HABITAT USE AND BEHAVIOUR OF FREE RANGE CATTLE ON FORESTED RANGE IN CENTRAL B.C.

by

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ABSTRACT

Cattle use, activities, and social organisation were investigated among habitat types in the Robinson Unit, Williams Lake Forest District during the 1996 and 1997 grazing seasons (15 May to 15 October). Habitat types were defined by vegetative associations and included Meadow, Wet Edge, Dry Edge, Clearcut, Forest, and Other. The numbers of insects, forage biomass and quality, and natural mineral levels were compared among these habitat types. In addition I used correspondence analysis to identify habitat variables associated with individual cattle activities.

Cattle concentrated in open habitats: Meadow, Wet Edge, Dry Edge, and Clearcut. During early morning foraging, cattle were often in riparian areas, while at other times they used non-riparian areas. Cattle use of edges (Wet and Dry) accounted for > 50% of observed use. At no time did cattle use Clearcut to the extent expected. Cattle did not perform activities with the same frequency in all habitat types, nor did calves and adult females perform activities with the same frequency.

Insect abundance, forage biomass and quality, and minerals differed among habitat types. Differences in biomass and minerals appeared to be associated with cattle habitat use. In some areas, the soil surface contained mineral (exchangeable cation) levels higher than those recorded for natural mineral licks.

Three ecological regimes were found to be of primary importance in correspondence analysis: moisture, shrub density, and climate. Grazing was associated with variables reflecting soil moisture and Browsing with moderate shrub/tree densities and cooler temperatures. Lying and Standing were associated with shade, high visibility, dry substrates, and proximity to roads. Variables not associated with specific cattle activities included: aspect, climate, poor visibility, obstacles, and moderate distances to roads and salt blocks.

I recommend that future research include: using identified variables as attractants for cattle, increasing cattle use of clearcuts and working with foresters to minimise damage to tree seedlings, investigating the role of trails and spatial memory in cattle distribution, and the relationship between salt blocks, cattle, and natural minerals. Managers should incorporate the importance of forage density, cattle use of edges, and anti-predator and grouping behaviours into daily management.

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from cocksure ignorance to thoughtful uncertainty"
T.H. Bell

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CHAPTER 1
GENERAL INTRODUCTION

In 1994, 222,957 beef cattle spent part of the year on Crown Land in British Columbia (B.C. Ministry of Forests 1996a). These animals, along with roughly 18,000 horses and sheep, made use of nearly one million animal unit months (AUMs) of forage (B.C. Ministry of Forests 1996a). Individuals responsible for these animals, producers and resource managers, face two challenges: how to achieve maximum economic returns and how to achieve them without reducing the quality or integrity of the public lands they rely on. As one of many uses of Crown Land, range use in B.C. is governed by both the Range Act (B.C. Ministry of Forests 1995) and the B.C. Forest Practices Code (FPC) implemented in 1994.

The first general guideline of the FPC (B.C. Ministry of Forests 1994) states that forest practices, including livestock production on Crown Land, can not be carried out if they result in damage to the environment. Specific sections of the FPC that affect livestock producers are those that involve: the herding of livestock across Crown Lands, the protection of biodiversity in general, the specific protection of soil and riparian areas, and the need to produce Range Use Plans (Province of B.C. 1995a) for renewal of all grazing tenures.

After implementation of the FPC, several regional land use commissions were formed to address compliance with the Code, and how this could be achieved. In the Cariboo-Chilcotin region, the impact of the FPC on beef cattle production was an issue of concern. Both FPC regulations and B.C.'s protected areas strategy were addressed in the Cariboo-Chilcotin Land Use Plan (CCLUP). The CCLUP (Province of B.C. 1995b) states that grazing is an acceptable land use in the region if it does not detract from other accepted land uses, such as the provision of critical habitat, protection of riparian areas, and forest regeneration, which are specified among Management Zone Sub-Units (Province of B.C. 1995b). Of these other uses, the protection of riparian areas is often emphasised.

Riparian areas are generally recognised to be important (Kauffman and Krueger 1984, Province of B.C. 1995c, Rautio and Bunnell 1994). These areas are defined as "land adjacent to streams, rivers, lakes, or wetlands (including wetlands) containing vegetation that, due to the presence of water, are distinctly different from the vegetation of adjacent upland areas" (Province of B.C. 1995c). A variety of physical and biological impacts have been linked to livestock in riparian areas including: soil compaction (Kauffman and Krueger 1984), reduced water infiltration

(Rauzi and Smith 1973), reduced water quality (Fleischner 1994), loss of aquatic and terrestrial habitat (Baker and Guthery 1990, Armour *et al.* 1991), and erosion (Kauffman *et al.* 1983). When cattle are mismanaged in riparian areas and damage occurs, measures of some kind must be undertaken to counter their impacts (Chaney *et al.* 1993, Cotton and Cotton n.d) and to prevent further damage. The sections of the FPC pertaining to livestock can be considered such a prevention attempt in B.C.

At present, it is uncertain how producers and managers will meet FPC requirements such as submitting plans to protect riparian areas, because there is little information on how cattle behave on, or use public lands in the interior of B.C. (Watson 1986, Wikeem *et al.* 1993). Quantitative information such as how and why cattle use different habitats is necessary before appropriate management decisions can be made. Habitat use is an aspect of animal behaviour and it is a function of behaviours such as animal activities, how animals arrange themselves with respect to one another (social organisation), and how animals use available resources.

This relationship (Figure 1) encompasses general ecological relationships that affect how animals, including cattle, use habitats, physical areas, their biotic and abiotic components where an animal can live, to meet their basic requirements for food, survival, and reproduction (Figure 2). At present, cattle management in B.C. relies primarily on herding and provision of supplemental minerals (e.g., salt blocks), and occasionally other methods. Fencing is used, but it is costly (B.C. Ministry of Forests 1996a) and cannot be used in all situations. These management efforts affect only particular parts of the ecological system (Figure 1) and are insufficient to meet the producers' or resource managers' expectations. Management of grazing land could benefit from an improved understanding of the ecological system involved in cattle use of Crown Land in B.C.

Information about habitat use is commonly collected for wildlife species, but not as frequently for range cattle. Knowledge of habitat use can aid in the allocation of resources by land managers (Ganskopp and Vavra 1986). It can also be used to predict animals' responses to changes that are often associated with various human activities (Cairns and Telfer 1980, Gavin 1991). If cattle producers are to be allocated resources on Crown Lands, the needs of their animal populations (herds) must be known.

Studies of animal behaviour provide answers to questions dealing with the causation, development, function, and evolution of animal activities (Tinbergen 1963). Historically, such

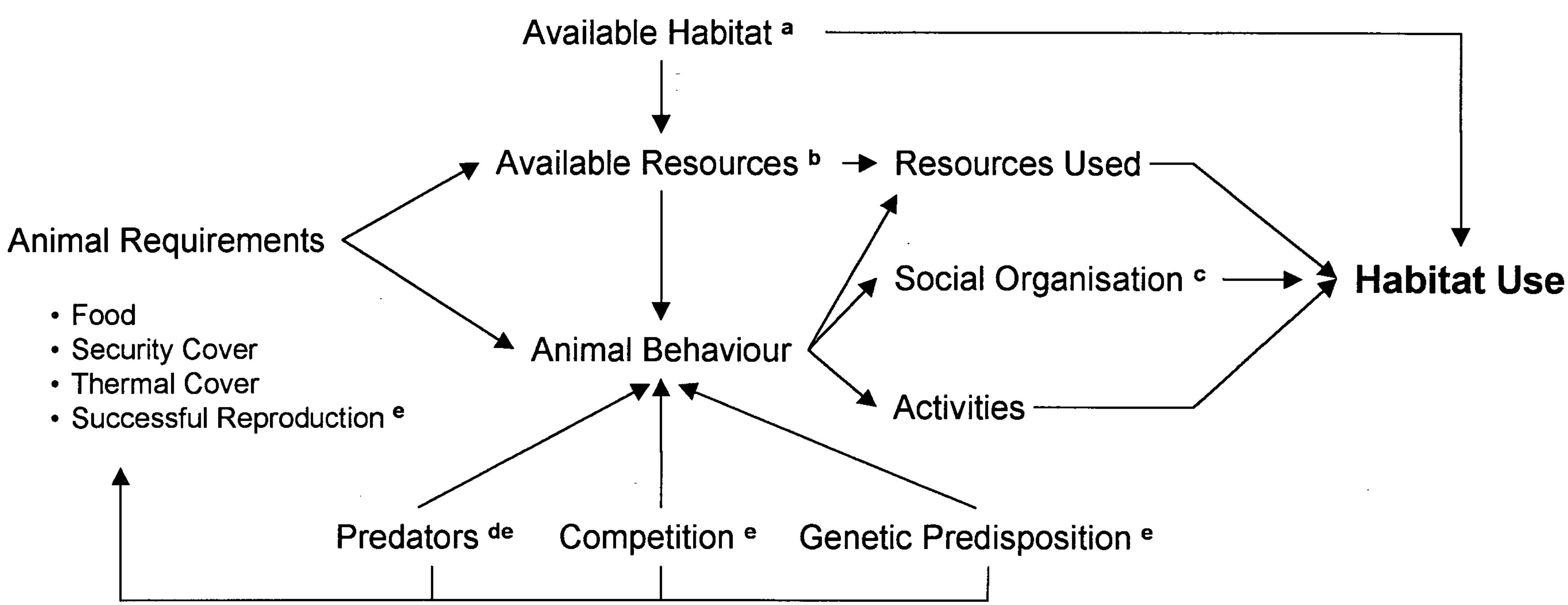

Figure 1. Descriptive model showing potential factors affecting habitat use by range cattle. Particular factors are indicatedas being affected by current management (see below).

a - current management: fencing and herding
b - current management: salt blocks, supplements (sometimes), water developments (sometimes), and insect repellent (sometimes)
c - current management: gathering cattle and herding
d - sometimes killed
e - not addressed in my study

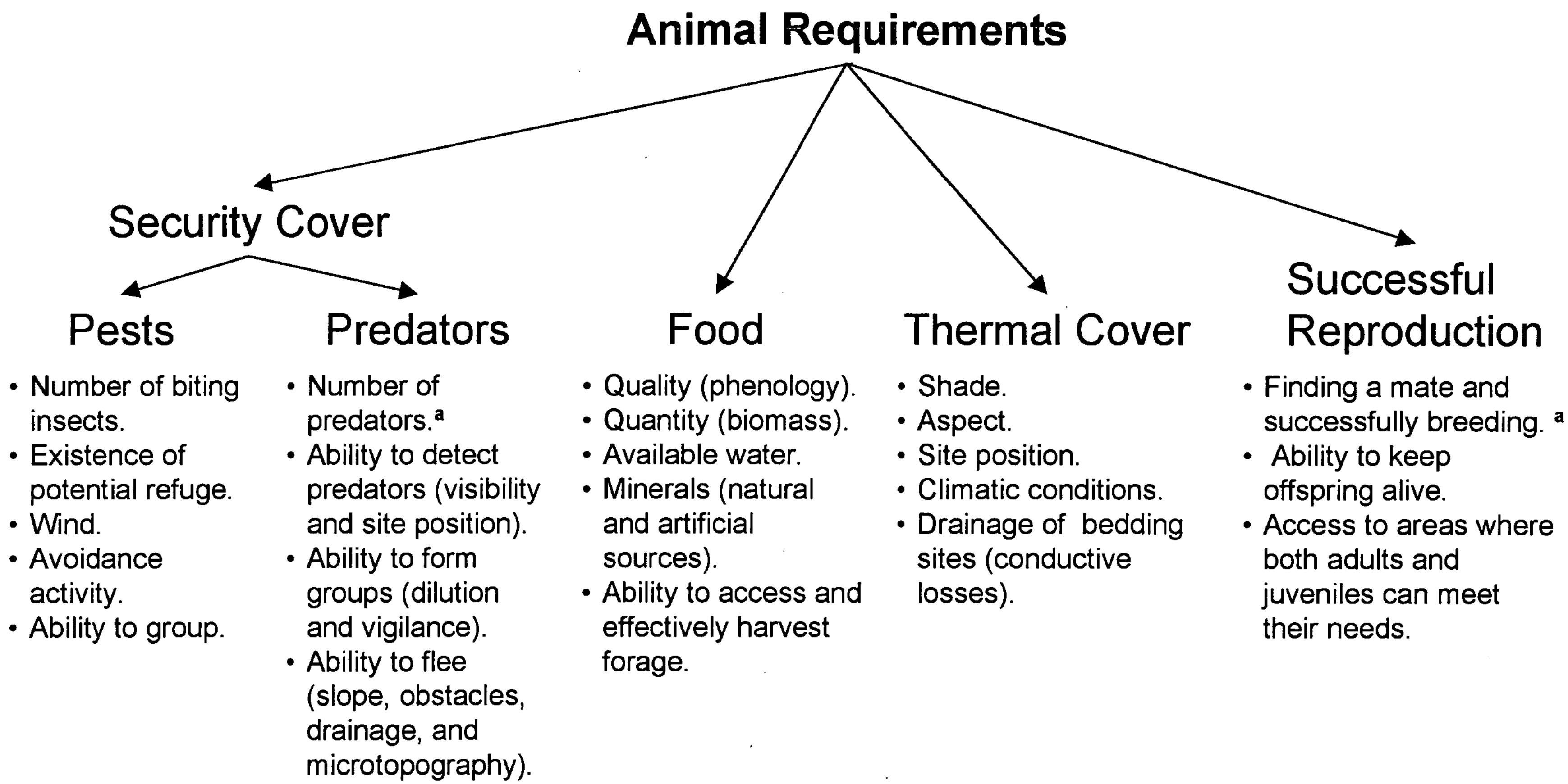

Figure 2. Resources and abilities I considered that ungulates need to meet their requirements for food, survival, and reproduction. Resources may be physical, (e.g., available water), or spatial, (e.g., enough space to form groups). The ability to travel to and access these resources is also required. **a** - not addressed in my study.

knowledge was exploited for domestication and hunting. More recently, its importance in wildlife habitat and population management has been realised (Gavin 1991, Murphy and Noon 1991). Knowledge of basic animal behaviour aids in understanding higher level behaviours, permits managers to make reasonable predictions, and allows for the exploitation or alteration of behaviour for management purposes. The application of behaviour has not been limited to wild populations, but has also been of significant value in domestic animal production. The exploitation of behavioural information is seen in everyday handling of livestock, in herding (Lott and Hart 1979), in reducing stress and aggression, and in constructing handling facilities (Grandin 1980, Stricklin and Kautz-Scanavy 1984). Animal behaviour is also beginning to be applied to range use issues (Kie and Boroski 1996).

Habitat use and behaviour of range cattle has been investigated in areas such as the Western United States, but direct extrapolation from these areas to the Cariboo-Chilcotin could be difficult for four reasons. First, grazing lands in the Western United States, predominantly grasslands, are very different from those in B.C., which are predominantly forested (Wikeem *et al.* 1993). Second, information from these areas often focuses on specific issues such as cattle use of shade or slope (Senft *et al.* 1985a), responses to grazing regimes (Gillen *et al.* 1984, Hepworth *et al.* 1991), or competition between cattle and wildlife (Hart *et al.* 1991, Jenks *et al.* 1996). Third, many of these studies were conducted using pastures (Tanner *et al.* 1984, Senft *et al.* 1985a, Smith *et al.* 1992), or small range units (Roath and Krueger 1982a, Marlow and Pogacnik 1986) which are quite different from the large, often > 200 km^2, grazing units used in the Cariboo-Chilcotin (B.C. Ministry of Forests 1996b). Finally, if producers and managers wish to fully understand how and why cattle use Crown Land, they must not only determine cattle habitat use and behaviour, but also the requirements of and the resources used by the animals.

Because animal behaviour, including habitat use, is a function of animal requirements and the resources animals use to meet them (Figure 2), then knowledge and management of these resources can be used to improve management. Range research regularly seeks to address the nutritional and thermal requirements of cattle as well as trade-offs between them, but for a variety of reasons (Gluesing and Balph 1980, Neuman *et al.* 1995), it has not addressed cattle's requirement to avoid predation. The risk of predation affects animal behaviour (Neuman *et al.* 1995), and anti-predator behaviour persists even when there is no active predation, probably because the perception of the risk of predation remains (Lima and Dill 1990, Neuman *et al.* 1995). If this is the case for cattle, then range researchers can not discount the importance of predator avoidance in cattle behaviour. This is particularly true in B.C., where cattle share the land base with potential predators. Cattle behaviour must be examined in the context of all of the animal's requirements.

In an effort to provide information to aid in future management and to address Watson's (1986) and Wikeem *et al.*'s (1993) calls for increased knowledge of range cattle ecology in B.C., I investigated cattle behaviour and habitat variables in a forested range unit. I quantified cattle use, activities, and social organisation across various habitat types on a forested range unit in the Cariboo-Chilcotin of B.C. (Chapter 2). As well, I compared the availability of particular habitat factors among the habitat types (Chapter 2). In the context of these quantitative comparisons, I determined which habitat variables were associated with specific cattle activities (Chapter 3) to generate hypotheses for future work. My data were gathered during the 1996 and 1997 grazing seasons (15 May to 15 October) on the Robinson Unit, in the Williams Lake Forest District.

STUDY AREA

The Robinson Unit, No. 6095 in the Williams Lake Forest District, is located approximately 80 km southwest of Williams Lake, B.C. (123° 15′ W latitude, 51° 40′ N longitude) near the community of Big Creek (Figure 3). The unit is on the border of the Williams Lake and Chilcotin Forest Districts and encompasses approximately 180 km^2 of the Fraser Plateau. This area has been classified as part of the Sub-Boreal Pine-Spruce Biogeoclimatic Zone and is characterised by a rolling landscape, a cool dry continental climate, and a short growing season (Meidinger and Pojar 1991). Since the establishment of a weather station in the area, in 1893, annual rainfall has averaged 194.2 mm, annual snowfall 123.6 cm, and mean daily temperature 2.5°C (G. Myers, Environment Canada, pers. comm. 1998).

The unit is at approximately 1,280 m above sea level and includes extensive lodgepole pine (*Pinus contorta*) forests with white spruce (*Picea glauca*) present on some moist sites. Stands of trembling aspen (*Populus tremuloides*) are common within the unit, particularly in areas of regeneration (after fire and/or harvest) and adjacent to natural grasslands. Douglas-fir (*Pseudotsuga menziesii*) occurs in the study area, but not in continuous stands. The forest understory is open and dominated by pinegrass (*Calamagrostis rubescens*), forbs, and kinnikinnick (*Arctostaphylos uva-ursi*). In addition to these forested areas, several non-forested wetlands are present. These include: shrub-carrs dominated by willow (*Salix* spp.) and scrub

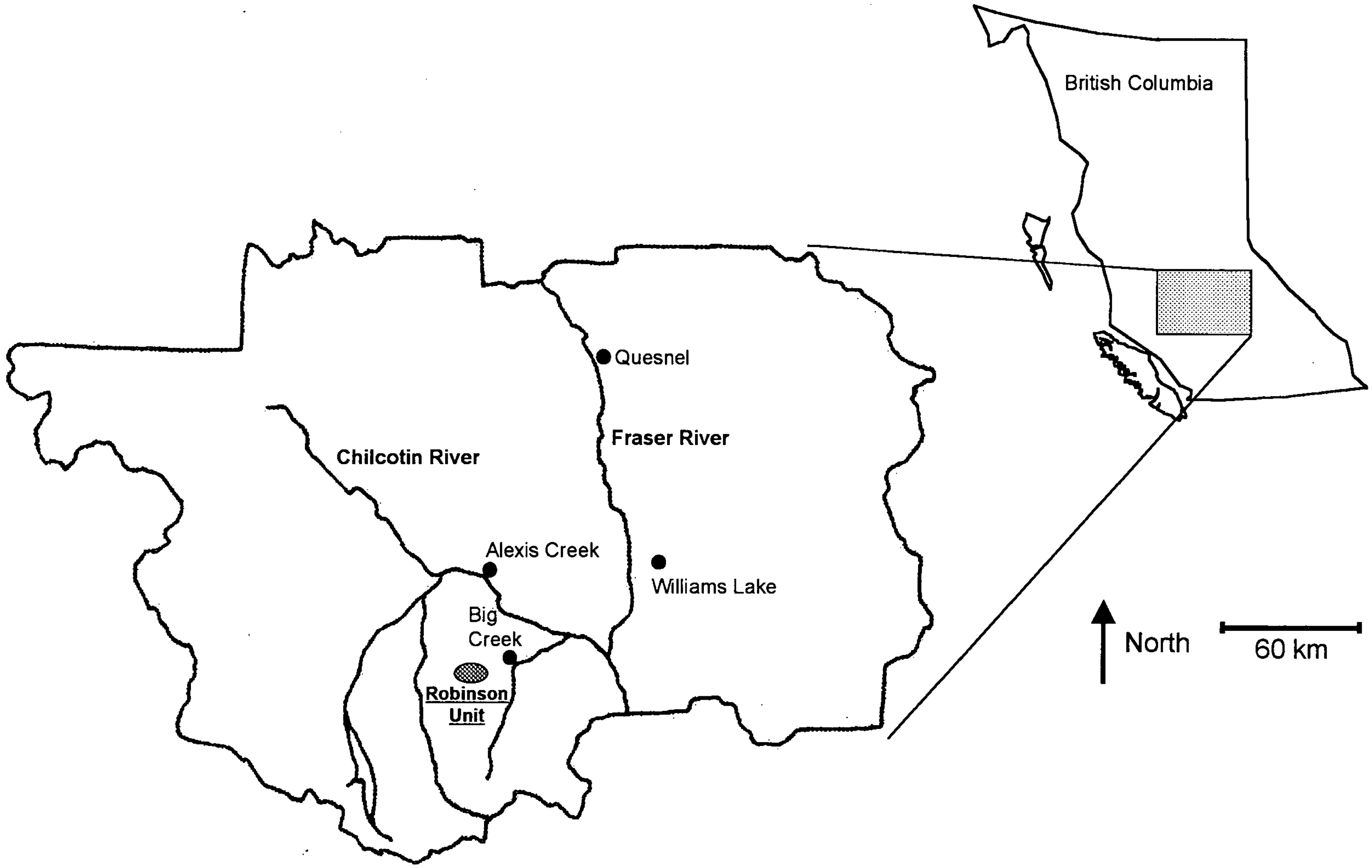

Figure 3. Map of Cariboo-Chilcotin region. The study site was located in the Robinson Unit near the community of Big Creek, B.C.

birch (*Betula glandulosa*); sedge (*Carex* spp.) dominated fens; and both wet and dry meadows containing sedges, rushes (*Juncus* spp.) and various grasses. All four types of wetlands are characteristic of the biogeoclimatic zone (Steen and Roberts 1988, Meidinger and Pojar 1991). Natural grassland openings, and several clearcuts (between approximately 5 and 20 years old), lakes, and areas of permanent open shallow water (Steen and Roberts 1988) are also scattered throughout the area.

