

# Phylogéographie, structure génétique et évolution morphologique de la souris domestique sur l'archipel des Orcades



Pascale Chevret

Ronan Ledevin

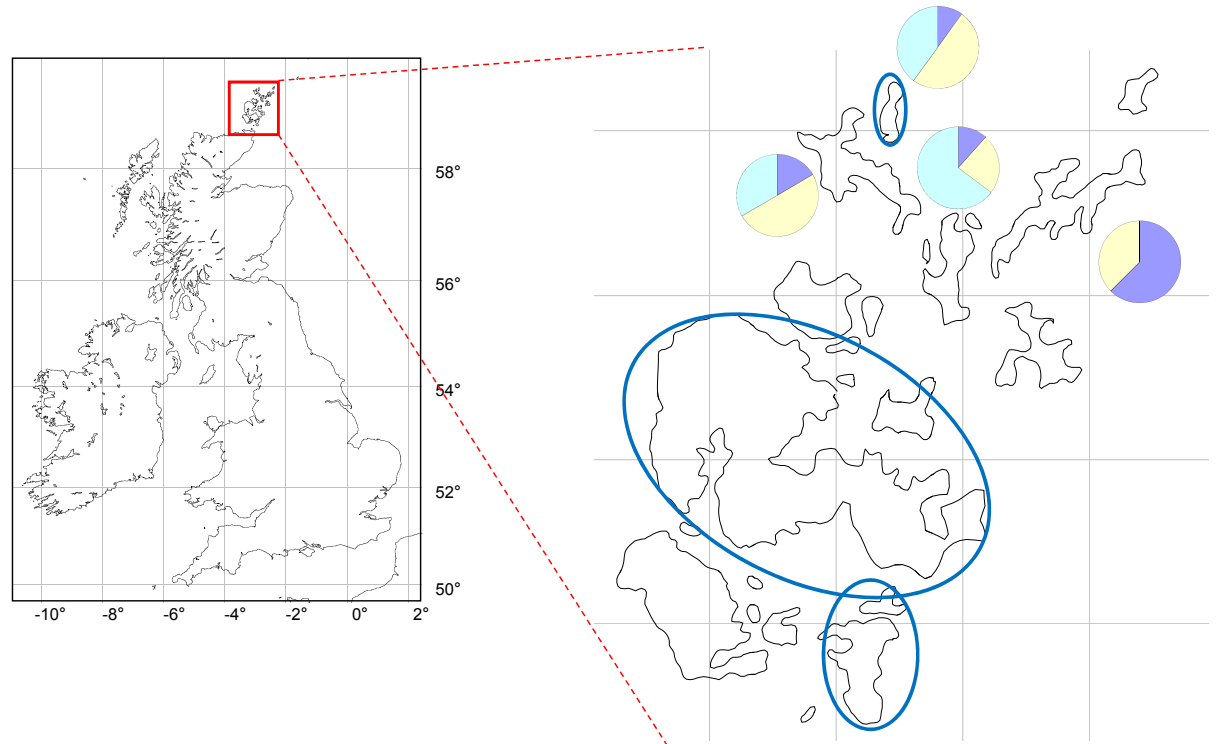
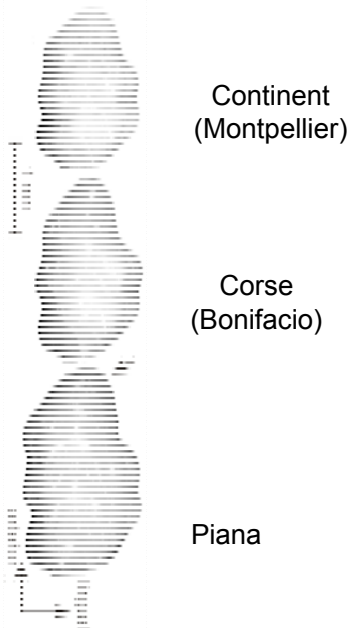
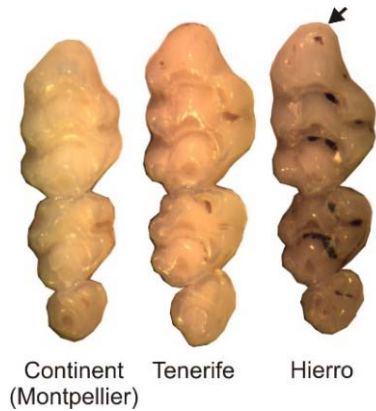
Sabrina Renaud



ANR  
BIGTOOTH

2012-2015

Archipel des Orcades  
Mission 1992 (Guila Ganem)  
Grande diversité morphologique

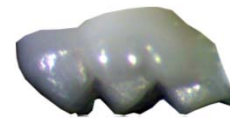


1ère molaire supérieure

■ normal

■ bourrelet

■ cuspidé



Les Orcades (Novembre 2012)

# Les Orcades

... Une espèce invasive commune...

**La souris domestique**  
**(*Mus musculus domesticus*)**

Une colonisation récente



Arrivée durant l'âge du fer  
~2500 yrs  
mtDNA : signature Viking  
~1200 yrs

« Orkney mtDNA lineage »



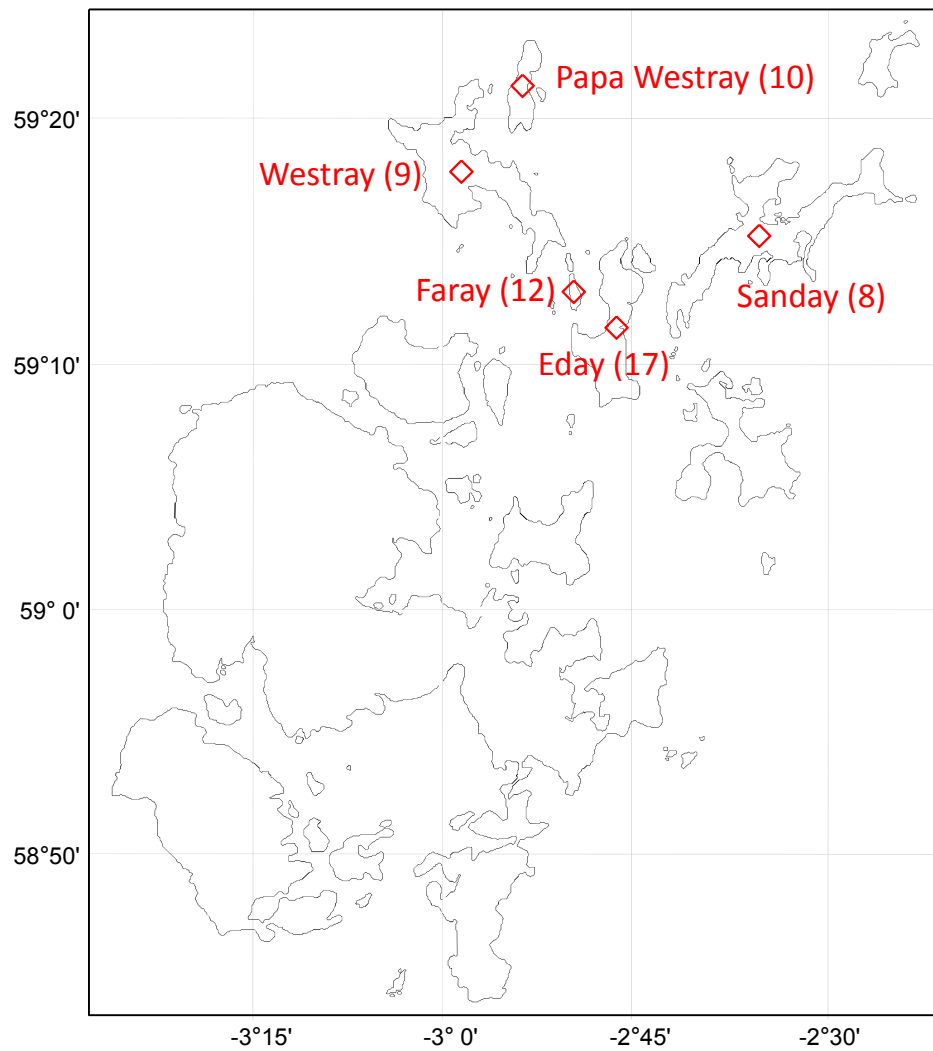
Evolution morphologique ?

