Oikos

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Hanoteaux, S., Tielbörger, K. and Seifan, M. 2013. Effects of spatial patterns on the pollination success of a less attractive species. – Oikos 122: 867–880.

Appendix A1

Model parameters

Values used for the model parameters in the simulations. If more than one value is given, combinations of these values were tested, as described in the Simulation experiment section.

A_i: attractiveness of species i, $A_i \in \{0.1, 0.9\}$(Appendix A3)

P_R: probability for a plant individual to contain reward (0.5, 1)

μ_{Seed}: mean of the normal distribution for the number of produced seeds (40)

δ_{Seed}: standard deviation of the normal distribution for the number of produced seeds (2.5)

d_{disp}: standard deviation of the normal distribution used for the dispersal of seeds (2.5, 5, 10)

P_{Empty}: probability of an establishment site to be unsuitable (0.05)

P_{Death}: probability of death before seed set (0.05)

D: percentage of attractive individuals at the beginning of the simulation (10, 50, 90)

R_{FOV}: radius of the field of view of the pollinators (also used in the calculation of the rescaled attractiveness) (2, 5, 10)

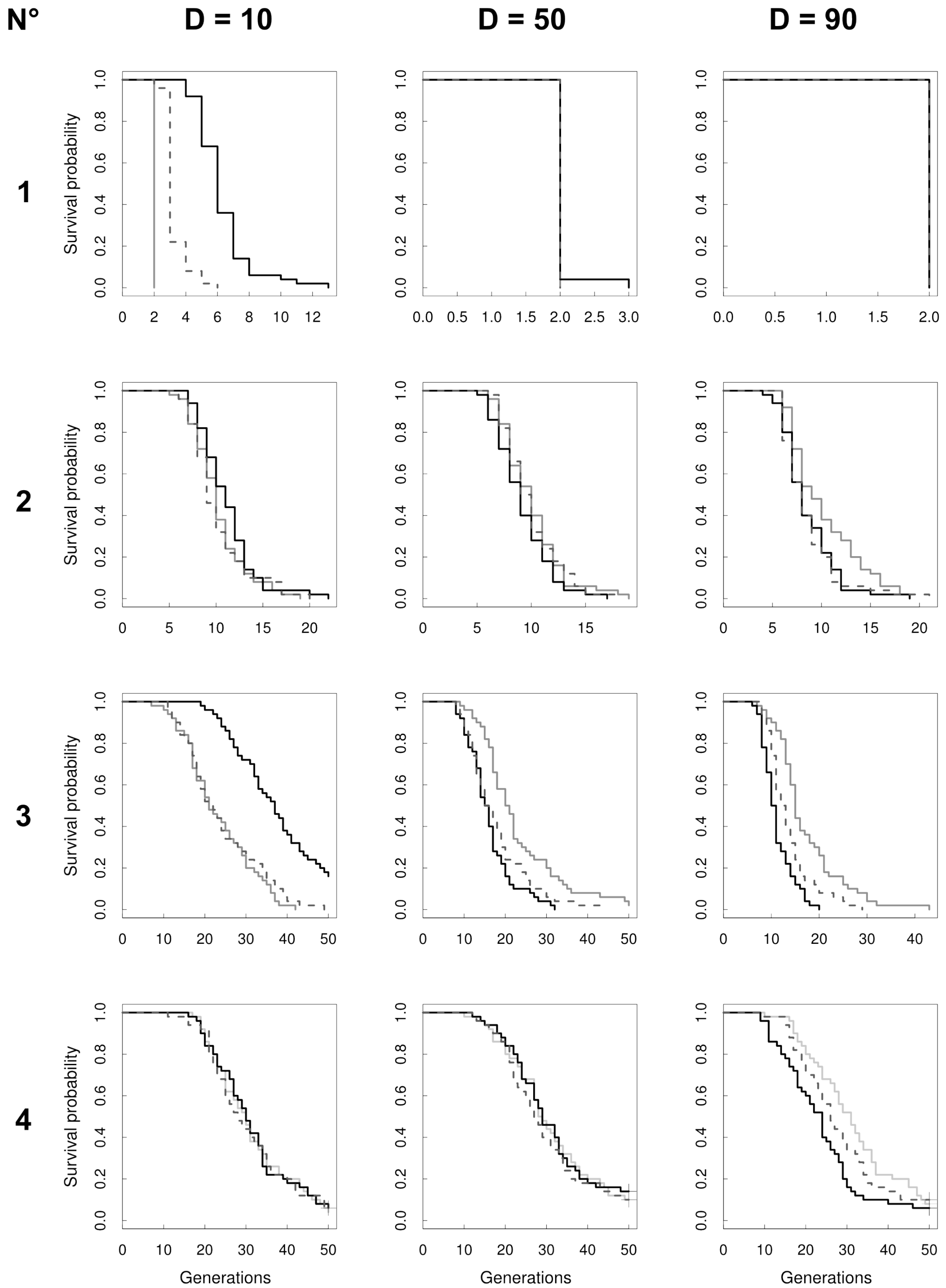
n: number of pollinators in the population (25, 50, 100)