In addition to cattle, other ungulates present in the Unit were moose (*Alces alces*), mule deer (*Odocoileus hemionus hemionus*), and feral horses (*Equus caballus*). Over the course of this study, wolves (*Canis lupus*), black bears (*Ursus americanus*), coyotes (*Canis latrans*) and a bobcat (*Lynx rufus*) were encountered. Cougars (*Puma concolor*) and grizzly bears (*Ursus arctos*) were reported to be present, but I did not observe them in the area.

The study area is currently being used for a variety of activities, including forestry, cattle grazing, hay production, back-country tourism, and subsistence and recreational hunting and fishing. Grazing has occurred intermittently in this area for about 80 years, with some licensees/permitees using meadows for hay production. One large fire, > 2600 ha, occurred in 1970, and the area was subsequently aerially seeded to mixed grass in 1971 (B.C. Ministry of Forests 1971). The recent history of the unit included repeated overuse of its largest natural grassland prior to 1992 (F. Knezevich, B.C. Ministry of Forests, pers. comm. 1996). Between 1992 and 1994, no livestock grazing occurred on the Robinson Unit, but beginning in 1995, 330 mixed-breed beef animals (Hereford, Black Angus, and Shorthorn), including calves, have been turned out each year between May 15 and October 15 (C. Armes, B.C. Ministry of Forests, pers. comm. 1996). During my study, 1,100 AUMs were allocated to this unit each year. Within the Williams Lake Forest District, AUMs allocated per unit are often proportional to the area of non-forested wetlands present (C. Armes, B.C. Ministry of Forests, pers. comm. 1996).

The current permittee, Mr. G. Puhallo, relies on herding and salt blocks to achieve management goals, including reduced use of the largest natural grassland. In general, Mr. Puhallo's goals include well distributed use of the Unit, avoidance of heavy grazing pressure on any given area (specifically one natural grassland and two meadows), reduced use of meadows containing upland larkspur (*Delphinium glaucum*) a naturally occurring toxic plant species, and higher use of clearcuts.

Between the 1996 and 1997 grazing seasons, a fence was built in a North - South direction in the Unit, creating 2 sub-units. During 1997, cattle were kept on the eastern, lower elevation side from turnout until August 1. I refer to this period as 'EARLY SEASON'. After this date, all cattle were moved to the western, higher elevation, side of the unit. Cattle were assumed to have stayed in this portion of the unit until the end of the grazing season in October. I refer to this period as 'LATE SEASON'. In an effort to accurately reflect the conditions cattle were experiencing, I conducted data collection in the sub-unit that was available to cattle at the time of sampling. Although the fence was not constructed in 1996, Mr. Puhallo attempted to obtain a similar distribution pattern by herding his cattle. I investigated habitat use as if the fence were present in both years.

CHAPTER 2

HABITAT USE, CATTLE BEHAVIOUR, AND HABITAT FACTORS

INTRODUCTION

Some habitat use patterns exhibited by cattle are a source of concern and potential conflict to those interested in the maintenance of natural systems. One such pattern is the heavy use of sensitive areas including riparian and grassland habitats. If the desire, and need, to change these use patterns exists, then it is important that managers understand why they exist. Three questions must be answered to achieve such comprehension: what areas are being used, what behaviour(s) are conducted there, and what factors are affecting their use?

Habitat use

Cattle commonly use areas in and around riparian and grassland habitats (Gillen *et al.* 1984, Pratt *et al.* 1986, Hart *et al.* 1991, Smith *et al.* 1992). Cattle are thought to use riparian areas for the same reasons as do other species (Kauffman and Krueger 1984, Gillen *et al.* 1985, Stevens *et al.* 1995), the unique complement of resources found there. Two of these resources, the abundance of forage and water, are obviously important for animals securing sufficient food, and have received much attention in research.

The consumption and/or destruction of a current year's vegetation (forage) in an area is defined as utilisation (Society for Range Management 1998). Many studies have focused on cattle utilisation of habitats and have appeared to equate it with habitat use (Kauffman *et al.* 1983, Marlow and Pogacnik 1986, Green and Kauffman 1995, Howery *et al.* 1996). Habitat use is not limited to the consumption of food, it can involve a simple association with an area and/or its resources (Litvaitis *et al.* 1996). When both utilisation and habitat use are reported, the emphasis is often placed on the utilisation data (Smith *et al.* 1992). While such reports provide good information on how cattle use rangelands to secure forage, they do not fully address the question of how cattle use the available area to meet all of their requirements. It is important to differentiate between these two measures.

Information on habitat use and utilisation by cattle in B.C. is limited. McLean *et al.* (1963) made the general statement that grazing (utilisation) at higher elevations in B.C. is restricted to "numerous wet meadows and park-like openings in the forest". As part of larger studies, McLean and Willms (1977) reported that cattle used open more than closed areas, and Preston (1984) found that habitat use by cattle was not random and that preference was shown for meadows (high preference) and "interface zones" (slight preference).

Behaviour

Much of the research on range cattle behaviour has focused on grazing, but some has also included resting activity. Grazing accounts for between 50% (DeMiguel *et al.* 1997) and 75% (Pinchak *et al.* 1991) of cattle's activity budgets and cattle use different portions of each day for specific activities (Compton and Brundage 1971). The general activity pattern of cattle includes early morning grazing (Low *et al.* 1981, Bailey *et al.* 1990), followed by resting (Roath and Krueger 1982a), late day foraging, and reduced activity during the night (Marlow and Pogacnik 1986, Pinchak *et al.* 1991).

Not only do cattle perform different activities at different times of day, but they perform them in different habitat types (Pratt *et al.* 1986). However, there is no agreement over which habitats are used for which activities. Cattle have been found to feed in lowlands (DeMiguel *et al.* 1997) and riparian areas (Marlow and Pogacnik 1986), and to rest in upland (Roath and Krueger 1982a) and forested areas (McLean and Willms 1977, Green and Kauffman 1995). In contrast to this pattern, Smith *et al.* (1992) and Howery *et al.* (1996) reported that feeding was concentrated in uplands and loafing (resting) in riparian areas. These are the two principal patterns reported, but other combinations exist.

Not only does cattle activity affect their distribution, but so does their social organisation (Roath and Krueger 1982a, Sato 1982). The importance of this aspect of behaviour in cattle distribution is not well understood. Studies that have addressed social organisation of cattle have reported a wide range of results. Some authors have reported the formation of distinct groups and/or subgroups within a herd (Bryce 1977, Pinchak *et al.* 1991, Howery *et al.* 1996) and small (< 10) group sizes (Herbel and Nelson 1966, DeMiguel *et al.* 1997), but others mention only larger (> 10) groups sizes (Pratt *et al.* 1986). Groups and subgroups are simply defined as divisions of the original herd(s).

With the exception of McLean and Willms' (1977) report regarding broad activity and habitat use patterns, Preston's (1984) study of diet selection, and Bryce's (1977) preliminary investigation of social organisation, little is known about the behaviour of range cattle in B.C. In his review of beef production in this Province, Watson (1986) stated that present management does not reflect cattle behaviour and that the next step in improving range use efficiency was to study their behaviour and ecology. In their 1993 report, Wikeem *et al.* (1993) suggested that there was still little information for several areas of the Province, including the Chilcotin.

If cattle use available habitats in a non-random manner and for specific activities, then we may begin to explain this in part, by determining which habitat factors differ among the available habitat types. Animal distribution across landscapes is accepted as being constrained by abiotic and biotic variables (Senft *et al.* 1987, Coughenour 1991, Bailey *et al.* 1996). Four specific factors known to influence the distribution of ungulates are: harassment by insects (Keiper and Berger 1983), forage abundance and quality (Smith *et al.* 1992), and the presence of minerals (McNaughton 1988).

Habitat factors

Insects

Harassment by insects has been documented for a variety of ungulate species including caribou (*Rangifer tarandus*), horses, and cattle. Harassment, particularly by biting species such as tabanids (horse and deer flies), can cause significant blood loss, disease, stress (Hughes *et al.* 1981), changes in habitat use (Keiper and Berger 1983, Toupin *et al.* 1996), and changes in individual and group behaviour (Ralley *et al.* 1993, Dougherty *et al.* 1994). Changes in individual behaviour, particularly the frequency of anti-pest behaviours (Ralley *et al.* 1993), increases positively with insect numbers (Dougherty *et al.* 1994). These responses can result in the animal's use of less productive areas, performance of energy inefficient behaviours, and increased stress levels. All of these could create problems for B.C. cattle producers.

Ungulates can be at risk for both predation and harassment by biting insects. Both of these risks can influence behaviour including habitat use (Festa-Bianchet 1988, Dougherty *et al.* 1994). Also, the risk of predation is assumed to be higher while grazers are foraging (Neuman *et al.* 1995) because of their head position (Underwood 1982). The increased risk must be balanced with the need for food intake. Cost-benefit analysis would dictate that any behaviour, including habitat use, which reduced the time required to harvest sufficient food, would be favoured. Areas with abundant and easily harvested forage should, therefore, be preferred for feeding. This is particularly true for large ruminants, such as cattle, that have the ability to quickly harvest large amounts of forage and travel to potentially safer areas to ruminate.

Forage

Much attention has been directed to the role that forage plays in habitat selection by range cattle and yet it remains far from understood. Cattle foraging behaviour has been thought to reflect optimal foraging theory (DeMiguel *et al.* 1997), the marginal value theorem (Bailey *et al.* 1990, Hepworth *et al.* 1991), and combinations of these theories with hierarchy theory (Senft *et al.* 1987). While these debates exist, it is accepted that forage is one of the driving factors in the selection of habitats by cattle. However, it is uncertain whether or not cattle respond to forage quality (Low *et al.* 1981, Bailey 1995), quantity (Kauffman *et al.* 1983, Smith *et al.* 1992, DeMiguel *et al.* 1997), or a combination of the two (Pinchak *et al.* 1991, Senft *et al.* 1987, Fritz *et al.* 1996).

Forage quality is known to decrease over the course of the grazing season. Typical changes include, decreases in succulence and protein content, and increases in fibre (Pinchak *et al.* 1991, Smith *et al.* 1992). These general trends have been well documented in B.C. (McLean *et al.* 1963, McLean 1972, Quinton and Ryder 1983). Forage availability also decreases over the grazing season as herbivores (wild and domestic) consume it.

Common forages available in B.C.'s Cariboo-Chilcotin include native and seeded grasses, sedges, rushes, forbs, and shrubs. McLean (1972) reported that up to 77% of ground cover in the Cariboo was dominated by pinegrass. The low feed value of this species in B.C. has been reported repeatedly (McLean and Tisdale 1960, McLean 1967, McLean *et al.* 1969). McLean *et al.* (1963) noted that, in many areas of the Province, grazing was restricted to wet meadows, composed of dense stands of sedges and some rushes.

Natural mineral levels

B.C. rangelands used for the production of beef cattle are deficient in many minerals (Richmond 1980). Consequently, sodium (Na) and other minerals are commonly provided on rangelands to meet the nutritional requirements of the animals (Quinton 1987), and to encourage more uniform use of range (Martin and Ward 1973, Miller and Krueger 1976). This supplementation is commonly referred to as "salting". While salting is one of the most frequently used management tools for range cattle in B.C. and other areas, it has mixed results (Reppert 1960, Cook 1966, Bryant 1982, Gillen *et al.* 1984).

One reason for mixed responses to salting is that cattle, like other ungulates, may make use of naturally occurring minerals (McNaughton 1988). Possible natural sources of minerals include licks, water, and vegetation which obtain exchangeable cations from the soil. Cattle use of mineral licks was reported by Jones and Hanson (1985), and additional pica behaviour such as "ingestion or chewing of wood, stones, bone or plastic...rabbit faeces" by cattle was mentioned by Wallisdervries (1996). In areas where natural mineral sources exist, heavy reliance on salting as a management tool may not be useful.

Objectives

To learn more about range cattle ecology, I asked a series of questions to address the following null hypotheses: 1) cattle will use habitat types in the Robinson Unit in a random manner, 2) cattle behaviour will be uniform among habitat types, 3) age/sex classes of cattle will not differ in their behaviour, and 4) habitat factors will be equal among habitat types.

This chapter is divided into three sections to deal with these hypotheses and questions. In the first section, habitat use, I determined: 1) the overall habitat use of cattle, 2) if this use differed from that seen during known foraging (utilisation) periods, and 3) if either pattern of use was random. In the second section, animal behaviour, I determined if: 1) cattle activities were performed with the same frequency within each habitat type, 2) the social organisation of cattle varied among habitat types or activities, and 3) activities were performed at the same frequency by young of the year (calves) and by adult females. In the third section, habitat factors, I determined if: 1) the relative levels of biting insects, forage biomass, and exchangeable cations were equal among habitat types, 2) forage quality, as indicated by phenological stage, was equal among habitat types at any given time, and 3) the frequency of anti-pest (biting insect) activities by cattle was equal among habitat types and times of day.

METHODS

Definition of habitat types

Originally, I recognised 9 habitat types, "areas of land covered by a relatively homogeneous plant community or successional stage" (Dunster and Dunster 1996), in the study area (Table 1). The habitat types selected had the following qualities: 1) functionally different, 2) spatially discreet, and 3) discernible from aerial photographs, and/or forest cover maps. Later, to meet the assumptions of the chi-square goodness-of-fit test (Siegel and Castellan 1988), Grassland was grouped with Meadow, Shrub-Carr with Wet Edge, and Open Forest with Dry Edge, reducing the number of habitats types to 6.

Table 1. Description of 9 habitat types in the Robinson Unit, Williams Lake Forest District.

Habitat Type	Defining Characteristics
Meadow	Herbaceous wetlands periodically saturated but rarely inundated with water (Steen and Roberts 1988). Wet meadows were dominated by sedges, rushes, and mosses while dry meadows included various grass species. A 'Riparian Area'.
Grassland	Naturally occurring non-forested areas dominated by grasses. These areas were found adjacent to meadows and open water. The producer referred to one such area as an alkali flat. Trembling aspen stands were present in grassland complexes.
Wet Edge	Transitional area between a riparian area and any other habitat type, includes Shrub-Carr. A 'Riparian Area'.
Shrub-Carr	Non-forested areas dominated by shrubs such as willows and scrub birch, developed on mineral material, having clear riparian influence, periodically saturated (Steen and Roberts 1988), often located between meadows or grasslands and forest. A 'Riparian Area'.
Dry Edge	Transitional area between two non-riparian zones or between a wet edge and a non-riparian zone, includes Open Forest.
Open Forest	Includes regenerating forests > 1.5 m (i.e., maximum height of cattle at shoulder) with open canopies, areas of selective logging or thinning, deciduous stands, and coniferous stands with open canopies and sparse stems.
Clearcut	Areas harvested approximately 5 to 20 prior to study with regenerating coniferous species ≤ 1.5 m (i.e., maximum height of cattle at shoulder). Often mechanically prepared and planted. May include areas seeded to domestic grasses and/or trembling aspen stands.
Forest	Includes pine, spruce, or fir stands with either closed canopies and/or dense stems.
Other	Roads, landings, open water (deeper than 2 m to differentiate from Steen and Robert's (1988) definition of open shallow water), and unclassified areas such as gravel pits and private land. May include 'Riparian Areas'.

Determination of relative habitat availability

I determined the availability of each habitat type using a grid dot count, n = 211,329, (Marcum and Loftsgaarden 1980) of 46 1:15,000 aerial photographs with a grid of 25 dots/cm^2. I used opportunistic ground reconnaissance to insure that no additional timber harvest had occurred since the photographs were taken in August 1993 (B.C. Ministry of Environment, Lands, and Parks 1993). In the single case where logging had occurred, adjustments were made to the relevant photographs. Areas on the photographs not available to cattle (large, deep lakes and private, fenced property), were not included in the totals.

Determination of cattle locations

During the 1996 season, cattle were located by: 1) opportunistic sightings while travelling through the study area, 2) following groups (long-term daylight tracking), and 3) using information provided by Mr. G. Puhallo. Between the 1996 and 1997 seasons, the search protocol was standardized. During the 1997 season, I located animals by: 1) repeatedly travelling 15 fixed transect routes, 2) aerial observations, 3) long-term daylight tracking, and 4) opportunistic sightings while involved in other aspects of the project.

Transects

In 1997, I travelled the 15 fixed transects in rotation and at different times of day: 0600-1000, 1000-1400, 1400-1800, and 1800-2200. Each transect was travelled at least once every two weeks. These transects were purposively established using three criteria:

1) Each transect was traversable in 4 h. Allowing for rough terrain and the time required to observe cattle, 6 km could be traversed by foot in 4 h. Overland transects (n = 13) were approximately 6 km long, driven transects (n = 2) were longer.
2) Transects covered the area available to cattle at the time of sampling (EARLY and LATE seasons).
3) Transects traversed more than one habitat type.

Animals were considered located if they were observed within a transect width of approximately 50 m. This width was based on visibility in the densest habitat type (Closed Forest) and served to reduce observer's bias towards open habitats.

Aerial surveys

As an index of cattle utilisation of the study area, I conducted aerial surveys from fixed-wing aircraft (2/month) in 1997, approximately 2 h after sunrise, to locate cattle during a known foraging period. Early morning feeding by cattle is well documented and is known to change with the onset of sunrise (Low *et al.* 1981). The use of flights allowed for almost simultaneous sampling of the study area. When animals were located, during either transects or flights, they were scan sampled (Martin and Bateson 1993). On the day following an aerial survey, I attempted to locate one of the groups detected from the air, and follow it for 24 h to conduct long-term daylight tracking. These groups were selected to cover the extent of the unit over the season and to facilitate access.

Long-term daylight tracking

Long-term daylight tracking was organised so that a group of cattle was located approximately at midday. Once a group was located, a 24 h clock began, and animals were scan sampled at 15 minute (min) intervals (Nelson and Furr 1966, Gary *et al.* 1970) until it became too dark to make observations. On the following day, scan sampling resumed as soon as there was sufficient light, and continued until the 24 h period was complete at approximately midday. Hours of darkness varied between approximately 5 and 11 over the duration of study.

Data collected

When observing the cattle, I was generally > 15 m from them. For every scan sample, the following data were collected: date, time, location in UTM (Universal Transverse Mercator) co-ordinates, sampling method, habitat type, group size and composition, inter-animal distance, activity state of group and of different age/sex classes, general climatic conditions, temperature, wind speed and direction, and when possible, the identification of individual animals. In addition, where possible, each location was flagged and marked on aerial photos to facilitate site investigations at a later date (see Chapter 3).

I used Frid's (1994) definition of a group as a guide for identifying groups. Although Frid (1994) defined a group as "a set of individuals which, in terms of the structural attributes of the environment, were under similar predation risk", I did not limit my definition by predation risk. I defined a group as a set of individuals which were associated with similar structural attributes of the environment and were spatially discrete from other cattle. The determination of spatial separation was, in some cases, subjective.

If approximately > 60% of the group was involved in a particular activity, it was recorded as the predominant activity. If the group was evenly divided among ≥ 2 activities, each activity was recorded and the observation was noted as 'mixed'. Group activities were recorded as one of the following states: browsing, copulating, courting, drinking, eliminating, grazing, grooming self, grooming other, lying, nursing, other social interactions, standing, taking salt, travelling, vigilance, vocalising, indeterminable, and other. Grazing included both search- and intense-grazing (Barton *et al.* 1992). Lying and standing activities included rumination because it was not always possible to detect if an animal was ruminating or not.

Travelling was further investigated during long-term daylight tracking. The location of the group was marked on aerial photographs during scan samples. Assuming straight lines of travel, I used these points to determine minimum distances travelled. Because of the small sample size (n = 16) only descriptive statistics were calculated for minimum distances travelled.

Organisation of observations

Observations from transects, aerial surveys, and every 5th interval during long-term daylight tracking were used to determine habitat use and behaviour of cattle at a coarse scale. Observations from each 15 min interval during long-term daylight tracking were used to investigate cattle behaviour on a finer scale. Throughout the study, these observations were referred to as 'COARSE' and 'FINE', respectively. Every 5th interval (i.e., 75 min) was assumed to be adequate to avoid pseudoreplication of habitat use. Early in the 1996 season, it was noted that over the course of 15 min, cattle could easily change habitats, and over 1 h, cattle could traverse several kilometres and many habitat types, as was reported by Hepworth *et al.* (1991). In the interest of distinguishing between overall habitat use and habitat use during a known feeding period, a second descriptor was required. I used 'AM' throughout this study to denote observations made during early morning flights and 'DAY' to denote all other observations.

Statistical analyses

I used chi-square tests of independence (Siegel and Castellan 1988) to determine if the sampling method (transects, aerial surveys, long-term daylight tracking, and opportunistic) affected estimates of habitat use. Early morning aerial surveys detected a different pattern of use than ground-based methods so I analysed them separately. The only difference I found for the ground-based methods, was the opportunistic observations from LATE 1997. I excluded these observations from analysis of habitat use. All remaining COARSE ground-based data (DAY) were pooled by season and analysed together.

The relative use of each habitat type by cattle was determined by proportion and standard error of proportion (Weimer 1987). Chi-square goodness-of-fit comparisons (Neu *et al.* 1974) were used to test if habitat use occurred randomly. In those cases where use was not random (i.e., use ≠ availability), Bonferroni simultaneous confidence intervals (Byers and Steinhorst 1984) were calculated to determine if the use was significantly more or less than expected. Because of the low use of Forest by cattle and the large proportion of the unit encompassed by this habitat type, chi-square analysis was performed excluding it, and therefore included only Meadow, Wet Edge, Dry Edge, and Clearcut habitat. Other was also excluded from the analysis.

I also used chi-square goodness-of-fit tests (Siegel and Castellan 1988) to investigate cattle activities within habitat types. For each year, I used group activities to determine the overall pattern of activity for cattle in terms of frequency of occurrence. I then used these frequencies of occurrence as the expected frequencies in a series of chi-square goodness-of-fit tests. I compared the expected and observed frequencies of activities for each of the 6 habitat types. When required, I conducted sub-divided chi-square analyses (Zar 1996) to determine which, if any, activity was predominant within a habitat type.

To meet the assumptions of the chi-square test, I grouped activities as Foraging and Non-Foraging for COARSE observations, and as Foraging, Resting, and Other for FINE observations. Foraging included browsing, drinking, grazing, taking salt; Resting included lying and standing; Other included eliminating, courting, copulating, nursing, other interactions, travelling, vigilance, vocalising, indeterminable, and all other activities including observations that were too 'mixed' to be either Foraging or Resting. I used chi-square tests of independence (Siegel and Castellan 1988) to determine if daily activities differed between adult females and young of the year (calves). No comparison could be made with activities of adult males because of small sample size.

To analyse the social organisation of cattle I calculated median group sizes and inter-animal distances for groups in each habitat type and activity. Medians were compared to the grand median using chi-square goodness-of-fit tests (Siegel and Castellan 1988). I also calculated typical group sizes (Jarman 1982) for groups in each habitat type and activity.

