Do the environment and human interference influence long-distance seed dispersal of *Taraxacum officinale*?

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Abstract

Dispersal, especially long-distance seed dispersal (LDD) is important for determining ecological and evolutionary aspects of populations as well as the survival strategies of them. The morphological trait of *Taraxacum officinale*, the pappus, enhances dispersal by wind and long-distance dispersal. Humans have also the potential for long-distance dispersal of seeds, but there is limited research on testing clothing as a vector. Therefore, this study aims to evaluate whether the spread of *T. officinale* is influenced by the environment and human interference with regard to long-distance dispersal. Seed dispersal of *T. officinale* was tested by wind and by humans in two different environment types. Open habitats like a meadow provide perfect conditions for LDD due to the lack of obstacles compared to more closed landscapes like forests. The number of seeds reaching a threshold of two meters were recorded for each vector. The results clearly show that the environment does not influence the spread of *T. officinale*. However, humans can cause more often LDD events of *T. officinale* then wind. Human-mediated dispersal is often associated with the invasion of alien species or weeds like dandelions, therefore it is important to understand and manage these vectors.

1 Introduction

According to Levin et al. (2003); Bullock et al. (2002), dispersal is defined as the unidirectional movement of organisms away from its place of birth where they might establish and reproduce. As a life-history trait, it influences not only ecological aspects like the dynamics of populations, abundance of species or community structure but also evolutionary aspects like the level of gene flow between populations, adaptation and speciation (Dieckmann 1999). Different kinds of selective pressures emerging from interactions between the individuals and their environment are responsible for the evolution of dispersal. Individuals try to avoid competition with relatives as well as the negative consequences of interbreeding with them. Furthermore, the colonization of unoccupied habitat patches helps them to avoid dangers like e.g. predators or pathogens. On the other hand, there are not only benefits of dispersal. There is an increased risk of mortality during dispersal and the individuals often have to make huge efforts to improve their dispersal structures (Dieckmann 1999; Soons und Ozinga 2005).

Plants are mostly dispersed as seeds, typically vector-mediated (Levin et al. 2003; Nathan et al. 2008). There is a wide variety of how plant seeds can be dispersed. For example, animals like insects or birds can act as a vector, or the elements like wind or water can help the seeds to establish new habitats. Even humans are involved in the dispersion process, however, mostly unintentionally (Bullock et al. 2002). In this study we want to focus on the spread of *Taraxacum officinale* (dandelion) seeds by wind and by humans.

How far seeds can be dispersed by wind is determined by plant and seed traits as well as environmental conditions. The trajectory distance is primary influenced by upward or downward currents in the air. With increasing wind velocity the trajectory distance will also increase, while it is simultaneously negatively affected by humidity and surface heating (Sheldon und Burrows 1973; Soons et al. 2004a). However, there is a difference in wind dispersal in open habitats compared to forests. Wind speed and updrafts in forests are less important in determining the dispersal distance (Tackenberg et al. 2003). Moreover, the dispersal potential and distance are influenced by seed release height and vegetation height (Soons et al. 2004a).

Humans can directly disperse seeds through their clothes or through human associated vectors, including all means of human transport, pets and livestock, equipment or food (Wichmann et al. 2009). Human-mediated dispersal exists since the beginning of mankind but is increasingly present nowadays because of higher mobility and modern lifestyles (Hodkinson und Thompson 1997). Especially hikers can disperse seeds over long distances, about 13 km in average. If these people travel by car, train or plane afterwards, the seeds are transported even further away. Factors determining the distance of seed dispersal by humans are the type and material of clothing, but also plant characteristics like the number and location of the seeds and their attachment structures (Ansong und Pickering 2014).

