



MINISTÈRE  
DE LA TRANSITION  
ÉCOLOGIQUE  
ET DE LA COHÉSION  
DES TERRITOIRES

*Liberté  
Égalité  
Fraternité*



Séminaire du  
**plan national d'actions**  
en faveur du Puffin des Baléares

24 au 26 juin 2024



# Climate change and migration

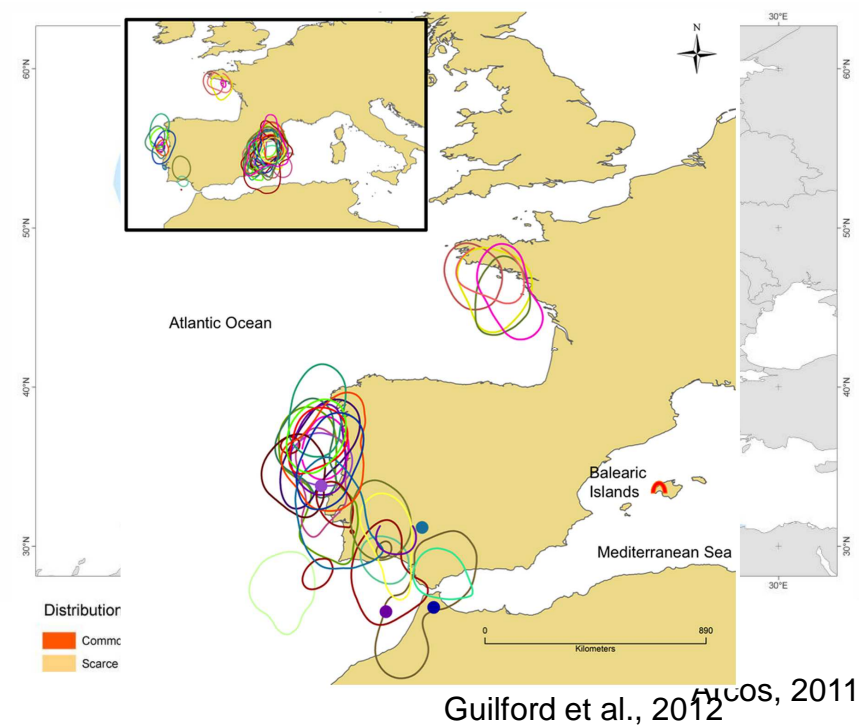
---

**Migratory plasticity facilitates range-shift in response to climate change**

Séminaire du  
**plan national d'actions**  
en faveur du Puffin des Baléares

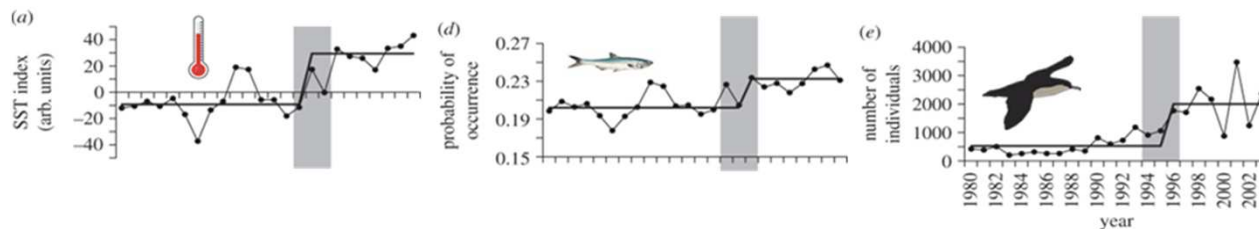
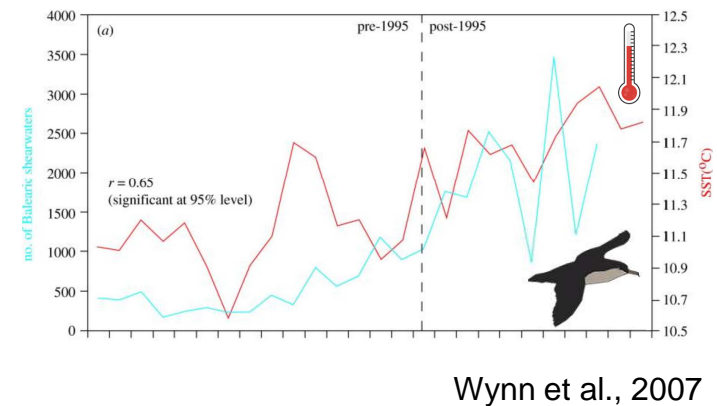
# Balearic shearwater migration

- Post-breeding migration occurs from early summer through to winter.
- Birds migrate into the eastern Atlantic, along the coasts of western Europe.
- There are two key migratory areas for birds from Mallorca: in the northern Bay of Biscay and around western Iberia.