Layout of sampling points

Habitat factors (forage, biting insects, minerals) were sampled in 1997 on both sides of the range unit. Although the number of habitat types and frequency of sampling differed among the factors discussed in this chapter (Table 2), a similar method was used in each case to establish the sampling points. For each factor, I purposively selected 3 replications of each habitat type to represent the East - West extent of the Unit and to facilitate access. In both EARLY and LATE seasons the areas investigated reflected the areas available to cattle. In each of the habitat replications, I systematically established 3 sampling points using a randomly located starting point (Cook and Stubbendieck 1986).

Table 2. Summary of sampling system used for insects, phenology, biomass, and minerals in the Robinson Unit, Williams Lake Forest District in 1997. Abbreviations include: MDW = Meadow, WE = Wet Edge, GL = Grassland, DE = Dry Edge, C = Clearcut, F = Forest, and O = Other.

Feature	Time of Sample	Habitats Sampled	Total No. of Samples
Insects	June-July[a]	MDW, WE, GL, DE, C, F	108
Insects	August-September[a]	MDW, WE, DE, C, F	120
Phenology	June 7	MDW, WE, GL, DE, C, F, O	105
Phenology	June 25	MDW, WE, GL, DE, C, F, O	63
Phenology	July 21	MDW, WE, GL, DE, C, F, O	63
Phenology	August 4	MDW, WE, DE, C, F, O	54
Phenology	September 2	MDW, WE, DE, C, F, O	54
Phenology	September 15	MDW, WE, DE, C, F, O	54
Biomass	June 25	MDW, WE, GL, DE, C, F, O	63
Biomass	August 4	MDW, WE, DE, C, F, O	54
Biomass	September 15	MDW, WE, DE, C, F, O	54
Soil	June 18	MDW, WE, GL, C, F, Crust[b]	54

[a] Two trapping attempts occurred during each of these time periods.
[b] Samples taken from surface crusts of soil.

Insects

Trap design was based on the Manitoba Fly Trap (Thorsteinson *et al.* 1965) and consisted of a black balloon inflated by mouth to a sphere of approximately 0.3 m in diameter. This shape and colour combination is highly attractive to tabanid species (Bracken *et al.* 1962). During each trapping attempt, I coated either 54 or 60 (Table 2) balloons with 'Stickem'® and secured them at a height of 1 m using stakes. Traps were left in place for 24 h. To ensure equal trapping time among stations, I collected the traps in the same order that they were established. I made several assumptions regarding the equal attractiveness of the traps in different habitats, assuming that differences such as lighting and temperature would not aversely affect trap success. Given these assumptions, the traps provided an index of insects among habitats at a given time. I conducted a trial trapping effort in late May 1997 to assess durability of balloons.

I counted trapped insects and identified them using a field guide (Borror and White 1970). Insects that I could not identify in the field were stored in 70% isopropyl alcohol, and later identified via dissecting microscopes using wing venation patterns (Borror and White 1970). I grouped insects into: Hymenoptera, Diptera (including Tabanidae and Simuliidae), Mosquitoes, Midges, and Other. Tabanidae, Simuliidae, and Mosquitoes were further grouped as 'biting insects', because they were thought to be the greatest potential pests to cattle.

Anti-pest activities by cattle

I assessed the level of insect harassment by observing a randomly selected adult female and recording the frequency of characteristic pest avoidance activities, such as head shakes, tail swishing, and leg stamping (Ralley *et al.* 1993). These observations were made for 1 h periods (4 times/day) during long-term daylight tracking. The 4 periods of the day were approximately: 0600-1000, 1000-1400, 1400-1800, and 1800-2000, and changed to reflect changes in day length over the course of the study. The observations were associated with whichever habitat the animal occupied at the time.

Phenological stages

At each sampling point, I visually estimated the percent ground cover, between the heights of 0-0.25 m and > 0.25-1.5 m in a 1-m^2 plot, for various classes: grass, sedge, rushes, forbs, water, moss, lichen, shrub, tree, rock, debris, and bare ground. I also estimated the percent of vegetation in each phenological stage. Phenological stages were based on Dierschke's (1972) descriptions and were grouped (S. Hemphill, U.B.C., pers. comm. 1997) as follows: 1-shoots above ground, 2-leaves unfolding, 3-blossoms recognisable, 4-fully developed vegetatively, 5-flowering begun, 6-in bloom, 7-bearing fruit, 8-yellowing, 9-fruit/seed dispersal, and 10-dead. I later re-grouped these stages to facilitate statistical analysis; stages 1-4 were known as 'Vegetative', stages 5-7 as 'Flower', and stages 8-10 as 'Yellow'.

Biomass sampling

After I estimated the phenological stages, I clipped the 1-m^2 plot to ground level using hand clippers. I clipped on 3 occasions, but no plot was clipped twice. When necessary, I established a new plot next to the initial plot. Grasses, sedges, reeds, and forbs were clipped as well as the current annual growth (CAG) of shrubs. I observed cattle consuming these types of vegetation during the 1996 field season. I did not clip moss and lichen but did clip other plants such as clover. Noxious species, were also sampled because they were available to cattle. Although browsing on trees was not observed during the 1996 season, such activity was noted in 1997. I sampled deciduous trees within plots for CAG below a height of 1.5 m (assumed maximum cattle browse height).

Sorting of biomass samples

Plant clippings were placed in airtight, labelled plastic bags and were frozen. I sorted clippings from late June 1997 by plant type (grass, sedge, forb, rush, deciduous shrub, coniferous shrub and other) and by year of growth. Because cattle are known to select current year's growth (Kauffman *et al.* 1983, Senft *et al.* 1985b), I retained growth from 1997, but not litter. Because of time constraints, I sorted August and September samples by year of growth only.

Determination of biomass by weight

Samples were dried to constant weight at 60 °C, then weighed to the nearest 0.01 g to determine available biomass. June 1997 weights were used to determine total and edible biomass, while samples from later periods were used to determine only total biomass. Total biomass was defined as all 1997 vegetation collected, and Edible biomass was defined as Total biomass minus the biomass of coniferous shrubs. Selected samples from Meadow and Clearcut, collected 25 June and 4 August 1997, were analysed for crude protein (CP) and acid detergent fibre (ADF) levels by M. Oryshack (1998).

Soil minerals

Soil pits were dug at each of the sampling points to determine rooting depth. Once this depth was determined, I gathered multiple soil cores to this depth, or to a maximum of 20 cm, using an Oakfield probe to obtain > 200 g of soil. Cores were air dried on brown paper and sieved to 2 mm. In 1996, white crust-like formations were noted on the soil in some grassland and meadow areas, and I decided to collect samples from these areas. Following the same sampling design, part of the crust material and some soil were scraped from the soil surface and treated the same as soil cores.

Norwest Labs (Vancouver, B.C.) analysed 18 samples, 3 from each of 6 habitat types (including crusts), for exchangeable calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) using an ammonium acetate extract and inductively coupled plasma (ICP) spectrometry with a 10% duplication rate. The high cost of commercial analysis prevented further determinations. Values are reported as millieqvialents (mEq) per 100g. The small number of samples analysed did not merit statistical analysis.

Statistical analyses

I used a Kruskal-Wallis one-way analysis of variance by ranks and a modified multiple comparison test (Siegel and Castellan 1988) to determine if significant differences ($P \leq 0.05$) in either total or biting insects occurred among habitat types during each season. I also used this test to determine if a significant difference ($P \leq 0.05$) existed in the frequency of avoidance activities shown by cattle, per 3-min interval (Ralley *et al.* 1993), among both habitat types and times of day.

I compared the median phenological stages among habitat types using a Kruskal-Wallis analysis of variance by ranks and a modified multiple comparison test (Siegel and Castellan 1988). A two way, Model I analysis of variance with replication (Zar 1996) was conducted on log transformed biomass data with habitat type and time being the two fixed factors. I then used a modified Tukey procedure for multiple comparisons (Zar 1996).

No significant difference ($P \leq 0.05$) in available biomass due to time was detected, so a more detailed analysis of 25 June 1997 biomass was conducted. Edible biomass (June) was compared among habitat types using a one way analysis of variance of log transformed data and a subsequent Tukey test (Zar 1996).

RESULTS

Availability of habitats

Forest was the most available habitat type in the study area, accounting for about 75% of the area in both sub-units. In descending order of area, other habitats available were Clearcuts, Wet Edge, Dry Edge, Meadow, and Other (Table 3). Forest was a contiguous habitat within which the other habitats were relatively widely and patchily distributed. A notable exception to this pattern was Clearcut habitat; the cuts were large and often contiguous, although of different ages.

Table 3. Habitat types available to cattle in the Robinson Unit, Williams Lake Forest District. Percent of total area is shown in parentheses.

	Amount of Habitat Available (km^2)					
Total Area (km^2)	Meadow	Wet Edge	Dry Edge	Clearcut	Forest	Other
Early Season 66.87	2.94 (4.40)	2.46 (3.68)	2.55 (3.81)	6.71 (10.03)	50.68 (75.79)	1.53 (2.29)
Late Season 116.85	2.73 (2.34)	4.69 (4.01)	3.72 (3.18)	16.21 (13.87)	88.07 (75.37)	1.43 (1.22)
Combined 183.73	5.67 (3.09)	7.15 (3.89)	6.27 (3.41)	22.92 (12.48)	138.75 (75.52)	2.96 (1.61)

Relative use of habitats

Cattle were most commonly (98.1%, n = 592) found in non-forested habitats in the Robinson Unit (Figure 4). Forest was used on only 11 occasions (1.9%). Cattle used different habitat types at different times of the day ($P \leq 0.05$). During early morning aerial observations (n = 116) cattle were primarily in Meadow (36%) and Wet Edge (34%) habitats whereas Dry Edge habitat accounted for only 16% of the observed use. When feeding during the early morning, cattle were infrequently found in either Clearcut (8%) or Other (5%). In contrast to this pattern detected from the air, observations during the entire daylight period on the ground (n = 476) showed that overall, cattle were most often in Dry Edge (36%). Other areas used by cattle during the daylight period included Meadow (21%), Wet Edge (17%), Clearcut (17%), and Other (8%).

Use and availability

Cattle did not use the Robinson unit randomly ($P < 0.001$). During AM observations (Figure 5) they used Meadow and Wet Edge almost twice as often as expected, based on the available area. In LATE 1997, use of Meadow was almost 4 times the expected level. While involved in early morning foraging, cattle used Dry Edge in proportion to its availability, but made less than expected use of Clearcut.

Results from ground sampling were different than those from aerial surveys. DAY data (Figure 6) show that cattle used Dry Edge more than expected, but only used riparian habitats (Meadow and Wet Edge) in approximate proportion to their availability. Cattle used Clearcut less than expected during the day.

Differences between seasons

Although seasonal differences in habitat type use were not specifically tested, the following descriptive differences are worth noting. In the 1996 DAY sample, cattle use of Wet Edge decreased (from 18 to 9%) between EARLY and LATE seasons. This corresponded to an increase in cattle use of Clearcut habitat (from 16 to 25%). However, in the 1997 DAY data, this pattern of use was reversed, with cattle use of Clearcut decreasing (from 23 to 2%) and use of Wet Edge increasing (from 21 to 39%). Also in 1997, aerial surveys showed an increase in cattle use of both Meadow (from 35 to 44%) and Dry Edge (from 13 to 22%), and a decrease in use of Clearcut (from 13 to 2%) and Wet Edge (from 40 to 33%) between seasons.

Time of activity

Based on long-term daylight tracking, cattle concentrated their foraging activity in early morning and late evening (Figure 7), with an average of 40% of daylight spent foraging. This pattern, justified the use and timing of aerial observations. Because the long-term daylight tracking periods were not on the same days each year, I believe the differences in patterns can be explained by differences in length of daylight and climatic conditions (Krysl and Hess 1993).

Activities within habitats

Cattle did not perform activities with the same frequency in all habitats. During early morning aerial surveys, cattle used Meadow as expected ($P > 0.5$) but foraged more than expected in Wet Edge ($P < 0.05$) and less than expected in all other areas ($P < 0.005$) (Figure 8). Different

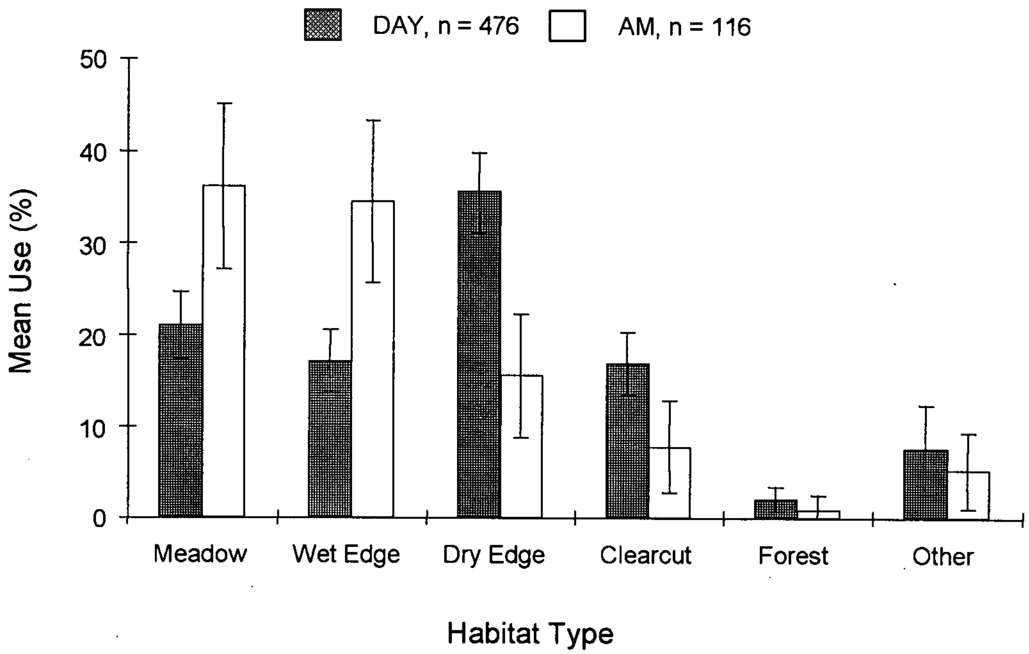

Figure 4. Relative (%) mean habitat use by cattle (± 2 standard errors of percentage), determined from 476 daylight and 116 early morning (AM) observations made during 1996 and 1997 in the Robinson Unit, Williams Lake Forest District.

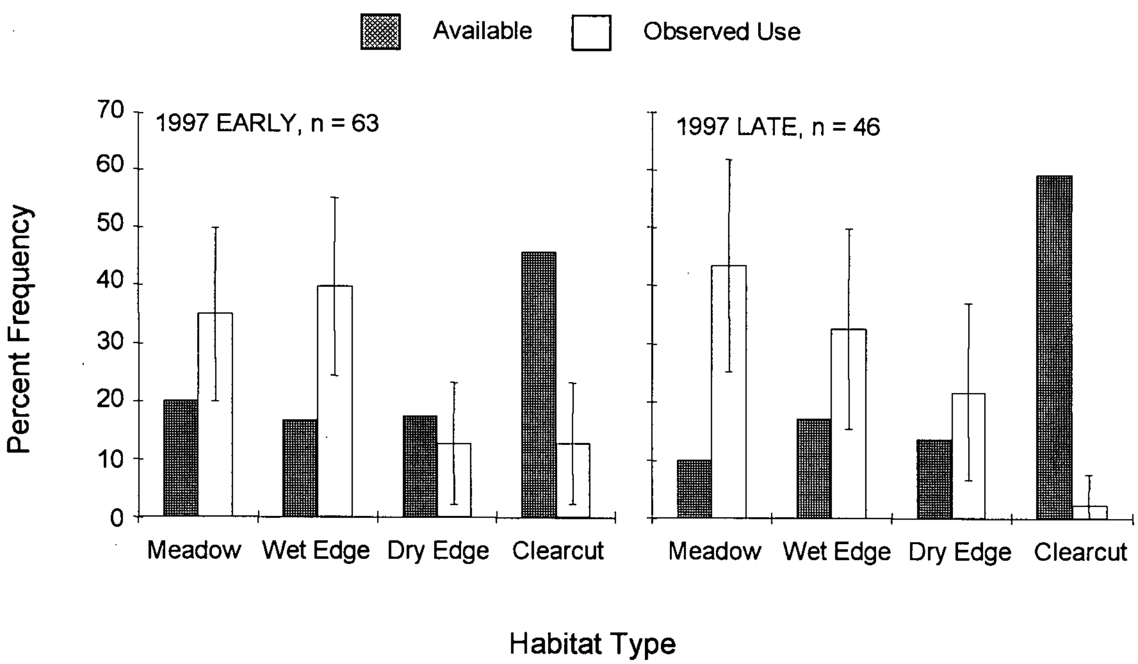

Figure 5. Percent frequency of habitat availability and use by cattle in the Robinson Unit, Williams Lake Forest District for early morning (AM) aerial observations, 1997. Shown by season and year with 95% Bonferroni simultaneous confidence intervals.

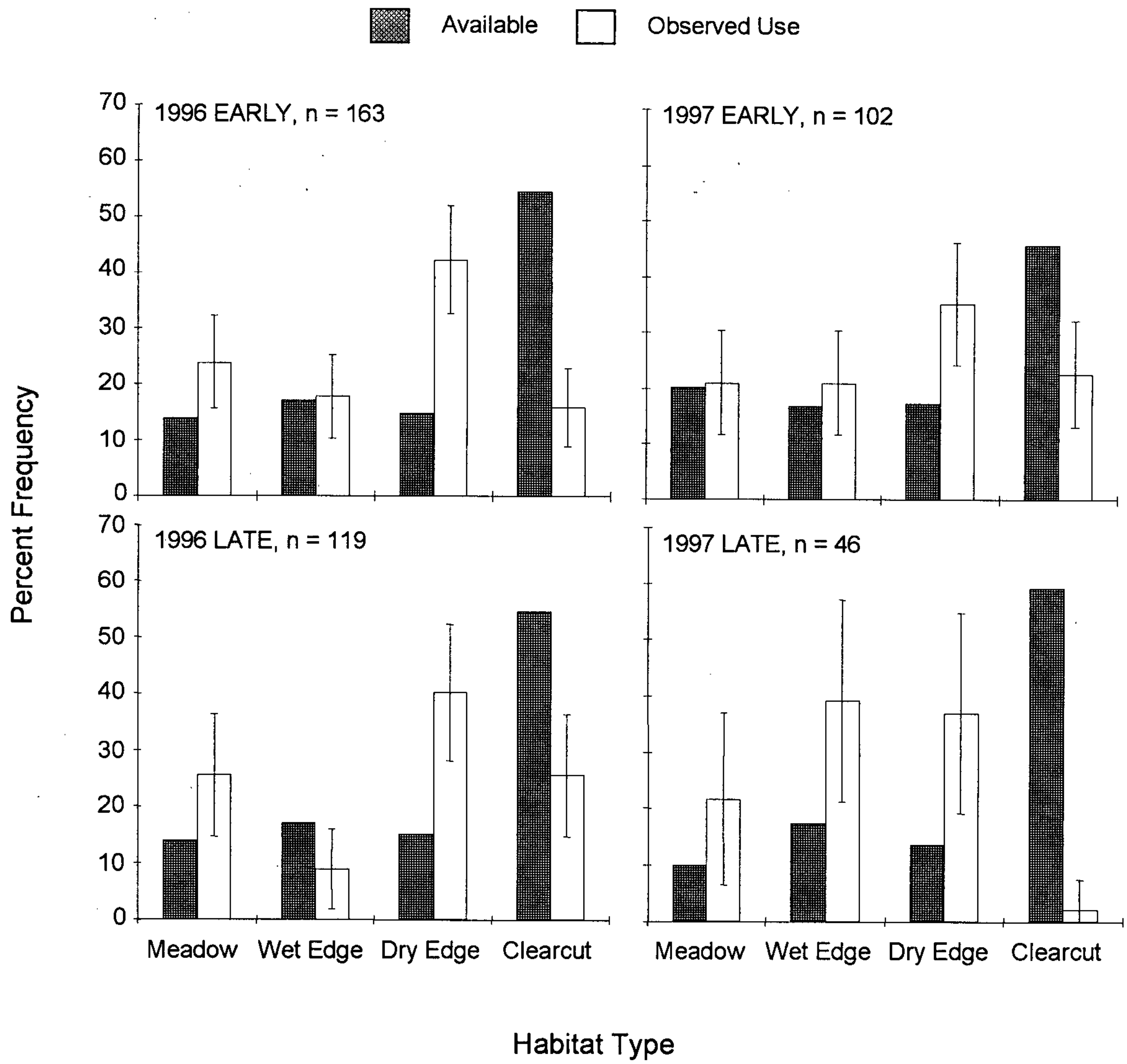

Figure 6. Percent frequency of habitat availability and use by cattle in the Robinson Unit, Williams Lake Forest District for DAY observations. Shown by season and year with 95% Bonferroni simultaneous confidence intervals.

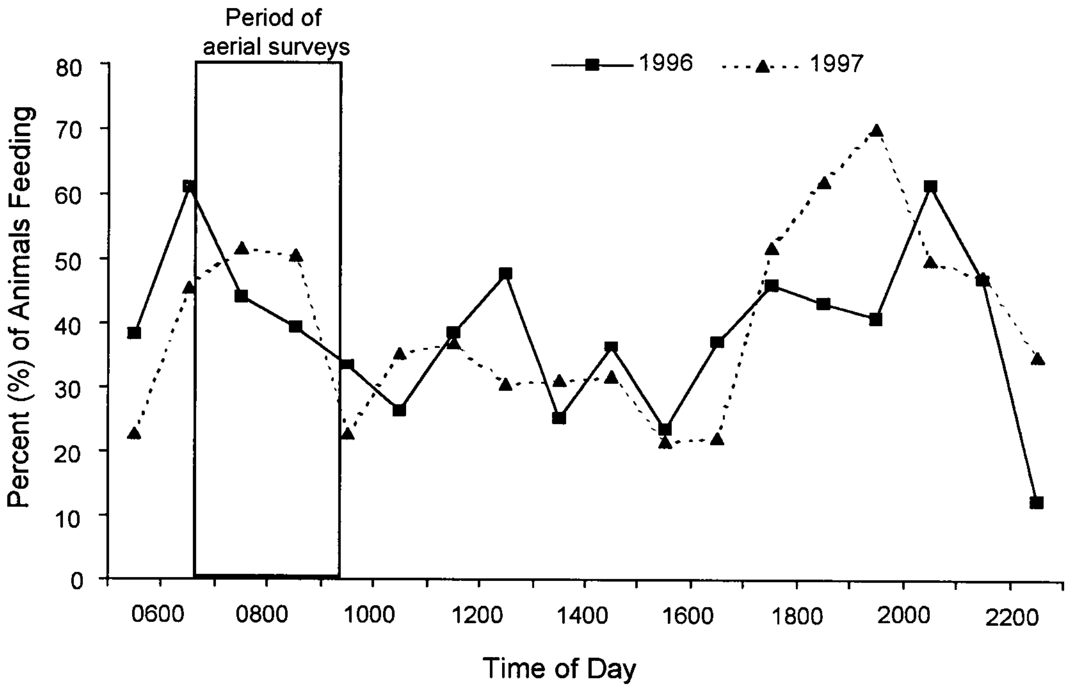

Figure 7. Percent of observed animals foraging by hour of day in the Robinson Unit, Williams Lake Forest District. 1996 data based on 8 long-term daylight tracking periods, with an approximate total of 28 group observations per hour. 1997 data based on 7 long-term daylight periods with an approximate total of 20 group observations per hour. Timing of aerial survey changed with sunrise between June and late September 1997.

