



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

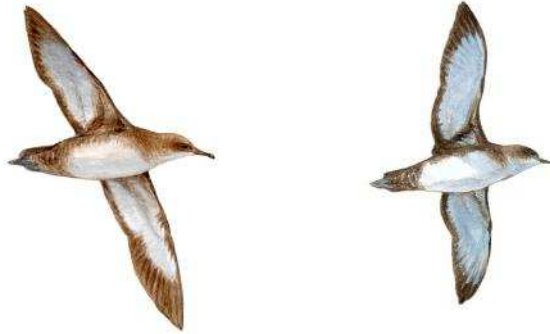


Global spatial ecology of Balearic and Yelkouan shearwaters



M. Gómez-Álvarez, V. Morera-Pujol, M. Louzao, J.M. Arcos, D. Garcia, O. Padget, T. Guilford, R. Austin, T. Militão, K. Bourgeois, J. González-Solís, S. Kapelij, M. Zenatello, N. Baccetti, M. Austad, N. Barbara, G. Karris, D. Portolou, S. Xirouchakis, C. Perón, D. Grémillet, R. Ramos

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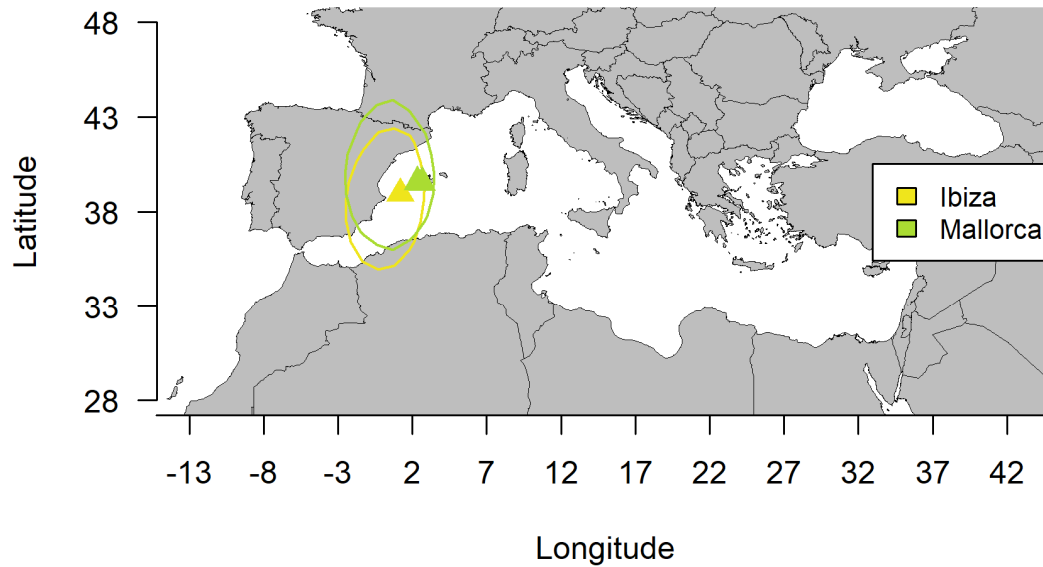
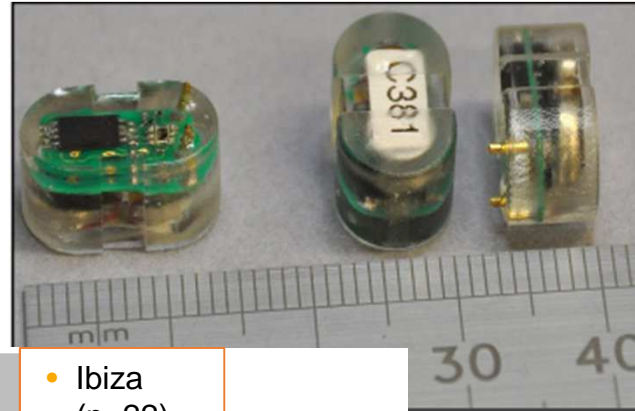
Introduction

- **Unclear taxonomic boundaries between Balearic and Yelkouan shearwaters.**
 - Morphology and colouration similarities (Austin et al., 2004)
 - Hybridisation in Minorca (Genovart et al., 2005)

} Early stage of evolutionary divergence (Ferrer Obiol et al., 2023)
- **Minimal contact during breeding and non-breeding seasons** (Austin et al., 2019; Militão et al., 2013)
- **Global spatial ecology** ← when? how?
 - Insights into the ecological divergence of these two taxa
 - Distribution and phenology at a metapopulation level

Materials & Methods

- Light-level geolocators (Global Sensor Locators, GLS)



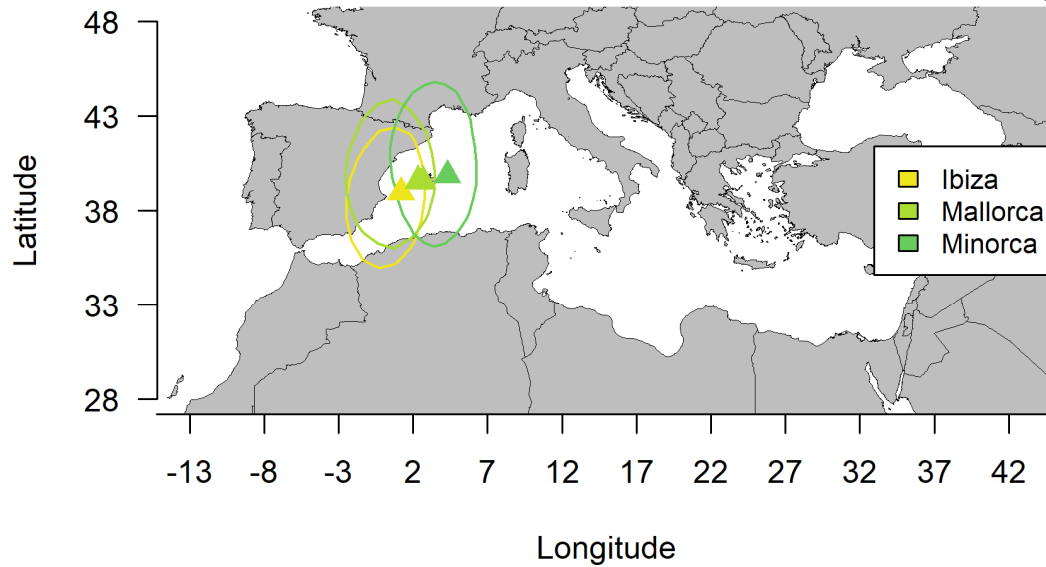
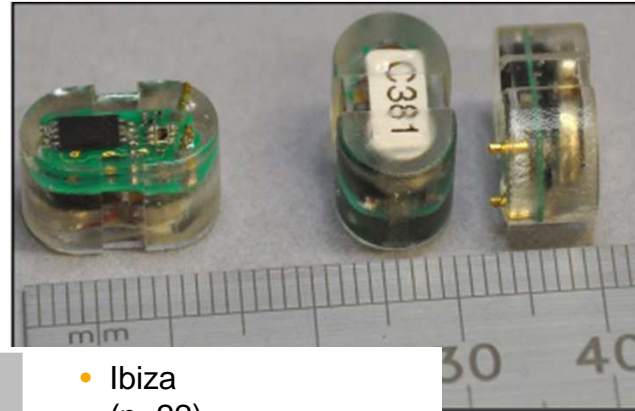
- Ibiza (n=22)

