

# Pastoral migration: mobile systems of livestock husbandry

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*Human livestock management attempts to mimic the natural migration pattern of large wild herbivores and to take advantage of ephemeral forage resources.*

M.A. Little, K. Galvin and P.W. Leslie (1988)

*Seasonal migration by white-eared kob is linked to shifting distributions of critical resources. Pastoralists living in the Boma region [of Sudan] also migrate with their livestock herds between a wet season range west of the Pibor River and the northern swamps during the dry season. . . . Traditional methods of livestock husbandry presumably designed to maximize secondary production, therefore mimic the evolved behaviour of natural populations of ungulates.*

J.M. Fryxell and A.R.E. Sinclair (1988)

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## 10.1 Introduction

Alone in this collection, this chapter investigates the migration of domesticated animals. Our objective is to explain how African and Eurasian pastoralists use migration to exploit the opportunities presented by climate, landscape and animal physiology or, inversely, how they have sought to modify or avoid the hazards posed by these natural factors. Our point of departure is an examination of the extent to which pastoral nomadic movement differs from wild ungulate migration, or mimics it.

In the Arctic the principal domestic and wild migratory ungulate species is identical—*Rangifer tarandus*; the two populations interbreed, individual reindeer shift from a domesticated to a feral state, and wild and domesticated herds occasionally occupy the same areas. In this case it is possible to observe directly how humans have altered migratory cycles by comparing wild and domesticated movement patterns.

In the tropics and the temperate zones, there are some wild analogues to the common domesticated herd species—feral cattle and camels, wild mustangs, undomesticated sheep and goat species—but direct comparisons between pastoral and wild herds are imprecise. Migratory wildebeest are not physiologically equivalent to the cattle of the East Africa plains, nor are saiga antelope exactly comparable to the domesticated sheep of the Central Asia steppes. In the Sahel and in many other areas there remain only

remnant populations of wild migratory ungulates that might provide a comparative baseline. In these circumstances direct comparison is insufficient and we must instead identify the factors that drive pastoral movements and consider how these factors depart from or replicate those that direct wild ungulate migrations.

Both wild ungulate and livestock migrations are influenced by at least three different sets of considerations:

- by the distribution, quality and quantity of food supplies,
- by competition from other livestock/ungulates for feed resources and
- by a wide variety of factors that may impede or facilitate access to resources.

The potential effect of these factors on pastoral movement is summarized below in a series of propositions. The middle sections of this chapter examine these propositions in light of field reports on pastoral migration in tropical Africa, temperate Asia, and the Arctic. Our objective is to identify the distinctive aspects of domestic herd migration with respect to the utilization of feed supplies, the regulation of access to natural resources, and the influence of non-forage constraints and incentives to movement. The chapter concludes with a discussion of the role of human agency in the determination of pastoral livestock migrations.

## 10.2 Propositions

### 10.2.1 Forage abundance and quality

Most migratory livestock are ruminants, including reindeer, cattle, sheep, goats, yaks and camels. Ruminant physiology makes grazers sensitive to variations in feed quality. With cattle, a modest increase in forage digestibility from 50 to 55%, produces an estimated 32% increase in the amount of energy digested per day. This increases the amount of energy available to the animal above maintenance by almost 200% and produces a 100% increase in weight gain (Malechek 1984, based on van Dyne *et al.* 1980 and Blaxter *et al.* 1961). This process of amplification, which has been termed the ‘multiplier effect,’ has also been documented among sub-arctic reindeer (White 1983). For ruminants (and for their owners should these exist) there are strong productive and reproductive reasons to select an optimal diet.

For the migratory ruminant, the abundance and quality of natural forage varies both in time and space. Temporal changes in forage can be summarized in terms of the forage-maturation hypothesis: ‘The protein content and digestibility of forages are often related negatively to maturation state, so immature plants found in areas with low vegetative biomass may be nutritionally superior to mature, high-biomass vegetation’ (Fryxell 1991, p. 479). The declining feed value of older plant material is caused by the accumulation of plant cell wall components, which dilute the concentration of nutrients and obstructs their digestive absorption (Owen-Smith and Novellie 1982; Georgiadis and McNaughton 1990). As a result, the nutritional value of grass tends to decline as leaves age, and old grass swards generally offer higher biomass but lower nutritional quality than younger swards (Langvatn and Hanley 1993). The inverse relationship between forage quality and quantity presents graziers with a dilemma—to maximize forage intake or diet quality, or to compromise between these objectives (Chapter 6).

Spatial gradients in forage quality and quantity are caused by regional variations in soils and climate, the main determinants of the growth and species composition of pastures. In the Arctic and

temperate zones, regions with cool, dry summers often produce the best quality forage (Langvatn and Albon 1986). Limited water supply or lower temperatures and light conditions at higher latitudes (van Soest 1982; Deinum 1984; Hay and Heide 1984; Wedin *et al.* 1984) or altitudes (Wilmshurst *et al.* 1995) reduce the proportion of plant cell walls relative to carbohydrates and protein, producing more digestible forage. But these higher latitudes or altitudes often experience severe winter weather that makes it difficult for large ungulate populations to survive in them year-round. Similarly, in the semi-arid tropics, regions of low rainfall tend to produce small amounts of high quality plant biomass, while wetter areas generally produce abundant forage of increasingly inferior quality (Breman and de Wit 1983; Holdo *et al.* 2009b). But the low-rainfall areas where animals can maximize their growth in the wet season are routinely places where water and feed for livestock are severely restricted in the dry season. While a small number of individuals can survive year-round in refuge habitats, what migrant animals seek in their seasonal ranges is a nutritional boost that permits breeding (Sinclair 1983). They therefore target high quality, low volume forage sources in seasons of biomass abundance, in spring in the northern latitudes and during the wet season in the semi-arid tropics. Grazing preferences become less selective and animals shift to high-volume forage sources in an attempt to meet maintenance nutritional requirements in seasons of forage scarcity, in the winter in cold climates and in the dry season in the semi-arid tropics:

*In...African ecosystems there is a strong rainfall gradient with an accompanying gradient in grass primary productivity and maximum standing crop... Wildebeest, white-eared kob, and domesticated livestock migrate down the productivity gradient during the wet season, when surface water is plentiful, but return up the productivity gradient during the dry season, when surface water is scarce. This could reflect an innate preference by... tropical species for grass swards at an intermediate stage of maturation that would parallel the elevational migration of many montane herbivores (Wilmshurst *et al.* 1999, p.1230).*

Seasonal ungulate migrations occur when animals survive periods of plant senescence in places that are distant from where the animals go to gain weight and reproduce. At the very least, migration links together two kinds of habitats—one that promotes animal growth and reproduction in seasons of forage abundance and favourable weather, and another that facilitates survival in seasons of dearth and severe weather. Subsequent sections of this chapter will argue that pastoral migrations achieve much more than keeping animals alternately well fed and out of harm's way, but this is the irreducible minimum that must be achieved.

### 10.2.2 Density dependent distributions

Even in a simplified, hypothetical migratory system consisting of three zones and three seasons, individual herds could follow eight different migratory routes and still—in the aggregate—produce zonal stocking rates consistent with resource availability in each zone in all three seasons (Behnke and Scoones 1993; Chapter 3). The free choice of diverse migratory routes by individuals may therefore produce an apparently uniform adaptive response to environmental conditions. This uniformity is achieved at the population level by the summation of various movements driven by different combinations of motives, 'a predictable pattern on a gross scale but entirely unpredictable on a fine scale' (Sinclair 1983, p. 251) Sinclair was referring to the movements of wildebeest and topi antelope; the ability of humans to explain their actions makes the movement patterns of domestic herds more readily intelligible at the individual level, as numerous anthropological accounts of pastoral migration have demonstrated (Stenning 1957; Cunnison 1966; McCabe 1994; Kerven *et al.* 2008.). The challenge for pastoral studies has rather been to move from illustrative individual cases to adequate accounts of the movements of entire livestock and human populations. In this respect, the broad arrows often used to depict pastoral movement patterns are cartographic crutches that aid communication but project a spurious uniformity (McCabe 1994).

Theories of the ideal free distribution or density dependent habitat selection (IFD/DDHS) systematically link individual choices to overall population distributions (Fretwell and Lucas 1970; Farnsworth and Beecham 1997; Sutherland 1983; Veeranagoudar *et al.* 2004; Ward *et al.* 2000). The fundamental idea behind these theories is that resource consumers respond simultaneously both to resource distributions and to the shifting distributions of other consumers. Consistent with this perspective, the role of animal density in sustaining mixed sedentary/migratory wildlife distributions has been expressed as follows:

*'Why, then, does an individual decide to be a resident or a migrant? The decision depends on the sizes of the two populations relative to their stable sizes. If all animals were migrants, then any individual who stayed behind in an area capable of supporting him year round, would have an initial advantage of superabundant food and hence no competition.... This advantage, of course, is only temporary, lasting until numbers have increased to the stable level; but for the first individuals it is a real advantage. Similarly, if all animals were resident, there would be an initial advantage to becoming migrant. Hence, the advantage depends only on what the other members of the populations are doing'* (Sinclair 1983, p. 256).

The final sentence of this quotation expresses the essential idea behind IFD/DDHS theory. Compare this statement with an anthropological description of pastoral decision-making, and the parallels are immediately obvious:

*Assessments also have to be made about the likely movements of other herds, for a potentially good area may become over-popular and over-crowded, reducing the availability of resources and perhaps creating competitive conflict between herdsmen, while a less favoured area may be under less pressure and therefore become preferable* (Gulliver 1975, p. 372).

Pastoral societies possess a variety of institutions—land tenure rules, systems of territorial control, social networks and organized violence—to manage resource appropriation and use. The interplay between these institutions, movement patterns, and the biological tendency towards free distribution has yet to be adequately explained.

### 10.2.3 Constrained resource matching

Herds may be chasing protein and calories across savannas, steppes or tundra, but this is not all they are doing. From a population-wide perspective, regional forage availability is the ‘common denominator driver’ of pastoral migration, a recurrent concern that is supplemented or supplanted by a variety of other biophysical or socio-economic considerations.

In the semi-arid tropics, movement systems can be sorted into two basic groups according to water availability: those in areas with abundant drinking water and unimpeded access to regional forage supplies, and those that are restricted to using that subset of the total forage supply that lies in the vicinity of scarce water supplies (for these water-constrained systems see Coppolillo 2000, 2001; Hary *et al.* 1996; Western 1975); systems can shift seasonally between these two poles, water-limited in dry seasons but not in wet seasons. In the better-watered parts of the temperate zone and in the Arctic, the importance of regional forage availability persists, but water constraints are replaced by considerations regarding the prevalence of predators and pests (wolves and flies for reindeer) and exposure to cold and snow (transhumant altitudinal systems). Especially at northern latitudes, the cost of humans moving may become an important consideration because substantial portable dwellings are needed to protect people from the cold, and these are expensive to move around. Irrespective of climatic zone, pastoral movements are adjusted to permit access to markets, services and employment opportunities, or to reflect land tenure restrictions or administrative boundaries. The location of arable land relative to pastures is a recurrent concern in agro-pastoral systems.

Pastoral migrations, like agriculture in general, exploit biophysical regularities to achieve a variety

of different human purposes, and are modified to reflect these purposes. The relevance of socio-economic variables to the organization of domestic herd movement introduces a level of complexity that obscures the expression of the biological processes that clearly structure undisturbed, wild migrations.

The following discussion combines ethnographic description and biological information to construct illustrative case studies of pastoral migration in the semi-arid tropics of sub-Saharan Africa, in temperate Asia, and in the Arctic. This review focuses on ‘horizontal’ migratory systems common in desert, savanna, steppe, tundra and plains environments. ‘Vertical’ movement systems that exploit extreme elevation gradients are common in temperate Asia, particularly along the arch of mountainous terrain that stretches from Iran through the Pamir, Tien Shan, and Himalaya mountains to the Tibetan Plateau and the western borders of China. These altitudinal movement systems are under-represented in the following discussion.