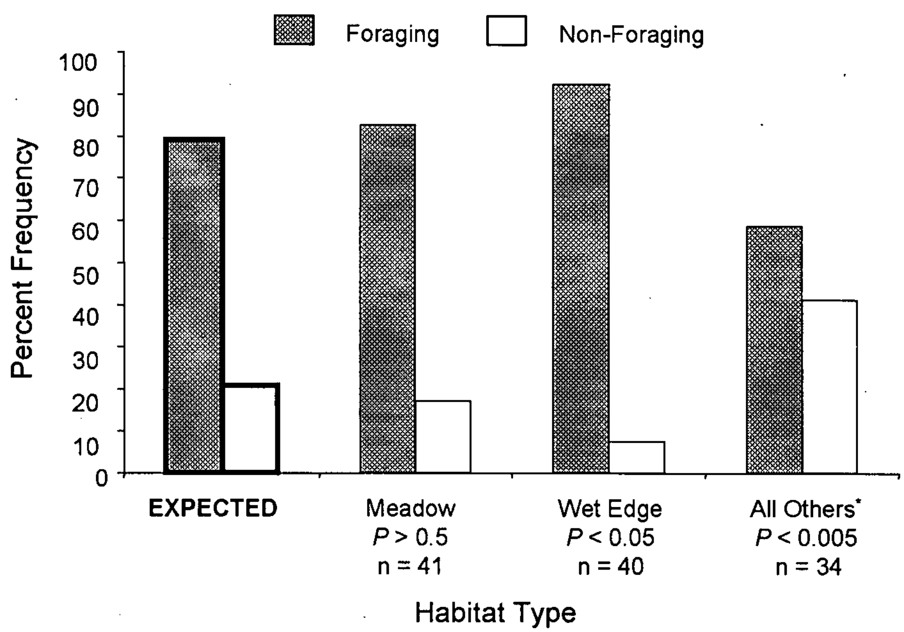

Figure 8. Comparison of expected and observed cattle activities within habitat types based on 115 early morning (AM) observations in the Robinson Unit, Williams Lake Forest District, 1997. All Others* includes Dry Edge, Clearcut, Forest and Other.

frequencies of activities were seen between AM and DAY observations ($P < 0.001$), with cattle spending more time foraging in early morning (79%) than during the entire day (< 50%).

Over the course of the entire daylight period, cattle foraged in Clearcut and Other as expected in both 1996 (Figure 9a) and 1997 (Figure 10a). However, cattle in Meadow foraged more than expected ($P < 0.05$), and those in Dry Edge and Forest foraged less than expected ($P < 0.025$). Cattle foraged in Wet Edge as expected in 1996, but in 1997, they foraged more than expected ($P < 0.01$). Long-term daylight tracking allowed for a more detailed examination of cattle activities within each habitat type (Figures 9b and 10b) and the results were consistent with the patterns reported above.

Travelling

Straight line measurements during long-term daylight tracking enabled me to determine the minimum distance travelled by a group of cattle over 24 hours. This distance ranged from 1.1 to 7.2 km (n = 16, mean = 3.4, SD = 1.8). It was noted, on several occasions, that animals travelled in a 'purposeful' (Pratt *et al.* 1986) manner between the last feeding site of the day and bedding site for the night.

Adults females and young of the year

During each year young of the year (calves) did not perform activities in the same frequencies as did adult females (Figure 11). Adult females spent more time foraging, and less time resting and performing other activities ($P < 0.001$) than did calves.

Group composition

Groups were predominantly composed of cow-calf pairs with a few sub-adult females. Adult males, while present in the study area were often encountered alone and were observed travelling between groups of females. There was one exception to this pattern, two males, about 3 years of age, that had been reared together, were often seen travelling together in the study area. Although not specifically investigated, it was noted that the groups were not static social units.

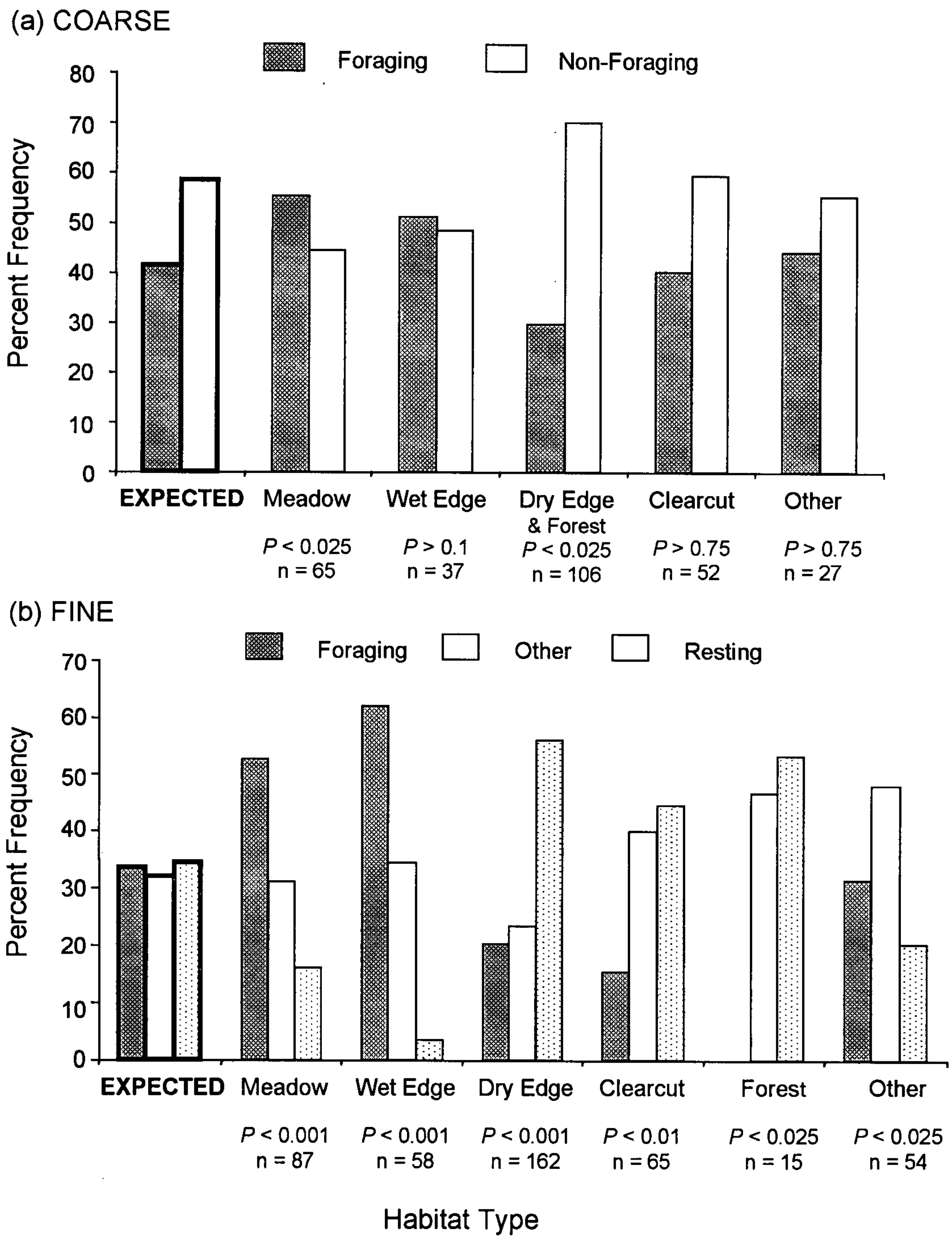

Figure 9. Comparison of expected and observed behaviours within each habitat type for (a) COARSE and (b) FINE observations, made in theRobinson Unit, Williams Lake Forest District in 1996. Sample size and results of chi-square analysis are presented, habitat types were occasionally grouped to meet assumptions of the test. * Indicates that no difference was found in sub-divided chi-square analysis.

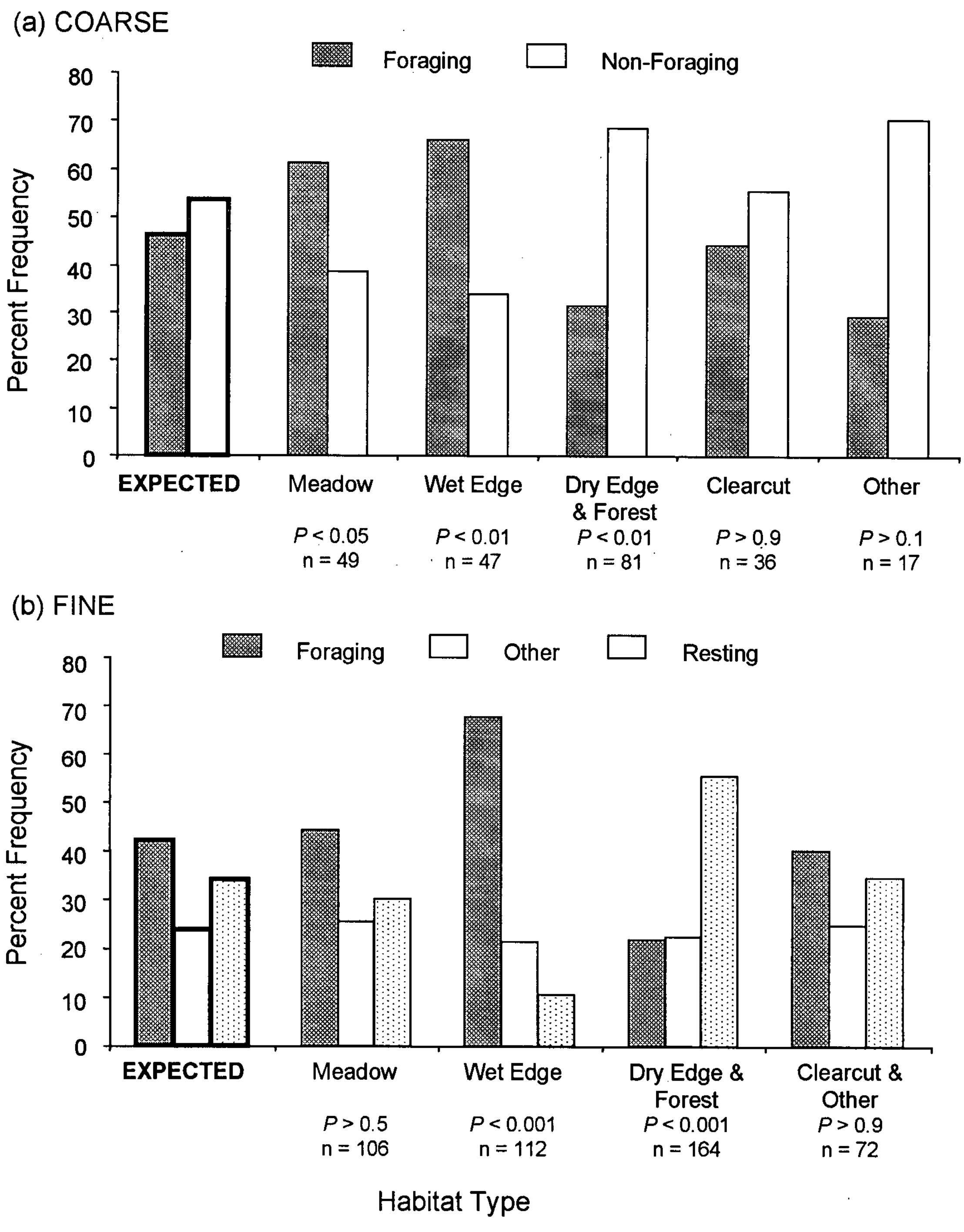

Figure 10. Comparison of expected and observed behaviours within each habitat type for (a) COARSE and (b) FINE observations, made in the Robinson Unit, Williams Lake Forest District in 1997. Sample size and results of chi-square analysis are presented, habitat types were occasionally grouped to meet assumptions of the test. * Indicates that no difference was found in sub-divided chi-square analysis.

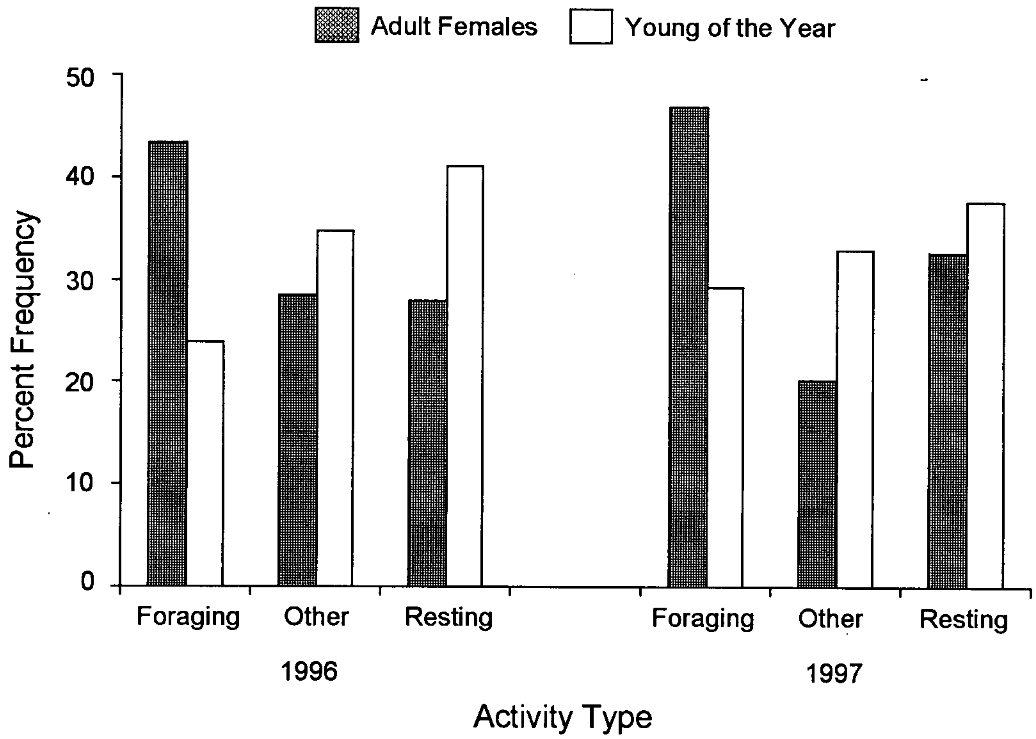

Figure 11. Percent of day spent in each of three activities by adult females and young of the year in the Robinson Unit, Williams Lake Forest District. A significant difference ($P < 0.001$) was found in activity ratios for each year. Based on 532 observations of adult females and 492 of calves in 1996,and 444 observations of adults and 402 observations of calves in 1997.

Group size

Group size ranged from 1 to 76 in 1996 and 1 to 92 in 1997. I suspected, but was unable to confirm, that the largest groups were actually aggregations of smaller groups. Aggregations could have formed naturally or, more likely, have been the result of gathering management by G. Puhallo. Median group sizes were highest while cattle were resting ($P < 0.025$) (Table 4). In 1996, cattle formed the largest groups ($P < 0.05$) in Dry Edge and Forest habitat, however, in 1997 no difference occurred among habitats.

Typical group sizes ranged from 15 animals in Clearcut to 31 animals in Other in 1996, but in 1997 the smallest group (15) were found in Forest and the largest (38) in Clearcut (Table 4). In 1996, cattle formed the smallest typical groups while foraging (20) and the largest (24) while resting. In 1997, cattle were in the smallest groups when performing other activities (23) and in the largest (28) when foraging. The gathering of groups for herding or other purposes may have resulted in artificially large typical group sizes.

Table 4. Group sizes among habitat and activity types in the Robinson Unit, Williams Lake Forest District.

	1996				1997			
	n	Mean	Median	Typical Group Size	n	Mean	Median	Typical Group Size
Foraging	116	14	10	28	200	10	7	20
Resting	110	17	13	26	91	14	10	24
Other activity	65	11	8	23	58	11	8	22
Meadow	65	15	12	25	90	12	8	23
Wet Edge	38	13	10	25	87	11	7	25
Dry Edge	106	16	12	25	98	11	9	16
Clearcut	51	15	7	38	45	10	9	15
Forest	4	7	3	15	6	9	6	16
Other areas	27	12	6	26	23	14	8	31
Overall	**291**	**15**	**10**	**27**	**349**	**11**	**9**	**21**

Inter-animal distance

Animals were closest together while they were Resting (Table 5). In both 1996 and 1997 the median inter-animal distance was less ($P < 0.001$) than the grand median, and less than the medians found for groups involved in Foraging and Other activities. No difference in inter-animal distance was found among habitat types in 1996 ($P > 0.25$). However, in 1997, a significant ($P <$

0.001) difference was found (Table 5) with cattle in Dry Edge and Other grouped closely together but cattle in Meadow and Wet Edge spread out.

Table 5. Median inter-animal distances, in animal lengths, among habitat and activity types in the Robinson Unit, Williams Lake Forest District.

	1996		1997	
	n	Median	n	Median
Foraging	112	2.00	104	1.96
Resting	106	1.33	74	0.91
Other activity	63	2.00	41	2.00
Meadow	62	2.00	46	2.11
Wet Edge	37	2.36	45	2.22
Dry Edge & Forest	109	1.65	77	1.17
Clearcut	50	1.67	33	1.82
Other areas	25	2.00	18	0.70
Overall	**283**[a]	**2.00**	**219**	**1.67**

[a] For activities overall n = 281.

Insects

In both EARLY and LATE seasons, the number of all insects caught differed among habitat types ($P < 0.05$) (Table 6), but the number of biting insects differed only among habitats during the LATE season ($P < 0.05$). The fewest insects (all and biting) were trapped in Clearcuts (Table 6). Although the relative number of insects trapped in other habitat types fluctuated, Wet Edge was consistently among the habitats with the highest number of insects (all and biting).

Less than 40 observations of insect avoidance activities were of sufficient length (10 min of uninterrupted visual contact) to be analysed. No difference in frequency of insect avoidance activities (0-12.79 per 3 min interval) was detected among either time of day ($P = 0.36$, n = 36) or habitat type ($P = 0.59$, n = 35). None of the group responses to insect harassment observed by Ralley *et al.* (1993) were seen during my study.

Table 6. Percent of insects (all species and biting species) trapped among habitat types in the Robinson Unit, Williams Lake Forest District in 1997. Shown by trapping period, no traps were set in Grassland areas in August-September.

Habitat Type	June-July 1997, n = 108		August-September 1997, n = 120	
	All Species Sum = 1887	Biting Species Sum = 162	All Species Sum = 1251	Biting Species Sum = 178
Meadow	38.10 [a]	9.88 [c]	19.10 [ef]	12.36 [gh]
Wet Edge	20.72 [ab]	29.63 [c]	23.10 [e]	28.09 [g]
Grassland	9.59 [ab]	16.67 [c]	NA	NA
Dry Edge	15.79 [ab]	20.99 [c]	22.86 [e]	21.35 [gh]
Clearcut	4.29 [b]	5.56 [c]	8.63 [ef]	3.37 [h]
Forest	11.50 [ab]	17.28 [c]	26.30 [e]	34.83 [g]

[a,b...] Percents followed by the same letter in each column were not significantly different ($P < 0.05$).
NA indicates habitat was unavailable to cattle at the time and a test was not applicable.

Phenological stage

Predominant phenological stages were equal among habitat types early and very late, in the grazing season (Table 7). During August and September, habitats characterised by tree overstories (Forest, Dry Edge, and Wet Edge) were less phenologically advanced ($P < 0.005$) than and those habitats without tree canopies (Clearcut, Meadow, and Other) (Table 7).

Table 7. Median predominant phenological stage among habitat types on 6 occasions during the 1997 grazing season in the Robinson Unit, Williams Lake Forest District.

Sampling Date	Habitat Types						
	Meadow	Wet Edge	Grassland	Dry Edge	Clearcut	Forest	Other
June 7	Vegetative[a]	Vegetative[a]	Vegetative[a]	Vegetative[a]	Vegetative[a]	Vegetative[a]	Vegetative[a]
June 25	Vegetative[b]	Vegetative[b]	Flower[b]	Vegetative[b]	Vegetative[b]	Vegetative[b]	Flower[b]
July 21	Flower[c]	Flower[c]	Flower[c]	Vegetative[c]	Vegetative[c]	Vegetative[c]	Flower[c]
August 4	Yellow[d]	Flower[de]	NA	Vegetative[e]	Yellow[de]	Flower[de]	Yellow[e]
Sept. 2	Yellow[fg]	Yellow[fg]	NA	Yellow[fg]	Yellow[fg]	Vegetative[f]	Yellow[g]
Sept. 15	Yellow[h]	Yellow[h]	NA	Yellow[h]	Yellow[h]	Yellow[h]	Yellow[h]

[a,b...] Phenological stages followed by the same letter in each row were not significantly different ($P < 0.005$).
NA indicates habitat was unavailable to cattle at the time and a test was not applicable.

Biomass

Biomass varied with habitat type ($P < 0.001$) but not with time ($P = 0.08$) (Figure 12). No interaction was found between habitat type and time ($P = 0.383$). Wet Edge and Meadow were the most productive habitat types. When edible biomass was compared among habitat types, Grassland, Wet Edge, and Meadow were equally productive and produced more ($P < 0.001$) than other areas. Forests provided the least edible biomass.

Biomass in Meadow was composed almost exclusively of sedge and rush species, and biomass in Wet Edge was composed of native grasses, rushes, and deciduous shrubs. Grassland, Dry Edge, Clearcut and Other areas were dominated by grasses and forbs. Grasses in Other areas (e.g. road sides and old skid trails) were presumed to be a result of seeding. Edible biomass in Forest was composed primarily of pinegrass and deciduous shrubs.

Soil minerals

In general, Forest and Clearcut had low levels of exchangeable cations and Grassland and Crust had high levels. Results for Meadow and Wet Edge, notably Shrub-Carr, were mixed. Exchangeable Ca ranged from 3.5 mEq/100 g in Forest to 79.6 mEq/100 g in Meadow (Figure 13). Exchangeable Mg varied between 1 mEq/100 g in Forest and 70.9 mEq/100 g in Crust. Exchangeable Na varied between undetectable levels (< 0.1 mEq/100 g) in Clearcut and Forest and 80.6 mEq/100 g in Crust. Finally, exchangeable K varied between undetectable levels (< 0.1 mEq/100 g) in Meadow to 4.47 mEq/100 g in Crust.