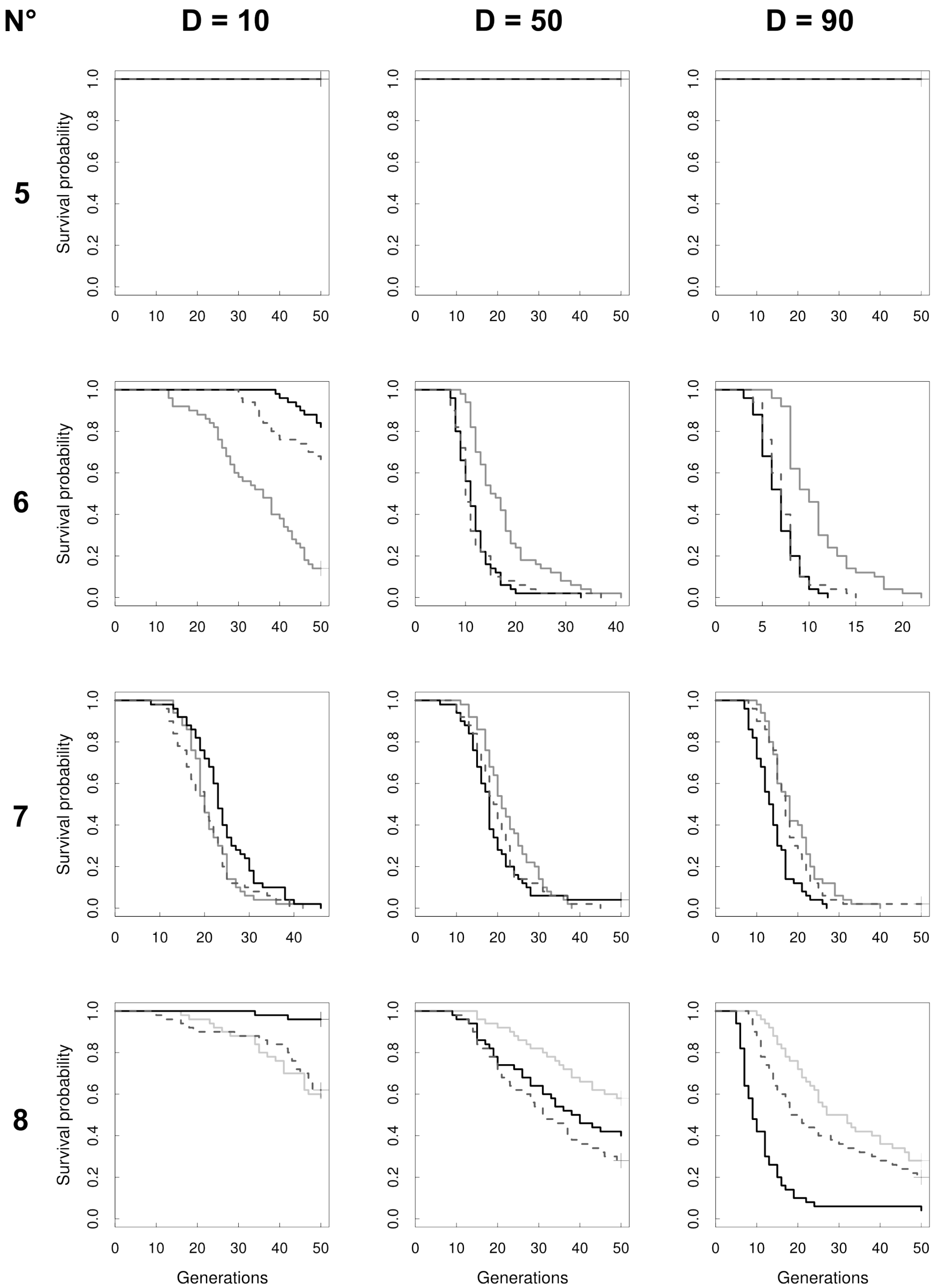
P_{Shift}: constancy parameter (0, 0.50, 1)

