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Spatial cluster analysis for large herbivore distributions: Amboseli ecosystem, Kenya

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ABSTRACT

We present an assessment of seasonal movements and species distributions in the Amboseli ecosystem, southern Kenya, using spatial cluster analysis for large herbivore populations over the period 1970 to 2010. Six large mammal species were grouped into zones of most similar use based on a spatial hierarchical cluster analysis. The herbivores clustered into metabolic biomass size classes, suggesting variability in migration and habitat utilization patterns at different scales. The analysis shows a steady loss of spatial spread and heterogeneity among six indicator species over the decades. The findings point to the spread of farming, loss of habitat, land subdivision, sedentarization and ivory poaching as key factors causing compression of species in and around Amboseli National Park. The national park and environs is the only cluster showing no loss of species heterogeneity. The analysis highlights large herbivores as more vulnerable to displacement and compression than small species. The hierarchical cluster analysis shows the use of spatial tools in detecting patterns of change across an ecosystem and identifying important areas for land conservation and restoration to sustain species migration and species diversity.

1. Introduction

African savannah ecosystems are characterized by extensive seasonal migrations of large herbivores (Sinclair et al., 2007). In recent decades, rapid human population and land use changes have caused a loss of populations and range among most large herbivores (Ogutu et al., 2011). Amboseli ecosystem in southern Kenya, which has been continuously studied since the 1960s, provides a rich dataset showing the impact of human activity on a savannah ecosystem and wildlife populations (Western and Nightingale, 2003). Despite the abundant documentation of population and habitat changes, little has been published on the spatial changes in wildlife movements and species richness patterns (Mose et al., 2013).

In this paper we present an assessment of species distributions and spatial utilization of selected species using spatial hierarchical cluster analysis of large herbivore populations from the 1970s to 2000s. The species include buffalo (BF), elephant (EL), Grant's gazelles (GG) Thomson's gazelles (TG), wildebeest (WL) and zebra (ZB). The analysis covers a range of body size to explore long term changes in spatial distribution and richness, the primary agents and the differential effects on species. We use spatial cluster analysis as a tool for detecting data patterns, the changes in pattern over time and the conservation implications.

2. Study area and methods

The 8500 km^2 (Fig. 1) Amboseli ecosystem straddling the Kenya–Tanzania border is defined by the seasonal movements of large herbivores and includes the 388 km^2 Amboseli National Park. Further details of the ecosystem are provided elsewhere (Western, 2006). Land subdivision, settlement, agriculture and loss of seasonal grazing (Okello, 2005) have led to range restriction and fragmentation of pastoral livestock and wildlife populations over the last four decades (Western, 2006; Worden, 2007).

In this study we present a change assessment of space utilization by selected species over four decades. The long term data has been collected across the Amboseli ecosystem by the Amboseli Conservation Program (ACP) (Western, 2014) since 1973, based on a 5 by 5 km grid system, using a light aircraft (Western et al., 2009). Animal species were counted spatially within a Universal Transverse Mercator (UTM) Grid covering approximately 25 km^2. The global population estimates (PE) and the standard error (SE) for each species were calculated using the Jolly method 2 (Jolly, 1969), where $\mathrm{PE} = N\bar{y}$ and $\mathrm{SE} = \sqrt{\frac{N(N-n)}{n}}$ in which $\bar{y}$ is the sample mean, s^2 is the sample variance, n is the sample size and N is the number of samples needed to give complete coverage of the study area. Here, N is the total number of units (grids in the entire study area), while n, represents the number of transects (Norton-griffiths, 1978) flown in the north–south direction (Fig. 1). Population density for each grid was calculated as the number of animals observed within grid divided by the area (km^2) of the grid.

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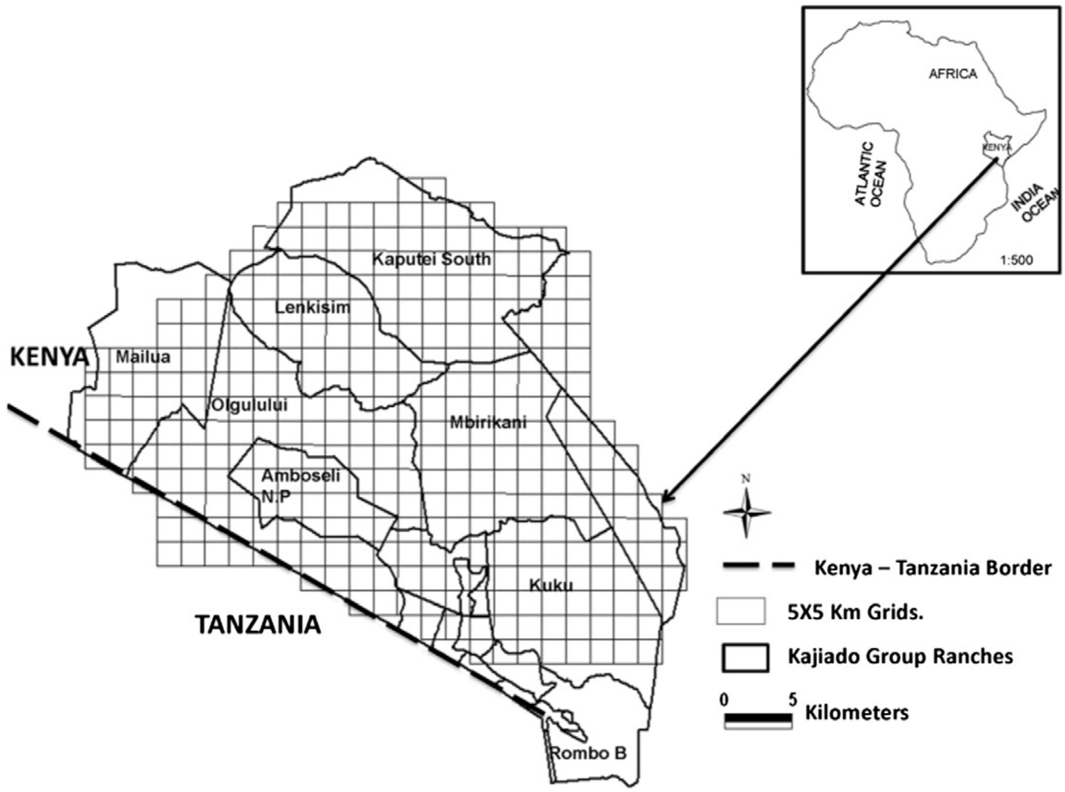