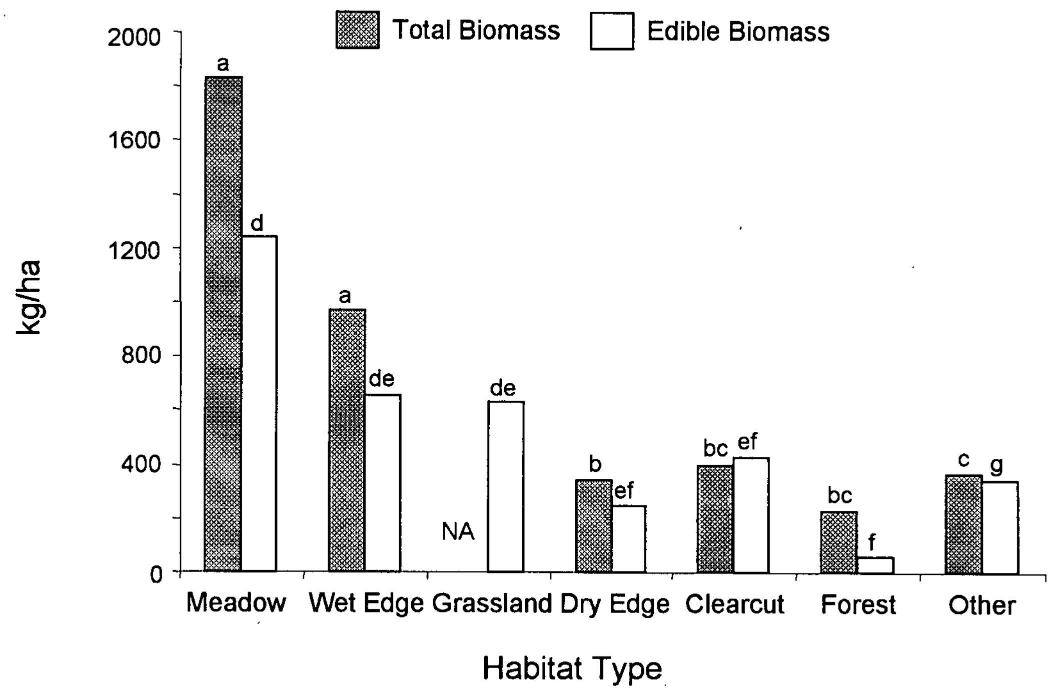

Figure 12. Mean biomass, kg/ha, (Total, n = 162, and Edible, n = 63) produced during 1997 in each habitat in the Robinson Unit, Williams Lake Forest District. Comparisons were made within each series, any means indicated by same letter were not significantly different ($P < 0.001$). NA indicates that this value was not determined.

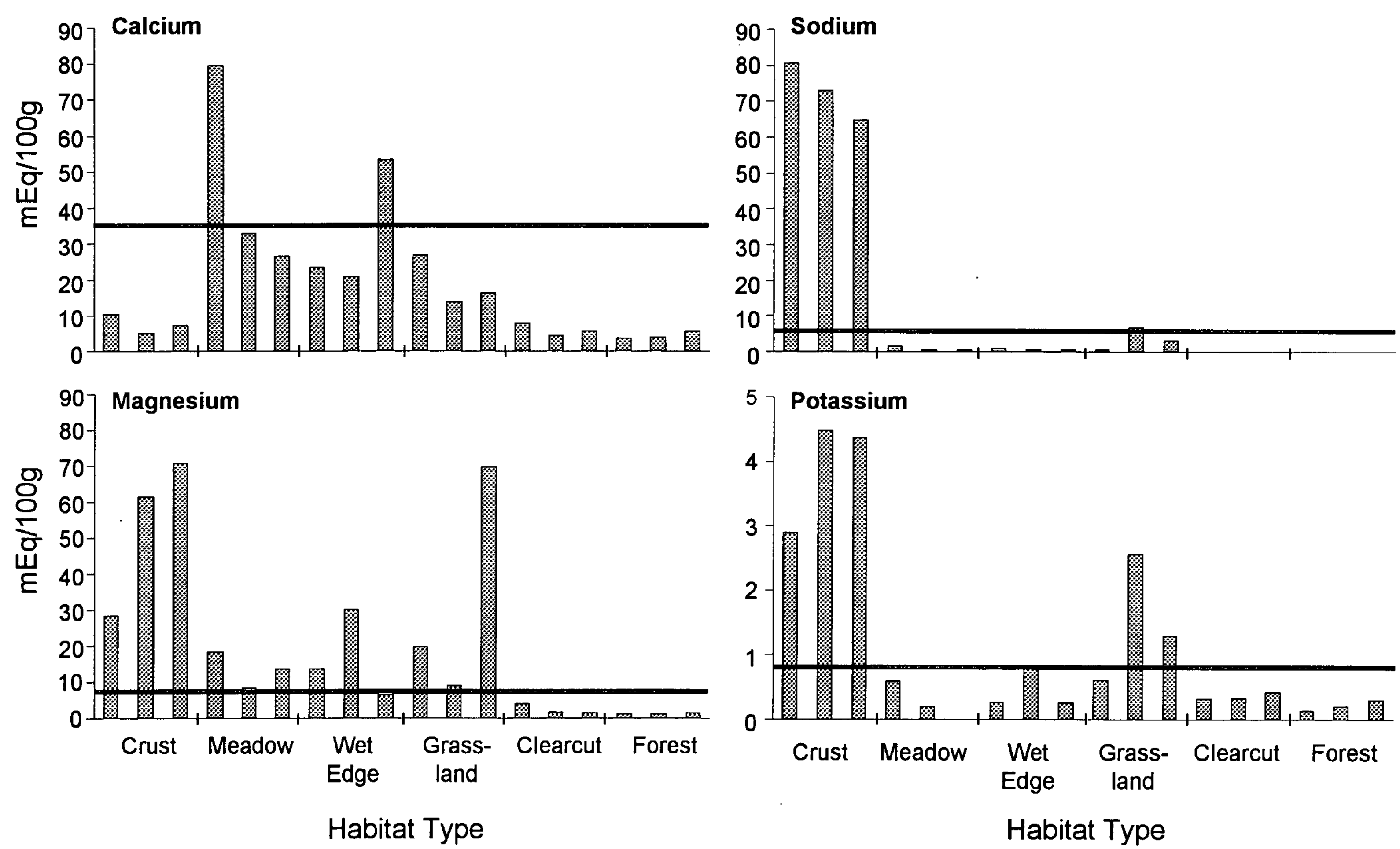

Figure 13. Milliequivalents (mEq/100g) of exchangeable cations sampled from various habitats in the Robinson Unit, Williams Lake Forest District. The horizontal bar in each graph indicates the mean concentration of each cation in mineral licks used by wild ungulates in Western North America (n = 80) (Jones and Hanson 1985). Crust indicates samples scraped from the soil surface. Minimum levels detectable in mEq/100g were: calcium 0.05, magnesium 0.05, sodium 0.05, and potassium 0.1.

DISCUSSION

Cattle concentrated in the open habitats (Meadow, Wet Edge, Dry Edge, and Clearcut) of the study area. During early morning foraging, they were often in riparian areas, while at other times of day they were frequently found in non-riparian areas. Cattle use of edges (Wet and Dry) accounted for > 50% of observed use. At no time did cattle use of Clearcut equal its availability. These findings support the alternate hypothesis that cattle use of the unit is not random.

Cattle did not perform activities with the same frequency in all habitats, nor did calves and adult females perform activities for the same length of time. These findings support my second and third alternate hypotheses. The alternate hypothesis that habitat factors (insects, phenology, biomass, and soil minerals) would differ among habitat types was also supported. However, only differences in biomass and soil minerals appear to be associated with the observed pattern of cattle habitat use. The findings summarised above support my contention that habitat factors and activities affect cattle use of available habitat types.

Forest habitat

Much of B.C. rangeland is forested, but in my study cattle made little use of Forest. The disproportionately high use of open habitats by the cattle has been reported in two previous studies in B.C. (McLean and Willms 1977, Preston 1984), and in other forested areas (Gillen *et al.* 1984, Tanner *et al.* 1984, Howery *et al.* 1996, Howery *et al.* 1998). Although Forest received little use, cattle regularly travelled through it. Cattle are known to travel to preferred habitat types (Roath and Krueger 1982a), and locations (Compton and Brundage 1971, Senft *et al.* 1985a, Pratt *et al.* 1986). In my study, cattle travelled through a large contiguous habitat (Forest) to reach and use, smaller and more dispersed habitat types. This movement, often over several kilometres, suggests that cattle had some spatial memory (Bailey *et al.* 1989a, Bailey *et al.* 1989b, Gillingham and Bunnell 1989) of the study area, and that the smaller and more dispersed habitat types were preferred to Forest. It is also possible that cattle, which were introduced into the area in 1995, learned to associate movement along existing trails with access to preferred resources. Trail construction (Vallentine 1989) and the removal of obstacles (Bailey and Rittenhouse 1989) have been suggested as means to improve cattle distribution.

In the Robinson Unit cattle formed small groups, subdivisions of the herd, perhaps to make use of the small and patchy habitats (DeMiguel *et al.* 1997). This may occur because cattle on the Robinson Unit did not have as much access to large, contiguous, open areas as did animals in other studies e.g., Pratt *et al.* (1986). The groups I observed did not appear to be socially static, and this may, in part, be due to the gentle terrain of the study area. In steep areas, groups have been reported to be more permanent (Roath and Krueger 1982a) because of the difficulty travelling in such areas (Coughenour 1991). The relatively gentle terrain of the Robinson Unit may also explain that, while cattle used easy travel routes such as logging roads (Roath and Krueger 1982a) and skid trails, they were not restricted to them. The cattle were also able to travel overland, through habitats such as Forest.

Of the factors I compared among habitat types, Forest did not appear to offer many resources to cattle. Forest could not be considered potential refuge from biting insects, nor could it be considered an abundant source of edible biomass or natural minerals. Forest contained some of the least mature, and presumably most palatable, vegetation but even this resource was not associated with use. This lack of use may occur because much of the available forage was pinegrass, a species that is considered to have limited attractiveness to cattle (Agriculture Canada 1979).

Riparian habitat

In contrast to Forest, riparian habitat types (Meadow and Wet Edge) in the study area received high levels of use. The high use of Meadow and Wet Edge, the two most productive habitats, during early morning foraging periods suggests a strong link between habitat factors and the habitat use. The concentration of cattle in riparian areas is a commonly reported pattern in utilisation studies (Kauffman *et al.* 1983, Green and Kauffman 1995, Howery *et al.* 1996), and is related habitat utilisation to the abundance of high quality forage (Kauffman *et al.* 1983, Pinchak *et al.* 1991, Smith *et al.* 1992, DeMiguel *et al.* 1997). Riparian habitats are very productive, containing large amounts of palatable forage (Kauffman *et al.* 1983, Marlow and Pogacnik 1986) and the riparian habitats in the Robinson Unit were no exception. Not only did Meadow exhibit high production, but it also contained plants such as sedges which form in dense stands allowing for efficient foraging.

If the assumption (Neuman *et al.* 1995) that grazing animals are most at risk of being preyed on while feeding then grazers should minimise the time spent foraging or forage in relatively large groups. In my study, cattle foraged in small groups (Table 4), this may have been necessary for them to exploit small areas such as Meadow (DeMiguel *et al.* 1997). Because the animals were in smaller groups, they would have experienced greater predation risk than those in larger groups (Hamilton 1971). This higher predation risk may have been tolerated by cattle because they could increase their efficiency in foraging. Cattle, which are large ruminants, should be able to reduce predation risk by quickly ingesting large amounts of abundant, possibly low quality, food (Underwood 1983, Illius and Gordon 1990). In my study, the proportion of day spent foraging (< 50%) was lower than values reported in other studies (Gillen *et al.* 1985, Pinchak *et al.* 1991). It is possible that cattle in this study were more efficient in terms of foraging because of the dense biomass available (Alden and Whittaker 1970) in Meadow.

In general, the importance of riparian areas as a forage source can decrease in temperate regions as the grazing season progresses. Removal of riparian biomass by herbivores, late season precipitation, and the subsequent re-growth of grasses, have been associated with increased use of upland areas late in the grazing season (Bryant 1982, Roath and Krueger 1982a, Marlow and Pogacnik 1986, Pinchak *et al.* 1991). My data showed that the disproportionate early morning use of Meadow increased late in 1997, indicating that riparian areas continued to provide a higher quantity of forage than did other habitats (Kauffman *et al.* 1983, Marlow and Pogacnik 1986). It is unlikely that the riparian areas continued to provide higher forage quality late in the season because of the forage's advanced phenological stage. If cattle were indeed seeking higher quality forage, it may explain the shift in use from Wet to Dry Edge seen in LATE 1997 AM observations. Cattle tend to increase their consumption of forbs (McLean *et al.* 1963), shrubs, and deciduous trees (Low *et al.* 1981, Roath and Krueger 1982b) as the grazing season progresses.

Another explanation for the continued use of Meadow could be that more meadow area became available to cattle as ephemerally flooded areas dried up. Cattle and other ungulates avoid flooded areas (Duncan 1983, Tanner *et al.* 1984, Wallisdervries 1996), utilising areas in inverse proportion to surface moisture (Clary and Booth 1993). This avoidance may be related to ease of movement and their reliance on flight behaviour to avoid predation. The risk of predation may have affected the cattle's use of habitat types, but the risk of biting insects did not appear to affect their use of Wet Edge, although these areas contained some of the highest numbers of these pests.

Duncan (1983) reported that tabanids were not the main determinant in the selection of feeding areas by horses, but areas with high tabanid density were avoided when flies were very active. A second behavioural approach to feeding in areas with high insect densities would be to have a faster feeding rate and consume more in each bite (Dougherty *et al.* 1994). It is possible that the concentrated use of the riparian areas, with their dense sedge stands, by cattle during morning foraging periods was linked to such strategies.

Although insects were not a driving factor in use at the habitat type level, it is possible that the presence of biting insects may have affected cattle use of specific sites. Anecdotal reports from 1996 suggested that a particular Meadow-Wet Edge complex contained many biting insects and was seldom used by cattle (G. Puhallo, pers. comm. 1996). Consistent use of this area by cattle could not be induced during the 1996 season even though the producer repeatedly herded cattle and provided salt at the site. However, during the 1997 season, cattle were often located in this same complex, suggesting that the importance of insects as a limiting factor may vary among years.

As reported above, provision of salt did not always result in the desired habitat use by cattle (G. Puhallo, pers. comm. 1996), and availability of natural mineral sources may be one reason for this. Riparian habitat types (Meadow and Wet Edge) had the highest detected levels of soil minerals, including crusts. Because of the grouping of habitat types required in the analysis, Grassland was grouped with Meadow. The mineral rich crusts sampled were located in Grassland, but visually similar crusts were found in Meadow and Wet Edge.

Although the source of crusts is unknown, the levels of minerals in them are, with the exception of Ca, similar to those found in Grassland soils. Grassland was the habitat where crusts were most commonly located. High Na values have been associated with urine patches which cattle have been known to lick (Wallisdervries 1996). Cattle also show preference for forage produced on these urine patches (Arnold and Dudzinski 1978). Although the crusts were high in exchangeable Na, the large surface areas of the crusts (some encompassed many square metres) make urine an unlikely source.

Jones and Hanson (1985) reported direct consumption of soil by cattle, this same behaviour was noted even when NaCl supplementation was provided (Wallisdervries 1996). Because of this tendency, and because mineral content of forage is directly related to soil mineral levels (McNaughton 1990), cattle distribution in the Robinson Unit may in part be explained by the presence of locally mineral rich areas, as reported for wild ungulates (McNaughton 1988, McNaughton 1990). If this is the case, it can be assumed that salting will not be a highly effective management tool (Richmond 1980) in the Robinson Unit.

Edge habitats

The pattern of habitat type use I detected in DAY observations differs from those commonly associated with cattle (Howery *et al.* 1996, Howery *et al.* 1998). The main difference was the high percent use of Dry Edge. Many studies do not report cattle use of edges separately from their use of other areas, or even the availability of these areas. Common habitat type groupings used include: riparian, upland steppe, and upland forest (Howery *et al.* 1998), channel, floodplain, and upland (Smith *et al.* 1992), or simply riparian and upland (Bryant 1982, Pinchak *et al.* 1991, Howery *et al.* 1996). Of the studies that used other habitat groupings, very few considered the availability of edges to cattle.

Both Preston (1984) and Tanner *et al.* (1984) found that edges were available, and that cattle demonstrated a preference for them. The importance of such transitional habitat types to cattle is evident if we consider that aurochs (*Bos primigenius*), the direct ancestor of European cattle (Zeuner 1963), lived in open forests, scrub-lands, and meadows (Clutton-Brock 1981, Nowak 1991). Other Bos species, notably the gaur (*B. gaurus*), banteng (*B. javanicus*), and kouprey (*B. sauveli*), while more distantly related to *B. taurus* than are aurochs, have also been reported to make use of edges to varying degrees (Schaller 1967, Halder 1976, Nowak 1991). The high overall use of edges by cattle (53%), the disproportionate use of Dry Edge, and the similarity of range in B.C. to ancestral habitat (Watson 1986) suggest that the value of these transitional areas in forested range units needs to be recognised and incorporated into management.

Dry Edge and Dry Edge/Forest were used for non-foraging activities, primarily resting. This activity/habitat combination allowed for the formation of large groups, or possibly aggregations, in which the animals were close together. The ability of animals to group can provide increased security from predation through dilution, increased vigilance, and interference (Hamilton 1971, Underwood 1982). Security can also be increased by being in proximity to an 'escape subcomponent' (Lima and Dill 1990). For animals, like cattle, that rely on flight and possibly group defence to avoid predation, using transitional areas for resting allowed them to be in close proximity to open ground, an 'escape subcomponent', and some degree of cover. Two cattle-predator encounters observed during my study involved such uses of open areas.

In addition to anti-predator benefits, use of both Wet and Dry Edges, may have allowed for the maintenance of mother-young bonds. Because adult females forage more and rest less than do calves, it would benefit each pair to use areas that facilitate these different activities, or, that were in close proximity to other areas that did. Edges provide such areas. Because it has been shown (Peterson and Woolfolk 1955) that calves are found in the same general location as adult cattle, it would be expected that edges would be used frequently - Wet Edge by foraging adults and the adjacent Dry Edge by resting calves. My findings suggest that cattle social organisation, predation risk, and the resources of physical space and habitat arrangement, may all play a role in determining their use of habitat types.

Clearcut habitat

Although use of Clearcut was low, cattle were more frequently found in them than in the more dense forest stands. This was also observed in Oregon (Gillen *et al.* 1984) and California (Kie and Boroski 1996). Even the relatively low number of biting insects found in Clearcut did not appear to encourage use of this habitat. The failure of cattle to use Clearcut as a refuge (Keiper and Berger 1983, Toupin *et al.* 1996) from biting insects and the lack of distinct anti-pest activity again suggests that insect harassment was not an important factor during my study.

In the Robinson Unit, Clearcut did not provide large amounts of biomass to cattle, but the available forage matured at the same rate as other habitats that received more use. The decreased use of Clearcut and increased use of Wet Edge in LATE 1997, a high precipitation year, does not fit the phenological data nor the growth model proposed by Bryant (1982). However, it does agree with the general decreased preference for Clearcut over time reported by Gillen *et al.* (1984). With the exception of landings and roadways, little evidence of grass seeding was seen in clearcuts in the Robinson Unit. Gillen *et al.* (1984) did note higher utilisation of clearcuts in areas that contained stands of introduced palatable grasses.

Like Forest, Clearcut soils did not contain abundant exchangeable cations. The similarity in cation levels detected in Clearcut and Forest soils was not surprising because burning, which can modify soil, has not been extensively used as a silvicultural prescription in this area.

Although cattle used Clearcut less than expected, it is interesting to note that while they were in Clearcut and Clearcut/Other habitat types they did not perform particular activities in frequencies that differed from expected. This was very different from behaviour that was exhibited in riparian areas and Dry Edge. The tendency of cattle to use Clearcut for activities as expected may be important for managers. If increased use of Clearcut were a management goal, managers would have no need to direct their efforts at overcoming natural activity patterns. Instead, they could simply focus their efforts on encouraging the desired activity.

If the proposed 5-year forest harvest plan is carried out in the study area, the amount of available Clearcut will increase from 12.5% to > 20%, with a corresponding decrease in Forest (G. Puhallo, pers. comm. 1998). Based on the results in this study, cattle use could be predicted in these new cut-blocks but the use would probably not reflect the area available. If increased use of Clearcut was an accepted goal in the study area and the Forest District, some form of management such as grass seeding or other specific developments (e.g., structures, trails, and water sources) could be beneficial. To be useful, any such range developments should reflect the habitat factors needed or desired by cattle.

CHAPTER 3

HABITAT VARIABLES ASSOCIATED WITH CATTLE ACTIVITIES

INTRODUCTION

Patterns of use of habitat types exhibited by cattle can lead to conflict among resource users and reduced efficiency for producers. Cattle on the Robinson Unit used different habitats for different activities. This pattern of use appeared to be associated with forage availability and the presence of natural mineral sources. These variables are among a variety that are known to affect the spatial distribution of animals (Coughenour 1991).

The distribution of range cattle is affected by climatic conditions (Marlow and Pogacnik 1986), temperature (Ehrenreich and Bjugstad 1966), availability of water and type of vegetation (Roath and Krueger 1982a, Kie and Boroski 1996), degree and length of slope (Gillen *et al.* 1984, Mueggler 1965), and distance to water (Valentine 1947). This variety of factors shows the importance of measuring more than a few habitat variables when considering the many requirements of animals and that no one factor should be used as a reliable index to predict cattle use of habitats (Clary *et al.* 1978, Cook 1966).

To predict and/or alter habitat use by cattle, it is important to identify which habitat variables they need or prefer. These requirements and preferences can be determined by investigating sites used by cattle. It is also important to identify those available variables that are of little or no consequence to the animals. Knowing which variables are important and which are not allows managers to focus their efforts.

It is important to investigate many habitat variables at once (Cook 1966). However, if conventional statistics were used with a large number of variables, a large number of tests would be required. This approach would be cumbersome and risk simultaneous inference because all data used would be from the same sites (Beal and Khamis 1991). It is more efficient, statistically and practically, to use a multivariate approach. Multivariate analyses involve analyses using a number of variables measured for several samples (Sokal and Rohlf 1969). In the case of habitat resources, this involves sampling the variables of interest in many sites used by the subject animals.

As is the case with many aspects of range use in B.C., little formal work has been done to identify variables that are important to cattle. This is particularly true of the Chilcotin region.

Because little work had been done no suitable hypotheses were available to test. Instead, I used a hypothesis generating approach. The objectives of this portion of my study were to determine: 1) which habitat variables were associated with specific cattle behaviours and 2) which habitat variables showed no clear association with either cattle presence or a specific cattle activity.