Searle et al. 2009  
Jones et al. 2011

# Echantillonnage dans l'archipel des Orcades

2 missions

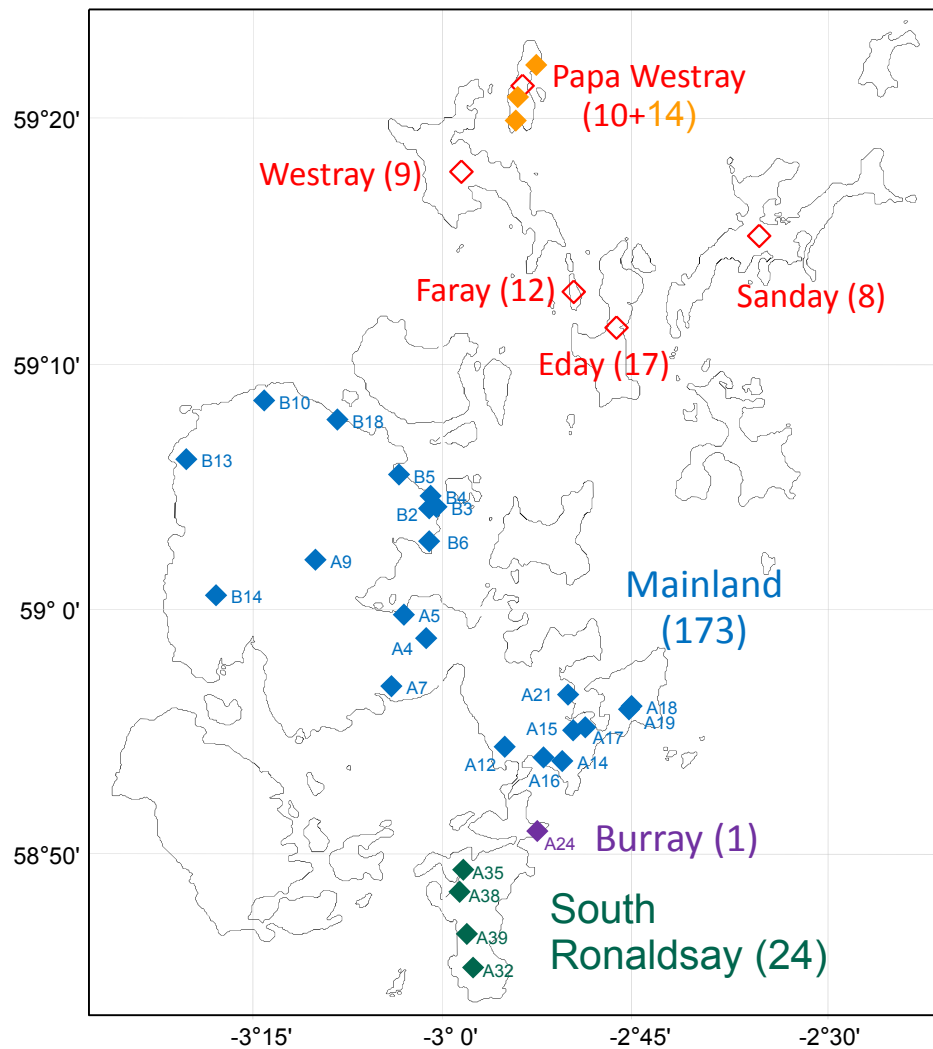
◇ 1992



# Echantillonnage dans l'archipel des Orcades

2 missions

◇ 1992    ◆ 2012



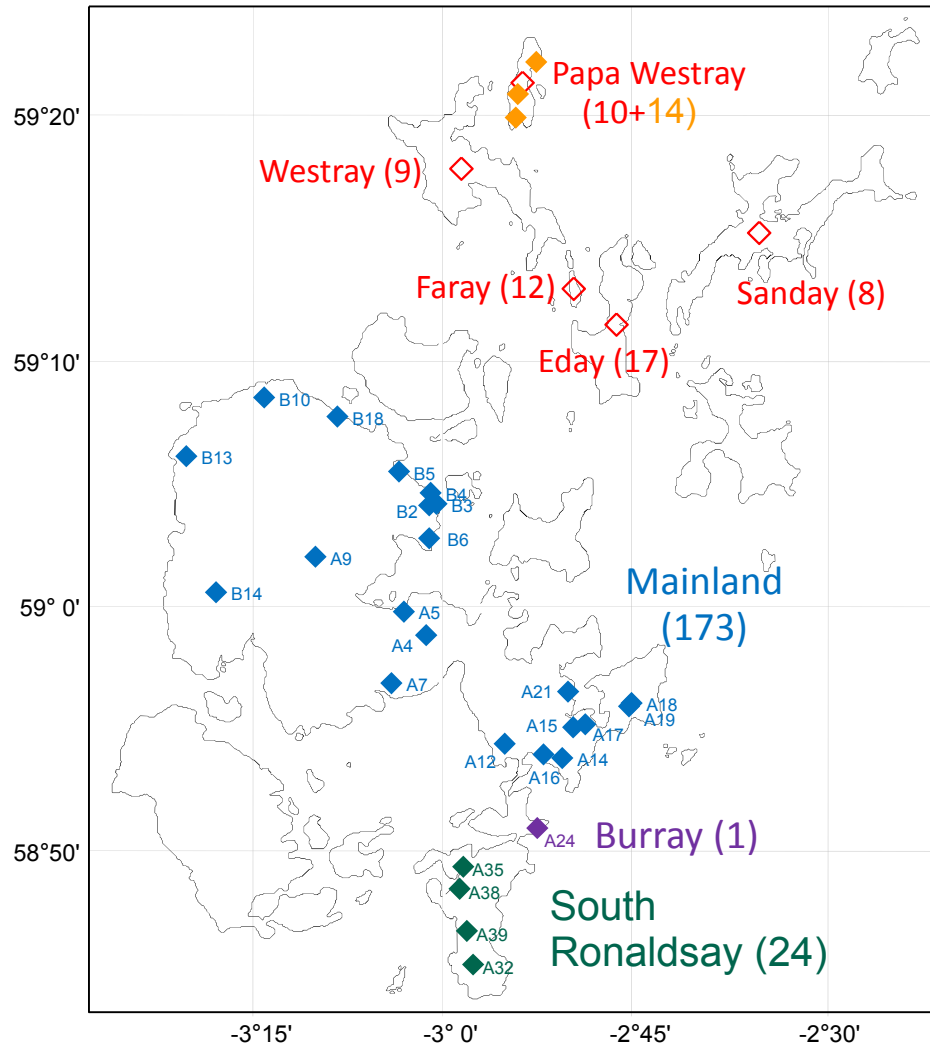
# Méthodes

2 missions

◇ 1992    ◆ 2012



**Analyses  
morphométriques et moléculaires**

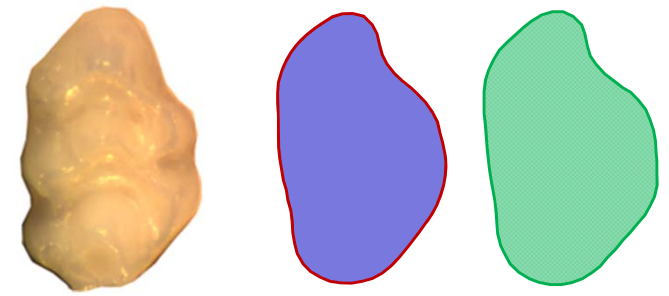


# Méthodes

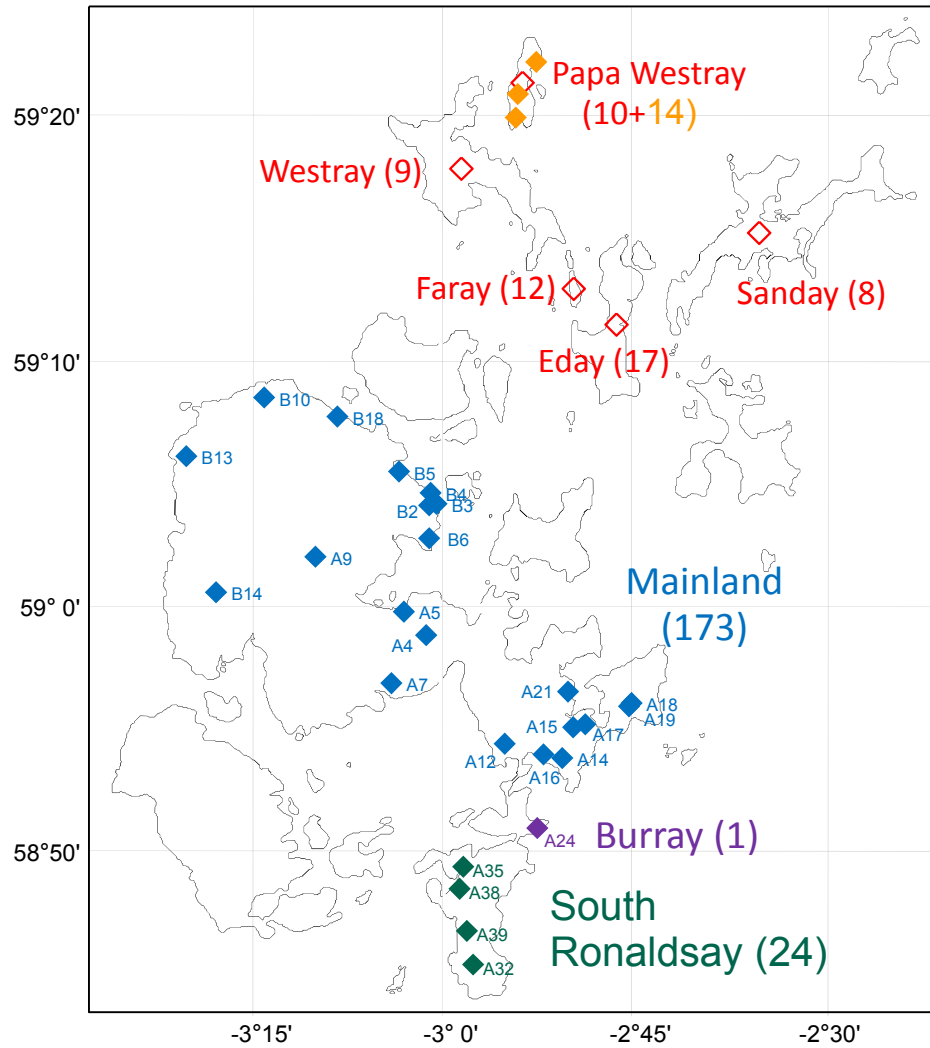
2 missions

◇ 1992    ◆ 2012

Analyses morphométriques : 249 souris  
1<sup>ère</sup> molaire sup., contour 2D



Variables de forme  
Analyses multivariées



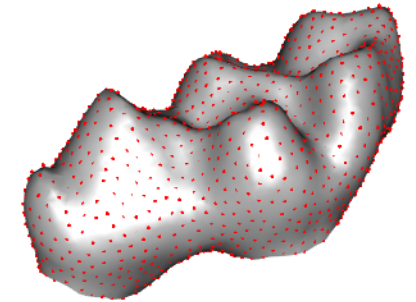
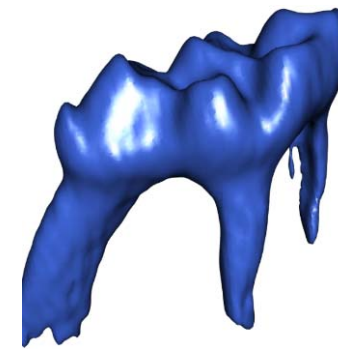
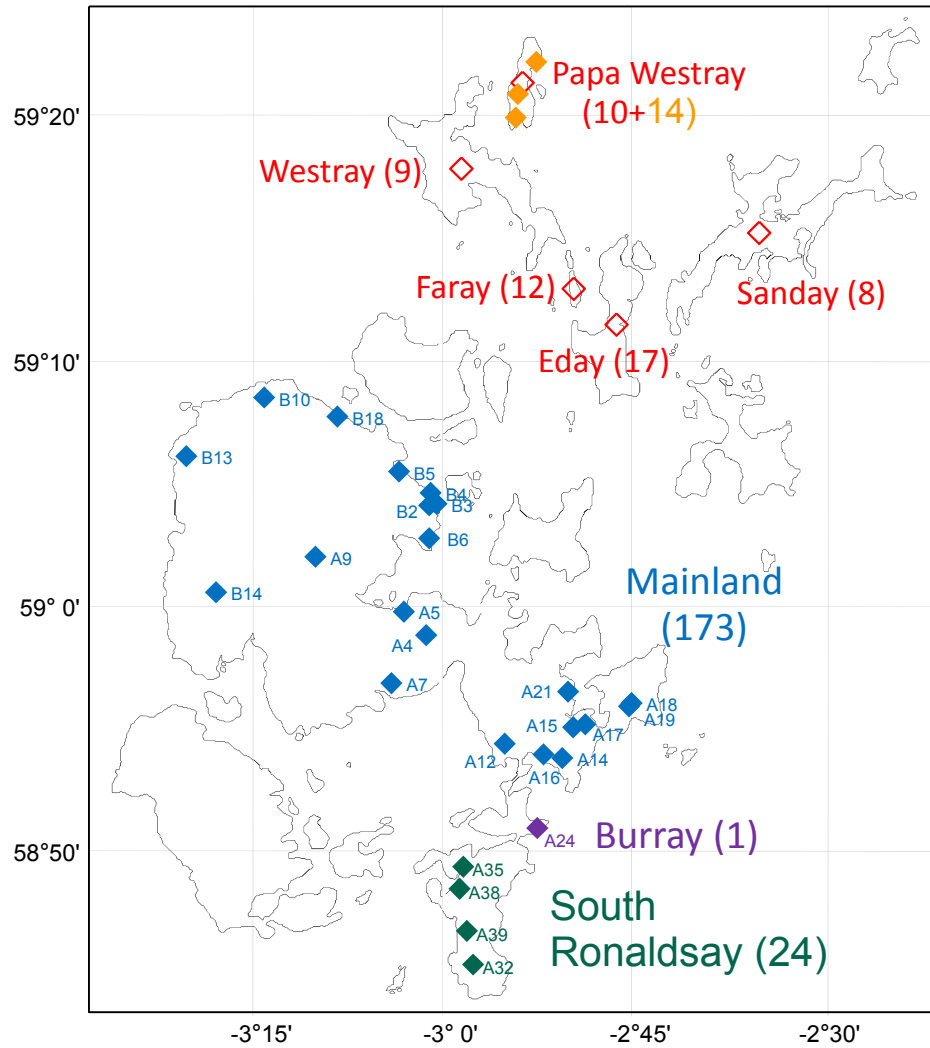
# Méthodes

2 missions

◇ 1992    ◆ 2012



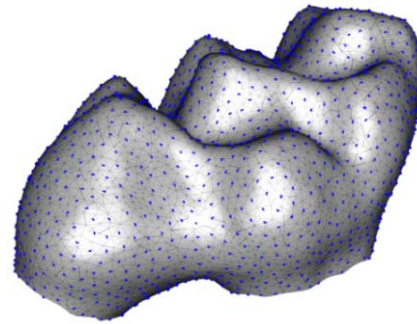
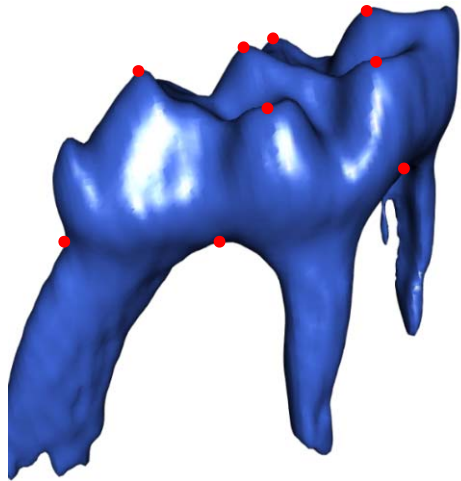
**Analyse morphométrique 3D: 30 souris**  
Faray, Eday, Papa Westray, Sanday



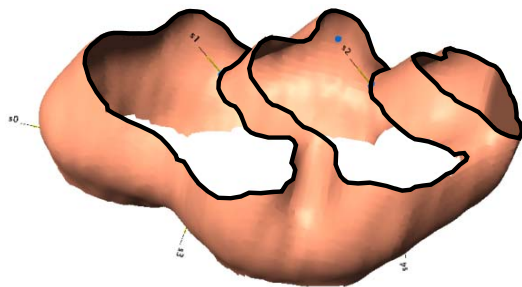
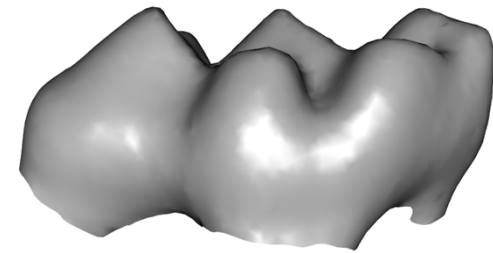
1<sup>ère</sup> molaire supérieure  
( $\mu$ -CT scan)



## 3D quantification of tooth shape



Adjustement of a template  
1588 sliding-landmarks



1532 sliding-landmarks

1532 x 3 variables...

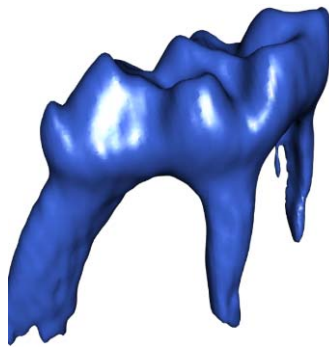
Reduction of dimensionality: PCA  
(Principal Component Analysis)

5 PCs ( $\Sigma > 60\%$ )



## Pourquoi et comment la forme de la dent évolue Evolution insulaire de la souris

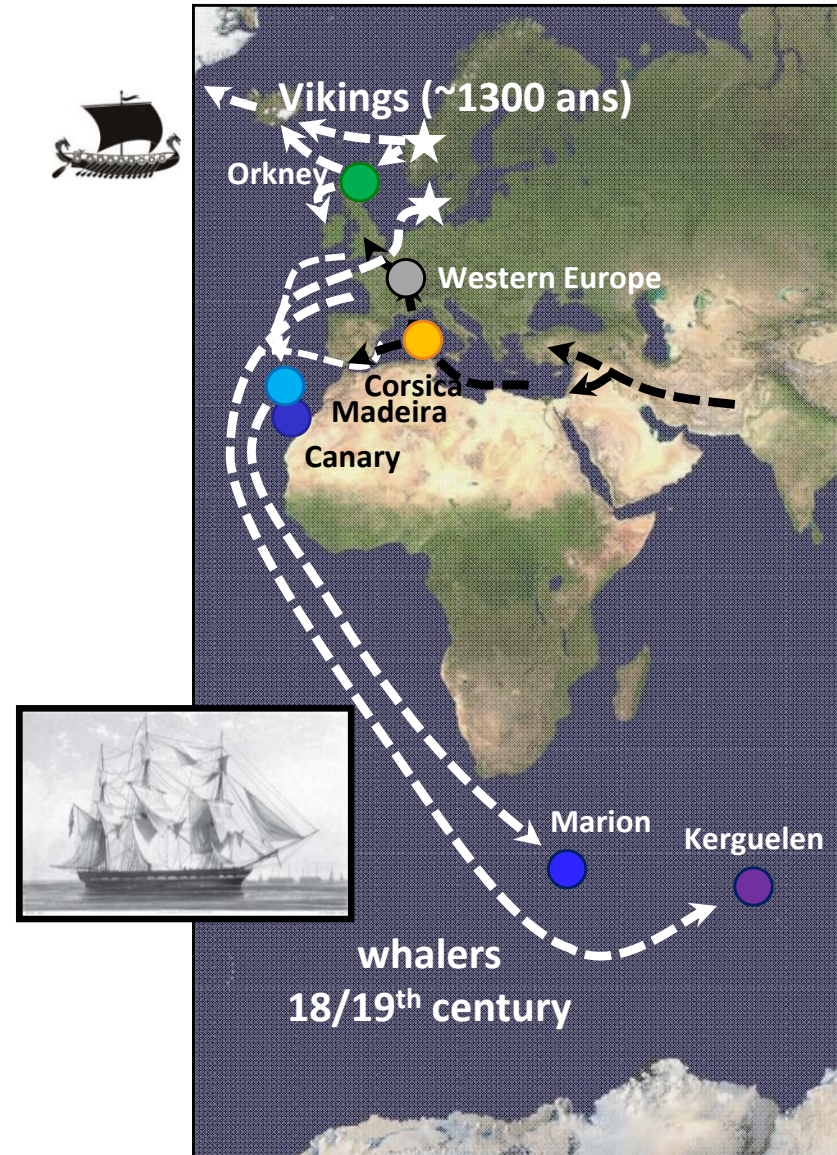
Population fondatrice  
(phylogénie)



Climat

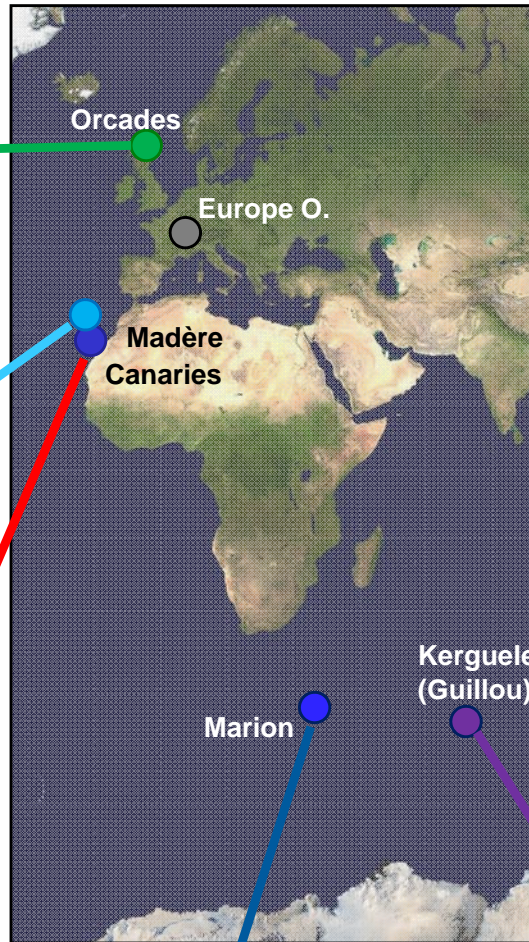
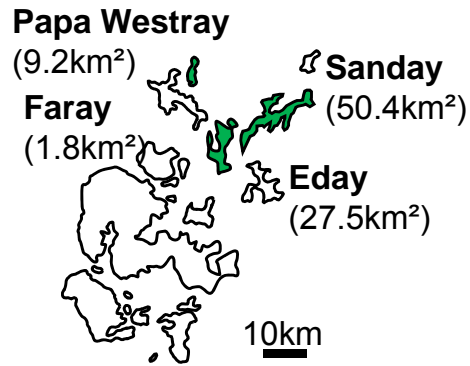


Ecologie



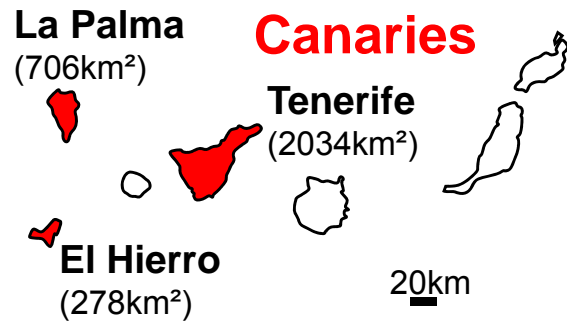
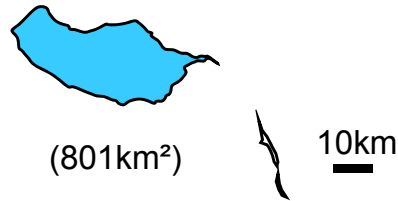
# Echantillonnage 3D

## Orcades

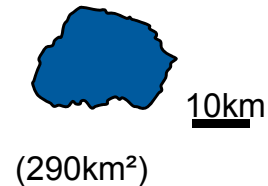


- ➔ Des conditions insulaires...
- ➔ Une phylogéographie complexe
- ➔ Grande gamme d'environnements

