Temporal variation in dispersal kernels in a metapopulation of the bog fritillary butterfly

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Nicolas Schtickzelle, Camille Turlure   &   Michel Baguette

www.uclouvain.be/quant-cons-biol

EcoEx-Moulis
Station d'Ecologie Expérimentale du CNRS
USR2936

UCL
UNIVERSITÉ CATHOLIQUE DE LOUVAIN

Spatial & temporal variation of dispersal

- Spatial variation of dispersal generally more documented than temporal variation

- Variations in space can be due to e.g.:
  - Level of fragmentation (e.g. Schtickzelle *et al.* 2006, Wang *et al.* 2011)
  - Habitat quality (e.g. Baguette *et al.* 2011)

- Variations in time can be due to e.g.:
  - Climatic conditions (e.g. Parmesan 2006)
  - Conspecific density (e.g. Baguette *et al.* 2011)

- Schtickzelle, N., Mennechez, G. & Baguette, M. (2006) Dispersal depression with habitat fragmentation in the bog fritillary butterfly. *Ecology*, 87, 1057-1065
- Wang, R.J., Ovaskainen, O., Cao, Y.D., Chen, H.Q., Zhou, Y., Xu, C.R. & Hanski, I. (2011) Dispersal in the Glanville fritillary butterfly in fragmented versus continuous landscapes: comparison between three methods. *Ecological Entomology*, 36, 251-260
- Baguette, M., Clobert, J. & Schtickzelle, N. (2011) Metapopulation dynamics of the bog fritillary butterfly: experimental changes in habitat quality induced negative density-dependent dispersal. *Ecography*, 34, 170-176
- Parmesan, C. (2006) Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology Evolution and Systematics*, 37, 637-669

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A well known butterfly metapopulation

- Bog fritillary *Boloria eunomia*: univoltine species, specialist of wet meadows and peat bogs

- Several metapopulations studied in Belgium since 1992

11 patches
2.5 ha

250m

Capture-Mark-Recapture in the Prés de la Lienne reserve:

- 19 independent datasets (non overlapping generations)
- 4755 marked butterflies
- 13147 (re)captures
- 6278 pairs of successive captures of same butterfly
- 2019 interpatch movements (proxy for dispersal events)

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Dispersal kernel as a measure of dispersal in metapopulations

- Dispersal kernels frequently used to model dispersal, especially for butterflies

- There are alternative methods to estimate dispersal from CMR (e.g. Virtual Migration model: Hanski et al. 2000; Disperse model: Ovaskainen 2004)

- Each method has strengths and weaknesses

- In our case, the landscape has not much changed over the 19 years, so dispersal kernels give a coherent and comparable picture of dispersal over time

- Hanski, I., Alho, J. & Moilanen, A. (2000) Estimating the parameters of survival and migration of individuals in metapopulations. *Ecology*, 81, 239-251
- Ovaskainen, O. (2004) Habitat-specific movement parameters estimated using mark-recapture data and a diffusion model. *Ecology*, 85, 242-257

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Estimating dispersal kernels

- *B. eunomia* can disperse all along their life and reproduce in each visited patch

- Pairs of successive captures of a butterfly are proxy for dispersal events

- The kernel is estimated by fitting, on the inverse cumulative distribution of dispersal events according to distance D, the function

$$P = a D^b$$

a is the emigration rate
b scales the decrease in P with D

Probability to disperse farther than distance D
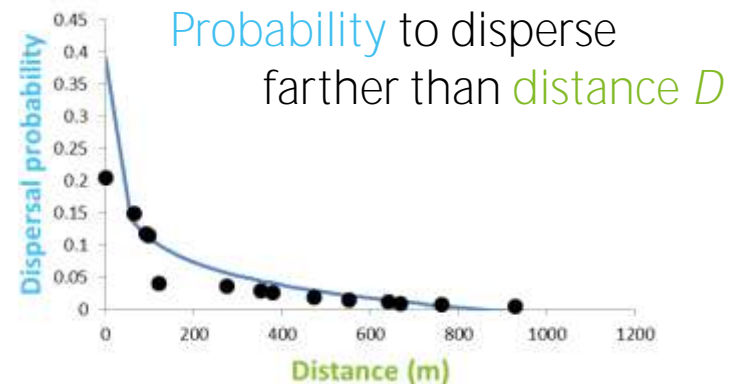
Step 1: Sex and year differences in dispersal kernels

- Dispersal kernel estimated for each year and sex

- Year & sex effects act as both
  - main effects
    (i.e. on a : overall magnitude of dispersal across the whole distance range)
  - interaction with D
    (i.e. on b : **decay of dispersal with distance)**

- **Model selection and multimodel averaging with AICc criterion** (Anderson 2008) used for statistical inference

- Anderson, D.R. (2008) *Model based inference in the life sciences*. Springer, New York

Step 1: Sex and year differences in dispersal kernels

- Overall dispersal frequency
  - higher for females than for males
  - varied according to the year (generation)
  - in a different way for each sex