# Impacts of climate change

- Sightings data suggest there may be a northwards range shift in the post-breeding migration (Wynn et al., 2007).
- This may be driven by shifts in prey availability resulting from climate change and rising sea temperatures (Luczak et al., 2011).
- An increasing proportion of the world population is migrating to seas off northern France.



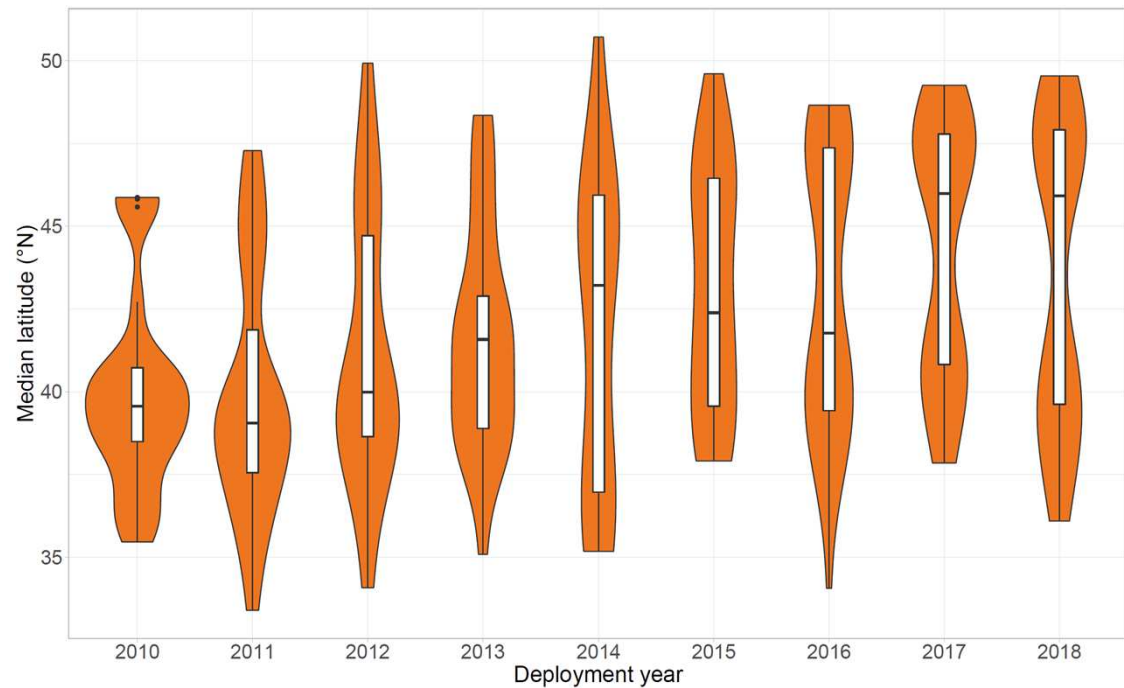
# Methods: long-term geolocator tracking

- Year-round migration tracking from 2010 to 2019
- Tracking from 4 colonies on Ibiza and Mallorca
- 274 tracks from 145 shearwaters
- Summarised the spatial and phenological aspects of each migration



## Results: range shift

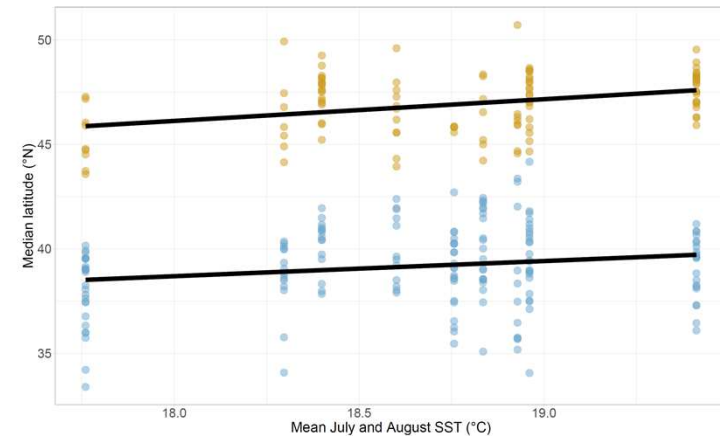
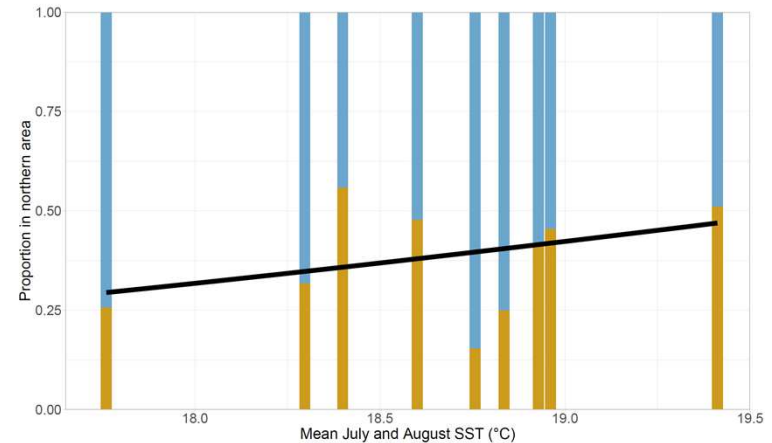
- **The post-breeding migration of Balearic shearwaters is shifting northwards.**  
25.5 km per year,  $F_{4,93} = 108.6$ ,  $p < 1 \times 10^{-15}$ .
- **This shift is best predicted by sea-surface temperature, implicating climate change.**  
 $\Delta AIC_c = -10.9$ .



