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Age structure as an indicator of poaching pressure: Insights from rapid assessments of elephant populations across space and time

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ABSTRACT

Detecting and monitoring illegal harvesting pressure on wild populations is challenging due to the cryptic nature of poaching activities. Although change in population age structure has been suggested as an indicator of harvesting pressure, few studies have tested its validity when based on short-term field surveys. Using data from rapid demographic assessment surveys carried out in 2009 at six sites in Tanzania, we examined whether African elephant populations experiencing contrasting levels of poaching pressure showed significant differences in their age structure, operational sex ratio (i.e. adult males to adult females), dependent individual to adult female ratio at the group level, and proportion of tuskless individuals. We also compared similar metrics between the population sampled in Ruaha National Park in 2009 and again in 2015 following a suspected increase in poaching. Elephant populations experiencing medium and high levels of poaching in 2009 were characterised by fewer calves and old individuals, a reduced number of adult males relative to adult females, and a lower ratio of calves to adult females within groups. We also found a higher proportion of tuskless individuals in poached populations (> 6%). Changes in age structure in the Ruaha population between 2009 and 15 were similar to those observed across sites in 2009. Our findings are consistent with previous work documenting how the loss of older individuals – targeted for their larger tusks – decreases recruitment and survival of elephant calves. Illegal killing for ivory is a huge threat to the survival of African elephants. In this context, the present study contributes towards validating the use of age structure as an indicator of poaching pressure in elephant populations, but also in other wildlife populations where illegal offtake is targeted at specific age classes.

1. Introduction

Illegal harvesting activities affecting wildlife populations can be hard to detect and monitor, especially in populations that are not under close observation (Gavin et al., 2010; Liberg et al., 2012). Although numerous indicators have been developed to help track illegal harvesting pressure on wild populations, including interview and market-based metrics (Jones et al., 2008; Harris et al., 2015), forensic observations (Manel et al., 2002; Retief et al., 2014), and behavioural responses (Caro, 2005; Goldenberg et al., 2017), these often lack clear links to both harvesting and demographic processes. In general, harvesting removes a subset of individuals from a given population, such as those with the brightest colours or largest horns, which can often be defined as belonging to a specific age class (Ginsberg and Milner-Gulland, 1994; Pozo et al., 2016). In the case of illegal and poorly regulated legal harvesting, it can be expected that selective over-harvesting of individuals according to age will result in changes to a population's structure, and most notably decreases in the frequency of individuals in the targeted age class.

Age structure has been put forward as an indicator with which to monitor populations of large herbivores (Noss, 1990; Rughetti, 2016). Indeed, age structural changes in wild populations are often investigated as part of long-term, individual-based studies, which typically examine demographic processes such as the survival, recruitment and mortality of study individuals (Langvatn and Loison, 1999; Milner et al., 2007; Moss, et al., 2011; Wittemyer et al., 2013). Although

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hugely valuable, such studies are scarce and rarely carried out on populations experiencing varying levels of legal and/or illegal harvesting, thus hindering the assessment of age structure as an indicator of harvesting pressure. When long-term datasets are not available, comparative studies may still be derived from rapid population surveys carried out over short periods of time and across multiple sites, yet indicators based on this approach have rarely been developed and tested (Tella et al., 2013).

In this study, we compare the age structure and level of tusklessness between African elephant (*Loxodonta africana*) populations experiencing contrasting levels of past and present poaching pressure in Tanzania. The illegal killing of elephants for ivory is leading to population declines across the African continent (Wittemyer et al., 2011; Wittemyer et al., 2014; Chase et al., 2016), however, recent censuses have highlighted alarming population declines in Tanzania (Chase et al., 2016), a country shown to be one of the main poaching hotspots in Africa (Wasser et al., 2015; Thouless et al., 2016). In this context, we use a rapid demographic assessment (RDA) method developed by Poole (1989) to quantify the population structure of poached populations. The RDA approach attempts to sex and age as many individuals as possible within a given population, with the overall aim of providing a snapshot of the population structure at a given point in time (Kioko et al., 2013). Despite being logistically more feasible than recently proposed methods based on aerial monitoring (Ferreira and van Aarde, 2008), few studies since Poole (1989) have promoted the RDA as a tool to evaluate changes in elephant population structure, and use these as indicators of poaching pressure.

