# A combination of empirical and modelled datasets reveals associations between deep diving seabirds and oceanographical processes at fine spatiotemporal scales in a high energy habitat

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# Collision Risks and Spatial Overlap

•Impacts of tidal stream turbines on seabird populations unknown.

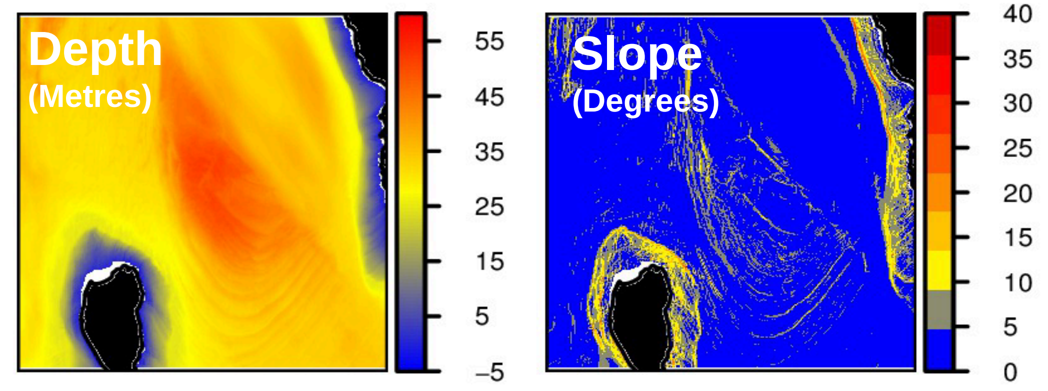
•Quantifying collision risks between deep diving seabirds and devices prioritised.

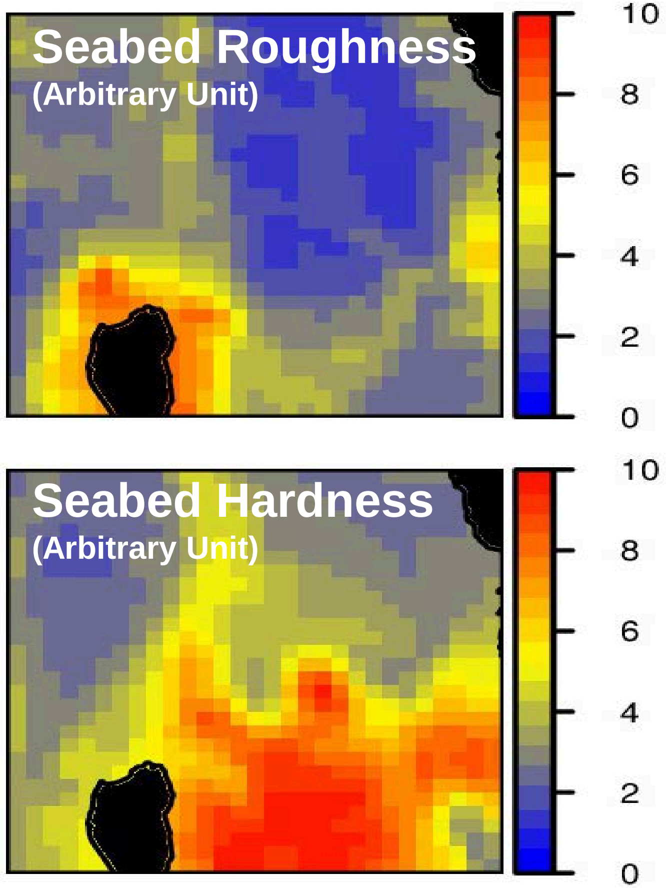
•Estimating spatial overlap an essential component of quantifying collision risk

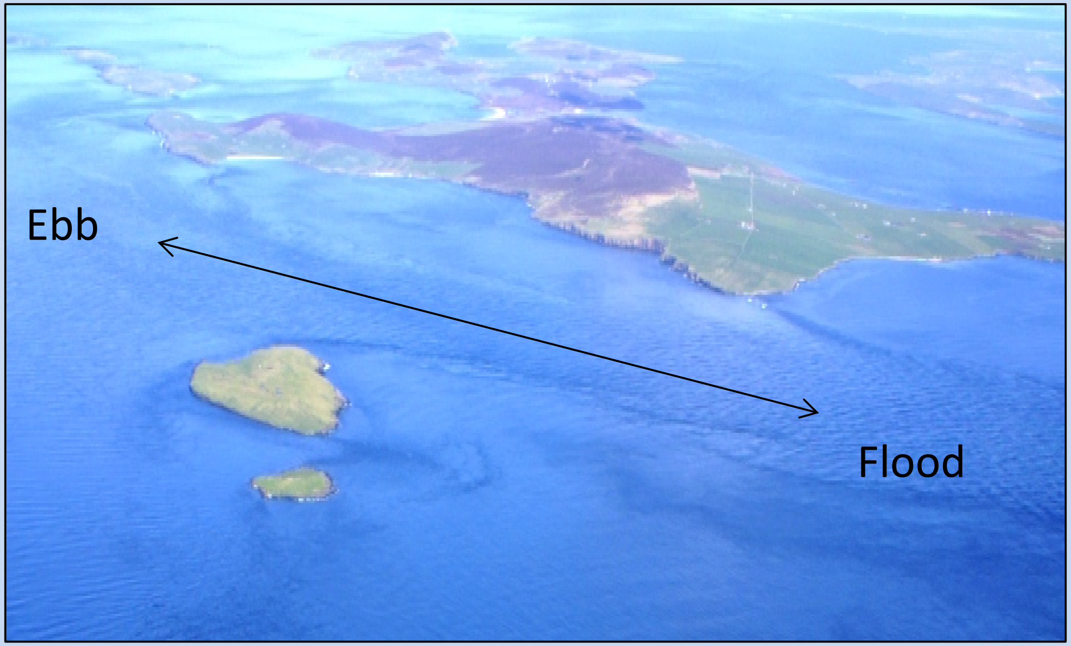
•Understand and predict seabird foraging distributions within the tidal pass habitats favoured for installations