T: threshold value in the first pollinator movement rule (0.05)

Appendix A2

Graphical results of the survival analysis




N°
D = 10
D = 50
D = 90
5
6
7
8
Survival probability
Generations

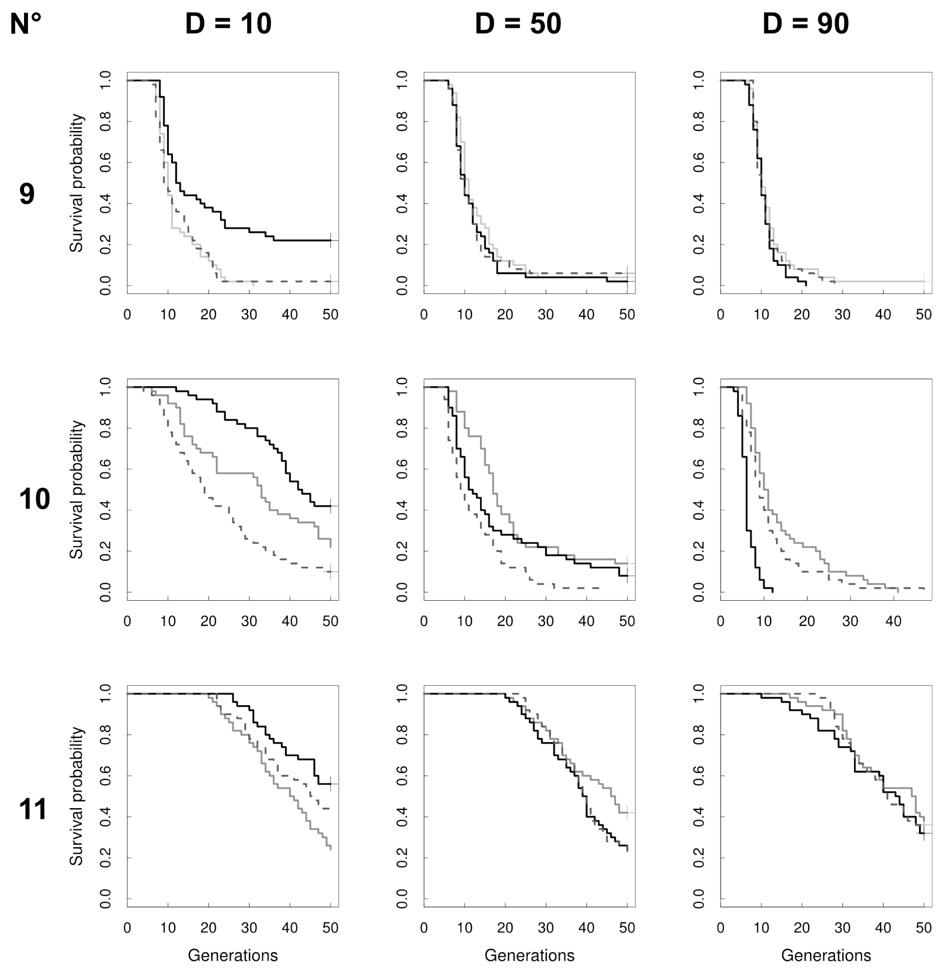


Figure A1. Kaplan–Meyer estimates of the survival curves (probability of survival in time) for the less attractive species for all the tested set of parameters. The numbers of simulations correspond to the number given in Table 2 for each set of parameters. Continuous black lines depict the survival curves for the S10 (strong monospecific aggregation) patterns, dashed grey lines for the S5 (intermediate monospecific aggregation) pattern and light grey lines for the S1 (weak monospecific aggregation) pattern. Results of the survival analysis are given in Table 3.

Appendix A3

Choice of the attractiveness values

The instantaneous pollinator preference G, as described in Eq. 2 (main text) motivated the choice of the parameter values for the attractiveness (A) of the plant species. Our aim was to enable pollinators to search and finally select a plant individual using their detection range (FOV), while taking into account two factors: 1) individuals belonging to the preferred species (i.e. the species which is more attractive according to the pollinator's experience) should always be chosen over the less preferred individuals; 2) closer plants are more likely to be selected than distant ones (due to energetic considerations), for plants having the same instantaneous pollinator preference. In the most extreme case of having only one preferred flower located at the corner cell of a pollinator's FOV (longest possible distance within its FOV) and the rest of the FOV occupied with less preferred individuals, this preferred flower should be chosen. In order to satisfy this rule, the instantaneous score S of the preferred flower in the corner