

Advances and Frontiers in Primate Seed Dispersal

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Abstract Primates play important roles as seed dispersers in many tropical ecosystems, such that studies of their seed dispersal services and impacts have gained interests among primatologists and ecologists in the past few decades. In this article, we first report that the number of scientific publications on primate seed dispersal has increased rapidly over the past 20 years, based on an extensive literature review. These publications encompass diverse primate taxa from the four geographic regions where they naturally occur. We then summarize the contributions to this Special Issue, which reflect on these progresses. Finally, we provide new directions for the next decade.

Keywords Frugivore · Tropical forests · Pre-dispersal · Post-dispersal · Fruit removal · Seed fate

For many angiosperms, seed dispersal by frugivorous animals is a key process for seed movement to new environments, species survival, and regeneration (Howe and Smallwood 1982; Terborgh *et al.* 2002; Wang and Smith 2002). Primates are considered one of the main seed dispersal agents in tropical forest ecosystems because they constitute a large proportion of the frugivore biomass in the tropics (Chapman 1995; Eisenberg and Thorington Jr. 1973). Their contribution to seed dispersal, and ultimately to plant survival and forest structure, has been studied since the 1980s. In 1998, the journal *American*

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Journal of Primatology published a Special Issue on primate seed dispersal, introducing progress in this research area at that time (Garber and Lambert 1998) (Fig. 1). Twenty years have passed since that milestone, and technological innovations, new theories, and a shift from species-based to community-based approaches in seed dispersal study have influenced primatologists and the study of primate seed dispersal. Now is the time to reflect on the progress of studies on primate seed dispersal over the past two decades, and identify patterns and directions for the next decade.

This Special Issue stems from a general interest among researchers who presented their work on primate seed dispersal at the symposium titled “Advances and Frontiers in Primate Seed Dispersal,” organized by Yamato Tsuji and Hiroki Sato, at the joint meeting of the International Primatological Society and the American Society of Primatologists in Chicago, Illinois, USA in August 2016. This issue presents research papers and reviews that illustrate different aspects of seed dispersal by primates, from pre- to post-dispersal phases (Fig. 1). It brings together a collection of articles that extend our knowledge of primate seed dispersal globally (from Africa, Asia, Madagascar, and Neotropics), review what is known, and identify commonalities across geographic locations, intercontinental and taxonomic differences, and gaps in our understanding of primate seed dispersal.

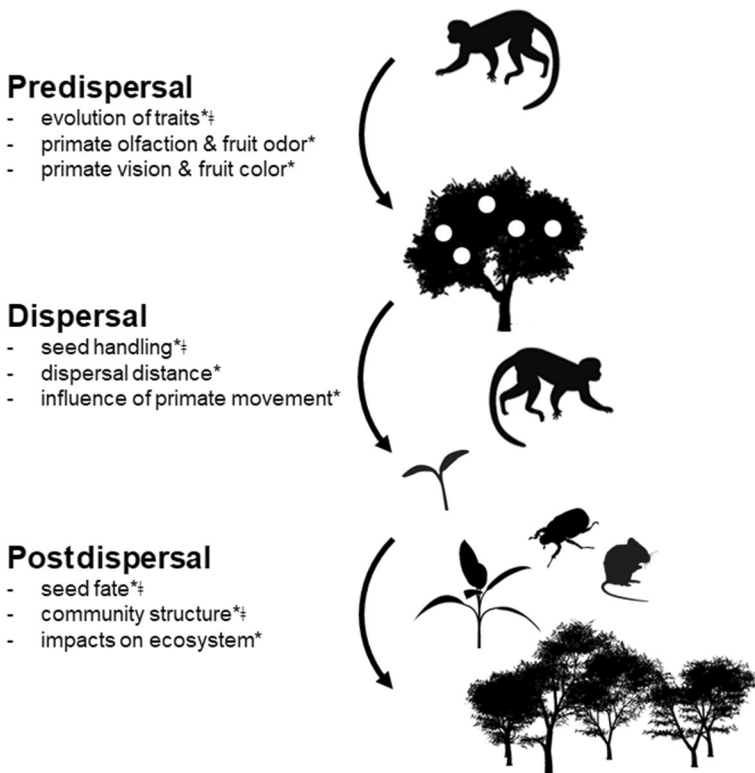


Fig. 1 An illustration of the different aspects of seed dispersal by primates, highlighting the components of each phases presented in this issue (*) and/or in the Special Issue published in 1998 in *American Journal of Primatology* (‡)