# Results: range shift

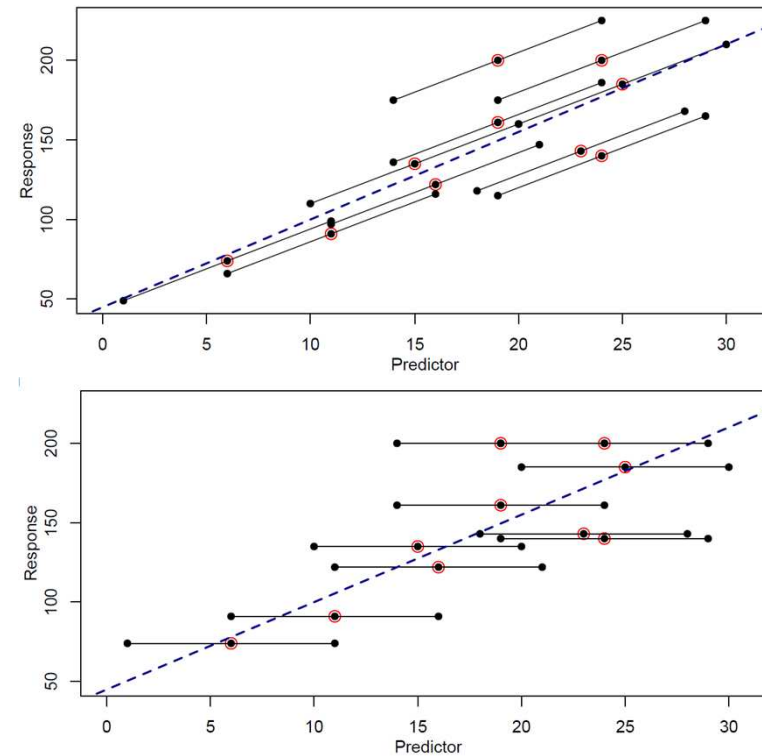
## The range shift has two parts:

- An increasing proportion of birds are migrating to the northern migratory area in Biscay and the English Channel.
- The latitudes birds migrate to within each area are shifting north.
- The question remains how this occurs. The range shift could occur because
  - i. Adult birds have fixed migratory behaviour but there is a selective effect favouring birds which migrate further north
  - ii. Adult birds are flexible in where they migrate to and respond to increases in temperature