## 10.3 Case studies

### 10.3.1 Sudano-Sahelian West Africa

The Sudano-Sahelian region of West Africa, stretching eastward from the Atlantic Ocean to Chad, is the bioclimatic region lying south of the Sahara Desert and north of the Guinean savanna zone. Vegetative structure in the region grades from Sudanian open savanna to the south (maximum long-term average annual rain of 1000 mm falling from June to September) to steppe vegetation to the north (minimum long-term average annual rain of 200 mm falling from July to August). Herbaceous vegetation is dominated by annual grasses in the Sahel with increasing presence of perennial grasses in the southern Sudanian zone.

Domesticated and wild grazers move across these rangelands in order to maintain access to both water and quality forage. During the rainy season, animals will also move to gain access to minerals (salt licks). Characteristics of the region’s climate and vegetation patterns strongly influence these movements. These include the following.

1. Vegetative production is patchily distributed as a result of the high spatial variability of rainfall. The degree of patchiness generally declines as one moves south into the Sudanian zone where vegetative productivity is limited less by moisture.
2. The forage quality of herbaceous patches is ephemeral. The nutrient concentration of herbaceous vegetation deteriorates rapidly at the end of the rainy season after seed set (Penning de Vries and Djitéye 1982). Vegetation stays greener longer to the south due to a longer rainy season and to the increased prevalence of perennial grasses that will resprout during the dry season if there is sufficient residual soil moisture.
3. Soils are ubiquitously poor in the region, while rainfall is variable and declines from south to north. The growth of herbaceous vegetation in the north of the Sudano-Sahelian zone is limited by water availability and tends to be sparse but of relatively high nutritive quality. In the south, plant growth is more abundant due to higher rainfall, but of lower quality (Penning de Vries and Djitéye 1982).
4. Animal presence has historically been limited by the increased challenge of trypanosomiasis as one moves south from the southern Sudanian to Guinean zone (average precipitation >1000 mm/year). Increased clearing of lignaceous cover for farming has however reduced tsetse fly habitat and therefore exposure to the disease (Bassett 1986; Bassett and Turner 2007).
5. The availability of surface water significantly declines with the end of the rainy season. Generally speaking, the period of surface water availability shortens as one moves north in the region. Supplying water to animals through alternatives (wells) often requires significant investments of labour by human caretakers.
6. Persistent heavy grazing pressure during the rainy season will have effects, particularly on the species composition of vegetation (Grouzis 1988; Hiernaux 1998; Penning de Vries and Djitéye 1982; Turner 1999c; Valenza 1981), increasing the prevalence of the short-cycle species (e.g. *Zornia glochidiata*, *Tribulus terrestris*) and those of lower palatability (e.g. *Sida cordifolia*, *Cassia tora*).

These characteristics place broad constraints on animal nutrition and the strategies for livestock

husbandry. Seasonally, forage quality drops significantly with drying and continues to decline as more nutritious plant parts (younger leaves) become rare in the vegetation due to a combination of grazing, termite activity and shattering. As a result, for animals unsupplemented by imported feed, most of the annual nutrition occurs during and immediately after the short rainy season (3–6 months), with the importance of selective grazing to acquire any nutrition increasing throughout the dry season. It is not uncommon in the zone for vegetative material remaining on heavily-grazed rainfed pastures to have minimal even negative nutritional value during the last couple of months of the dry season (April–May). These nutritional constraints are shown dramatically by studies tracking weight changes in livestock, which find weight gains during the rainy season followed by a couple of months of weight maintenance, followed by a longer period of weight loss sometimes exceeding the weight gains during the previous rainy season (Ayantunde 1998; Ayantunde *et al.* 2001).

The period of weight loss is predictable and, therefore, livestock husbandry is largely focused on maximizing gains during the short rainy season and extending the period of weight maintenance during the beginning of the dry season. This typically involves moving livestock to areas distant from areas of higher human population densities, most particularly to the northern Sahel where pastures are more extensive and vegetation of higher nutritive quality (Schlecht, Hiernaux, and Turner 2001; Penning de Vries and Djitéye 1982). Due to changes in the relative quality of forage and water sources at particular locations in the north and south, appropriate management will often require movements between these locations as the rainy and dry seasons progress (Breman and de Wit 1983; Le Houérou 1989).

#### 10.3.1.1 General patterns of livestock migration

Historically the greatest concentrations of human population in the region have existed in the southern Sahelian and Sudanian zones (600–900 mm/year)—an area allowing both farming and livestock husbandry. The characteristics listed above help shape patterns of livestock movement from this

band at different spatiotemporal scales. At the broadest scale ( $\approx 100\text{--}500$  km), livestock have historically moved to the northern pastures during the rainy season to take advantage of the brief, but highly nutritious, growth of annual grasses (these long-range seasonal movements are commonly referred to as 'transhumance'). After the end of the rainy season, animals move south from the northern pastures to take advantage of the greater availability of surface water. In some cases this movement will extend into the Guinean zone at the end of the dry season (April–May) to take advantage of the earlier rains there.

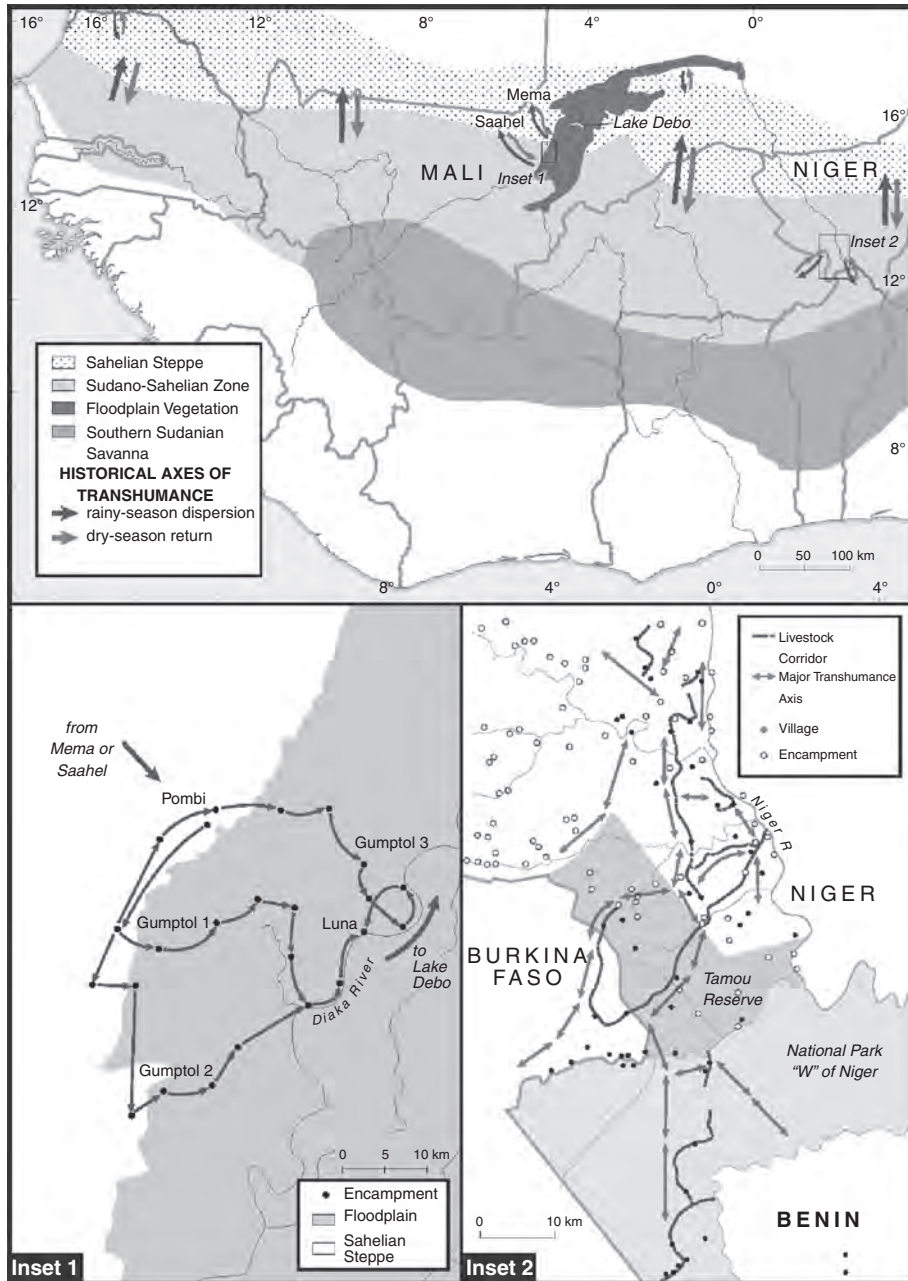
The strong rationale for movements along a N–S axis is illustrated by the fact that this pattern of seasonal movement is common no matter where a herding family lives along the axis (Benoit 1979; Gallais 1975; Bassett and Turner 2007; de Bruijn and van Dijk 1995; Bonfiglioli 1988). Pastoralists in the north will move southwards from their home area at the end of the rainy season to pastures in the southern Sahel and Sudanian zone, sometimes being the guest of those that they have hosted during the rainy season. Those located in middle latitudes along the N–S axis may show two periods of transhumance away from home base: to the north during the rainy season and to the south during the late dry season. The corridors followed to make these movements are best seen as braided networks of paths linking different water/encampment points. The route followed within these braided networks depends in part on the forage/water availability at potential way stations. In areas of heavy cultivation pressure, those paths that remain are narrower, less weblike and more linear than those observed in the pastoral zone (Cissé 1981; Turner 1999b; Marty 1993; Garin *et al.* 1990). The actual choice of the paths to follow reflects not only fluctuating forage/water conditions but the geography of the social networks of those managing herds (Bassett and Turner 2007). Livestock are a mobile store of wealth that is vulnerable to theft, and the risk of livestock loss increases in areas where herd managers have few social contacts.

At an intermediate scale ( $\approx 15\text{--}100$  km), livestock movements during the dry season have been oriented toward floodplain pastures—utilizing these pastures for periods of 0.5–6 months. On floodplain

pastures, livestock take advantage of the increased availability of surface water and greener vegetation while avoiding deep water and diseases prevalent during the wet season (Cissé 1981; Beauvilain 1977; Schmitz 1986). Reliance on floodplain pastures has declined over time as these pastures have increasingly been converted to crops. Away from floodplain areas, the extension of cropped fields in some areas of the Sudanian zone necessitates intermediate-scale movements to areas where natural pastures are less interrupted by cropped fields (Fig. 10.1).

Observers of remnant wildlife populations in the region have identified analogous N–S movements and, at more intermediate scales, movements to and from floodplains (Barnes 1999; Green 1988; Le Pendu and Ciofolo 1999; Poche 1974). However, finer-scale daily movements ( $\approx 3\text{--}15$  km) of domesticated livestock diverge from those of wildlife in their point-centred nature. Cattle, sheep, and goats are managed not only for meat but for milk production. Under the open range conditions of the region, this goal necessitates separating dams from their offspring in order to capture for humans a portion of the milk produced. As a result, finer-scale grazing movements generally are loops departing and returning to fixed points (village, hamlet, pastoral encampment, water point) where the mothers are milked before being reunited with their young (Turner and Hiernaux 2008).

