Effect of climate change on disper

Effects of Climate change

Climate change has led to massive habitat loss and fragmentation, which in turn has affected many natural populations all over the world. (reviewed by Root et al. 2003)

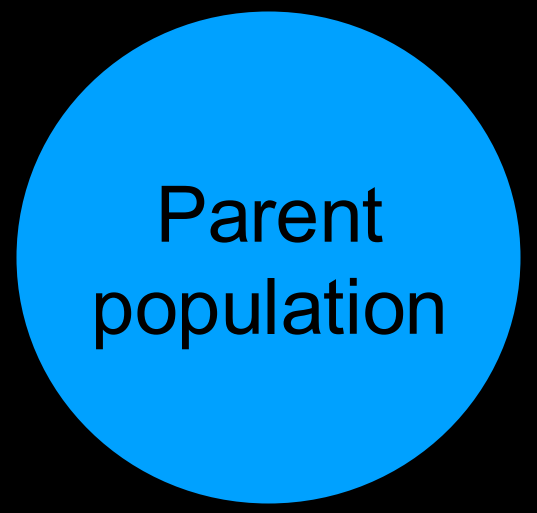
Ongoing rapid climate change is resulting in the geographic shifting of species' to suitable environmental conditions (IPCC 2007, Chen et al. 2011).

For both these responses, dispersal is a central process; it determines the potential spread rate of a population and, the process by which genes are moved between populations, the rate of adaptation to changing conditions and potential for evolutionary rescue (Bell and Gonzalez 2011).

What is dispersal ?

Dispersal is movement of an individual, or multiple individuals, from site of birth to the site of reproduction (natal or pre-breeding dispersal) or its movement between successive sites of reproduction (post-breeding dispersal).

Any movement that has the potential to lead to gene flow.



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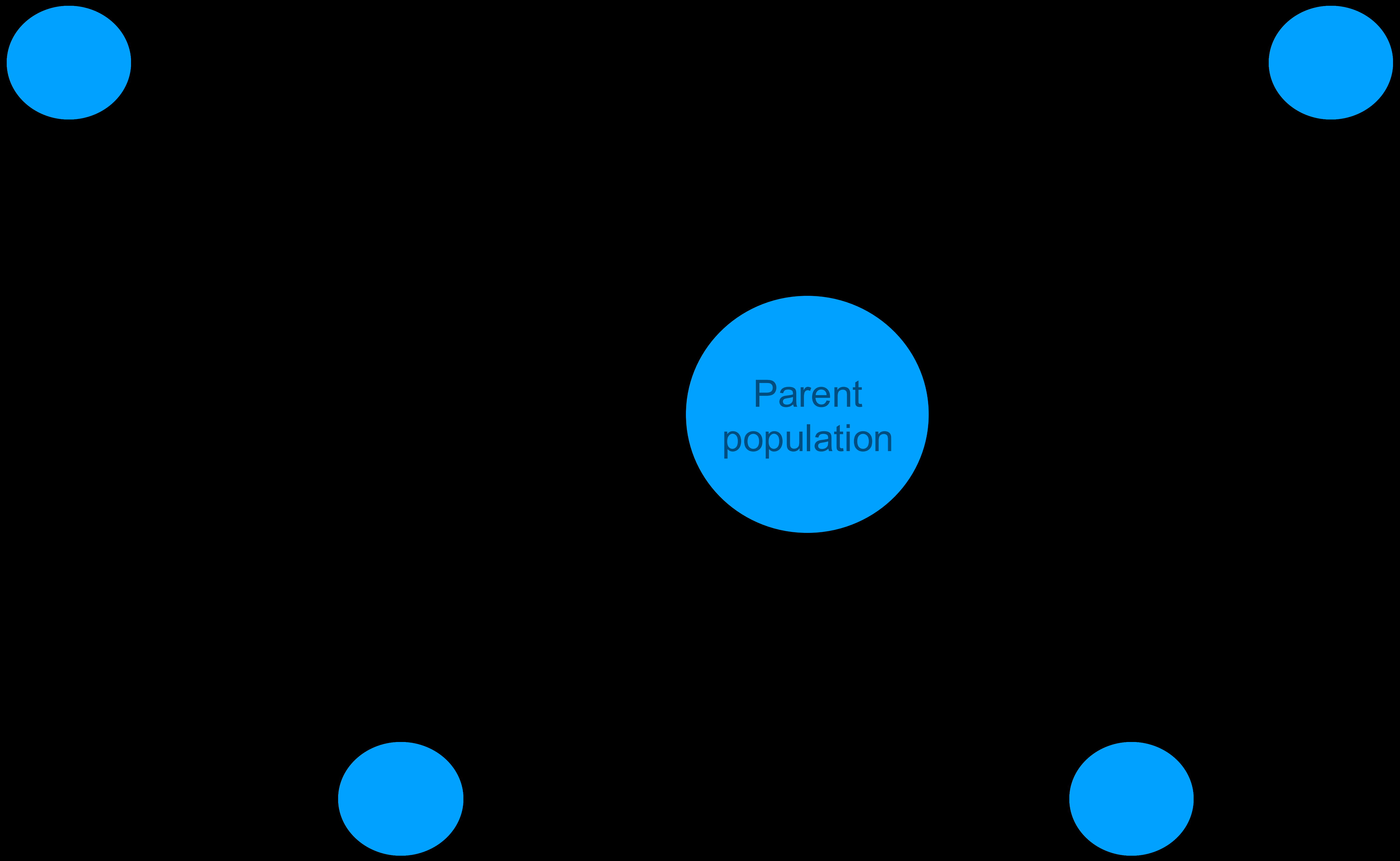
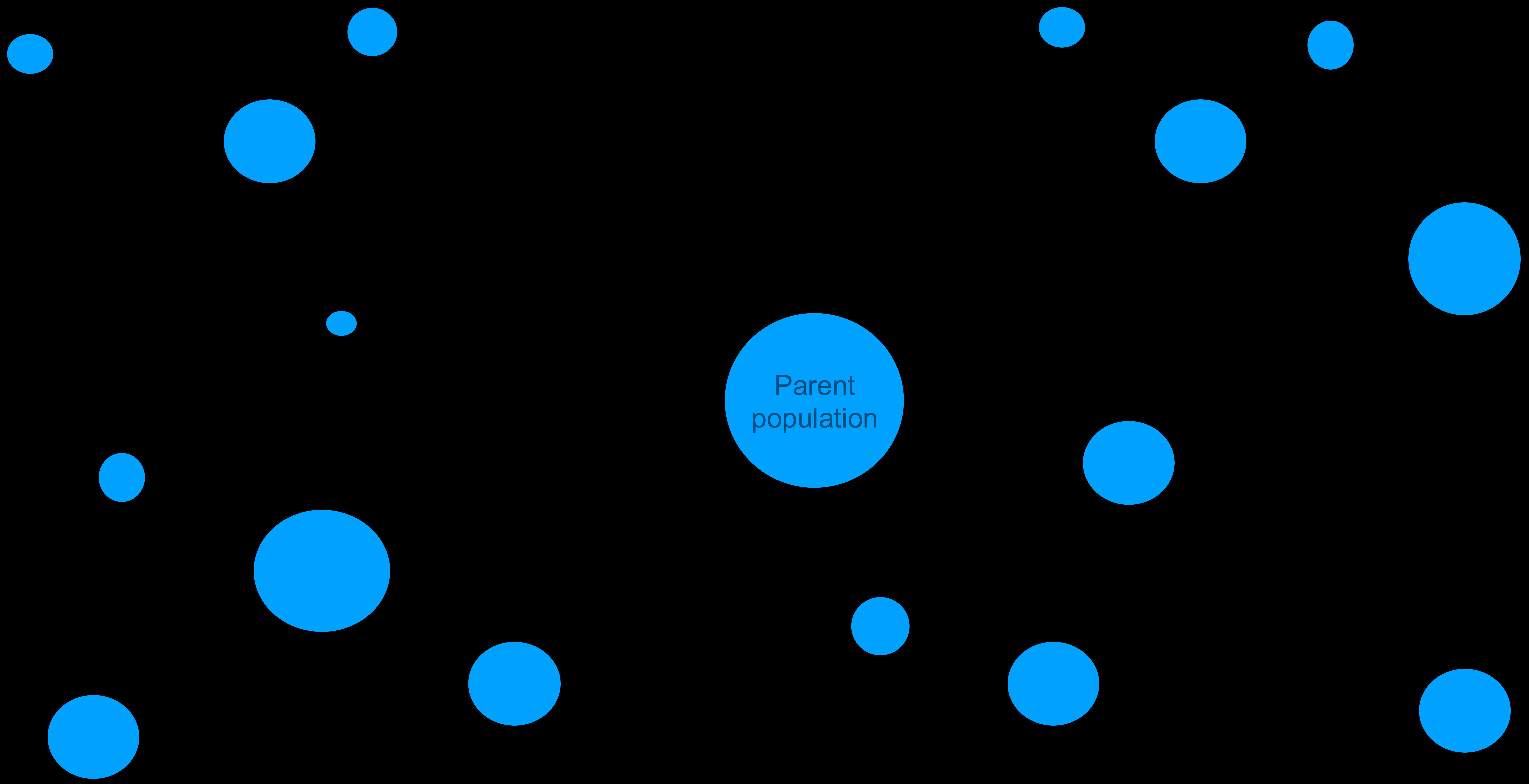
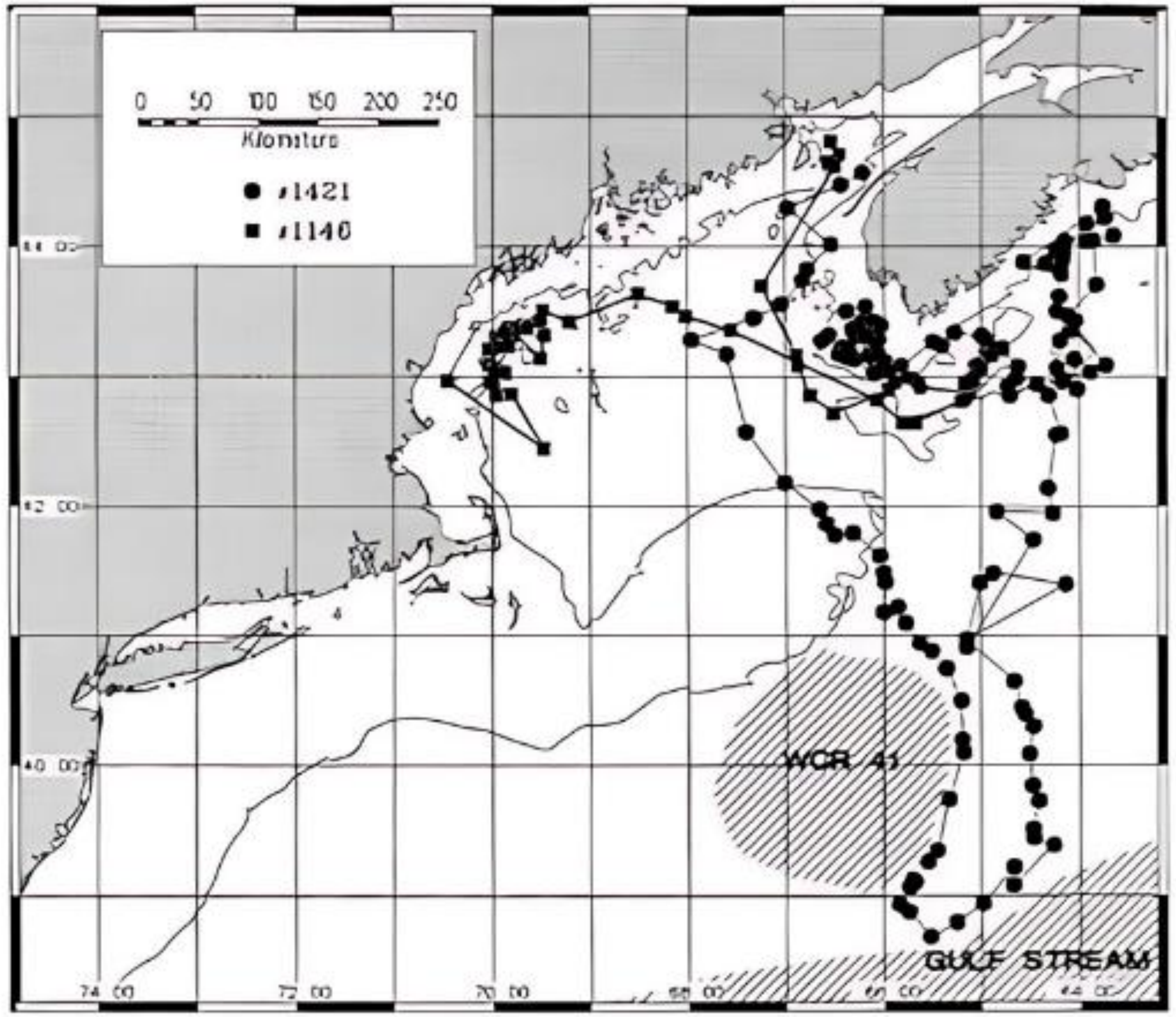