The model species for this study is *T. officinale* (dandelion), a perennial herb species particularly found on grasslands and typically dispersed by wind. The seeds of the plant are equipped with a pappus, which serves as a parachute and therefore causes a rather low falling velocity (Tackenberg et al. 2003). The inflorescence of the dandelion is composed of up to 250 yellow florets (Holm et al. 1997). When the seeds are mature, the stem grows to reach a maximum height of about 75 cm for an effective dispersal of the seeds (Richardson 1985). According to Sheldon and Burrows (1973) the seeds can be dispersed over max. 0.76 , 1.52 and 2.27 metres with wind speeds of 5.47, 10.94 and 16.41 km h^{-1} respectively. Thanks to its phenotypic variability, *T. officinale* is well adapted to pastures, hay fields, roadsides and other disturbed vegetations (Holm et al. 1997; Stewart-Wade et al. 2002).

This study aims to evaluate whether the spread of *T. officinale* is influenced by the environment and human interference with regard to long-distance dispersal (LDD). Although dandelions are perfectly adapted to wind dispersal, thanks to their pappus, the predicted dispersal distance is less than 2.15 m (Soons und Ozinga 2005). However, *T. officinale* is a species with traits that enhance long-distance seed dispersal. They usually disperse the majority of their seeds over a longer distance compared to other species, with small amounts of seeds even spread over large distances (Soons et al. 2004b). These few events are considered as LDD and are important for the survival strategy of such plants. LDD helps not only to increase the frequency and speed of colonization of empty habitat patches but also increases gene flow between occupied patches and results in a reduced probability of extinction (Soons und Ozinga 2005). Although humans have the potential for LDD of seeds there is limited research on testing clothing as a vector (Mount und Pickering 2009). According to Nathan et al. (2008) there might be a difference between open habitats and forests for LDD events. Open habitats like meadows provide perfect conditions for LDD due to the lack of obstacles which hamper the movement of seeds and their vectors, compared to more closed landscapes like forests.

2 Methods

2.1 Experiment design

The data sampling for the study was conducted in the park area of the health clinic in Bad Buchau on 14th of July, 2018. The relevant ecosystem is therefore a mown meadow. Seeds of *T. officinales* were already collected. Both wind and human dispersal of these seeds were tested in two different environments, in open space and in the vicinity of trees (Figure 1). For each environment type there were 15 randomly chosen plots. In addition, three repetitions per vector (wind or human) were done at each plot. A bamboo stick marked the starting point of the walk (for testing dispersal by humans) which was also the seed releasing point. For both vector types, a threshold of two meters was set up, based on a further project where the mean dispersal distance of *T. officinale* seeds by wind was about two meters. The seeds for testing wind dispersal were released at the height of about 75 cm (marked at the bamboo stick) because this is the maximum height for an effective dispersal of their seeds (Richardson 1985). Per repetition, one person attached five seeds to their trousers and walked two meters, while the other person released five seeds into the wind at the same time. After each repetition the number of seeds reaching the 2-meter distance was recorded. Each person conducted the walking part for 15 plots and the releasing part for the other 15 plots. In total 180 observations were made and an overall amount of 900 seeds were released.

Figure 1: Project methodology in the different environment types. Picture left: near trees, picture right: open space

2.2 Statistical methods

All of the statistical analysis was done using the statistical software R (R Core Team 2017).

The collected data include information about:

Type = type of the plot (open space, near trees)
Vector = the vector of seed dispersal (wind, human)
Start = number of seeds at beginning (always five)
End = number of seeds that reached two meters by dispersal
Person = the person who carried/released seeds in a single repetition
Plot = the plot of the study

A matrix of the dispersal rate (“*dis_rate”*) was calculated as follows:

dis_rate = (*success, fail*)
success (seeds that successfully reached two meters) = *End*
fail (seeds that failed to reach two meters) = *Start* - *End*

A generalized linear mixed-effects model was used, using the package “lme4” (Bates et al. 2015) with the *dis_rate* as response variable. The fixed effect explanatory variables are *Vector*, *Type*, and the interaction of both. In addition, there is a random effect of *Person* and of *Plot* nested within *Person* (*1|person/plot*) on the intercept.

$$dis\_rate = a+b1*Vector+b2*Type+b3*Vector*Type+\rho+\epsilon \qquad \text{(I)}$$

p = random effect as (1|person/plot)
ϵ = error distribution

The “blmeco” function (Korner-Nievergelt et al. 2015) was then used to test the full model for overdispersion. With the “dredge” function of the package “MuMIn” (Barton 2018) the full model was simplified to test which model describes the data best. This selection was based on the Akaike Information Criterion value (AIC).