- Mallorca (n=78)

PUFMAU

Materials & Methods

- Light-level geolocators (Global Sensor Locators, GLS)



- Ibiza (n=22)

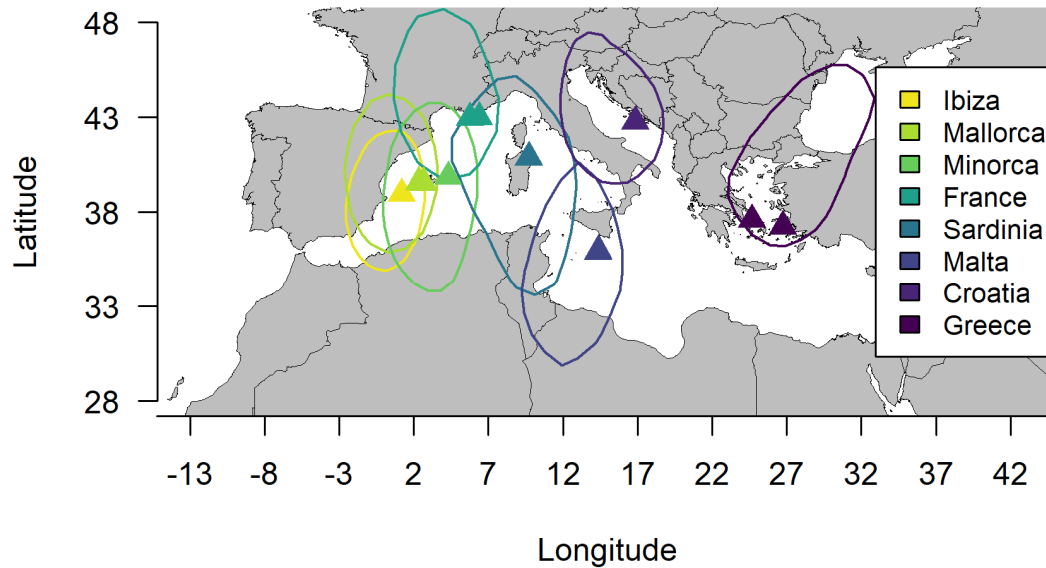
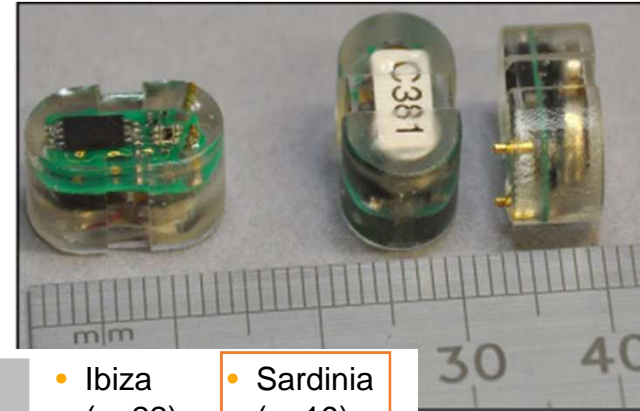
- Mallorca (n=78)

- Minorca (n=15)

HYBRID

Materials & Methods

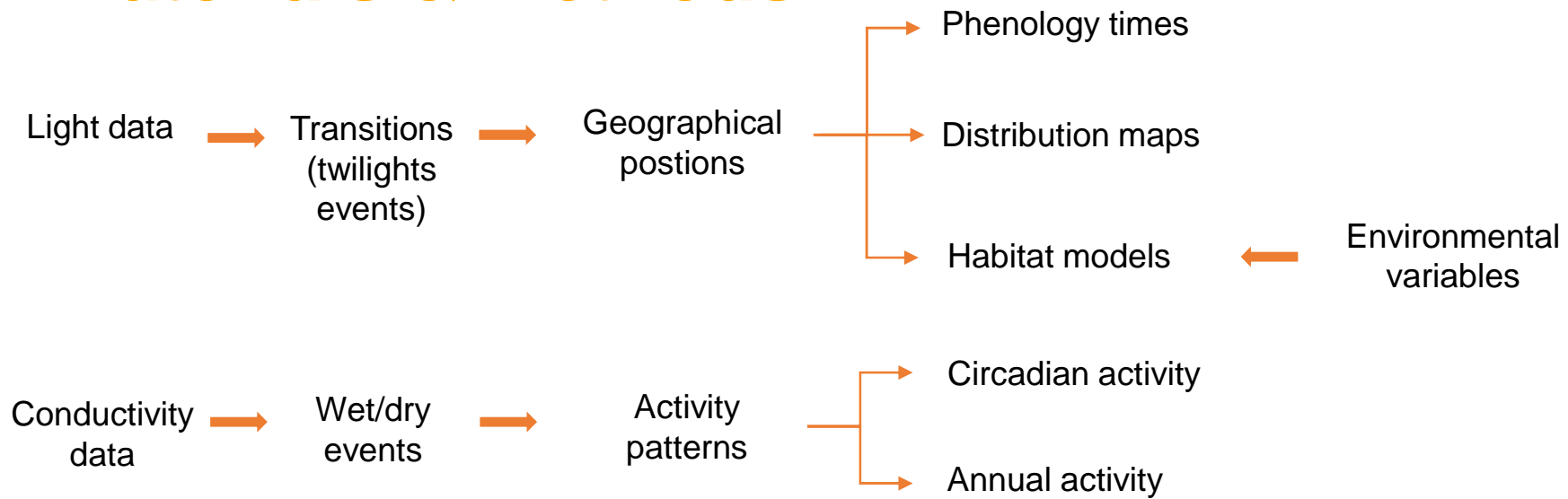
- Light-level geolocators (Global Sensor Locators, GLS)



