

# Supplementary Material

## What is long-distance dispersal? And a taxonomy of dispersal events

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# 1 Methods

2 **Species and Study Site.** The tree species we use as a case study to illustrate  
3 different types of dispersal events, *Prunus mahaleb* (L.) (Rosaceae), is a shrub or  
4 small tree that produces fleshy fruits that are consumed by frugivores, who disperse  
5 seeds after regurgitating or defecating them. This species is frequently visited  
6 during July to mid-August by small- and medium-sized birds and carnivorous  
7 mammals that include fruits in their diets during late summer to winter (Jordano  
8 & Schupp, 2000). *P. mahaleb* occurs in a patchy distribution at the regional scale,  
9 with relatively isolated populations consisting of dozens to hundreds of trees. Our  
10 study population included a total of 196 adult reproductive trees distributed over  
11 an area of 26 ha in patches of variable density. Other populations within 20 km  
12 exist as scattered patches of 10–150 trees, with some containing  $\geq 1,000$  trees. The  
13 nearest population is 1.5 km away. Additional information on the study population  
14 and description of methodological approaches is reported by Jordano *et al.* (2007)  
15 and Garcia *et al.* (2009) and references therein.

16 **Sampling dispersed seeds.** To estimate the relative contribution of each dis-  
17 persal vector to the different categories of dispersal events defined in Table 1,  
18 we first collected dispersed seeds, following different sampling schemes according  
19 to the functional group of dispersal vector. We used this grouping of frugivores  
20 giving the difficulties of resolving the identification of scats, pellets and regurgi-  
21 tated seeds down to species level just based on visual cues. We differentiated four  
22 major frugivore types: large carnivorous mammals (such as foxes, badgers, and  
23 stone martens); two species of medium- and large-sized frugivorous birds, mistle  
24 thrushes (*T. viscivorus*), and carrion crows (*C. corone*); and a pool of small-sized  
25 frugivorous birds, including warblers, redstarts, and robins (Jordano *et al.*, 2007).

26 Seeds were collected in 1997–1999 and 2003–2005. The sampling schemes are  
27 described in detail elsewhere (Jordano *et al.*, 2007; Garcia *et al.*, 2009) and include  
28 a combination of seed traps and direct sampling of mammal feces along fixed  
29 transects. We haphazardly collected 130 samples of mammal feces during the  
30 *P. mahaleb* fruit ripening period and recorded their location relative to potential

31 source trees. Overall, we genotyped 167 seeds from 20 fecal samples. Most samples  
32 were from red fox (*Vulpes vulpes*) and stone marten (*Martes foina*); some ( 10  
33 samples) were from badger (*Meles meles*) (Jordano *et al.*, 2007).

34 In addition we sampled directly the pellets of large corvids (*Corvus corone*) and  
35 from *Turdus viscivorus*, the latter by direct sampling beneath pine trees and scats  
36 from seed traps (see Jordano *et al.*, 2007, for details). Finally, a seed sample di-  
37 rectly from seed traps included seeds dispersed by small- and medium-sized passer-  
38 ines, such as *Phoenicurus ochruros*, *Turdus merula*, *Erithacus rubecula*, *Sylvia com-*  
39 *munis*, *Sylvia atricapilla*, etc. (Jordano *et al.*, 2007). The total seed sample thus  
40 consisted of seed endocarps collected from the seed traps (mostly small passerines)  
41 ( $n=465$ ), mammal scats ( $n=167$ ), and *C. corone* pellets ( $n=23$ ) (see Table 1 in  
42 Jordano *et al.*, 2007).

43 **Seed genotyping.** We used material described in Jordano *et al.* (2007), and  
44 genotyping methods described in detail in previous work (Godoy & Jordano, 2001;  
45 Garcia *et al.*, 2007, 2009). Briefly, we used a set of 10 polymorphic microsatellite  
46 markers (simple DNA sequence repeats) (Godoy & Jordano, 2001) to obtain the  
47 multilocus genotypes of both of the adult trees (candidate source trees from the  
48 study population) and the sample of seed endocarps. Given that all adult trees  
49 in the population had a distinct multilocus genotype, an unambiguous assignment  
50 of each seed to its source tree could be made. When a full match between the  
51 endocarp genotype and any of the adult-tree genotypes in the population was not  
52 possible, we assumed that the seed came from another population. To assess the  
53 effect of genotyping errors, we reexamined the exclusion of genotypes due to a single  
54 locus mismatch, two loci mismatches, etc. At the analysis level, any exclusion of  
55 identity between a seed and a potential mother tree based on mismatches of only  
56 one or two loci was rechecked. We used GIMLET software (Valière, 2002) to find  
57 the matching adult multilocus genotype for each endocarp with eight or more  
58 loci successfully typed. Because each seed belonged to one of the four groups of  
59 dispersers, we could thus derive the relative contribution of each frugivore group  
60 to different classes of seed dispersal events and to seed immigration.