# Fall Of Warness, Orkney, UK

- Typical tidal pass habitat
- Strong bidirectional currents
- Complex topography
- Complex bathymetry



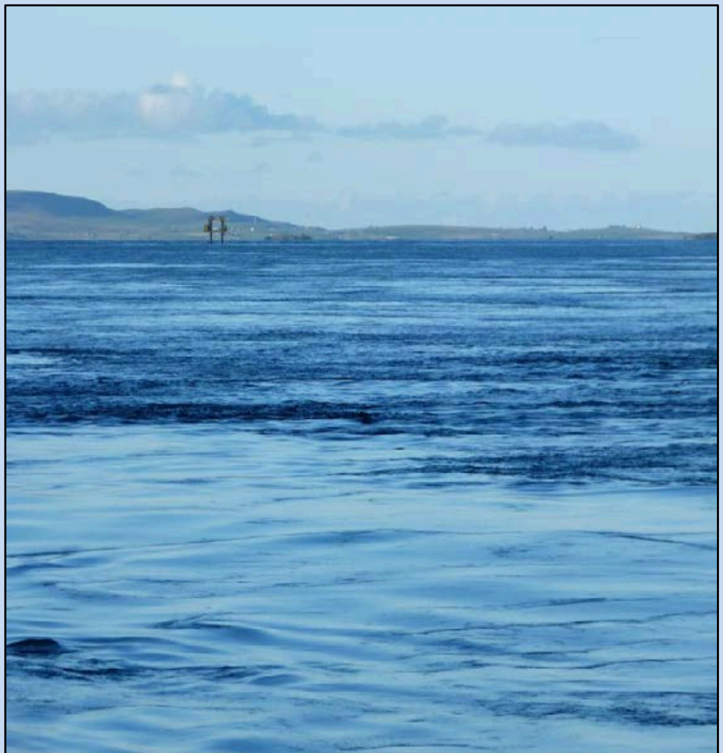




Bathymetry is from multibeam sonar
Seabed characteristics are from echosounder

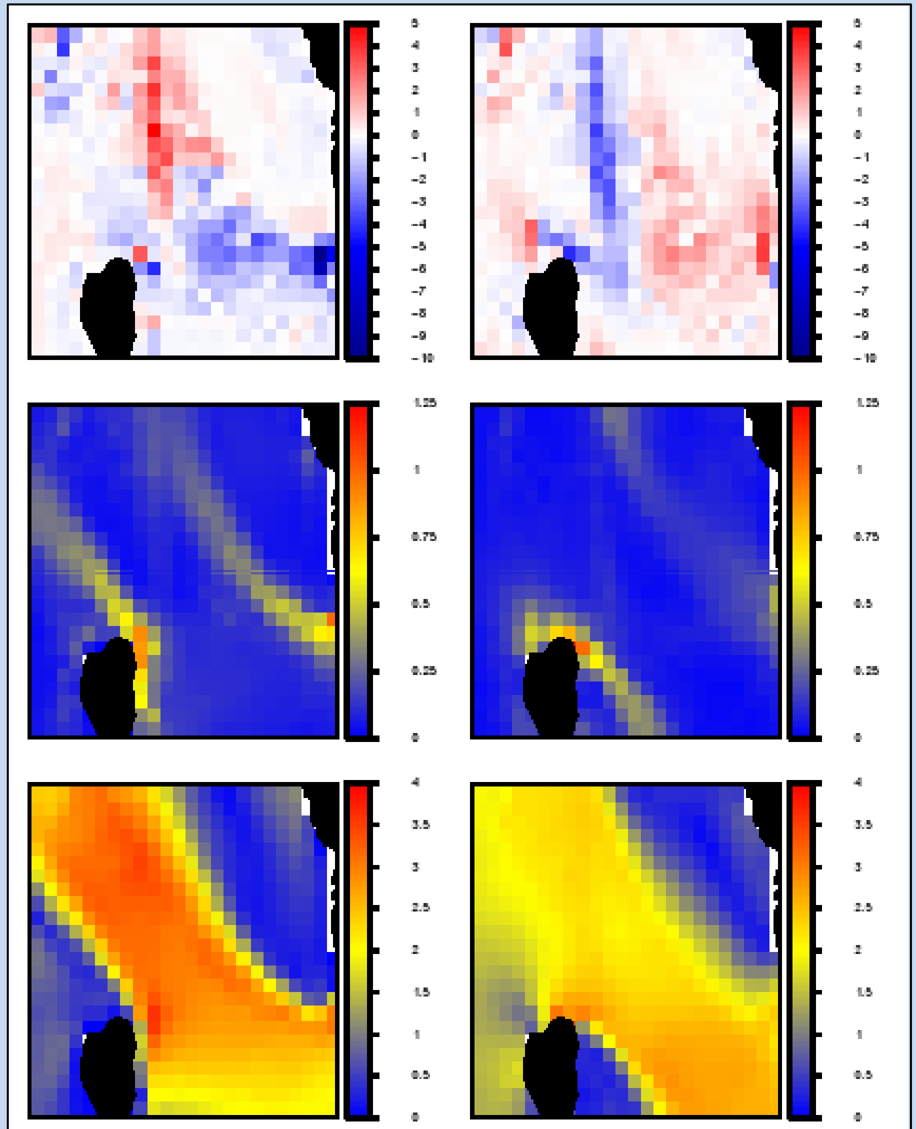