- Ibiza (n=22)
- Mallorca (n=70)
- Minorca (n=12)
- France (n=39)
- Sardinia (n=19)
- Malta (n=9)
- Croatia (n=9)
- Greece (n=9)

PUFYEL

Materials & Methods



Materials & Methods

Phenology ← LMM & Model selection to test the effect of taxa (PUFMAU, HYBRID, PUFYEL)

N = 147 trips

Distribution mapping ← Kernel Density Estimation (KDE 50%) of each population

N = 192 trips

Habitat modelling ← BART (Bayesian Additive Regression Trees)

- 8 populations (including HYBRID)
- 2 Taxa (PUFMAU & PUFYEL)
- Suprataxa

N = 192 trips

Activity modelling ← GLMM, GAMM & Model selection to test the effect of taxa (PUFMAU, HYBRID, PUFYEL)

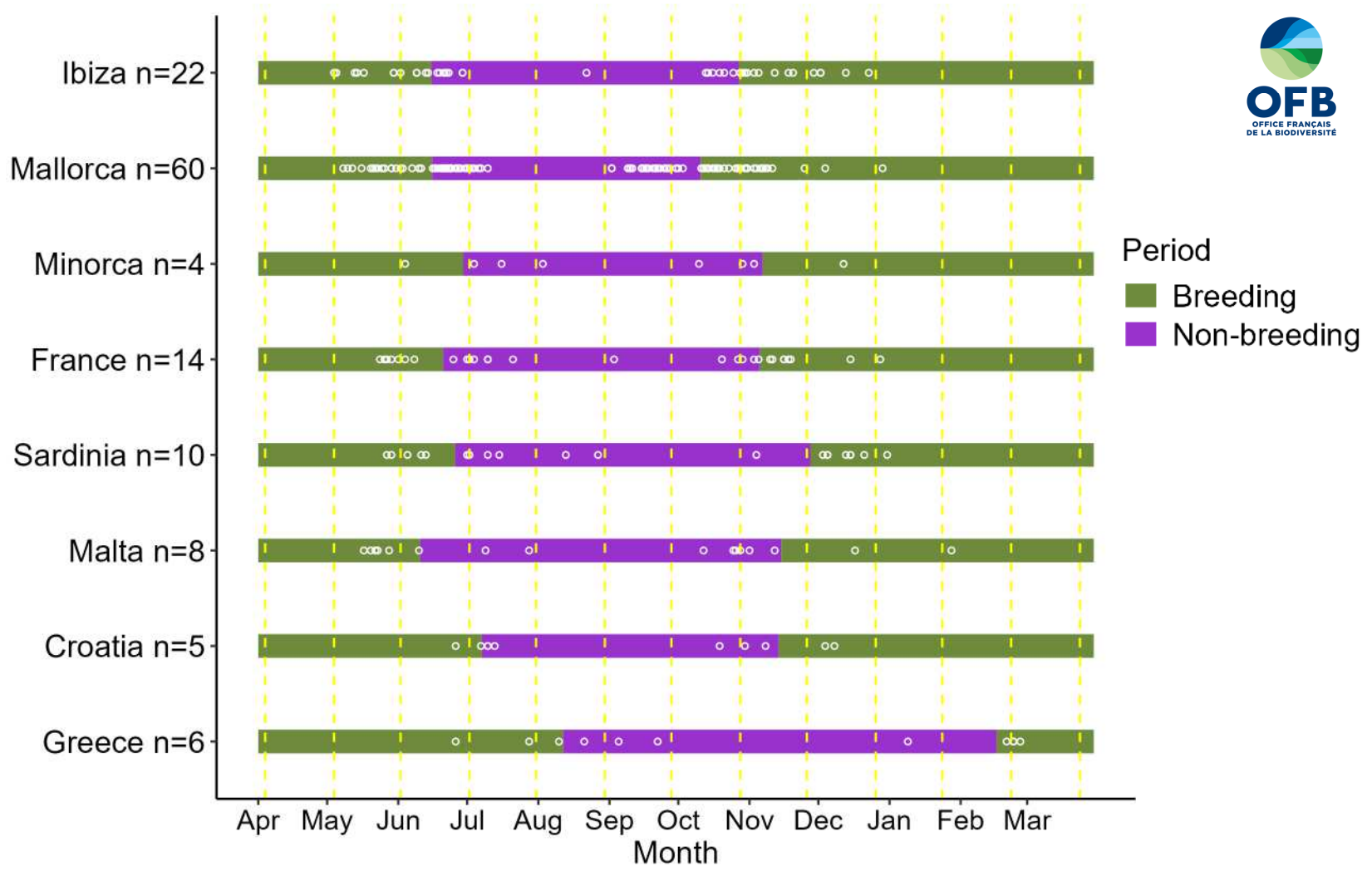
N = 170 trips

N° of positions
corrected by
sample effort
and population
size

Phenology models

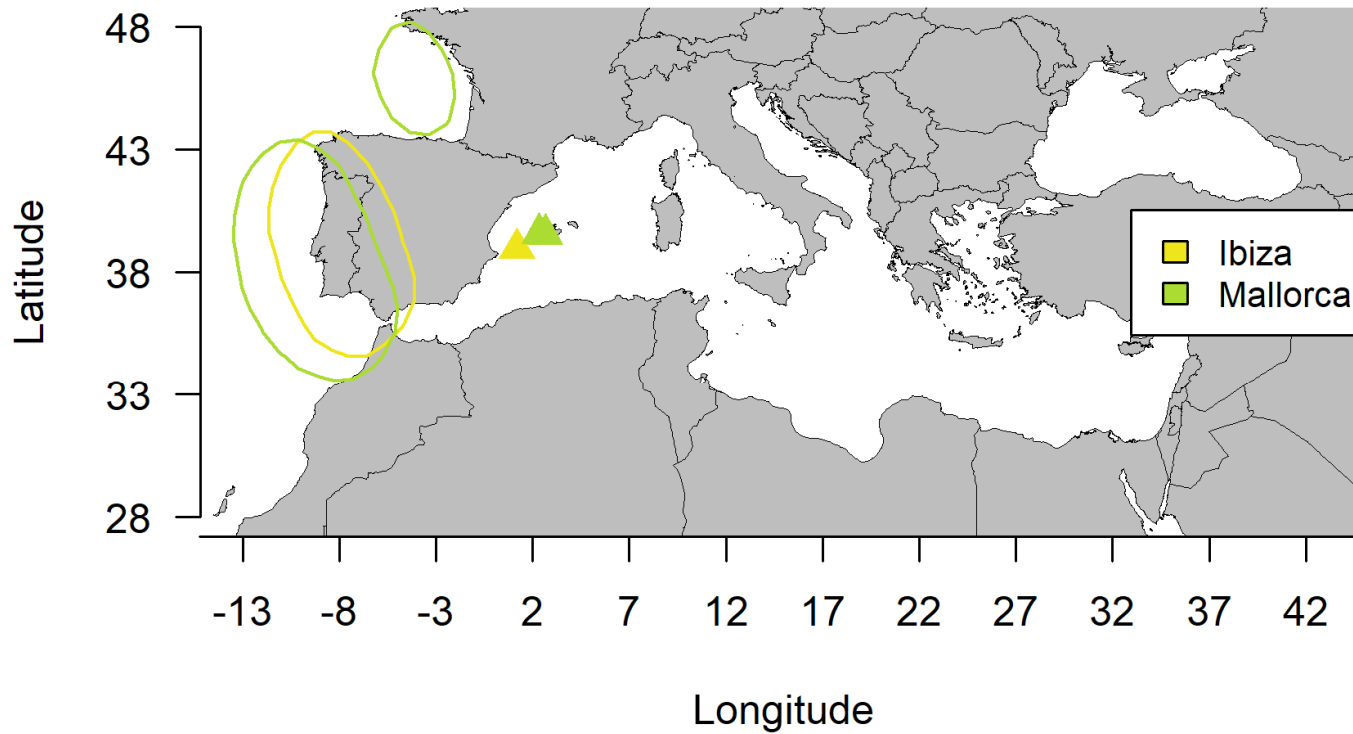
Results

	Start migration	End migration	Migration duration
AICc			
Taxon	1255.9	1219.0	1258.4
NULL	1268.1	1234.7	1273.3
<i>Fixed effects</i>			
PUFMAU	15-06 ± 14.5	19-10 ± 26.3	122.8 ± 13.0
HYBRID	29-06 ± 26.7	06-11 ± 39.1	123.1 ± 23.2
PUFYEL	03-07 ± 17.5	03-12 ± 17.6	151.6 ± 10.9
<i>Random effects</i>			
Population (within taxon)	398.7 ± 20.0	1336.2 ± 36.6	242.0 ± 15.6
Year	14.42 ± 3.8	51.8 ± 7.2	131.7 ± 11.5
Ring	0.0 ± 0.0	214.8 ± 14.7	224.0 ± 15.0
Residual	483.7 ± 22.0	464.2 ± 21.5	747.9 ± 27.3



