Human Ecology, Vol. 31, No. 1, March 2003 (© 2003)

Political Change and Factors Limiting Numbers of Wild and Domestic Ungulates in Kazakhstan

S. Robinson[1] and E. J. Milner-Gulland[2,3]

We examine factors regulating numbers of domestic livestock and saiga antelopes during the major periods of Kazakhstan's history. In the pre-Soviet period livestock migrations were relatively unrestricted and covered huge distances. Little winter feed or veterinary care was provided for domestic livestock and numbers were regulated largely by winter snow or ice cover. Drought affected fecundity but did not cause large-scale mortality. During the Soviet period the provision of winter feed shielded domestic livestock from winter mortality while hunting controls allowed saiga numbers to recover from overhunting. Livestock and saiga numbers during this period were high and there is evidence that productivity was affected. However, there were no crashes in livestock numbers linked to high densities, probably because rainfall variability is relatively low and catastrophic droughts are rare. Today livestock numbers in Kazakhstan have crashed because of the withdrawal of state support and the use of animals as currency. The collapse of the state also meant the end of hunting controls and increased poverty, which has lead to widespread saiga poaching and dramatic population declines.

KEY WORDS: Pastoralism; livestock; saiga antelope; density dependence; Soviet Union.

INTRODUCTION

There has been much debate in recent years concerning relationships among grazers, climate, and vegetation on rangelands. This centers on the proposition (Behnke and Abel, 1996; Ellis *et al.*, 1995; Scoones, 1992) that

[1]Ecology and Epidemiology Group, Department of Biological Sciences, University of Warwick, Coventry CV4 7AL, UK.
[2]Department of Environmental Science and Technology, South Kensington Campus, Imperial College, London SW7 2AZ, UK.
[3]To whom correspondence should be addressed; e-mail: e.j.milner-gulland@imperial.ac.uk.

0300-7839/03/0300-0087/0 © 2003 Plenum Publishing Corporation

in many cases rangelands may not be in equilibrium. In these cases, it is suggested that forage resources are regulated by climatic fluctuations to such an extent that herbivory has little impact and density-dependent regulation of herbivores is weak.

The rangelands of Kazakhstan are characterized by low rainfall and severe winters. They are populated by both domestic and wild ungulates, the most numerous of which is the saiga antelope (*Saiga tatarica*). This century has seen a transition from an extensive nomadic pastoralism to a more intensive seminomadic or sedentary system supported by supplementary fodder. Since the 1990s, decollectivization and the loss of state support have caused huge upheavals in the livestock sector leading to a crash in animal numbers. In this paper, we analyze the factors that have limited ungulate populations in these different periods of Kazakh history, and evaluate the importance of density-dependent and density-independent processes in the different grazing systems. We also analyze the Soviet literature and data on rangeland science, wild ungulate populations, and livestock production, much of which has never before been available to Western readers.

First we describe pre-Soviet herding systems and the changes that occurred with the incursion of the first Russian settlers. Factors limiting numbers of domestic and wild ungulates during this period are then analyzed. The second section describes grazing systems during the Soviet period and the changes that allowed huge increases in livestock numbers and thus a possible increase in density-dependent regulation. Overgrazing was widely reported in the 1970s and 1980s. We discuss its effects on the livestock sector and ask what lessons have been learned, which may be of value to Kazakhstan's newly privatized and chaotic livestock sector.

LIMITS TO PRODUCTION IN THE PRE-SOVIET ERA: NOMADIC HERDING SYSTEMS

The Distribution and Movement of Ungulates

The ecosystems of Kazakhstan are generally harsh, with low rainfall, and crucially, the effective elimination of a large part of the northern pasture in winter because of deep snow cover. Temperatures in the deserts and steppes of Kazakhstan reach $-40°$C in winter and $45°$C in summer, and rainfall varies from an average of 130 mm/year in the desert zone (Kyzyl Orda) to more than 300 mm in the steppe zone (Karaganda). As might be expected, Kazakh pastoralists were traditionally highly migratory. They generally stayed in the desert zone in winter, moving to summer pastures in the steppe zone to the north or high into the mountains. Such migrations could span up to 700 km in

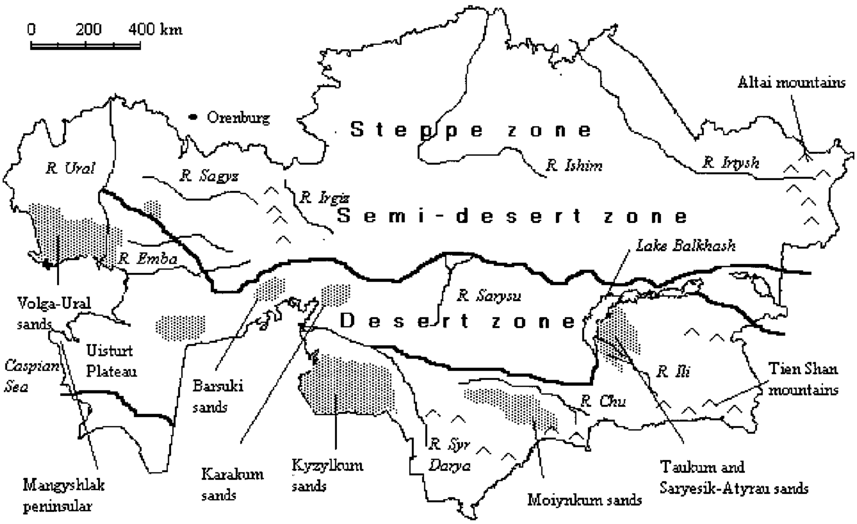

Fig. 1. Ecological zones of Kazakhstan. Stippled zones show winter pastures on sandy soils. The clay desert zone is shown within bold lines (Kirichenko, 1980).

the desert and steppe regions. Before Russia took an interest in the country, most Kazakhs were purely pastoralists, practicing little agriculture or hay production, and thus had little supplementary feed for their animals (Matley, 1994a). However according to Bezhkovich (1973), several Russian explorers in the nineteenth century reported that Kazakhs in the Semireche region of southwest Kazakhstan did practice some cultivation of wheat and millet and were growing hay before the arrival of the Russians.

Figure 1 shows the vegetation zones of Kazakhstan. The seasonal pastures are dominated by perennial species, annuals being few and appearing mostly in wet years. The winter pastures in the sandy deserts were particularly important for livestock. This is due to the shrubby nature of their vegetation (*Haloxylon* and *Calligonum* spp.), which is accessible in deep snow, and the fact that many of these deserts have dunes, whose south-facing slopes allow fast snow melt. Other favored wintering grounds were along rivers and in the foothills of the Tien Shan mountains. The clay soils of the desert and semidesert regions are mostly covered with *Artemesia* species. These are unpalatable in summer because of a buildup of ether oils, and this provides a further stimulus for migration to the northern *Stipa* and Festuca-dominated pastures or to alpine pastures in the Tien Shan. The *Artemesia* pastures, however, provide very good fodder during the return migration in the autumn, and enable stock to increase their fat reserves for the winter (Fedorovich, 1973).

Traditionally Kazakhstan was partitioned between three major tribes: the Great, Little, and Middle Hordes. According to references in Zhambakin (1995) and Olcott (1995), in the fifteenth century the Middle and Great Hordes wintered along the river Chu and in the Moiynkum desert, moving to summer pastures along the River Ishim. Members of the Middle Horde also occupied pastures in the east of Kazakhstan, spending summer in the Altai mountains, and winter along the River Irtysh. The Great Horde controlled pastures in the Tien Shan mountains, to which some of them would go in the summer from the Moiynkum or Taukum deserts.

The Little Horde spent winter along the Syr Darya river or in the Pri-Aral Karakum or Barsuki sands, moving in the summer to just south of Orenburg, outside the boundaries of modern Kazakhstan. One group also spent winter along the shores of the Caspian sea and summer in the basins of the Emba and Sagyz rivers. However, these migrations were not fixed and depended from year to year on climatic conditions. For example if there was drought in the summer territory of one horde, it might move further north, or into the territory of another horde (Zhambakin, 1995). This flexibility of migration was one of the first things to disappear with the coming of Europeans to Kazakhstan.