- Decay of dispersal probability with distance
  - did not significantly differ between sexes or years
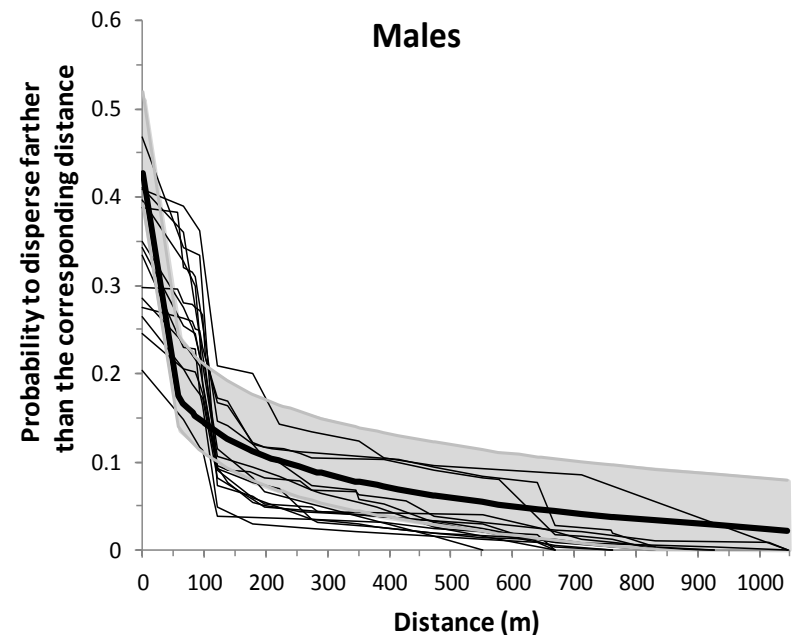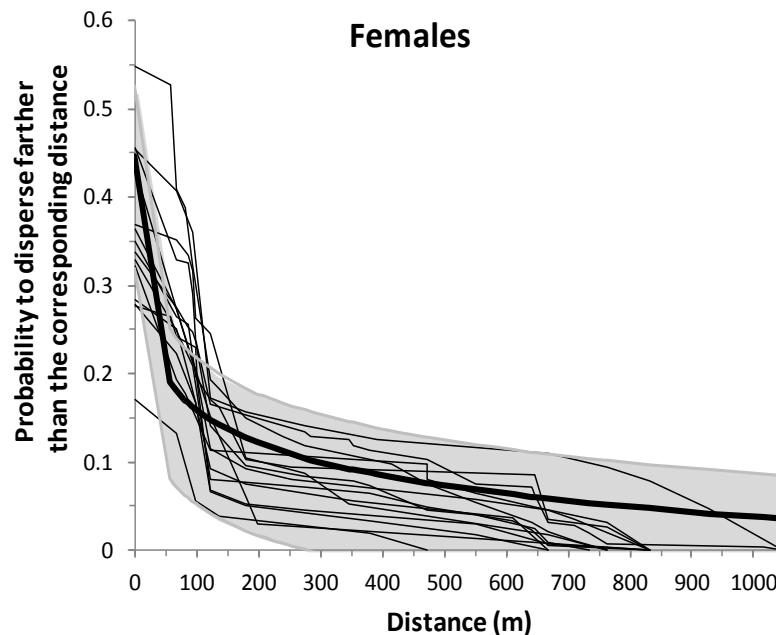
Step 2: Can we explain temporal differences ?

- Year effect can (only partly) be explained by effects of
  - Total population size (Ntot)
  - Sex ratio (SR)
  - Weather (W) (quality of weather for butterfly activity during flight period)

Explanatory variable	Level	AICc weight	P value	Parameter estimate	SE
Intercept		.	.	0.1106	0.0040
Sex	F	100%	0.000	0.0124	0.0061
Ntot		99%	0.001	-0.0100	0.0049
Sex-ratio		75%	0.117	0.0037	0.0034
Weather		43%	0.639	-0.0001	0.0017
Sex*Ntot	F	98%	0.000	0.0212	0.0063
Sex*Sex-ratio	F	26%	0.112	0.0016	0.0023
Sex*Weather	F	13%	0.380	0.0005	0.0010
D		.	.	-0.0816	0.0038
Sex *D	F	65%	0.024	0.0008	0.0040
Ntot *D		92%	0.002	-0.0033	0.0051
Sex-ratio *D		28%	0.096	-0.0008	0.0012
Weather *D		12%	0.454	0.0000	0.0004
Sex*Ntot *D	F	51%	0.001	-0.0071	0.0047
Sex*Sex-ratio *D	F	2%	0.109	-0.0001	0.0002
Sex*Weather *D	F	1%	0.228	-0.0001	0.0001

The decay with distance was also sharper in years in which butterflies were more abundant, this effect again being more pronounced for females than for males.
A change in one standard deviation of Ntot induced a decay of dispersal with distance 13% higher for females, and 4% higher for males.

Take home messages

- Dispersal can be highly variable even for a given species*landscape combination

- We therefore caution scientists to be careful when generalising dispersal kernels, whatever the generalisation is: between years, sexes, landscapes, or even species

- Blind adherence to a dispersal kernel, especially when estimated on only one dataset, would have dramatic consequences on the predictions of dispersal and more generally any process depending on dispersal, such as metapopulation functioning or viability