3 Results

3.1 The full model

The full model (I), as stated in the statistical methods, considers the effects from vector (*Vector*) and environment type (*Type*) as well as the interaction of both. R-squared test shows that the fixed effects can explain 12.4% of the variance in the response variable, while both fixed and random effects can explain 28.5% of that. Figure 2 demonstrates the original data distribution and the prediction by the full model. The proportion of seeds reaching the two meters distance was lower in dispersal by wind compared to the spread by humans.

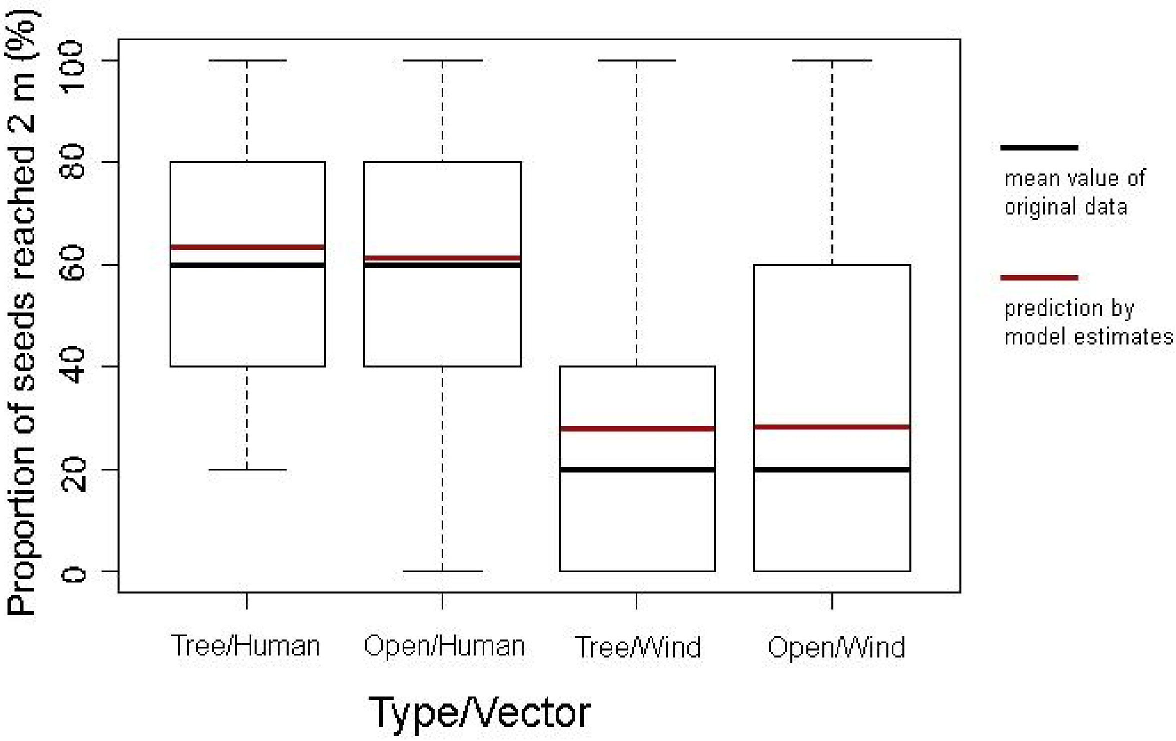

Figure 2: Proportion of seeds reached two meters by different vectors in different environments. Predictions are made by full model.