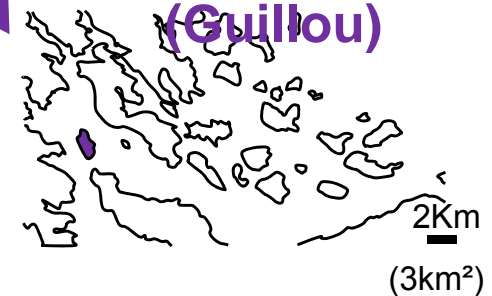
## Madère



## Marion

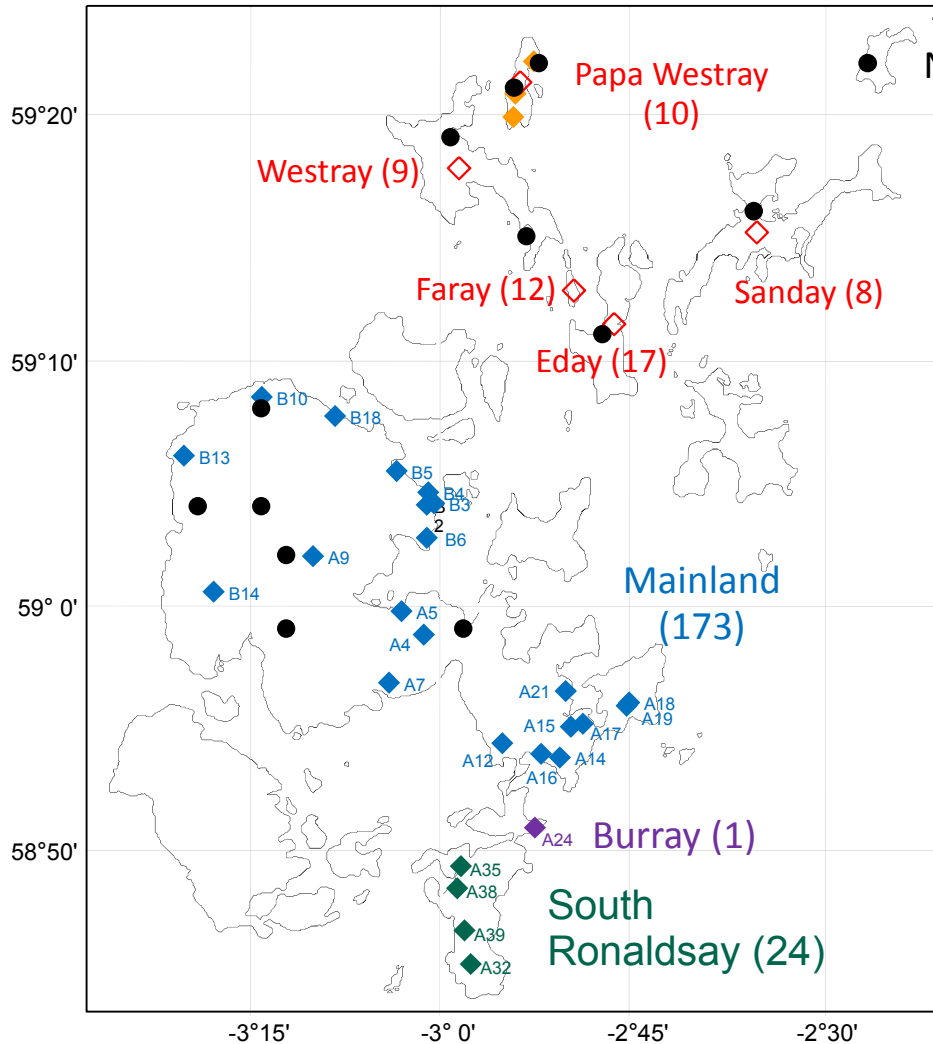


## Kerguelen (Guillou)



# Méthodes

2 missions



◇ 1992    ◆ 2012



Analyses morphométriques : 2D, 3D

Marqueurs moléculaires

- séquences mitochondriales D-Loop (123 souris)



+ séquences publiées ●

Phylogéographie et réseau

- 21 marqueurs microsatellites (264 souris)



Structure génétique

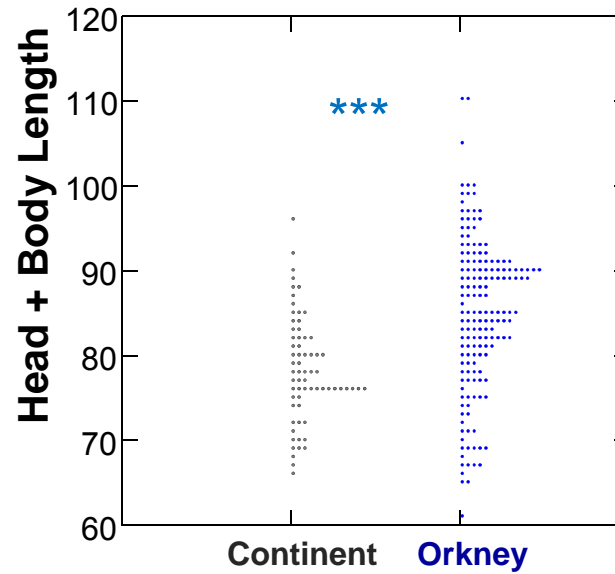
Phylogéographie + Morphométrie 3D : 90 souris

Génétique + Morphométrie 2D: 209 souris

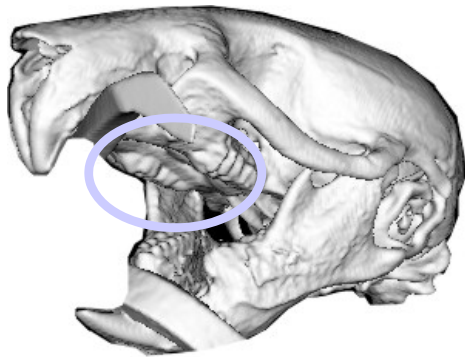
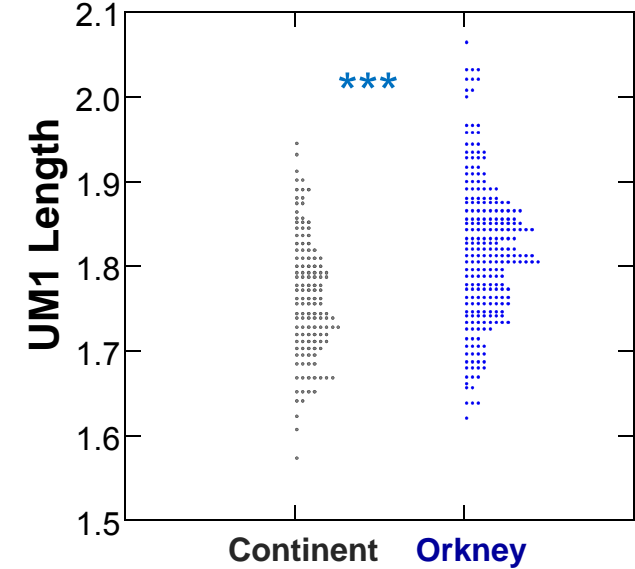
# Souris des Orcades, un cas d'évolution insulaire ?



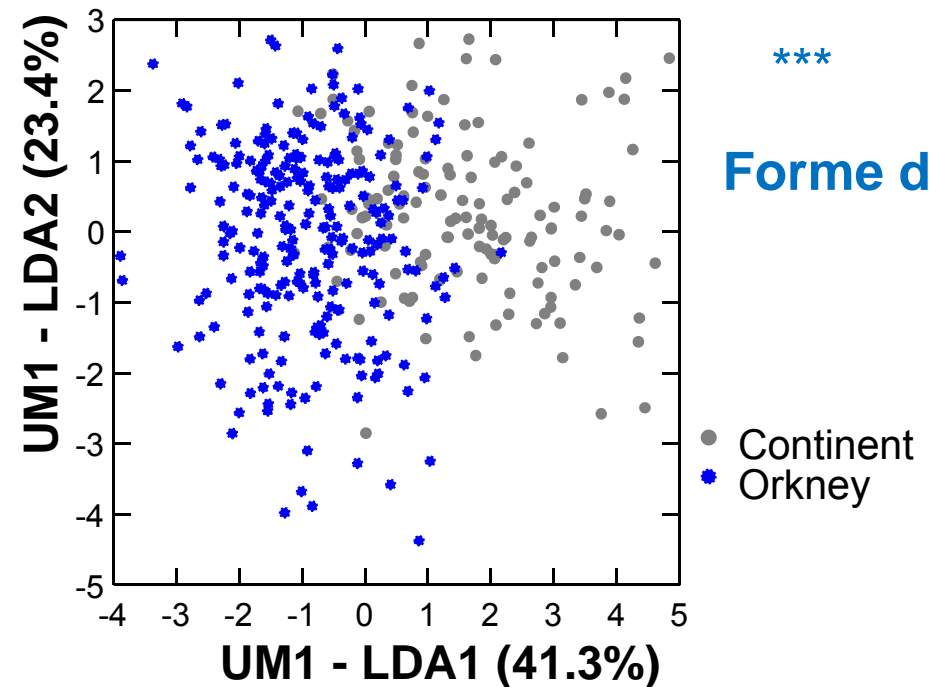
**Caractère d'intérêt**  
**La molaire supérieure**



**Taille des dents**



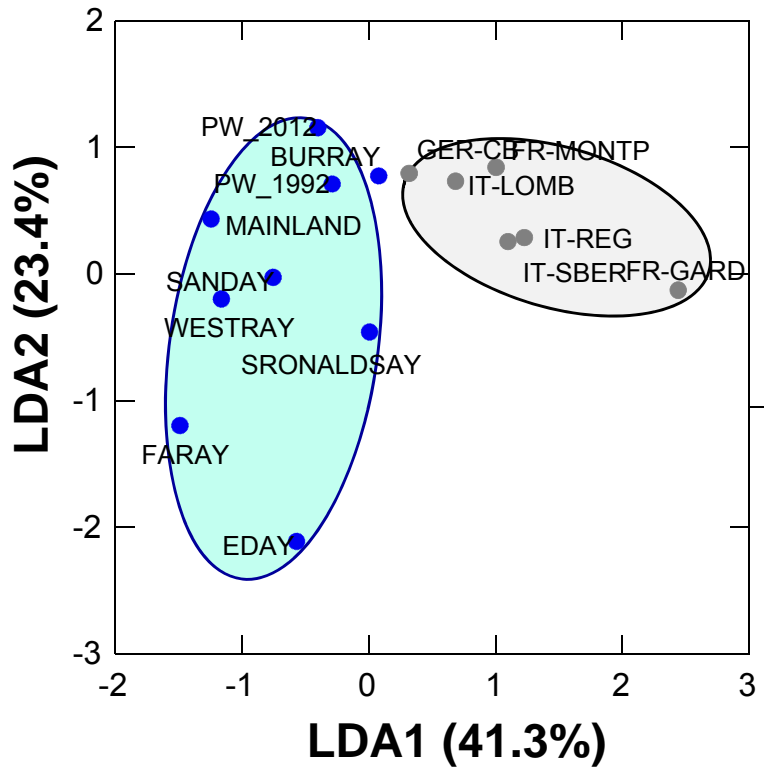
**Evolution morphologique !**



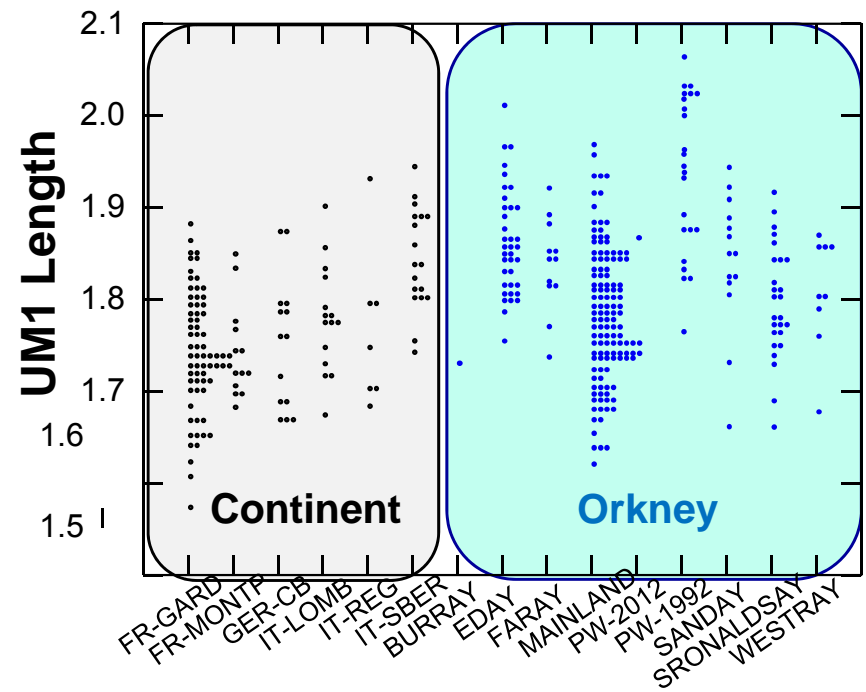
# Différentes îles, et les souris ?



Forme des dents

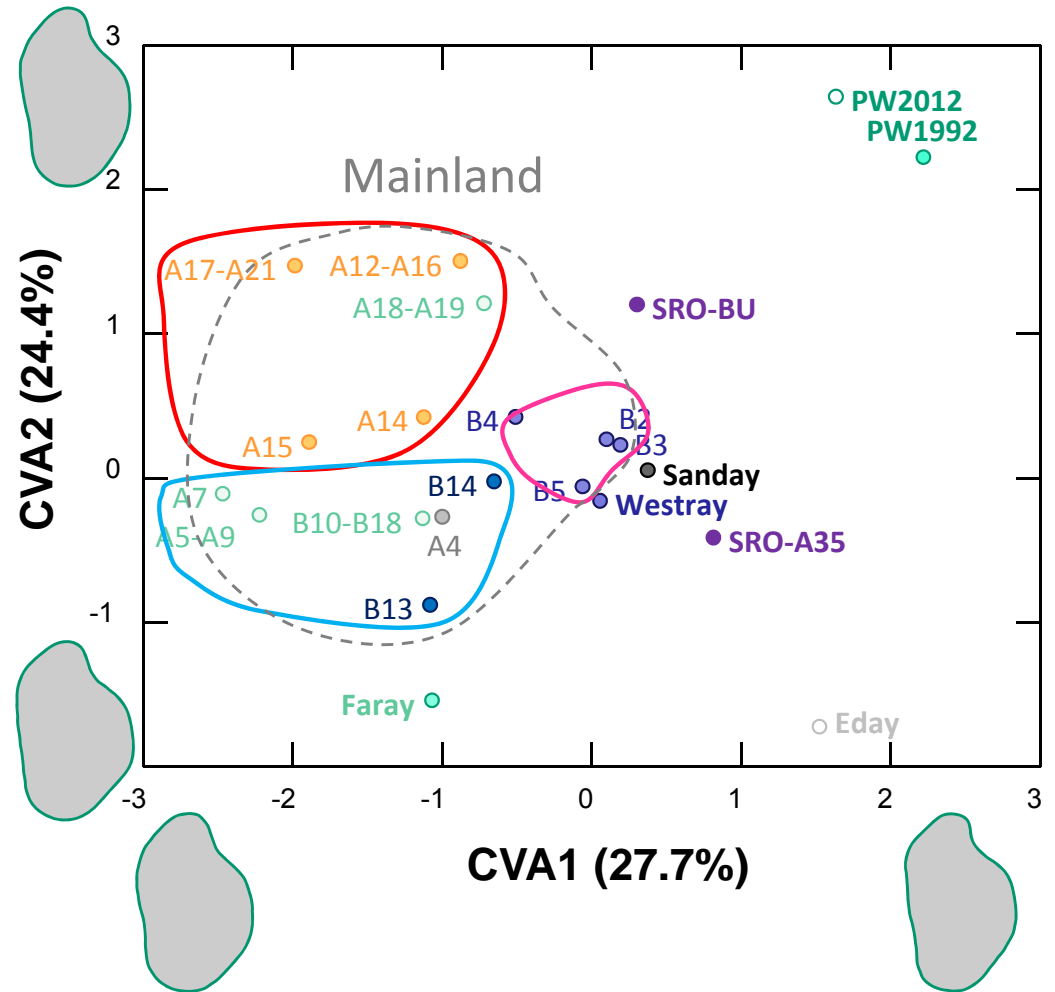
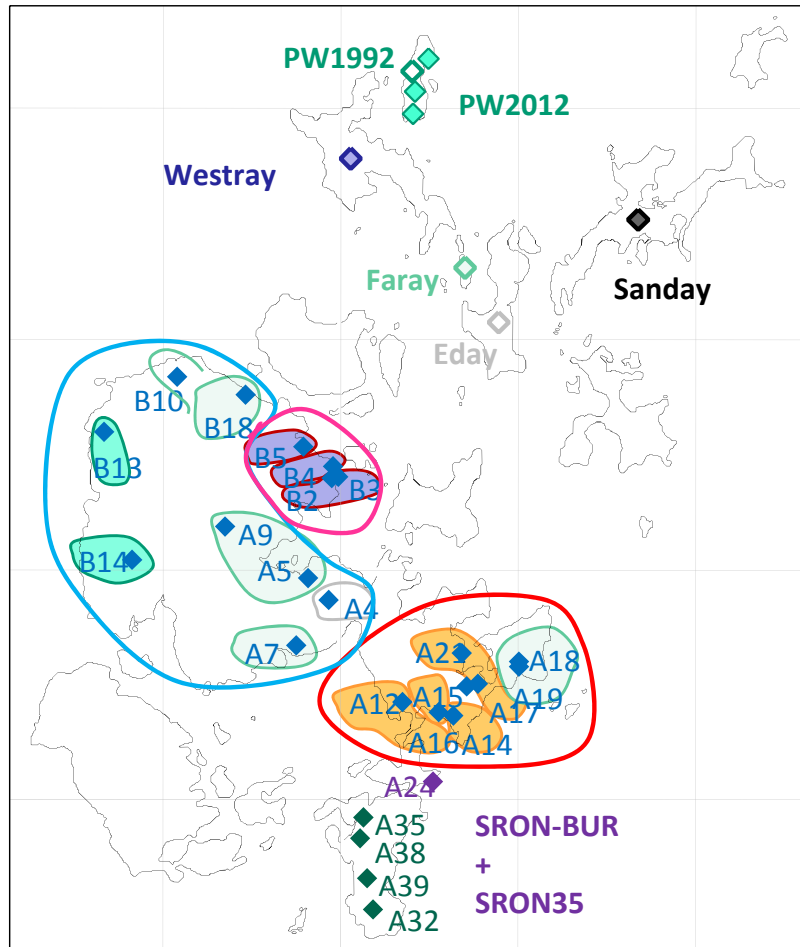


