Biological Conservation 215 (2017) 46–50

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Short communication

Partial migration links local surface-water management to large-scale elephant conservation in the world's largest transfrontier conservation area

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ARTICLE INFO

Keywords:
Connectivity
Land sharing
Management
Migration
Protected area
Water

ABSTRACT

Successful conservation of large mammals requires vast areas to maintain viable populations. This often requires to embrace large-scale approaches that extend beyond the borders of formally protected areas. However, the quality of the scientific knowledge about animal movement across large conservation areas vary, and could limit the effectiveness of conservation efforts. Here we used GPS tracking to conduct the first study of large-scale movements of African elephants (*Loxodonta africana*) in Hwange NP (Zimbabwe), which is an unfenced park part of the Kavango-Zambezi Transfrontier Conservation Area, the world's largest terrestrial conservation area. We show that some, but not all, elephants migrate seasonally, with wet- to dry-season movements linked to the provision of water in Hwange NP. The distance between the most distant locations of individual elephants reaches 260 km. In this partial migration system influenced by management practices, over 20% of the elephants have wet-season ranges established in Botswana, outside of protected areas in private or communal wildlife management areas. Our results call for the urgent drafting of a regional action plan, involving all stakeholders identified by our study and their neighbours, to predict and react to what would happen if water provision in Hwange NP was to suddenly change because of management practices or extreme climate change. Beyond this critical conservation issue for the world's largest elephant meta-population, our results also highlight the relevance of large-scale conservation areas combined with integrative planning involving national wildlife management institutions and the private and communal sector.

1. Introduction

The conservation of large mammals requires the protection of vast areas to maintain viable populations (Macdonald et al., 2013). This is often neither feasible, nor desirable, given trade-offs between land sparing and other factors, particularly the livelihoods of human populations (Fischer et al., 2011). As a result, large mammal conservation needs to embrace an integrative view that extends beyond the borders of protected areas and includes all stakeholders (Cumming et al., 2015).

The recent development of Transfrontier Conservation Areas (hereafter TFCA) attempts to overcome this challenge. For instance, the Kavango-Zambezi (KAZA) TFCA, covering five countries in southern Africa and now the world's largest terrestrial conservation area (520,000 km^2)(Fig. A1), was legally established in 2011. It currently hosts over 50% of all African savannah elephants (*Loxodonta africana*) (Chase et al., 2016), and elephant conservation and management, and the maintenance of connectivity between protected areas, is at the heart of this project (see www.kavangozambezi.org).

To be successful, such approach requires understanding the spatio-temporal dynamics of the populations of target species. Additionally,

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http://dx.doi.org/10.1016/j.biocon.2017.09.003
Received 19 May 2017; Received in revised form 25 July 2017; Accepted 5 September 2017

grasping the extent to which management actions can affect populations locally, but also beyond the border of the management area, is critical. Information about the patterns and drivers of animal movement is therefore particularly valuable, especially when focusing on long-ranging migratory species (Bolger et al., 2008).

The amount and quality of the scientific knowledge about animal movement across large-scale conservation areas vary however. This is understandable because monitoring animal movement across large areas remains logistically challenging and expensive. In some cases, movements are obvious, such as the simultaneous migration of hundreds of thousands of animals (e.g. the Serengeti wildebeest *Connochaetes taurinus*). In others, local knowledge, sometimes supported by census data, could be suggestive of some animal redistribution in the landscape (Bruce et al., 2014). However, in many cases, movement data could improve the effectiveness of conservation efforts. For instance, it may help in supporting or revising the current limits of conservation areas or in designing corridors within these. By clearly identifying linkages between areas, studies could also reveal which stakeholders influence and/or manage the same animals. Finally, improved knowledge could generate acceptance of a common view of the functioning of the system by stakeholders, thus facilitating the integrative management approach.