3.2 The best model

The results of model selection with the "dredge" function are shown in Table 1. The model having only *Vector* as an explanatory variable was selected as the best model, because of the lowest AIC value:

dis_rate = a+b1*Vector +ρ+ϵ (II)
p = random effect as (1|person/plot)
ϵ = error distribution

Table 1: Model selection results ranked by AIC. The first one is the best model.

Model	df	AIC	delta	weight
Vector	4	579.9	0.00	0.552
Type+Vector	5	581.9	2.00	0.203
Null model	3	582.9	2.97	0.125
Type+Vector+Type:Vector(Full model)	6	584.0	4.03	0.074
Type	4	584.9	4.92	0.047

The model with *Type* and *Vector* as explanatory variables describes the data as second-best, whereas the full model and the model including only *Type* have the highest AIC value and therefore describe the data worst. Analysing the best model including vector as explanatory variable and the random effects results in a significant influence of *Vector* on the proportion of successfully dispersed seeds ($\chi^2_{1,3}$ = 5.065, $p<0.05$). Figure 3 shows the predictions made by the best model as well as the original data distribution sorted by vectors. Humans are much more effective in dispersing *T. officinale* seeds two meters compared to wind. The estimated proportion of seeds reaching the 2-meter distance by humans is 63 %, whereas only 27 % of seeds dispersed by wind will reach the threshold.

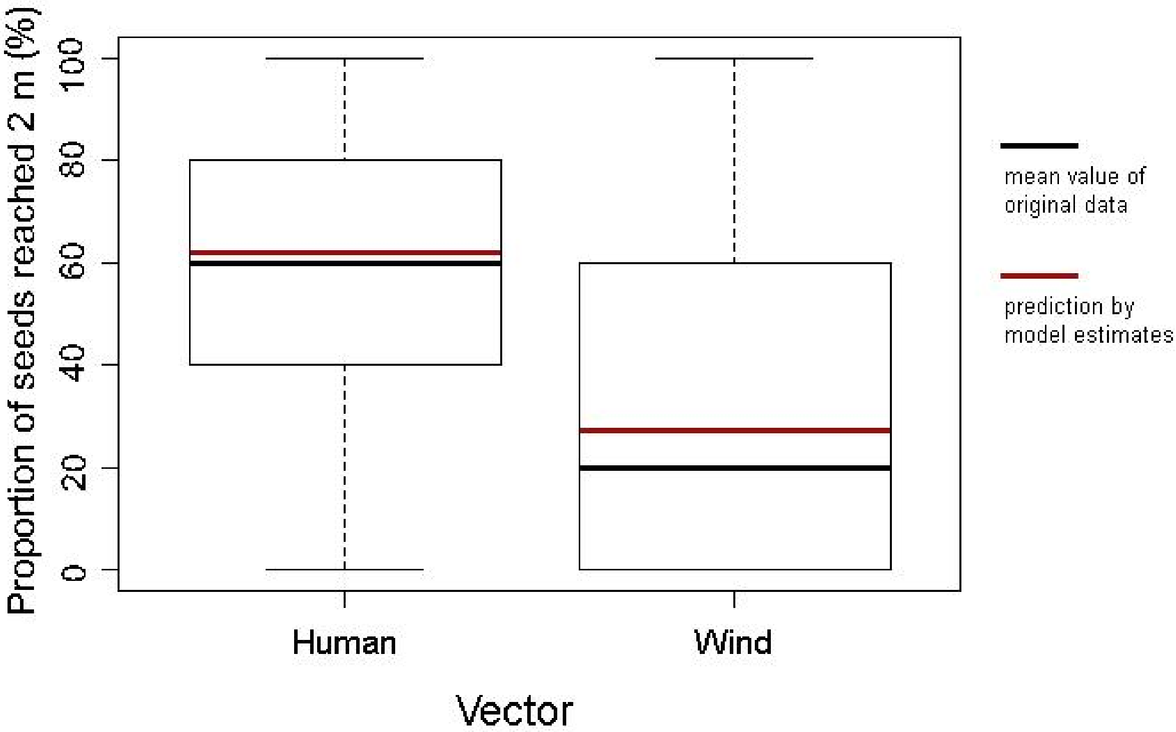

Figure 3: Proportion of seeds reached two meters by different vectors.
Predictions are made by best model.