Any movement that has the potential to lead to gene flow.

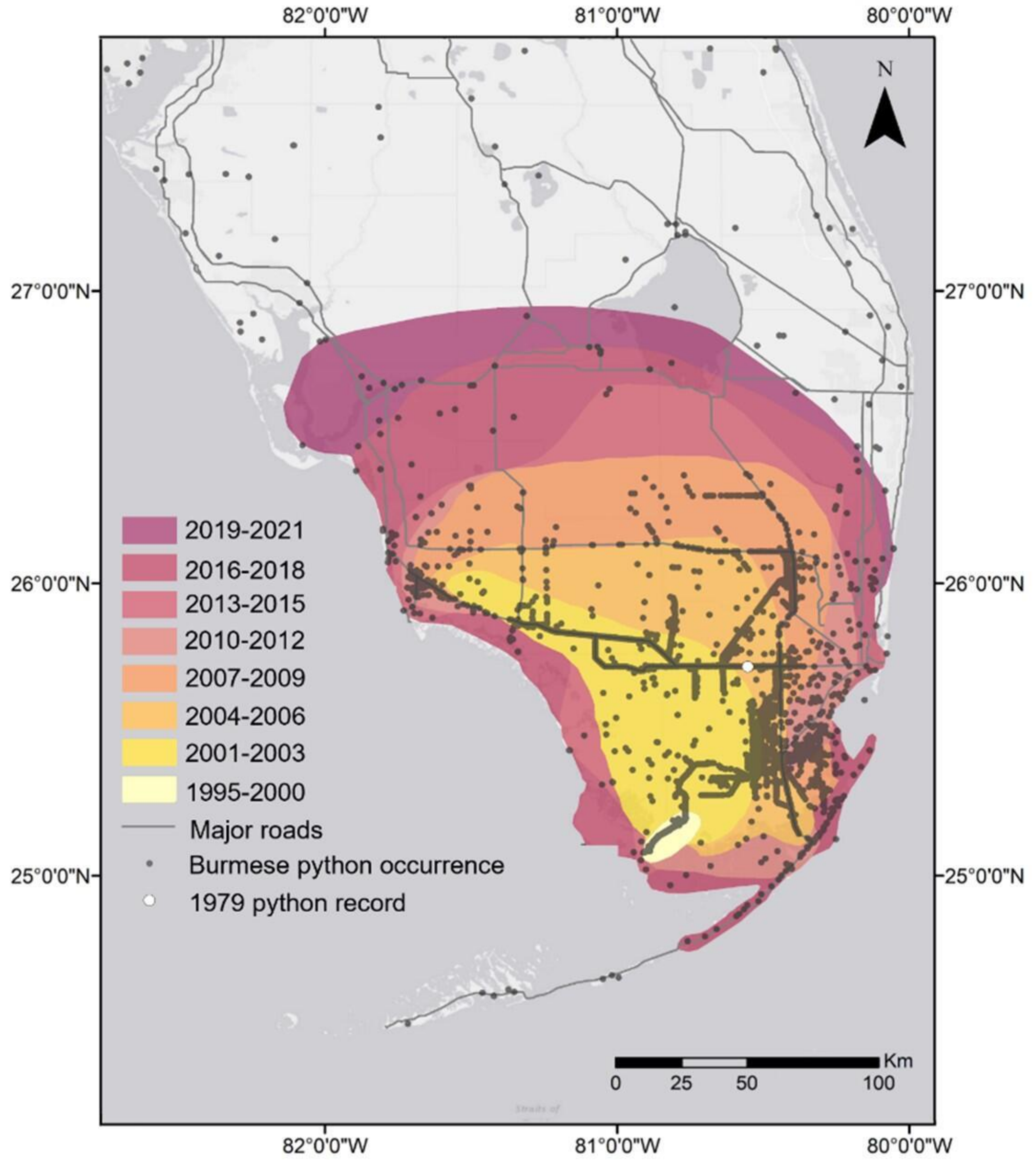


Any movement that has the potential to lead to gene flow.



Satellite monitored movements of two male northern right whales (Eubalaena glacialis; #1421 and #1146)

Showing their ability to disperse large distances unimpeded



Geographic spread of Burmese python records in southern Florida between 1979 and 2021

By [Wetland and Aquatic Research Center]

Types of dispersal

Passive dispersal

Gravity dispersal (mainly seeds)

Wind dispersal (seed as well as pollen)

Water dispersal (mainly seeds)

Animal dispersal (seed as well as pollen)

Active dispersal

Active dispersal involves movement of the entire organism through its own ability and is common in both adult and juvenile animals.

Why should we be studying the effects of climate change on dispersal?

Why should we be studying the effects of climate change on dispersal?

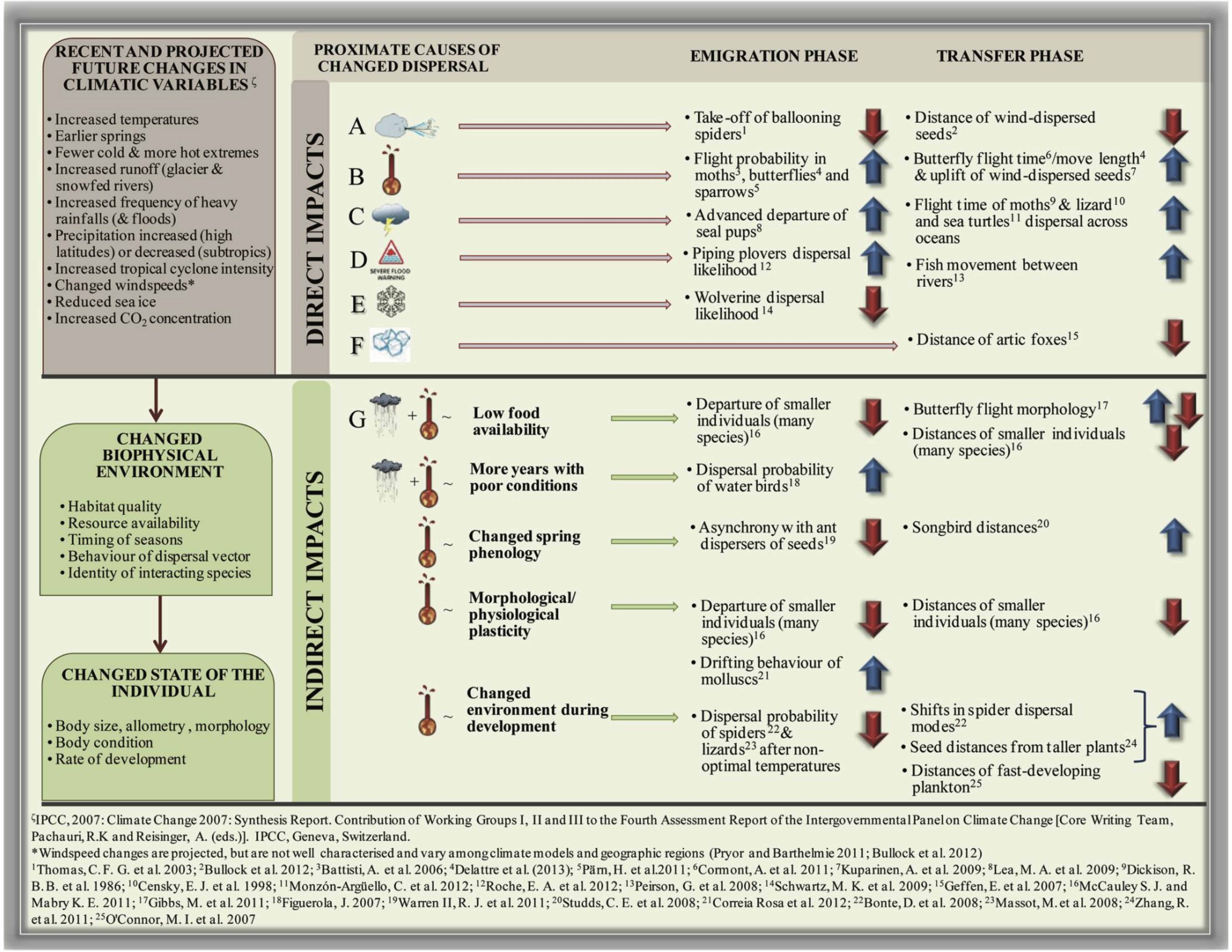
- Ongoing rapid climate change is resulting in the geographic shifting of species' suitable environmental conditions (IPCC 2007, Chen et al. 2011).
- Species might survive this rapid change by shifting their distributions or through evolution such that populations become adapted to the new local climatic conditions (Berg et al. 2010, Bellard et al. 2012).
- For both these responses, dispersal is a central process; it determines the potential spread rate of a population and, as the process by which genes are moved between populations, it influences the rate of adaptation to changing conditions and the potential for evolutionary rescue (Bell and Gonzalez 2011).
- Despite this, the great majority of studies projecting future species' distributions do not explicitly account for dispersal (Thomas et al. 2004, Thuiller et al. 2006).