While access to forage and water is a major determinant of the movements of livestock in the region, it is important to recognize that actual patterns of livestock mobility may diverge from the patterns just described. Livestock herders are interested not only in locating their herds in areas with water and high densities of quality fodder, but also in being able to convert livestock production to grain and cash in order to support their families. Therefore, movements will not only be affected by the conversion of pastures to croplands but also by the variable access to milk markets and levels of security offered by different destinations. Moreover, livestock movements, particularly those distant from the home base, require the allocation of an adequate number of herders, which may or may not be feasible given the demands of the herd manager's other productive activities (e.g. farming



**Figure 10.1** Sahelian migratory patterns. Seasonal movements (transhumance) of livestock herds in Sudano-Sahelian West Africa typically lead to northerly movements during the rainy season with a return at the beginning of the dry season (top panel). Herds follow corridors that join encampment points. Major deviations from this pattern occur in some places along the southern portion of the zone where herds move southward during the mid-to-late dry season to catch the earlier rains and return northward during the mid-to-late rainy season. An example of this pattern is followed by the FulBe of the Say region of Niger (Inset 2; bottom right panel) who move their herds southward into Burkina Faso or Benin. These movements are increasingly blocked not only by cropland expansion but by stricter enforcement of protected area boundaries. Historically, floodplains have represented major dry-season pasture resources. Pastoralists' access to these pastures has been eroded over time. One area where this movement pattern persists is the Inland Niger Delta of Mali. Along the western edge of the floodplain (Inset 1; bottom left panel), herds move to either the Mema or Saahel during the rainy season; return to the floodplain in the early dry season; and converge toward the deeper part of the floodplain (Lake Debo) as the dry season proceeds. Over the last 40 years, growing land-use competition and reduced flooding have necessitated shifts in the floodplain paths (*gumptol*) followed by the herds (Inset 1 presents shifts in *gumptol* location (1 to 2 to 3) due to such pressures).



etc.) and his effective access to labour (Turner and Hiernaux 2008). Socioeconomic trends in the region have contributed to; a growing fraction of the regional herd being owned by those who are not herding specialists, and allocations of labour away from herding to other productive pursuits (Habou and Danguioua 1991; Turner 2009). As a result, longer-range livestock mobility has declined, with a growing fraction of livestock managed year-round in the Sudanian zone (Turner and Hiernaux 2008).

#### 10.3.1.2 *Nutritional trade-offs of livestock movements*

Despite the fact that the region's biogeography requires livestock movements, decisions by herd managers whether to move to particular destinations are often not clear cut. Not only are there risks to livestock movements from human-caused insecurity, but the nutritional calculus is not always clear (Schlecht, Hiernaux, and Turner 2001; Colin de Verdière 1995; Andriansen 2003). This is because the energy expended by animals as well as the stress put on them in moving longer distances with less opportunity to eat and drink (e.g. at the end of rainy season) may outweigh the benefits of the greater access to forage/water at the destination. Despite the romanticism attached to the pastoral lifestyle by western observers, this calculus very much shapes the movement decisions made by pastoralists themselves. Moving with livestock is not driven by cultural attachment but by conscious and sometimes agonizing decisions. The nutritional trade-offs surrounding livestock movements become increasingly unforfeiting at the end of the dry season and beginning of the rainy season. At the end of the dry season, livestock movements generally decline despite increasing pasture scarcity reflecting not only the general poor quality of natural pastures but the weakness of livestock. Early rains lead to patches of early grass growth. Decisions on whether or not to move to these areas are some of the most difficult that a herd manager faces throughout the year. Miscalculations can result in the loss of a significant portion of a herd. Under better conditions, decisions to move, while beneficial to most of the herd, may result in the death of the weakest animals along the way.

#### 10.3.1.3 *Livestock mobility and the environment*

Vegetation and soil structure in the region is most sensitive to livestock grazing during the short rainy season (Hiernaux and Turner 1996; Penning de Vries and Djitéye 1982; Turner 1999c). The effects during the long dry season are much less pronounced given that grasses have seeded and dry soils are less vulnerable to compaction. Therefore, dispersal of grazing animals over a wider area during the rainy season is less likely to result in ecologically-damaging grazing pressure than if livestock are congregated near human population centres. With all else equal, this supports the historic pattern of south-to-north transhumance movements during the rainy season (Breman and de Wit 1983). Consistent with general arguments made for rotational grazing and holistic rangeland management, short bouts of heavy, non-selective grazing pressure on Sahelian annual grasslands have less effect on species composition, grassland productivity and soil structure than more persistent grazing pressure during the rainy season (Turner 1999c). Such temporal patterns of grazing pressure are more likely to be produced by more mobile pastoral systems of livestock management where livestock often remain for not more than three days at any one location. One important caveat to this conclusion is that when distinct waves of herd visitations occur throughout the rainy season, the grazing pattern experienced locally may not diverge significantly from more sedentary systems.

#### 10.3.1.4 *The role of human management and livestock mobility*

One important question is the role of human management in the efficiency of adjustments of livestock grazing to the changing spatial distributions of available forage. While variation exists at the species and individual level, domestic livestock show abilities (similar to those of wildlife) to move to areas with higher forage potential outside of their immediate sensory range. For example, Sahelian herders learn to look for lost cattle at the beginning of the rainy season along transhumance corridors to the north and likewise along the same corridors to the south at the end of the rainy season. At more local scales, goats are particularly aggressive seekers of palatable forage across village landscapes, compared to cattle and

sheep. Sheep, when left on their own, may choose to remain near villages during the dry season rather than venturing forth in search of forage.

Herders play an important role during the rainy season by keeping livestock out of cropped fields. But is this their only role? How does herding affect the ability of livestock to access forage on open pastures? In the abstract, one could argue that herders will play a positive role in this regard. First, herders arguably can access a wider range of geographic information about forage/water availability through their social networks than can the animals under their care. Second, herders aim to offer animals in the herd a range of forage types to meet the needs of all members of the herd. For example, during the transition periods from dry-to-rainy and rainy-to-dry seasons, the ruminants of different animals adjust at different rates to forage of different qualities and moisture contents. In their daily grazing orbits, herders will intentionally lead animals along routes that provide a mix of dry and green vegetation from which animals can choose. They are well aware of the types of vegetation preferred by different individuals in the herd during such transition periods. An important empirical question is whether wild ungulate herds would access similar mixes of fodder types from orbits led by lead animals. While it is difficult to find cases of domestic livestock going on transhumance without herders, studies of local grazing patterns of herded and free pastured animals in the region have found that herding does have statistically significant effects, not only increasing the dispersal of animals around villages and water points but increasing the time spent in areas of high densities of palatable fodder (Turner and Hiernaux 2008; Faugère *et al.* 1990a, 1990b).

### 10.3.2 Temperate Asia: Steppes of Mongolia

Pastoral environments in Mongolia and northern China are arid to semi-arid steppes with maximum elevations of 4000 m. The distribution of precipitation is unimodal with most rainfall falling in the summer months, and the dry season coinciding with winter. Spring snowstorms are not uncommon and severe winter weather is a regular feature (Fernandez-Gimenez 1997). Winter minimum tem-

peratures reach below  $-40^{\circ}\text{C}$  and summer temperatures can exceed  $32^{\circ}\text{C}$  (Fernandez-Gimenez 1997; Erdenebaatar 2003; Wang 2003; Bedunah and Harris 2005). Most pastoralists in this region herd a diversity of livestock species, including sheep, goats, cattle, horses and camels. At higher elevations and more northern latitudes, yaks replace cattle and camels are scarce or absent, while cattle are often scarce in the more arid desert steppe.

Contemporary migrations are primarily elevational (Fernandez-Gimenez 1997; Erdenebaatar 2003; Wang 2003; Bedunah and Harris 2005) although, in historical times, Mongolian pastoralists in some regions made long-distance latitudinal migrations (Fernandez-Gimenez 1999; Humphrey and Sneath 1999). Both historical and current movement patterns vary greatly with local geography, and distances moved are often highly variable within and between locales, and within and among years in a given location (Fernandez-Gimenez 1999; Humphrey and Sneath 1999; Erdenebaatar 2003; Fernandez-Gimenez and Batbuyan 2004; Fernandez-Gimenez *et al.* 2007).

Key environmental drivers of herd migrations include the following.

1. Plant production and forage quality and quantity vary over space at multiple scales, as well as seasonally and inter-annually. At the broadest spatial scale, Mongolia's ecological zones are arrayed along latitudinal and elevational gradients with increasing precipitation at higher latitudes and elevations, corresponding to higher production and greater species richness, but not necessarily higher nutritional quality. Within ecological zones, soils, topography and grazing pressure drive species composition and production in the mountain steppe and steppe zones, with spatial and temporal variability in rainfall playing a greater role in the desert steppe (Fernandez-Gimenez and Allen-Diaz 2001). Within years, forage quality is highest in late spring and declines as plants senesce. At longer time scales, prolonged droughts, which affect forage abundance and quality, drive long-distance moves and result in temporary or permanent relocation of herds and households.

2. The quality and quantity of water for livestock and domestic consumption is a key driver of herd

movements. Water is most abundant during the summer rains. However, water quality in stationary sources such as desert springs declines in the summer, leading to increased gastrointestinal problems for livestock and people, and influencing movements towards free-flowing water (rivers) and deep wells. In the winter, herders in many areas rely on snow for domestic water, and this may limit their use of some pasture if snow is insufficient. The abundance of natural surface water sources has declined significantly over the last decade potentially due to climate change (Batima 2006). In addition, many wells constructed during the socialist collective era have fallen into disrepair since privatization in 1992 and are no longer functioning. The declining availability of surface and well water is a serious constraint on mobility and pasture use.

3. Mongolia has an extreme continental climate with warm summers and cold, dry winters. High winds are common, especially in the autumn and spring. These climatic conditions motivate herders to seek sheltered campsites during the cold and windy seasons, especially when animals are giving birth in the early spring.

4. Severe winter storms known as *dzud* have historically occurred on a 5–8 year cycle. These storms often render forage inaccessible if snows are deep, and act as a density-independent limitation on livestock populations. When *dzud* occurs, herders who are able to, move their animals to avoid livestock mortality, sometimes long distances.

The environmental and social drivers of herd migrations on the Mongolian steppe are illustrated in the following case study of Jinst Sum (district) located in Bayankhongor Aimag (province) in the Gobi desert-steppe region of western central Mongolia. Pastoral herd movement patterns in this area have changed over time with shifting political regimes and administrative boundaries (Fernandez-Gimenez 1999; Humphrey and Sneath 1999). However, basic elements of the movement patterns have remained consistent, even as the average distance moved and the range of habitats used has become more limited, or fluctuated with environmental and economic conditions.