4 Discussion

With regard to our experiment, human interference showed a significant effect on the spread of *Taraxacum officinale*, while environment changes showed little influence. The experiment simulated only the first step in the dispersal process of a seed. This could be repeated several times in the whole dispersal process, which means that a seed could be carried by wind or human for a distance several times before it reaches the final destination where it starts to germinate.

4.1 Environmental influence

Open space and near trees on the same type of mown meadow are considered as the environmental change in our experiment. During the experiment we noticed that the wind speed might be different in each plot, but it seems to be independent of whether there are trees nearby or not. The trees also failed to stop the seeds from dispersal. The seeds always found a way out: either went through a gap or dispersed in the opposite direction. Therefore, we can´t agree with Nathan et al. (2008); Schurr et al. (2005) that open landscapes provide favourable conditions for LDD as well as seeds dispersed by wind also have higher LDD there. The conclusion could be drawn that the dispersal of *T. officinale* seeds was hardly influenced by this kind of environmental change. But further studies are required to find out if other kinds of environmental changes could influence the dispersal of dandelions.

4.2 Human interference

In our experiment, human interference showed high efficiency in spreading *T. officinale*, even larger than its natural vector wind. Over 63 % of the seeds will be dispersed more than two meters by human. Therefore, a reasonable hypothesis could be made that human interference plays an important role in the spread of *T. officinale* in long-distance. In studies modelling the dispersal distances of seeds from different types of clothing, nearly all seeds have fallen off within the first few meters, with values ranging from 55 % to 100 % from trousers (Bullock und Primack 1977; Pickering et al. 2011). However, some seeds can be carried even further, attached to trouser material about 2.4 km, but this varies among species and the type of clothing. Another study of Wichmann et al. (2009) found that *Brassica* could be dispersed 50 times further by humans than the maximum value calculated for their primary vector wind. Nevertheless, a lot of facts determine the seed dispersal by humans. Where the seeds become attached, on internal or external surfaces of clothing, also determines how far the seeds may be transported (Scott 2009). In addition, seeds with adhesive structures like hairs or hooks are also more likely to be dispersed further away because of higher attachment rates compared to seeds without such structures (Mount und Pickering 2009; Pickering et al. 2011).

4.3 Random effects

The random effects of plot and person explained quite a large proportion of variance in the response variable (28.5-12.4=16.1%), even larger than the fixed effects. The difference in trousers material and walking style might be influencing the results. This should be considered in a possible further study.

4.4 Conclusion

In summary, it can be concluded that the vector is influencing the dispersal of dandelions, while the environment has no effect. The proportion of seeds reaching the threshold is higher in human dispersal than in wind dispersal. When there is a lot of upward current in the air, the seeds will also be dispersed more than two meters. Combining our findings to other studies, it can be assumed that when the seeds are dispersed even further than their predicted dispersal distance, this can be interpreted as long distance dispersal events of dandelion seeds. Here human interference is playing an important role. Especially human-mediated dispersal is often associated with biological invasions and the spread of weeds (Ansong und Pickering 2014). Dandelion is a problematic weed throughout the Northern United States, which is reducing the corn yields there (Wilson und Michiels 2003). In addition, *T. officinale* is host for many plant pests and viruses (Stewart-Wade et al. 2002). Therefore, it is important to understand and manage different dispersal vectors to avoid the spread of such undesired plants. Humans can reduce the risk of spreading seeds like weed species by washing clothing, cleaning footwear or just by carefully looking at their clothing.

5 References

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