Linking colony size with quantitative estimates of ecosystem services of African fruit bats

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Animal-mediated seed dispersal is a pivotal component of functioning forest ecosystems all over the globe. Animals that disperse seeds away from their parental plants increase the seeds’ chances of survival by releasing them from competition and specialised predators and so contribute to maintain the biodiversity of forests. Furthermore, seeds dispersed into deforested areas provide the opportunity for reforestation. Forest regeneration especially depends on animals that cover large distances easily and cross forest gaps, in particular large-bodied frugivores or mobile species such as birds and bats [1]. Yet, frugivores have started to disappear from forests everywhere, with potentially dramatic consequences for forest composition, regeneration and overall forest biomass [2,3]. Identifying which species contribute substantially to the dispersal of viable seeds, and how these services are affected by fluctuations in population size, is thus pivotal to the understanding and conservation of forest ecosystems [4]. Here, using simulations based on tracking data, gut retention times and foraging ecology with colony monitoring data, high-resolution tracking data and foraging trials (n = 20), we estimated seed dispersal by three colonies of Eidolon in West Africa using a movement model integrating Eidolon foraging ecology with colony monitoring data, high-resolution tracking data (n = 43), and gut retention of small seeds estimated from feeding trials (n = 20).

In this simulation study, we quantitatively estimated seed dispersal by three colonies of Eidolon in West Africa using a movement model integrating Eidolon foraging ecology with colony monitoring data, high-resolution tracking data (n = 43), and gut retention of small seeds estimated from feeding trials (n = 20). We simulated foraging movements of all bats present at the colonies during the dry and wet season, and quantified seed dispersal and dispersal distances. These predictions were made under the theoretical assumption that all

Figure 1. Results of the seed dispersal simulations.
(A) Seed dispersal distances for each of the focal colonies. Violin plots show the entire distribution of simulated seed dispersal events. Points indicate the median dispersal distance, and the line represents the range between the 25% and 75% quantiles. (B) Spatial density of dispersed seeds within the area from which foraging locations for simulated bats were sampled as a function of colony size. Maps in (C) and (D) show the range of foraging movements for the Accra colony during the dry season (note that Accra is a coastal town). All hexagons have a diameter of 2.5 km, and summarize the results of events occurring in each hexagon representing an area of 5.3 km². (C) Total number (N = 338,000) of simulated seed dispersal events predicted to occur during a single night. (D) Number of simulated dispersal events occurring over deforested areas. See Figure S2 for the results for the Kibi and Ouagadougou colonies.
individuals feed exclusively on small-seeded fruit. We also quantified seed dispersal into deforested areas as an estimate of the colonies’ contribution to forest regeneration, and approximated the potential value of these ecosystem services (for details on data collection and analyses, see Supplemental information; for documented R-code and data, see Data S1).

We found that the average bat covered a distance of 67.1 km from its foraging tree to the colony, and visited one to three different trees each night. It dispersed seeds over distances of up to 95 km, with averages ranging between 12.6 and 21.4 km, depending on colony and season (Figure 1A). For the entire colony in Accra (Ghana), which consists of about 152,000 individuals during the dry season, we estimated up to 338,000 dry season, we estimated up to 338,000 dispersal events during a single night, producing an average seed rain of 26.2 dispersal events per km² (Figure 1A).

During the wet season, when the colony is occupied by only 4,000 individuals, the number of dispersal events per night dropped to a mere 5,500. Results for the colonies in Kibi (Ghana) and Ouagadougou (Burkina Faso) scaled similarly with colony size.

We used seed rain over clear-cut areas to estimate the potential contribution of Eidolon to forest ecosystem services. Especially in Ghana, deforestation affects 128,733 ha on average per year, and reduces the country’s gross revenue by US$133,650,000 every year [9]. During the dry season, at peak colony size in Accra and Kibi, bats dispersed seeds into 826.5 and 270.5 ha of the areas deforested in the period between 2001 and 2016 (Figures 1C,D). Complete reforestation of these areas could contribute an additional annual gross revenue of US$858,068 (Accra) and US$280,832 (Kibi) through e.g. stumpage fees. During the wet season, when no forest bats migrate away, this potential contribution dropped to 11.5 ha (Accra; additional annual gross revenue of US$11,939) and 24.5 ha (Kibi; US$25,436). In this naturally sparsely forested savanna habitat surrounding the colony in Ouagadougou, the number of dispersal events into clear-cut areas were negligible. The estimates for additional gross revenue were made for fully matured forest for which seed rain as provided by Eidolon is merely a first step.

Especially in forested landscapes, Eidolon form enormous colonies consisting of hundreds of thousands of individuals. Conservative figures put the global population size of the species at about 10 million individuals, suggesting that such super-colonies might assist forest regeneration through substantial seed dispersal, and thereby help to maintain valuable forest ecosystem services. Yet, populations of Eidolon and many other frugivores are in decline, and forests are becoming increasingly fragmented throughout the tropics [6]. This development severely endangers not only the functioning and maintenance of forest ecosystems [3], but together with increasing deforestation also the livelihood of people. Quantitative studies that estimate the effect of these species on the landscape level and link them to population size remain scarce. Our study indicates that the loss of Eidolon might endanger the functioning of forest ecosystem by limiting recruitment and gene flow. Below a certain threshold level, the beneficial effects of seed dispersal services provided by Eidolon might decrease disproportionately, and even collapse entirely [10]. The protection of large fruit bat colonies should thus be a winning strategy.

AUTHOR CONTRIBUTIONS

M.T., M.O., J.F. and D.D. conceived the experiment; M.A., J.F., M.W., and D.D. collected the data; M.T. performed the analyses; M.T., M.O., and D.D. wrote the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.

REFERENCES