Using RDA data on 2631 elephants, we examine whether elephant populations experiencing low, medium, and high levels of poaching prior to 2009 show significant differences in their age structure, operational sex ratio (i.e. adult males to adult females), dependent individual to adult female ratio at the group level, and proportion of tuskless individuals. We then compare similar metrics between the population sampled in Ruaha National Park (hereafter, Ruaha) in 2009 and in 2015 following a suspected increase in the level of poaching. Although Ruaha holds one of the largest populations of elephants in Tanzania – estimated at 15,836 in 2015 (TAWIRI, 2015) – it has been highlighted as a centre for poaching post-2011 (Wasser et al., 2015). Given that poaching targets older bulls and matriarchs for their larger tusks (Poole, 1989; Mondol et al., 2014), we expected increased poaching pressure to lead to reductions in the proportion of older individuals, but also to an increase in the proportion of individuals lacking tusks (Chiyo et al., 2015, Raubenheimer and Miniggio, 2016). Based on previous studies, we also hypothesised that the loss of old individuals – and matriarchs in particular – would lead to reduced calf recruitment and survival (Gobush et al., 2008; Wittemyer et al., 2013; Turkalo et al., 2016), and consequently a reduction in the proportion of young individuals. Based on our findings, we discuss the value of age structure as an indicator with which to monitor poaching pressure across both space and time.

2. Materials and methods

2.1. Study sites

Demographic data were collected on elephant populations in six study sites across Tanzania (Fig. 1). Four out of the six populations were surveyed within national parks (NPs; Tarangire, Serengeti, Ruaha, and Katavi) that permit photographic tourism only, whilst two populations were surveyed within game reserves (GRs) designated for both photographic tourism and trophy hunting (Selous and Ugalla). All study sites are characterised by distinct wet and dry seasons, which generally occur between November–April and May–October, respectively. Annual rainfall across the study sites in 2009 ranged from 439.6 mm in Ugalla GR to 707.6 mm in Selous GR (Fig. 1).

2.2. Poaching levels

Historical patterns of poaching intensity across Tanzania are unreliably documented and primarily anecdotal (Mduma et al., 2010). Although all of the elephant populations considered in this study experienced poaching in the 1970s and 80s (Poole and Thomsen, 1989), recent and current poaching levels vary considerably from one site to another (Thouless et al., 2016). We classified study populations as experiencing low, medium, and high levels of poaching based on population trends in the three years prior to the 2009 surveys (Fig. 2). Populations in Tarangire and Serengeti were categorised as undergoing low levels of poaching as they demonstrated rapid growth between 2006 and 2009 (Fig. 2). In contrast, populations in Ruaha and Katavi were found to be stable between 2006 and 2009, with suspected but unreliably documented poaching occurring at both sites (Martin and Caro, 2013; Fig. 2). These populations were thus classified as experiencing a medium level of poaching. Lastly, elephant populations in Selous and Ugalla underwent dramatic declines between 2006 and 2009 (Fig. 2), due to high levels of illegal killing (Wasser et al., 2009; Wilfred and MacColl, 2014).

2.3. Data collection

An RDA survey was carried out at each of the six study sites during 2009–10 (Fig. 1) following the method described by Poole (1989). Observers were trained in ageing and sexing elephants on the northern sub-population of Tarangire NP, which has been the focus of a continuous study since 1993 (Foley and Faust, 2010). Observer accuracy and inter-observer consistency were tested until they had reached a satisfactory level (> 95% accuracy on known individuals). The observers then surveyed each study site for two to four weeks, with the exception of Tarangire NP, where all sub-populations of elephants were surveyed over three days.

The primary aim of RDA surveys is to record the age, sex and unique physical attributes of as many different elephants as possible in a given population, as well as record the size of the group they are in (Poole, 1989). Selection of survey areas within study sites followed local advice on where elephants were most likely to be encountered. Search area was shifted by at least 10 km each survey day. Surveys were carried out in a motorised vehicle and followed road networks. All recorded individuals were geo-referenced using a Global Positioning System and, whenever possible, portrait photos and/or identification notes were taken. Together these data were used to ensure no double counting of individuals had occurred. In all study sites, a minimum sample size of 300 individuals was sought.

Elephants spotted from the road were approached to within 20–50 m so as to maximise viewing quality whist minimising disturbance. Individuals were sexed and assigned to one of seven age classes (0–4, 5–9, 10–14, 15–19, 20–24, 25–39 and 40+; inclusive of the last age shown) based on shoulder height, back length, head and body shape, and size of tusks (Poole, 1989; Moss, 1996). Age-assignments were made relative to other individuals in the same population, thereby minimising bias associated with differing height across populations. Individuals under 10 years of age were sometimes difficult to sex, and their gender was recorded as “unknown” when this was the case.

Demographic data pertaining to the Ruaha population in 2015 were collated from monthly road transect surveys and opportunistic monitoring carried out between May and October 2015 (Fig. 1). Observers followed the same protocol for approaching and ageing elephants as that used in the 2009 surveys. Data were collected as part of an ongoing elephant monitoring study implemented by the Southern Tanzania