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The changing role of bio-physical and socio-economic drivers in determining livestock distributions: A historical perspective from Kazakhstan

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ABSTRACT

Despite worldwide trends towards intensive livestock production, some extensive systems retain comparative advantages, particularly in arid regions. In such variable environments, the extent to which natural pastures can contribute to animal nutrition depends on how livestock are distributed with respect to forage resources in time and space. Animal movements are governed by the interactions of bio-physical, economic and institutional drivers and constraints, all of which are dynamic in time and space, making disentangling the relative importance of different drivers challenging. We examine a large migratory system in central Kazakhstan, using unique long-term data in the context of major socio-economic change, to explore the changing role of bio-physical variables in shaping livestock movement. We explore the determinants of livestock distributions across broad ecological zones in pre-Soviet, Soviet and current time-periods. Differences between zones were examined using Soviet literature, recent interviews with herders and satellite imagery. At the site level, we combined data on livestock locations and density for 2003 and 2012 with bio-physical data from remote sensing. Taken together, these data suggest that the importance of bio-physical variables in determining inter-zonal movements and their timing have decreased over time, whilst the significance of economic and institutional factors appears to have increased. Although resource density may still be a "pull factor" driving movement in some situations, there is evidence that "push factors" such as snow cover, presence of harmful insects and temperature combine with herd size to influence movements between zones, leading to a reduction in the matching between grazing distribution and forage resources. These changes reflect the move to livestock management by small household units owning highly variable numbers of animals. They are representative of global trends in pastoral systems, in which reduction in mobility is linked to declines in collective management institutions, increasing integration of pastoralists in the wider economy and land tenure change.

1. Introduction

1.1. Extensive pastoral systems: global trends

Recent decades have seen a global trend towards intensification of livestock production systems (de Haan et al., 2010; FAO, 2009). Yet in arid regions, extensive systems have a comparative advantage, as they require few inputs and can produce value from land which cannot be used for other purposes. Moderately stocked, well managed grazing systems are compatible with environmental goals such as carbon sequestration, and do not replace other ecosystems by logging, draining or ploughing (Toutain et al., 2010). Natural forage production on arid rangelands is highly variable in space and time; the potential economic and environmental advantages to be gained from pastoral land use are thus dependent on livestock movement (Coughenour, 2008a). Yet such systems have seen a cessation or shortening of livestock migrations in recent years (Reid et al., 2008). Pastures have become increasingly fragmented and even fenced; some areas are overused whilst others have been abandoned. This has implications for ecosystem function and resilience, livestock productivity and the sustainability of rural livelihoods from Africa to China (Boone and Hobbs, 2003; Li et al., 2007; Rohde et al., 2006).

Influenced by insights into the non-equilibrium nature of rangeland dynamics (Behnke et al., 1993; Ellis and Swift, 1988), these concerns have led to new thinking on appropriate ways to legislate for, and manage, livestock mobility, resulting in the promotion of common property systems and re-examination of open access systems (Turner, 2011). Yet this 'new paradigm' is by no means accepted by all — the perceived environmental and commercial advantages of highly secure individual property rights have underpinned the decision by many governments to promote pasture privatisation programmes. One focus of research informing these debates is the factors which influence animal

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distributions over the landscape (Behnke et al., 2011; Coughenour, 2008a; Dörre and Borchardt, 2012; Turner et al., 2005; Vanselow et al., 2012). Improved understanding of the natural, economic and political drivers of livestock movement (mediated through pastoralists' decision making) can inform policies to support sustainable rangeland management.

1.2. Kazakhstan — pasture reserves of global significance

Our study country, Kazakhstan is a rapidly growing developing nation with large oil and gas reserves and a growing demand for livestock products (Government of Kazakhstan and the World Bank, 2004). It is located in one of the few regions of the world where animal feed production actually decreased in recent years, following the post-Soviet collapse in imports and subsidies (de Haan et al., 2010) and a feed deficit is seen as a major factor behind the country's low livestock production efficiency parameters (Government of Kazakhstan and the World Bank, 2004; Tazhibaev et al., 2014). Today the country is modernising its livestock sector, and in particular beef production, through breed improvements, subsidies on feed prices, and investments in export-oriented feedlots (Ministry of Agriculture of the Republic of Kazakhstan, 2013, 2014). Yet, in these key strategy documents, it is also suggested that pastures may make a critical contribution to cost reduction in the livestock sector. Extensive production, which is dominated by family farms, holding both cattle and 18 million head of small stock, may also become a target for government support. At 1.8 million km^2, Kazakhstan is ranked fifth in terms of area of grazing land (FAOSTAT). It has been estimated that within arid pastures, comprising 80% of these grazing lands, natural vegetation comprises over 90% of livestock food intake, and agricultural activities other than livestock raising are marginal or impossible (Thornton et al., 2002). Yet rangeland resources are underutilised — it has been estimated that only about 30% of the total area are currently grazed (Government of Kazakhstan and the World Bank, 2004; Tazhibaev et al., 2014). There is evidence that loss of livestock mobility into remote areas has had negative effects on livestock nutrition (Kerven et al., 2004). Although government policy currently favours intensification, the presence of large areas of abandoned pasture and current debates within Kazakhstan around subsidies, pastoral property rights reform and approaches to supporting mobile pastoralism, make this a particularly interesting case in which to examine the drivers of livestock movement.