61 **Contribution of dispersal vectors to types of dispersal events.** We con-  
62 sidered each dispersed seed as an independent replicate, because each represented  
63 a dispersal event from the perspective of plant population genetics, i.e., an in-  
64 dependent "arrival" event resulting from the dispersal process mediated by the  
65 frugivore.

66 Once the maternal source tree of each individual seed was identified (or its prove-  
67 nance from outside the study population determined) we assessed the dispersal  
68 distance and grouped the seeds separately as coming from trees located within  
69 or outside the population. In addition, for seeds originating from local trees we  
70 determined whether dispersal distances were  $\geq 45$  m to sort out  $LDD_{loc}$  dispersal  
71 events from  $SDD_{loc}$  events. All the events involving immigrant seeds were con-  
72 sidered  $LDD_{ss}$  by definition, given that the neighborhood size was very reduced  
73 (radius= 0.045 km) relative to the geographic limits of the study population (max-  
74 imum length for a within-population dispersal event: 1220 m)(Garcia *et al.*, 2009).  
75 Along this reasoning,  $LDD_{neigh}$  events were considered non-existent in this partic-  
76 ular case study given that neighborhood size area was smaller than the population  
77 area.

Table S1. Summary of neighborhood area sizes and estimated neighborhood radius for tree species with different combinations of dispersal modes. Data from Nason *et al.* (1998); Smouse *et al.* (2001); Garcia *et al.* (2005, 2007); Dutech *et al.* (2005) and present study.

Species	Pollinator	Seed disperser	Density ( $ha^{-1}$ )	Breeding unit ( $km^2$ )	Radius (km)
<i>Ficus dugandii</i>	Fig wasp	Vertebrates	0.004	631.7	14.2
<i>Ficus obtusifolia</i>	Fig wasp	Vertebrates	0.072	105.9	5.8
<i>Prunus mahaleb</i>	Bees, flies	Vertebrates	0.003	0.87	0.042
<i>Frangula alnus</i>	Bees, flies	Vertebrates	0.0004	0.45	0.013
<i>Astrocaryum mexicanum</i>	Beetle	Vertebrates	1364.0	0.011	0.06
<i>Calophyllum longifolium</i>	Bees	Vertebrates	0.28	1.241	0.629
<i>Platypodium elegans</i>	Bees	Wind	0.78	0.866	0.525
<i>Quercus lobata</i>	Wind	Vertebrates	3.0	0.072	0.719
<i>Quercus alba</i>	Wind	Vertebrates	92.8	0.0009	0.017
<i>Cedrus atlantica</i>	Wind	Wind	61.7	0.151	0.22
<i>Fraxinus americana</i>	Wind	Wind	24.7	0.008	0.05
<i>Pseudotsuga menziesii</i>	Wind	Wind	25.0	0.078	0.158

## References

- Dutech, C., Sork, V.L., Irwin, A.J., Smouse, P.E. & Davis, F.W. (2005) Gene flow and fine-scale genetic structure in a wind-pollinated tree species *Quercus lobata* (Fagaceae). *American Journal of Botany*, **92**, 252–261.
- Garcia, C., Arroyo, J., Godoy, J. & Jordano, P. (2005) Mating patterns, pollen dispersal, and the ecological maternal neighbourhood in a *Prunus mahaleb* L. population. *Molecular Ecology*, **14**, 1821–1830, doi:10.1111/j.1365-294X.2005.02542.x.
- Garcia, C., Jordano, P. & Godoy, J.A. (2007) Contemporary pollen and seed dispersal in a *Prunus mahaleb* population: patterns in distance and direction. *Molecular Ecology*, **16**, 1947–1955, doi:10.1111/j.1365-294X.2006.03126.x.
- Garcia, C., Jordano, P., Arroyo, J.M. & Godoy, J.A. (2009) Maternal genetic correlations in the seed rain: effects of frugivore activity in heterogeneous landscapes. *Journal of Ecology*, **97**(6), 1424–1435, doi:10.1111/j.1365-2745.2009.01577.x.
- Godoy, J.A. & Jordano, P. (2001) Seed dispersal by animals: exact identification of source trees with endocarp DNA microsatellites. *Molecular Ecology*, **10**(9), 2275–2283.
- Jordano, P., García, C., Godoy, J.A. & García-Castaño, J.L. (2007) Differential contribution of frugivores to complex seed dispersal patterns. *Proceedings Of The National Academy Of Sciences Of The United States Of America*, **104**(9), 3278–3282, doi:10.1073/pnas.0606793104.
- Jordano, P. & Schupp, E.W. (2000) Seed disperser effectiveness: the quantity component and patterns of seed rain for *Prunus mahaleb*. *Ecological Monographs*, **70**(4), 591–615, doi:10.2307/2657187?ref=no-x-route:1d70d282eb4ed20cce6eac7274a631bb.
- Nason, J.D., Herre, E. & Hamrick, J.L. (1998) The breeding structure of a tropical keystone plant resource. *Nature*, **391**, 685–687.