As the Kazakh grazing lands were appropriated by the tsar, migratory movements of the Kazakh people declined both in distance and frequency. Perhaps the greatest changes wrought by the Russian "invasion" occurred in the 50 years leading up to the Russian revolution (Olcott, 1995). The Steppe Act of 1891 effectively claimed all the Kazakh lands for the crown, and Kazakhs in many areas had to pay rent on land in order to use it (Zhambakin, 1995). In Aktiubinsk *oblast* (province) at the end of the nineteenth century, Kazakhs were already moving only 20–40 km from their winter pastures, and in South Kazakhstan *oblast* the majority of the population were sedentarized by 1908 (Zhambakin, 1995). By 1917 almost 75% of the population had some form of permanent winter quarters, and some had brick structures for animals and humans (Olcott, 1995). This was probably partly aided by the introduction of the scythe, which allowed them to cut and store hay for the winter (Matley, 1994b). However, many of the former migrations remained, and Kazakhs in Mangyshlak, Syr Darya, and Central Kazakhstan were still entirely nomadic at this time, until the disaster of collectivization in the 1930s (Argynbaev, 1973). Figure 2 shows the major seasonal migrations of the Kazakhs in 1926–1930.

The saiga antelope is the only wild ungulate found in large numbers in Kazakhstan, and is similar in size to a sheep. It has similar seasonal migrations to those undertaken by domestic animals before the Soviet period, major movements being from the Moiynkum desert to the Ishim Basin, from the Volga Ural sands northwards, and from the Ustiurt plateau to the Emba river.

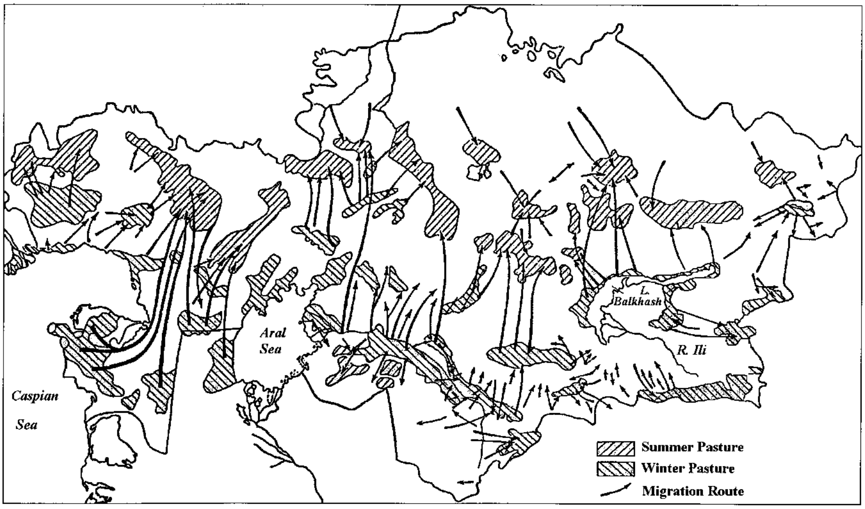

Fig. 2. Major seasonal migrations of the Kazakhs in 1926–1930 (map reproduced from Fedorovich (1973) after data of M. G. Sakharova). See Fig. 1 for place names.

Fragmentary evidence suggests that it was common throughout Kazakhstan in the fourteenth to seventeenth centuries and was hunted for its meat, hide, and horns (Bekenov *et al.*, 1998).

Limiting Factors in the Pre-Soviet Period

Here we consider possible limiting factors to livestock and wild ungulate numbers in the period before the Russians, a period when human influence was low and herders did not provide winter feed or medicines for their animals. In Kazakhstan there are several climatic factors that might be expected to affect livestock and wild ungulate numbers. Foremost among these are the amount and timing of precipitation.

Snow Cover: Dzhut

Dzhut is a Kazakh term referring either to conditions when melting snow refreezes to form an icy layer covering the grass, or to unusually heavy snow falls (Fadeev and Sludskii, 1982; Zhambakin, 1995). Animals cannot obtain food under snow when the depth is much over 30 cm, or 20 cm when the snow is dense (Sludskii, 1963), so such falls would qualify as *dzhuts*.

Table I. Recovery of Stock Numbers in Turgai Oblast after the Dzhut of 1879–1880. (Source Sludskii, 1963.)

Year	Stock numbers (millions)
1879	3.66
1881	1.79
1885	2.11
1890	3.31

Dzhut occur every 3–4 years in Kazakhstan, and severe cases causing high stock mortality occurred every 10–12 years before winter fodder provision became significant in the Soviet period (Sludskii, 1963). Sludskii (1963) suggests that often stock numbers would take roughly 10 years to recover from these events, leading to "boom and bust" fluctuations of 10–12 years regulated by *dzhut*. One example he gives is of the *dzhut* of 1879 in which 48% of stock died in central Kazakhstan. Figures available for Turgai *oblast* show the recovery was still not complete after 11 years (Table I). There were mild *dzhut* in 1881–1882 and 1888–1889 which probably retarded recovery. The next severe *dzhut* after the period shown in Table I occurred in 1891–1892 and caused stock numbers to crash once again, this time by 32%. This suggests that, although by this time many Kazakhs had started to cultivate, in the country as a whole livestock were still highly susceptible to winter mortality.

The saiga antelope, too, is highly vulnerable to *dzhut* events. For example, the Betpak-dala population was reduced by 20% in the winter of 1976–1977 and by 37% in 1985–1986. References in Bekenov *et al.* (1998) suggest that *dzhut* were one of the main causes of the saiga's reduction in range in the early twentieth century. It seems likely that *dzhut* cause increases in saiga mortality rather than decreases in fecundity, as an analysis by Coulson *et al.* (2000) found that while fecundity was related to winter temperatures, there was no relation between fecundity and winter precipitation. The timeseries analyzed included two *dzhut* years.

Rainfall

When searching for limits to ungulate production it is useful to know whether the rangeland in question is an equilibrium system sometimes perturbed by droughts, or shows nonequilibrium dynamics characterized by large interannual fluctuations in biomass levels, with corresponding fluctuations in livestock numbers (Ellis *et al.*, 1993). Shepherd and Caughley (1987) suggest that when the coefficient of variation of rainfall exceeds about 30% then the long-term performance of a system is better characterized in terms of its variability than by measures of mean values. Caughley (1987), in models

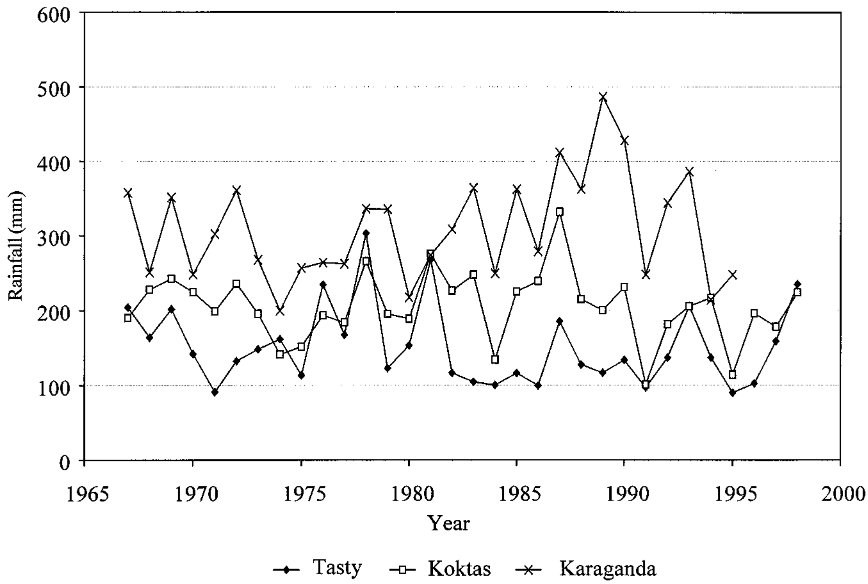

Fig. 3. Rainfall patterns in the period of 1967–1998 at three meteorological stations: Tasty (desert zone), Koktas (semidesert zone), and Karaganda (steppe zone).

of kangaroo population dynamics, demonstrates an inverse relationship between mean population size and rainfall variation arising from reproductive lags whereby animal numbers recover more slowly than forage production.