must be higher than the score of an adjacent less preferred flower. To calculate this, we compared the instantaneous score S of a less attractive plant individual close by (i.e. adjacent cell) for the pollinators with that of the more preferred plant species at the corner of the pollinator's field of view, using the rule described in Eq. 3:

$$S_{NP}^{d=1} < S_{P}^{d=\left(R_{FOV}.\sqrt{2}\right)} \tag{3}$$

where $S_{NP}^{d=1}$ is the score for a less preferred flower at distance = 1 cell , and $S_{P}^{d=\left(R_{FOV}.\sqrt{2}\right)}$ is the score of a preferred flower at the corner cell of the pollinator's FOV (i.e. greatest distance possible in the FOV). Using Eq. 2, inequality 3 can be rewritten as:

$$G_{NP} < G_{P} + \frac{1}{R_{FOV}.\sqrt{2}} - \frac{1}{2} \tag{4}$$

where G_{NP} and G_{P} are the instantaneous preference value for a less preferred and a preferred flower, respectively. Assigning the value of 0.9 for G_{P}, critical values for G_{NP} can be computed. These values are given in Table 5. In order to make sure that a pollinator would move to the preferred flower even if this is located in the corner cell of its FOV, the instantaneous preference value of a less preferred flower should be smaller than 0.47. To ensure these differences, we chose the value of 0.1 for the instantaneous preference of a less preferred flower. Hence, the attractiveness value of the less attractive species was also equal to 0.1.

R_{FOV}	$G_{NP} <$	$S_{NP}^{d=1}$	$s_P^{d=\left(R_{FOV}.\sqrt{2}\right)}$
2	0.66	0.6	1.23
5	0.52	0.6	1.07
10	0.47	0.6	0.99

Table A1. Critical values for instantaneous preference values for the less preferred species ($G_{NP} <$) as well as the values for the score of a less preferred flower at distance 1 ($S_{NP}^{d=1}$) and the score values for preferred flowers at the corner at the FOV of pollinators ($s_P^{d=\left(R_{FOV}.\sqrt{2}\right)}$).