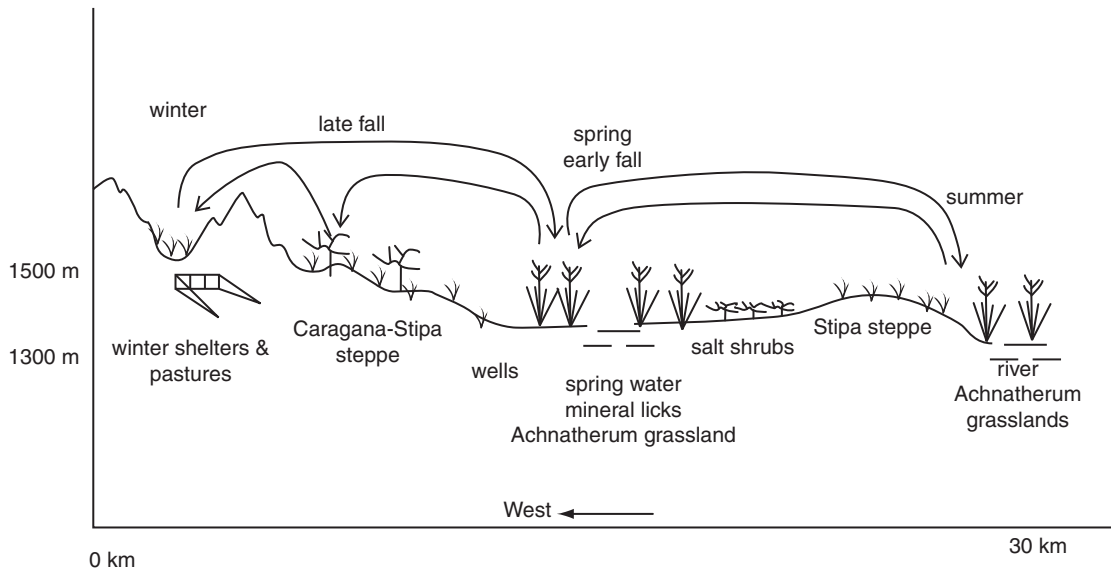
Jinst Sum is located on a broad plain between the Khangai and Gobi Altai Mountain ranges, and averages 1380 m in elevation. A low range of

foothills called Narin Khar Ridge bisects the district from the west. The Tuin River flows through Jinst from its headwaters in the Khangai mountains to the North towards the large inland lake, Orog Nuur, located just south of the district's southern boundary. Orog Lake, like several smaller springs in the district, is surrounded by a lush desert marshland. Natural water sources in the district include the Tuin River, and two natural marshes, Khar Us (Black Water) and Khuis Us (Navel Water). In addition, herds water at a number of hand-dug and mechanical wells scattered across the landscape.

Pastoralists in Jinst typically move at least four times annually between 3 or 4 distinct seasonal pasture areas (Table 10.1, Fig. 10.2). Here, we describe the broad patterns of movement of households and herds dominated by small stock. It is important to note, however, that within seasons different livestock species are herded to different plant communities within a seasonal pasture area, as appropriate to each species' dietary needs. Spring and early autumn pastures are located in desert marsh riparian areas with good spring water supplemented by numerous wells at their peripheries. The vegetation in these areas is dominated by the tall, coarse-textured grass *Achnatherum splendens*, which is high in structural carbohydrates and relatively low in protein content. Production in these areas is high, and forage quality is low during most of the year. *A. splendens*, called *ders* in Mongolian, is most palatable to a wide range of livestock in early spring, when tender new growth is sprouting. Its tall structure and the large amount of standing dried biomass in *ders* areas affords shelter from spring winds for small stock and young animals, and high-volume forage for mature large stock (primarily horses and camels). Often these riparian oases are located adjacent to surrounding salt-shrub communities, which are low in grass production, but contain a number of halophytic species with moderate to high nutritional value (e.g. *Salsola passerina*, *Anabasis brevifolia*), which are preferred by camels and goats. The salt content of plants and soil in these communities is thought by herders to be important in helping animals consolidate their fat in the autumn, and the mineral salt is also collected for human use. Standing biomass in these salt shrub communities is relatively low, 16.5 g/m<sup>2</sup>, but still higher than the

**Table 10.1** Summary of production objectives, environmental and social pasture/campsite selection, and movement criteria for the Jinst Soum, Mongolia case study (Source: Fernandez-Gimenez (1997)).

	Spring	Summer	Autumn	Winter
<b>Production objectives</b>	Early: conserve fat; late: recuperate from winter; early and late: good birth and survival rate	Put on fat; milk production	Consolidate fat; gain fitness/resistance for winter	Conserve fat
<b>Environmental criteria</b>	Warm (south-facing slope), sheltered (lee-side); deep, dry bedding ground; water nearby; early snowmelt; early grass growth	Cold, clear water; few insects; forage quality and quantity	Open steppe Salt and mineral licks; highly nutritious plants ( <i>Allium</i> , <i>Artemisia</i> ); good cold water; cool, hard-surfaced bedding grounds	Warm; sheltered; deep, dry bedding ground; standing forage reserve; shallow snow or water (wells)
<b>Social/economic factors</b>	Labour; transportation; campsite possession or access rights; access to markets and services	Number of neighbours; access to markets and services	Number of neighbours; labour; transportation; access to markets and services	Labour; transportation; campsite possession or access rights; access to markets and services
<b>Habitat</b>	Desert marsh	River banks and lake shores	Open steppe	Sheltered mountain valleys, canyons, or foothills; usually far from natural fresh water;
<b>Movement criteria</b>	Reproductive cycle (before lambing/kidding becomes intense) water availability; Greening of grass	Grass growth; weather; water quality	Weather; phenological changes in plants; animal behaviour	cold temperature; snow for domestic use



**Figure 10.2** Schematic cross-section of seasonal movements in Jinst Soum, Mongolia.

herbaceous production of the upland steppe (Fernandez-Gimenez and Allen-Diaz 2001). Rights to spring camps are usually governed by customary use and informal tenure arrangements, although increasingly households hold formal possession licences over spring campsites.

In the summer, herds move away from still-water riparian oases as the water grows brackish and foetid, making people and animals sick, and the insects become intolerable. During the hot summer months in the Gobi, Jinst herders camp on the banks of the Tuin River, where their herds have access to riparian grazing lawns (typically *Elymus chinensis* and various *Carex* species), as well as the upland desert-steppe vegetation (perennial bunchgrasses, primarily *Stipa gobica* and *S. glareosa*, interspersed with forbs and scattered leguminous shrubs), water is cool and plentiful, and the breezes keep the insects away. Summer pastures are essentially open access, with no exclusive rights to graze permitted. Thus, herders distribute themselves where they choose, but take into account both the benefits and drawbacks of proximity to and abundance of neighbours. Herders' main objectives in the summer are to maintain high levels of milk production in lactating animals, and to enable animals to recover and fatten after winter.

In the autumn, especially late autumn when temperatures cool, herders move out into the expansive desert-steppe uplands, obtaining water from wells, or trekking their herds to the springs every 3 days. Here, they seek highly nutritious plants to fatten their animals, including wild onions, *Artemisia* subshrubs, and salt shrub species. Typical herbaceous standing biomass in these desert-steppe communities is 10.75–13.6 g/m<sup>2</sup> (this estimate does not include the shrub component; Fernandez-Gimenez and Allen-Diaz 2001).

Migration from autumn to winter camps is triggered by colder temperatures and the arrival of snow. Winter camps are the most permanent bases in this mobile society and, by the end of the 20th century, most households or herding camps held long-term possession licences giving them formal exclusive rights to their winter campsites. In Jinst, most winter campsites are located in sheltered mountain valleys and canyons, usually on south-facing slopes and protected from the prevailing winds. Water is obtained from snow, wells, or from ice blocks transported from the frozen river. Winter forage is standing dry grass, usually the upland desert-steppe bunchgrasses, *S. gobica* and *S. glareosa*. In the desert steppe, little fodder is cut and stored, although *ders* is occasionally stockpiled as hay, and

some herders prepare small amounts of home-made concentrate feed from a combination of grasses and high protein forbs. In winter, the shallow but extensive snow cover (for water), finite forage supply, and requirements for a deep, dry bedding ground for livestock, lead herders to disperse their camps, composed of only a few households, over a wide area, in contrast to the aggregated settlement pattern along the river during the summer.

In addition to this regular pattern of seasonal transhumance, herders of Jinst and other parts of Mongolia sometimes take their herds on treks that are much longer in distance and duration, usually in response to prolonged drought or severe winter conditions. Changing economic opportunities and constraints following the transition to a market economy in the early 1990s also influenced herd mobility, often in ways that are suboptimal from a forage matching standpoint. That is, herders remained longer in areas that were over-crowded and where the quality or quantity of forage was insufficient, because they lacked access to transportation, or desired proximity to markets, schools, or other social services. Patterns of mobility in Jinst are dynamic in response to both climate-driven forage availability and economic factors (Fernandez-Gimenez *et al.* 2007). In the absence of formal individual or collective tenure over pasture areas, droughts and forage shortages have led some herders to migrate far outside of their customary transhumance cycles, encroaching on the customary territories of other groups of herders in neighbouring districts or provinces, consuming winter grazing reserves and creating conflicts over pasture (Fernandez-Gimenez *et al.* 2008).

There are few wild ungulates in Jinst today, however important populations persist in other regions of Mongolia, including some with similar ecological characteristics. Recent research on the migration patterns and diets of Mongolian gazelle (*Procapra gutturosa* Pallas) permits a tentative comparison of influences on livestock and wildlife movements on the Mongolian steppes, and particularly the similarities and differences in diet due to seasonal foraging patterns and the influence of herding on domestic stock. Mongolian gazelles today primarily inhabit Mongolia's eastern steppes, but their range extends into the eastern part of the Gobi (Yoshihara

*et al.* 2008). The diet of the Mongolian gazelle varies seasonally, in ways similar to the seasonal foraging patterns observed for herded small stock in Jinst. In a study of Mongolian gazelles in China, protein consumption was highest in spring, wild onions dominated the diet in summer, and grasses were the primary food source in winter (Jiang *et al.* 2002). A study of food resources used by Mongolian gazelles and livestock at three sites in Mongolia found that in the easternmost steppe site there was a high degree of diet overlap between sheep/goats and gazelles. However, diets of domestic stock and gazelles diverged significantly at the desert-steppe site, leading the authors to conclude that herding of sheep and goats strongly influenced their diets at this site (Yoshihara *et al.* 2008). Other studies have found that production alone (estimated by NDVI values) did not fully explain gazelle migration patterns (Ito *et al.* 2006), or that gazelles appeared to prefer areas of intermediate productivity (Mueller *et al.* 2007), indicating support for a trade-off between quality and quantity of the food available. NDVI values best predicted habitat use in the winter months (Leimgruber *et al.* 2001; Ito *et al.* 2006).

In summary, Jinst herders balance a variety of biophysical and social factors in making movement decisions. Forage availability and quality govern some decisions, especially at smaller spatial scales, whereby pastoralists herd different livestock species to different plant communities and microhabitats based on their dietary preferences and needs. Although specific data on seasonal diet composition are lacking, we infer, based on our knowledge of herd movements and habitat use, that quality is highest in the late spring and early summer, when herds use salt-shrub communities, and new growth of *Achnatherum splendens* and *Stipa* species is available. In early autumn, quality is also likely to be higher, giving herds a nutritional boost just prior to and during the breeding season for camels and small stock, as animals consume more protein-rich forbs (*Allium* species) and shrubs (e.g. *Artemisia xerophytica*), which are believed by herders to help animals consolidate fat. Both diet quality and forage quantity are lowest during late winter and early spring, when animals rely on standing dry biomass for maintenance. These patterns show overall similarity to one diet study of Mongolian gazelles, and both wildlife and domestic

stock make use of pastures with high amounts of relatively poor-quality standing biomass in the winter and early spring, the annual forage bottleneck. However, livestock production is water-limited, and herders in the semi-arid Gobi region clearly balance considerations about water quality and quantity with those of forage quality and quantity, as well as economic factors. As changing climate and land use affect the availability of surface water, water has become an increasingly important determinant of, or constraint to, movement. Herders consider the density of other households when deciding where to camp in summer, when abundant fresh water is a limiting factor, and distribute themselves broadly across the landscape in winter, when forage is more limiting than water. However, social and economic factors, such as the need to be close to settlements for access to schools, markets or services, increasingly override biophysical considerations, resulting in increasing degradation around settlements (Okayasu *et al.* 2007). These mounting social and economic constraints may account, in part, for observed divergence of Mongolian gazelle diets and the diets of small stock in the Gobi region (Yoshihara *et al.* 2007).