1.3. Understanding movement: scale considerations and theoretical frameworks

The majority of investigations which attempt to map and model livestock movement, follow daily grazing trajectories of individual animals moving between patches (Putfarken et al., 2008; Rinella et al., 2011; Senft et al., 1985). In semi-arid and arid systems, in which animals are both herded and restricted to water sources or other 'central places', the herd is the unit of interest (Coppolillo, 2001; Coppolillo, 2000; Turner et al., 2005). In these studies, mapping of livestock movements is limited to the daily grazing radius from the central point. Only a small number of studies on domestic livestock have investigated animal densities between multiple central points (Ogutu et al., 2010) at large scales (e.g. McCarthy, 2007; Moritz et al., 2014; Pin-Diop et al., 2007; Vanselow et al., 2012). This between site-level is most appropriate to the understanding and management of entire migratory systems, but most studies at this scale focus on a single component (season or ecological zone) of a larger system.

A framework within which site selection may be considered is the theory of 'Ideal Free Distribution' (IFD) which was originally developed to explain wild animal distributions (Fretwell, 1972; Fretwell and Lucas, 1970). This theory predicts that, where movements are not restricted, animals will distribute themselves according to the density of their feed resources, thus 'matching' or 'tracking' resource availability. Pastoralists having no considerations other than the maximisation of forage availability for their livestock might be expected to behave in the same way. The theory thus constitutes a useful null hypothesis when investigating the extent to which livestock mobility is related to resource distribution. Few studies have used the IFD as a framework for exploring the drivers of livestock distributions, with Moritz et al. (2014) a rare exception. That study showed that predictions from the IFD were borne out within a single ecological zone and season. Using IFD as an analytical framework enables the evaluation of the importance of resource distribution in determining site use, in comparison with other factors. In the absence of a control or counterfactual, one way to disentangle the relative contribution of resource distribution over other potential drivers of livestock movement is to explore changes in livestock distributions as potential drivers vary over time, at different spatial and temporal scales (Bassett and Turner, 2007) and such a historical approach is also taken in this paper.

1.4. Study aims and system characteristics

Our major goal is to explore the changing role of bio-physical variables in shaping livestock movement across an entire migratory system. We take advantage of our long-term knowledge of this system to explore the relative influence of different components of resource density and other bio-physical variables on livestock distributions, under radically different economic and institutional circumstances, using IFD as an analytical framework. We firstly conduct a qualitative analysis of historical change in livestock distributions between broad ecological zones, followed by an analysis of more recent monthly site specific data for herds within these zones. This enables us better to understand the drivers of movement between ecological zones over the year, the importance of variability between specific chosen sites within zones and the consequences of historical changes in zonal migration in terms of forage resources foregone.

Central Kazakhstan is the site of an ancient migratory pastoralist system, in which livestock have traditionally moved up to 800 km between five ecological zones, migrating between summer pastures in the north and winter pastures in the south (Kazakh Academy of Sciences, 1980; Mansurova, 1984; Olcott, 1995). In Soviet times, this migration was formalised and constrained, and research into pasture composition and quality (e.g. Kirichenko, 1980; Kurochkina and Osmanova, 1973) was used to inform grazing plans. Following the break-up of the Soviet Union in the early 1990s, livestock numbers collapsed, flocks came under private ownership, and migrations virtually ceased (Behnke, 2003; Kerven et al., 2006; Robinson and Milner-Gulland, 2003b). Today, in a very different economic and institutional context, the set of factors affecting animal distributions, and their relative importance to decision making is very different from that of the past. This system exemplifies the dynamic challenges, benefits and constraints to movement in changing circumstances, and is uniquely well documented, both from Soviet era literature and from our own research since 1998 (Kerven et al., 2004, 2006; Robinson and Milner-Gulland, 2003b). The study area includes multiple ecological zones used by the same livestock at different times of the year, and the factors determining bio-physical suitability of each zone vary by season. Site selection operates at two levels: between zones and within zones, where a "site" is a well or watering place where livestock are based in a given month or season.

When examining a system such as this, one obvious inference is that animals are distributed in order to track resources most efficiently. Here, this assumption is corroborated by the fact that a wild ungulate, the saiga antelope (*Saiga tatarica*) follows a similar migratory pattern to that observed in pre-Soviet times (Bekenov et al., 1998). However, this is clearly not the whole story, given that the livestock migration has not persisted through changing economic and institutional circumstances; there is also the question as to which natural resources exactly livestock are tracking (e.g. biomass, edibility, water) and how the importance of these different resource types varies by season and year, and at different spatial and temporal scales.