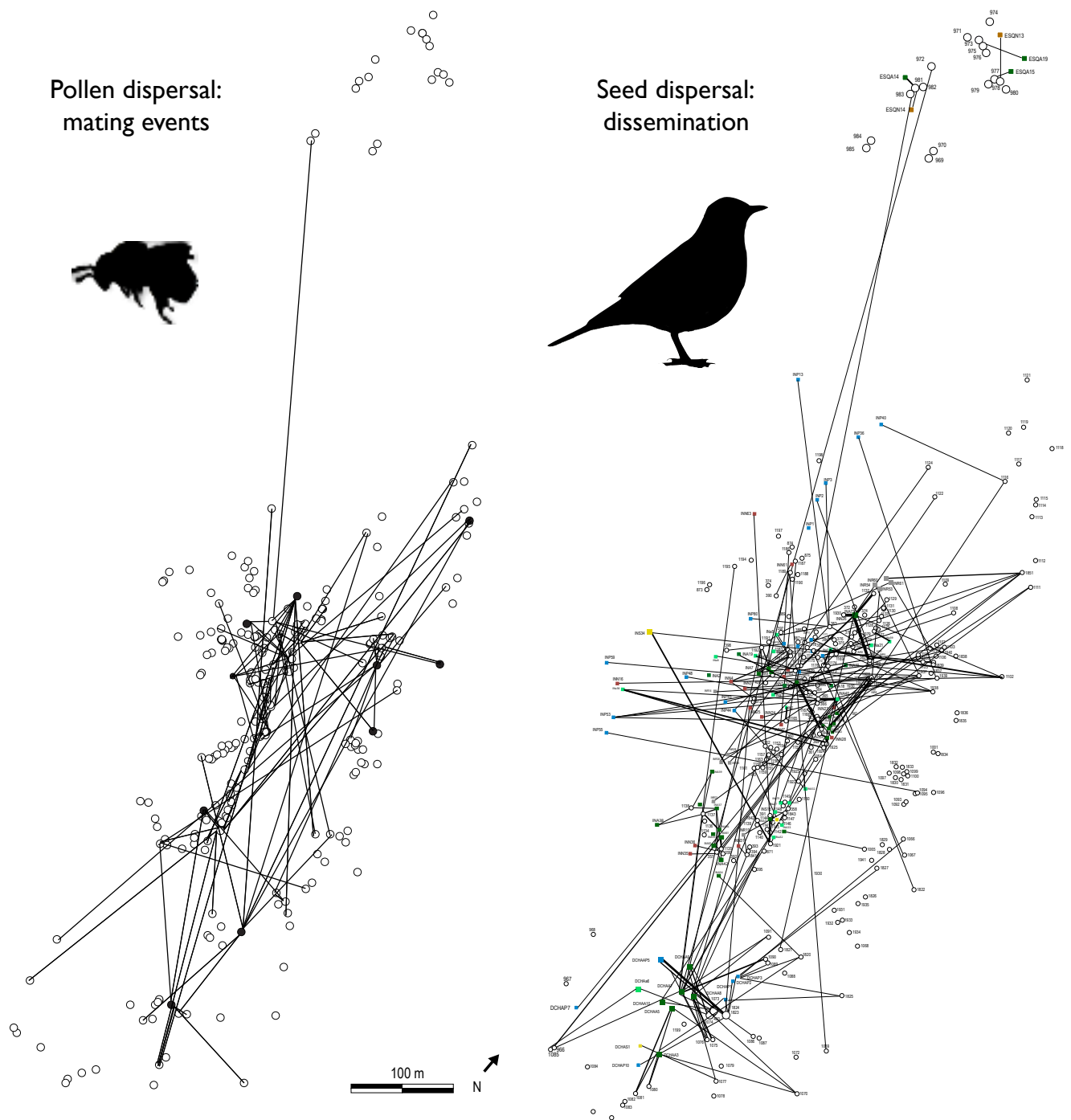


Figure S1. Dispersal events for pollen (left) and seeds (right) traced for *Prunus mahaleb* trees (white dots). All the adult, reproductive, trees in the population are mapped. Lines indicate mating events of pollen dispersal among trees (left) or seed dissemination events from source fruiting trees to seed traps (squares; right). Line thickness is proportional to the number of events recorded.