Taille des dents



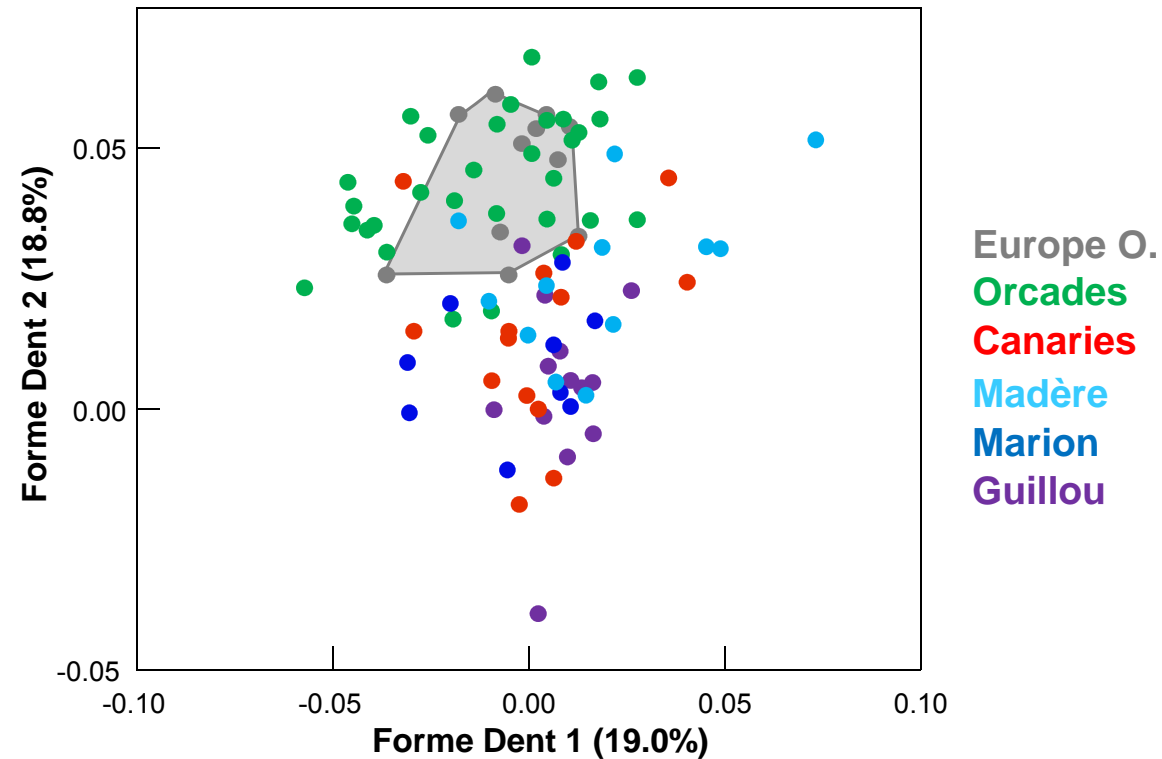
Evolution de la diversité locale ?

# Différentiation morphologique 2D



## Patrons de différenciation de forme 3D

ACP sur variables de forme



Variation îles >> continent



Différences entre archipels (Orcades  $\neq$  des autres)

**Quels processus derrière cette variation insulaire?**

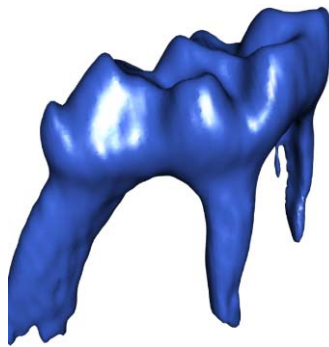




# Pourquoi et comment la forme de la dent évolue

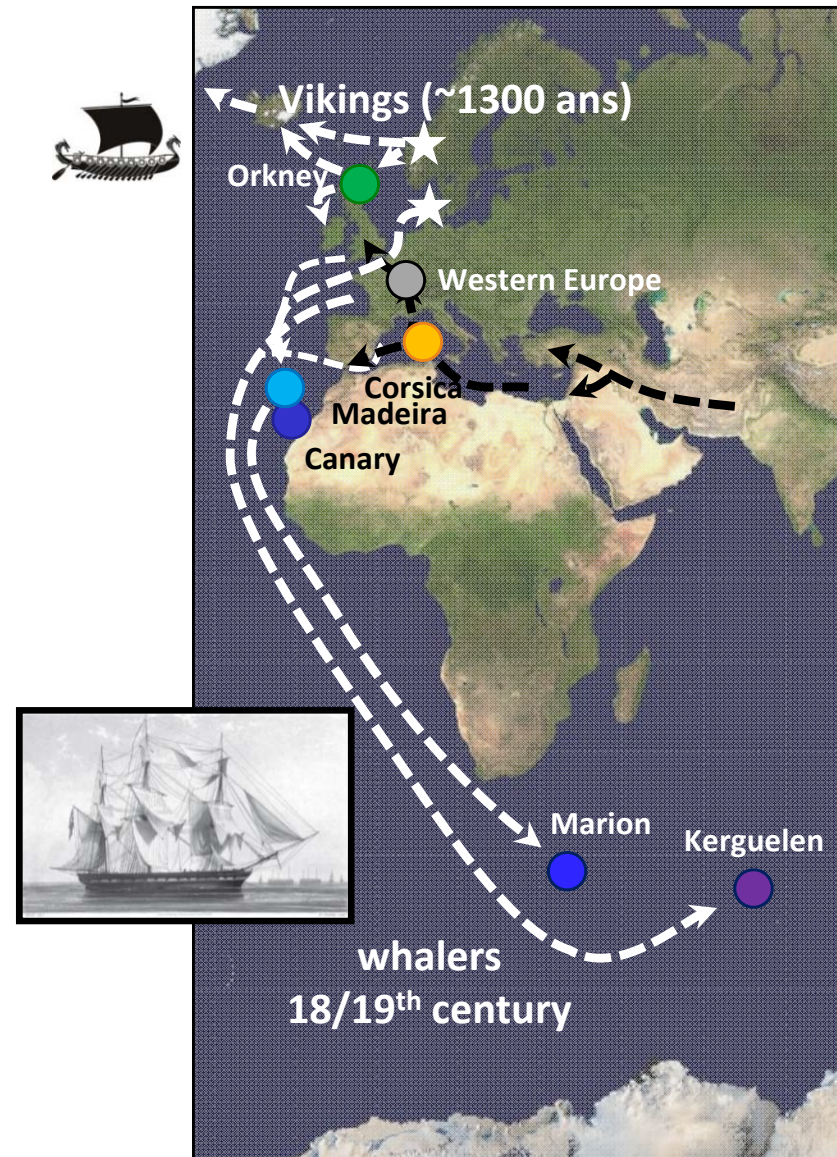
## Evolution insulaire de la souris

Population fondatrice  
(phylogénie)

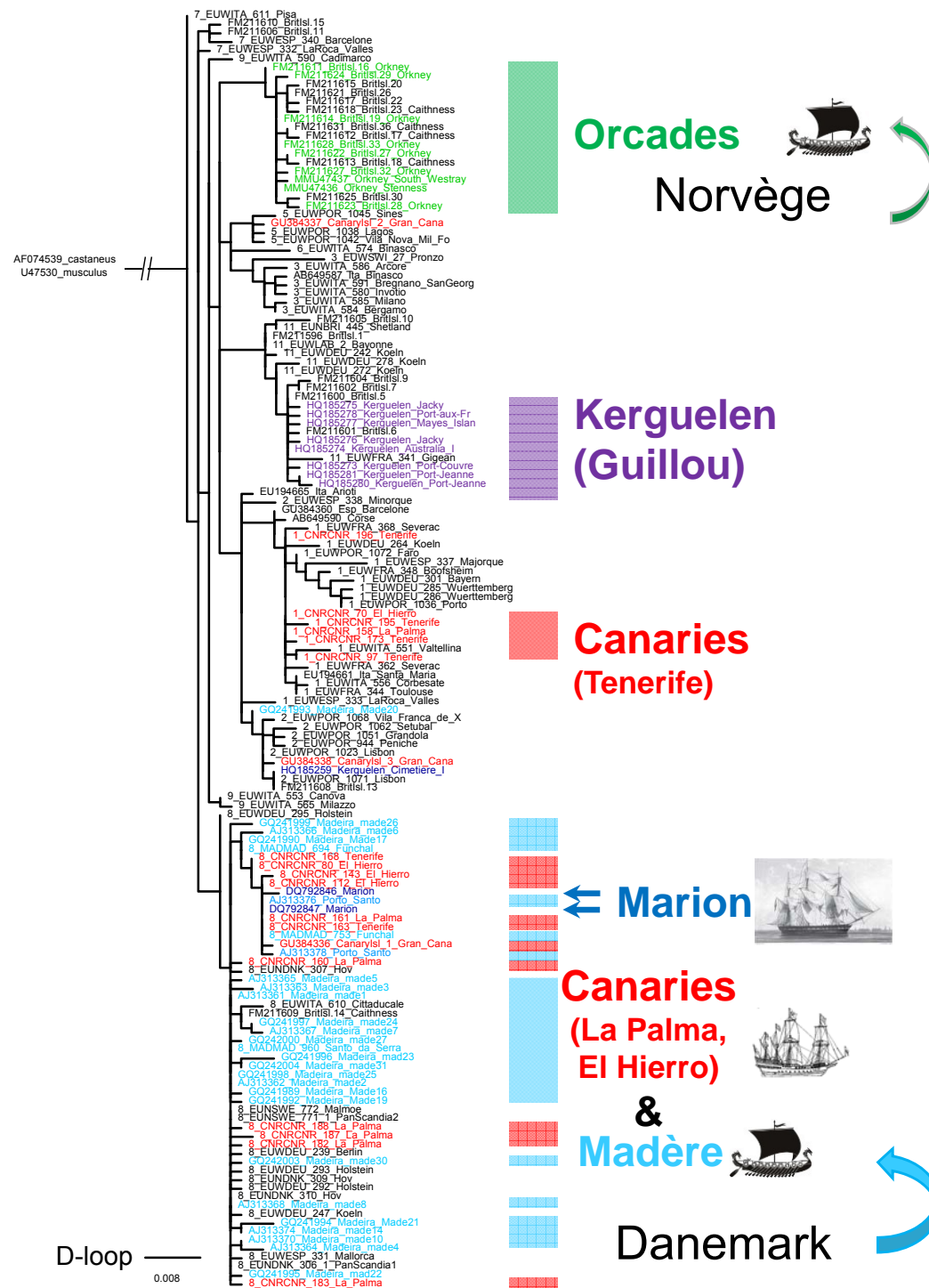
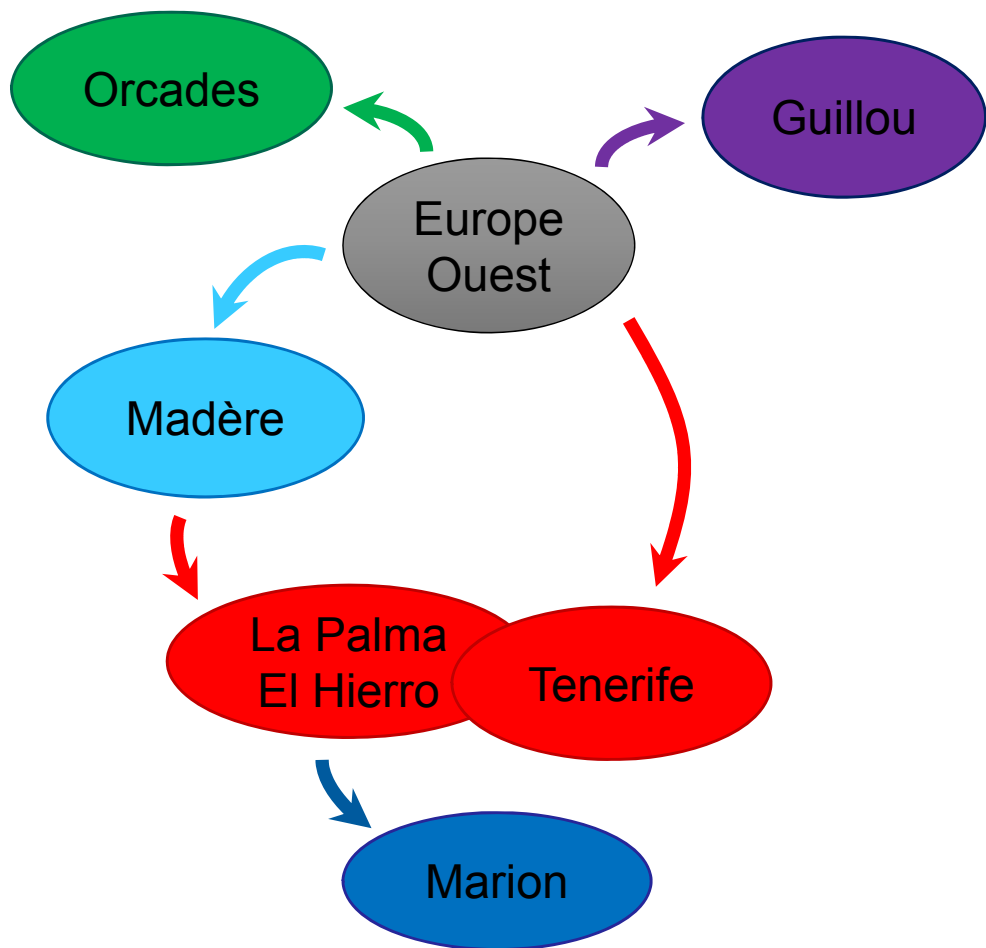


