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Review

The value of disturbance-tolerant cercopithecine monkeys as seed dispersers in degraded habitats

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ABSTRACT

Habitat disturbance has caused a global decline in populations of frugivores, with critical consequences for seed dispersal. Large-seeded plants are especially threatened as they depend on a restricted number of large-bodied dispersers that are vulnerable to extinction and cannot maintain populations in most disturbed habitats. Cercopithecine monkeys are potentially key seed dispersers in disturbed habitats, because of the robustness of some species to disturbance and their ability to disperse large seeds. However, the potential ecological roles of the more disturbance-tolerant species are rarely discussed. This review evaluates the seed dispersal role of cercopithecines in disturbed habitats by investigating their ability to tolerate habitat disturbance, their seed dispersal abilities, and the threats to species survival. Cercopithecines are characterised by ecological flexibility; most species adjust their diet, group size, home range size and, often, feeding methods according to resource availability and habitat structure. Consequently, 79% of species are tolerant of varying degrees of habitat disturbance. Cercopithecines are often inconsistent seed dispersers, but they have the capacity to disperse many seeds, large seeds and to disperse them across large distances. They may be among the most important frugivores in altered environments in Asia and Africa. However, many disturbance-tolerant cercopithecine species are targeted by local people as pests, which poses a major threat to their conservation. In conclusion, the management of all disturbance-tolerant cercopithecine species should be re-evaluated given their importance in the regeneration of degraded Asian and African habitats.

Contents

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1. Introduction

Seed dispersal is a critical process in ecosystem maintenance and recovery, but is negatively impacted by all forms of ecosystem disturbance (McConkey et al., 2012). Decline in frugivore diversity and abundance (Dirzo, 2001) causes a reduction in the quantity of seeds being dispersed, changes in seed dispersal patterns and, ultimately, alteration of plant assemblages (Markl et al., 2012; McConkey et al., 2012; Muller-Landau, 2007). These changes further affect the vulnerability of ecosystems to added threats such as invasive species and climate change (Brook et al., 2008; McConkey et al., 2012). Seed dispersal becomes especially critical for forest regeneration as land degradation becomes more severe and less floristic resources are available (da Silva et al., 1996; Duncan and Chapman, 2002). This problem results partially from the low number of animal-dispersed seeds that are brought into some disturbed areas (Duncan and Chapman, 1999; Vulinec et al., 2006), because the associated low fruit abundance makes them unattractive to potential dispersers (da Silva et al., 1996), and partially from low establishment of dispersed seeds (Balcomb and Chapman, 2003).

The largest frugivores within an ecosystem provide an irreplaceable seed dispersal service, because smaller animals are generally unable to manipulate the large fruits these animals forage on (Babweteera et al., 2007; Campos-Arceiz and Blake, 2011; Forget et al., 2007; Otani, 2010; Tutin et al., 1991). However, these large frugivores are frequently the most vulnerable in disturbed habitats, because of their large or specialised food requirements and/or because they are targeted by hunters (Campos-Arceiz and Blake, 2011; Corlett, 2007; Sethi and Howe, 2009; Stoner et al., 2007). Conservation management of the largest frugivores is confounded by the large tracts of undisturbed habitat these animals require, and populations cannot be maintained in the long term in regions with a high human presence (Hill et al., 2002; Laurance et al., 2006; Naughton-Treves, 1998). For the long-term regeneration of disturbed habitats or maintenance of permanent habitat fragments, it is critical to identify frugivores that can persist in degraded regions and those which are capable of dispersing the larger seeds within these habitats.