Figure 3 shows rainfall variability at meteorological stations in the desert and semidesert zones of Central Kazakhstan. These data tell us that rainfall, although low, rarely drops below 100 mm/year. Even in the desert zone it stays between 100 and 250 mm with remarkably few exceptions. The most telling rainfall statistic is its coefficient of variation. This varies from 34% in the desert zone to 25% in the semidesert zone (using 30-year data sets). Such rainfall variability is *low* on a world scale (Le Houérou *et al.*, 1988). The rainfall data suggest that these rangelands are an equilibrium system and that livestock mortality from drought may have been low. This is supported by the literature, in which evidence for the effects of drought on stock mortality or productivity is scarce. There is information on one mass mortality event in 1928, when 25% of all livestock in the south and west of the country died because of drought (Channon and Channon, 1990). Sludskii (1963) notes that the effects of *dzhut* can be considerably worsened by a preceding drought year as the vegetation is shorter and harder to reach under the snow, but drought in itself does not often seem to be a direct cause of mass mortality.

However, according to Fedorovich (1973) the effects of drought are serious. He states that annual rainfall variability is much higher in the lower rainfall desert areas, where it varies by a factor of 10 or more, than in the semidesert and steppe areas where it varies by a factor of six and four respectively. This is also seen in the coefficients of variations above, and fits the general pattern of higher variability being linked to lower rainfall. According to Le Houérou *et al.* (1988) high variability of rainfall leads to still higher variability of plant production, and Fedorovich (1973) reports variability among grass species as high as 1:40 in the semidesert zone, as rainfall over a certain threshold may cause a burst of annuals, which are totally absent in dry years. He states that mortality events due to drought were common in Kazakhstan, but cites an example from Turkmenistan where stock numbers dropped by 1 million in 1959–1960 because of drought.

There are no data on the effects of rainfall on livestock productivity; however, some do exist for the saiga antelope. Saiga may have one or two young each year depending on age and condition. Rashek (1963) collected data on litter sizes for a population of saiga on Barsa Kelm'es Island in the Aral Sea. There is a significant relationship between mean litter size and rainfall in the previous year (Fig. 4). This suggests vegetation growth does affect fecundity. However, migration is not possible on this island, which is not a realistic situation for the other populations of saiga, nor for domestic animals under the traditional system.

Fadeev and Sludskii (1982) suggest that, in free-ranging populations of saigas, drought has strong effects on nutrition, general condition of the animal, fertility, development of calves, and length of lactation. The authors state that in Kazakhstan drought years occur quite frequently, and can cause raised mortality of calves. According to their data, 1976 was the third drought year in a row, resulting in infertility in 31.8% of young females, and embryo reabsorption in 31% (figures in a normal year would be 7.7% and 3.4% respectively). Adults were affected to a lesser extent. Overall, including all age groups, the number of embryos per female fell from an average of 1.5 to 1, and lactation finished 1–1.5 months earlier than usual. Despite this, the overwhelming climatic factor limiting saiga numbers is *dzhut*, and there are no references to large-scale adult mortality due to drought. Coulson *et al.* (2000) found no relationships between summer rainfall and female fertility in their analysis of fecundity rates for 1986–1996.

Disease and Hunting

Tursunbaev (1973) notes that disease was second only to *dzhut* as a factor causing stock mortality in the pre-Soviet period. Rinderpest, foot

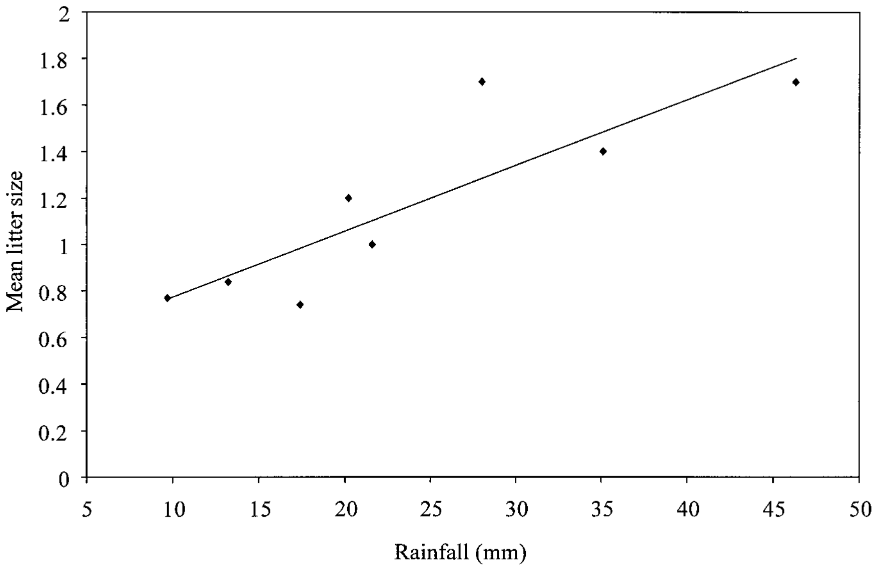

Fig. 4. The relationship between rainfall and litter size for saiga antelope living on Barsa Kel'mes Island, 1956–1964. $R^2 = 0.74$, $P < 0.01$. (Source Rashek, 1963.)

and mouth disease (FMD), and glanders are mentioned as major diseases. The scale of mortality in domestic stock is not given, but data do exist for the saiga antelope suggesting that disease is a major killer. Pasteurellosis reduced the Ural population of saiga from 150,000 to 40,000 in 1984 and was held responsible for the death of 270,000 animals in the Turgai region in 1988 (Bekenov *et al.*, 1998). FMD was reported to have caused the deaths of 50,000 calves in 1967 (Bekenov *et al.*, 1998) but does not usually kill large numbers of adults.

Most of the parasites and diseases that affect livestock also affect saiga. Particularly in the case of FMD, there has been much concern among Soviet scientists about disease transmission between the species; this is likely to occur whenever saiga and livestock are in close proximity (Lundervold, 2001).

Hunting is a factor affecting the saiga antelope. In the middle of the nineteenth century saiga numbers fell dramatically because of hunting for the horn trade to China. A hunting ban was introduced in 1919 but contraband trading continued until 1927–1928 when saiga numbers were at a minimum and the species was almost extinct (Bekenov *et al.*, 1998). Hunting was therefore the most serious limiting factor affecting saiga numbers just before and in the first few years of the Soviet period.

Summary

Overall, the timing and amount of precipitation in Kazakhstan is the crucial climatic factor regulating domestic livestock numbers. Although rainfall variability is low this does not mean that stock numbers ever reached a density-dependent equilibrium with the vegetation because, as we have seen, livestock numbers in pre-Soviet Kazakhstan were regulated by snow depth in winter rather by vegetation biomass itself. Concerning the saiga, *dzhut*, disease, and later, hunting were the major factors affecting numbers; it is likely that they would also never have reached a density-dependent equilibrium with the vegetation. There are no quantitative data on the effects of disease on domestic stock before the Soviet period so it is difficult to draw meaningful conclusions about the effect of this limiting factor. Similarly, there are no data available to quantify the level of interaction between saiga and domestic livestock, although data from later periods suggest disease as a key mediating factor.

PASTORALISM IN THE SOVIET PERIOD

During the Soviet period, the introduction of winter feed removed *dzhut* as a major limiting factor of domestic livestock populations and saiga hunting became strictly regulated. In this section we analyze the Soviet system and how it altered the limiting factors regulating ungulate numbers on Kazakhstan's rangelands.