# Fall Of Warness, Orkney, UK

- Ebb-Flood Tidal Cycle
- Variations in feature location
- Upwelling/Downwelling
- Turbulence
- Current Speeds



FVCOM 3D Hydrodynamic Model Outputs

**Ebb** | **Flood**



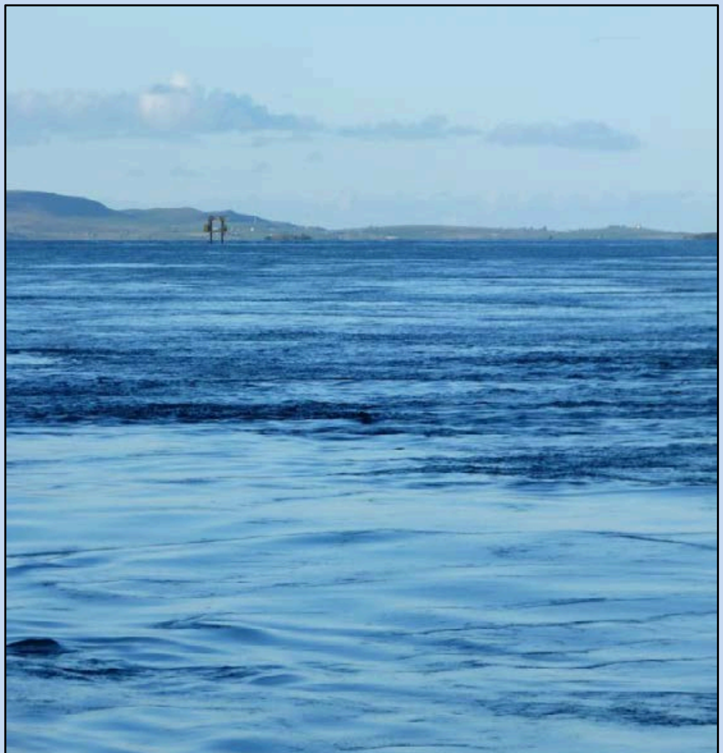
**Upwelling** ( cm/s)