Appendix A4

Reproduction and dispersal of plant individuals

If a plant individual was pollinated, it produced N_{Seed} seeds, N_{Seed} being drawn from a normal distribution with mean μ_{Seed} and standard deviation δ_{Seed}. Seeds produced by plant individuals were then dispersed locally among the grid. The cell to which a certain seed was dispersed was determined by a distance from the mother plant and an angle. The angle was randomly generated out of a uniform distribution while the distance was drawn out of a normal distribution with mean zero and standard deviation d_{disp}. Once seeds were dispersed, the grid occupancy for the next generation was determined. Each cell had a probability $P_{Empty} = 0.05$ to be unsuitable for establishment of plant individuals. If a cell was suitable for plant growth, species k had a probability of $P_k = \frac{N_k}{\sum N}$ (k = 1, 2) to occupy that cell for the next generation, with N_k being the amount of seeds of species k in the cell and N the total amount of seeds in the cell. We also considered mortality: each individual had a probability PDeath of 0.05 to die before seed set.

Appendix A5

Threshold value used in the pollinators' first movement rules

In the first step of the pollinator behaviour, a threshold value T was used. This parameter reflects the 'pickiness' of pollinators when choosing the position from which they will start their foraging bouts. This parameter value was chosen to ensure that the innate pollinator's preference will be taken into consideration while distributing pollinators among grid cells before the actual start of their foraging bouts. When a pollinator is at the edge of a patch composed only by attractive individuals and the patch is of a size equal to the pollinator's FOV, the threshold value determines how far the pollinator will penetrate this patch and on which cell it will land at the beginning of its foraging bout (Fig. A2). We can then calculate the rescaled attractiveness values (see section Pollinator foraging rules, main text) of all the cells in this pollinator's FOV and the differences in rescaled attractiveness values associated with the movement of the pollinator in the indicated direction (Fig. A3), for each of the three FOV sizes tested. Depending on the size of the patch, pollinator can move 3, 6 or 11 cells (for R_{FOV} = 2, 5, 10 respectively) before reaching the centre of the patch.

As can be seen in Fig. A3, pollinators with a R_{FOV} = 2 will land in the middle of the patch (i.e. after moving three times). For pollinators having a larger FOV, the threshold will be reached after moving 5 or 4 cells into the patch, for R_{FOV} = 5 and 10, respectively. Hence, we can assume that this threshold value is appropriate as it will guide pollinators to land on flowers deep within patches of attractive individuals. This implies that our model involved a conservative behavioural rule which reflects the innate preferences of pollinators.

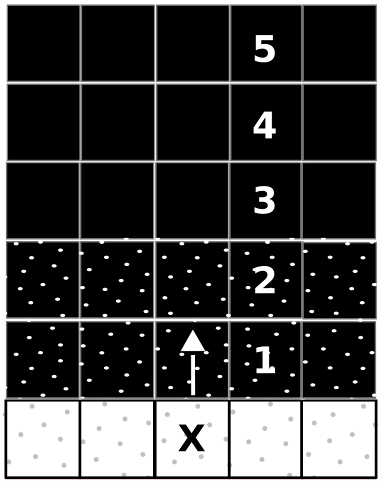


Figure A2. Pollinator at position X (on less attractive flower, white cells) facing a patch of attractive individuals (black cells). Dotted areas represent the portion of the field within the pollinator's FOV (for a $R_{FOV} = 2$; only part of the FOV is depicted). The arrow indicates the direction of the pollinator's movement.