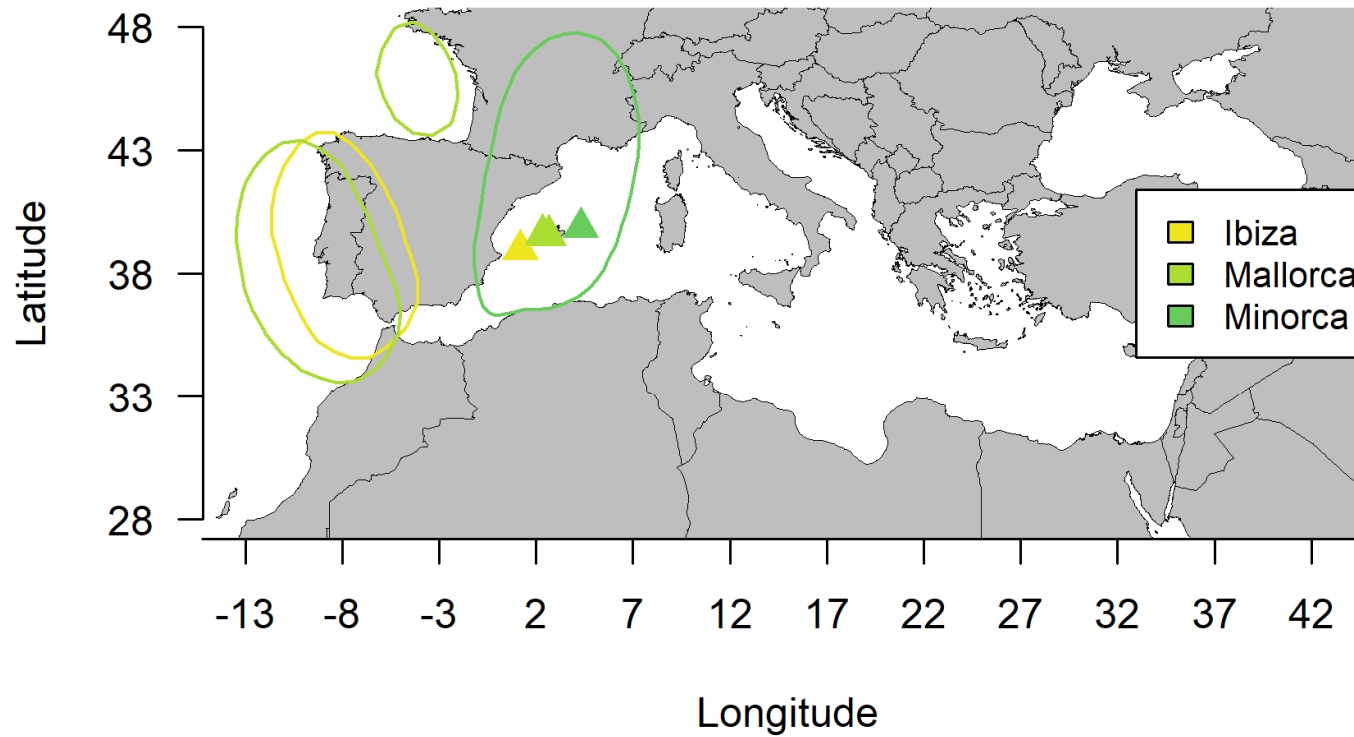
Non-breeding distribution

Results



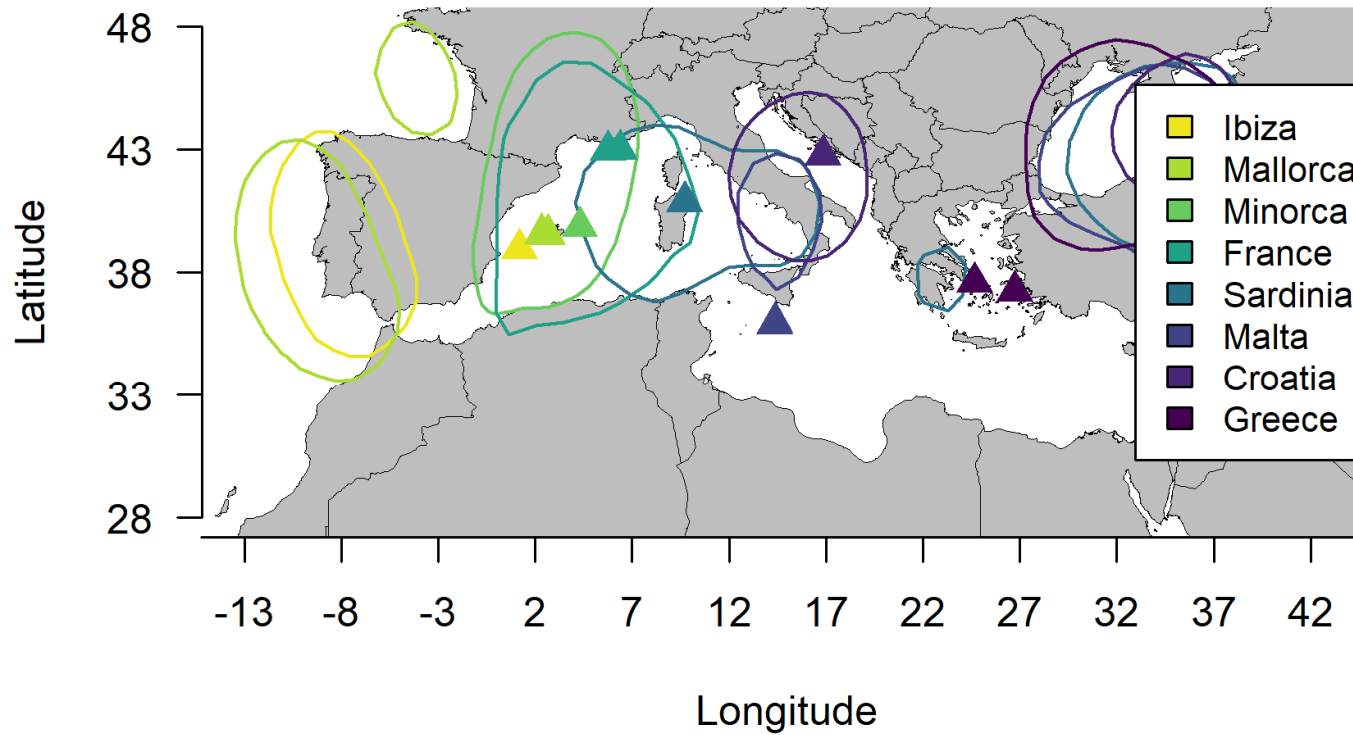
Non-breeding distribution

Results



Non-breeding distribution

Results



Habitat models: Breeding period

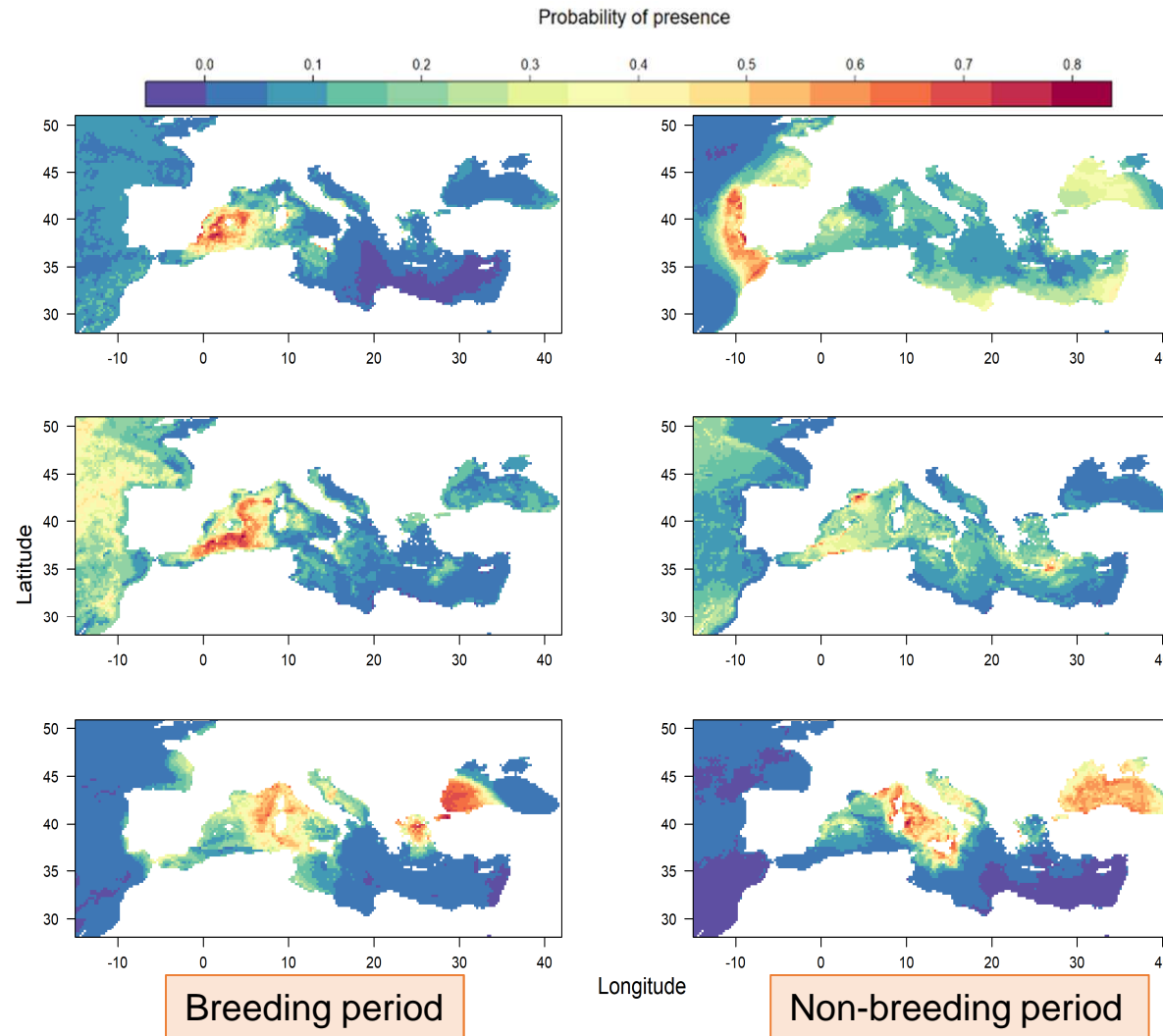
Population/ Group	AUC	CHLa mean breed	CHLa var breed	CHLa mean nonbreed	CHLa var nonbreed	SST mean breed	SST var breed	SST mean nonbreed	SST var nonbreed	SSS mean breed	Wind mean breed	BATHYSLOPE	DIST COL
Ibiza	0,965		0,171		0,169			0,164		0,147	0,169		0,180
Mallorca	0,968		0,259					0,264		0,218			0,259
France	0,970		0,165			0,168			0,162	0,167	0,165		0,173
Sardinia	0,882					0,215	0,177			0,224		0,178	0,206
Malta	0,911				0,141	0,136		0,148		0,131		0,147	0,138
Croatia	0,971		0,172				0,166		0,159		0,168	0,171	0,163
Greece	0,946				0,103	0,096	0,088	0,113	0,094	0,098	0,102	0,09	0,100
PUFMAU	0,969		0,205		0,201			0,196		0,183			0,215
Minorca (Hybrid)	0,974		0,207		0,208					0,178		0,206	0,201
PUFYEL	0,862					0,165		0,151		0,183	0,157	0,163	0,181
Suprataxon	0,844					0,156	0,152	0,158		0,189		0,159	0,187