**Turbulence** (Eddy Viscosity)

**Speed** (m/s)

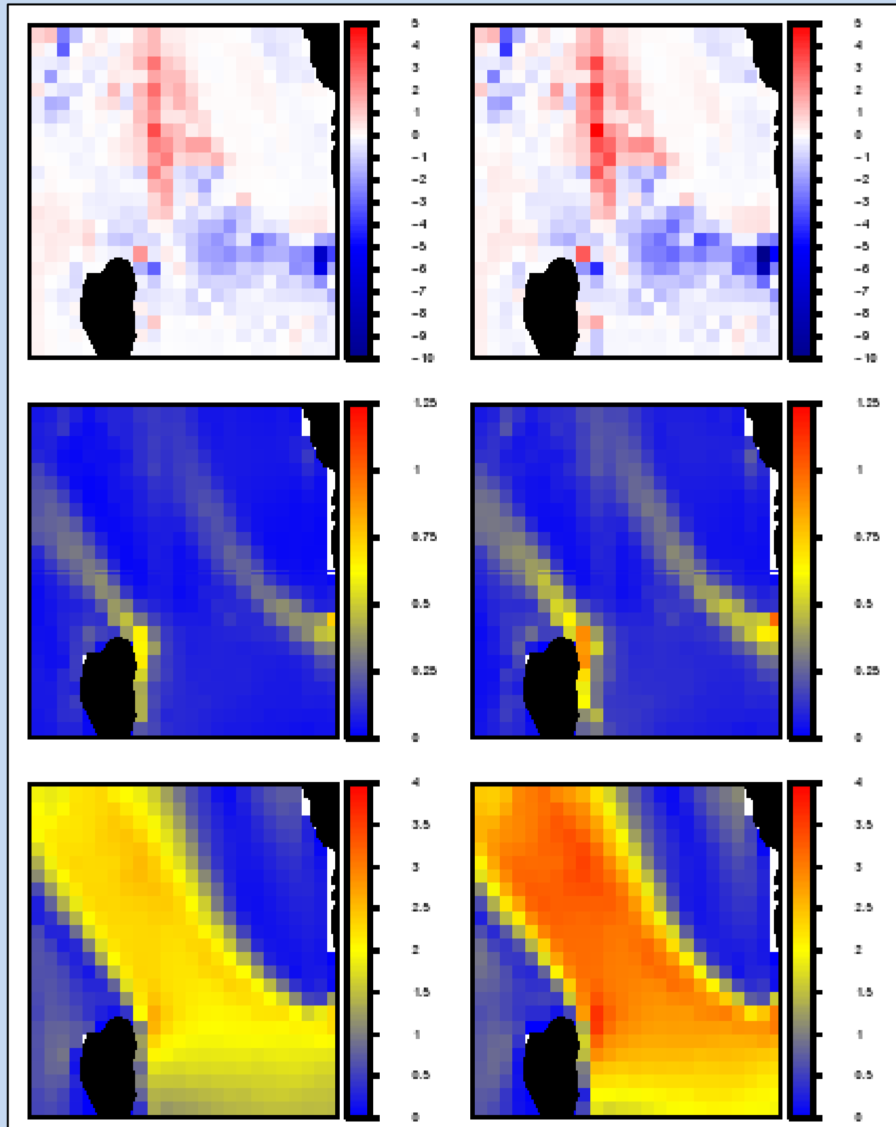
# Fall Of Warness, Orkney, UK

- •Neap-Spring Tidal Cycle
- •Variations in feature extent
- •Upwelling/Downwelling
- •Turbulence
- •Current Speeds



FVCOM 3D Hydrodynamic Model Outputs →

**Neap** (Ebb) **Spring** (Ebb)



**Upwelling** ( cm/s)

**Turbulence** (Eddy Viscosity)

**Speed** (m/s)

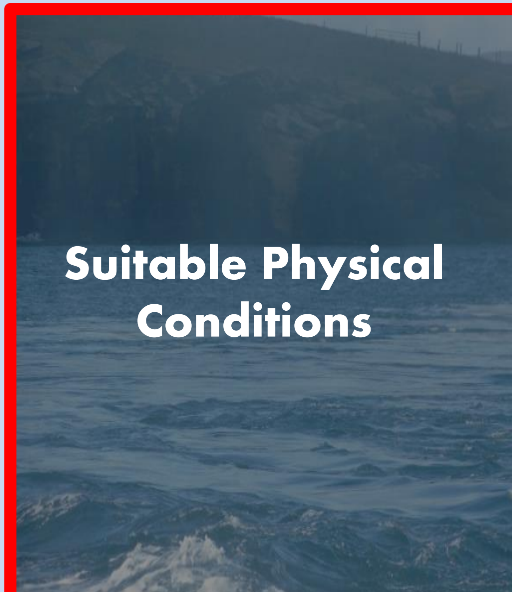
# Understanding and Predicting Seabird Distributions

•Seabird associate with physical conditions that promote prey availability.

•Prey availability difficult to collect and quantify over entire tidal pass habitats.

•Understanding associations between seabirds and physical conditions enables predictions of distributions.

•Concurrent seabird and physical datasets need collecting over several seasons and tidal states.