### 10.3.3 Arctic case study: Nenets reindeer nomads East and West of the Polar Urals

Reindeer pastoralism is practised in Eurasia by approximately 20 indigenous groups in the Arctic and subarctic involving roughly 100 000 people and 2 million reindeer (ACIA 2004). Traditionally, reindeer pastoralism was highly mobile but few groups continue to practise long-distance nomadism.

In the Arctic and subarctic, unlike in many other pastoral regions, diversification of the species composition of herds is not an option due to difficult climatic conditions. The exception is eastern Siberia, where an ethnically mixed community of Eveny and Sakha herd reindeer, horses and genetically unique breeds of northern cattle under extreme conditions (Maj 2009; Takakura 2002; Granberg *et al.* 2009). In all other regions of the North, herders who want to spread risk or dampen the volatility of natural disasters engage in additional non-pastoral activities such as fishing, hunting, gathering and wage labour.

The Arctic as a pastoral habitat is characterized by:

1. low plant productivity limited by a climate that leaves the pastures free of snow roughly between May and September;
2. a low number of plant functional types with value for reindeer grazing, mainly tundra grassland (e.g. *Carex* spp., *Eriophorum* spp., *Poaceae* spp), shrub tundra (e.g. *Salix* spp, *Betula nana*) and lichen ranges (*Lichenophyta*, e.g. *Cladonia* spp. *Cetraria* spp);
3. mostly frozen soils throughout the year. In many Asian areas of the Arctic in summer the active layer above the permafrost level is less than 1.5 m, though there are very few permafrost areas under reindeer pastures in the European Arctic;
4. precipitation between 370 and 500 mm in the high Arctic, slightly more in the subarctic. The yearly distribution of that precipitation is changing with a changing climate (Frey and Smith 2003);
5. generally low temperatures but much surface water from countless rivers and lakes, so that water supply is never a problem for livestock. The combination of low precipitation and abundant surface water makes the arctic a 'dry wetland.'

Migratory reindeer herds generally follow plant growth, advancing north with the greening of spring pastures and retreating south as plants senesce in autumn. The most common (but not the only) migration pattern is for reindeer to move between lichen-rich winter pastures in a forest zone and herbaceous summer pastures at windy locations on the coast, where insect harassment is reduced, or at higher altitude. The diet of reindeer can be broadly characterized as a gradient between these two extremes, shifting from a dependence on lichen consumption in winter to maximizing the consumption of green plants in summer, supplemented in autumn by berries and mushrooms. Summer is the season for gaining weight, often on salty coastal pastures that, according to Yamal herders, 'increase the appetite of the reindeer and make them grow faster and fatter'. Lichen pastures are useful for surviving the winter by maintaining the body mass built up in summer. Late winter/spring pastures are often the seasonal 'bottleneck' determining the survival rate of the herd over the year.

Among both domestic and wild reindeer we find highly mobile populations as well as localized populations, with the reindeer in Taimyr covering the largest distances for wild reindeer—up to 1500 km annually (Geller and Vorzhonov 1975; Klokov 1997)—and the Siberian Nentsy and European Komi reindeer covering the longest distances for domestic reindeer accompanied by herders—1200 km annually (Stammler 2005; Habeck 2005; Dwyer and Istomin 2008). In many cases pastures serve as habitats for both ‘migrant’ and ‘resident’ (more localized and less migratory) reindeer, such as on the coast of the Barents Sea (European Russia), the Northern Yamal and Taz Peninsulas of West Siberia, and the Taimyr Peninsula (wild reindeer). Where the two patterns of movement coexist, ‘resident’ animals are fatter in good years because ‘migrants’ lose body weight on their long-distance movements. On the other hand, in bad years ‘migrant’ animals benefit from greater flexibility in obtaining forage during extreme weather events such as the icing-over of pastures.

Less migratory herds do not change ecological zones, but instead over-winter in treeless areas in the high North, or stay year-round in the forest in the more temperate zones (Stammler 2005 for northern Yamal Nentsy; Yoshida 1997 for Gydan Nentsy; Dwyer and Istomin 2008 for Taz Nentsy). Migration between these localized herds is influenced by the same factors as long-distance migratory systems, but they play out on a different geographical scale and herders have more scope to determine their own hierarchy of criteria for pasture quality at particular times of the year. For example, some coastal pastures suitable for summer use are also lichen-rich and suitable for winter occupation. As lichens are more valued than salinity by most herders, coastal locations that are open year-round are often preserved for winter grazing and summer is spent elsewhere.

Vegetation is only one—and not always the most important—consideration governing movement (Kitti *et al.* 2006). Depending on the relative importance of reindeer herding and fishing for household income, migration routes for the former are adjusted to match the seasonality of the latter. On the West Siberian Yamal Peninsula, many private reindeer herders choose their migration routes to match

good fishing lakes in the summer. Even though there is significantly more mosquito harassment around these lakes, the value of the fishing in summer outweighs the disadvantages of insect harassment for the herd. A better option for small herd owners is to place their animals with bigger herds for efficient summer fattening on wind-exposed pastures, while they fish in rivers and lakes. Such herders resume reindeer herding in autumn, when they move back south to pastures that again are chosen for their proximity to good locations for ice-fishing. In other cases, herders whose reindeer follow localized grazing patterns can detach camp movements from herd migration, in which case the camp follows a nomadic migration route that combines hunting/fishing considerations with the occasional need to be close to the herd (see the second case study, below). In general, as herd mobility is reduced, hunting and fishing become more important in the household economy.

The following case studies describe a typical long-distance migration corridor used by mobile camps with large herds in the Yamal Peninsula, and a second more localized migration pattern exemplified by a Nentsy community on the shore of the Barents Sea in the European North of Russia.

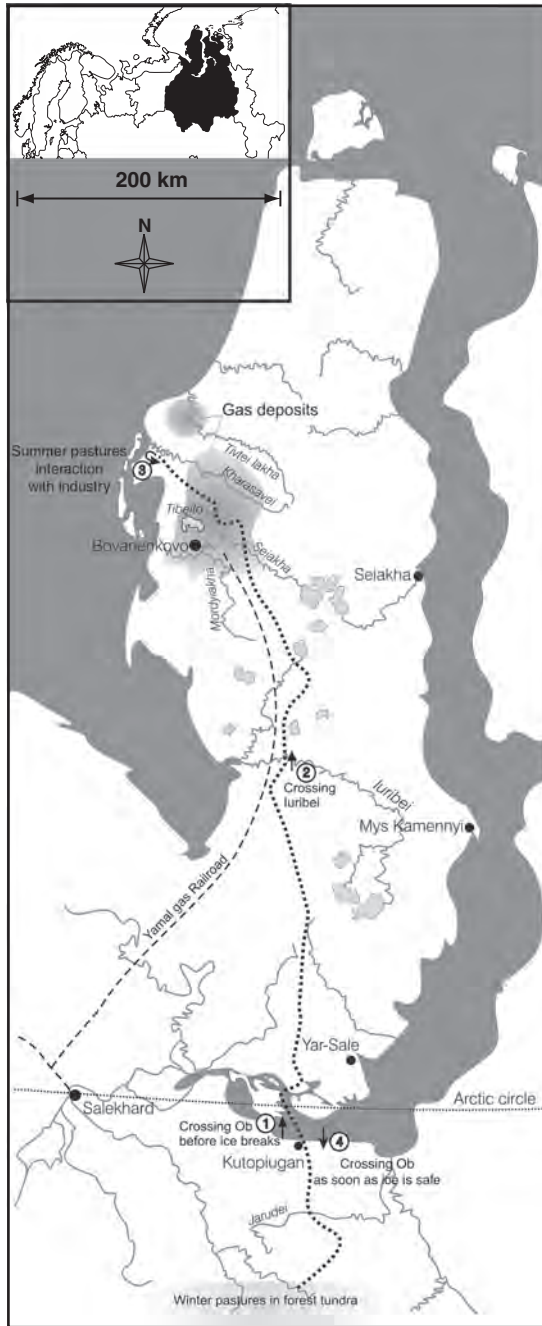
#### 10.3.3.1 Case 1: Long-distance migration by large ‘migrant’ herds

Movements of people and animals among the Nentsy are influenced by a complex set of non-botanical factors, most important of which are pollution by industry, different land rights regimes and post-Soviet reorganisation, distance from human harassment/poachers, proximity to markets, soil humidity/dryness, pasture elevation/windiness, mosquito harassment, coastal salinity, noise harassment (pipelines, roads, railroads, wind parks), freezing over of pastures and snow depth (Fig. 10.3). Table 10.2 summarizes the interplay between vegetation condition and these additional factors in establishing a system of long-distance migration.

#### 10.3.3.2 Case 2: Short-distance migration of a smaller ‘resident’ herd

Table 10.3 summarizes the interplay of socioeconomic and biophysical factors in establishing a system of short-distance migration. In this second





**Figure 10.3** The seasonal migration cycle of a Nentsy reindeer nomad camp, Yamal Peninsula. Modified from Stammler (2005, p. 104).

example, the close observation of the whole environment, including the pastures, permits herders to make optimal use of a confined territory.

This herd moves in an area that is small enough to detach the camp location from herd location where necessary. Herders make use of the territory for fishing, hunting and gathering, which influences camp location. In localized migratory systems, herders commonly use large rivers and lakes as 'natural fences', a practice that is effective from May until October, when these bodies of water freeze over and no longer form a barrier to animal movements. In the example described here (Table 10.3 and Fig. 10.4), when the herd is on a peninsula during the rut, water forms a barrier from three sides, while the camp location on the only open side 'closes the bag' and traps the herd until it calms down. Only then is the herd released and guided towards lichen pastures on the coast. These herds also graze on pastures that are seasonally flooded by salt water, which minimizes the need for herders to supply additional salt for their animals.

#### 10.3.3.3 Decisionmaking in migration

The primary bottlenecks that impede both localized and long-distance movements are constricted passageways in early spring and late autumn. Humans push their herds through these pastures as quickly as possible. In the first case, this happens according to a sophisticated timetable, as these passageways are used by successive waves of camps and herds. Delayed exit from these passages by early waves of animals can lead to mixing with incoming herds. Separating mixed herds is laborious and herders try to avoid it if at all possible.

