. Crystals replaced in three microwave towers, thus eliminating phase shift problems.
Sept. 1991	AATS down for about 2 weeks due to malfunctioning local reference collar.
Fall 1991	System recording up to 2,500 locations per day for over 100 animals; more than 737,000 locations to date.
Spring 1992	New software written to aid in postprocessing of telemetry data.
July 1992	Upgrade to dual chain loran-C system by Trimble Navigation, with additional signals from Williams Lake, BC, Haver, MT, and Searchlight, NV, towers. New configuration allows triangulation with four signals instead of only two, thereby yielding better resolution. Upgrade cost of $250,000 funded by Washington Office of FS through Pacific Northwest Region (National Forest System) and Research (Pacific Northwest Research Station).
Summer 1992	Position bias in AATS due to topography tested by comparing ground points as determined with loran-C collars to points determined with GPS.
Nov. 1992	Radio collars placed at fixed positions to test corrections of topographic bias.

Date	Event
Spring 1993	Helicopters used to capture deer and elk for attaching radio collars.
June 1993	Work begun to test performance bias of telemetry system ("black hole" effect).
July 1993	Lightning strikes two towers, damaging equipment and temporarily reducing level of coverage.
Spring 1994	Experimental heart rate transmitters implanted in two elk and two cattle. Problem with lead attachment to muscles is detected, but correctable.
June 1994	Lightning strikes Headquarters II, interrupting functionality and synchronizing of equipment, thereby reducing system efficiency for the remainder of 1994. Problem fixed before 1995 field season.
July 1994	Loran-C collars placed at fixed locations to assess bias in performance of AATS.
Spring 1995	Twenty-five new deer radio collars received from Starlink, Inc.
Jan. 1996	Battery in loran-C collar vents violently while being worked on in laboratory. Diodes added to all new radio-collar battery packs as safety measure.

Appendix 4

Bibliography

Skovlin's (1991) summary of the history of and past research in the Starkey Experimental Forest and Range includes a bibliography of scientific publications from 1942 to 1988. The following list of publications does not duplicate those references and is associated exclusively with the Starkey Project. The reader is referred to Skovlin's work for earlier publications about the SEFR, prior to the start of the Starkey Project. Titles for articles in preparation are tentative.

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Appendix 5

Common and Scientific Names of Species

Plants

Grasses and grasslike plants—

Bearded bluebunch wheatgrass	*Agropyron spicatum* (Pursh) Scribn. & Sm.
Onespike danthonia	*Danthonia unispicata* (Thurb.) Munro ex. Macoun
Sandberg bluegrass	*Poa secunda* Presl.

Trees—

Douglas-fir (interior)	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws.
Western larch	*Larix occidentalis* Nutt.

Animals

Mammals—

Black bear	*Ursus americanus*
Cattle	*Bos taurus*
Cougar	*Felis concolor*
Coyote	*Canis latrans*
Red deer	*Cervus elaphus elaphus*
Rocky Mountain elk	*Cervus elaphus nelsoni*
Rocky Mountain mule deer	*Odocoileus hemionus hemionus*
Sheep	*Ovis aries*

Birds—

Pileated woodpecker	*Dryocopus pileatus*
Vaux's swift	*Chaetura vauxi*

Insects—

Douglas-fir tussock moth	*Orgyia pseudotsugata*
Western spruce budworm	*Choristoneura occidentalis*

Rowland, Mary M.; Bryant, Larry D.; Johnson, Bruce K.; Noyes, James H.; Wisdom, Michael J.; Thomas, Jack Ward. 1997. The Starkey project: history, facilities, and data collection methods for ungulate research. Gen. Tech. Rep. PNW-GTR-396. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 62 p.

In the 1980s, management plans incorporated restrictions on timber harvest to maintain cover for Rocky Mountain elk *(Cervus elaphus nelsoni)* and mule deer *(Odocoileus hemionus hemionus)* in National Forests of the West. The Starkey Project, in northeastern Oregon, was begun to address questions about habitat needs and models for ungulates. Activities at Starkey include trapping and handling of deer and elk, radio telemetry, traffic monitoring, hunting, timber harvest, and livestock grazing. A bibliography of Starkey publications is included

Keywords: Deer, elk, cattle, forest management, ungulates, radio telemetry, habitat, Starkey Project, technology transfer, wildlife research, Blue Mountains, Oregon.