# Methods: detecting plasticity

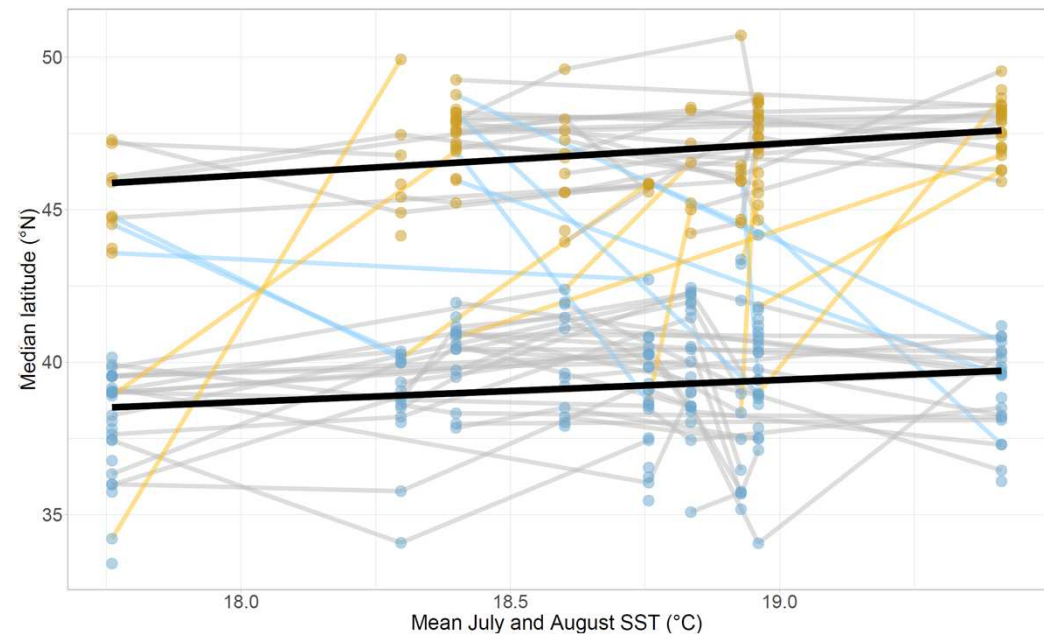
- For the relationships between temperature and migratory destination, we calculated within- and between-individual slopes using the method from van de Pol & Wright (2009).
- A significant within-individual slope indicates plasticity.
- A significant difference between the within- and between-individual slope indicates selection.





## Results: selection and plasticity

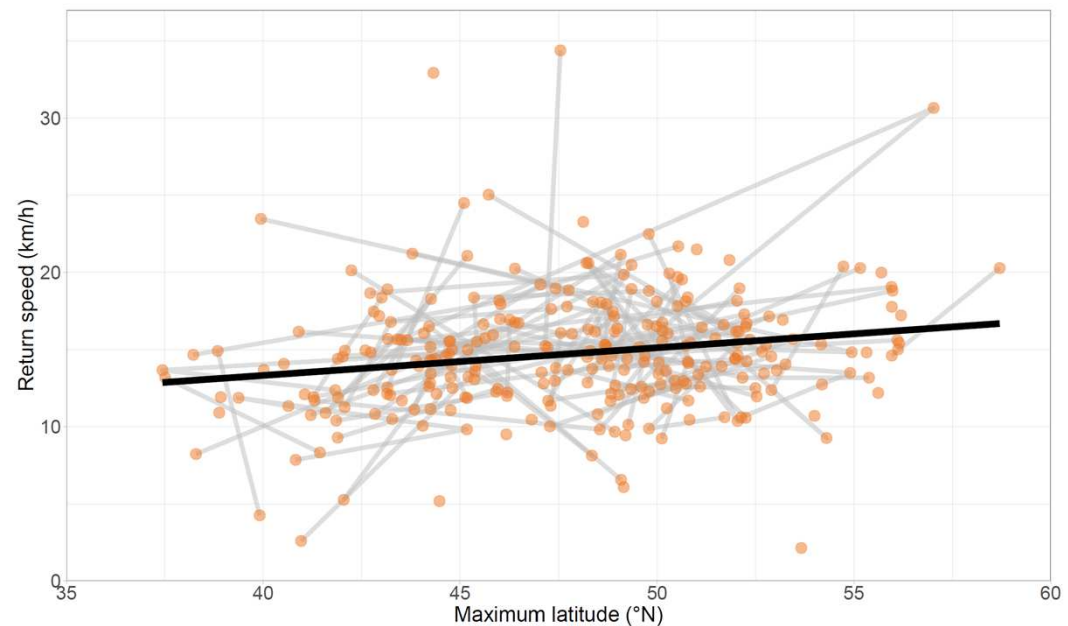
- The probability of migrating to the northern area increased significantly with temperature between individuals.  
Log odds 1.79 per °C,  $\chi^2_1 = 4.6$ ,  $P = 0.033$ .
- However, the probability of migrating to the northern or southern area did not change within individuals, suggesting a selection effect.  
 $\chi^2_1 = 0.0001$ ,  $P = 0.988$ .
- There was a positive within-individual slope of migratory latitude against temperature.  
0.6° latitude per °C,  $\chi^2_1 = 4.1$ ,  $P = 0.044$ .
- This was not significantly different to the between-individual slope, indicating no detectable effect of selection.