In this editorial, we first review the literature to identify the trend in the number of publications on primate seed dispersal over time and across geographical regions to provide a context to the contributions. We then introduce each contribution to this Special Issue and conclude with reflections on the current and future state of research on this field.

Publications on Primate Seed Dispersal

We searched the literature for publications reporting primate seed dispersal, using the Web of Science™ database, covering articles published from 1979 to December 2017 (accessed January 22, 2018). We used the key words “primate” and “seed dispers*” in our search. We included full-length research articles, short communications, and commentaries, but excluded reviews and studies published as abstracts only. We did not include contributions to edited volumes; those in journals and newsletters published by the IUCN/SSC Primate Specialist Group, which are not indexed by Web of Science; and gray literature. We examined only research papers published in English. We selected articles that discuss any aspect of seed dispersal by any primate taxa as their primary focus, and excluded those that mention primate seed dispersal to support other claims. Our search returned 358 publications that potentially met our criteria; though this review presents valuable information, it is not intended to be exhaustive. Based on these data, published research on primate seed dispersal has increased rapidly in the past 20 years (Fig. 2a), encompassing diverse primate taxa from the four geographic regions where primates occur naturally (Fig. 2b).

Contributions to this Special Issue

For this Special Issue, we attempted to include studies from the four geographic regions of primate natural habitat: Africa, Asia, Madagascar, and Neotropics. This issue

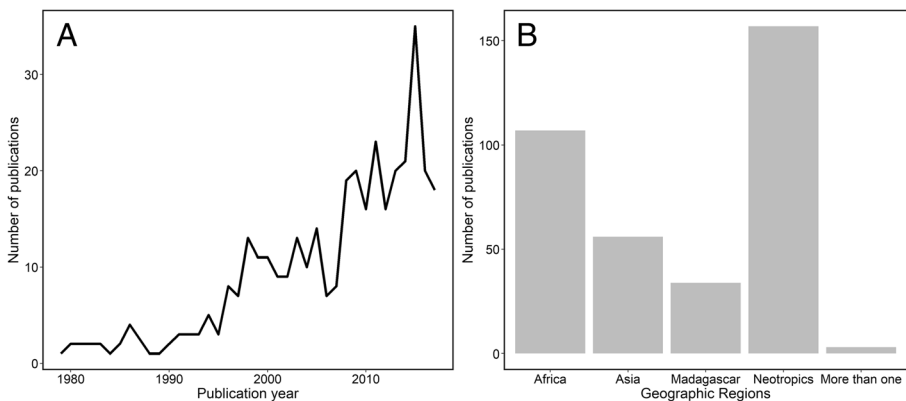


Fig. 2 (a) Number of published research articles on primate seed dispersal from 1979 to December 2017 and (b) number of research articles on primate seed dispersal in the four geographic regions where primates naturally occur, published during that time period (key words: “primate” and “seed dispers*” using the Web of Science™ database)