Climat

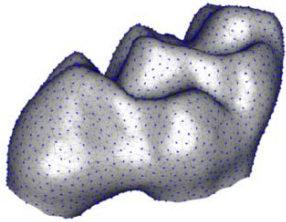
Ecologie



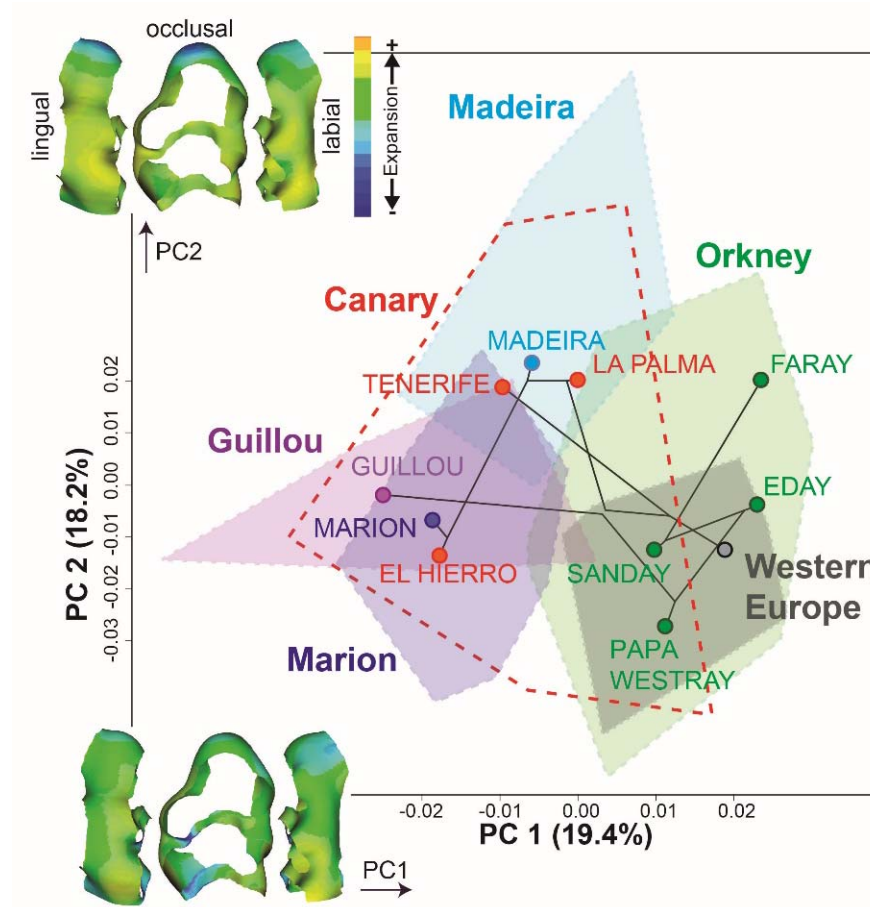
# Phylogéographie



# Patrons de différentiation de forme 3D



Occurrences  
d'évolution convergente



**Iles:**  
Disparité  
morphologique

**Europe de l'Ouest :**  
Homogénéité  
morphologique

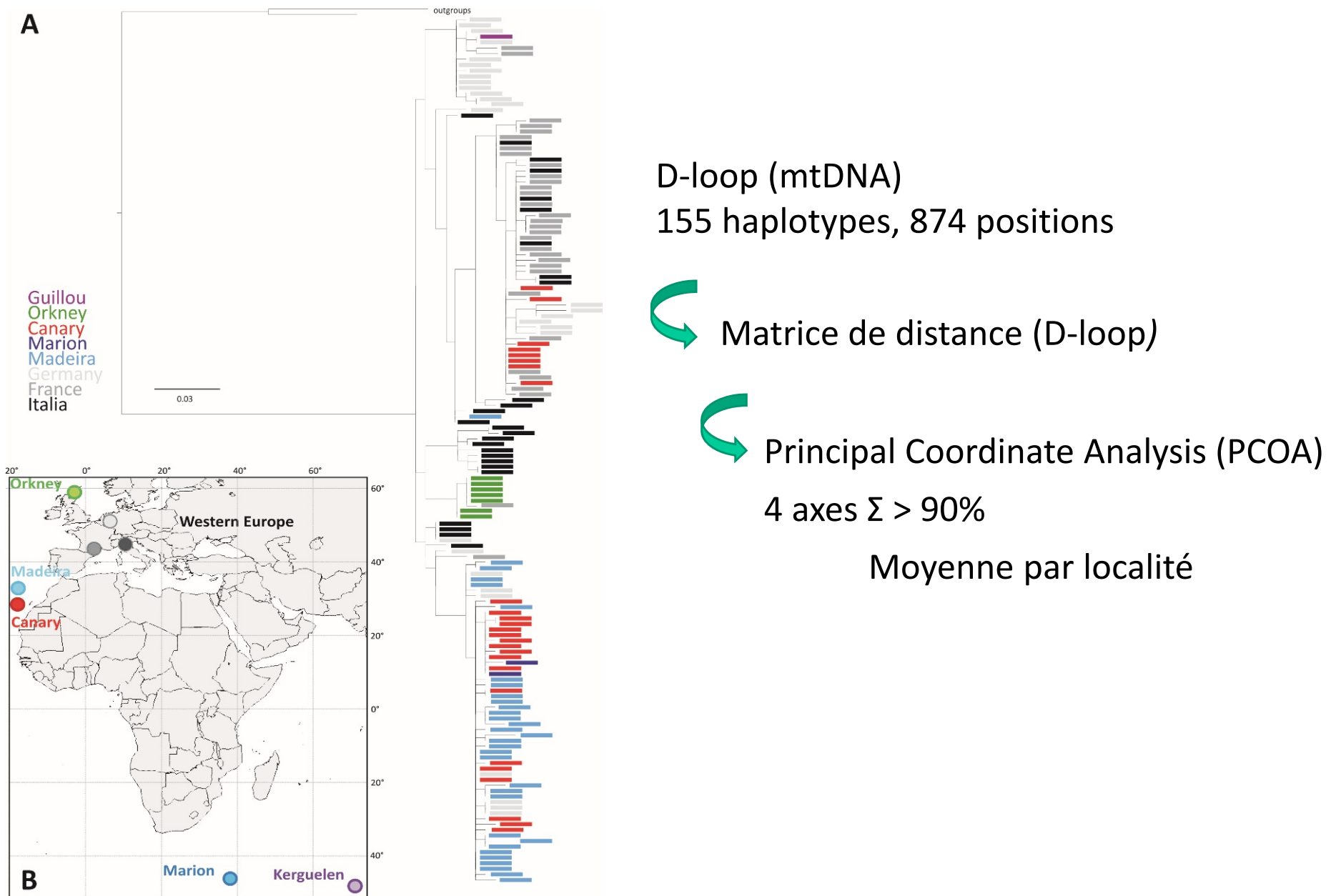
Facteurs ?

~ **Phylogénie**

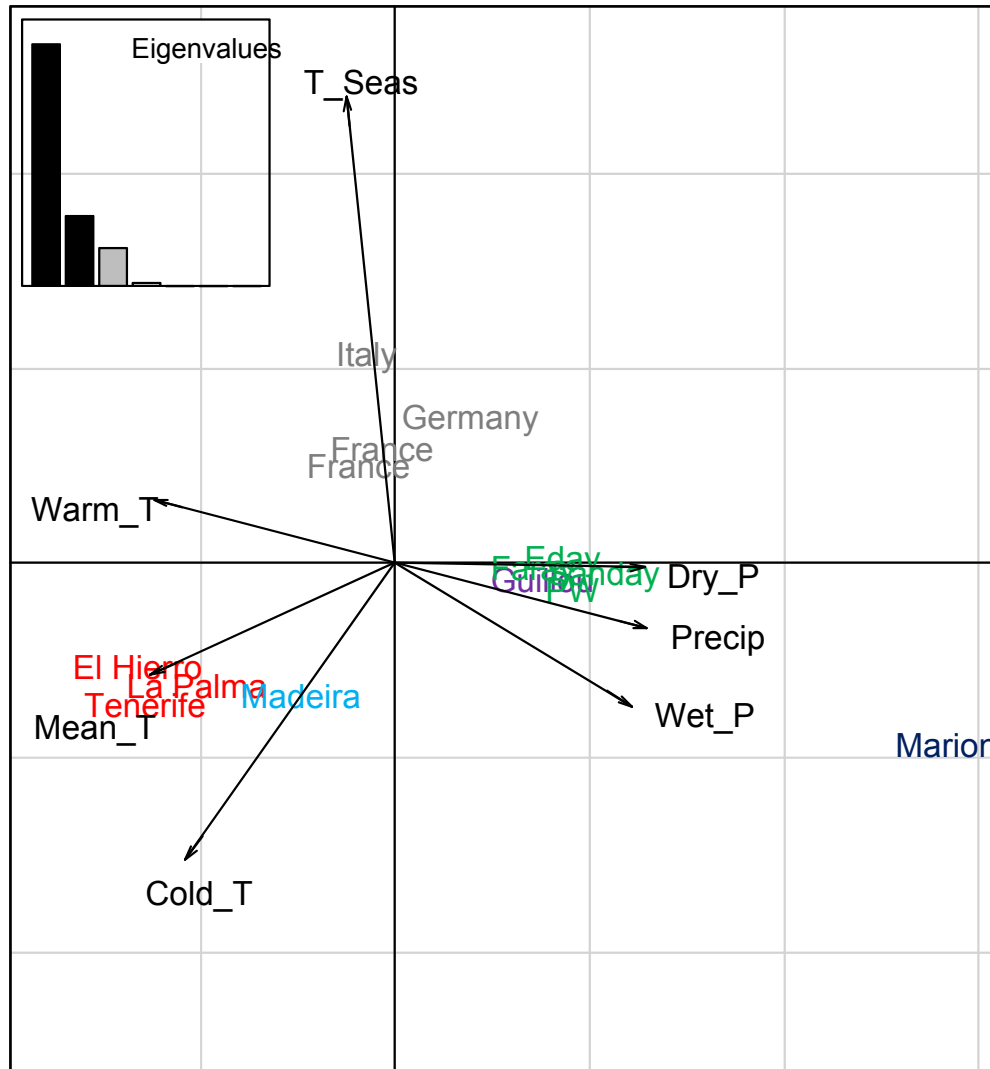
~ **Écologie** (compétition [ou pas] avec le mulot)

~ **Environnement** (variables bioclimatiques)

# Comparaison de la forme de la dent avec les facteurs explicatifs (1) Phylogénie



# Comparaison de la forme de la dent avec les facteurs explicatifs (2) Climat



**WorldClim - Global Climate Data**  
Free climate data for ecological modeling and GIS

19 climatic data available



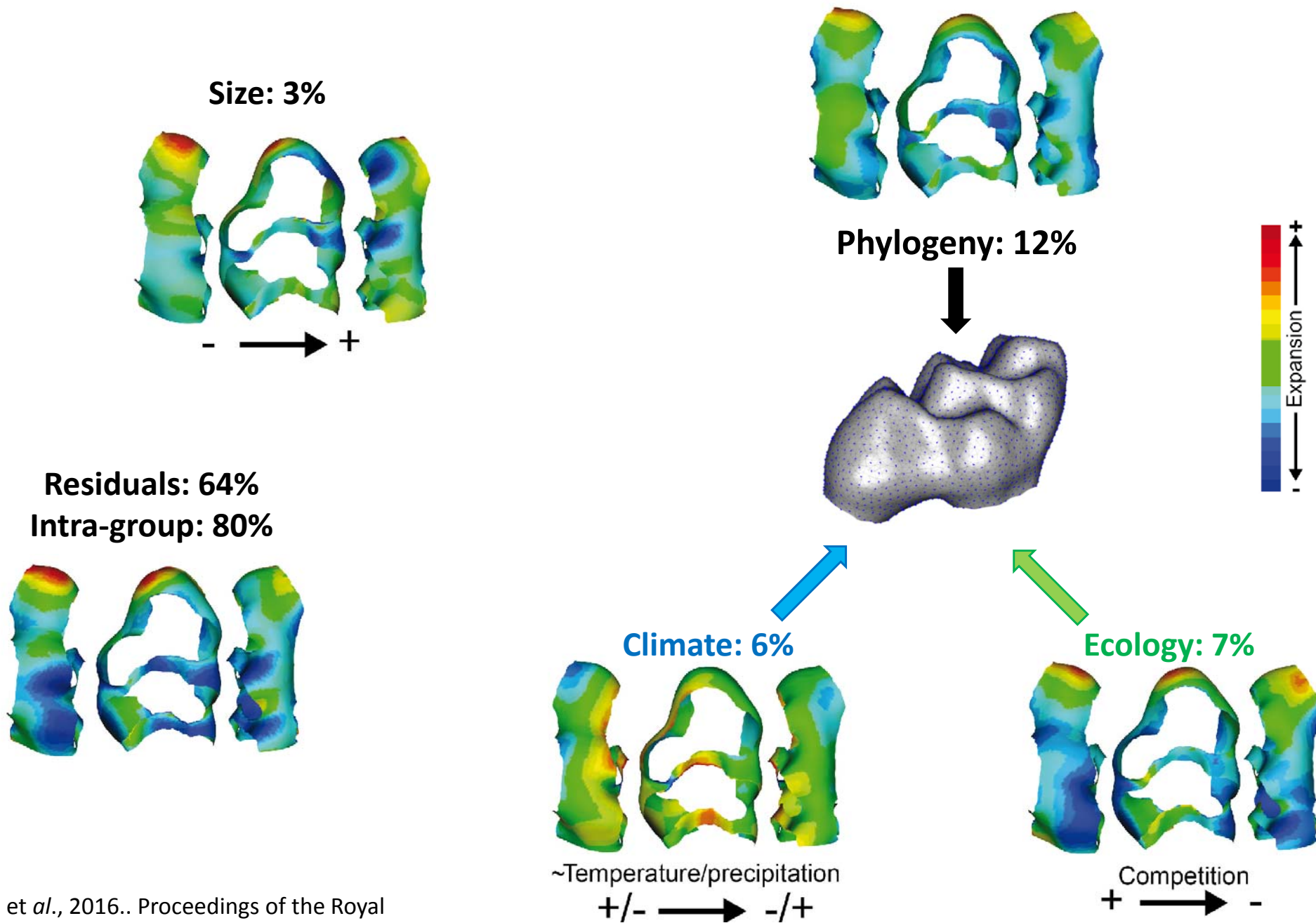
- Annual mean temperature
- Temperature seasonality
- Mean warmest quarter
- Mean coldest quarter
- Annual precipitation
- Precipitation of the wettest quarter
- Precipitation of the driest quarter



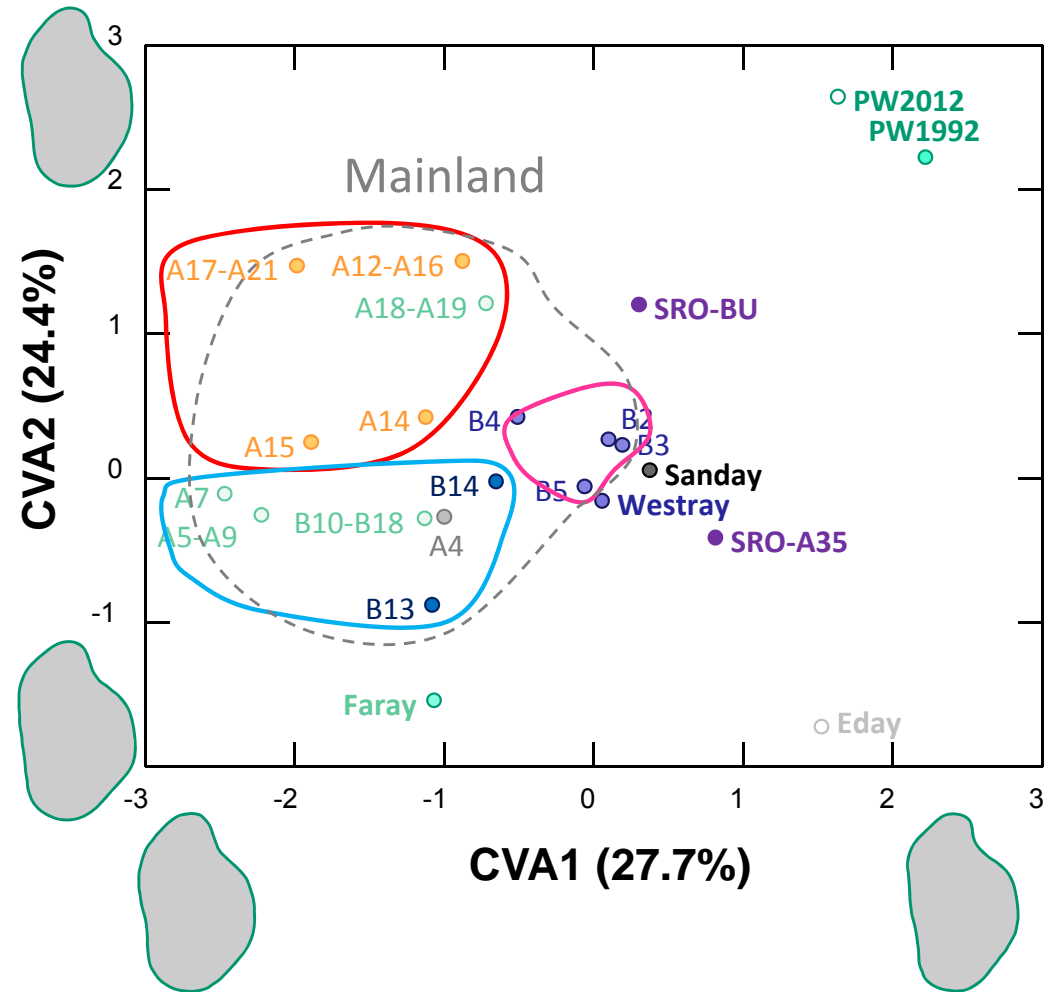
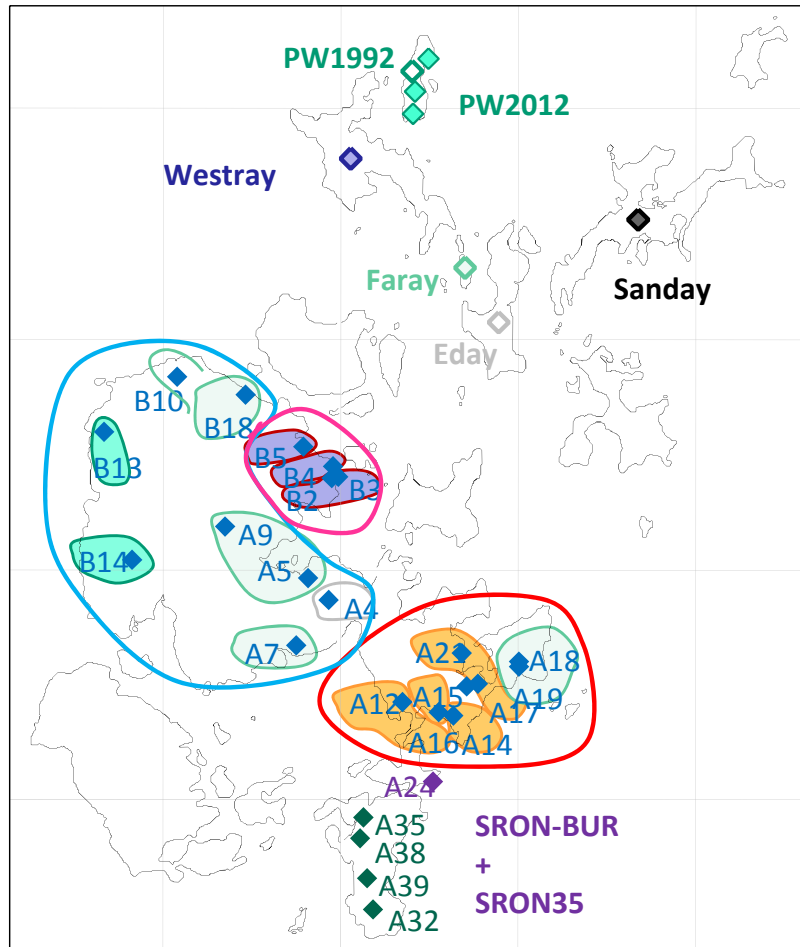
Principal Component Analysis (PCA)

3 axes  $\Sigma > 90\%$

# Comparaison de la forme de la dent avec les facteurs explicatifs



## Différentiation morphologique 2D



Corrélations avec la structure et diversité génétiques ?