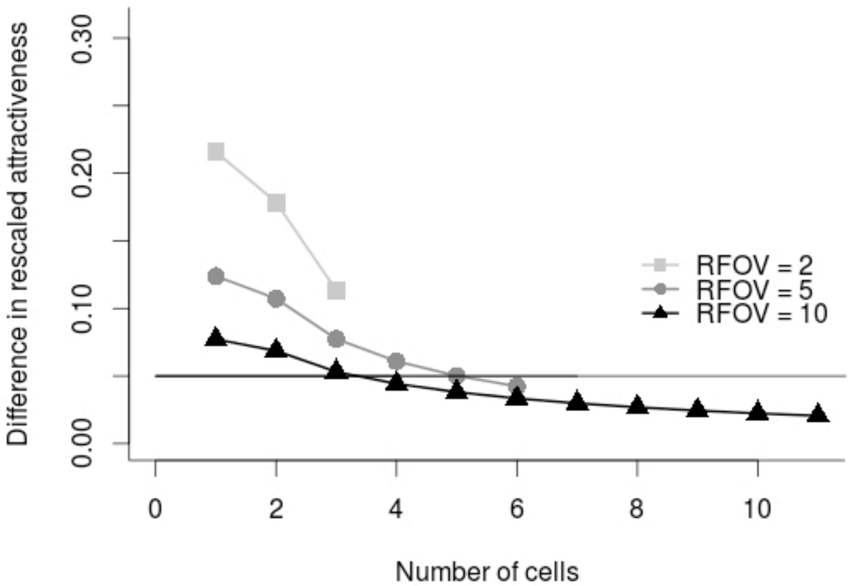


Figure A3. Differences of rescaled attractiveness for a pollinator facing a patch of attractive species (as depicted in Fig. A2) as a function of the pollinator's movement distance (in number of cells), from the edge of the attractive flower patch (position X in Fig. A2). The line at 0.05 indicates the threshold value (T) used in the model. Pollinators will land on the first cell for which this value falls below the 0.05 line.

Appendix A6

Species final abundance as a function of reward variation and pollinator population sizes.

		D = 10				D = 50				D = 90			
P_R	Species	Reg	S1	S5	S10	Reg	S1	S5	S10	Reg	S1	S5	S10
0.5	A	5081	5085	5071	4647	5016	5039	4991	5095	5111	5083	5123	5131
0.5	NA	2	3	2	199	83	41	4	0	4	3	0	0
1	A	2068	2048	1960	2019	2009	2011	2004	1999	2006	1976	2022	1994
1	NA	1157	1199	1197	1191	1191	1204	1199	1187	1190	1204	1189	1191

Table A2. Mean population sizes at generation 50 for the attractive (A) and the less attractive (NA) species in relation to starting densities of attractive plant individuals (D = 10: low density of the attractive species and high density of the less attractive one; D = 50: similar densities of the two plant species; D = 90: high density of the attractive species and low density of the less attractive one) and to reward variation (P_R = 0.5 or P_R = 1; with or without variation). Mean population sizes are rounded and given in numbers of cells. Remaining parameter values were P_{Shift} = 1, R_{FOV} = 5, d_{disp} = 5 and n = 50.

		D = 10				D = 50				D= 90			
n	Species	Reg	S1	S5	S10	Reg	S1	S5	S10	Reg	S1	S5	S10
25	A	2117	2012	2213	1480	2075	2065	2271	2136	2185	2221	2218	2212
25	NA	84	189	66	461	90	109	5	64	23	6	3	0
50	A	5081	5085	5071	4647	5016	5039	4991	5095	5111	5083	5123	5131
50	NA	2	3	2	199	83	41	4	0	4	3	0	0
100	A	7599	7903	7778	7391	7710	7724	7970	7976	7697	7828	7919	7820
100	NA	70	40	58	91	66	68	35	33	73	64	47	61

Table A3. Mean population sizes at generation 50 for the attractive (A) and the less attractive (NA) species along a gradient of three starting densities (D = 10: low density of the attractive species and high density of the less attractive one; D = 50: similar densities of the two plant species; D = 90: high density of the attractive species and low density of the less attractive one) for the three pollinator populations sizes (n). All the population sizes are rounded and given in numbers of cells. Remaining parameter values were PShift = 1, RFOV = 5,d_{disp} = 5 and P_R = 0.5.