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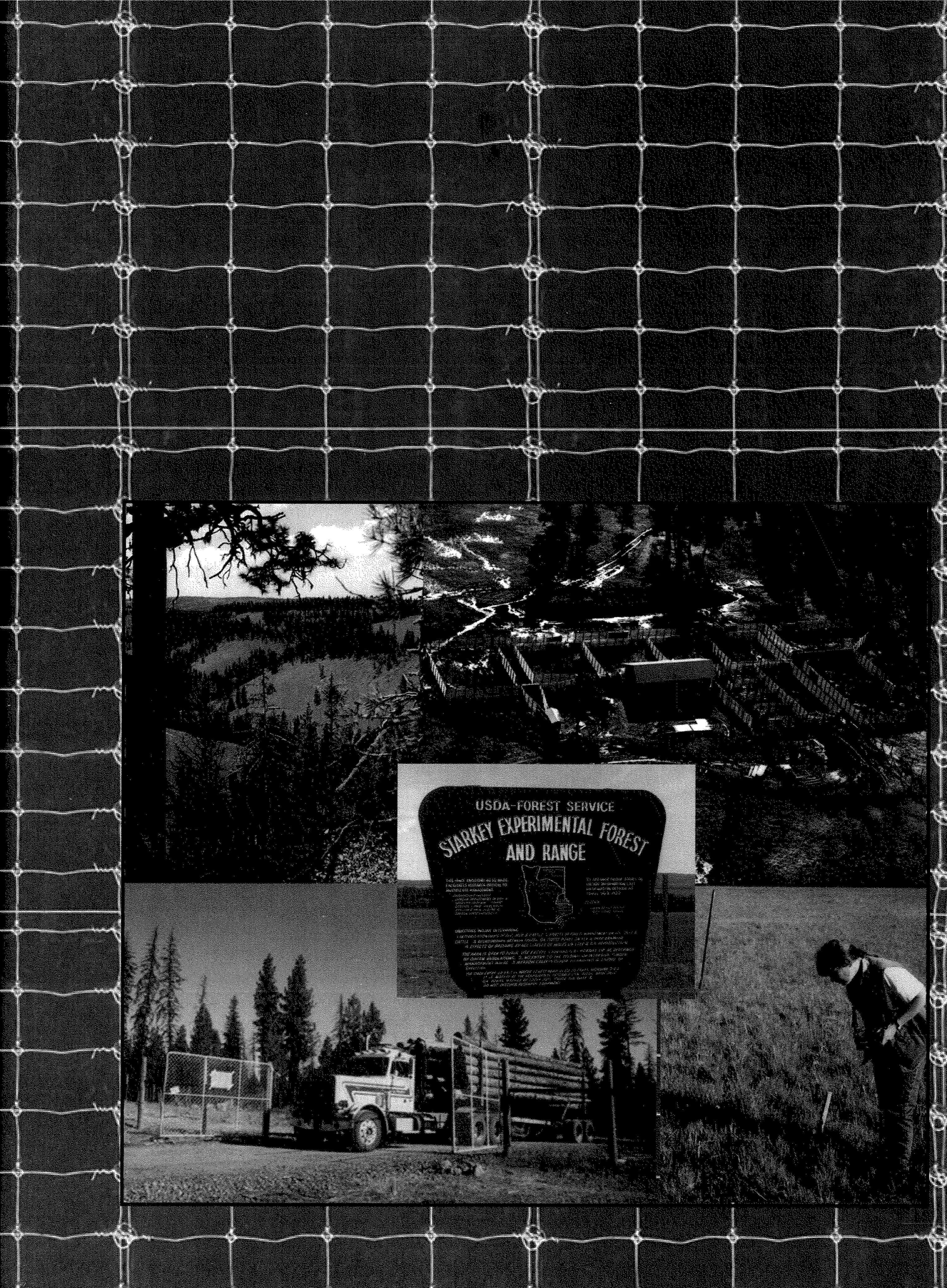
USDA-FOREST SERVICE
STARKEY EXPERIMENTAL FOREST
AND RANGE