Farming Systems

After 1930, the Kazakh population suffered enforced settlement through collectivization. This resulted in huge famines as livestock died of hunger or were shot to avoid collectivization. Over 80% of the Kazakh herd was lost and over 1 million Kazakhs died (Olcott, 1995). The failure of sedentarization of nomads was officially recognized by the 1940s and the system was adapted to allow for a limited form of nomadism, which continued until the early 1990s.

Under the Soviet system, farms were of two types, *kolkhoz* (collective farm) and *sovkhoz* (state farm). The former were farms owned by their members, who had to deliver an assigned amount of produce to the state every year. Any surplus was to be used for sowing, after which members received their shares calculated on the basis of "workdays" that they had put in for the *kolkhoz*. *Sovkhoz* were state enterprises in which each worker had a wage paid by the state, with bonuses if the state quota was exceeded.

In the 1950s many *kolkhoz* were converted to *sovkhoz*, as these tended to be regarded more favorably by the government. *Sovkhoz* were large farms, containing, at their peak in the 1980s, an average of 540 workers and their families (*Goskomstat*, 1987). Each had a school, hospital, social facilities, vets, accountants, technicians, and agricultural experts as well as workers such as shepherds who were more directly involved in pastoral activities.

Although most livestock were state owned, people were allowed limited numbers of private stock and small garden plots, the production from which was sold to urban residents in farmers' markets, or even to the state. This became more important in the 1980s, when limits to owning animals privately were abolished, and the importance of personal plots for meeting production targets and increasing living standards was officially recognized (Podol'skii and Ivanov, 1984). By 1988, individually owned produce provided Kazakhstan with 30.9% of its meat, 43% of its milk, and 30% of its eggs (Werner, 1994).

After collectivization in the 1930s, enormous areas of arid pasture in central and southeastern Kazakhstan were left without livestock for long periods. The newly created *sovkhoz* had strictly defined boundaries, with no stock movement outside them. In the 1940s the numbers of animals started to increase, and in the winter of 1941–1942 cattle and sheep began to be driven to remote pastures. In March 1942, the communist party passed a resolution to increase the numbers of stock, which included provision for the use of remote pastures. The Moiynkum desert started to be used again in this period as winter pasture for farms in southern Kazakhstan (Alimaev *et al.*, 1986). During the 1950s, the best summer pastures in the steppe regions were ploughed up for grain production, so any expansion of the livestock sector had to occur in the other vegetation zones.

In the 1960s, 155 specialized sheep-raising *sovkhoz* were created on state reserve land in the semidesert and desert regions, with a stock of 50,000–60,000 sheep each (Asanov and Alimaev, 1990). Wells were sunk and water was extracted by pump where the water table was deep, or even brought in by tanker, so opening up new areas for grazing. The pastures that would have formerly been used briefly during migratory periods started to be used for months at a time, and movement in some areas started to contract again as the new *sovkhoz* blocked migration routes.

Migration, although primarily conducted on horseback, benefited from considerable technical support. Families could use tractors to help transport their yurts and food, and were supplied with petrol for well pumps. In some areas water tankers were used when migrations crossed waterless zones (for example stock in Almaty *oblast* migrated from the mountains to the Taukum desert on the shores of Lake Balkhash, (Fig. 1)). Vets visited the shepherds during the summer, and in certain areas trucks brought fresh food supplies to

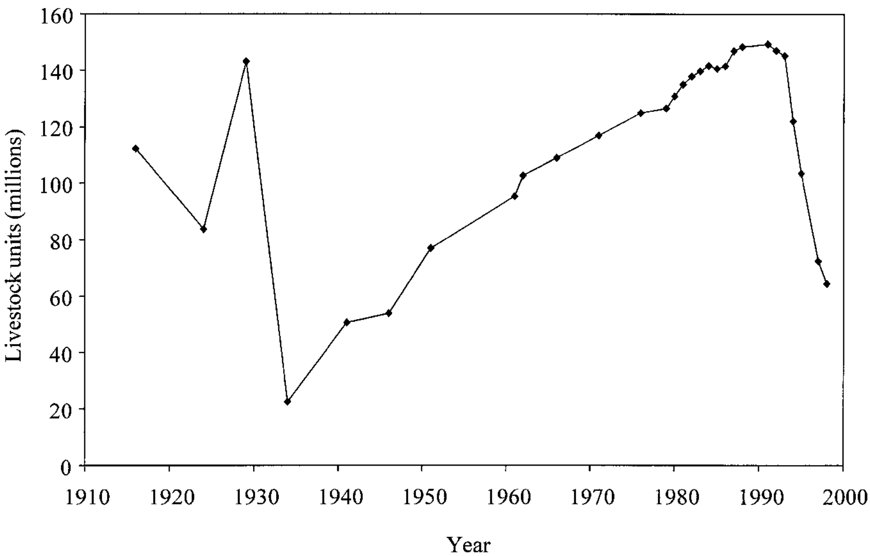

Fig. 5. Numbers of livestock in Kazakhstan during the twentieth century. The effects of collectivization, the increase in livestock numbers in the Soviet period, and the crash in numbers after independence are visible. (Source Goskomstat 1984, 1985, 1987, 1996, 1998; Mately 1994b.)

shepherds and their families once a month. Those members of the shepherds' families who had to remain at the village (e.g., children of school age) were fed by the *sovkhoz* during the summer. Through these efforts the Soviets managed to make use of even the remotest pastures, and to reach a high of 36 million sheep in the mid 1980s, double the number in 1916 (Fig. 5), while at the same time living standards and opportunities for pastoralists improved.

Stock movement patterns in the later socialist period (after 1960) are of two major types: Type 1: Long distance migrations across ecological zones. These usually involved movements to pastures on state reserve land remote from the *sovkhoz*, in other *raions* (districts), *oblasts* (provinces), or even other republics. These migrations were often several hundred kilometres long. Type 2: Short distance movements, occurring within the farm territory, and which did not always entail a move with each season. These were between about 10 and 120 km long and were usually within one ecological zone.

The long distance migrations were mainly from farms in the south situated between a good winter site such as a sandy desert and a good summer pasture such as Sary Arka or the Tien Shan mountains. They would generally involve mass movements of hundreds of thousands of animals from entire *raions*.

The short distance migrations occurred mainly on farms further north in the semidesert zone, in which each individual *sovkhoz* would be split into units of seasonal land use. On some of the new farms built in the 1960s, stock could be on the same pasture for three seasons, (autumn-winter-spring, or spring-summer-autumn), movement often simply involving rotations between adjacent wells. According to Zhambakin (1995), such grazing regimes can lead to pasture degradation.

The difference between the two types of movement was never clear cut, and even in the more northerly *oblasts*, if significant amounts of particularly useful pasture existed, such as those on sands or along rivers, these would be set aside as state reserve land, and used by several farms from the area, who would drive animals there on a seasonal basis. Conversely, in southern areas some farms stopped sending their animals north in the summer, and they thus stayed on the autumn-spring pasture for the summer also. According to I. Alimaev (personal communication) such practices were particularly damaging.

Many of the new sheep raising *sovkhoz* on which type 2 migrations were practiced were built in areas, such as southern Karaganda *oblast*, where there were no snow-free pastures and sheep had to be stall-fed all winter. Conversely many of the more southerly farms were built in areas in which grain, or in some cases even hay, could not be produced because of low rainfall. Of the 697 specialized sheep raising *sovkhoz* and *kolkhoz* in the country, 450 could not produce grain, and 98 could not even produce hay (Zhambakin, 1995). Therefore although sheep on these farms could be kept on pasture for most of the winter, they were always dependent on externally produced feed for 1–2 months. Winter feed usually took the form of grain-based concentrates (*kombikorm*), hay, and maize silage.