Will climate change reduce or enhance individual dispersal abilities?

Factors affecting dispersal

- Abiotic factors
  Non-living factors in the environment, such as wind, rain, temperature, or climate conditions. For example, wind and rain can carry seeds, and unfavorable weather conditions may encourage individuals to move to a new location.
- Biological factors
  Factors related to the species, such as mobility, reproductive ability, and prey resource availability. For example, species with low dispersal ability, such as those that need a large area of habitat to survive, may be more affected by habitat fragmentation.
- Physical barriers
  Landscape features, such as mountains, rivers, and lakes, that can prevent organisms from relocating. Anthropogenic barriers, such as roads, farming, and river dams, can also limit dispersal.

Table 1. Effects of climate change on individual dispersal. Climate change is predicted to lead to lower windspeeds (A), higher temperatures (B), increased frequency of storms (C), flooding (D), reduced snow (E) and ice (F) cover, and changed rainfall (G). Each of these climatic factors has been shown to affect dispersal in a range of organisms from all taxa, either through a direct impact on the individual during dispersal, or indirectly by altering the biophysical environment or the state of the dispersing organism. Key empirical examples in both marine and terrestrial ecosystems of these effects are described (red arrows depicting decreases, blue arrows increases an increase). The arrows indicate how predicted changes in specific climatic factors would alter the propensity to emigrate or the distance dispersed during transfer. *Windspeed changes are projected, but are not well characterised and vary among climate models and geographic regions (Pryor and Barthelmie 2011, Bullock et al. 2012). [1]IPCC 2007, [5]Delattre et al. 2013.



RECENT AND PROJECTED FUTURE CHANGES IN CLIMATIC VARIABLES [ς]

- Increased temperatures
- Earlier springs
- Fewer cold & more hot extremes
- Increased runoff (glacier & snowfed rivers)
- Increased frequency of heavy rainfalls (& floods)
- Precipitation increased (high latitudes) or decreased (subtropics)
- Increased tropical cyclone intensity
- Changed windspeeds*
- Reduced sea ice
- Increased CO_2 concentration

CHANGED BIOPHYSICAL ENVIRONMENT

- Habitat quality
- Resource availability
- Timing of seasons
- Behaviour of dispersal vector
- Identity of interacting species

CHANGED STATE OF THE INDIVIDUAL

- Body size, allometry, morphology
- Body condition
- Rate of development

	PROXIMATE CAUSES OF CHANGED DISPERSAL	EMIGRATION PHASE		TRANSFER PHASE	
DIRECT IMPACTS	A	Take-off of ballooning spiders[1]	↓	Distance of wind-dispersed seeds[2]	↓
	B	Flight probability in moths[3], butterflies[4] and sparrows[5]	↑	Butterfly flight time[6]/move length[4] & uplift of wind-dispersed seeds[7]	↑
	C	Advanced departure of seal pups[8]	↑	Flight time of moths[9] & lizard[10] and sea turtles[11] dispersal across oceans	↑
	D (SEVERE FLOOD WARNING)	Piping plovers dispersal likelihood[12]	↑	Fish movement between rivers[13]	↑
	E	Wolverine dispersal likelihood[14]	↓		
	F			Distance of artic foxes[15]	↓
INDIRECT IMPACTS	G + ~ Low food availability	Departure of smaller individuals (many species)[16]	↓	Butterfly flight morphology[17]; Distances of smaller individuals (many species)[16]	↑↓; ↓
	+ ~ More years with poor conditions	Dispersal probability of water birds[18]	↑		
	~ Changed spring phenology	Asynchrony with ant dispersers of seeds[19]	↓	Songbird distances[20]	↑
	~ Morphological/ physiological plasticity	Departure of smaller individuals (many species)[16]	↓	Distances of smaller individuals (many species)[16]	↓
		Drifting behaviour of molluscs[21]	↑		
	~ Changed environment during development	Dispersal probability of spiders[22] & lizards[23] after non-optimal temperatures	↓	Shifts in spider dispersal modes[22]; Seed distances from taller plants[24]	↑
				Distances of fast-developing plankton[25]	↓

[ς]IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland.

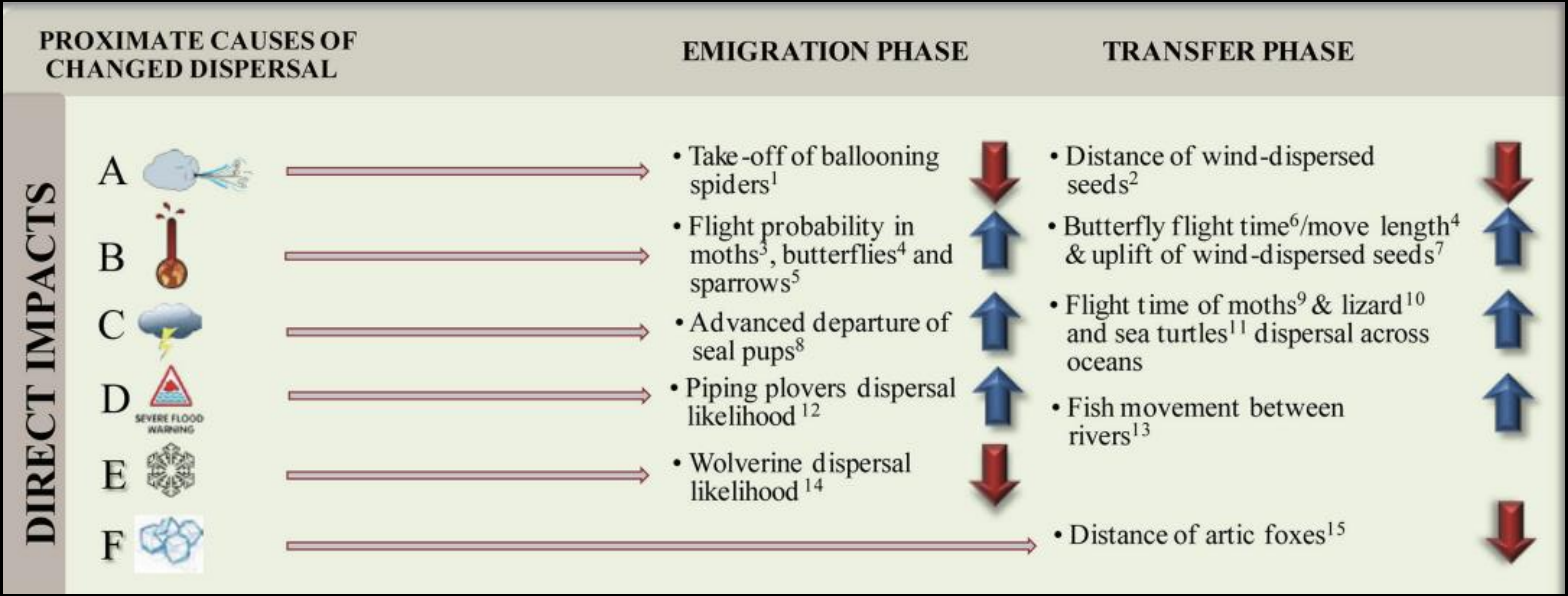
*Windspeed changes are projected, but are not well characterised and vary among climate models and geographic regions (Pryor and Barthelmie 2011; Bullock et al. 2012)

[1]Thomas, C. F. G. et al. 2003; [2]Bullock et al. 2012; [3]Battisti, A. et al. 2006; [4]Delattre et al. (2013); [5]Pärn, H. et al. 2011; [6]Cormont, A. et al. 2011; [7]Kuparinen, A. et al. 2009; [8]Lea, M. A. et al. 2009; [9]Dickison, R. B. B. et al. 1986; [10]Censky, E. J. et al. 1998; [11]Monzón-Argüello, C. et al. 2012; [12]Roche, E. A. et al. 2012; [13]Peirson, G. et al. 2008; [14]Schwartz, M. K. et al. 2009; [15]Geffen, E. et al. 2007; [16]McCauley S. J. and Mabry K. E. 2011; [17]Gibbs, M. et al. 2011; [18]Figuerola, J. 2007; [19]Warren II, R. J. et al. 2011; [20]Studds, C. E. et al. 2008; [21]Correia Rosa et al. 2012; [22]Bonte, D. et al. 2008; [23]Massot, M. et al. 2008; [24]Zhang, R. et al. 2011; [25]O'Connor, M. I. et al. 2007

Major climatic change that can affect the dispersal directly

- Wind speed ↓
- Temperatures ↑
- Frequency of storms ↑
- Flooding ↑
- Snow cover ↓
- Ice cover ↓
- Changed rainfall patterns

(IPCC,2007:Climate Change 2007:Synthesis report,IPCC ,Geneva, Switzerland)