# Phylogeographie

D-loop de *Mus musculus domesticus*

Archipel des Orcades : 149 D-loop  
18 haplotypes (9 nouveaux)



0.02



# Phylogeographie

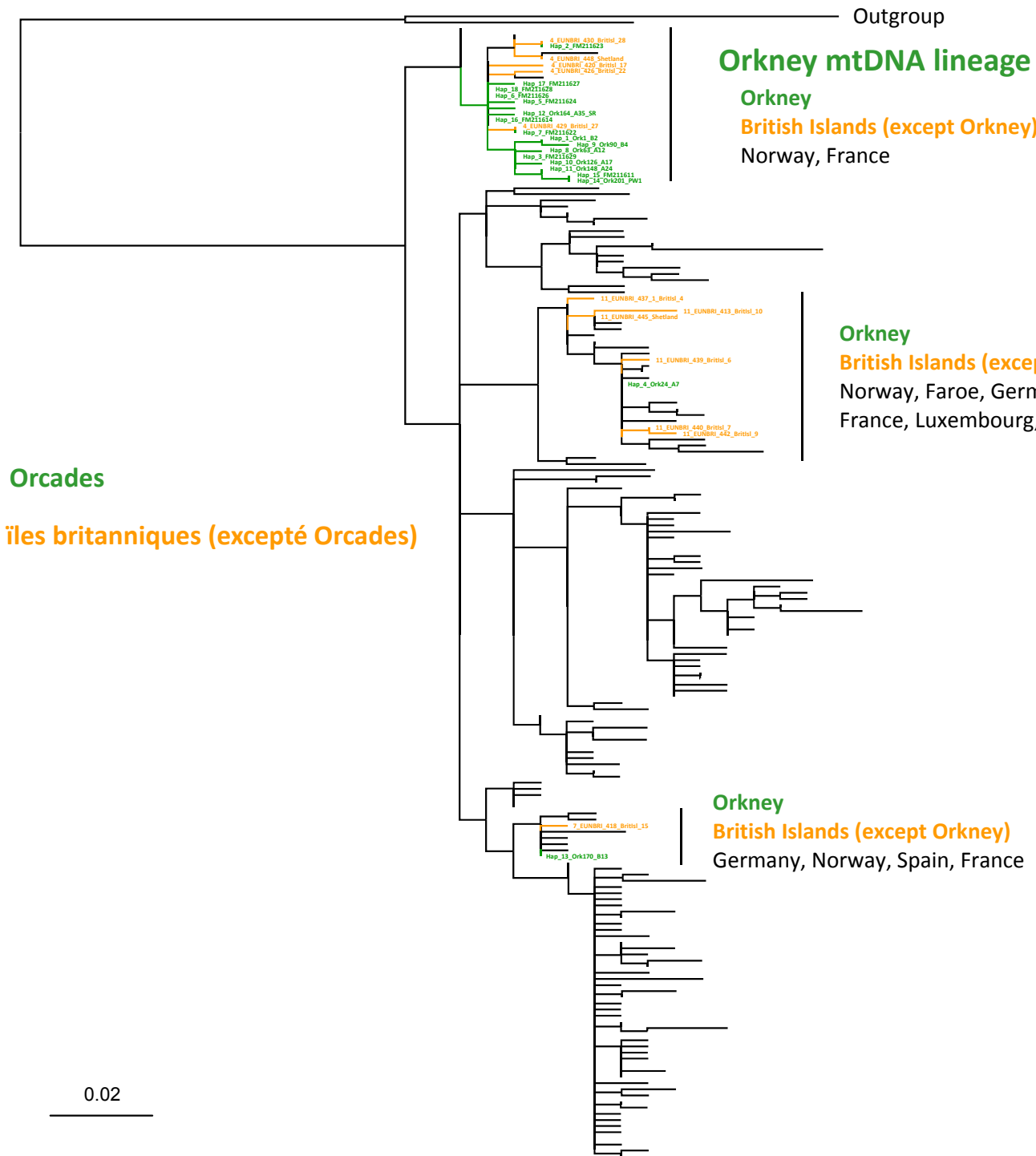
D-loop de *Mus musculus domesticus*

Archipel des Orcades : 149 D-loop  
18 haplotypes (9 nouveaux)

Toujours associés à des haplotypes

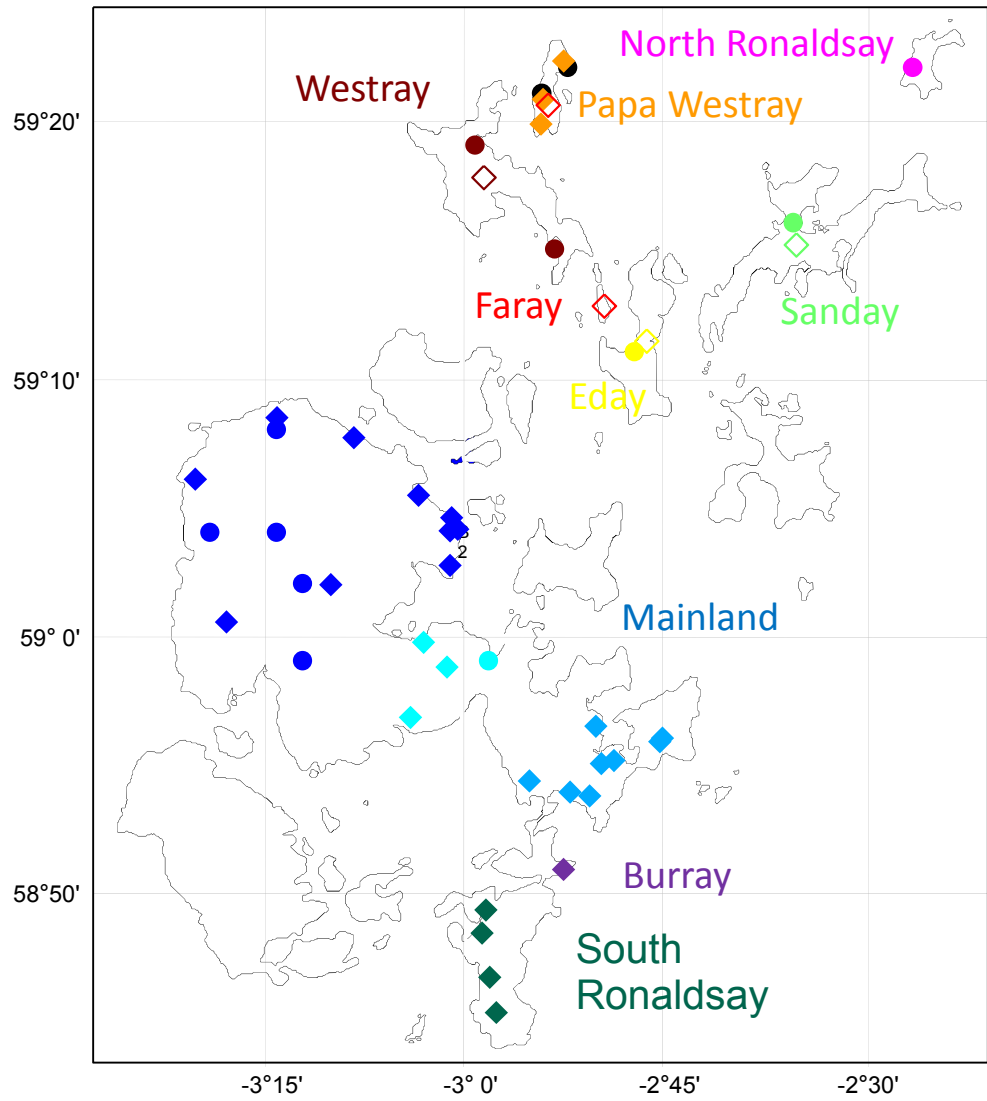
- autres îles britanniques

- Europe NO

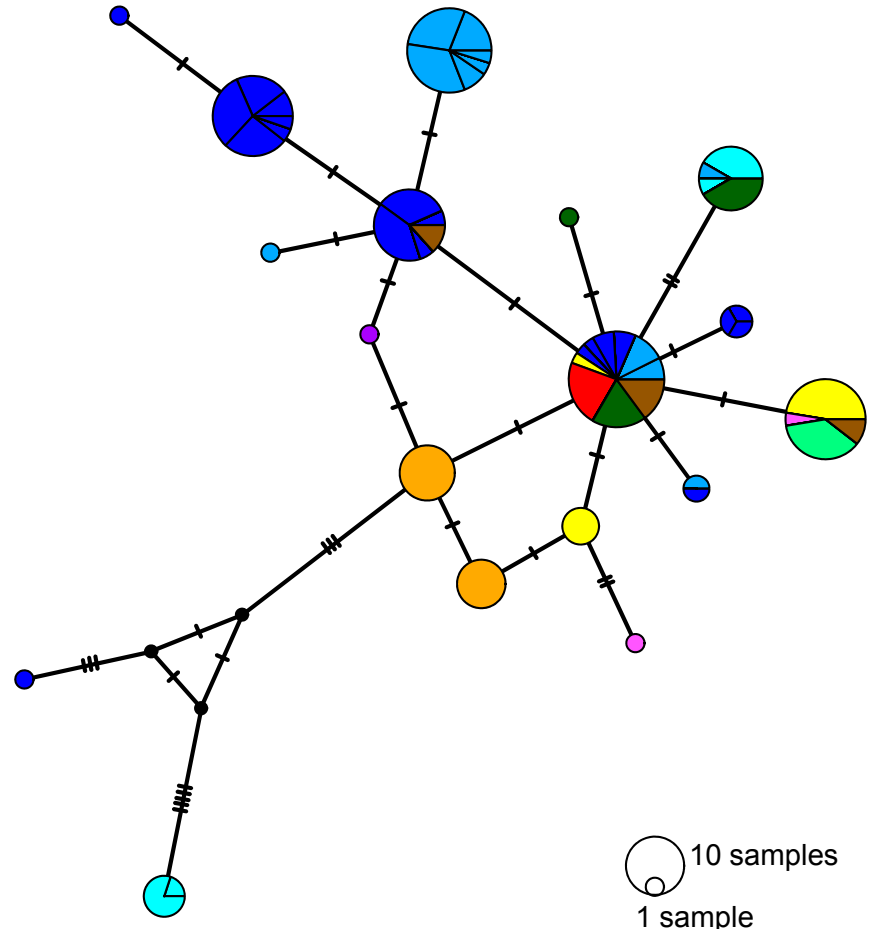


# Les Orcades

## Network (149 D-loop sequences)



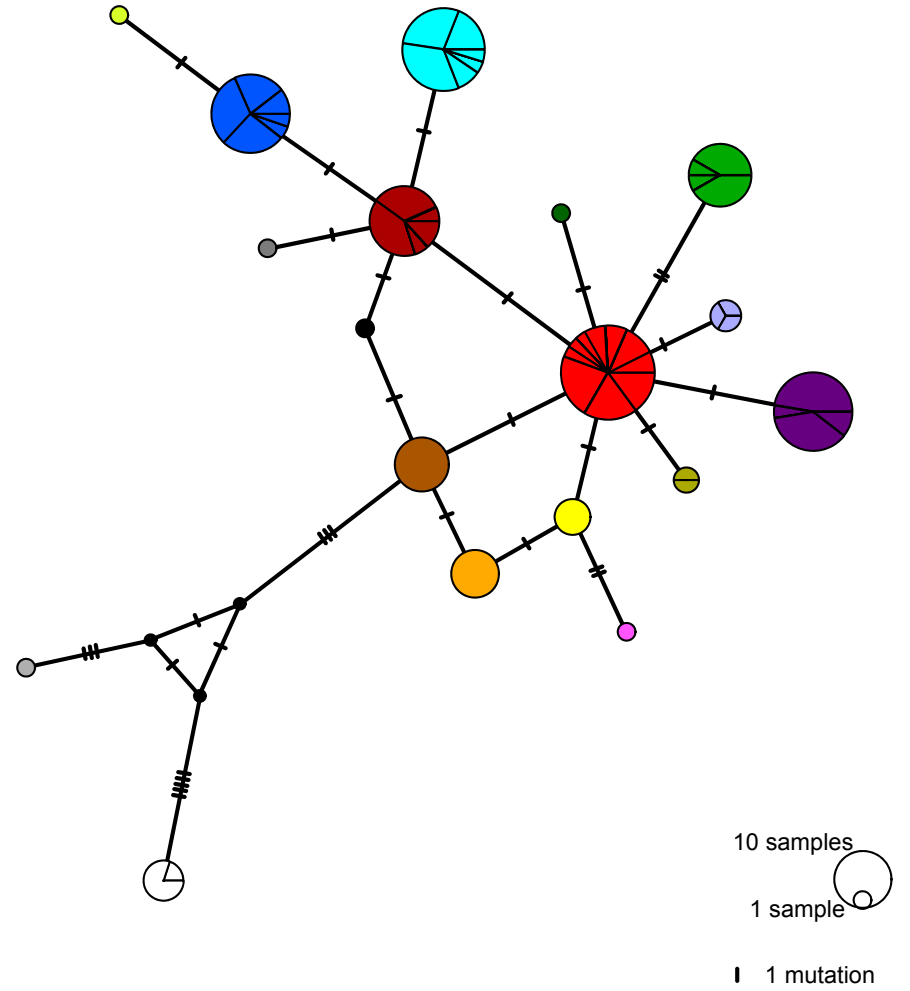
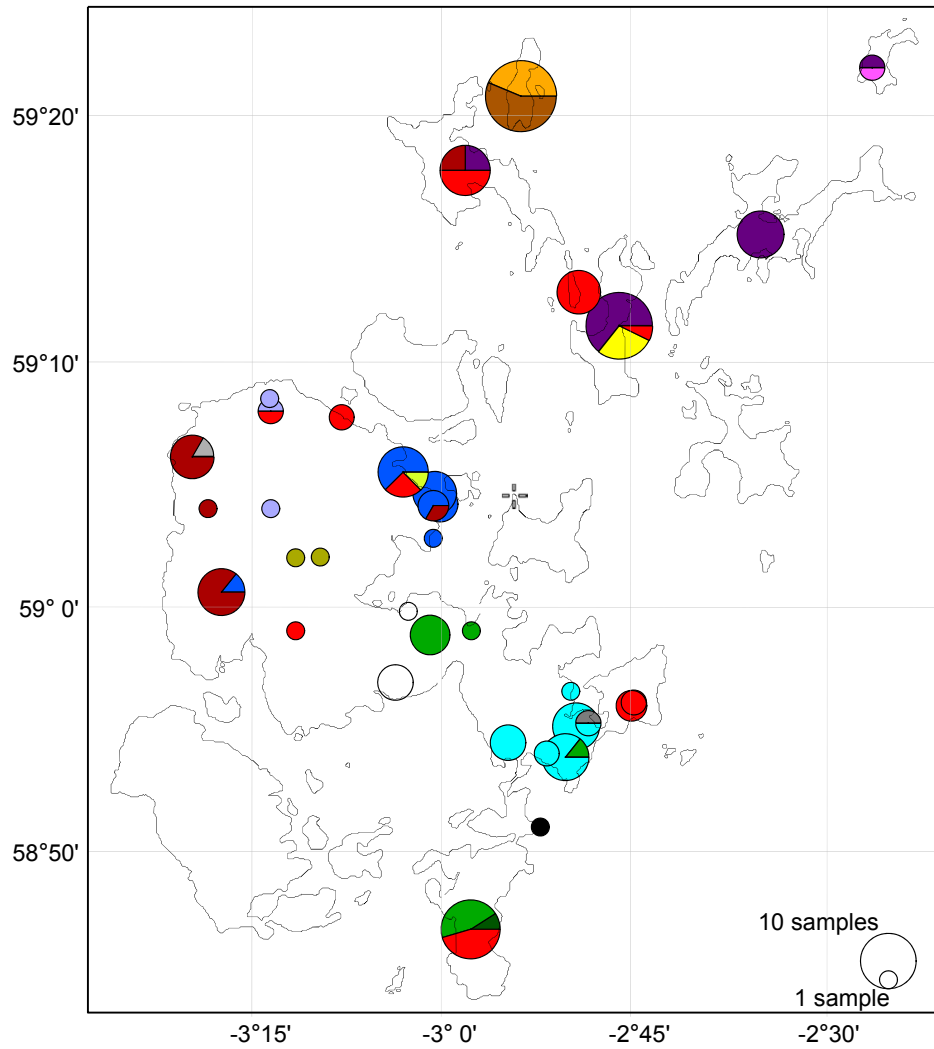
◇ 1992    ◆ 2012    ● séquences publiées