To summarize, during the Soviet period, and especially after the 1960s, the whole of Kazakhstan was partitioned into a patchwork of units, each with its land use and type defined by the state. Each farm, and indeed each herd was allocated grazing locations for each season. Shepherds took no decisions at all as to where they went with the animals in their charge. All decisions were taken by the farm management. However, upon closer inspection it can be seen that some of the longer migrations that remained followed the routes of earlier traditional movements. For example, the migrations from the Moiynkum desert, Kyzylkum desert, and Syr Darya river toward summer pastures near the river Ishim (Figs. 1 and 2) survived in a shortened form. In both cases stock did not go as far as before, because the former summer pastures were taken up by new farms. These farms were heavily dependent on winter feed, and their stock stayed all year round in these areas, barring migrations from southern farms.

Limits to Livestock Production in the Soviet Era: Density-Dependent Effects

The provision of winter fodder in the Soviet period removed *dzhut* as a major constraint to domestic livestock numbers. This, combined with improved veterinary care, allowed sheep numbers to rise to 36 million in the mid 1980s. However, there is evidence from the literature that rising animal numbers were having adverse effects on the pasture. According to Kharin and Kiriltseva (1988), 60% of Kazazkhstan's arid areas (i.e., the desert zone), or 30% of its overall pastures were degraded. These authors blame animal production as the chief cause of this. Other authors suggest that not only animal numbers, but also changes in the number and timing of seasonal movements were to blame (Asanov and Alimaev, 1990).

Most Soviet authors describe the process of degradation as a change in species composition accompanied by a loss in productivity in following years (Bykov, 1985; Kirichenko 1980; Zonov, 1974). For example Kirichenko (1980) describes how desert pasture dominated by *Artemesia terrae-albae* and *Haloxylon* species is particularly sensitive to heavy grazing, these species being replaced progressively by edible annuals such as *Ceratocarpus utriculosis* and *Alyssum desertorum*, and then inedible annuals such as *Peganum tataricum* and *Atriplex tataricum*. The average biomass in the growing season drops from 483 to 100 kg/ha under heavy grazing pressure. Other similar descriptions of land degradation processes (Bykov, 1985; Zonov, 1974) also describe decreases in soil humus content and changes in soil structure. In general the winter and autumn pastures, particularly those on sands, are most often described as being in critical condition (Babaev, 1985; Dzhanpeisov *et al.*, 1990; Zhambakin, 1995), although in reality it is difficult to judge real grazing pressure in these areas due to supplementary winter feed provision (Robinson, 2000).

Were these events having adverse effects on the livestock sector, or did the increasing amount of supplementary fodder mean that animals were "sheltered" from the effects of their own grazing? According to Asanov and Alimaev (1990), degradation did begin to affect the productivity of the livestock sector, causing increased mortality and lower birth rates. We investigate this through an analysis of the official data.

Birth and death rates, fleece weights, and liveweights of sheep for the whole country and for the *oblasts* of interest were obtained from *Goskomstat* (the state statistical agency) for the 1960s onwards. Liveweight is strongly related to nutritional status (AFRC, 1993; Elsen *et al.*, 1988). Fleece growth is also affected by nutrition (AFRC, 1993) and fleece weight in lactating ewes has been related to herbage allowance in controlled experiments (Rattray *et al.*, 1982).

The figures were compiled for all animals by each farm and sent to *raion* and *oblast* centers so that averages could be calculated at district and provincial levels. Therefore, the data are not sample-based, but are averages of all animals in the regions specified. The sheep liveweight is for lambs sold in the autumn for meat. There are likely to be several sources of error and bias in these data. Firstly, directors may have lied directly to disguise shortcomings of their farms. Secondly, weak sheep may have been slaughtered, and so be missing from the death-rate statistics, which were supposed to include only deaths from natural causes. Both these biases mean that death-rate statistics may be underestimates. Sheep breeds or lambing times may have changed during the period, which could be an explanation for changes in liveweight and fleece weight unrelated to nutritional status.

Sheep numbers increased from just under 30 million in 1960, levelling off in the 1980s at 36.6 million. The trend of death rates, birth rates, fleece weights, and liveweights during this increase in sheep numbers is shown in Fig. 6. Despite the nonlinearity of the effects, there is a significant positive correlation between death rates and numbers ($R^2 = 0.839^{**}$) and between birth rate and numbers ($R^2 = 0.591^{*}$). The relationship between liveweight and numbers was highly significant ($R^2 = 0.93^{***}$) but that between fleece weight and numbers was nonsignificant.

We cannot say for certain whether these decreases in sheep condition were due to increasing competition for natural forage, decreasing quality or quantity of winter food provision, or some other reason, such as disease or changes in sheep breeds. Figure 7 shows just one indicator of supplementary fodder availability: hay production per livestock unit. While this does not represent total fodder availability it does suggest that the winter fodder provision kept pace with growing animal numbers.

Several authors, including Behnke and Abel (1996) and Wilson and Macleod (1991), have pointed out that even if it can be shown that competition for forage is causing an increase in mortality and fall in birth rates this is by no means proof of long-term damage to pasture productivity. Indeed such decreases in condition are accepted by most rangeland managers so long as overall system output does not suffer. In Kazakhstan as a whole, meat production (from all stock types) rose during the period in question (Fig. 8) suggesting that overgrazing was not reducing the total output of the livestock sector.

The Saiga Antelope in the Soviet Period

After near extinction at the start of the twentieth century, the saiga population increased to reach a high point of 1.2 million in 1974. Factors

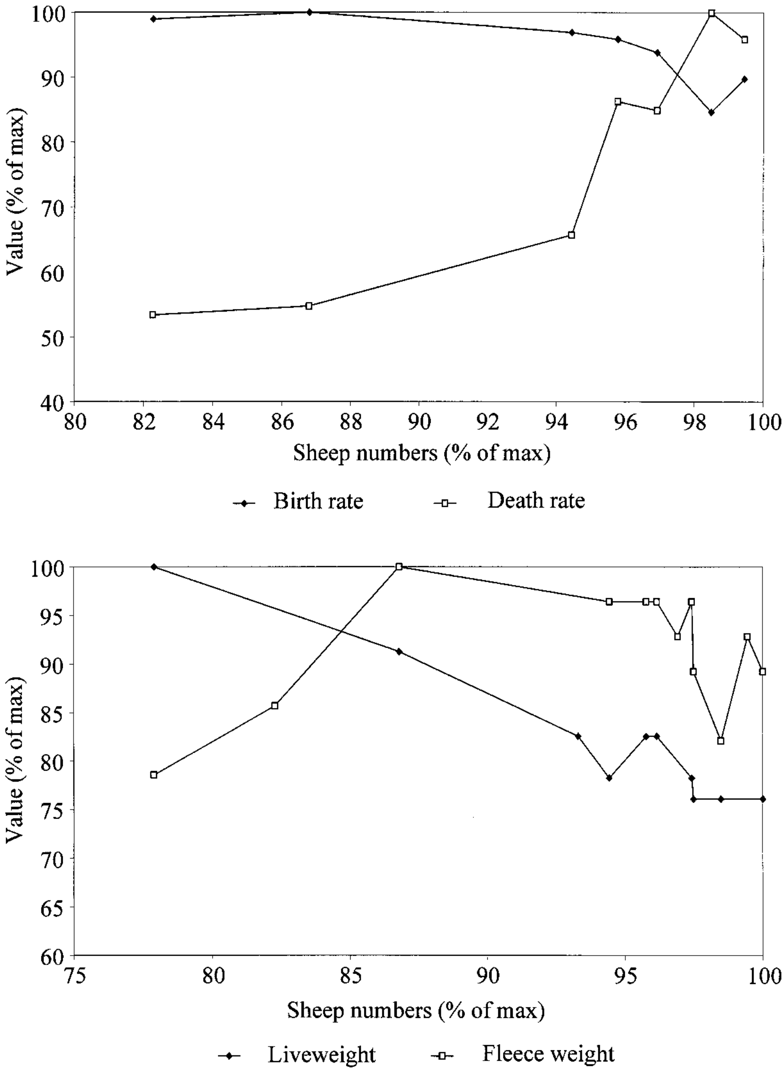

Fig. 6. Changes in animal condition with numbers for Kazakhstan. All figures are plotted as percentages of maximum values for comparison. Note the different scales of the axes. Actual maxima are numbers, 36.6 million; birth rate, 98 per 100 ewes; death rate, 7.3%; live weight, 42 kg; fleece weight, 2.8 kg. (a) Liveweight and fleece weight. (b) Birth and death rates. (Data from Goskomstat 1984, 1985, 1987.)