# Results: speed

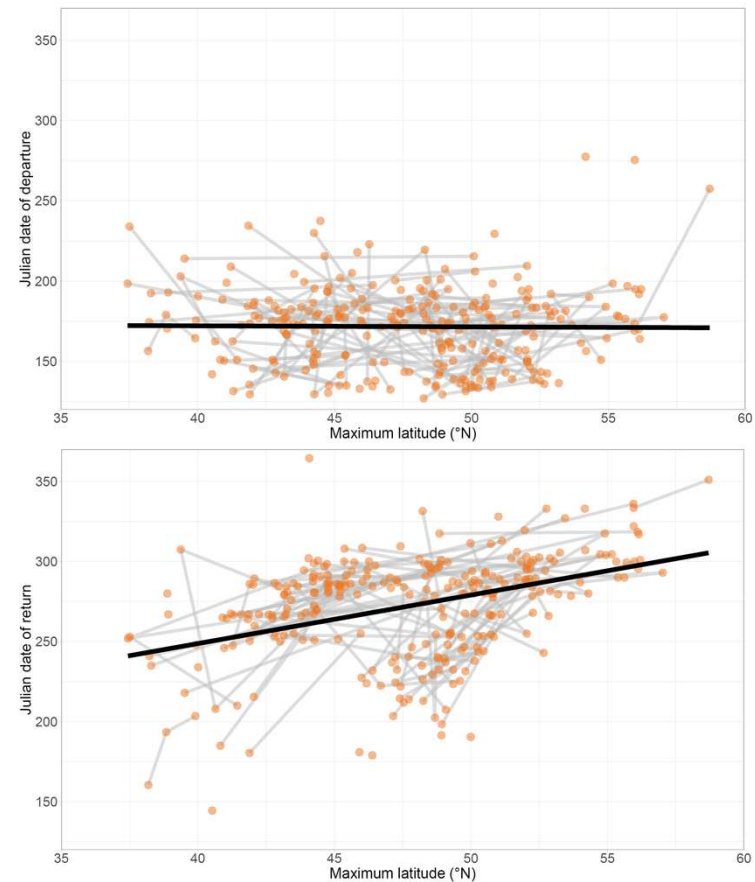
## Shearwaters increase their migration speeds when they migrate further north

- **Average return speeds increase with maximum latitude.**  
0.23 km/h per 1° latitude,  $\chi^2_1 = 8.5$ ,  $P = 0.004$ .
- **This response is present at the very start of return migration, indicating that shearwaters are able to anticipate the increased distance.**  
0.071 km/h per 100 km,  $F_{1,272} = 8.9$ ,  $P = 0.003$ .



# Results: phenology

- **Departure at the start of migration did not change with migratory latitude.**  
 $\chi^2_1 = 1.9$ ,  $P = 0.171$ .
- **However, shearwaters migrating further north returned later.**  
5.4 day per  $1^\circ$ ,  $\chi^2_1 = 81.8$ ,  $P < 1 \times 10^{-15}$ .
- **This was a very large delay.**  
Birds returning from furthest north arrived almost 50 days later than those from furthest south.



## Further questions

- **It seems positive that individual shearwaters can respond flexibly to climate change.**  
But whether this response is adaptive is unclear.
- Increased return speeds over longer distances may result in physiological costs.
- The increase in return speed is insufficient to avoid delayed return to the Mediterranean, which may impact pre-breeding foraging and courtship.
- The delayed return to the Mediterranean may also constrain breeding phenology.
- The selective effect on migratory area may be natural selection or learning during the immature stage.



# Conclusions

- **Northwards range shift** in the post-breeding migration of Balearic shearwaters, likely bringing more of the population into French waters.
- Range shift takes two forms: a **selective** increase in the proportion of birds migrating to the northern area and a **plastic** shift in the latitudes of each area.
- This shift has knock-on effects on **migration speed** and **phenology**.
- The impacts on the breeding success and survival of shearwaters are unknown.



# Acknowledgements

- **This work is the result of a collaboration with authors who have contributed over many years:**  
Joe Wynn, José Manuel Arcos, Rhiannon Austin, Josephine Blagrove, Sarah Bond, Gemma Carrasco, Karine Delord, Lewis Fisher-Reeves, David García, Natasha Gillies, Tim Guilford, Isobel Hawkins, Paris Jagers, Christian Kirk, Maite Louzao, Lou Maurice, Miguel McMinn, Thierry Micol, Joe Morford, Greg Morgan, Jason Moss, Elisa Miquel Riera, Ana Rodriguez, Katrina Siddiqi-Davies, Henri Weimerskirch, Russell Wynn and Oliver Padget
- **Funders:**  
Future of the Atlantic Marine Environment project, LIFE+ INDEMARES, the Ibiza Preservation Fund, Microsoft Research Cambridge, Natural England, the RSPB, ACAP, the Leverhulme Trust and UKRI.