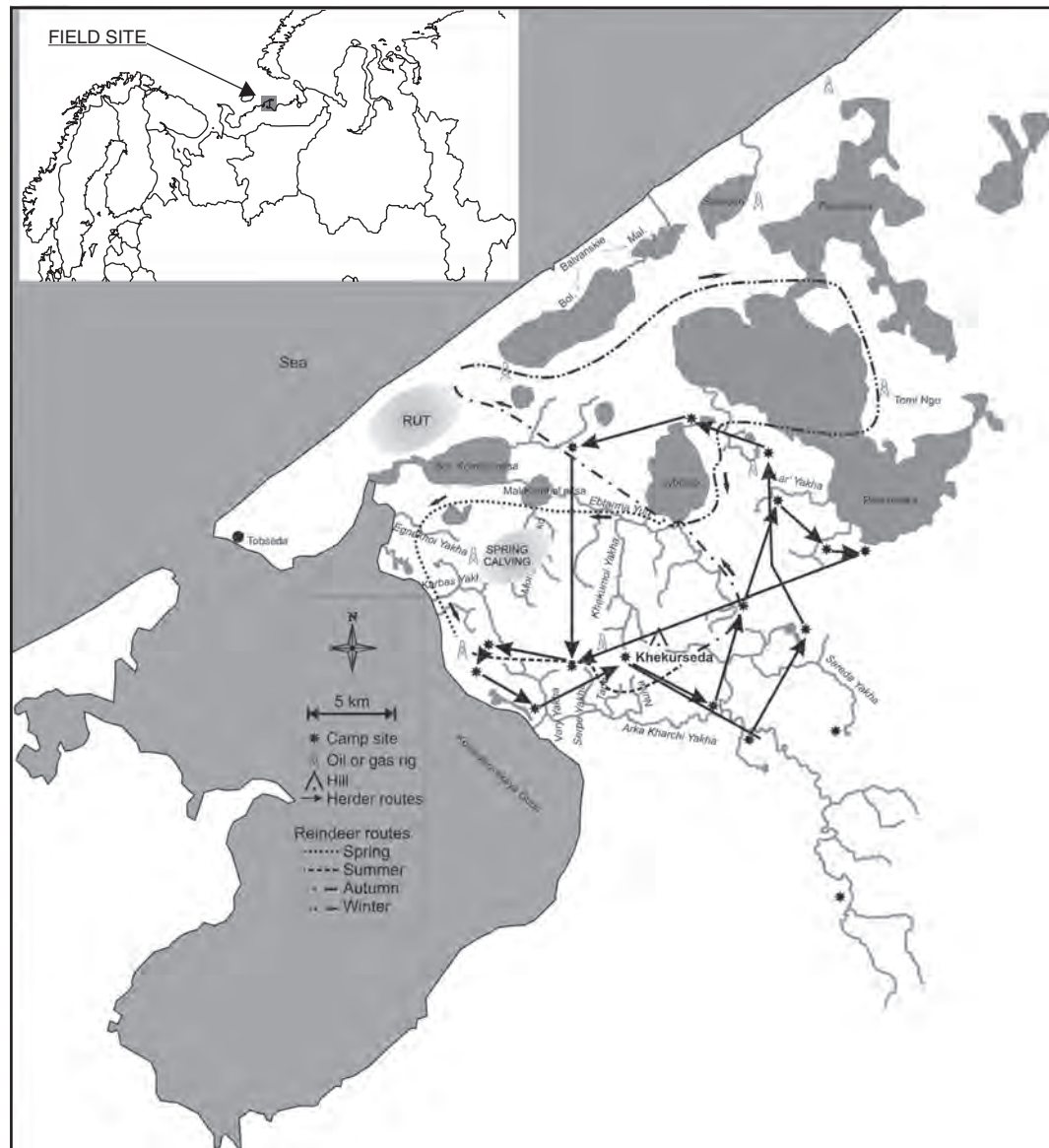
Particularly important for structuring migration are decisions about whether to cross rivers. In the previous example of long-distance migration, the Yuribei River must be crossed before the ice breaks in spring, otherwise camps and herds are delayed for months waiting until the water level falls. Further north, the Se-Yakha River must be crossed before the main mosquito eruptions, which requires the herds to navigate through difficult industrial gas installations along the migration route. Arriving at their northern destination on time promotes the optimal weight gain of the animals. Lingering on northern pastures before moving back south is also

**Table 10.2** The seasonal migration cycle of a Nentsy reindeer nomad camp, Yamal Peninsula. The herd is of approximately 5000 reindeer, managed by 50 people, travelling an overall distance of 1100 km. Southern winter pastures at 65.30 NL, northern pastures at 70.55 NL (Source: Stammer (2005, pp. 91–118); see summary table pp. 101–103)

Season and approximate months	Movement	Pasture conditions	Other considerations
Early spring: March–April	Start migration northwards from forest zone with frequent movements and new camps every 2–3 days.	Lichen-rich pastures in the forest zone; with movement north changing from forest zone to treeless tundra; migratory corridors narrow and are grazed intensively by several herds one after another.	The ‘Day of Reindeer Herder’ festival, the year’s biggest party and main yearly stop in village to get supplies.
Late spring: April–May	Rush to the north before calving as long as watercourses are frozen and easy to cross. If rivers break-up before crossing, then passage to summer pastures is blocked for months.	Transitory pastures, used by many camps; a mix of lichen and first snow-free green patches. By many herders seen as the main bottleneck of the year.	Calving often happens on the move; herders must balance the need for frozen snow to ease movement at night, versus the need for times of rest on snow-free patches for calving.
Summer: June–July	Continue north to the coast, reaching it with the start of mosquito harassment. Careful balance of feeding, drinking, resting time required for optimal weight gains. Staying at northernmost coastal area one week in August.	Selective grazing of the first leaves of dwarf bushes ( <i>Betula</i> , <i>Salix</i> ), and fresh grass. Salty coastal grass and pastures exposed to wind are important for reindeer appetite.	Movement is more and more restricted by the presence of extractive industry (e.g. crossing Bovanenkovo gas deposit).
Early autumn: August–September	Turn back south, crossing major rivers before water levels rise in autumn.	Feeding on mature green plants, being distracted by mushrooms and berries leading to increased herd restlessness.	Navigating through industrial installations and trading with their workers.
Late autumn: October–November	Continue south, crossing rivers as soon as they freeze over.	Proportion of lichen in pastures increases as snow falls. Narrow transitory corridor pastures, heavily used by competing camps. Danger of pastures icing-over with sudden temperature and precipitation changes.	Change to winter gear and set up the stove. Bulls are restless because of rut. Prepare for the annual reindeer count and select corral for slaughter; figure out property relations in animals and socialize with neighbours.
Winter: December–March	Cross into the forest zone; the pace of movement slows, herds are not watched every day, and camps are not relocated for 2 weeks or more.	Lichen-rich pastures to sustain animals during winter cold down to -50°C. Snow-depth possibly restricting pasture access.	Counting and slaughter animals and fetch from town yearly income and welfare payments.

**Table 10.3** The seasonal migration cycle of a Nentsy reindeer nomad camp, Kolokolkova Bay, Barents Sea. The herd is of approximately 500 reindeer, managed by 12 people, of which four are active herders. Overall distance: approximately 100 km for camp, 150 for herd. Pasture area between 68.30 and 69.00 NL (Source: Stammler fieldwork 2004 summer; Stammler and Vitebsky fieldwork 2005 spring)

Season (and approximate months)	Herd movement	Camp movement	Pasture conditions	Other considerations
Early spring: March–April	Move to the shore.	Moving from campsite encircled by lakes to a site 5 km east of the herd.	First green plants appear on salty pastures that flood later during the spring thaw.	Bulls move ahead of the rest of the herd.
Late spring: April–May	Females move inland to calving ground.	Move 5 km south from a hill to the shore of a small river, to prevent the herd returning to its previous calving ground.	Slightly elevated terrain with the most available snow-free patches.	Humans observe but do not interfere in calving except to adopt calves that are abandoned by their mothers.
Summer: June–July	Undivided herd moves to highest elevation in the area.	The camp and herd are united on Khekurseda hill. From this site people make fishing trips to a large nearby lake.	A windy site that minimizes mosquito harassment, but is also littered with stones that injure the animals' hooves.	Could move to the coast, but use of these lichen pastures is deferred until winter.
Early autumn: August–September	Move down slope along small rivers flowing north.	Southernmost camp site near the areas biggest river, for fishing; from here the camp is moved northwards to a large lake for autumn fishing.	Herd feeds on shrubs along rivers—last snow-free green food.	Mushroom season; the herd is restless but controlled by open water that forms a natural barrier.
Late autumn: October–November	Move to a small coastal peninsula for the rut.	Move west to a lakeshore closer to the rutting grounds. Herders from this camp move 15 km to 'lock' the herd on the 'rut-peninsula'.	Poor, lichen-free forage located on sandy lowland.	The peninsula is convenient for keeping the restless herd together. Avoid lichen areas to prevent trampling during rut.
Winter: December–March	Move to northern coastal areas in late winter, turning inland along the valleys of small rivers.	Stay close to the northern coast to guard the deer, or alternatively guide the herd northeast where more extensive pastures are available to accommodate herd growth.	Lichen-rich, salty pastures—ideal forage. The last green feed of the year is available, preserved under the snow along rivers.	There are alternative winter pastures from which to choose, depending on when large lakes with connections to the sea finally freeze over.



**Figure 10.4** Schematic migration map of a Nentsy reindeer herding camp in a confined territory in European Russia (Source: Hand-drawn map by Petr Taleev during fieldwork of Stammler and Vitebsky, May 2005. Digitized by Arto Majoinen).

attractive, but must be weighed against the 450 km trek that must be completed in autumn to bring the herds close to the slaughterhouse.

In Case 2, the migration route described in the table was established only in 2003 after a private cooperative separated their herd and camps from a former state farm. The movements of this group

demonstrate how people ‘design’ migration routes in a relatively confined area. Unlike the long linear corridor migrations, localized herders make use of their limited area by moving in loops and figure eight patterns. The two fixed points in these annual cycles are the calving and the rutting sites. Both are identified by the herders and introduced to the

herd in a process of mutual learning and forgetting. In this case humans establish new habits for the reindeer herd, which in the early years tends to wander off to previous calving and rutting places that have become inaccessible for political reasons. By observing herd behaviour at the new locations, humans learn the favourable characteristics of the new pastures while the herd forgets the old pastures, an intimate partnership in migratory decision-making involving both humans and animals. Far from being unstructured ‘without any established migration route’ (Dwyer and Istomin 2008), these localized movements are established in a process of trial and error over several years (see Beach and Stammler 2006).

Similar processes take place whenever political or administrative decisions render pastures inaccessible for herders and herds, following the reorganization of land rights in Russia (Stammler 2005), the fencing of herding territories in Finland, or the closing of national borders in the Nordic countries (Kumpula 2006). As natural resource and infrastructural development advances across the Arctic, these processes are likely to recur in many more cases (Tuisku 2002; Stammler and Peskov 2008).

#### 10.3.3.4 *‘Push and Pull’ factors in migration*

To structure the rhythm of their migration, herders may alternately push the herd from behind, pull it from the front, or stop it from advancing too quickly. Placing a camp or a herding team in front of the herd to slow its progress is one way to decrease the extent of mobility among domestic reindeer. In autumn during rutting, the herders may place themselves in front of the herd in order to ‘brake’ the pace of bulls advancing for lichen-rich pastures. Alternatively, reindeer among the Nentsy may prefer to linger in spring on lichen-rich pastures until herders push them to begin the spring migration. Having to cross a river by a certain time causes herders to push their animals, and pushing is particularly important during calving, when weak calves may be tied to sledges to prevent them from lagging behind. Herders may also decide to move on when they find that it becomes increasingly difficult to keep their herd together on a particular pasture, as restless reindeer spread out. In this situation herders may find it convenient to keep their

reindeer happy and move with them to different pastures, before unhappy reindeer abandon their human keepers. In other situations the instinct of females to return to their former calving places may facilitate herd movement.

Lichen-rich pastures are preferably not used during the rut due to the trampling pressure of restless bulls (see above Case 2), which destroys lichen grounds. Lichen-preservation is a broadly accepted strategy by the people leading herd movements. Camps should not be placed on lichen grounds, and reindeer should not graze lichen in summer when the lichen are dry and of less value (Stammler 2005).

#### 10.3.3.5 *Day-to-day ‘symbiotic domesticity’*

Finding a good pasture on a day-to-day basis is a symbiotic activity between herder and herd, herder and lead animals. Driving a reindeer in harness exemplifies this relationship. At the macro level, an experienced reindeer driven in harness will know the general direction of an established migration route. At the meso level, the sledge driver will use the harness to determine the path taken, which is then followed by other sledge caravans and the herd, if camp and herd migrate together. This meso-level decision-making incorporates human knowledge of the land, for example avoiding contaminated sites, large concentrations of predators or humans, iced-over pastures, busy roads, or taking into account human needs such as passing through a trading post. On the micro level, however, it is again the reindeer that help determine the detailed direction and pace of movement—for example, using their judgment to avoid dense shrubs or stop at a particularly good feeding spot.