Fig. 1. Representation of Amboseli ecosystem in southern Kenya showing the protected Amboseli National Park and the surrounding pastoral lands managed as local community group ranches.

2.1. Spatial hierarchical clustering

We selected the top three grids utilized by each of the species across all the ecosystem based on grid population densities starting in the 1970s. The selection allowed for the possibility of different species utilizing the same 25 km^2 grid (Fig. 1). The centroids of the grids formed the spatial points presented here as latitude and longitude, together with additional attributes (marks) representing the selected species (*latitude*, *longitude*, *species*) in a given decade. We computed a distance matrix and applied hierarchical spatial point clustering.

An exploratory analysis using a *cluster dendrogram graphic* suggested four (4) clusters. We then aggregated the spatial points together with their attributes (selected species) into clusters based on distance and hierarchical spatial point clustering (Carvalho et al., 2009). This technique groups a set of objects into classes or clusters so that objects within a cluster have high similarity in comparison to other clusters, but are dissimilar to objects in other clusters (Lu, 2000). Here, the grouping was based on the distance between the spatial points which represent the areas of high species utilization, depending on their population density in the grids. These clusters were then mapped over the Amboseli

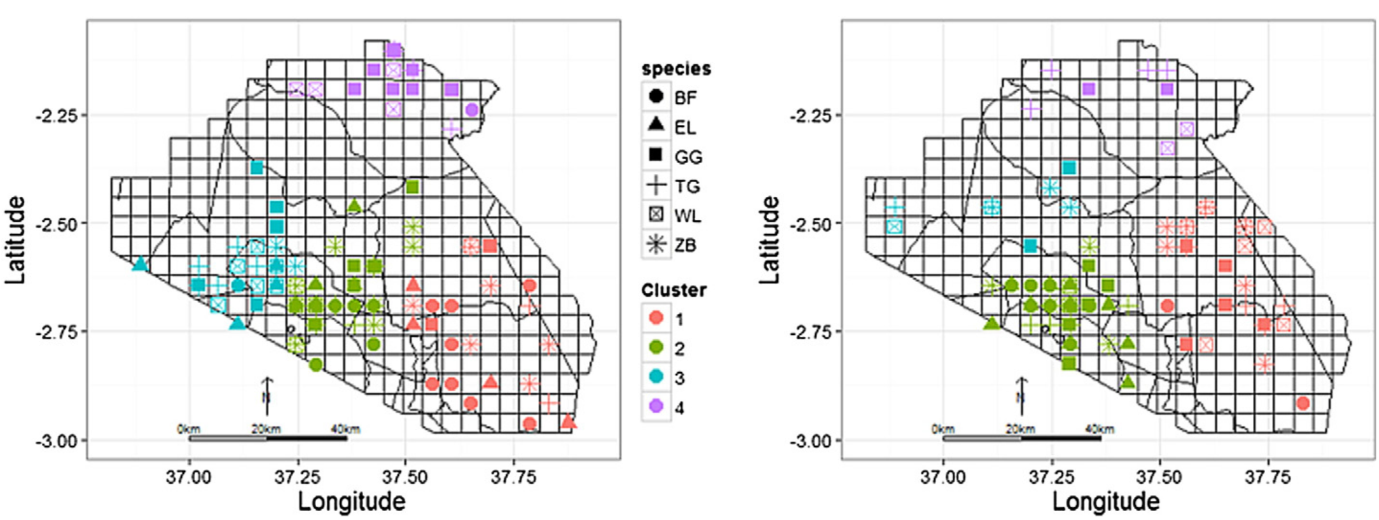

Fig. 2. Spatial cluster analysis of species distribution based on most utilized grids for the 1970s (left) and 2000s (right). Four clusters (1, 2, 3, and 4) were identified as shown. Bigger species (elephant (EL) and buffalo (BF)) have been exclusively pushed to the center of the ecosystem over the last four decades. Zebra (ZB), wildebeest (WL), Grant's gazelles (GG) and Thomson's gazelles (TG) are more spread out across the clusters in the 2000s.