Habitat models: Non-breeding period

Population/ Group	AUC	CHLa mean breed	CHLa var breed	CHLa mean nonbreed	CHLa var nonbreed	SST mean breed	SST var breed	SST mean nonbreed	SST var nonbreed	SSS mean nonbreed	Wind mean nonbreed	BATHY SLOPE	DIST COL	
Ibiza	0,905		0,120			0,126	0,128	0,126		0,121	0,129	0,126	0,124	
Mallorca	0,934		0,166					0,164	0,166	0,164	0,172		0,168	
France	0,971		0,247						0,235			0,247	0,267	
Sardinia	0,919				0,159	0,172		0,160		0,178	0,173		0,158	
Malta	0,935								0,197	0,18	0,208	0,204	0,21	
Croatia	0,988					0,142	0,137		0,131	0,136	0,155	0,143	0,156	
Greece	0,896					0,332		0,355		0,313				
PUFMAU	0,910							0,193	0,202	0,198	0,203		0,204	
Minorca (Hybrid)	0,909									0,202	0,196	0,200	0,206	0,197
PUFYEL	0,884		0,140		0,131	0,149		0,142		0,162	0,135		0,140	
Suprataxon	0,873					0,196		0,198		0,216	0,188		0,202	

Results

Habitat models



PUFMAU

Hybrid

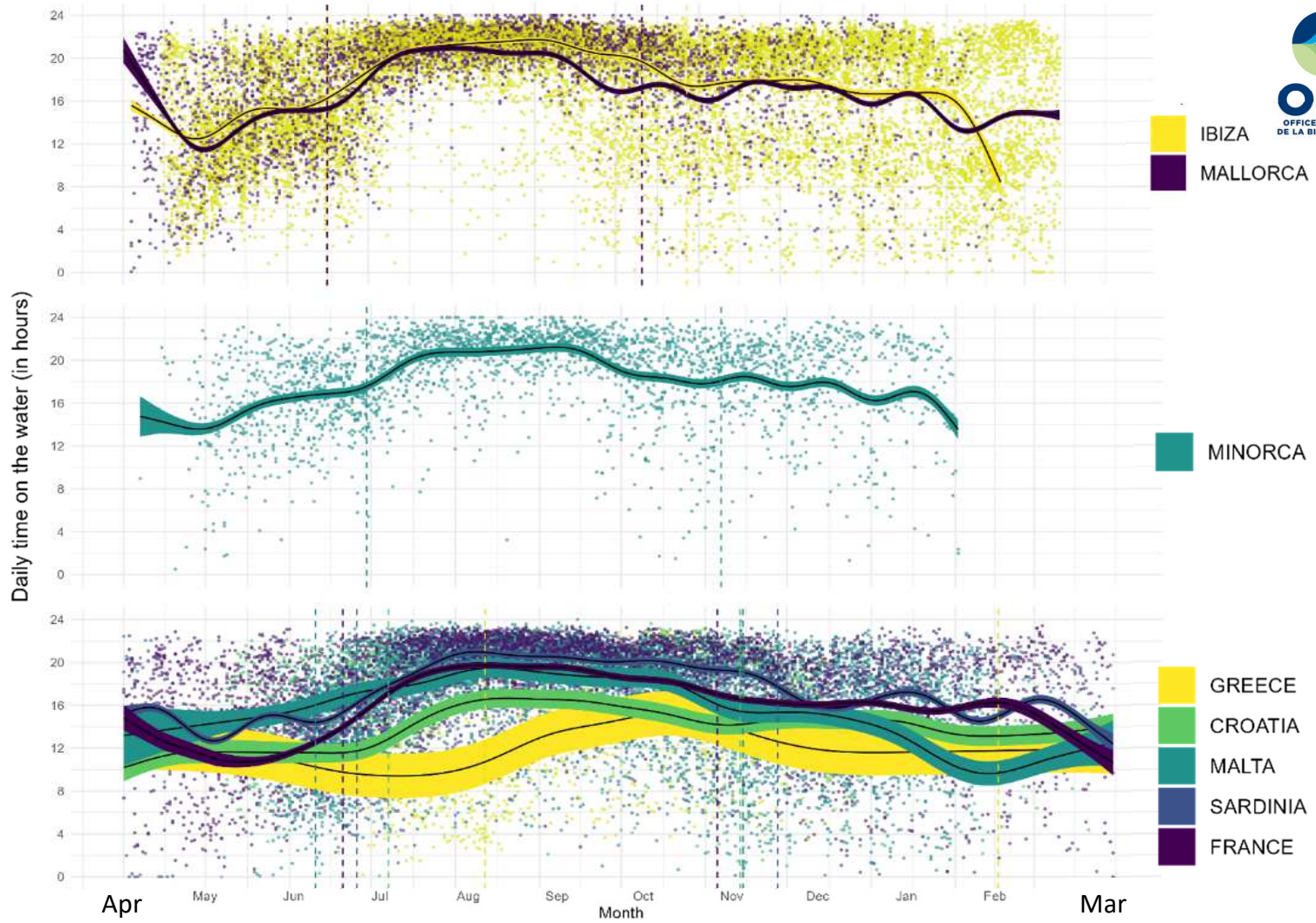
PUFYEL

Annual activity (Daily time on the water)