Cercopithecine monkeys are one of the most species-rich and broadly distributed subfamilies of primates in the world (Marini et al., 2012). While some species are dependent on undisturbed habitats, others are among the most conspicuous primates in heavily disturbed regions (Biquand et al., 1994; Gross-Camp and Kaplin, 2011; Richard et al., 1989; Rowe and Myers, 2011; Twinomugisha et al., 2006). Cercopithecine monkeys are considered important seed dispersers in many habitats where they have been studied (e.g., tropical forests (Kaplin and Moermond, 1998), temperate forests (Tsujino and Yumoto, 2009), savannas (Slater and du Toit, 2002)). Some species may currently be providing critical services in disturbed habitats in Asia and Africa (Agmen et al., 2010). However, the role of most species is under-appreciated because species that are most tolerant to disturbance are frequently considered to be pests and may be actively persecuted (Hill and Webber, 2010).

The aim in this review was to determine how prevalent disturbance-tolerance was among cercopithecine species, and to evaluate their importance as seed dispersers in disturbed habitats. To achieve the second part of our aim, we reviewed studies on seed dispersal in all habitats and identified behavioural and ecological factors that influence seed dispersal and are potentially modified by disturbance. We asked the following questions: (1) what proportion, and taxa, of cercopithecines are tolerant of different degrees of disturbance? (2) What morphological, behavioural and ecological characters are associated with disturbance-tolerance in cercopithecines? (3) How do these characteristics influence the seed dispersal role of cercopithecines in disturbed habitats? (4) What are the major threats to cercopithecines in disturbed habitats?

2. Materials and methods

The tolerance of cercopithecine species to habitat disturbance was assessed from their ability to maintain permanent populations in disturbed habitats, and therefore when using the term "tolerant" in this study, we are making reference to the presence of populations within disturbed habitats. Tolerance ranking was primarily determined from the current IUCN redlist (2013), using the list of habitats occupied. This list notes species that occurred in secondary forests (recorded in our study as low tolerance, T1), rural gardens, plantations, pastures, and heavily degraded former forest (collectively recorded as medium tolerance, T2), and urban areas (high tolerance, T3). Species not recorded in any of these habitats were noted to be intolerant (I). For species recorded in several habitats, the most disturbed habitat occupied served to define the tolerance score. Then, following literature reviews on all species, we altered the tolerance ranking when evidence for a different ranking was found. Since only *Cercocebus chrysogaster* was noted to be data deficient on the redlist, we assume our rankings are representative of the species' abilities to tolerate disturbance, rather than a function of the data available. A recently described species, *Cercopithecus lomamiensis* (Hart et al., 2012), currently has no listing on the IUCN Redlist and was not given a tolerance ranking.

Data on eco-ethological characteristics of cercopithecines are presented in Appendix A. These were taken mainly from Rowe and Myers (2011), and Sargis et al. (2008) for locomotion, Murray (1975) for cheek pouch size and use, and Enstam and Isbell (2007) for percentage of fruit in diet. Exhaustive literature reviews were conducted for seed dispersal studies on all cercopithecine species, and for all research conducted in disturbed areas on cercopithecines. We also reviewed studies on the behavioural ecology of cercopithecines to determine what environmental factors influence their behaviour and may have consequences for seed dispersal in disturbed habitats. Data from all accessible studies are reported regardless of study length.

To assess the relative importance of factors determining the tolerance (Intolerant (I), Low (T1), Medium (T2), or High (T3) tolerance) of cercopithecine species, we fitted generalised linear mixed models (GLMM). We first chose traits according to the following criteria: (1) the ability of traits to define the flexibility of a species to changing environmental conditions, (2) data were available for most species, (3) data could be divided into broad categories which encompassed the intra-specific variability that may be present (and is not a function of study length), and (4) data were not a function of study length (e.g., home range size). Thus, traits included in the GLMMs were vegetation type (Forest, Forest + Non-forest, Non-forest (i.e., wetlands, savanna, shrubland, grassland, rocky areas and caves)), locomotion mode (Terrestrial, Semi-terrestrial, Arboreal), predominant diet item (Frugivorous, Folivorous, Faunivorous or Omnivorous when fruit, vegetation and animal matter are all consumed in significant proportions (i.e., over