Predictions of foraging Distributions

# Seabird Distributions

Vessel Based Observers

103 transects

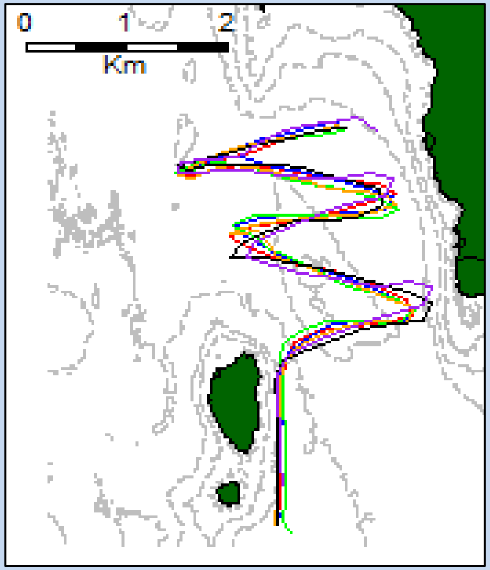
May and October

2012 and 2013

Zigzag route against currents

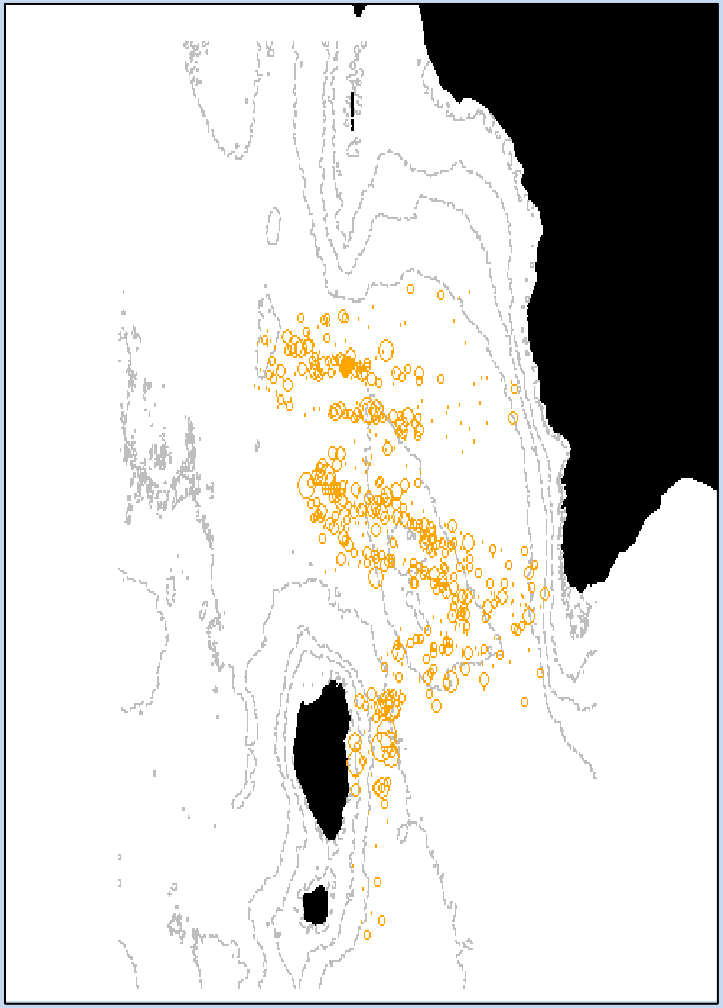
Only seabirds upon the sea surface recorded

Positions calculated to an estimated accuracy of several hundred metres




# Seabird Distributions

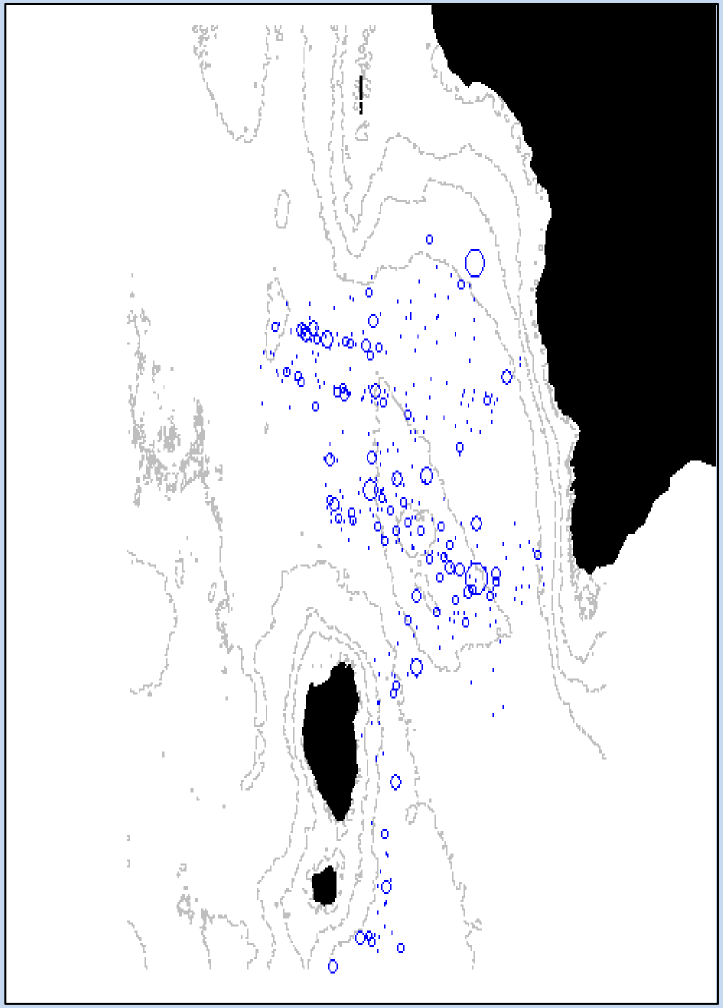
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