METHODS

After cattle were located and scan sampled (see Chapter 2), the site occupied by cattle was marked. After cattle had left the area, I re-visited the site and conducted a site investigation following the methods in Higgins *et al.* (1996) and Litvaitis *et al.* (1996).

Investigation of activity sites

I centred circular 0.04-ha plots within each site to reflect a single habitat type. The numbers of trees (≥ 1.5 m) and shrubs (< 1.5 m) in each plot were counted. The height of 1.5 m was equated with the shoulder height of cattle. Next, I determined the predominant aspect, percent slope, site position, microtopography, and drainage of the plot. If the distance from the centre of the plot to water was < 100 m, I measured it directly, otherwise it was determined using 1:15,000 aerial photographs. I did the same to determine distances to salt blocks and roads.

I then established a transect equivalent to the radius of each plot (11.28 m) in a randomly selected direction (150°) from the centre of the plot. I travelled this transect and recorded the number of obstacles along it. An obstacle was defined as any object > 0.45 m tall and/or > 0.45 m wide. I assessed visibility by determining how much of a marked cover pole, held at the end of the transect, was visible to an observer at the centre of the plot looking at a height of about 1.25 m. I recorded the diameter at breast height (DBH) of trees encountered (any part of stem) on the transect. Percent and type of ground cover ≤ 1.5 m and 'crown cover' > 1.5 m were recorded in five 1-m^2 subplots evenly distributed along each transect.

Categories and habitat variables

Data collected during site investigations included both qualitative and quantitative variables and to analyse them, I established qualitative classes for each variable (Table 8). I then arranged the data by the cattle activity (e.g. Grazing, Standing, Travelling) recorded at the site and used a contingency table composed of rows of cattle activities and columns of habitat variables to conduct correspondence analysis (CA). Because I used the time between the 1996 and 1997 to refine my methods, some of the factors assessed differ slightly between years. Hence I will focus on the 1997 results.

Table 8. Classes of habitat variables and cattle activities used in 1996 and 1997 correspondence analyses (CA).

Habitat Variables			Cattle Activity
1996 and 1997	1996 Only	1997 Only	1996 and 1997
0 Trees per 100 m^2	0% Slope	Crest-Midslope	Browsing
1-10 Trees per 100 m^2	1-9% Slope	Lower Slope-Toe	Grazing
11-30 Trees per 100 m^2	10-18% Slope	Level-Depression	Interacting [b]
> 30 Trees per 100 m^2	> 18% Slope	Rapid-Well Drained	Lying
0 Shrubs per 100 m^2	Wind	Moderately Drained	Mixed Activities [b]
1-10 Shrubs per 100 m^2	No Wind	Poor-Very Poorly Drained	Resting
11-30 Shrubs per 100 m^2	Rain	Wind 0 kmp	Standing
> 30 Shrubs per 100 m^2	No Rain	Wind < 3.22 kph	Travelling
North Aspect		Wind > 3.22 kph	Salting [c]
East Aspect		No Cloud	
South Aspect		Light Cloud	
West Aspect		Moderate-Heavy Cloud	
No Aspect			
0 Obstacles per 11.28 m			
1 Obstacle per 11.28 m			
> 1 Obstacle per 11.28 m			
0% Visibility			
1-45% Visibility			
46-91% Visibility			
92-100% Visibility			
0% Shade			
1-25% Shade			
26-75% Shade			
76-100% Shade [a]			
0–50 m to Salt Block			
51-100 m to Salt Block			
101-500 m to Salt Block			
> 500 m to Salt Block			
0-50 m to Road			
51-100 m to Road			
101-500 m to Road			
> 500 m to Road			
0-50 m to Water			
51-100 m to Water			
101–500 m to Water			
> 500 m to Water			
Temperature < 10°C			
Temperature 11-20°C			
Temperature > 20°C			

[a] Recorded in both 1996 and 1997, but not used in 1996 CA because it appeared as an aberrant point.
[b] These 2 activities were grouped in 1996.
[c] Salting was excluded because of obligatory association with "0-50m to Salt Block", which interfered with the interpretation.

Correspondence analysis (CA)

While I stated that a multivariate approach would be superior to a univariate approach, some multivariate analyses are difficult to use with ecological data. The difficulties arise because many tests rely on interval data and involve assumptions of normal distributions and linear relationships between variables (Beardall *et al.* 1984). Such linear relationships often do not exist between behaviours and ecological variables (Senft *et al.* 1983). Some analyses, including correspondence analysis (CA), do not rely on these assumptions. The only assumption involved in CA is that the data used are non-negative (Beardall *et al.* 1984). Correspondence analysis is a multivariate ordination technique similar to principal component analysis (PCA) that provides both numeric and graphical output (Ben-Shahar and Skinner 1988). One of the differences between CA and PCA is that CA is a non-parametric method that can use nominal and ordinal data (Ben-Shahar and Skinner 1988, Montaña and Greig-Smith 1990).

Greenacre (1981) described CA as "a technique for displaying the rows and columns of a 2-way contingency table as points in corresponding low-dimensional space". Each cell in the contingency table represents the number of times the row variable and column variable have been recorded together (DeMiguel *et al.* 1997). Correspondence analysis can then be used to describe "ecological affinities" between variables (Beardall *et al.* 1984). It is important to note that the relationships described reflect associations between variables, and not cause and effect (Ben-Shahar and Skinner 1988).

Correspondence analysis has been used in ecological studies to determine which habitat variables are associated with the presence/absence of a species at a series of specific sites (Hill 1974, Greenacre and Vrba 1984, Ben-Shahar and Skinner 1988, Montaña and Greig-Smith 1990). DeMiguel *et al.* (1997) demonstrated that this technique could also be used when activity classes replaced species, and that CA can be used without considering individual sampling sites.

I used a FORTRAN based program provided by M. Rodriguez (DeMiguel *et al.* 1997) to conduct CA. The program structure limited the contingency table size to 51 columns and approximately 36 rows. Because of this limitation, I did not include percent ground cover and microtopography in the analysis. The ground cover data set was too large for the program. I indexed ground cover at each site after cattle had left the area, and therefore it is difficult to say whether the ground cover was a product of cattle presence or if it was a habitat variable required or preferred by cattle. I had originally incorporated microtopography in the CA, but found that almost all sites investigated fell into a single microtopography class, indicating that microtopography would not be associated with a specific activity. Because of the limited capacity of the program, I chose to ignore microtopography. The program I used, like other CA programs, is composed of 3 basic steps.

CA steps

In the first step, the relative frequencies (profiles) of each row and column in the contingency table are weighted by their average profiles and displayed in multidimensional space resulting in 2 clouds of points (Beardall *et al.* 1984). These clouds, which are superimposed, are defined by the masses and vectors of the points, as well as by the masses of the clouds' centroids. The second step, is to define the metric structure of the cloud of points (Greenacre and Vrba 1984) using a chi-square metric to define the distances among points and centroids. The final step, is to fit the cloud of points to a lower dimensional space using principal axes. Principal axes are constructed within the superimposed cloud using the points and centroids.

The first principal axis is placed so that it accounts for the greatest variance within the cloud. All subsequent axes are placed such that they 1) are at 90 degrees to the previous axis, and 2) account for the next greatest level of variance. Using these axes allows the data to be viewed in lower dimensional space, which in turn allows the researcher to see how relatively close the points are. In lower dimensional space, the centroid of the multidimensional cloud becomes the origin of the axis. Even in the lower dimensional representation, data points retain their "true relative positions" (Greenacre and Vrba 1984) from higher dimensional space. It is important to note that the axes incorporate relative distances only. As a result, no unit of measurement is included in the displays. Once the axes are defined, the CA is complete and can be interpreted.

Interpretation of CA

While several authors report using CA in their work, few report the details of methods used in interpreting the results. Correspondence analysis yields numeric and graphic output, and both must be used in the interpretation. Interpretation of CA has been questioned because of its subjective nature, so care must be taken (Beardall *et al.* 1984). One way to reduce subjectivity, is to use the numerical output to define the boundaries of interpretation.

Interpretation of numerical output

Numerical outputs used include: 1) eigen-values indicating how much variance each axis accounts for; 2) absolute contributions (AC) which indicate the influence of each point on the orientation of each axis; and 3) relative contributions (RC) which indicate how closely each point is correlated to each axis. Following DeMiguel *et al.* (1997), the first 3 principal axes were used in interpretation, and only variables that had AC values > 2.0 for at least one axis were considered.

Absolute contributions of every point were used to determine which axis they most influenced and the scale of that influence. The point(s) with the highest AC are said to dominate the axis (Beardall *et al.* 1984). Relative contributions of every point were used to determine the point's quality, where quality is defined as the sum of the two highest RCs (Beardall *et al.* 1984). Determining these contributions is necessary to facilitate interpretation of graphical output.

Interpreting graphical output

The 1-dimension projection of each axis was interpreted with respect to AC values. It is possible to identify which variables are contrasted on each axis. Often, an axis is dominated by ecological gradients (Montaña and Greig-Smith 1990) such as moisture regime or soil condition. Once the dominant variables of each axis were determined, the axes were combined and interpreted in a series of 2-dimensional representations.

Each 2-dimensional projection was interpreted with respect to RC values. Each point is interpreted in the projection (axis 1 vs. axis 2, axis 1 vs. axis 3, and axis 2 vs. axis 3) in which its quality is highest. Two-dimensional projections of points were used to identify associations among habitat variables, and between habitat variables and animal activity classes. Because a 2-dimensional projection is an approximate representation of how the points are arranged in multidimensional space, it is not the absolute distance between points that describes their association, but the relative distance. The relative distance between 2 points can be indexed by finding the angle that results when lines are drawn from the origin to each of the points (Beardall *et al.* 1984). The smaller the angle, the more strongly the variables are correlated (Beardall *et al.* 1984). It is important to note that in CA, each consecutive axis accounts for less variability and so the strength of each 2-dimensional representation changes; axis 1 vs. axis 2 is the strongest, axis 1 vs. axis 3 is moderate, and axis 2 vs. axis 3 is the weakest.

RESULTS

A total of 583 activity sites were investigated and used in the CA, 256 in 1996, and 327 in 1997. In the 1997 CA, the first three axes accounted for a total of 72% of the total variance: 45, 14, and 13% respectively. The moisture regime dominated the first axis, shrub density the second, and climatic conditions the third (Figures 14 and 15). The first axis contrasted Grazing and Standing activities and the second, Lying and Resting against Browsing. Less common behaviours including Travelling and Interacting were associated with the third axis with no apparent contrast. I will focus my attention on the most prevalent activities, those involving foraging and resting. Factors that were associated with cattle presence were grouped by activity (Figures 14 and 15).

Grazing cattle were strongly associated with factors pertaining to soil moisture (drainage, free water, low site position) and related factors such as low densities of trees. Browsing cattle were associated with moderate shrub and tree densities, proximity to salt blocks and to a lesser extent higher site positions and cooler temperatures (Figure 14). These two foraging activities were contrasted against one another on the second axis, which was dominated by shrub densities. Browsing was the only cattle activity associated with higher shrub densities.

Grazing was also contrasted, along the first axis, against the resting behaviours, Lying and Standing, which were closely associated. Lying and Standing were associated with shade resources, high visibility, dry substrates, and close proximity to roads (Figures 14 and 15). Even though weather conditions were reflected in the third 2-dimensional projection, few associations were possible because of their weakness. However, Resting activities were associated with higher temperature (11-20°C) and > 3.22 kph winds.

Although I focused on foraging and resting activities, I will also discuss Travelling. As previously mentioned, cattle used Forest for travelling. Cattle when travelling were associated most with moderate shrub and tree densities and also with moderate proximity to supplemental salt. Travel activity was moderately associated with close proximity to roads, which suggests that cattle made use of easy travel routes when available.

Variables not associated with specific cattle actives, either because of low AC values (Table 9) or simply because of lack of association, can be grouped into 6 general categories: aspect, climatic conditions, poor visibility, moderate to long distances to roads and salt blocks, and obstacles. In my description of how the CA was conducted, I mentioned that microtopography was excluded because almost all the data points fell into a single class. In all

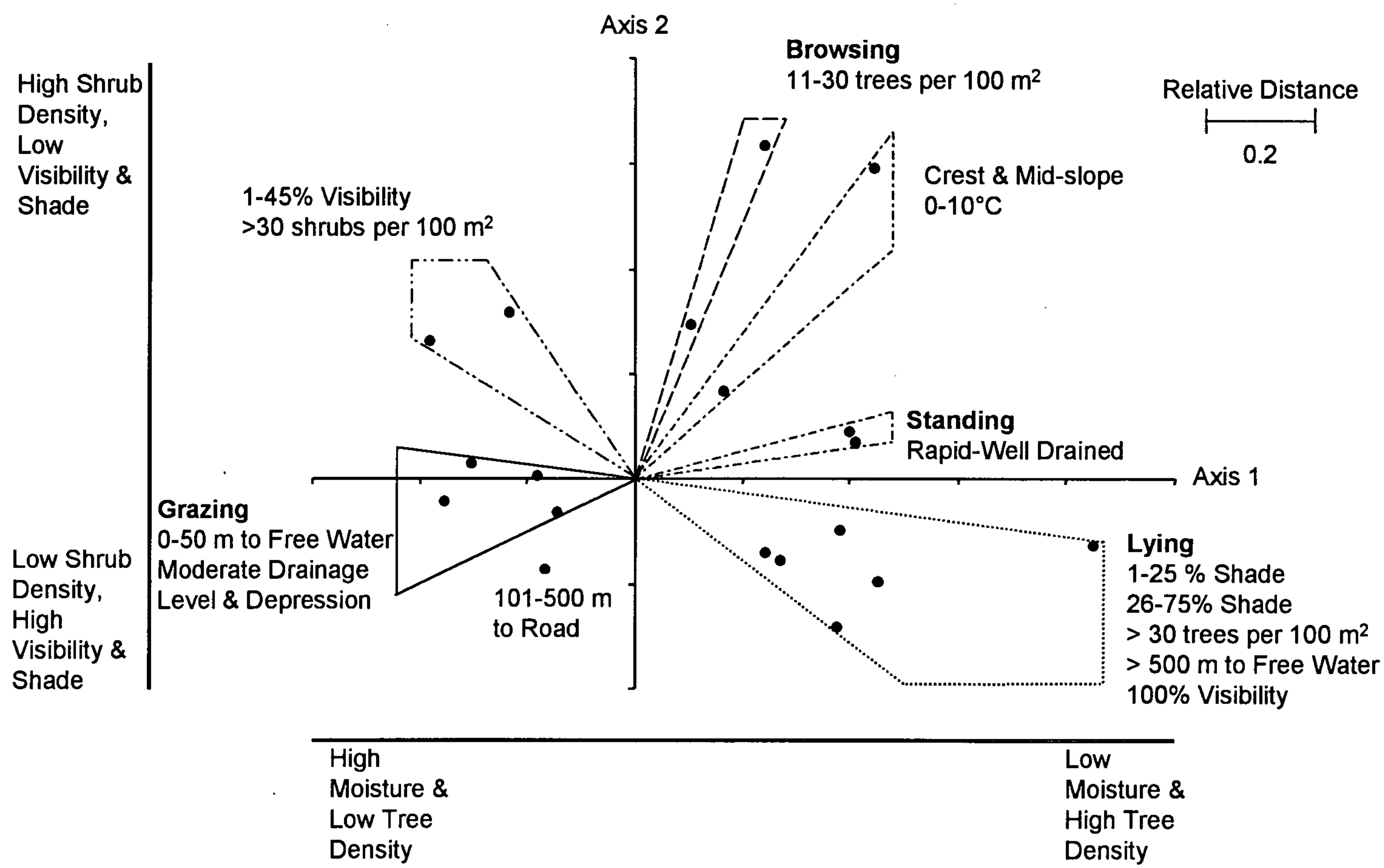

Figure 14. Projection of 1997 cattle activities and habitat variables onto the plane of the first and second principal axes. Activities and variables are shown in groups of strongest association and activities are listed in bold type. Variables which dominate the individual axes are also shown.

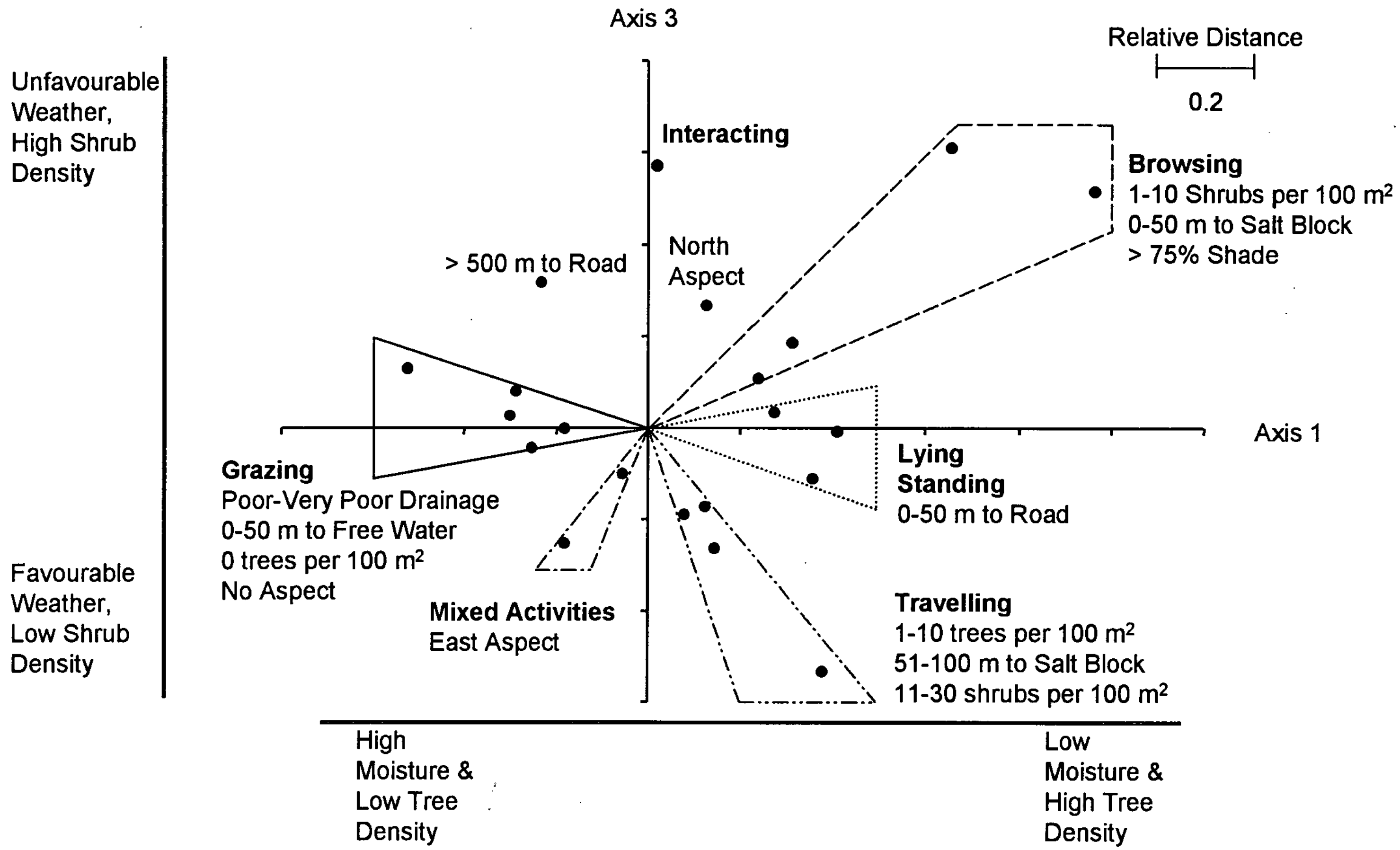

Figure 15. Projection of 1997 cattle activities and habitat variables onto the plane of the first and third principal axes. Activities and variables are shown in groups of strongest association and activities are listed in bold type. Variables which dominate the individual axes are also shown.

activities, most animals were found in smooth to micromounded sites (Luttmerding *et al.* 1990). However, grazing animals were sometimes found in moderate to extremely mounded sites (Luttmerding *et al.* 1990).

Table 9. Variables with low (< 2.00) absolute contributions (AC) to the 1997 correspondence analysis. Each variable is shown with its highest AC value and the associated axis.

Variable	Highest AC	Axis
46-91% Visibility	1.84	2
0 Shrubs per 100 m^2	1.77	2
Wind < 3.22 kph	1.68	3
South Aspect	1.67	1
Temperature > 20°C	1.57	2
No Cloud	1.57	1
Lower Slope-Toe	1.53	1
0% Shade	1.41	1
101-500 m to Water	1.41	1
West Aspect	1.39	1
51-100 m to Road	0.97	2
0 Obstacles per 11.28 m	0.80	2
0% Visibility	0.77	2
Wind 0 kph	0.74	3
> 500 m to Salt Block	0.61	1
1 Obstacle per 11.28 m	0.38	3
101–500 m to Salt Block	0.26	2

Because some resources were measured/indexed differently in the 1996 and 1997 field seasons, I did not attempt direct comparisons between the results of the two CAs. However, similar trends in general resource association can be seen, particularly for feeding and resting activities, between the 1996 (Appendix A) and 1997 results.

DISCUSSION

Of all the variables investigated in this CA, those associated with the moisture regime were consistently among the most influential. The availability of water has received much attention in cattle distribution studies and is accepted as affecting habitat use by cattle (Roath and Krueger 1982a, Pinchak *et al.* 1991, Gillen *et al.* 1984, Howery *et al.* 1996, Howery *et al.* 1998). In some arid areas, it is considered to be the single most important factor affecting distribution (Pickup and Bastin 1997). The importance of water is commonly linked to its role as a nutrient, and as a factor affecting microclimates. It is also important to consider the role that water, both surface and ground, plays is in the development of plant communities and biomass production. Because habitat variables like water have many potential roles, it is important to not only to identify which variables are associated with animal use, but also what requirements the animals are trying to meet by using them.

Water resources (proximity to, and drainage) were strongly associated with Grazing (DeMiguel *et al.* 1997) not Resting activities, suggesting that the role of water in creation of favourable microclimates was not of prime importance. In those studies where this role of water was found to be important, riparian areas used for loafing or resting activities apparently contained the only shade available (Senft *et al.* 1985a, Smith *et al.* 1992), or in cases with no shade, access to free water which animals used to cool themselves via wallowing (Senft *et al.* 1985a). In the Robinson Unit, shade was available in non-riparian habitats. In another case, riparian areas were not found to provide more favourable microclimate (Gillen *et al.* 1985) than other habitats. I found no evidence to suggest that microclimate was the key reason for cattle grazing in proximity to water, but what about their requirements for water as a nutrient?