Results

	Period	
	Breeding	Non-breeding
AICc		
Taxon	116680.8	106018.7
NULL	116685.2	106021.6
<i>Fixed effects</i>		
PUFMAU	14.2 ± 1.1	19.2 ± 1.6
HYBRID	2.4 ± 1.0	0.7 ± 2.4
PUFYEL	-0.3 ± 0.7	-1.2 ± 2.1
<i>Random effects</i>		
Population (within taxon)	0.2 ± 0.4	1.3 ± 1.2
Year	5.6 ± 2.4	0.7 ± 0.8
Ring	2.9 ± 1.7	3.6 ± 1.9
Residual	24.6 ± 5.0	10.7 ± 3.3

PUFMAU



HYBRID

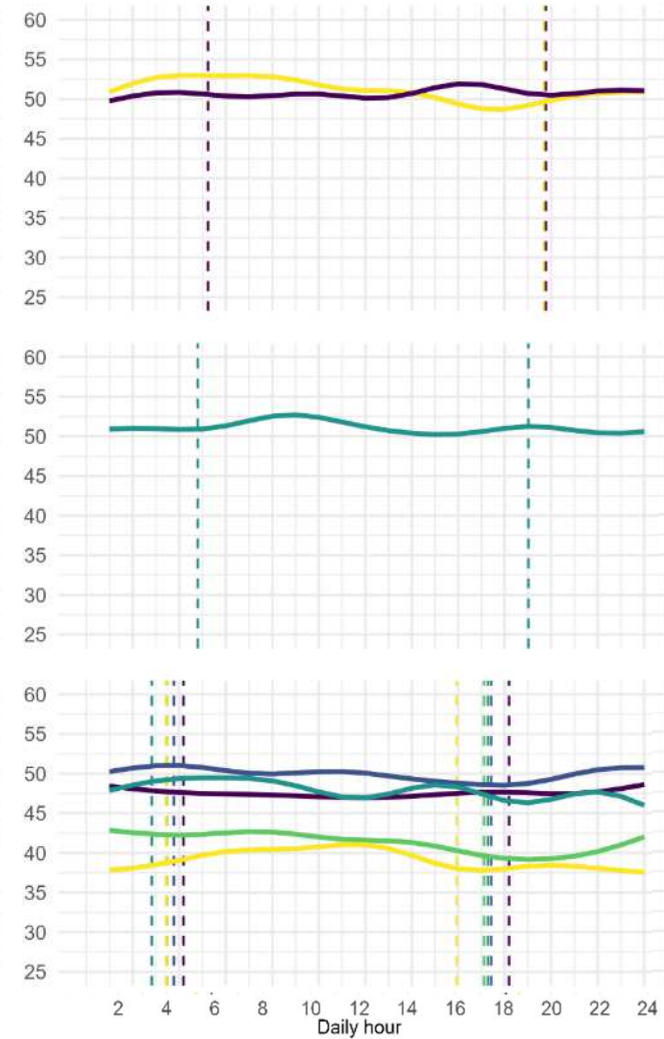
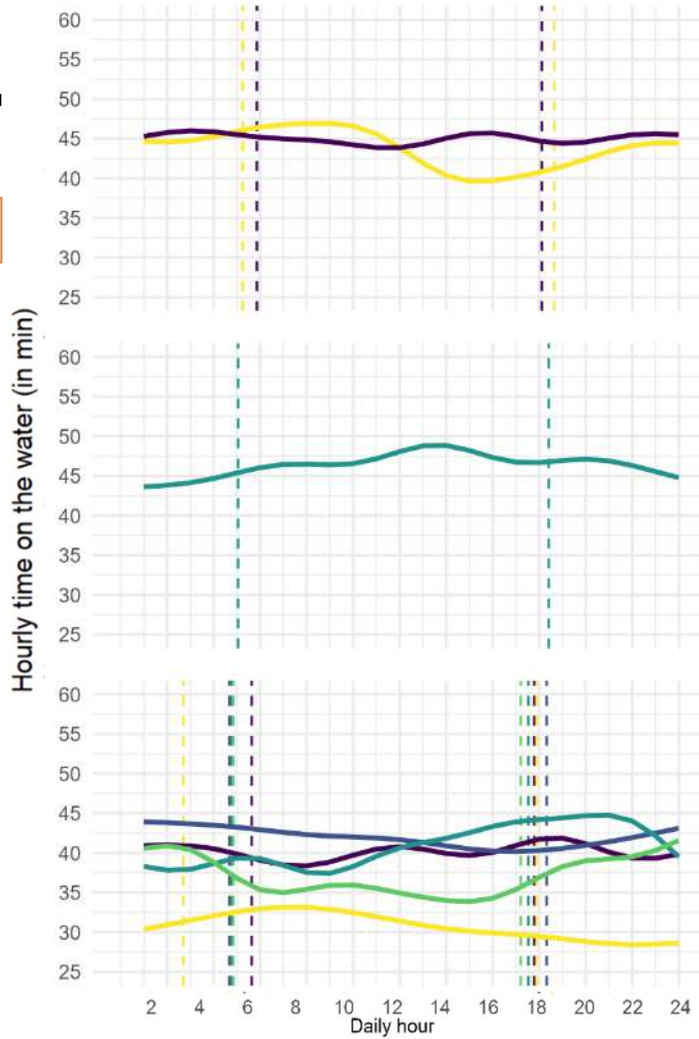
PUFYEL

Results

Circadian activity (Hourly time on the water)