PROXIMATE CAUSES OF CHANGED DISPERSAL
EMIGRATION PHASE
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DIRECT IMPACTS
A
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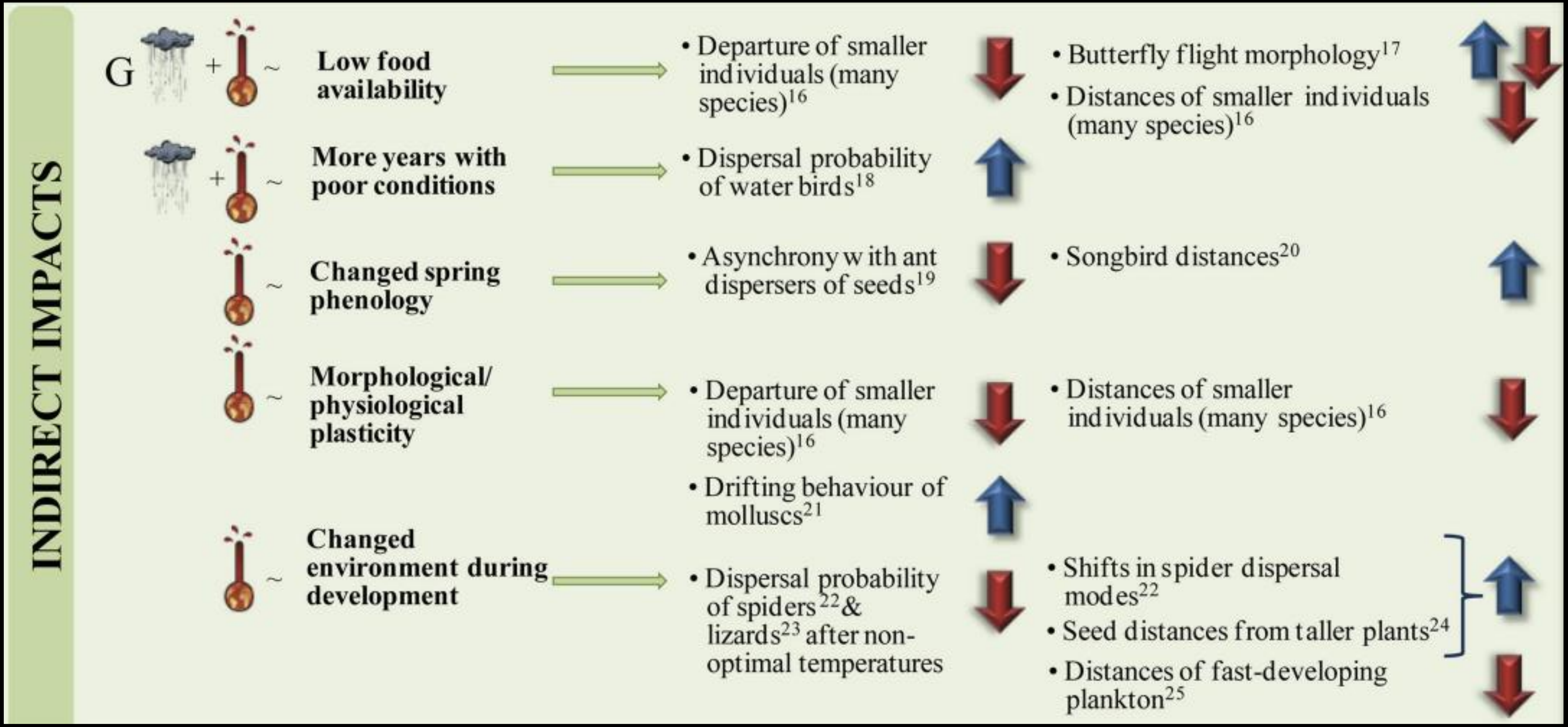
F
• Distance of artic foxes[15]

Indirect changes caused by climate change that can affect dispersal

- higher temp. ~ Changed spring patterns
- higher temp. ~ Morphological/Phenological plasticity
- higher temp. ~ Changed environment during development
- Changed rainfall + higher temp. ~ Low food availability
- Changed rainfall + higher temp. ~ More years with poor conditions


INDIRECT IMPACTS
G
+
~
Low food availability
• Departure of smaller individuals (many species)16
• Butterfly flight morphology17
• Distances of smaller individuals (many species)16
More years with poor conditions
• Dispersal probability of water birds18
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• Drifting behaviour of molluscs21
Changed environment during development
• Dispersal probability of spiders22 & lizards23 after non-optimal temperatures
• Shifts in spider dispersal modes22
• Seed distances from taller plants24
• Distances of fast-developing plankton25

Biotic changes due to climate change that can effect dispersal

- When individuals or populations influence one another, climate changes can also result from spatial mismatches in such species relationships due to the dispersal limitations of each [6].
- Climate changes can reduce suitable overlapping areas differently for each species in the community [1], considering that species could move at different speeds and directions [2], leading to biota redistribution [3].
- Following climate change, species interactions may be disrupted [4] and new interactions developed [5].
- Areas projected to be climatically suitable in the future can be inaccessible to the species [7] due to species dispersal limitations or habitat connectivity [8] are not commonly integrated into ecological niche models (ENMs) [9].

Physical barriers due to climate change that can effect dispersal

Not in the time scale which I am interested in

Physical barriers due to climate change that can effect dispersal

There are none (or I don’t know of any)

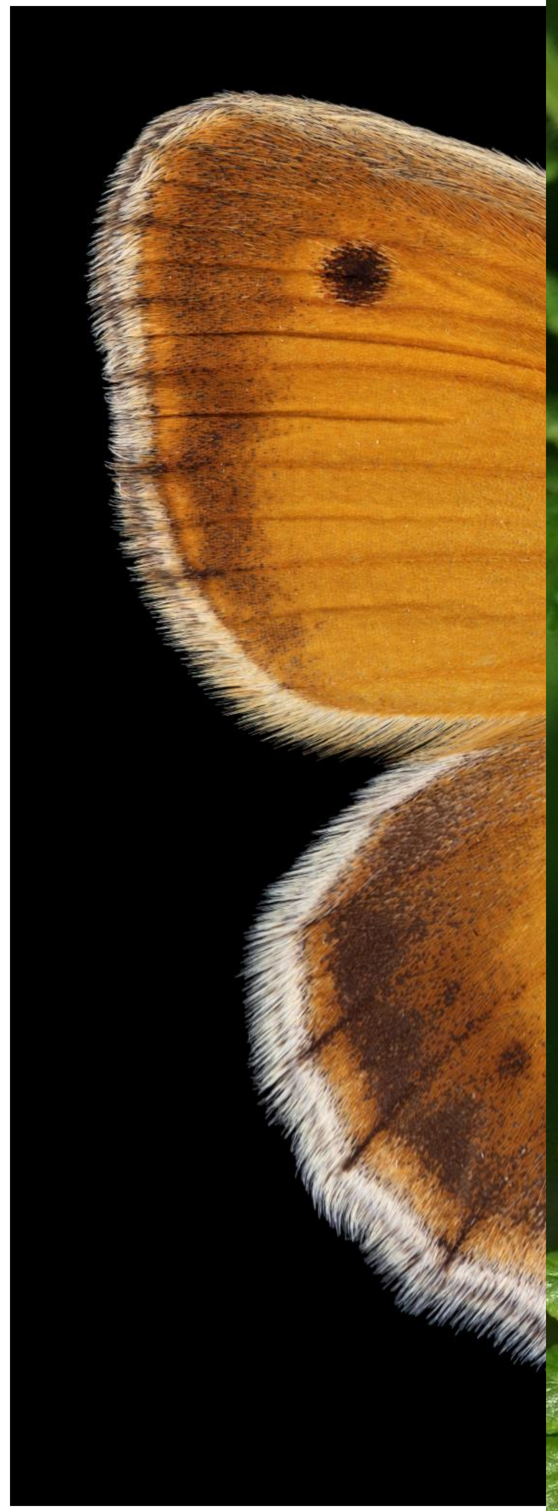
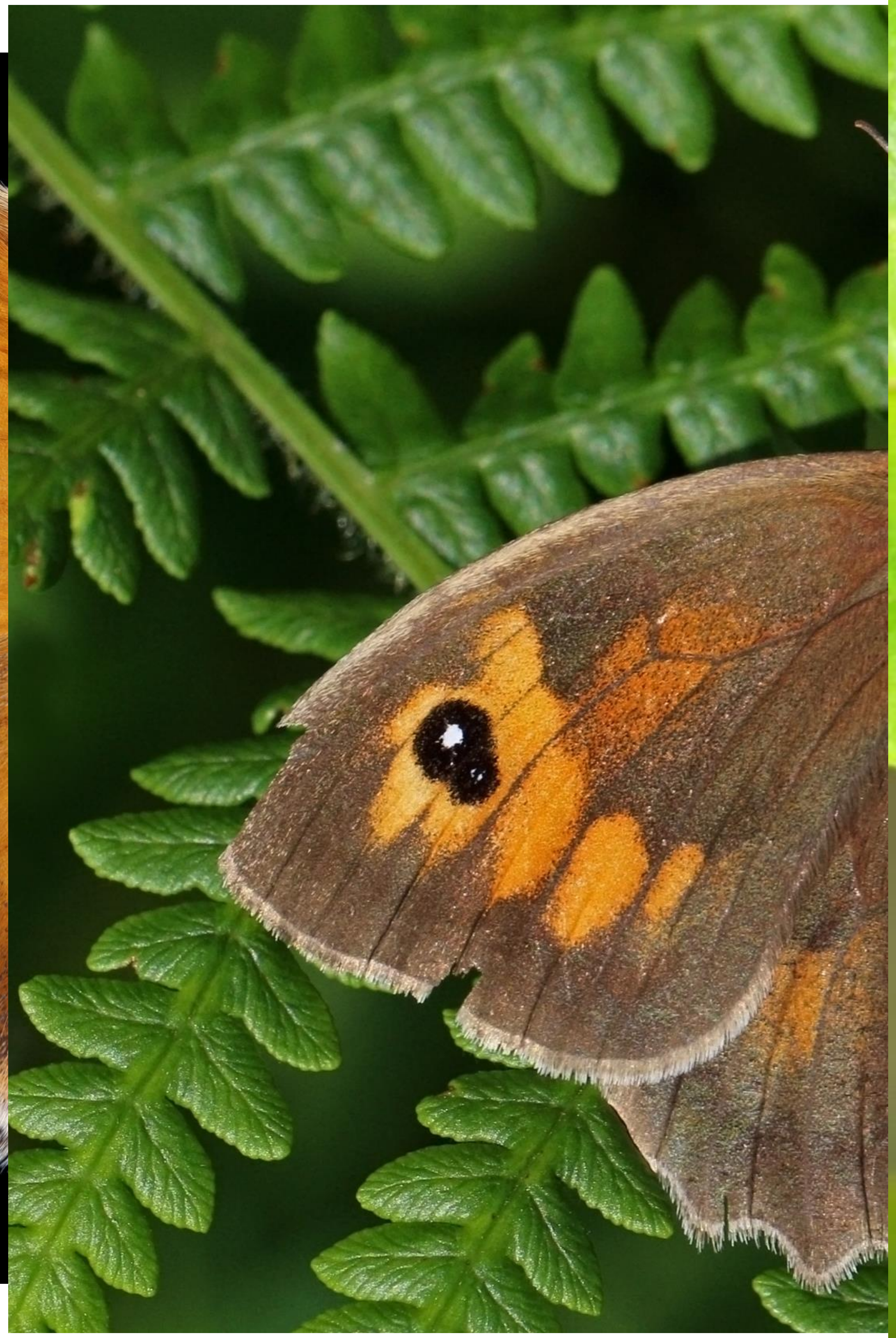
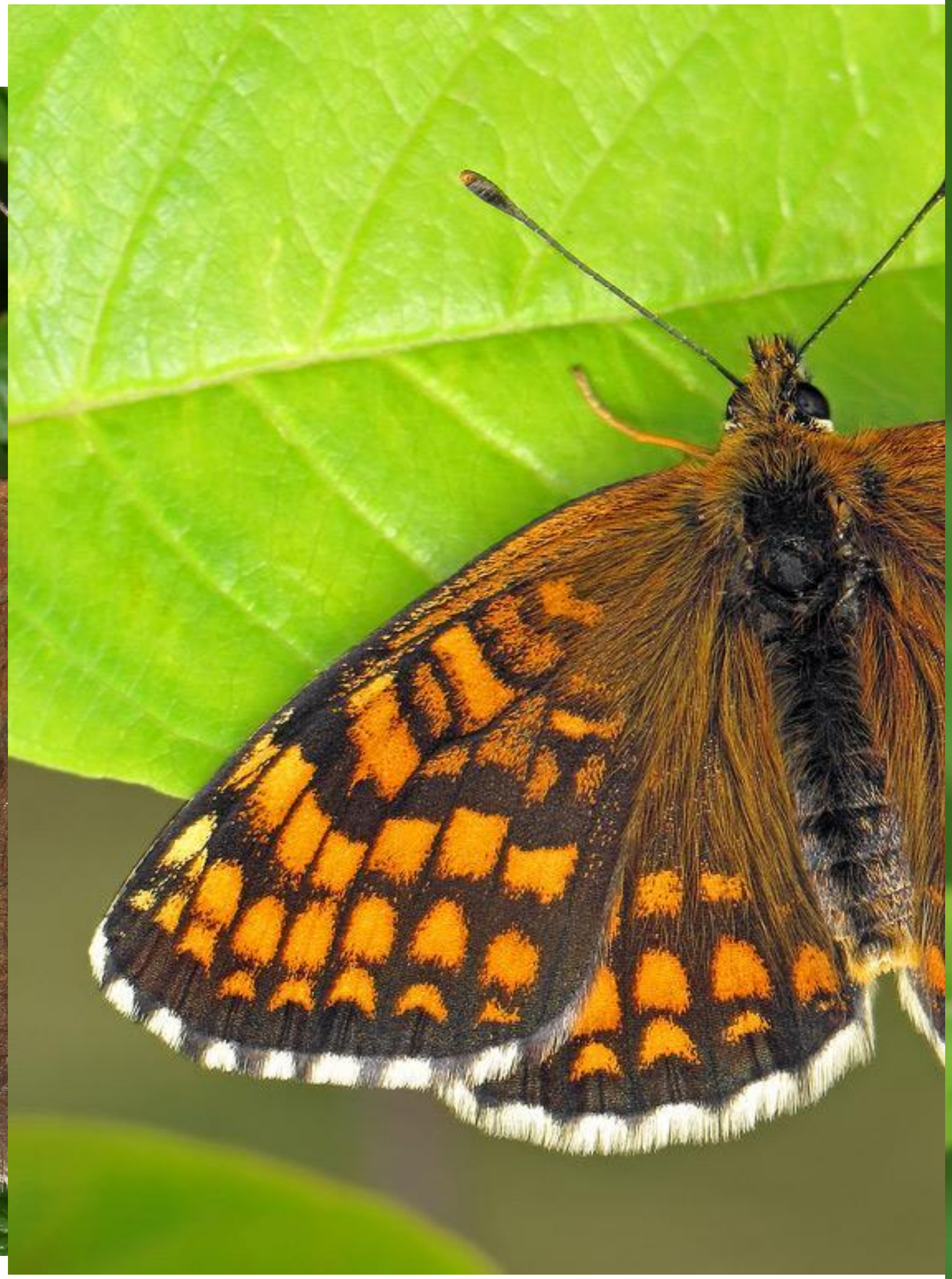
Physical barriers due to climate change that can effect dispersal