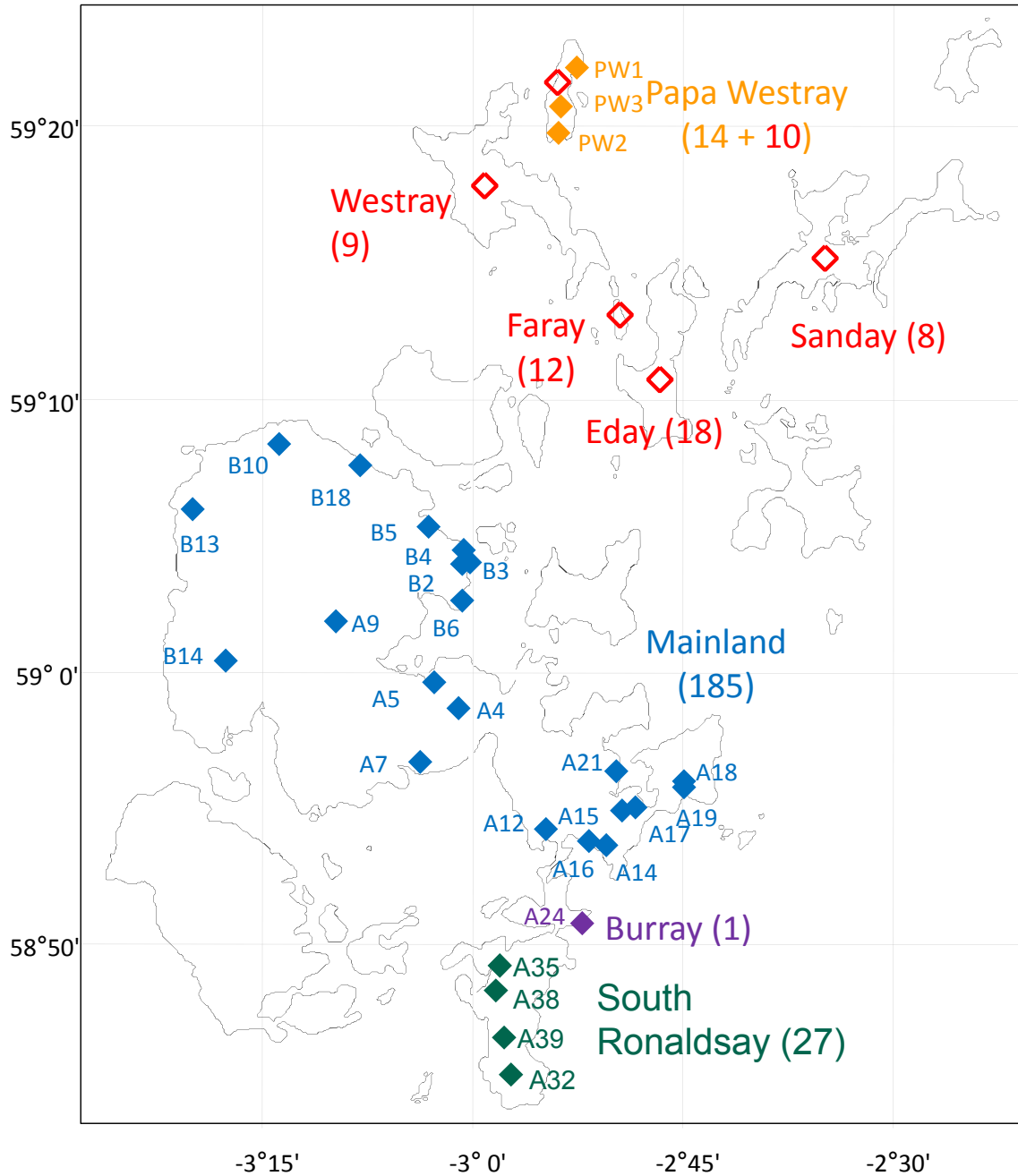


○ 10 samples  
○ 1 sample  
| 1 mutation

# Les Orcades

Network (149 D-loop sequences)





## 21 microsatellites

7-19 allèles / locus (moyenne 11.4)

### Mainland

Loci polymorphes : 21

Moyenne : 9 allèles /locus

Ho : 0.45/ He : 0.63

### Ilots (sauf Faray)

Loci polymorphes : 16-21

Moyenne : 3.1-4.7 allèles/locus

Ho : 0.26-0.44 / He : 0.36-0.55

### Faray

Loci polymorphes : 9

Moyenne : 1.6 allèles/locus

Ho : 0.06 / He : 0.13

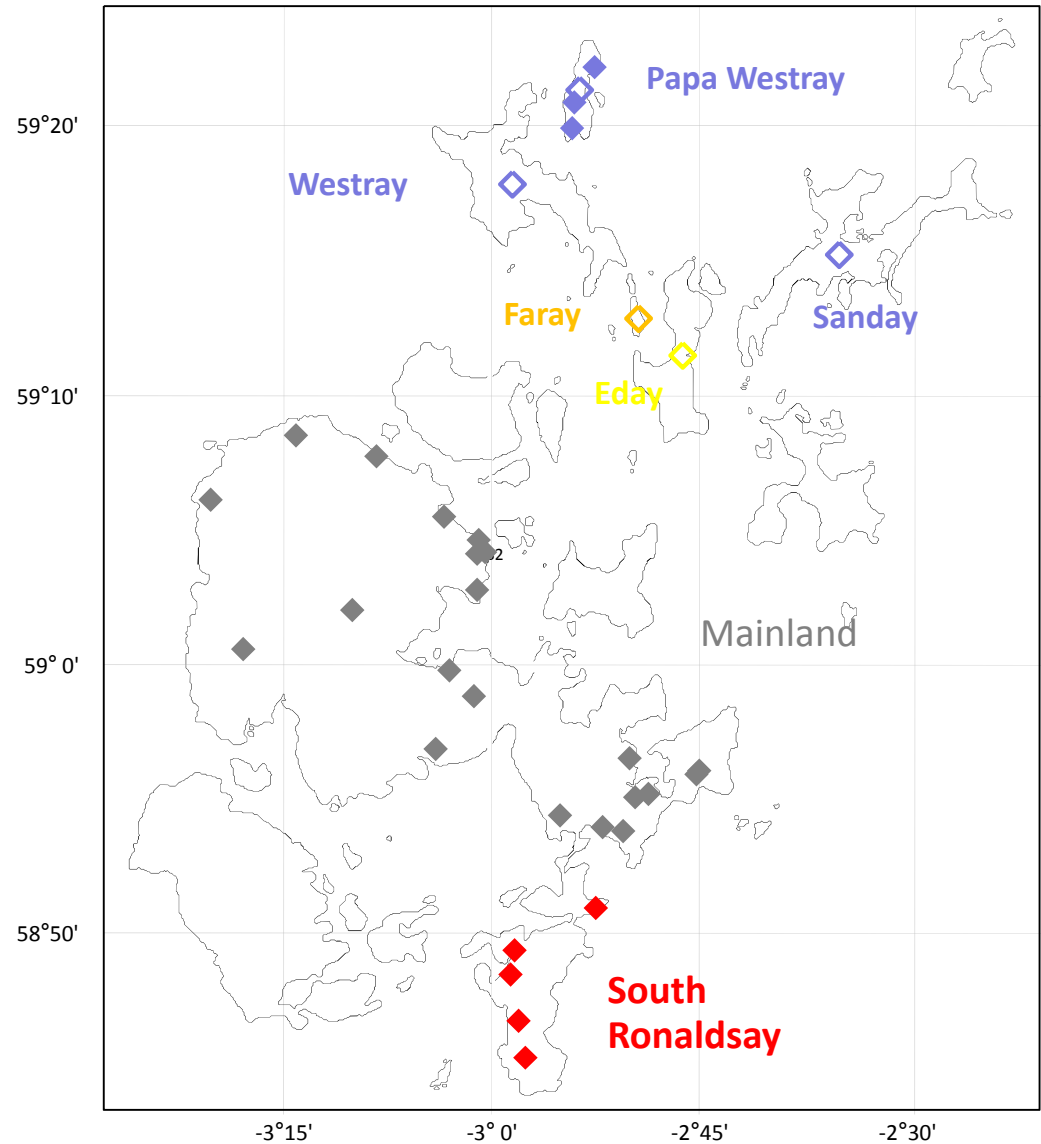
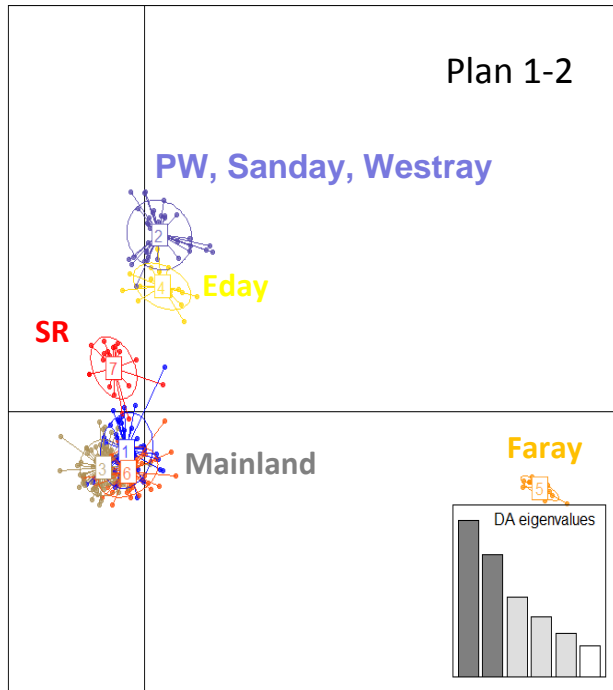
## Determination de la structure génétique

- DAPC (adegenet)

- Structure

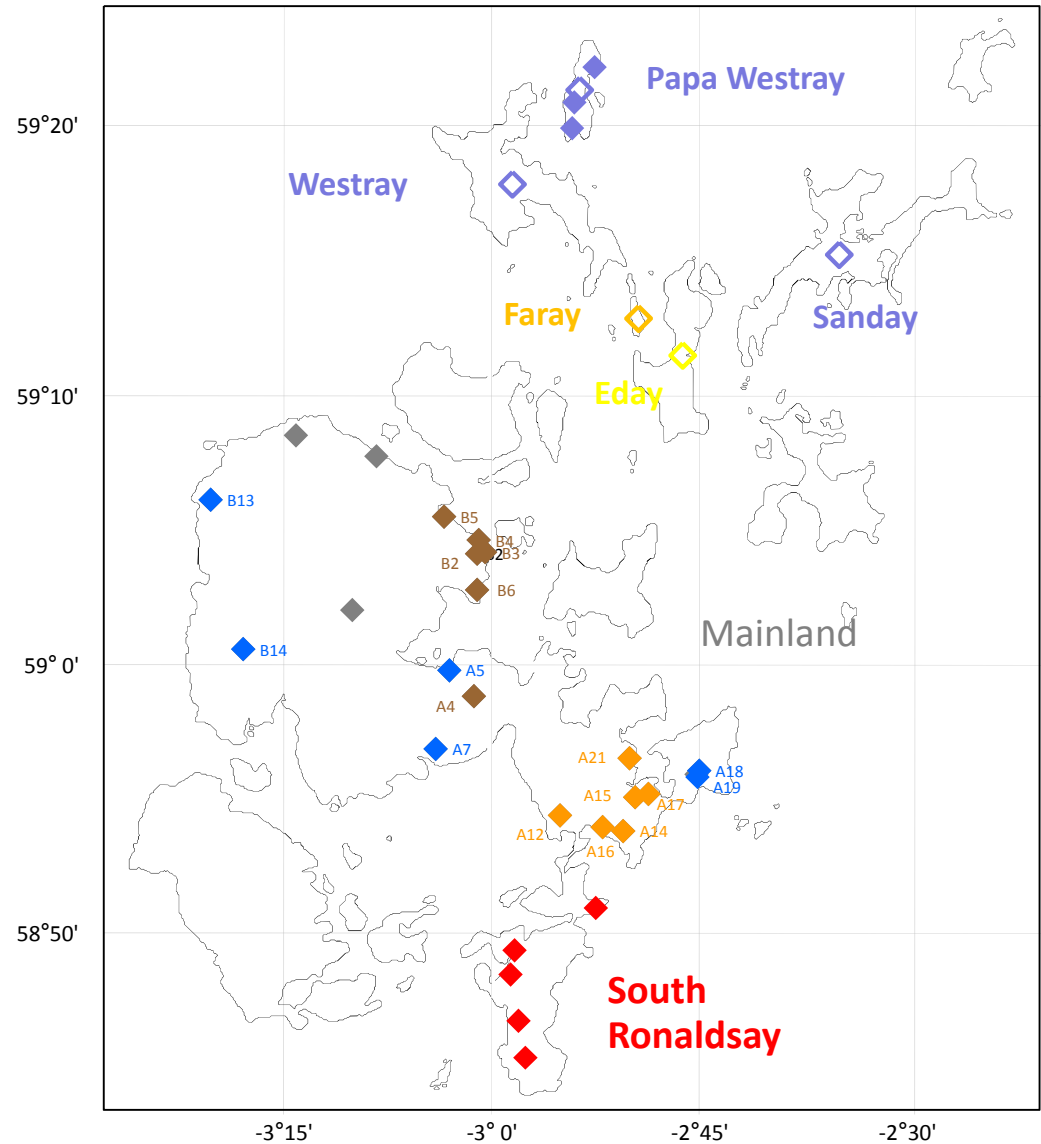
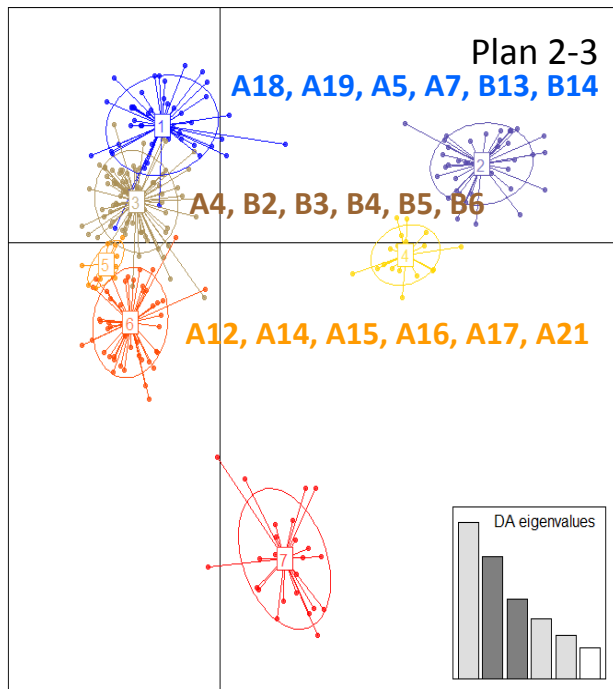
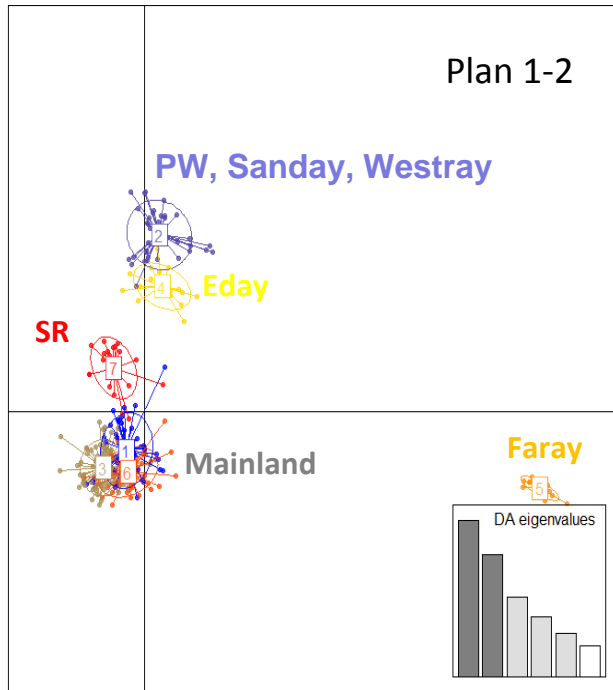
# Discriminant analysis of principal components (DAPC)