presents research articles and reviews for various primate species, addressing different aspects of seed dispersal, from pre- to post-dispersal phases (Fig. 1). At the pre-dispersal phase, Nevo and Valenta (2018) review the ecology and evolution of fruit odor as related to primate olfaction, which may influence primate fruit selection behavior and ultimately their seed dispersal services. Valenta *et al.* (2018) provide an overview of how fruit color influences primate selection for fruits, discussing methodological advances in the field of sequencing, spectrometry, and modeling to identify and interpret the linkages between fruit color and primate selection of fruits. At the dispersal phase, Tsuji and Su (2018) review knowledge of the collective traits that define the role of macaques as seed dispersers in Asian regions. Sato (2018) shows a temporal change in seed dispersal distances in lemurs with respect to behavioral changes for coping with the remarkable seasonality in Madagascar. Finally, at the post-dispersal phase, Culot *et al.* (2018) show how the characteristics of primary seed dispersal by one mixed-species group of tamarin species (*Saguinus mystax* and *Leontocebus nigrifrons*) affect seed burial by dung beetles and seed/seedling survival, and show that seed burial increases dispersal effectiveness more strongly in secondary than primary forest. Razafindratsima *et al.* (2018) report that losing lemur seed dispersers may result in a decrease of the potential of a Malagasy rainforest to store carbon. This Special Issue also presents work that review and summarize what researchers have accomplished in the past 20 years in several regions in terms of primate seed dispersal, with detailed recommendations for future studies (Andresen *et al.* 2018; Chapman and Dunham 2018; McConkey 2018). Together, these articles highlight recent advances in the field of primate seed dispersal, including new perspectives on our understanding of the importance of primate frugivores for forest ecosystems at multiple spatial and ecological scales, and the consequences of primate decline and loss for forest integrity and human well-being.

Future Directions

Although there has been an increase in our knowledge and understanding of the nature, mechanism, and impacts of seed dispersal by primates at multiple scales, further studies are needed. In the last decades, researchers have gathered an impressive amount of data about the role of primates as seed dispersers. However, a gap in knowledge still exists on the relative role of primates compared to other frugivores. It is thus urgent to include primates in studies of plant–animal networks (see McConkey and Brockelman 2011) to better assess their importance and specific roles within the frugivore community. Of course, compiling plant–animal interactions in highly diverse environments such as tropical and subtropical forests is a challenging task. However, the increased availability of datasets in open-access repositories and collaborations with ornithologists and mammalogists should help reach this objective. The detailed comparison between primates and other frugivores should focus on various aspects of the seed dispersal process such as fruit traits (Flörchinger *et al.* 2010; Gautier-Hion *et al.* 1985), seed removal (Gross-Camp *et al.* 2009; Lambert 2011), seed germination (Fuzessy *et al.* 2016), seed dispersal distances (Clark *et al.* 2005; Fuzessy *et al.* 2017), and post-dispersal seed fate (Culot *et al.* 2017; Lugon *et al.* 2017; McConkey *et al.* 2015). The formal inclusion of these data into the seed dispersal effectiveness (SDE) framework (Culot *et al.* 2015; Schupp *et al.* 2010) will enable the evaluation of the relative contribution of primates as seed dispersal agents in the ecosystem.

New technologies, such as more advanced and more efficient GPS devices, together with new analytical tools and paradigms to study animal movements (Nathan *et al.* 2008) as well as the availability of phylogenetic tools to include evolutionary perspectives (Razafindratsima and Dunham 2016), open new avenues for primatologists interested in studies of primate seed dispersal. Traditionally, the study of primates is usually done through primate follows with the detailed registration of their behavior and locations. Such data are rare in other animal groups. Coupling detailed behavioral and movement data with new statistical tools gives a unique opportunity to better understand primate use of space through movement modeling and infer the consequences for primate seed dispersal (see Bialozyt *et al.* 2014).

Finally, as clearly pointed out by Arroyo-Rodríguez and Fahrig (2014), there is an urgent need to adopt a landscape perspective in primate studies. If we want to predict the anthropogenic effects of habitat loss and forest fragmentation on the role of primates as seed dispersers, we need to collect data in areas of distinct fragmentation degree, which is also a challenging task if traditional methods are applied. A turning point will be reached in primate seed dispersal studies when we will be able to use new technologies and/or to adopt new approaches to deal with the difficulty of increasing the number of studied groups while still taking advantage of the detailed data obtained through traditional methods.

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Compliance with ethical standards

Conflict of Interest The authors declare no conflict of interest.

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