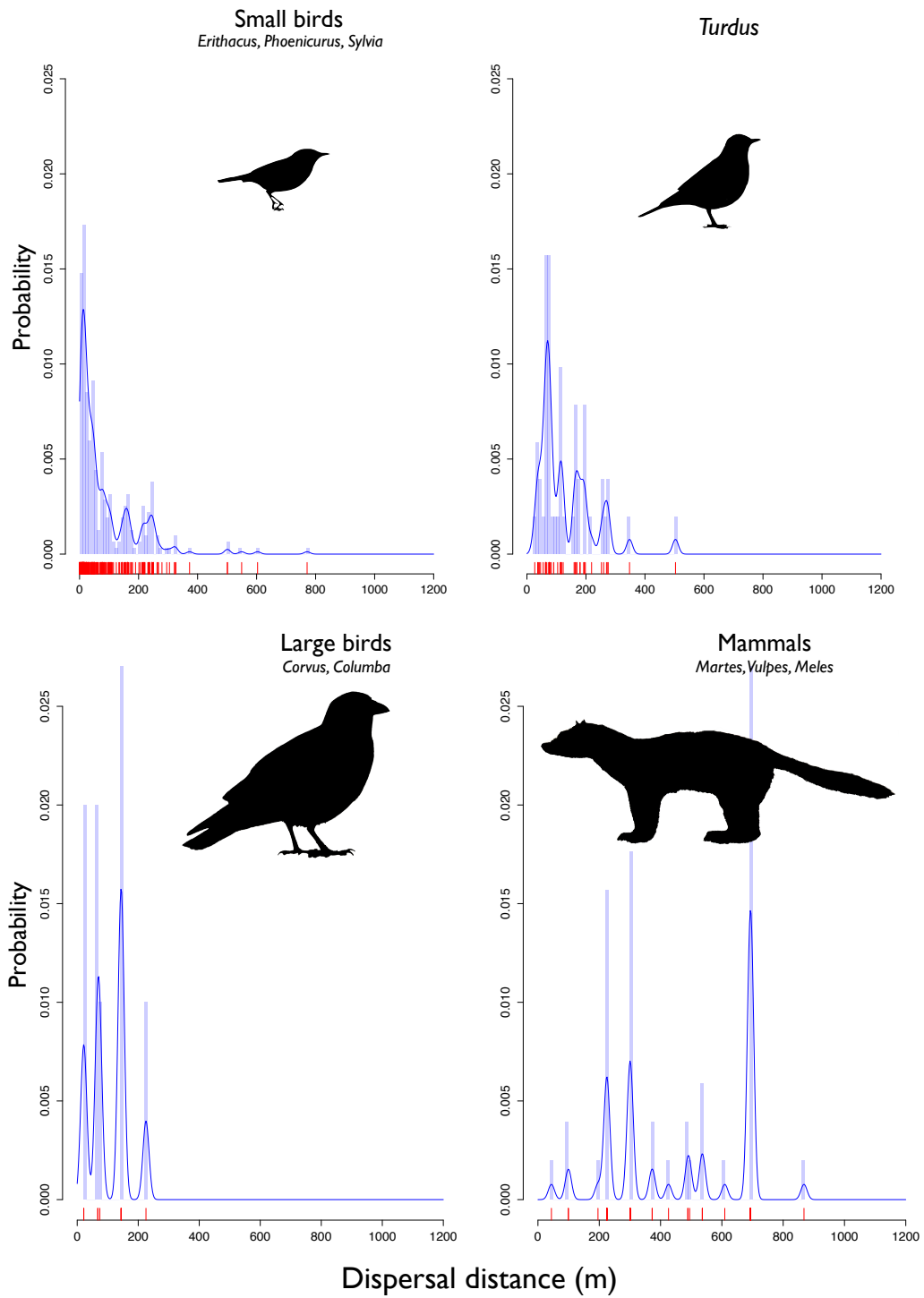


Figure S2. Differential contributions of functional groups of frugivores to the short- ( $SDD_{loc}$ ) and long-distance ( $LDD_{loc}$ ) local seed dispersal events for *Prunus mahaleb*.



- Smouse, P.E., Dyer, R.J., Westfall, R.D. & Sork, V.L. (2001) Two-generation analysis of pollen flow across a landscape. I. Male gamete heterogeneity among females. *Evolution*, **55**(2), 260–271.
- Valière, N. (2002) GIMLET: a computer program for analysing genetic individual identification data. *Molecular Ecology Notes*, **2**, 377–379, doi:10.1046/j.1471-8286.2002.00228.x.