During the worst periods of harassment by mosquitoes, herders and herd together determine times of feeding, drinking and rest. Reindeer are guided back to the barren ground site in front of the camp several times a day, where they lie down and rest. Annoyed by the insects, they would otherwise run far against the wind, and ‘forget’ resting and feeding and lose weight. After feeding, herders may direct the herd in circular movements to a lake or river for drinking, before they go back to the barren ground site. In this way humans act in partnership with their animals to protect them.

### 10.3.3.6 Domesticated versus wild reindeer

Reindeer are exceptional because significant numbers of both domesticated and wild reindeer share the same habitat. Reindeer domestication began at least four centuries ago but is thought to be in an early phase and incomplete; sub-species identification is still under discussion (Roed *et al.* 2008). Comparative studies of wild and domestic variations of *Rangifer tarandus tarandus* emphasize differences in foraging behaviour, morphology, and intra-species diversification between different varieties of domestic reindeer and between wild and domestic animals (Zabrodin *et al.* 1979; Krupnik 1993; Geist 1999; Stammler 2005).

Some authors credit the differences between domestic reindeer populations to the selection process of indigenous herders (Baskin 1991). Geist argues that 'humans could give the reindeer habits that are useful in its control and exploitation' (1999, p. 317). Among these habits is a less mobile foraging behaviour, leading domestic reindeer to use up to 40% of available forage per unit of pasture, whereas wild reindeer use only 1–4% (Yuzhakov and Mukhachev 2001). Socio-culturally, there is little doubt that reindeer herders and hunters perceive wild and domestic reindeer as different animals. In most native languages, the terms for wild and domestic animals are not etymologically related (Vitebsky 2005; Beach and Stammler 2006). Herders say that wild reindeer are stronger and bigger than their domestic counterparts. Domesticated reindeer that are not closely managed become feral but can be re-domesticated, which is impossible with wild reindeer (Beach and Stammler 2006).

In the late 20th century, domestic and wild reindeer herds have mixed in many places in the Arctic. In these cases the domestic animals lose out: during the rut, wild bulls are stronger than domestic ones, leading to a 'half-wild' generation of calves that is not tractable for herding. In places that experience large increases in wild reindeer populations, many herders have lost their entire domestic herds to bigger wild herds, causing financial damage as well as cultural change (Klokov 1997 for Taimyr; Gray 2006 for Chukotka; Finstad *et al.* 2006 for Alaska). In Northwest Yakutia, however, coexistence may be possible and even beneficial for herders, who hunt wild reindeer for meat and also maintain their

domestic herds as a more predictable resource base (Ventsel 2006).

Most domestic reindeer in the Russian half of the Arctic are managed in what is called 'close herding', while most reindeer in Fennoscandia and Alaska are managed in 'loose' herding (Baskin 1991) or ranching (Ingold 1980; Beach 1981), while some herders in Russia employ a combination of both systems (Takakura 2004). In close herding, reindeer are supervised and their movement monitored round-the-clock for most of the year except in late winter/early spring (Takakura 2004; Stammler 2005; Dwyer and Istomin 2008), which means that herders and reindeer negotiate on a day-to-day basis (and in summer even an hourly basis) the pasture to be used by the herd. In 'loose herding' and ranching, on the other hand, the herd is gathered only periodically to perform basic veterinary activities, cull animals for market and brand young animals. In close herding one of the main objectives of human influence is to prevent herd dispersion and mixing with other herds, a practice that has become unnecessary with the introduction of fencing and ranching in Fennoscandia. In these extensive systems the relationship between owners and their herds resembles the interaction between reindeer hunters and the wild animals that they ambush in autumn for slaughter. Property rights are the main distinguishing feature—pastoral animals are recognized as property when they are alive, while hunted animals are owned only after they are killed (Ingold 1980).

Building fences in Fennoscandia has reduced human mobility, with nomadic reindeer herders settling down in the period after WWII up to the 1960s. In the polar Ural Mountains of Russia, reindeer herders have also reduced their migration due to partial sedentarization in winter time, which led to the abandonment of winter pastures and the shortening of migration routes by around 150 km. There are still cases of fully nomadic migration of people and animals over thousands of kilometres (Stammler 2005; Habeck 2005; Dwyer and Istomin 2008). Long-distance migration has tended to survive when herders are able to minimize the costs of movement by using reindeer for transport. Conversely, the use of purchased inputs for transport, such as snowmobiles, generally contributes to

a reduction in mobility and eventually to sedentarization (Pelto 1987; Stammer 2009).

Over the centuries reindeer pastoralism has moved through various phases. It apparently began with humans accompanying wild herds along routes determined by natural environmental factors and was gradually modified with the domestication, pacification and control of behaviourally modified domesticated reindeer. In the last century migration cycles have been shortened in response to technical innovations such as fencing, cost considerations, and administrative restrictions, a process that has frequently culminated in the settlement of human populations and the confinement of reindeer behind fences.

#### **10.4 Conclusions: similarities and differences between wild ungulate and livestock migrations**

This book synthesizes current knowledge about the migratory habits of wild animals. At an impressionistic level, pastoral and wild ungulate migrations are remarkably similar, and it is not immediately clear what sets domesticated migratory systems apart from those of other migratory species. At least three sets of variables drive both wild ungulate and livestock migrations: the distribution of resources, competition for these resources, and constraints on access to them. Both the distinctive features of pastoralism and its common heritage with other migratory systems are revealed by the way in which pastoral movements address these issues of resource availability.

Old World pastoralism spans the tropics to the Arctic, making productive use of biomes as varied as deserts and savannas, marshes, mountains, high meadows, plains, taiga and tundra. The cases presented in this chapter provide a small but geographically dispersed sample of this diversity, and support the following conclusions.

##### **10.4.1 The management of forage supplies**

Forage quality is often inversely related to abundance, both over time as plants mature and along fertility and productivity gradients in heterogeneous landscapes. There is a broad similarity between

the way in which pastoral livestock and wild ungulates exploit this variability. For both, optimizing reproduction is a function of maximizing nutritive intake by targeting areas of high quality forage when food is abundant and shifting to areas that produce peak vegetative biomass when food is scarce. Long-distance meridional pastoral movements in Eurasia and Africa conform to the predicted oscillation between refuge areas during periods of plant dormancy (the dry season in the semi-arid tropics or winter in the temperate or Arctic zones) versus breeding grounds in periods of plant growth (the rainy season in the tropics and summer in the northern latitudes).

Like remnant wildlife populations in the region, cattle populations shift northward into the Sahel during the rains to exploit the brief but nutritious florescence of annual vegetation, retreating south to floodplain pastures as the dry season intensifies. Both wild reindeer/caribou and domestic reindeer herds move to herbaceous pastures for calving as 'snow melt triggers green-up, the burst of plant growth which has the highest nutrient value' (Gunn 1998, p. 320). Before the collapse of the Soviet Union, the same nutritional considerations drove long-distance sheep and saiga migrations on the Kazakh steppes, which tracked the advancing wave of green-up northward in spring and retreated to the south in autumn with advancing snow cover (Singh *et al.* 2010; Bekenov *et al.* 1998; Robinson and Milner-Gulland 2003; Fedorovich 1973).

Localized migratory movements—exemplified in this discussion by migrations on the Mongolian steppe and among Nentsy herders along the Barents Sea—are influenced by the same forage considerations as long-distance migratory systems, but play out on a restricted geographical scale (Coughenour *et al.* 1990; Coppock *et al.* 1986; Behnke 1999; Alimaev 2003; Behnke *et al.* 2008; Wachter *et al.* 1993). Extremely localized systems may not look migratory at all. In a normal rainfall year village cattle in Zimbabwe move no more than a few kilometres up or down a catena, exploiting the distinct vegetation resources on offer in different microenvironments at different times (Scoones 1995).

The seasonal trade-off between forage quality and quantity is also reflected in the way contemporary migratory pastoralists provide supplementary

feed for their animals. In Fennoscandia, where herd movement is limited by fences, additional feeding is used to mitigate extreme weather events. Natural hay and home-made concentrates are a component of the winter diets of Mongolian herds; crop residues and other forms of supplementation are important additions to the dry-season rations of Sahelian livestock. What sets contemporary migratory husbandry systems apart from more intensive forms of livestock farming is not the absence of supplementation, but how it is used. In intensive systems, feed supplementation and cultivated forage are used to maintain high, steady levels of growth and output. Under these conditions, prolonged periods of weight loss or low performance simply waste feed and money and are indicative of poor management.

The seasonal oscillation between scarcity and plenty in migratory systems sets a different husbandry challenge. The fluctuating weights of Sahelian cattle illustrate the problem. In the dry season cattle in the Sahel routinely start to starve, and in drought years they continue starving until they die (see Ellis and Swift 1988 for the Turkana of East Africa). In the northern latitudes, the comparable crisis period occurs in late winter or early spring, when emaciated animals struggle to survive until warmer weather brings fresh grazing. Provided that they make it through the crisis, migratory breeds quickly regain condition and weight when favourable conditions return. The trick is to keep as many animals as possible alive until that time.

If they use preserved feed supplies at all, pastoralists typically use them to maintain animal numbers during periods of forage deficits, in the expectation that growth and reproduction will return when natural forage is plentiful, provided enough animals survive. Animals are fed not to make them fat, but simply to keep them alive. By buffering pastoral livestock against fluctuations in forage supplies, feed supplementation can maintain larger livestock populations than those attained by natural ungulate populations that are subject to the full rigours of climatic variation (Kerven 2004; Bayer and Waters-Bayer 1994). The occasional use of stored feed or grazing reserves (Fernandez-Gimenez and Le Febre 2006) epitomizes the transitional nature of migratory pastoralism—an agricultural

production system, but one that attempts to exploit, and occasionally supplement but not replace, naturally occurring livestock feed sources.

The burning of tropical pastures provides another example of the gradual pastoral transition from natural to managed grazing. Because they are generally located in areas of higher rainfall where stock water is more readily available, tall-grass savannas provide dry-season refuges for Sahelian herds. In the dry season these pastures are mature and high in bulk but low in quality. Pastoralists frequently burn these pastures early in the dry season to stimulate protein-rich re-growth based on residual soil moisture, or to render fresh growth accessible to grazing by removing unpalatable stubble (Laris 2002; Hiernaux and Diarra 1984). In order to restart natural plant maturation processes artificially, herders set intentional fires that are subtly different from the natural wildfires that would otherwise occur in these regions.

#### 10.4.2 Patterns of movement and distribution

Rarely is there a single right way to move.

*... If a move is to be made, then there must be a choice of timing, of direction, of distance, and of new location. This choice is not in practice simply a matter of reaching a decision through the assembly and assessment of information on resources, for usually there is no obviously single best choice but a variety of possibilities. Information is seldom complete in any case, and the techniques of its assessment are not wholly efficient. Opinion is involved, and this can vary from herdsman to herdsman. But in any case seldom is there but one time and direction of movement clearly indicated. There is a range of opportunities of roughly equal pastoral advantage (Gulliver 1975, p. 371–2).*

The preceding quotation refers to the Turkana pastoralists of East Africa, but is applicable to a wide variety of pastoral systems. As previously noted, in the Sahel the early rains are a period of particular uncertainty. In the Arctic unpredictable icing-over and re-freezing can make forage



suddenly unavailable (Forbes and Stammer 2009; Rees *et al.* 2008). In inherently risky environments there often are no obviously superior, safe options; opinions differ, herds move in different directions, and chance rewards some and punishes others. This occurred in the winter of 2006/07 when a spell of warm weather and heavy rain were followed twice by a rapid fall in temperatures in the West Siberian Yamal Peninsula. During the 2006 icing event, herders visited or called ahead to villages along their migratory routes to enquire about pasture conditions. Having received encouraging news about pastures further to the south, some herd owners decided to continue their migration in that direction, while others cancelled half of their normal yearly migration and remained north of the iced pastures. On their return trip north the following spring, those who had chosen the southern option were hit by a further unexpected icing event that depressed calf survival rates to less than fifty percent. Herders who had decided that year to cancel their migration and remain north of the iced pastures had a normal calf survival rate of over 80%.