Case study

Case study

Butterflies - in ‘De Hoge Veluwe’’ National Park in Netherlands

During the summer of 2006-07


Case study

Butterflies - in ‘De Hoge Veluwe’’ National Park in Netherlands

During the summer of 2006-07

Small heath *(Coenonympha pamphilus L.)*

- common resident in the Netherlands
- open mosaic habitats such as grasslands, dunes, roadside verges, and gardens
- bivoltine (May 20–July 20, July 29–September 5)
- not very mobile

Case study

Butterflies - in 'De Hoge Veluwe'' National Park in Netherlands

During the summer of 2006-07

Meadow brown *(Maniola jurtina L.)*

- common resident in the Netherlands.
- univoltine (June 26 – August 15)
- quite mobile

Case study

Butterflies - in 'De Hoge Veluwe'' National Park in Netherlands

During the summer of 2006-07

Heath fritillary, *(Melitaea athalia Rott.)*

- very rare resident in the Netherlands, (nowadays restricted to the Veluwe area).
- Suitable habitats are sunny, open places in forests such as woodland edges, newly felled woodlands and clearings in coppice.
- univoltine (June 16–July 15) and sedentary.

Case study

Butterflies - in 'De Hoge Veluwe'' National Park in Netherlands

During the summer of 2006-07

Silver-studded blue, *(Plebejus argus L.)*

- scarce resident in the Netherlands (vulnerable on the Dutch Red List.)
- univoltine species (June 26–August 5) sedentary.
- lives both in dry and wet heathlands with sparse vegetation and patches of bare ground.

They recorded flight behaviour and mobility of four butterfly species under variable weather conditions. Because dispersal differs widely between species, we consider two habitat generalist and two specialist species.

In practice, butterfly dispersal is difficult to measure. Butterflies are not robust enough to carry biotelemetry transmitters (Van Dyck and Baguette 2005).

In this paper we therefore use a proxy for dispersal, and assume that dispersal propensity will increase as individuals of species fly over longer bout durations, increase their tendency to start flying, spend more time flying, and fly over longer distances (cf. Morales and Ellner 2002; Nathan et al. 2008; Van Dyck and Baguette 2005).

Variables that could influence the activity and dispersal of flies : -

- Ambient temperature (mercury thermometer placed in the shade,°C)
- Wind speed (observer's estimation or measured with anemometer , Bft)
- Cloudiness (observer's estimation in percentage cover)
- A proxy for solar radiation.

Method

Butterfly was caught in net → Sex was determined → Coded with permanent marker (Underside of both hindwing)

→ Released from net → Allow butterfly to acclimatise

→ Behaviour observations started

- Flying
- Nectaring
- Resting
- Basking
- Testing
- Ovipositing

At the beginning of each track, we measured temperature, wind speed and cloud cover. At the end of the observation we re-measured temperature, wind speed, and determined the temperature difference between the black and white surfaces (further referred to as radiation; Table 1).

Cox's proportional hazards model

- Used to analyse which weather variables affected the tendency of a butterfly to terminate a bout.

Hazard - The instantaneous risk of an event occurring at a specific time, given that the event hasn't happened yet. (here the event is termination of flight).

It was assumed that butterflies have a basic tendency to stop a specific behaviour (base

- **Hazard Rate [h (t ; x$_i$ . . . . , x$_p$)] =** $\dfrac{\textbf{Hazard}}{\textbf{Time}}$ → **Observed Hazard rate (H [t])** ; → **Baseline hazard (H$_o$[t])**

- **Hazard Ratio -** $\dfrac{[\, h_1\ (t\ ;\ x_i \ldots, x_p)\,]}{[\, h_2\ (t\ ;\ x_i \ldots, x_p)\,]}$

$$h(t; x_i, \ldots, x_p) = h_0(t) \cdot \exp\left(\sum_{i=1}^{p} \beta_i x_i\right) \quad \text{[in probability per time unit]}$$

- If hazard ratio > 1~ increase in the covariate is associated with an increased risk of the event.
- If a particular covariate x_i does not influence the observed hazard rate, then β_i does not differ significantly from 0.
- Kaplan–Meier survival curves should be parallel for all covariate categories, i.e. should not cross in order to be able to assume proportionality estimating the effect size in Cox model.

- where $h(t; x_i, \ldots, x_p)$ - the observed hazard rate at time t with p fixed covariates having values $(x_i, \ldots, x_p)$
- h_0 is the baseline hazard
- t is the time since the last bout termination
- x_i is the vector of covariates.
- β_i - co-efficient to be found from regression.