Cattle obviously need to ingest large quantities of water, but does the water in question need to be consumed as free water? I observed few ($n = 16$) instances of cattle drinking during this two year study, even during long-term daylight tracking. However, I did observe frequent consumption of forage that was either growing in open water, or in areas with water very near the soil surface. It is possible that these forage sources provided much of the animals' daily requirements for water. I found that cattle often fed in dense sedge meadows (see Chapter 2), and Clary and Booth (1993) showed that sedges in a mountain meadow community contained up to 75% moisture and that moisture was one of the factors influencing forage use.

The areas used by cattle for foraging in this study, Meadow and Wet Edge, are riparian areas. By their very definition, riparian areas are a direct product of moisture regimes. I suggest that the primary importance of these areas to cattle is not a more favourable microclimate, nor even the availability of free water, but that they provide the most abundant forage with a high moisture content. Access to such areas enables cattle to meet their food and water requirements efficiently.

In contrast to Grazing, Resting (Standing and Lying) actives were associated with dry substrates located far from free water or wet soils. It is possible that these dry sites provided cattle with an increased ability to flee from threats, comfort, and beneficial heat exchange. It is also possible that these two resources were simply associated with other resources desired or needed by cattle such as shade. Resting activities were associated with shade (DeMiguel *et al.* 1997), which in some cases has been shown to be very important in distribution and cattle gains (McIlvain and Shoop 1971, Pratt *et al.* 1986).

Within the study area, shade was often associated with lodgepole pine stands which flourish on dry soils. Because of the self pruning nature of lodgepole pine, few branches were present below 2 m, resulting in high visibility, a security benefit. It is interesting to note that no activity was associated with areas of 0% visibility. Resting was also associated with long distances to free water (> 500 m). This is in contrast to many studies that report that cattle were commonly found < 500 m from water (Hart *et al.* 1991, Pinchak *et al.* 1991, Kie and Boroski 1996). In my study area, free water was commonly found in only a part of a riparian area although the remainder of the area often had water close to the surface. Cattle may have travelled far from free water simply to find dry areas to rest.

As was seen earlier (Chapter 2), and in previous CA analysis (DeMiguel *et al.* 1997), much of the Resting activity occurred in Dry Edge areas, in moderate-to-large groups. According to theories of anti-predator behaviour, cattle would benefit from such groups through increased dilution and vigilance (Underwood 1982). It is possible that cattle were simply aggregating at select resting sites, but resting sites did not appear to be a limited resource within the study area.

Resting was associated with shaded areas, but also with warm temperatures and wind which may have reflected attempts to avoid biting insects (DeMiguel *et al.* 1997). Resting was one of the few activities associated with climatic conditions. While weather conditions have been shown to affect cattle behaviour (Ehrenreich and Bjugstad 1966, Krysl and Hess 1993), Malechek and Smith (1976) felt that such associations existed for given weather events and particular activities, and were generally not the case for activities and 'components of weather'. I found little association between climatic variables and cattle activity. This may be because the temperate climate of the area and time of year did not create the stressful conditions (winter or high temperatures) that have been associated with changes in cattle behaviour (Beaver and Olson 1997, DeMiguel *et al.* 1997, Krysl and Hess 1993).

The favourable climatic conditions and abundance of natural shade, may also explain why aspect did not show a clear association (McLean and Willms 1977, Roath and Krueger 1982a, Senft *et al.* 1985a) with cattle presence or activities, with the exception of Mixed activities. In addition to aspect, neither the presence nor absence of obstacles appeared to be associated with cattle activities or use of an area. The same can be said of microtopography. These findings suggest that debris present in Clearcut and Forest was not a deterrent to use of these areas, but, perhaps the lack of other resources was. Besides Resting, Browsing was the only other activity associated with climatic variables; in this case, with cool temperatures (< 10°C). Other work has showed that browsing increases as the season progresses (Roath and Krueger 1982b). As the grazing season progresses into the fall, both ambient temperatures and forage quality generally decreased.

Browsing was also associated, in both 1996 and 1997, with moderate-to-high site positions/percent slope. The depressed site positions and level ground of riparian areas were associated with Grazing, and low-to-moderate site positions/percent slope showed no clear associations. While slope has been shown to affect cattle behaviour (Mueggler 1965, Gillen *et al.* 1984), it did not appear to limit cattle in this case, perhaps because of the overall gentle topography of the area (Miller and Krueger 1976, Clary *et al.* 1978).

Gentle topography may be one reason why cattle were able to travel through habitats such as Forest. This did not preclude their use of roads, as seen by their use of Other areas and the moderate association between Travelling and proximity to roads. However, the overall importance of distance to roads appears to be low. A similar pattern was seen for salt blocks. Salt blocks may serve as an attractant to cattle at distances < 100 m, or when cattle are actively herded to them, but apparently not at longer distances. Cattle activities, with the exception of Salting, were not associated with proximity to salt blocks. This may be related to the presence of natural mineral sources in the study area. Although I did not measure use of natural sources of minerals, cattle did use areas with crusts more than expected. Similarly, I did not record direct consumption of soil, but consumption need not be direct because minerals would be obtained through plants and water. I did, however, observe digging by cattle, but I do not know whether this was an attempt to dislodge insects, use natural source minerals, or for another reason.

CHAPTER 4
RESEARCH AND MANAGEMENT RECOMMENDATIONS

Cattle, like other animals, use available areas to meet their requirements. Current range management in B.C. does not appear to be completely successful in terms of either production or protection, in altering this use. It is important that cattle activities, social organisation, and resource use be considered in the future management of both the range resources and cattle herds in this Province. Some specific recommendations include:

Land managers should decide if reductions in use of and impacts on riparian and other specific areas, justify the manipulation of cattle use of other habitat types. This is particularly true for clearcut areas, where the manipulation may involve either delayed planting of logged areas or acceptance of some level of seedling damage.

Undertake trials to determine if cattle use of clearcuts can be promoted. Cattle used the Clearcut habitat type less than expected throughout this study. While concerns of damage to tree seedlings by cattle do exist, clearcuts appear to be the one habitat in which cattle use could be encouraged through management. Because cattle were equally likely to forage, rest, or perform other activities in Clearcut, it is likely that managers can choose to promote any or all of these activities by altering the appropriate resources. Any such trials should be undertaken in co-operation with the forest industry and should include investigations on minimising tree seedling damage by cattle.

The role of trails in habitat use by cattle should be investigated. Cattle make use of both roadways and previously existing trails. It is possible that construction of new access routes or alteration of current trails could result in more uniform use of the unit and/or a particular habitat type. This could be particularly important for preferred, yet patchy, habitat types such as Meadow.

Incorporate cattle use of edges in planning range and other uses of Crown Land. These areas reflect the ancestral habitat of cattle, provide favourable combinations of resources, and are common in B.C. rangelands. Edge habitats have received little attention in range research, but were used more than expected in mine and other studies. Range researchers in B.C. are in a relatively unique position to investigate these habitat types further.

Findings from studies of riparian habitats made in other areas should be interpreted and applied with caution. In many cases, riparian areas present on B.C. rangeland are different from those in other areas such as the Western United States.

Maintain and strengthen the current guidelines in the Chilcotin, that AUMs be assigned in proportion to wetlands present in the unit. Of the resources compared among habitat types, forage biomass appeared to be associated with cattle use. Because foraging behaviour occurred predominantly in areas of the highest biomass, care should be taken to reflect this pattern in the assignment of AUMs within range units to avoid overstocking.

Consider cattle's requirement to avoid predation along with their associated behaviours, in range management and research. Although the risk of predation is probably small in many areas of B.C., cattle continue to act in response to predation risks, real or perceived.

Research is required on the relationship between cattle, natural mineral sources, and salt blocks. Cattle habitat use in my study appeared to be associated with high levels of exchangeable cations in the soil. Many producers rely on salt as a major management tool, this may not be very successful if cattle are using natural mineral sources. Salting, as a distribution tool, should only be used as part of a broader management approach and not on its own.

Investigate habitat variables associated with cattle habitat use during the winter. Although I was able to identify several variables that were and were not associated with cattle activities, it is possible that these associations may differ among seasons. In many cases, cattle are present on Crown Land for a portion of the winter and probably have different requirements (e.g., thermal cover).

For those habitat variables shown to be associated with cattle activities, undertake manipulative trials to determine if altering complements of variables will result in different patterns of use. It is important that complements of, and not individual, variables should be used in such trials because, as shown by CA, cattle activities were associated with groups of variables.

In forested areas, producers and managers should expect cattle to arrange themselves in smaller groups than in grassland settings. This response should be actively incorporated in management plans. This is particularly important in B.C. where much of the range is forested with small natural openings.

If managers wish to change patterns of cattle habitat type use, additional research into other aspects of cattle behaviour must be conducted. These include: social learning, spatial memory, home range, and site fidelity. Collaboration with individuals and organisations already involved in such studies would be an efficient approach.

LITERATURE CITED

Agriculture Canada. 1979. Range management handbook for B.C. A. McLean (ed.). Agriculture Canada.

Alden, W.G. and I.A.M. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. Aust. J. Agric. Res. 21:755. *Cited in*: Krysl, L.J. and B.W. Hess. 1993. Influence of supplementation on behavior of grazing cattle. J. Anim. Sci. 71:2546-2555.

Armour, C.L., D.A. Duff. and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16:7-11.

Arnold, G.W. and M.L. Dudzinski. 1978. Ethology of free-ranging domestic animals. Elsevier Scientific Publishing Co. New York, NY.

B.C. Ministry of Environment, Lands, and Parks. 1993. Aerial Photographs, series 30BCC93.

B.C. Ministry of Forests. 1971. Range Map C-265 Robinson. Province of British Columbia. Victoria, B.C.

B.C. Ministry of Forests. 1994. Bill 40: Forest practices code of British Columbia act. Province of British Columbia. Victoria, B.C.

B.C. Ministry of Forests. 1995. Range act: Ministry of Forests unofficial consolidation. Province of British Columbia. Victoria, B.C.

B.C. Ministry of Forests. 1996a. Ministry of Forests annual report 1994-1995. Province of British Columbia. Victoria, B.C.

B.C. Ministry of Forests. 1996b. Stock range map, Williams Lake District. Province of British Columbia. Victoria, B.C.

Bailey, D.W. 1995. Daily selection of feeding areas by cattle in homogeneous and heterogeneous environments. Appl. Anim. Behav. Sci. 45:183-200.

Bailey, D.W. and L.R. Rittenhouse. 1989. Management of cattle distribution. Rangelands 11:159-161.

Bailey, D.W. J.E. Gross, E.A. Laca, L.R. Rittenhouse, M.B. Coughenour, D.M. Swift, and P.L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. J. Range Manage. 49:386-400.

Bailey, D.W., L.R. Rittenhouse, R.H. Hart, and R.W. Richards. 1989a. Characteristics of spatial memory in cattle. Appl. Anim. Behav. Sci. 23:331-340.

Bailey, D.W., L.R. Rittenhouse, R.H. Hart, D.M. Swift, and R.W. Richards. 1989b. Association of relative food availabilities and locations by cattle. J. Range Manage. 42:480-482.

Bailey, D.W., J.W. Walker, and L.R. Rittenhouse. 1990. Sequential analysis of cattle location: day-to-day movement patterns. Appl. Anim. Behav. Sci. 25:137-148.

Baker, D.L. and F.S. Guthery. 1990. Effects of continuous grazing on habitat and density of ground-foraging birds in south Texas. J. Range Manage. 43:2-5.

Barton, R.K., L.J. Krysl, M.B. Judkins, D.W. Holcombe, J.T. Broesder, S.A. Gunter, and S.W. Beam. 1992. Time of daily supplementation for steers grazing dormant intermediate wheatgrass pasture. J. Anim. Sci 70:547. *Cited in*: Krysl, L.J. and B.W. Hess. 1993. Influence of supplementation on behavior of grazing cattle. J. Anim. Sci. 71:2546-2555.

Beal, K.G. and H.J. Khamis. 1991. A problem in statistical analysis: simultaneous inference. The Condor 93:1023-1025.

Beardall, G.M., S.C.J. Joubert, and P.F. Retief. 1984. An evaluation of the use of correspondence analysis for the analysis of herbivore-habitat selection. S. Afr. J. Wildl. Res. 14:79-88.

Beaver, J.M. and B.E. Olson. 1997. Winter range use by cattle of different ages in southwestern Montana. Appl. Anim. Behav. Sci. 51:1-13.

Ben-Shahar, R. and J.D. Skinner. 1988. Habitat preferences of African ungulates derived by uni- and multivariate analyses. Ecology 69:1479-1485.

Borror, D.J. and R.E. White. 1970. The Peterson field guide series: A field guide to insects: America north of Mexico. Peterson, R.T. (ed.), Houghton Mifflin Co. New York, NY.

Bracken, G.K., W. Hanec, and A.J. Thorsteinson. 1962. The orientation of horse flies and deer flies (Tabanidae: Diptera). II. The role of some visual factors in the attractiveness of decoy silhouettes. Can. J. Zool. 40:685-695.

Bryant, L.D. 1982. Response of livestock to riparian zone exclusion. J. Range Manage. 35:780-785.

Bryce, B.P. 1977. Aspects of social behaviour and organization of range cattle (*Bos taurus* L.) in south eastern British Columbia. B.Sc. Thesis Univ. British Columbia. Vancouver, B.C.

Byers, C.R. and R.K. Steinhorst. 1984. Clarification of a technique for analysis of utilization-availablity data. J. Wildl. Manage. 48:1050-1053.

Cairns, A.L. and E.S. Telfer. 1980. Habitat use by 4 sympatric ungulates in boreal mixed wood forest. J. Wildl. Manage. 44:849-857.

Chaney, E., W. Elmore, and W.S. Platts. 1993. Managing change: livestock grazing on western riparian areas. U.S. E.P.A., Northwest Resource Info. Center Inc. ID.

Clary, W.P. and G.D. Booth. 1993. Early season utilization of mountain meadow riparian pastures. J. Range Manage. 46:493-497.

Clary, W.P., P.F. Ffolliott., and F.R. Larson. 1978. Factors affecting forage consumption by cattle in Arizona ponderosa pine forests. J. Range Manage. 31:9-11.

Clutton-Brock, J. 1981. Domesticated animals from early times. London and William Heinemann Ltd. London, UK.

Compton, T.L. and A.L. Brundage. 1971. Cattle behavior on subalpine range in southcentral Alaska. J. Anim. Sci. 32:339-342.

Cook, C.W. 1966. Factors affecting utilization of mountain slopes by cattle. J. Range Manage. 19:200-204.

Cook, C.W. and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society of Range Management. Denver, CO.

Cotton, S.E. and A.C. Cotton. n.d. Wyoming CRM: enhancing our environment. Wyoming Dept. Ag., Cheyenne, WY.

Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching, and native ungulates ecosystems. J. Range Manage. 44:530-542.

DeMiguel, J.M., M.A. Rodriguez, and A. Gomez-Sal. 1997. Determination of animal behavior-environment relationships by correspondence analysis. J. Range Manage. 50:85-93.

Dierschke, H. 1972. On the recording and presentation of phenological phenomena in plant communities. *In:* W. Junk, (ed.), 1970 Internat'l Symp. for Vegetation Science. The Hague, Netherlands. *Cited in:* Luttmerding, H. A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold (eds.), 1990. Describing ecosystems in the field, 2nd edition. Ministry of Environment. Victoria, B.C.

Dougherty, C.T., F.W. Knapp, P.B. Burrus, D.C. Willis, and P.L. Cornelius. 1994. Moderation of grazing behavior of beef cattle by stable flies (*Stomoxys calcitrans*). Appl. Anim. Sci. 40:113-127.

Duncan, P. 1983. Determinants of the use of habitat by horses in a Mediterranean wetland. J. Anim. Ecol. 52:93-109.

Dunster, J. and K. Dunster. 1996. Dictionary of natural resource management. UBC Press. Vancouver, B.C.

Ehrenreich, J.H. and A.J. Bjugstad. 1966. Cattle grazing time is related to temperature and humidity. J. Range Manage. 19:141-142.

Festa-Bianchet, M. 1988. Seasonal range selection in bighorn sheep: conflicts between forage quality, forage quantity, and predator avoidance. Oecologia. 75:580-586.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Cons. Bio. 8:629-644.

Frid, A. 1994. Vigilance while feeding by female Dall's sheep (*Ovis dali dali* Nelson, 1884): interactions among predation risk factors. M.Sc. Thesis. Univ. British Columbia. Vancouver, B.C.

Fritz, H., M. DeGarine-Wichatitsky, and G. Letessier. 1996. Habitat use by sympatric wild and domestic herbivores in an African savanna woodland: the influence of cattle spatial behaviour. J. Appl. Ecol. 33:589-598.

Ganskopp, D. and M. Vavra. 1986. Habitat use by feral horses in the northern sagebrush steppe. J. Range Manage. 39:207-212.

Gary, L.A., G.W. Sherritt, and E.B. Hale. 1970. Behavior of Charolais cattle on pasture. J. Anim. Sci. 30:203-206.

Gavin, T.A. 1991. Why ask "why?": The importance of evolutionary biology in wildlife science. J. Wildl. Manage. 55:760-766.

Gillen, R.L., W.C. Krueger, and R.F. Miller. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. J. Range Manage. 37:549-553.

Gillen, R.L., W.C. Krueger, and R.F. Miller. 1985. Cattle use of riparian meadows in the Blue Mountains of northeastern Oregon. J. Range Manage. 38:205-209.

Gillingham, M.P. and F.L. Bunnell. 1989. Effects of learning on food selection and searching behaviour of deer. Can. J. Zool. 67:24-32.

Gluesing, E.A. and D.F. Balph. 1980. Behavioral patterns of domestic sheep and their relationship to coyote predation. Appl. Anim. Ethol. 6:315-330.

Grandin, T. 1980. Observations of cattle behavior applied to the design of cattle-handling facilities. Appl. Anim. Ethol. 6:19-31.

Green, D.M. and J.B. Kauffman. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. J. Range Manage. 48:307-313.

Greenacre, M.J. 1981. Practical correspondence analysis, p.119-146. *In:* V. Barnett (ed.), Interpreting multivariate data. John Wiley and Sons. Toronto, ON.

Greenacre, M.J. and E.S. Vrba. 1984. Graphical display and interpretation of antelope census data in African wildlife areas, using correspondence analysis. Ecology 65:984-997.

Halder, U. 1976. Ökologie und verhalten des Banteng (Bos javanicus) in Java: eine feldstudie. Verlag Paul Parey. Hamburg und Berlin.

Hamilton, W.D. 1971. Geometry for the selfish herd. J. Theor. Biol. 31:295-311.

Hart, R.H., K.W. Hepworth, M.A., Smith, and J.W. Waggoner Jr. 1991. Cattle grazing behaviour on a foothill elk winter range in southeastern Wyoming. J. Range Manage. 44:262-266.

Hepworth, K.W., P.S. Test, R.H. Hart, J.W. Waggoner Jr., and M.A. Smith. 1991. Grazing systems stocking rates, and cattle behaviour in southeastern Wyoming. J. Range Manage. 44:259-262.

Herbel, C.H. and A.B. Nelson. 1966. Activities of Herford and Santa Gertrudis cattle on a southern New Mexico range. J. Range Manage. 19:173-176.

Higgins, K.F., J.L. Oldemeyer, K.J. Jenkins, G.K. Clambey, and R.F. Harlow. 1996. Vegetation sampling and measurement, p. 567-591. *In:* T.A. Bookhout (ed.), Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, MD.

Hill, M.O. 1974. Correspondence analysis: a neglected multivariate method. Appl. Statist. 23:340-354.

Howery, L.D., F.D. Provenza, R.E. Banner, and C.B. Scott. 1996. Differences in home range and habitat use among individuals in a cattle herd. Appl. Anim. Behav. Sci. 49:305-320.

Howery, L.D., F.D. Provenza, R.E. Banner, and C.B. Scott. 1998. Social and environmental factors influence cattle distribution on rangeland. Appl. Anim. Behav. Sci. 55:231-244.

Hughes, R.D., P. Duncan, and J. Dawson. 1981. Interaction between Camargue horses and horseflies (Diptera: Tabanidae). Bull. Ent. Res. 71:227-242.

Illius, A.W. and I.J. Gordon. 1990. Constraints on diet selection and foraging behaviour in mammalian herbivores, p.369-393. *In:* R.N. Hughes (ed.), Behavioural mechanisms of food selection. Springer-Verlag. New York, NY.

Jarman, P.J. 1982. Prospects for interspecific comparison in socio-biology, p. 323-342. *In:* King's College socio-biology group, Cambridge (ed.), Current problems in socio-biology. Cambridge Univ. Press. Cambridge, UK.

Jenks, J.A., D.M. Leslie Jr., R.L. Lochmiller, M.A. Melchoirs, and F.T. McCollum III. 1996. Competition in sympatric white-tailed deer and cattle populations in southern pine forests of Oklahoma and Arkansas, USA. Acta. Theriologica 41:287-306.

Jones, R.L. and H.C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. The Iowa State Univ. Press. Ames, IW.

Kauffman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications... A review. J. Range Manage. 37:430-438.

Kauffman, J.B., W.C. Krueger, and M. Vavra. 1983. Impacts of cattle on streambanks in Northeastern Oregon. J. Range Manage. 36:683-685.

Keiper, R.R. and J. Berger. 1983. Refuge-seeking and pest avoidance by feral horses in desert and island environments. Appl. Anim. Ethol. 9:111-120.

Kie, J.G. and B.B. Boroski. 1996. Cattle distribution, habitats, and diets in the Sierra Nevada of California. J. Range Manage. 49:1996.

Krysl, L.J. and B.W. Hess. 1993. Influence of supplementation on behavior of grazing cattle. J. Anim. Sci. 71:2546-2555.

Lima, S.L. and L.M. Dill. 1990. Behavioral decisions made under the risk of predation: a review and prospectus. Can. J. Zool. 68:619-640.

Litvaitis, J.A., K. Titus, and E.M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods, p. 254-274. *In:* T.A. Bookhout (ed.), Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesada, MD.

Lott, D.E. and B.L. Hart. 1979. Applied ethology in a nomadic cattle culture. Appl. Anim. Ethol. 5:309-319.

Low, W.A., R.L. Tweedie, C.B.H. Edwards, R.M. Hodder, K.W.J. Malafant, and R.B. Cunningham. 1981. The influence of environment on daily maintenance behaviour of free-ranging Shorthorn cows in central Australia. I. General introduction and descriptive analysis of day-long activities. Appl. Anim. Ethol. 7:11-26.

Luttmerding, H. A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold (eds.), 1990. Describing ecosystems in the field, 2nd edition. Ministry of Environment. Victoria, B.C.

Malechek, J.C. and B.M. Smith. 1976. Behavior of range cows in response to winter weather. J. Range Manage. 29:9-12.

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

Marlow, C.B. and T.M. Pogacnik. 1986. Cattle feeding and resting patterns in a foothills riparian zone. J. Range Manage. 39:212-217.

Martin, P. and P. Bateson. 1993. Measuring Behaviour: an introductory guide, 2nd edition. Cambridge university Press. New York, NY.