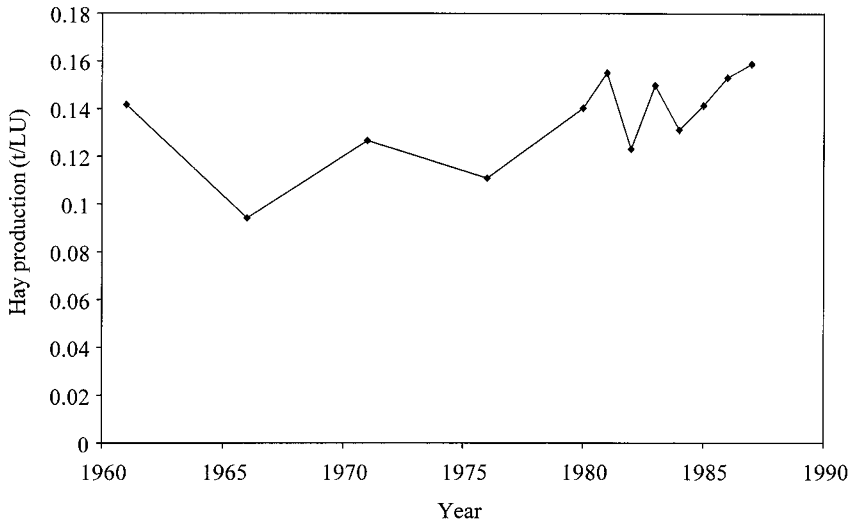

Fig. 7. Hay production per livestock unit (LU) (data from Goskomstat). One LU is equivalent to 1 horse, 1 cow, or 10 sheep (Zhambakin, 1995).

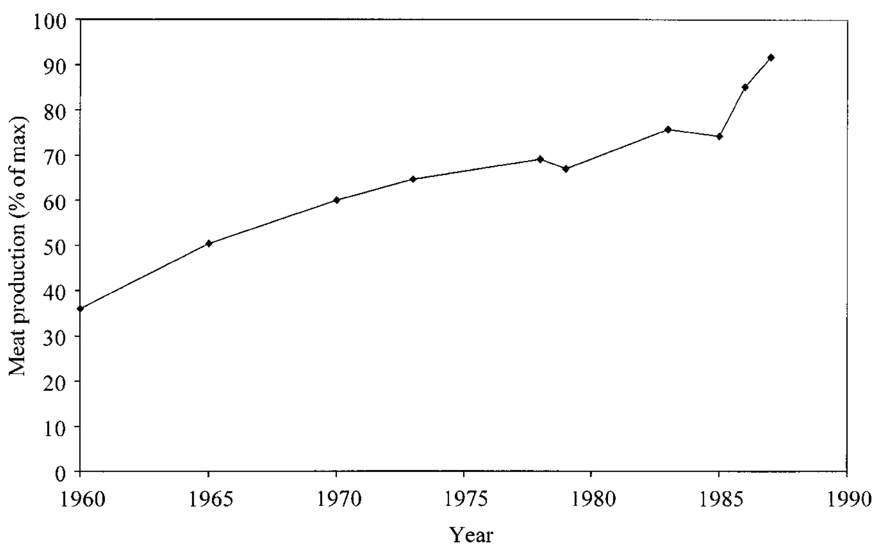

Fig. 8. Total meat production in Kazakhstan in the period of 1960–1987.

facilitating this included collectivization, which resulted in huge areas of empty steppe, closing of the Chinese border (reducing the demand for horns), and few *dzhuts*. Soviet management also had a part to play and hunting was generally well regulated. All hunting was organized by the state, quotas were based on yearly counts, and poaching severely punished. Although offtake in the 1970s was considered too high, it was cut back in the 1980s to a sustainable level of 15–20%. It was cut back still further in subsequent years because of concern about the decrease in the population growth rate caused by increased stress on saiga populations from human factors such as increased poaching and intensive agricultural activity (Bekenov *et al.*, 1998). It was also cut back in years when *dzhut* seriously reduced population levels, for example the early 1980s (Fig. 9).

Despite saiga population recovery, their geographical range never expanded to its previous size. The virgin lands campaign of the 1950s led to the ploughing of vast areas of steppe in north Kazakhstan, resulting in a reduction of the saiga's northerly range. General agricultural development resulted in the split of the saiga into the three isolated populations in

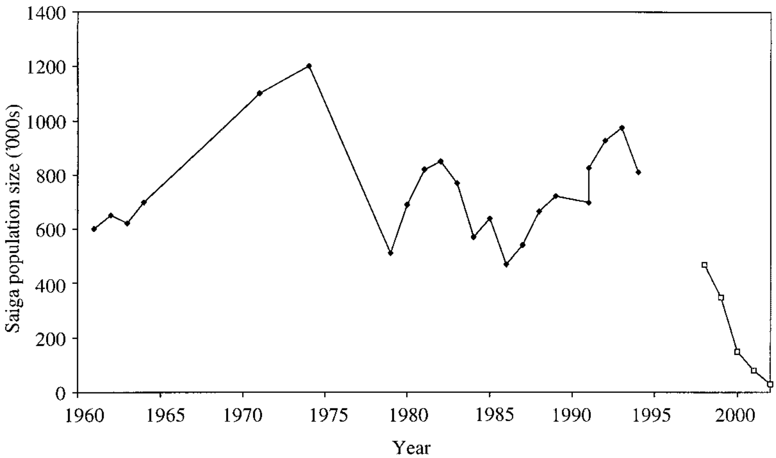

Fig. 9. Saiga numbers in Kazakhstan since the 1950s. Data points represented by filled symbols indicate that counts of all three populations were conducted by aerial survey. Open symbols indicate that data for one or more of the three populations are dubious, as they are extrapolated from counts of 50% of the range area (estimate = 2 × actual count), or that they are the product of vehicle surveys. Vehicle surveys are not easily comparable to aerial surveys, and are much more prone to error and bias (and particularly to underestimating population size). The population collapse due to poaching after independence is clearly visible from the data. Source Milner-Gulland *et al.* (2001) and unpublished field surveys by the Institute of Zoology, Kazakhstan (Iu.A. Grachev, personal communication).

existence today: Betpak-dala, Ustiurt, and Ural. Saigas were also severely impacted by disease in this period, particularly by FMD. In the period of 1955–1974 there was a series of outbreaks in both saigas and livestock. After the introduction of an effective vaccine for livestock in 1974, outbreaks of FMD ceased to be recorded in saigas, suggesting that reinfection from livestock is necessary for FMD persistence in saigas (Lundervold, 2001).

Density Dependence and the Saiga Antelope

Saether (1997) suggests that density-dependent mortality outside the breeding season may be an important regulatory factor for wild ungulates. Coulson *et al.* (2000) used the number of embryos in heavily pregnant saigas over the period of 1986–1996 to determine which density-dependent and density-independent factors affect fecundity. They found relationships between the likelihood of twinning in adults and population density, as well as between twinning rates and winter temperature. The finding of density dependence in saiga fecundity is surprising, because while saiga numbers varied between 210,000 and 500,000 over the period, sheep numbers stood at 1.3 million and cattle at 600,000 in Dzhezkazgan and Karaganda *oblasts* alone, which do not comprise the whole range of the Betpak-dala saiga population. However, density dependence does not necessarily act through simple forage biomass, but may also act through other factors such as predation, disease, or the predictability of finding resources. For example in *dzhut* years, key resources such as larger shrubs may be limiting. Density dependence is also likely to act through mortality. However mortality rates are much harder to quantify in the field, so no data are available to assess levels of density-dependent mortality.