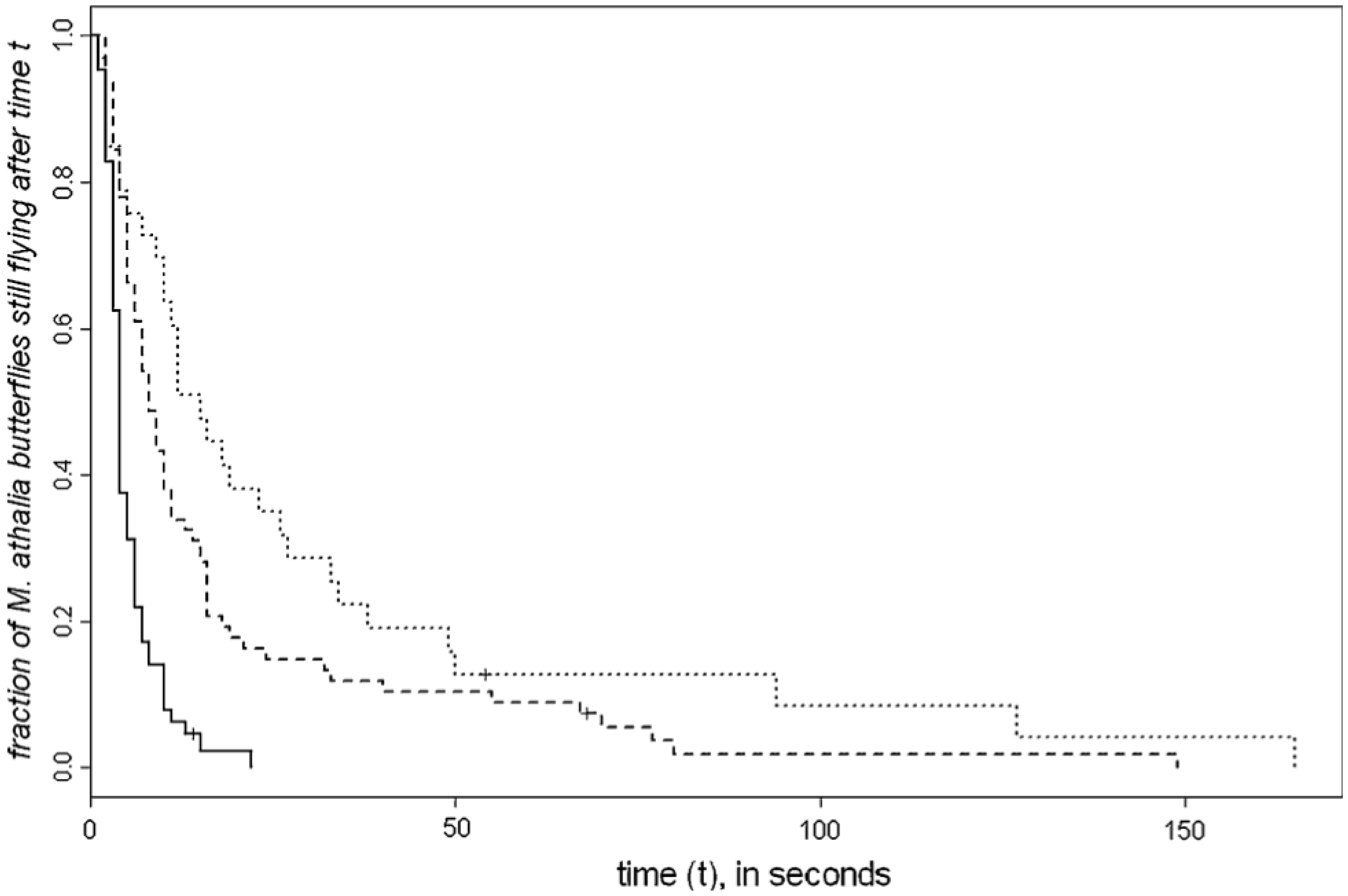


Fig. 4 Kaplan–Meier survival curve for flying bouts of *M. athalia* with temperature as single covariate. Under low temperature (*solid line*; less or equal to 14°C), butterflies terminate flying bouts sooner than under intermediate temperature (between 14 and 25°C; *dashed line*; $P = 2.9\text{E} - 08$) and high temperature (more than 25°C; *dotted line*; $P = 1.1\text{E} - 09$).

Weather variables were clustered into ‘low’, ‘intermediate’, and ‘high’ categories to distinguish optimum or unidirectional effects of weather variables on the duration of bouts

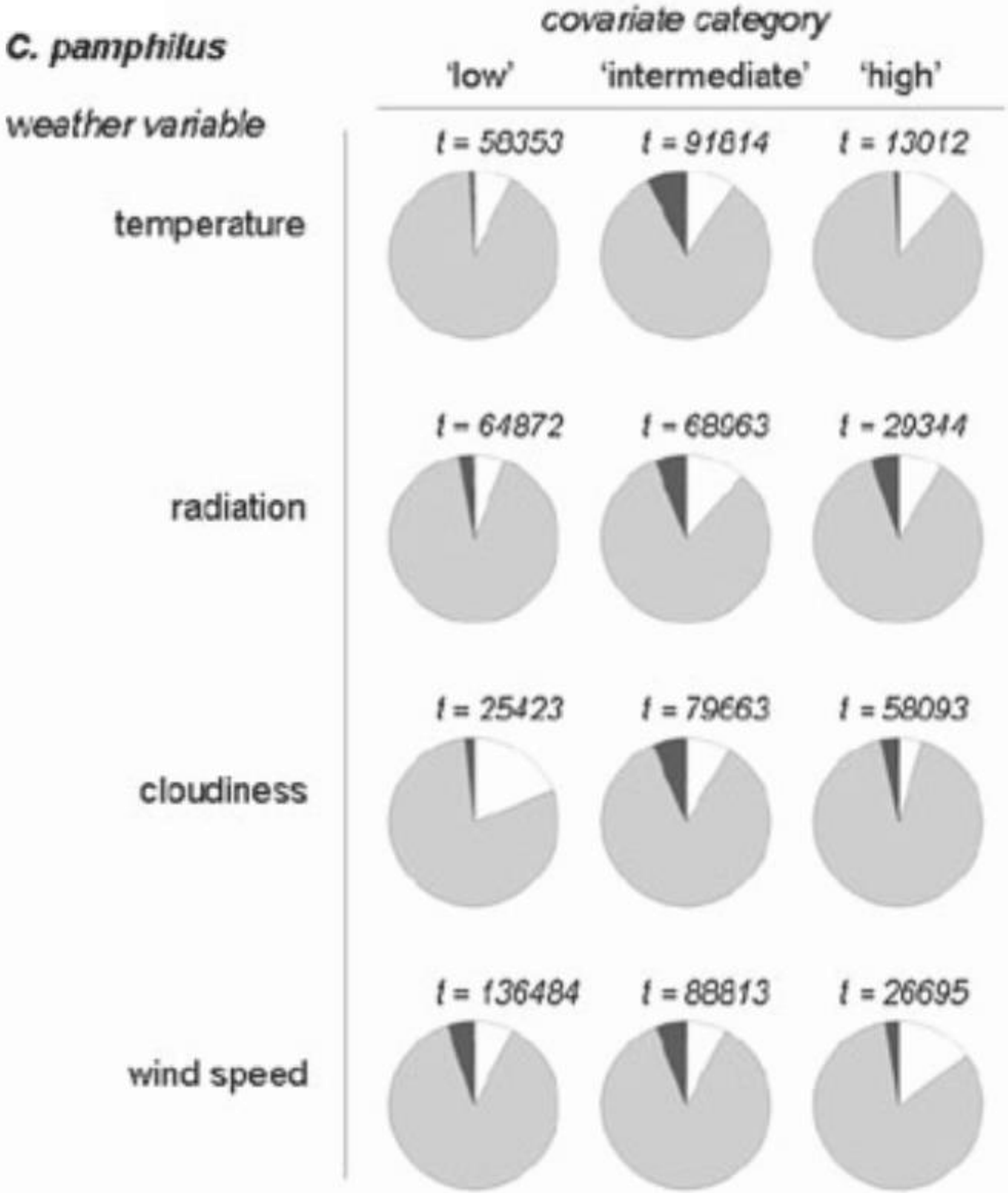
Table 2 Clustering of weather variables into ‘low’, ‘intermediate’, and ‘high’ categories per species, resulting from Kaplan–Meier survival curves for flying bouts

Weather variable	Category	*C. pamphilus*	*M. jurtina*	*M. athalia*	*P. argus*
Temperature (T; in °C)	Low	$T \leq 19.5$	$T \leq 20$	$T \leq 14$	$T \leq 22$
	Intermediate	$19.5 < T \leq 25.5$	$20 < T \leq 31$	$14 < T \leq 25$	$22 < T \leq 28$
	High	$T > 25.5$	$T > 31$	$T > 25$	$T > 28$
Radiation (R; in °C)	Low	$R \leq 12$	$R \leq 10$	$R \leq 14$	$R \leq 17$
	Intermediate	$12 < R \leq 28$	$10 < R \leq 20$	$14 < R \leq 31$	$17 < R \leq 20$
	High	$R > 28$	$R > 20$	$R > 31$	$R > 20$
Cloudiness (C; in %)	Low	$C \leq 15$	$C \leq 15$	$C \leq 25$	$C = 0$
	Intermediate	$15 < C \leq 60$	$15 < C \leq 70$	$25 < C \leq 70$	$0 < C \leq 20$
	High	$C > 60$	$C > 70$	$C > 70$	$C > 20$
Wind speed (W; in Bft)	Low	$W \leq 1$	$W \leq 2$	$W \leq 3$	$W \leq 2$
	Intermediate	$1 < W \leq 2$	$2 < W \leq 4$	$3 < W \leq 4$	$2 < W \leq 3$
	High	$W > 2$	$W > 4$	$W > 4$	$W > 3$

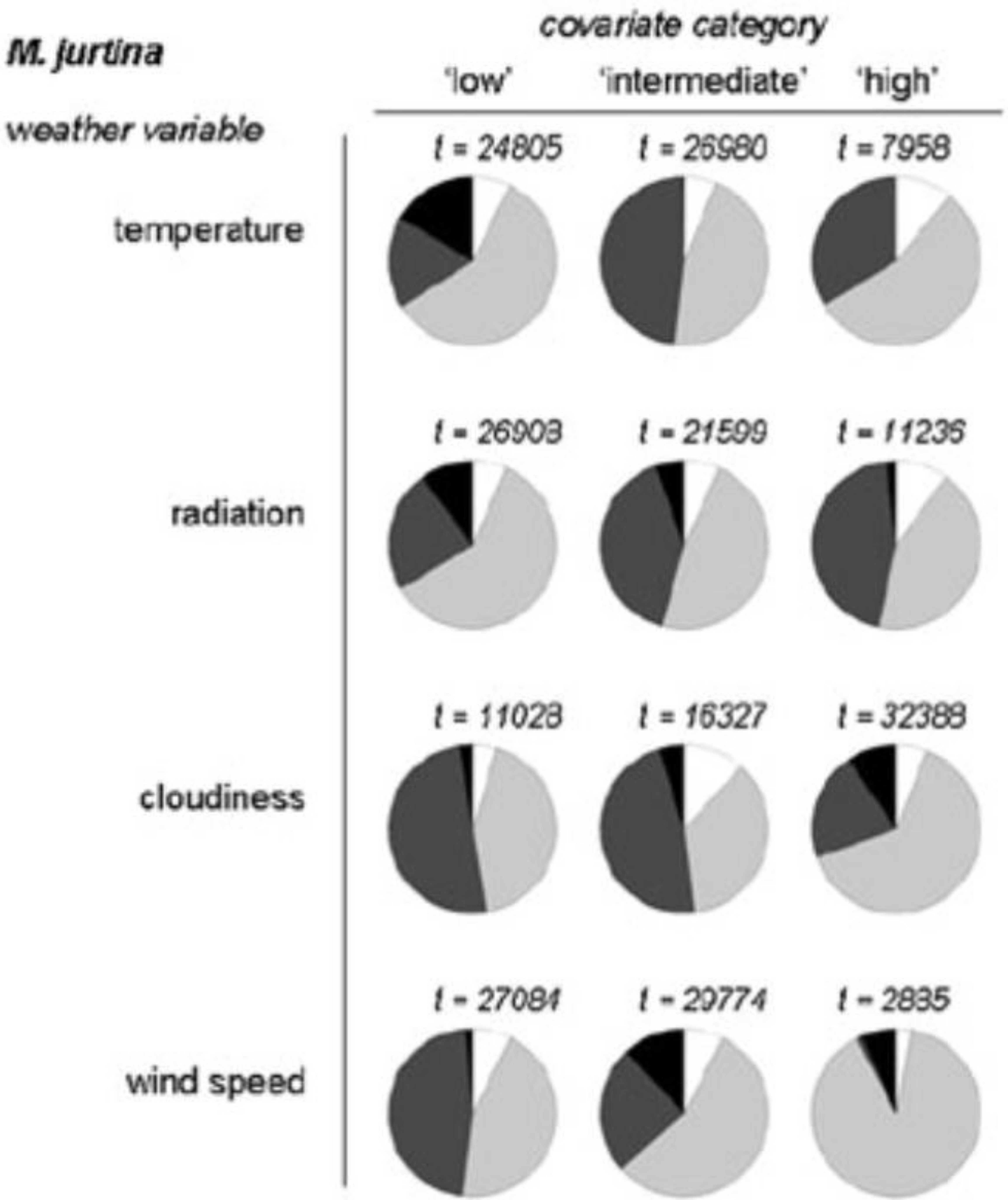
Table 4 Results survival analysis for non-flight behaviour based on multivariate Cox's proportional hazards model