**<u>Atlantic Puffin *Fratercula arctica*</u>**
Feed primarily within water column
Present during May

# Seabird Distributions

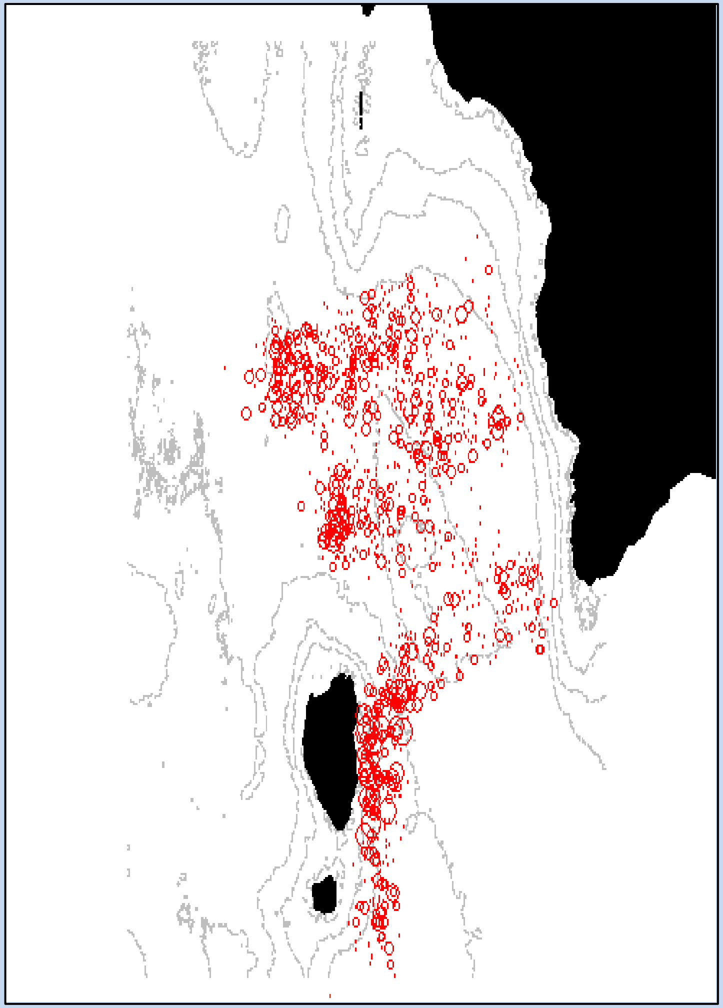
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



**Common Guillemot *Uria aalge***
Feed primarily within water column
Present during May

# Seabird Distributions

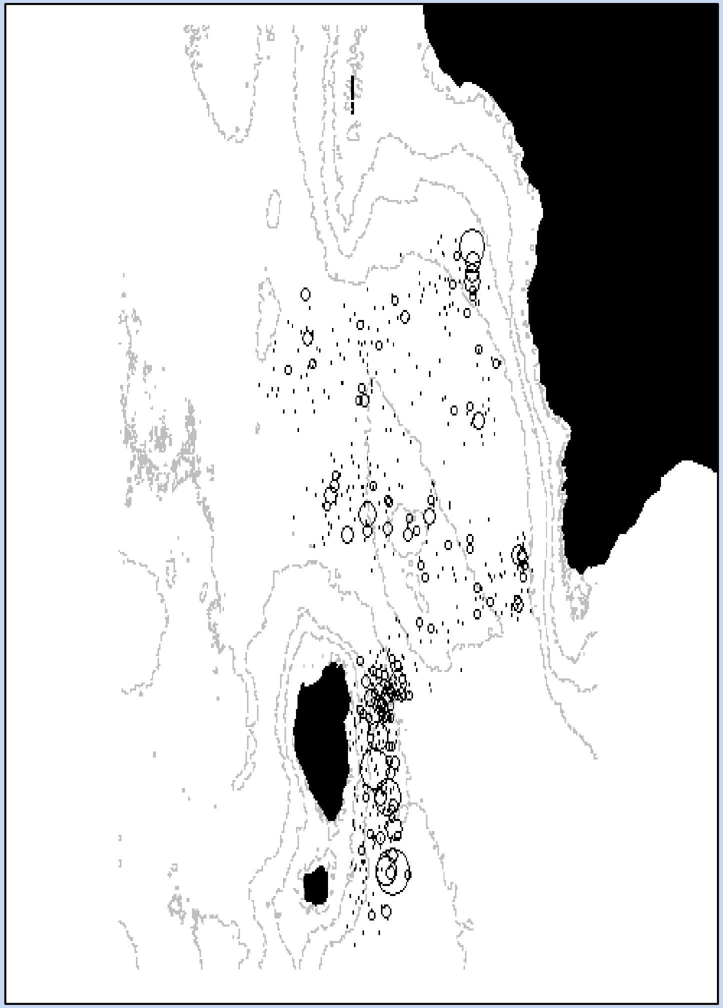
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