DAPC « find cluster » K = 7



# Discriminant analysis of principal components (DAPC)

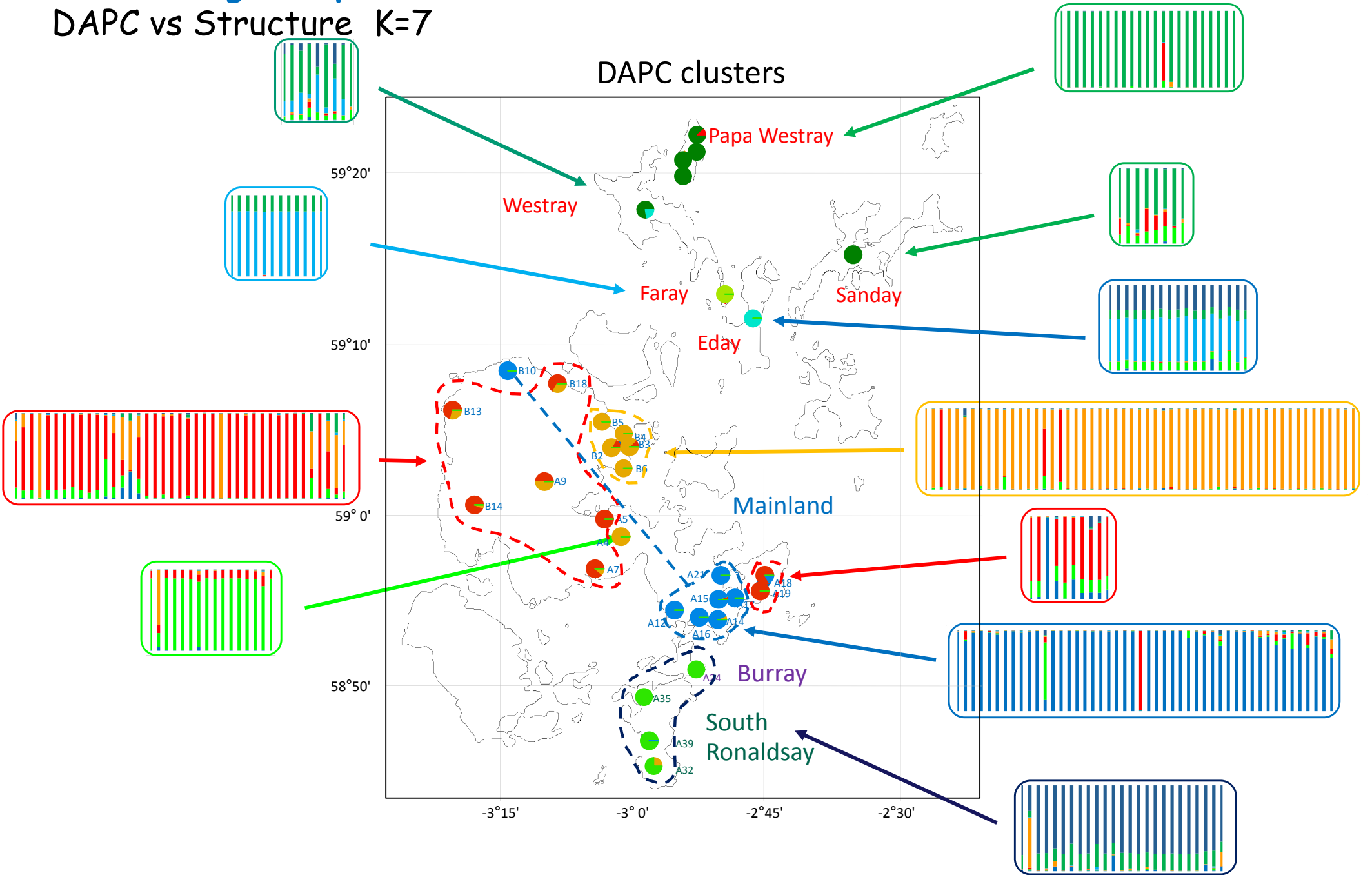
DAPC « find cluster » K = 7



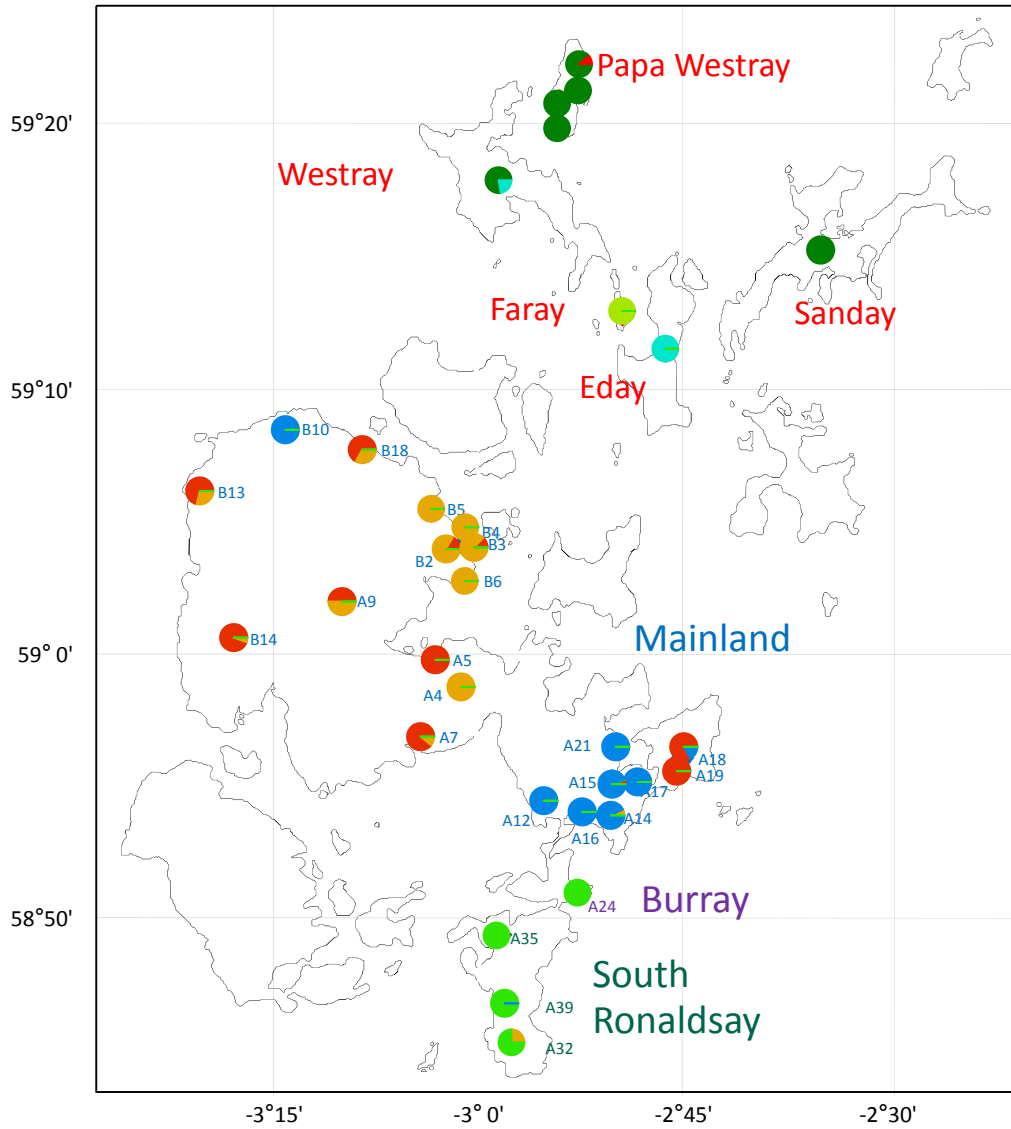
# Structure génétique

## DAPC vs Structure K=7

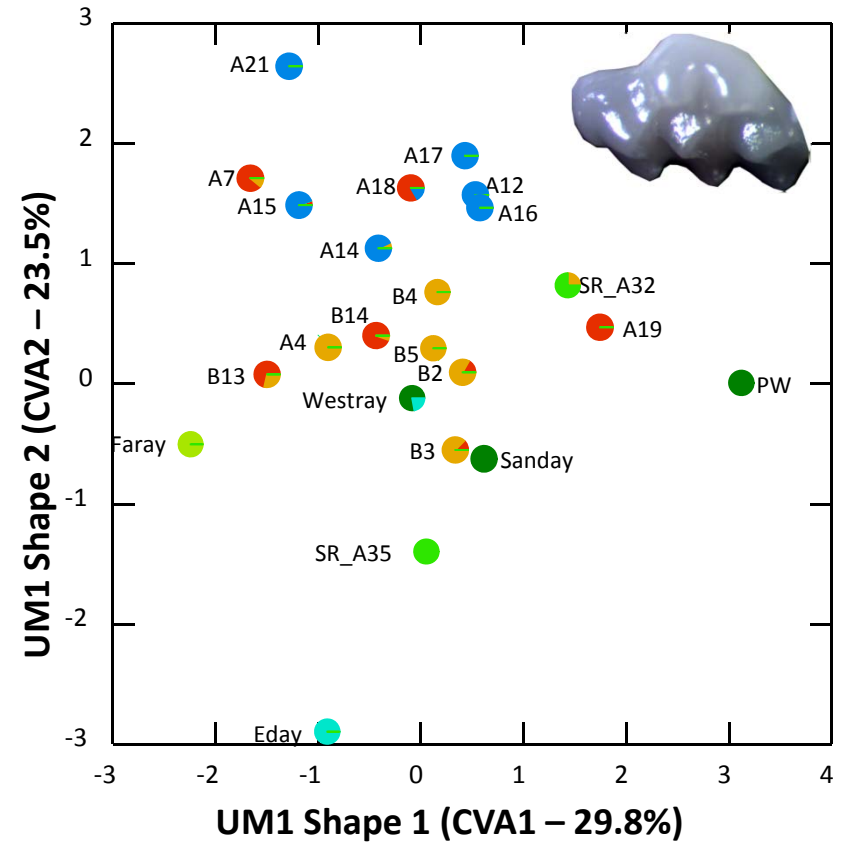
### DAPC clusters



# Evolution morphométrique et génétique



Corrélation  
évolution morphologique et moléculaire



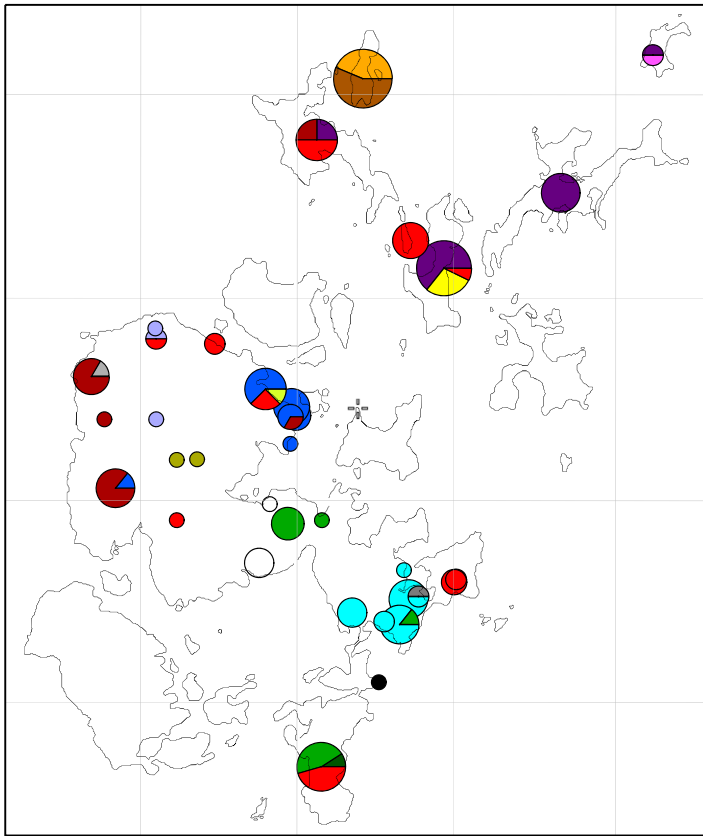
## Mantel test

Morphométrie (4 CVAs) } R = 0.496  
Genétique (5 DAPCs) } P = 0.002

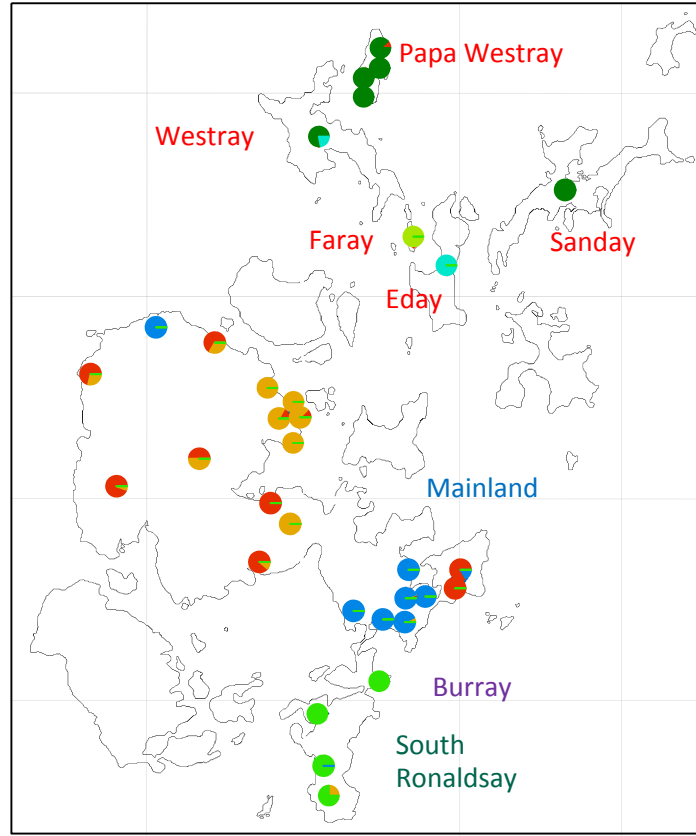
Morphométrie (4 CVAs) } R = 0.494  
Genétique (Nei et al.) } P = 0.0001



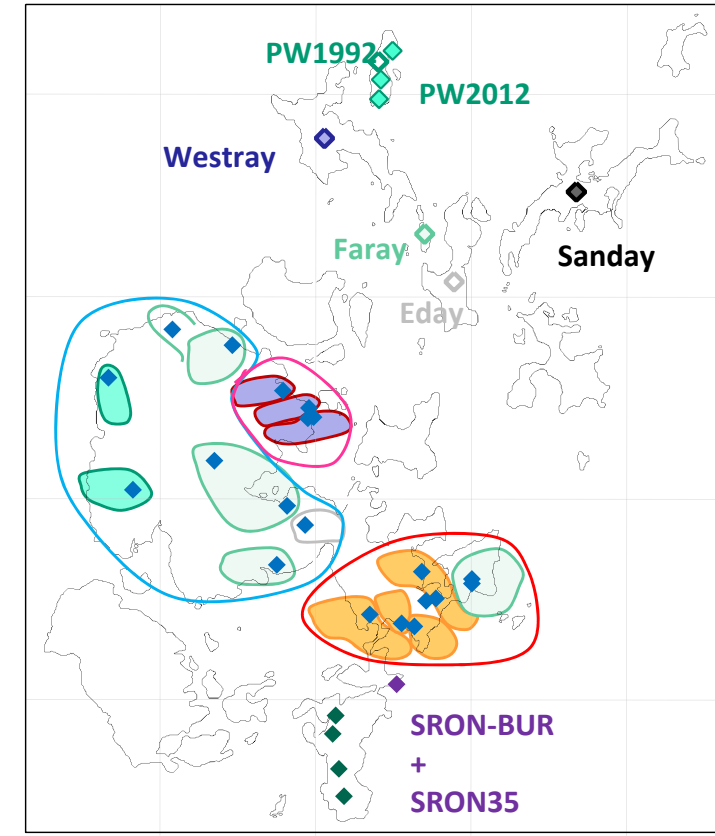
## Mitochondrial data



## Microsatellite data



## Morphometrical data



- Congruence entre les 3 approches
- Différenciation entre Mainland et les autres îles
- Structure intra-mainland

# La souris des Orcades

## Conclusions

- Diversification morphologique importante
- La phylogénie 1<sup>er</sup> facteur explicatif des variations de forme
- Congruence entre les différents marqueurs
- Structuration génétique

## Perspectives

- Analyse morphométrie/molécules au niveau individuel
- Origine de la structure sur Mainland
- Données Radseq :
  - Mainland (84 souris) (Cornell)
  - Papa Westray + South Ronaldsay (~ 20 souris supplémentaires)





## Bigtooth field team

*Jean-Christophe Auffray*

*Pascale Chevret*

*Sylvie Agret*

*Annie Orth*

*Josette Catalan*

*Lionel Hautier*