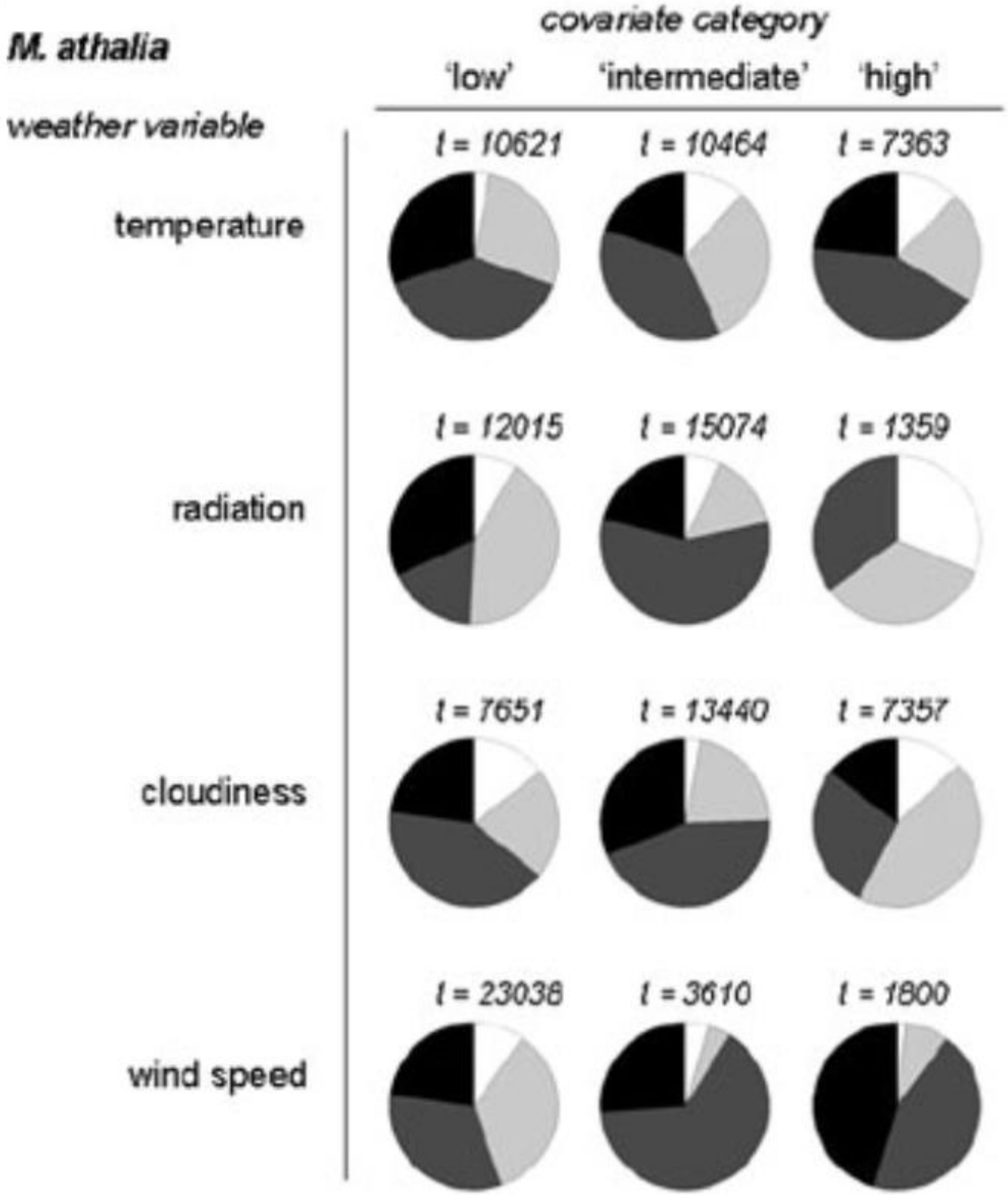
Covariate	Species					
	C. pamphilus ($n = 870$)			*M. jurtina* ($n = 406$)		
	Coef	*P*	l:i:h	Coef	*P*	l:i:h
Gender (male)	0.324	0.0003		0.039	0.82	
Year (2007)	0.169	0.082		0.6124	0.078	
Low:intermediate temperature	−0.112	0.2	a:a:na	0.779	0.018	a:b:b
Low:high temperature	NA	NA		0.716	0.039	
Intermediate:high temperature	NA	NA		−0.063	0.72	
Low:intermediate radiation	0.282	0.004	a:b:b	−0.004	0.98	a:a:a
Low:high radiation	0.32	0.004		−0.222	0.21	
Intermediate:high radiation	0.038	0.68		−0.218	0.18	
Low:intermediate cloudiness	−0.23	0.026	a:b:c	0.457	0.015	ac:b:c
Low:high cloudiness	−0.651	0.0000		0.109	0.55	
Intermediate:high cloudiness	−0.422	0.002		−0.348	0.017	
Low:intermediate wind speed	−0.071	0.41	a:a:na	−0.113	0.39	a:a:a
Low:high wind speed	NA	NA		−0.343	0.36	
Intermediate:high wind speed	NA	NA		−0.230	0.52	

Results

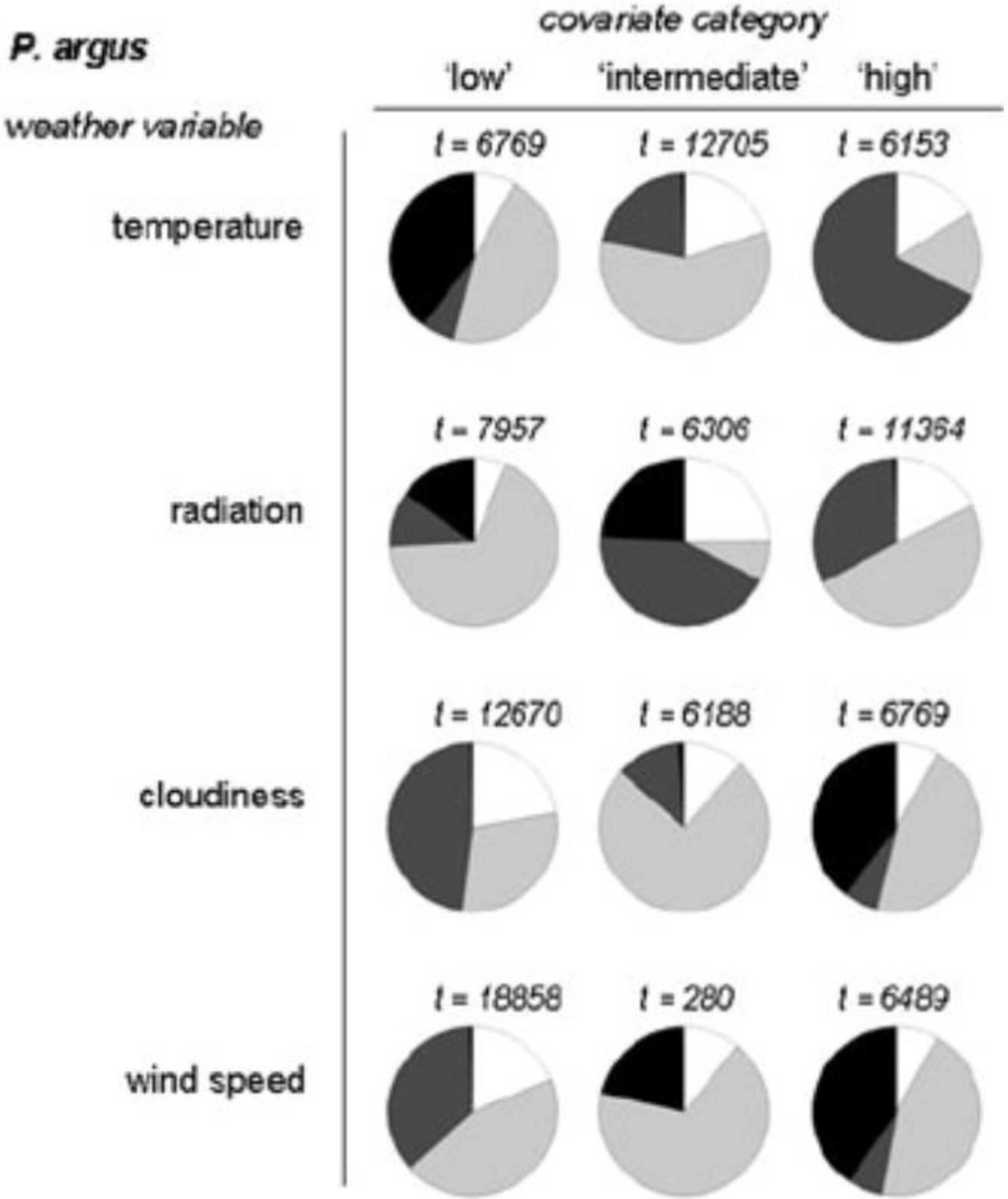


flying; resting; nectaring; basking; t = recorded time (s)