**<u>Black Guillemot *Cepphus grylle*</u>**
Feed primarily upon seabed
Present during May and October.

# Seabird Distributions

4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



**European Shag *Phalacrocorax aristotelis***
Feed primarily upon seabed
Present during May and October.

# General Linear Mixed Effect Models

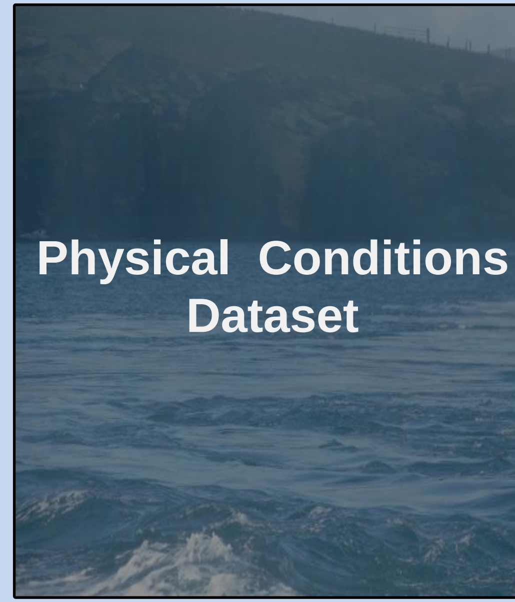
**Seabird Abundances**
Atlantic Puffin (May)
Black Guillemot (May, Oct)
Common Guillemot (May)
European Shag (May, Oct)

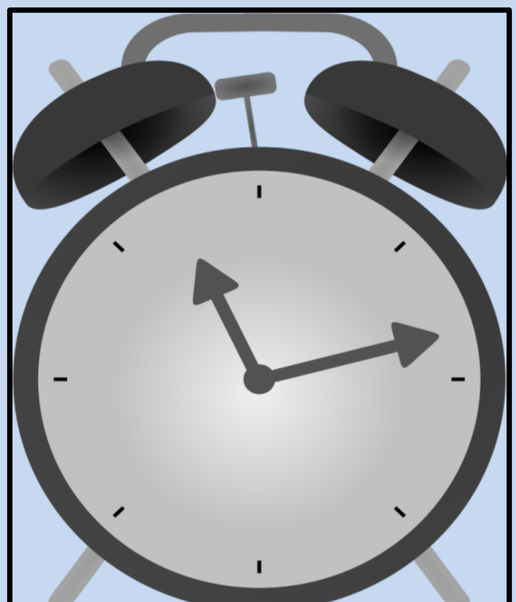
**Environmental Variables**
Speed
Turbulence
Upward Currents
Seabed (Roughness/Hardness)

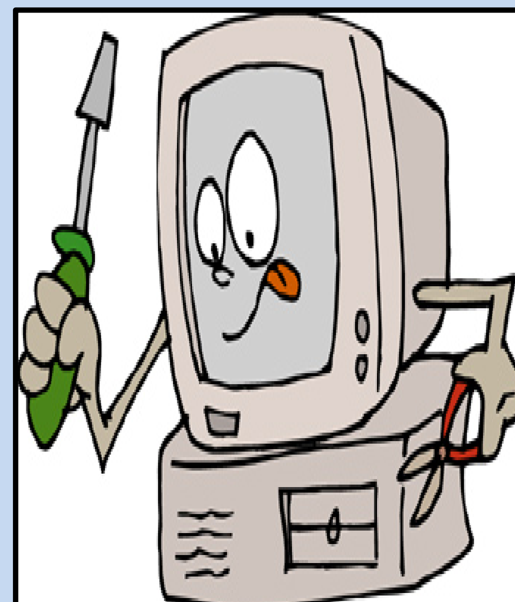
**Random Variables**
DateTime

**Run Model**
Poisson Distribution
Selected Models using p-values

**Predictions**
Used Model Coefficients



# Model Outputs

•Variations in microhabitat associations among species.

•Seasonal variations in species microhabitat associations.

•Variations in microhabitat associations complexities.

•Benthic foragers always associated with soft/rough substrate.