If pasture degradation did occur due to the large increase in livestock numbers from the 1960s to 1980s, it might well be reflected in changes in saiga vital rates, as saiga too are dependent on pasture quality. Unfortunately data to address this question are limited. Fecundity rates in saigas varied around a mean of 1.5 embryos per female over the entire period of 1964–1996 (Bekenov *et al.*, 1998; Fadeev and Sludskii, 1982). Over the period of 1964–1978, when livestock numbers were increasing, interannual variations in embryo numbers were attributed to changes in pasture quality and availability caused by climatic variability and not to pasture degradation (Fadeev & Sludskii, 1982). However, if pasture degradation was occuring this could well have interacted with climatic variability to influence the observed variation. Again, mortality rates are likely to be more informative, but the data do not exist.

LIMITS TO DOMESTIC AND WILD UNGULATES TODAY

Since independence Kazakhstan's fast track reform program has led to the loss of input subsidies and to farm privatization. At the same time the Soviet markets and state buying system have collapsed and this, combined with hyperinflation, has made livestock the major currency in Kazakhstan's rural areas (Behnke, in press; Robinson, 2000). Animals were bartered away and by 1998 sheep numbers had dropped to 30% of 1990 figures (Fig. 5). The highly supported migrations, and universally available provision of concentrates for winter feed have become things of the past. Collectives are breaking up into small private farms, most of which have few animals and are virtually sedentary.

Some farms visited in the course of field study lost many thousands of animals in the first winters after privatization. The recent *dzhut* in Mongolia, which caused the deaths of millions of livestock (Anonymous, 2000) also highlights the potential problems arising from a lack of winter feed. Although such an event has not yet occurred in Kazakhstan, livestock husbandry has become unviable in areas where hay cannot be cut, because stock are not being moved.

Also serious at the present time are economic barriers to increasing stock numbers. People are finding it very difficult to rebuild herds when animals are still the only form of currency. In particular, in remote areas far from markets, the economies of scale that once supported livestock husbandry no longer exist. Both livestock and functional infrastructure such as wells and barns are at their lowest levels in these areas (Behnke, in press). In the absence of export markets for livestock products, proximity to local markets now has a strong influence on livestock numbers and distribution.

The factors affecting the saiga antelope have also changed. With the loss of the old Soviet management systems poaching has seen a big increase and is now a major threat, causing massive population declines (Fig. 9). This poaching is exacerbated by the loss of livestock, leaving a hungry population stranded in the steppe (Robinson, 2000). The Chinese border has reopened, and the demand for saiga horn is high. Another reemerging threat is disease; since independence vaccination programs have become sporadic, and outbreaks of FMD have occurred in livestock (Lundervold, 2001). Although contact rates between livestock and saigas are lower than previously, there is a risk that this highly infectious disease could be transmitted to saigas. This could cause an epidemic among saigas, which could also spread the disease to livestock in other areas.

DISCUSSION

The literature reviewed here suggests that ungulate numbers in Kazakhstan's rangelands were predominantly regulated by severe winters until the twentieth Century. Additional important factors were disease and, for the saiga antelope, hunting at the end of the nineteenth century.

During the Soviet period, winter fodder removed the major limit to livestock numbers, and numbers increased. Loss of pasture productivity through overgrazing was widely reported in the literature. However, density-dependent effects on overall stock numbers cannot be conclusively established. Stock numbers started to plateau during the 1980s, but did not cause pasture destruction to the extent of causing major decreases in productivity. However, during the Brezhnev years the target for Kazakhstan's sheep sector was 50 million head, while in reality numbers never exceeded 36 million. This suggests that some limiting factor was operating. Here it is instructive to look at other areas of Central and Inner Asia.

According to Erdenijab (1996), 38% of the pasture in Inner Mongolia, China, was degraded in 1988, caused in part by a fourfold increase in livestock numbers since 1947. Similar patterns are also seen in Buryatia, Russian Federation (Gomboev, 1996). This area was described as one of the most degraded in Inner Asia, and Humphrey and Sneath (1996) describe livestock production practices there as unsustainable. However, in neither case did livestock numbers shown a sharp decrease in number in response to decreased fodder availability. It is possible that livestock both in these areas and in Kazakhstan had overgrazed the pasture down to a steady state equilibrium (Ellis *et al.*, 1998; Noy-Meir, 1975), while an extreme drought, which might knock the systems into disaster, had simply not yet occurred. However, there is no evidence in any literature of a density-dependent livestock crash in any part of Central or Inner Asia despite the widely reported overgrazing.

Van de Koppel *et al.* (1997) have argued that systems in which herbivory is uncoupled from vegetation condition by feed supplements (such as occurred in the Moiynkum desert and indeed on winter pastures all over Central Asia) may result in irreversible vegetation collapse and soil degradation before animal productivity is affected. However, in this case, it might be expected that wild ungulates such as the saiga antelope would show productivity decreases. There is no evidence of this.

A preliminary analysis of stocking rates in the Moiynkum desert suggests that they could have come close to those causing unacceptable offtakes (Robinson, 2000). However, the continued mobility of livestock grazing in the area is a mitigating factor. Humphrey and Sneath (1996) have noted that the low mobility combined with cultivation of fodder crops which occurred in Buryatia caused severe environmental degradation, while in those countries such as Tuva and Mongolia, which have retained migratory behavior, the state of the environment is much better.

Although the livestock sector does not seem to have been directly affected by density in terms of meat output, the costs of increased stock numbers were high in other ways. Even according to *Goskomstat* figures, the cost of producing one tonne of sheep liveweight rose from 689 to 1745 roubles between 1971 and 1987, and the livestock sector had to be heavily subsidized. The inefficiency of the livestock sector may be one reason for its crisis today; it is very probable that under conditions of a market economy such high livestock numbers may never have been viable.

ACKNOWLEDGMENTS

We gratefully acknowledge the financial support of INTAS (project KZ-96-2056) and the University of Warwick. We are very grateful to Ilya Alimaev, Larisa Stogova, Sayat Temirbekov, Iu.A. Grachev, Carol Kerven, and Roy Behnke for their help and advice.

REFERENCES

AFRC (Agricultural and Fisheries Research Council) (1993). *Energy and Protein Requirements of Ruminants*. CAB International, Wallingford, UK.

Alimaev, I. I., Zhambakin, A., and Pryanoshnikov, S. N. (1986). Rangeland farming in Kazakhstan. *Problems of Desert Development* 3: 14–19.

Anonymous (2000, April 29). The nomad's despair. *The Economist*

Argynbaev, Kh. (1973). On the agriculture of the Kazakhs of Kopal Yesd, Semireche Oblast. In *Essays on the Agricultural History of the Peoples of Central Asia and Kazakhstan*, Nauka, Leningrad, pp. 154–160.

Asanov, K. A., and Alimaev, I. I. (1990). New forms of organisation and management of arid pastures of Kazakstan. *Problems of Desert Development* 5: 42–49.

Babaev, A. G. (ed.). (1985). *Map of Anthropogenic Desertification of Arid Zones of the USSR*. Institute of Deserts, Ashkabad, Turkmenistan.

Behnke, R. (in press). Reconfiguring property rights and land use in pastoral Kazakstan. In Kerven, C., and Akiner S. (eds.), *From State farms to Private Flocks: Prospects for Pastoralism in Kazakstan and Turkmenistan*.

Behnke, R., and Abel, N. (1996). Revisited: The overstocking controversy in Semi-Arid Africa. *World Animal Review* 2: 4–27.

Bekenov, A. B., Grachev, Iu. A., and Milner-Gulland, E. J. (1998). The ecology and management of the saiga antelope in Kazakhstan. *Mammal Review* 28: 1–52.

Bezhkovich, A. C. (1973). Historical and ethnographic aspects of Kyrgyz arable agriculture. In *Essays on the Agricultural History of the Peoples of Central Asia and Kazakhstan*, Nauka, Leningrad, pp. 32–69.