M. jurtina
covariate category
'low'
'intermediate'
'high'
weather variable
temperature
t = 24805
t = 26980
t = 7958
radiation
t = 26903
t = 21599
t = 11236
cloudiness
t = 11028
t = 16327
t = 32388
wind speed
t = 27084
t = 29774
t = 2835
flying; resting; nectaring; basking; t = recorded time (s)



flying; resting; nectaring; basking; t = recorded time (s)



flying; resting; nectaring; basking; t = recorded time (s)

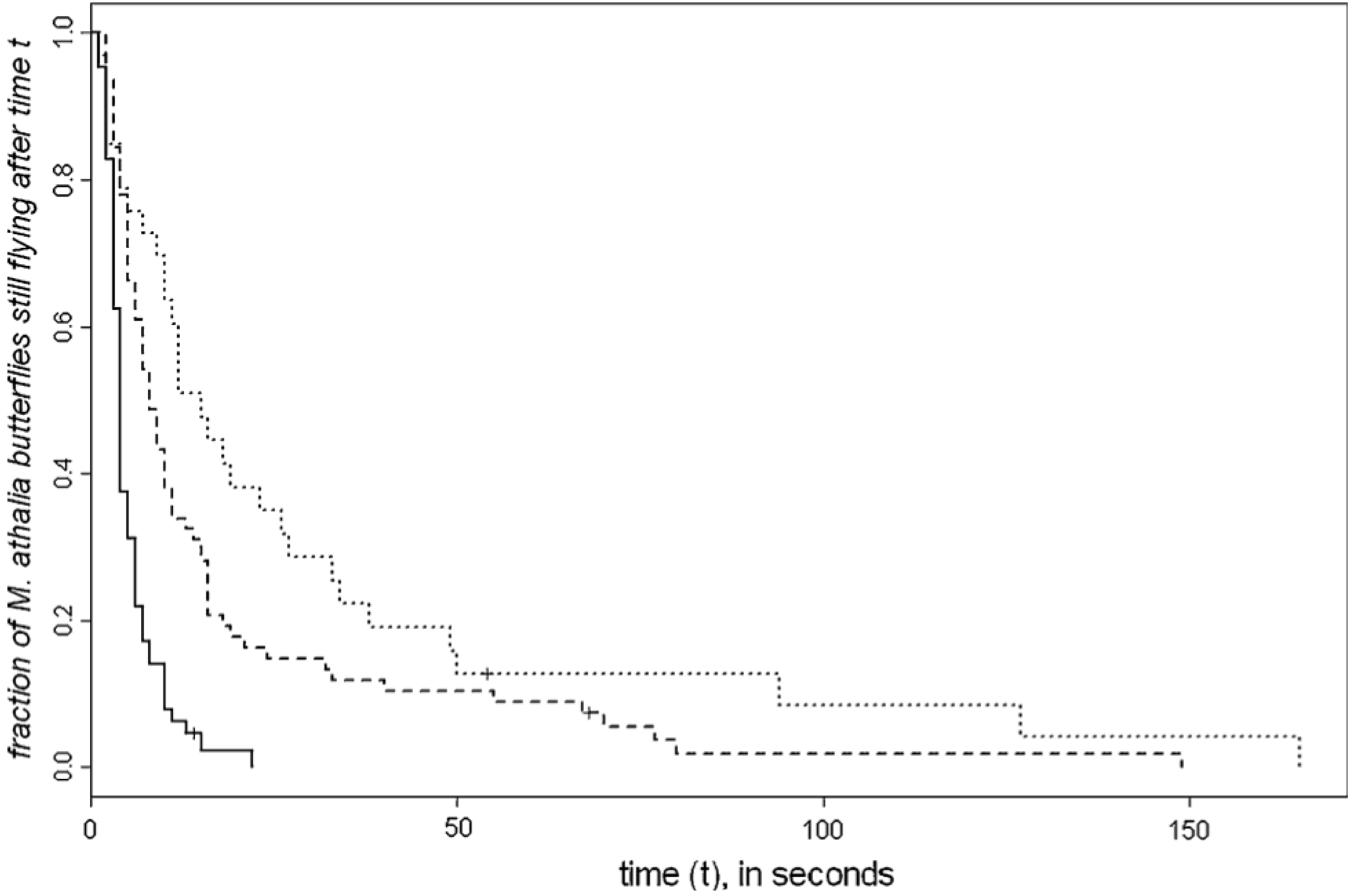


Fig. 4 Kaplan–Meier survival curve for flying bouts of *M. athalia* with temperature as single covariate. Under low temperature (*solid line*; less or equal to 14°C), butterflies terminate flying bouts sooner than under intermediate temperature (between 14 and 25°C; *dashed line*; $P = 2.9\text{E} - 08$) and high temperature (more than 25°C; *dotted line*; $P = 1.1\text{E} - 09$).

Conclusion

It was shown that:-

1. Duration of flying bouts and net displacement of butterflies generally increased with temperature

2. Duration of flying bouts and proportion of time spent flying decreased with cloudiness.

3. When butterflies fly longer bouts, start flying more readily, spend more time flying, and fly over longer distances, we expect dispersal propensity to increase.

4. Furthermore, the higher the flight activity, the higher the probability to leave a patch. We have shown that colonisation frequencies increased with temperature and radiation and decreased with cloudiness.

So, It’s not all black n white.

References

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- Causes and Consequences of Dispersal in Plants and Animals, By: Emily K. Croteau (Watershed Studies Institute, Murray State University) © 2010 Nature Education
- Burmese pythons in Florida: A synthesis of biology, impacts, and management tools
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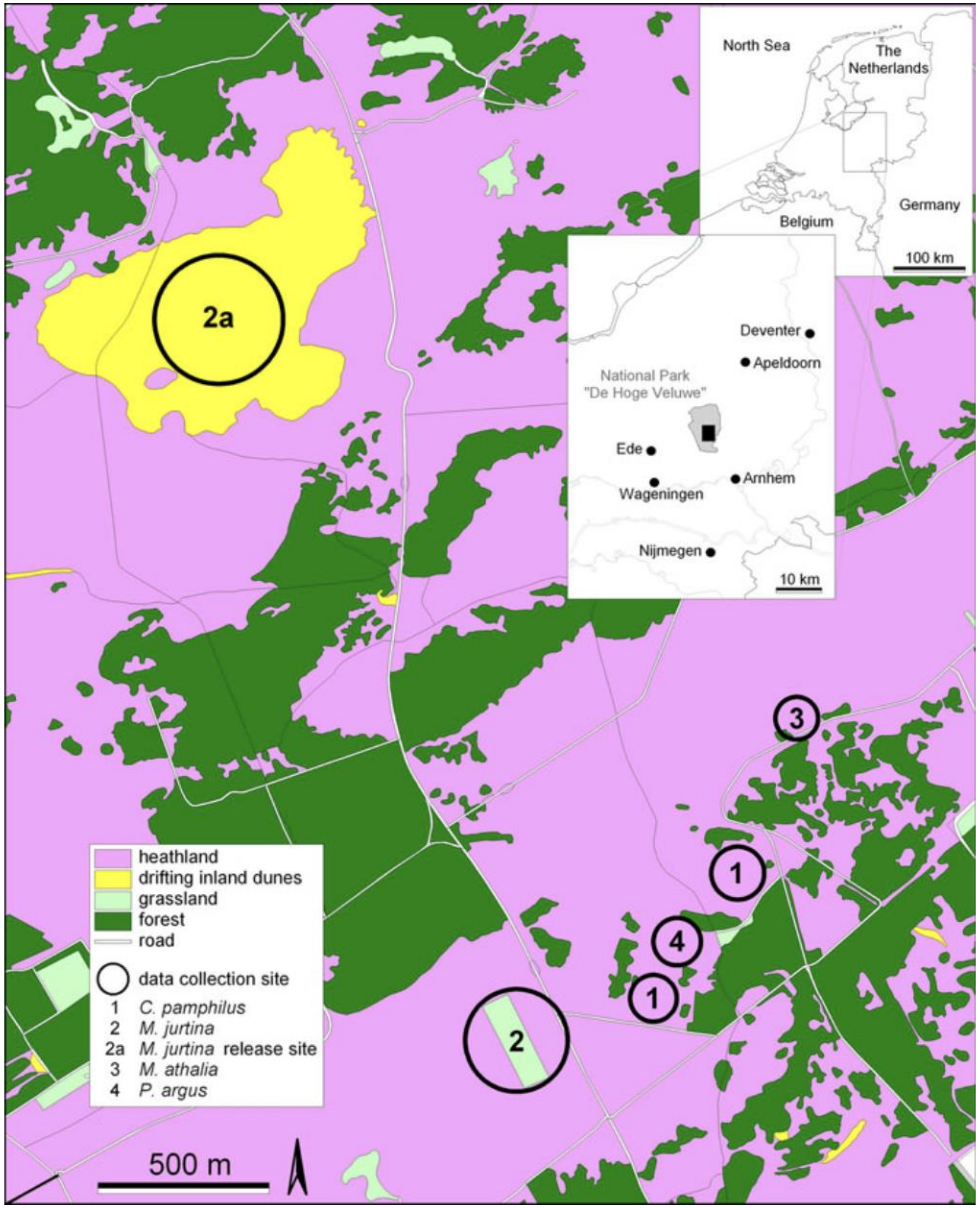
- How Does Changing Environment Influence Plant Seed Movements as Populations of Dispersal Vectors Decline? Jonathan O. Hernandez Muhammad Naeem [2] and Wajid Zaman [3,]*
- Dispersal abilities favor commensalism in animal-plant interactions under climate changePriscila Lemes ,Fabiana G. Barbosa ,Babak Naimi ,Miguel B. Araújo et al.
- Effect of local weather on butterfly flight behaviour, movement, and colonization: significance for dispersal under climate change by Anouk Cormont Agnieszka et al.

Climate report n Map

In the Netherlands, the summer of 2006 was hot and dry in June and July (July was on average the hottest month since the beginning of the records by the Royal Netherlands Meteorological Institute in 1706), while August was relatively chilly and rainy. After a very mild spring, the weather during the summer of 2007 was changeable and rainy.

Table 1 Means (standard deviation) of temperature, radiation, cloudiness, and wind speed during the fieldwork in 2006 and 2007

Year	Temperature (°C)	Radiation (°C)	Cloudiness (%)	Wind speed (Bft)
2006	26.5 (4.7)	17.6 (8.3)	47.0 (39.5)	3.3 (1.7)
2007	19.5 (3.4)	16.3 (9.1)	52.4 (28.0)	3.6 (2.3)



Thank you