Martin, S.C. and D.E. Ward. 1973. Salt and meal-salt help distribute cattle use on semidesert range. J. Range Manage. 26:94-97.

McIlvain, E.H. and M.C. Shoop. 1971. Shade for improving cattle gains and rangeland use. J. Range Manage. 24:181-184.

McLean, A. 1967. Beef production on lodgepole pine-pinegrass range in southern British Columbia. J. Range Manage. 20:214-216.

McLean, A. 1972. Beef production on lodgepole pine-pinegrass range in the Cariboo region of British Columbia. J. Range Manage. 25:10-11.

McLean, A. and E.W. Tisdale. 1960. Chemical compositions of native forage plants in British Columbia in relation to grazing practices. Can. J. Plant Sci. 40:405-423.

McLean, A. and W. Willms. 1977. Cattle diets and distribution on spring-fall and summer ranges near Kamloops, British Columbia. Can. J. Anim. Sci. 57:81-92.

McLean, A., S. Freyman, J.E. Miltimore, and D.M. Bowden. 1969. Evaluation of pinegrass as range forage. Can. J. Plant Sci. 49:351-359.

McLean, A., H.H. Nicholson, and A.L. Van Ryswyk. 1963. Growth, productivity and chemical composition of a sub-alpine meadow in interior British Columbia. J. Range Manage. 16:235-240.

McNaughton, S.J. 1988. Mineral nutrition and spatial concentrations of African ungulates. Nature 334:343-345.

McNaughton, S.J. 1990. Mineral nutrition and seasonal movement of African migratory ungulates. Nature 354:613-615.

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. Research Branch, Ministry of Forests. Crown Publications, Victoria, B.C.

Miller, R.F. and W.C. Krueger. 1976. Cattle use on summer foothill rangelands in northeastern Oregon. J. Range Manage. 29:367-371.

Montaña, C. and P. Greig-Smith. 1990. Correspondence analysis of species by environmental variable matrices. J. Veg. Sci. 1:453-460.

Mueggler, W.F. 1965. Cattle distribution on steep slopes. J. Range Manage. 18:255-257.

Murphy, D.D. and B.D. Noon. 1991. Coping with uncertainty in wildlife biology. J. Wildl. Manage. 55:773-782.

Nelson, A.B. and R.D. Furr. 1966. Interval of observation of grazing habits of range beef cows. J. Range Manage. 18:26-29.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Neuman, J.A., A.J. Parsons, J.H.M. Thornley, P.D. Penning, and J.R. Krebs. 1995. Optimal diet selection by a generalist grazing herbivore. Functional Ecol. 9:255-268.

Nowak, R.M. 1991. Walker's mammals of the world, 5th edition, Vol. 2. John Hopkins Univ. Press. London, UK.

Oryshack, M. 1998. Comparison of clearcut and meadow habitats on the Robinson unit, #6095 in the Williams Lake Forest District. B.Sc. Thesis. Univ. of British Columbia. Vancouver, B.C.

Peterson, R.A. and E.J. Woolfolk. 1955. Behavior of Hereford cows and calves on short grass range. J. Range Manage. 8:51-57.

Pickup, G. and G.N. Bastin. 1997. Spatial distribution of cattle in arid rangelands as detected by patterns of change in vegetation cover. J. Appl. Ecol. 34:657-667.

Pinchak, W.E., M.A. Smith, R.H. Hart, and J.W. Waggoner, Jr. 1991. Beef cattle distribution patterns on foothill range. J. Range Manage. 44:267-275.

Pratt, R.M., R.J. Putman, J.R. Ekins, and P.J. Edwards. 1986. Use of habitat by free-ranging cattle and ponies in the New Forest, southern England. J. Appl. Ecol. 23:539-557.

Preston, S.K. 1984. A habitat-use and dietary analysis of a monogastric versus a ruminant herbivore, on forested range. M.Sc. Thesis. Univ. British Columbia. Vancouver, B.C.

Province of British Columbia. June 1995a. Range Management Guidebook, Forest Practices Code of British Columbia. Province of British Columbia. Victoria, B.C.

Province of British Columbia. 1995b. Cariboo-Chilcotin Land Use Plan, Ninety-day Implementation Process Final Report. Province of British Columbia. Victoria, B.C.

Province of British Columbia. December 1995c. Riparian Management Area Guidebook, Forest Practices Code of British Columbia. Province of British Columbia. Victoria, B.C.

Quinton, D.A. 1987. Beef cattle nutrition and performance on seeded clearcuts in southern interior British Columbia. Can. J. Anim. Sci. 67:919-928.

Quinton, D.A. and J.C. Ryder. 1983. Nutrient distribution in major shrubs and grasses in interior British Columbia. B.C. Ministry of Agriculture and Food. Victoria, B.C.

Ralley, W.E., T.D. Galloway, and G.H. Crow. 1993. Individual and group behaviour of pastured cattle in response to attack by biting flies. Can. J. Zool. 71:725-734.

Rautio, S.L. and P. Bunnell. 1994. Problem analysis of integrated resource management of riparian areas in British Columbia. B.C. Ministry of Forests. Victoria, B.C.

Rauzi, F. and F.M. Smith. 1973. Infiltration rates: three soils with three grazing levels in northeastern Colorado. J. Range Manage. 26:126-129.

Reppert, J.N. 1960. Forage preference and grazing habits of cattle at the eastern Colorado range station. J. Range Manage. 13:58-65.

Richmond, R.J. 1980. B.C. Cow-calf manual. B.C. Ministry of Agriculture and Food. Victoria, B.C.

Roath, L.R. and W.C. Krueger. 1982a. Cattle grazing and behaviour on a forested range. J. Range Manage. 35:332-338.

Roath, L.R. and W.C. Krueger. 1982b. Cattle grazing influence on a mountain riparian zone. J. Range Manage. 35:100-103.

Sato, S. 1982. Leadership during actual grazing in a small herd of cattle. Appl. Anim. Ethol. 8:53-65.

Schaller, G.B. 1967. The deer and the tiger: a study of wildlife in India. Univ. Chicago Press. Chicago, IL

Senft, R.L., M.B. Coughenour, D.W. Bailey, L.R. Rittenhouse, O.E. Sala, and D.M. Swift. 1987. Large herbivore foraging and ecological hierarchies. BioScience 37:789-799.

Senft, R.L., L.R. Rittenhouse, and R.G. Woodmansee. 1983. The use of regression models to predict spatial patterns of cattle behavior. J. Range Manage. 36:553-557.

Senft, R.L., L.R. Rittenhouse, and R.G. Woodmansee. 1985a. Factors influencing selection of resting sites by cattle on shortgrass steppe. J. Range Manage. 38:295-299.

Senft, R.L., L.R. Rittenhouse, and R.G. Woodmansee. 1985b. Factors influencing patterns of grazing behavior on shortgrass steppe. J. Range Manage. 38:82-87.

Siegel, S. and N.J. Castellan Jr. 1988. Nonparametric statistics for the behavioural sciences. 2nd edition. McGraw-Hill. New York, NY.

Smith, M.A., D. Rodgers, J.L. Dodd, and Q.D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. J. Range Manage. 45:385-390.

Society for Range Management, Glossary Update Task Group. 1998. Glossary of terms used in range management. 4th edition. SRM. Denver, CO.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry: The principles and practice of statistics in biological research. W.H. Freeman and Co. San Francisco, CA.

Steen, O. and A. Roberts. 1988. Guide to wetland ecosystems of the very dry montane interior douglas-fir subzone eastern Fraser plateau variant (IDFb2) in the Cariboo forest Region, B.C. Research Branch, Ministry of Forests and Lands. Victoria, B.C.

Stevens, V., F. Backhouse, and A. Eriksson. 1995. Riparian management in British Columbia: an important step towards maintaining biodiversity. Province of B.C. Victoria, B.C.

Stricklin, W.R. and C.C. Kautz-Scanavy. 1984. The role of behavior in cattle production: A review of research. Appl. Anim. Ethology 11:35-40.

Tanner, G.W., L.D. Sandoval, and F.G. Martin. 1984. Cattle behaviour on a south Florida range. J. Range Manage. 37:248-251.

Thorsteinson, A.J., G.K. Bracken, and W. Hanec. 1965. The orientation behaviour of horse flies and deer flies (Tabanidae, Diptera). III. The use of traps in the study of orientation of tabanids in the field. Ent. Exp. & Appl. 8:189-192.

Tinbergen, N. 1963. On aims and methods of ethology. Z. Tierpsychol. 20:410-433. *Cited in:* Martin, P. and P. Bateson. 1993. Measuring Behaviour: an introductory guide, 2nd edition. Cambridge university Press. New York, NY.

Toupin, B., J. Huot, and M. Manseau. 1996. Effect of insect harassment on the behaviour of the Riviere George Caribou. Artic 49:375-382.

Underwood, R. 1982. Vigilance behaviour in grazing African antelopes. Behaviour 79:81-107.

Underwood, R. 1983. The feeding behaviour of grazing African ungulates. Behaviour 84:195-242.

Valentine, K.A. 1947. Distance from water as a factor in grazing capacity of rangeland. J. Forestry 45:749-754.

Vallentine, J.F. 1989. Range development and improvements. 3rd edition. Academic Press, Inc. San Diego, CA.

Wallisdervries, M.F. 1996. Nutritional limitations of free-ranging cattle: the importance of habitat quality. J. Appl. Ecol. 33:688-702.

Watson, D. 1986. Behavioural aspects of beef cattle production on open range in British Columbia an applied literature review. M.Sc. Major Assignment. Univ. British Columbia. Vancouver, B.C.

Weimer, R.C. 1987. Statistics, 2nd edition. WmC. Brown Publ. Dubuque, IW.

Wikeem, B.M., A. McLean, A. Bawtree, and D. Quinton. 1993. An overview of the forage resource and beef production on Crown Land in British Columbia. Can. J. Anim. Sci. 73:779-794.

Zar, J.H. 1996. Biostatistical Analysis, 3rd edition. Prentice Hall. Upper Saddle River, NJ.

Zeuner, F.E. 1963. A history of domesticated animals. Hutchinson of London. London, UK.

APPENDIX A

THE RESULTS OF THE 1996 CORRESPONDENCE ANALYSIS

In the 1996 CA, the first 3 axes accounted for a total of 70% of the total variance: 29, 27, and 15% respectively.

Table A. Variables with low (< 2.00) absolute contributions (AC) to the 1996 correspondence analysis. Each variable is shown with its highest AC value and the associated axis.

Variable	Highest AC	Axis
0-50 m to Road	1.87	1
51-100 m to Water	1.67	3
0 Obstacles per 11.28 m	1.57	1
101–500 m to Salt Block	1.34	3
> 500 m to Water	1.29	1
> 30 Trees per 100 m^2	1.27	2
1 Obstacle per 11.28 m	1.19	1
Wind	1.14	3
0% Shade	1.09	2
> 500 m to Road	1.04	1
Temperature 11-20°C	0.91	1
West Aspect	0.85	2
1-5° Slope	0.69	1
No Wind	0.51	3
> 500 m to Salt Block	0.49	2
No Rain	0.22	3

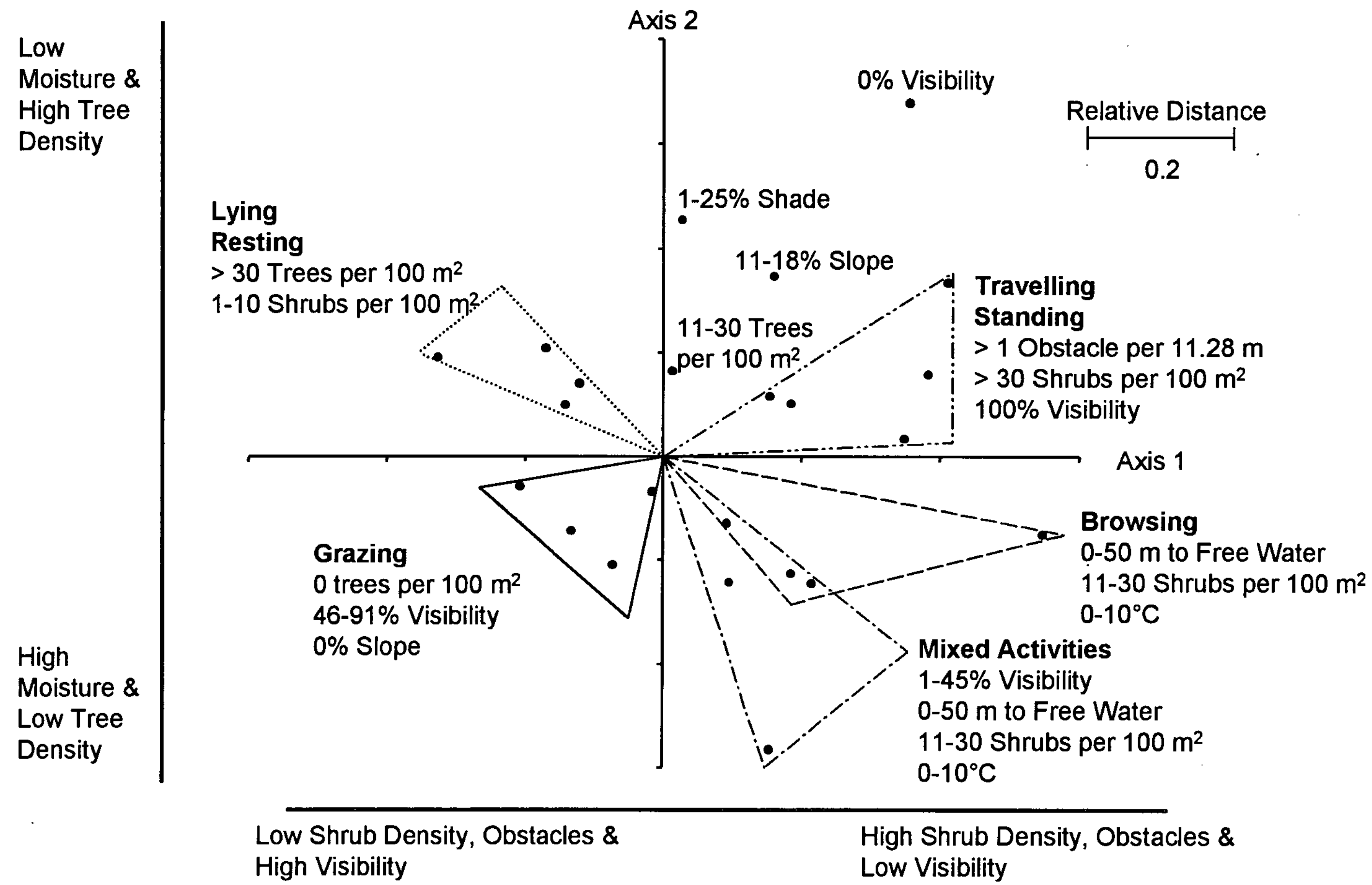

Figure A. Projection of 1996 cattle activities and habitat variables onto the plane of the first and second principal axes. Activities and variables are shown in groups of strongest association and activities are listed in bold type. Variables which dominate the individual axes are also shown.

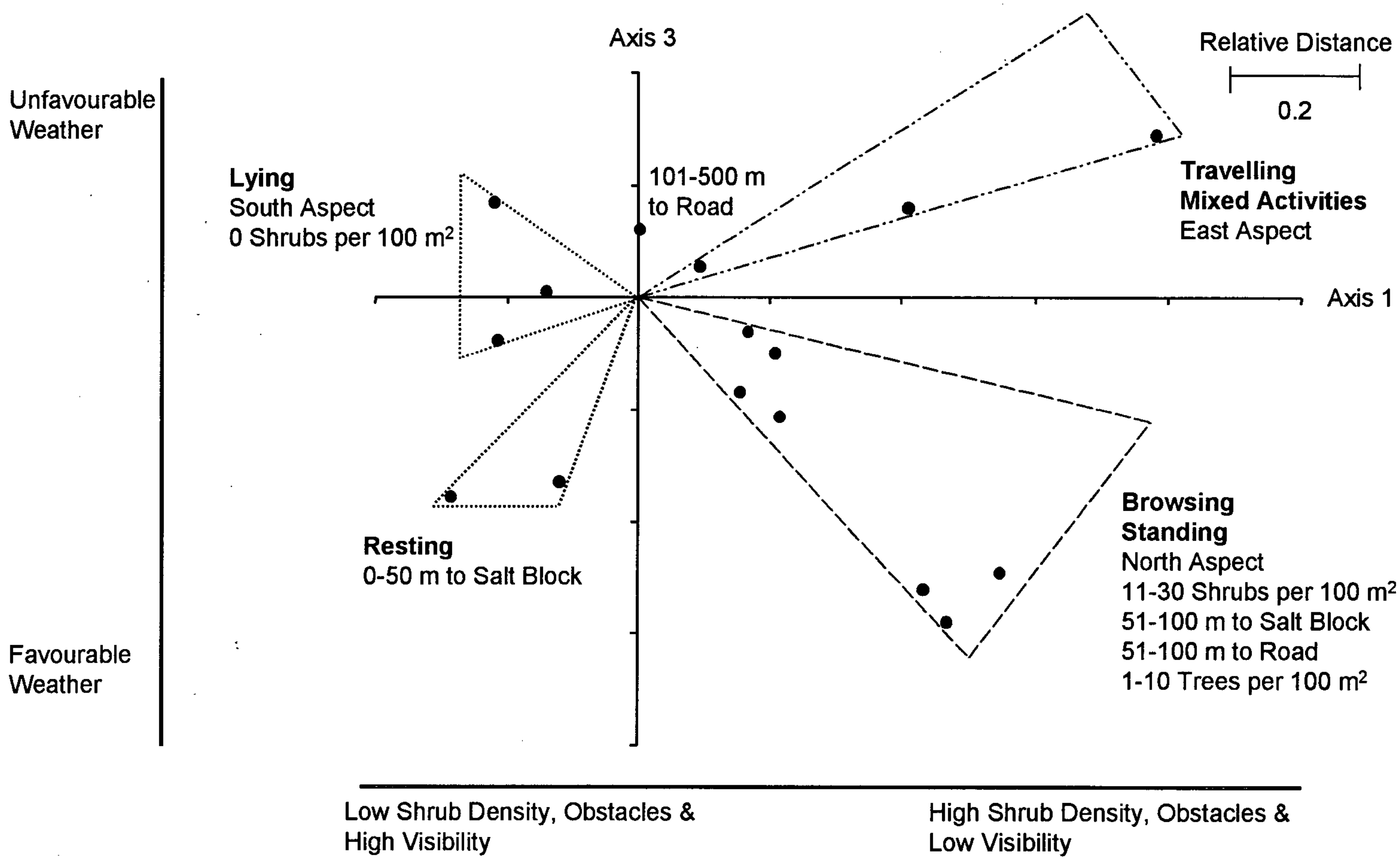

Figure B. Projection of 1996 cattle activities and habitat variables onto the plane of the first and third principal axes. Activities and variables are shown in groups of strongest association and activities are listed in bold type. Variables which dominate the individual axes are also shown.

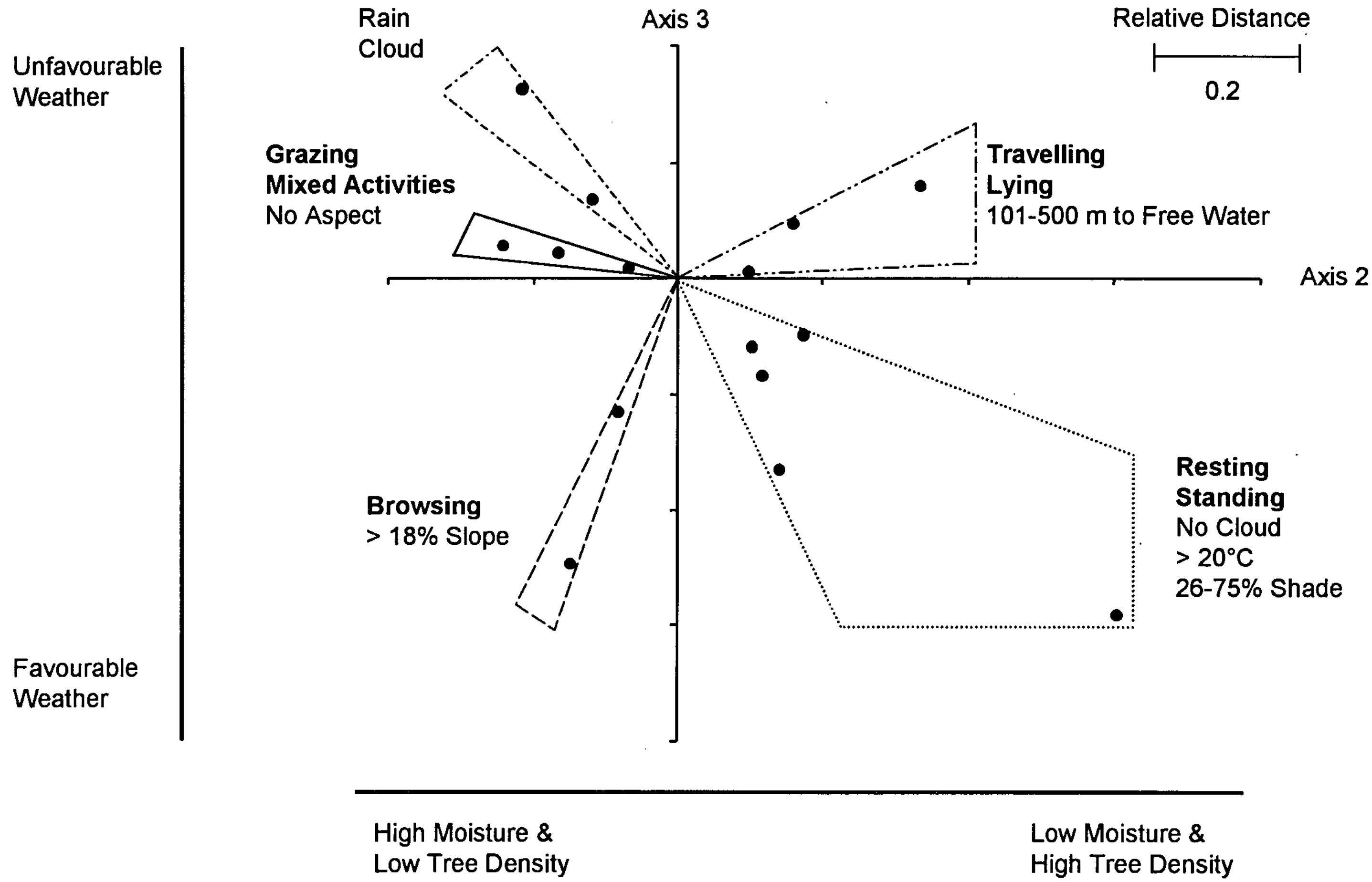

Figure C. Projection of 1996 cattle activities and habitat variables onto the plane of the second and third principal axes. Activities and variables are shown in groups of strongest association and activities are listed in bold type. Variables which dominate the individual axes are also shown.