Bykov, B. A. (1985). Anthropogenic effects on desert pastures. *Problems of Desert Development* 1: 20–26.

Caughley, G. (1987). Ecological relationships. In Caughley, G., Shepherd, N., and Short, J. (eds.), *Kangaroos: Their Ecology and Mangement in the Sheep Rangelands of Australia*, Cambridge University Press, Cambridge, UK, pp. 159–187.

Channon, J., and Channon, S. (1990). *The Livestock Sector in the USSR with Particular Reference to Soviet Central Asia: A Bibliographical Study of Works in Russian From 1917 to the Present Day*, Institute of Development Studies, University of Sussex, Brighton.

Coulson, T., Milner-Gulland, E. J., and Clutton-Brock, T. (2000). A comparison of the relative roles of density and climatic variation on fecundity rates in three contrasting ungulate populations. *Proceedings of the Royal Society of London B* 267: 1771–1779.

Dzhanpeisov, R., Alimbaev, A. K., Minyat, V. E., and Smagulov, T. A. (1990). Degradation of soils of mountain and desert pastures in Kazakhstan. *Problems of Desert Development* 4: 19–26.

Ellis, E. J., Coughenour, M. B., and Swift, D. M. (1995). Climate variability, ecosystem stability, and the implications for range and livestock development. In Benkhe, R. J., Scoones, I., and Kerven, C. (eds.), *Range Ecology at Disequilibrium*, ODI/IIED/Commonwealth Secretariat, London, pp. 31–41.

Ellis, E. J., Milne, J., and Alimaev, I. (1998). Pasture regeneration. In Kerven, C. (eds.), *Workshop Results on Impacts of Privatisation on Range and Livestock Management in Semi-Arid Central Asia*, Overseas Development Institute, London, pp. 17–18.

Elsen, J. M., Wallach, D., and Charpenteau, J. L. (1988). The calculation of herbage intake of grazing sheep: A detailed comparison between models. *Agricultural Systems* 26: 123–160.

Erdenijab, E. (1996). An economic assessment of pasture degradation. In Humphrey, C., and Sneath, D. (eds.), *Culture and the Environment in Inner Asia: 1 The Pastoral Economy and the Environment*, White Horse Press, Cambridge, UK, pp. 189–194.

Fadeev, V. A., and Sludskii, A. A. (1982). *Saiga v Kazakhstan* [The Saiga in Kazakhstan]. Alma-Ata, USSR.

Fedorovich B. A. (1973). Natural conditions of the arid ones of the USSR and ways of development of their livestock sectors. In *Essays on the Agricultural History of the Peoples of Central Asia and Kazakhstan*, Nauka, Leningrad, pp. 207–222.

Gomboev, B. O. (1996). The structure and process of land use. In Humphrey, C., and Sneath, D. (eds.), *Culture and the Environment in Inner Asia: 1 The Pastoral Economy and the Environment*, White Horse Press, Cambridge, UK, pp. 12–53.

Goskomstat [State Statistical Committee] (1984, 1985, 1987). *Narodnoe Khozyastvo Kazakstana, Statisticheskii Yezhegodnik* [The Economy of Kazakstan, Statistics Yearbook]. Goskomstat, Almaty, Kazakhstan.

Goskomstat [State Statistical Committee] (1996, 1998). *Sel'skoe Khozyastvo Respublika Kazakhstan* [Agricultural Statistics of the Republic of Kazakstan]. Goskomstat, Almaty, Kazakhstan.

Humphrey, C., and Sneath, D. (1996). Pastoralism and institutional change in inner asia: Comparative perspectives from the MECCIA research project, Pastoral Development Network Paper 39b, Overseas Development Institute, London.

Kharin, N. G., and Kiriltseva, A. A. (1988). New data on areas of desertified lands in the arid zone of the USSR. *Problems of Desert Development* 4: 3–8.

Kirichenko, N. G. (1980). *Pastbisha Pustin' Kazakhstana* [Desert Pastures of Kazakhstan]. Nauka, Almaty, Kazakhstan.

Le Houérou, H. N., Bingham, R. L., and Skerbek W. (1988). Relationships between the variability of primary production and the variability of annual precipitation in world arid lands. *Journal of Arid Environments* 15: 1–18.

Lundervold, M. (2001) *Infectious Diseases of Saiga Antelopes and Domestic Livestock in Kazakhstan*, PhD Thesis, University of Warwick, UK.

Matley, I. M. (1994a). The population and the land. In Allworth, E. (eds.), *Central Asia: 120 Years of Russian Rule*, Duke University Press, Durham, USA, pp. 92–130.

Matley, I. M. (1994b). Agricultural development. In Allworth, E. (eds.), *Central Asia: 120 Years of Russian Rule*, Duke University Press, Durham, USA, pp. 266–308.

Milner-Gulland, E. J., Kholodova, M. V., Bekenov, A. B., Bukreeva, O. M., Grachev, Iu. A., Lushchekina, A. A., Amgalan, L. (2001) Dramatic declines in saiga antelope populations. *Oryx* 35: 340–345.

Noy-Meir, I. (1975). Stability of grazing systems: An application of predator-prey graphs. *Journal of Ecology* 63: 459–481.

Olcott, M. (1995). *The Kazakhs*. Hoover Institution Press, Stanford, USA.

Podol'skii, L. I., and Ivanov, A. I. (1984). Economic and social problems of raising the efficiency of land resource utilization in Kazakhstan. *Problems of Desert Development* 4: 3–8.

Rashek, V. L. (1963). Material on reproduction among saiga on Barsa-Kel'mes Island (Aral Sea). *Trudi Instituta Zoologii AN KazSSR* [Proceedings of the zoological institute of the Kazakhstan Academy of Sciences] 20: 164–193.

Rattray, P. V., Jausch, K. T., Duganzich D. M., MacLean, K. S., and Lynch, R. J. (1982). Influence of feeding post-lambing on ewe and lamb performance at grazing. *Proceedings of the New Zealand Society of Animal Production* 42: 179–182.

Robinson, S. (2000). *Pastoralism and Land Degradation in Kazakhstan*, PhD Thesis, University of Warwick, UK.

Saether, B. (1997). Environmental stochasticity and population dynamics of large herbivores: A search for mechanisms. *Trends in Ecology and Evolution* 12: 143–149.

Scoones, I. (1992). Coping with drought: Reponses of herders and livestock in contrasting savanna environments in Southern Zimbabwe. *Human Ecology* 20: 31–52.

Shepherd, N., and Caughley, G. (1987). Options for management of Kangaroos. In Caughley, G., Shepherd, N., and Short, J. (eds.), *Kangaroos: Their Ecology and Mangement in the Sheep Rangelands of Australia*. Cambridge University Press, Cambridge, UK, pp. 196–210.

Sludskii, A. A. (1963). Dzhut in Eurasian steppes and deserts. *Trudii Instituta Zoologii AN KazSSR* [Proceedings of the Zoological Institute of the Kazakstan Academy of Sciences] 20: 5–88.

Tursunbaev A. (1973). Settlement of the nomads and semi-nomads of Central Asia and Kazakhstan. In *Essays on the Agricultural History of the Peoples of Central Asia and Kazakhstan*, Nauka, Leningrad, pp. 223–234.

Van de Koppel, J., Reitkerk, M., and Weissing F. J. (1997). Catastrophic vegetation shifts and soil degradation in terrestrial grazing systems. *Trends in Evolution and Ecology* 12: 352–356.

Werner, C. (1994). A preliminary assessment of attitudes toward the privatisation of agriculture in contemporary Kazakhstan. *Central Asian Survey* 13: 295–303.

Wilson, A., and Macleod, D. (1991). Overgrazing: Present or absent? *Journal of Range Management* 44: 475–482.

Zhambakin, Z. A. (1995). *Pastbisha Kazakhstana* [Pastures of Kazakhstan]. Kainar, Almaty.

Zonov, A. G. (1974). Wind erosion in grazing lands north of Betpak-dala. *Problems of Desert Development* 3: 38–42.