We conducted our study in Hwange National Park, Zimbabwe. This large unfenced park borders Botswana and is part of the KAZA TFCA (Fig. A1). Artificial water provisioning within the north-eastern section of Hwange NP (Fig. A1) has allowed the increase of the Hwange elephant population from < 1000 individuals in the 1930′s (Davison, 1967) to an estimated 45,000 individuals in the 2014 dry season (Chase et al., 2016). Recent road censuses conducted within the area of the Park where artificial waterholes are maintained show strong a seasonal increase in elephant numbers during the dry seasons (Chamaillé-Jammes et al., 2009). This seasonal increase is more important during dry years when more of the natural pans of the rest of the Park dry up (Chamaillé-Jammes et al., 2007a, 2007b). Because demographic processes cannot explain these increases, nor any of the other factors considered (e.g. human disturbance outside the Park), we parsimoniously assumed that access to surface water is a key driver of large scale seasonal movements of elephants inside, and possibly outside, the Park. Here, we used GPS tracking to conduct the first study of large scale elephant movements in Hwange NP and explored the links to other areas of KAZA. We discuss how our results highlight the relevance of TFCAs and provide clear directions to improve the conservation and management of the world's largest elephant population.

2. Methods

2.1. Study area

Hwange NP covers ∼15000 km^2 of semi-arid wooded savannas. Mean annual rainfall is ∼600 mm and most of the rain falls between November and April, during which natural pans fill up. Most of these pan dry up during the course of the dry season (Chamaillé-Jammes et al., 2007b). As there is no permanent river in the Park, during the dry season water is mostly available at the artificial waterholes in which groundwater is continuously pumped (Fig. A1). In the dry season, elephant breeding herds do not forage > 15 km away from water (Chamaillé-Jammes et al., 2013). The limited distribution of water, combined with one of the highest densities in the world (∼3 elephants per km^2; Chase et al., 2016), regulate the dynamics of the population (Chamaillé-Jammes et al., 2008).

2.2. Elephant movement data

Thirty-three GPS collars were deployed on adult females in different breeding herds. All elephants were captured in the eastern section of Hwange NP (Fig. A1). Collars were deployed in August 2009 (n = 10), November 2012 (n = 13), November 2014 (n = 8) and February 2015 (n = 2). See Fig. A2 for an overview of monitoring periods. The frequency of location acquisition varied between collars, and for this study focusing on large-scale movements we retained only one location per day. The data have been archived, and can be visualized, on movebank.org (study name: African elephant (Migration) Chamaillé-Jammes Hwange NP).

2.3. Analysis of seasonal range overlaps

We used a location-based kernel approach (Worton, 1989) to estimate, for each individual, the ranges (90% utilization distribution) of elephants during the core of the wet and dry seasons. We selected the core of the seasons to avoid confounding effects of transit that would artificially inflate the overlap between ranges. Based on seasonal rainfall patterns (Chamaille-Jammes et al., 2006), the core wet season was defined as the February/March period, and the core dry season as the September/October period. We then estimated the amount of range overlap using the Bhattacharyya's coefficient (Benhamou et al., 2014). We also measured the distance between range centroids to inform on range separation when overlap was nil.

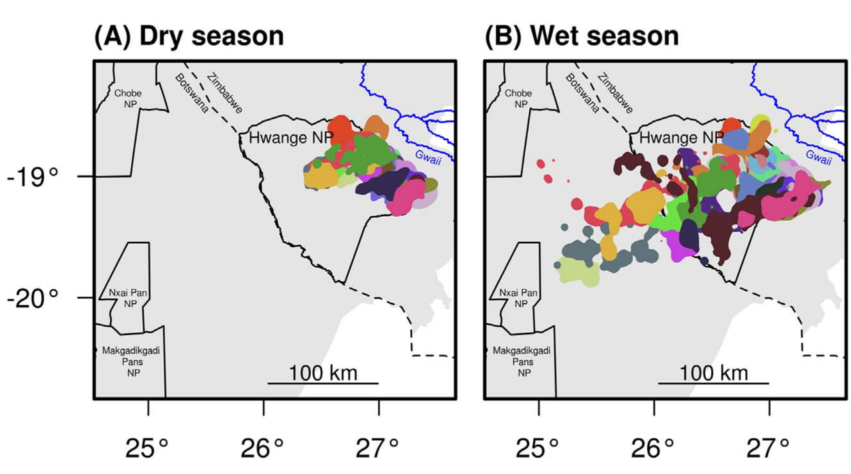

Fig. 1. (A) Dry-season and (B) wet-season ranges of elephants collared in Hwange NP. Each individual is associated with a different color. The area in grey is within the boundary of the Kavango-Zambezi Transfrontier Conservation Area. Limits of Hwange, Chobe, Nxai and Makgadikgadi Pans National Parks are shown.