	Period	
	Breeding	Non-breeding
AICc		
Taxon	4053204	4115713
NULL	4053212	4115721
<i>Fixed effects</i>		
PUFMAU	36.7 ± 3.5	48.7 ± 3.4
HYBRID	7.1 ± 4.9	1.7 ± 5.8
PUFYEL	-1.3 ± 3.7	-4.1 ± 4.1
<i>Random effects</i>		
Population (within taxon)	9.2 ± 3.0	18.7 ± 4.3
Year	24.5 ± 5.0	2.3 ± 1.5
Ring	30.2 ± 5.5	28.9 ± 5.4
Residual	473.9 ± 21.8	258.1 ± 16.1

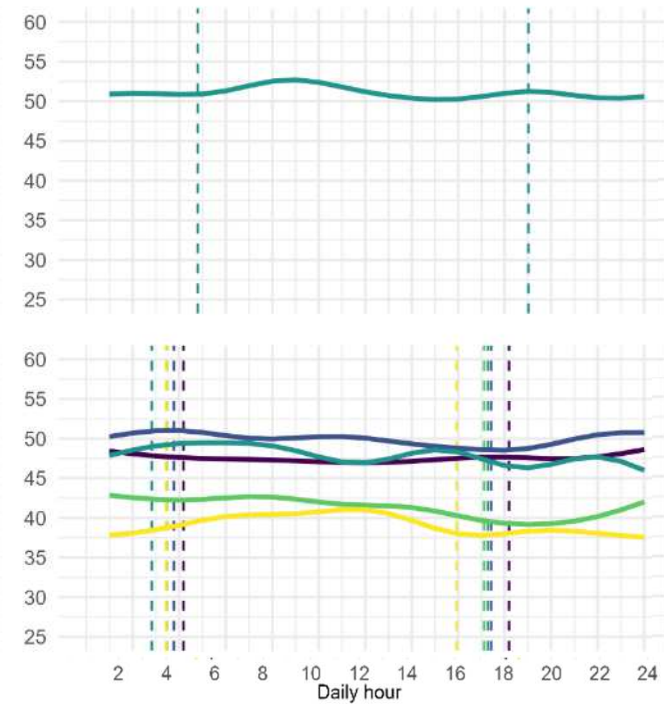
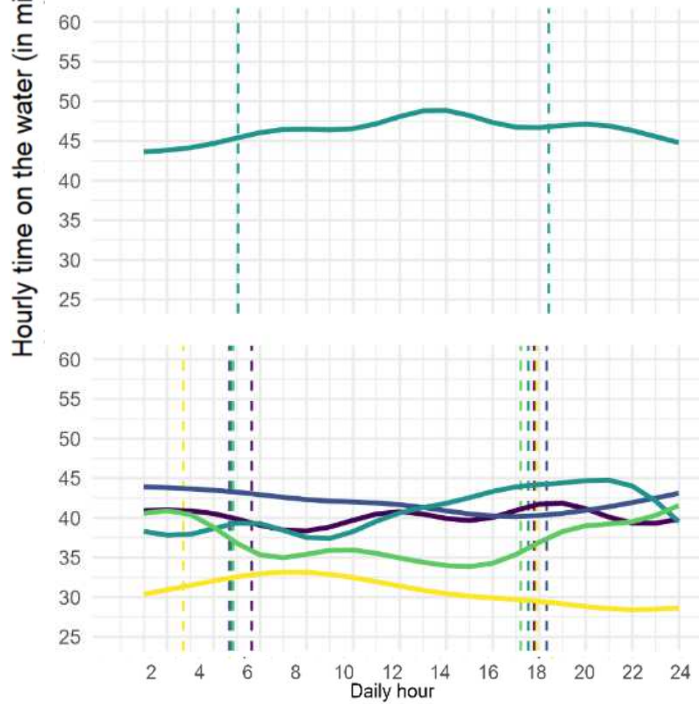
PUFMAU



 IBIZA
 MALLORCA

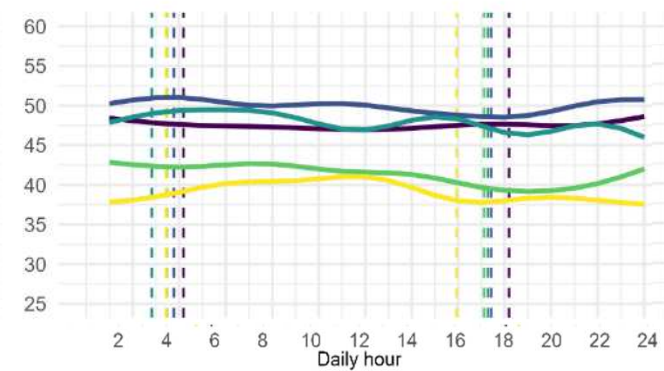
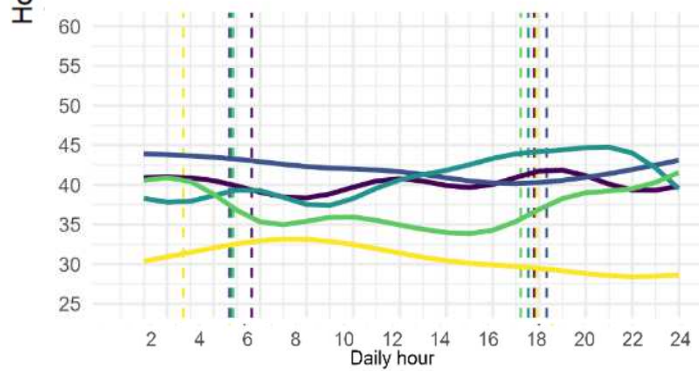
 MINORCA

HYBRID



 GREECE
 CROATIA
 MALTA
 SARDINIA
 FRANCE

PUFYEL



Discussion

- **No differences in phenology and activity** between PUFMAU and PUFYEL.
- **Complete segregation pattern** during non-breeding season.
- **Habitats differ among taxa**, which could promote local adaptation by different selective pressures.
- Furthermore, the low fit value of the **suprataxa model** provides evidences of **ecological divergence**
- Despite the limited sample size from the **hybrid population**, we observed **intermediate features** in relation to **distribution and phenology**.
- In alignment with genomic studies, we support the early and incomplete divergence between PUFMAU and PUFYEL, but we suggest that the **spatial segregation** and **habitat conditions** at sea may contribute to their **linage separation**.

Thank you!



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