Apart from differing estimates of risk and imperfect knowledge, herders' movement decisions are also influenced by their variable resource endowments and tenure rights. Even within a reasonably homogeneous pastoral community, this diversity can foster complex and apparently contradictory movement patterns. A recurrent source of intra-community variability in agro-pastoral systems is the location of arable fields and homesteads. Based in different locations, herders who are also farmers tend to view the landscape from the perspective of their home location, and adjust their movements in response to their individual situation (de Boer and Prins 1989). Intra-community variability in movement patterns is also caused by variations in herd wealth, with large flocks or herds tending to be more mobile than small ones (Robinson and Milner-Gulland 2003; Kerven *et al.* 2008). Stock owners' distinctive social networks and land tenure rights and the variable species composition or age and sex structure of their livestock holdings also sends herds moving in different directions. In sum, 'human, livestock, environmental, and political factors, [result] in a pattern of movement that varies

from herd owner to herd owner and from year to year' (McCabe 1983, p. 117).

When there is one obviously superior movement pattern, coordinated use often becomes necessary and queuing emerges along busy trek routes or at migratory bottlenecks, as illustrated in the Arctic case study in this chapter, or around congested water points in semi-arid areas. When it is clearly advantageous for them to do so, pastoralists have the capacity to coordinate movement and resource use. With respect to mobility and residence, however, decision-making in pastoral societies tends to devolve to independent social units—individual households or small groups of households. Something approximating free distributions would appear to emerge from the multiple, serial negotiations between these geographically dispersed, differentially endowed and relatively free agents. Rigorous testing of this hypothesis is difficult since it requires movement records on entire pastoral populations relative to seasonally shifting natural resource configurations (for attempts in this direction see Behnke *et al.* 2008; Finke 2000).

The heterogeneous, temporally unstable and unpredictable distribution of resources favours reciprocity in harsh environments where producers can ill afford to under-exploit transient resource concentrations. This openness is often culturally embedded in indigenous resource tenure and use systems. Fernandez-Gimenez has described the 'vagueness, permeability, and overlap of boundaries around pastoral resources and user groups' in Mongolia (Fernandez-Gimenez 2002, p. 49). Referring to pastoral Africa as a whole, Behnke characterized pastoral tenure systems as having 'fuzzy or indeterminate social and territorial boundaries' (Behnke 1994, p. 15; Goodhue and McCarthy 1999); and for West Africa Turner describes 'porous systems of pastoral usufruct' that are 'socially malleable' and 'typically display an unbounded, point-centred spatial pattern' (Turner 1999a, pp. 103, 108). In economic terms, what pastoralists are trading among themselves are not products or services, but access rights to the ephemeral natural resource concentrations that are needed to sustain production. As in more conventional trading systems, when debts accumulate,

culturally prescribed notions of reciprocity encourage an eventual settling of accounts, from which all parties stand to benefit. These are not the bounded, resource-conserving systems commonly described in the literature on common property resource management. Indeed, these are in neo-classical economic terms a theoretical oxymoron—systems of tenure rights that regulate open access—a uniquely migratory perspective on the notion of property.

### 10.4.3 Non-forage constraints

Wild ungulate populations do not perfectly match their forage resources and neither do livestock—again a fundamental similarity (Senft *et al.* 1987 Bailey *et al.* 1996). Water is a recurrent constraint, but restricts movement in different ways in different climatic zones. In the semi-arid tropics, water dependency is a physiological barrier to the free movement of any species—domestic or wild—that must drink in the dry season. In the Arctic and subarctic where surface water is common and drinking is not an issue, bogs, rivers and lakes create physical barriers to passage, separating both domestic and wild herds from potential grazing areas.

Insect pests and parasites affect livestock in all three case study regions covered in this chapter, but the extent to which pests inflict sufficient damage to alter movement patterns is variable. In Turkmenistan, for example, sheep flocks that normally reside in the desert are forced into irrigated agricultural areas in drought years. Here the flocks find abundant feed from roadsides, ditches and crop residues, but are infected by liver and intestinal parasites from polluted drinking water. According to shepherds, mortality rates are roughly proportional to the length of time flocks spend in the area, so shepherds try to leave as soon as possible, and most do not use infected areas in years of normal rainfall (Behnke 2008). In some instances moving away from the problem is neither advantageous nor necessary. In The Gambia of West Africa, cattle preserve high levels of green grazing in their diets by moving seasonally into areas with the highest rates of tsetse infestation when tsetse populations are at a maximum. The in-coming cattle pay very little ‘penalty’

in terms of increased trypanosomiasis infection, apparently because large numbers of migrant animals share the fly burden and dilute the individual risk of infection (Wacher *et al.* 1993).

There are also some distinctively human constraints that impinge on the movement of domestic herds. As all the preceding case studies emphasized, optimizing pastoral production may be only one among several objectives for pastoral households, such as access to wage employment or alternative income sources, markets, education and social services, or the amenities afforded by a settled way of life. Matching animal numbers to feed resources may be compromised in an attempt to satisfy these multiple (often non-pastoral) objectives. Mongolian herders cluster around overgrazed settlements that provide services and potential employment; Arctic herders go fishing.

On the other hand, human knowledge, foresight and technical ingenuity can also serve to remove natural barriers to pasture exploitation. In both the Sahel and Arctic, herding has a quantifiable positive impact on foraging by domesticated herds. The deferred use of critical pasture reserves, the scheduling of complex movements through topographical or industrial bottlenecks, and infrastructure (boreholes in the tropics or animal shelters in cold climates) minimize the impact of natural constraints. Interventions can be as sophisticated as modern veterinary medicine, or as simple as the smoke from a cattle byre that wards off biting insects. These activities improve the degree of matching between feed resources and animal populations or overcome species-specific physiological limitations, e.g., with respect to dependence on drinking water, exposure to heat or cold, susceptibility to disease:

*While wild ungulates cannot usually fully utilize landscapes, production-oriented systems attempt to sustainably extract as much from an ecosystem as possible. Wildlife distributions are often limited by localized deficiencies of water, minerals, and navigable terrain. Production livestock systems attempt to remove these landscape constraints by manipulating resources or animal behaviour (Coughenour 1991, p. 539).*

#### 10.4.4 The human difference

The similarity between wild ungulate and pastoral movements is close enough that one might be tempted to conclude that there is no difference, and that pastoral livestock distributions are a mechanistic reaction to environmental conditions. This would be a mistake. Pastoral migrations may appear to be a natural response to the exigencies of the landscape, but they are sustained by social institutions that encourage discipline within and between communities of herders (deferred pasture use, inter-tribal raiding, land tenure restrictions, etc.). Pastoralists also do not simply match livestock to existing forage resources; each year and over the long term they shape their feed supply, removing 'landscape constraints by manipulating resources or animal behaviour...[to]...significantly alter the plant-herbivore balance' (Coughenour 1991, p. 539).

Appearances aside, these are culturally regulated agricultural systems operating in human-modified landscapes. The illusion of naturalness rests on the relatively light impact of pastoralists on the landscapes they use, in comparison with other forms of land use, and on the unobtrusive style of pastoral livestock management. Given clear-cut biological incentives, skilful herding routinely facilitates the movement of animals in directions that they would anyway be inclined to go, rather than restricting or coercing their movement, or delivering inputs to the animals, as occurs in more intensive livestock production systems. Human vigilance and sustained intervention are intermittently needed to maintain advantageous patterns of herd movement, for example when crops are standing in fields close to pastures. Herd tracking studies have demonstrated that herded animals are better distributed with respect to available forage within a grazing radius than free pastured animals (Turner *et al.* 2005). But when predators are not a risk, pastoral livestock (and especially the larger-bodied herd species such as cattle, yaks, horses and camels) may spend from hours to months on their own without these movement systems breaking down into chaos at the landscape scale.

Mechanistic biological models explain aspects of these migratory systems. This chapter has shown that ungulate migrations can be usefully analysed in

terms of spatial and temporal fluctuations in forage availability, irrespective of whether the animals are domesticated or wild, long or short-distance movers. But there are limitations to this approach. The capacity of density dependent habitat selection theory to explain the spatial distributions of domestic herds remains untested, but it will probably provide only a partial explanation for land use systems that must balance the pressures for free and optimal livestock distributions against the restrictions of property rights and administrative boundaries. More generally, the diversity of socio-economic variables that impinge upon pastoral migration complicates any attempt to generalize about the organization of these movement systems. Movement is a livestock husbandry practice used by pastoralists to achieve wide ranging cultural, social and economic goals, and it is subordinate to these larger concerns.

#### 10.4.5 A closing note on the environmental consequences of large-scale migratory pastoralism

The advantages for rangeland conservation of intermittent use and resting versus continuous use are documented across a wide spectrum of grazing environments (Galvin *et al.* 2008). 'It is no accident that the world's large populations are of migratory species' writes Sinclair with obvious approval (1983, p. 250). Misgivings by some scientists and policy-makers about the sustainability of migratory livestock systems tend, perhaps unsurprisingly, to focus on the issue of livestock numbers. It is recognized that large wild migratory populations can have equally large environmental impacts (Chapter 9). Writing about the resident wildebeest populations of the western Serengeti, Sinclair observed:

*The residents have the double disadvantage of increased predation and increased food competition when the migrants arrive and literally remove all the food. When this happens, the migrants move on (an example of a paradoxical strategy where the intruder has an advantage over a resident) (1983, p. 256).*

Sinclair was referring to wildlife; the tone is often less dispassionate when similar observations are made about the actual or modelled environmental

impacts of migrant livestock. What is at issue here is not science but aesthetics or economic self-interest. Environmental impacts that are acceptable and 'natural' when perpetrated by wildlife are often characterized as unacceptable degradation when potentially caused by migratory livestock (Illius and O'Connor 1999; Murray and Illius 1996; Prins 1989), or by someone else's migratory livestock (Adams 1982).

Alternatively, it is possible to view both migratory wildlife and mobile livestock as fence-wrecking despoilers of modern, sedentary, commercial ranching:

*Recently there has been [in tropical African savannas] some collectivization of nomads into ranches and discussion of the problems of overgrazing, but there is little emphasis on management in the sense of rational utilization of the grazing resource. The problem is complicated by substantial economic returns from tourists, who come to see the wild animals. But the needs of wild animals in large herds conflict with sedentary pastoralism, particularly if the pastoralists fence their land (Fisher et al. 1996, p. 396).*

Unfashionable in scientific circles, the biases expressed in this statement probably represent the majority opinion among policy-makers and

administrators in developing Asian and African countries.

And herein lies a final parallel between wild ungulate and pastoral migratory systems—both are under threat. In part, this threat comes from habitat loss and resource fragmentation caused by expanding human populations and economic development (Behnke 2008), processes that research on pastoral migration probably can do little to mitigate. From Ethiopia to China, however, central government authorities also mistrust and denigrate that minority of their citizens who are migratory pastoralists. The Ethiopian government would like to settle these people, if only it had the power to do so. The Chinese government does have that power and is doing so, on an unprecedented scale with state-sponsored fencing programmes, the clearance of 'degraded' rangelands and the forced resettlement of entire indigenous communities (Yeh 2005; Yan et al. 2005; Brown et al. 2008). Official justifications for these policies recite the shibboleths in the preceding quotation—the dangers of overgrazing and irrational resource utilization versus the technical and economic advantages of fencing. Provided government-sponsored policy is based on evidence and susceptible to reform, a clearer understanding of the causes and consequences of pastoral movement will serve both the interests of science and better policy.