•Pelagic foragers always associated with fast current speeds

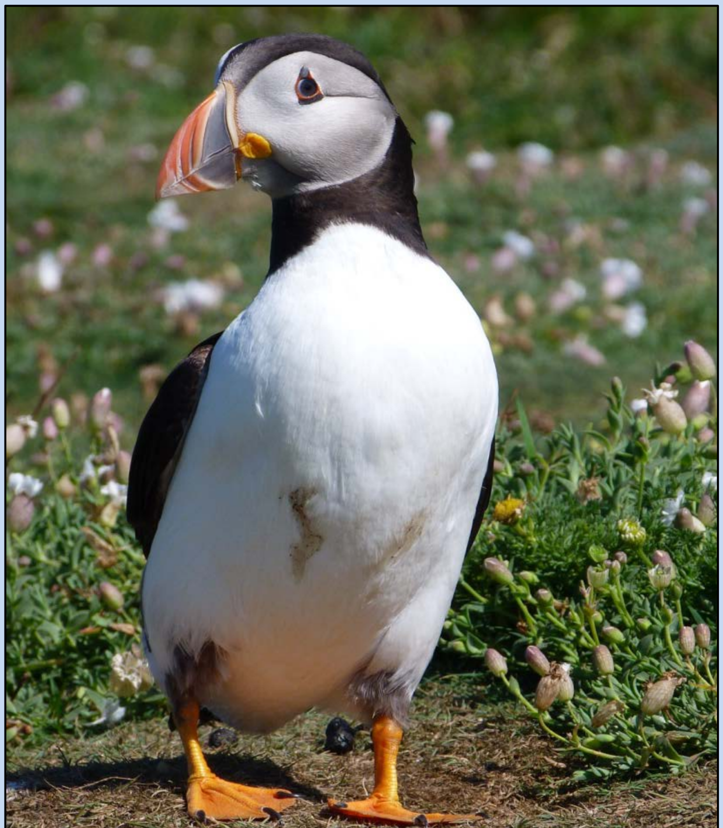
| Season | Species | Speed | Turbulence | Upwelling | Substrate |
|---|---|---|---|---|---|
| Summer | Atlantic Puffin | Positive | Positive | | |
| Summer | Common Guillemot | Positive | | | |
| Summer | Black Guillemot | Negative | Positive | Downwelling | Soft/Rough |
| Winter | Black Guillemot | Positive | | Neither | Soft/Rough |
| Summer | European Shag | | | Downwelling | Soft/Rough |
| Winter | European Shag | Negative | | | Soft/Rough |

# Predicted Distributions

## Atlantic Puffin (Summer)

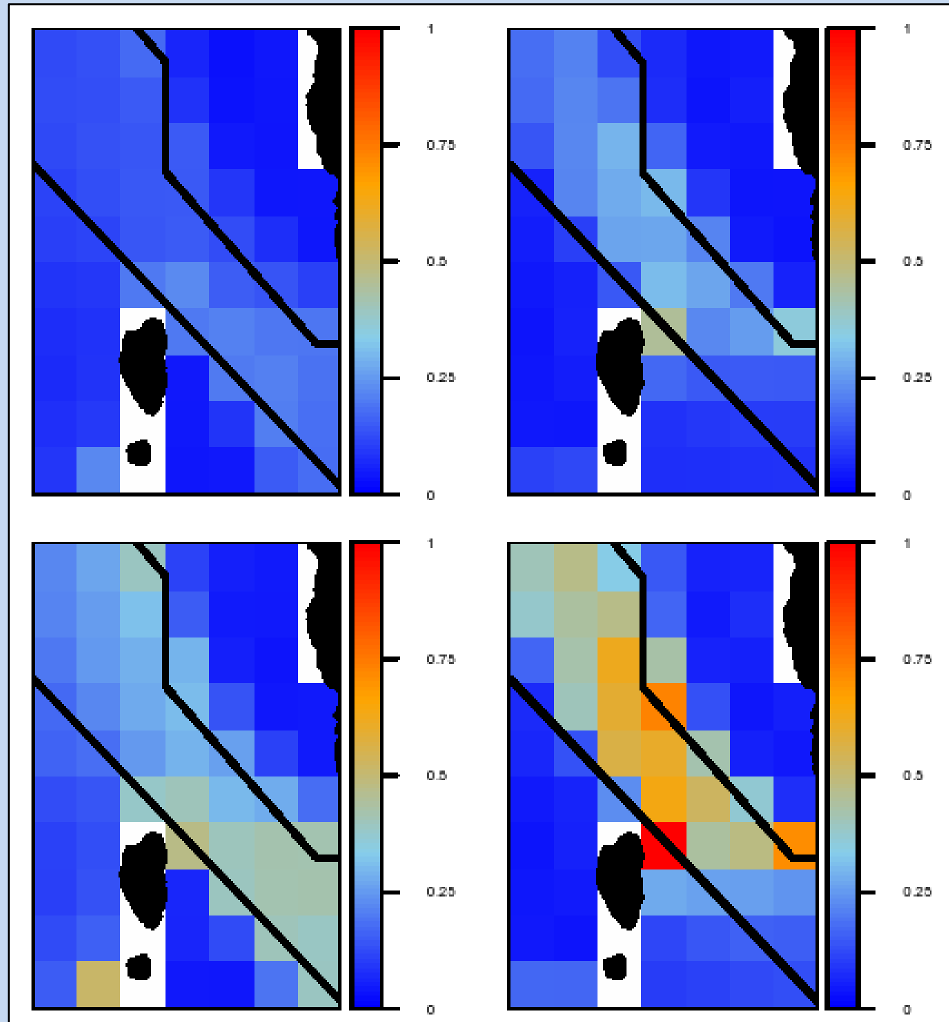
High Spatial Overlap
Increases during spring tides
Increases during ebb tides

**Black Lines = Turbine Area**



Flood

Ebb




Neap

Spring

# Predicted Distributions

## Common Guillemot (Summer)

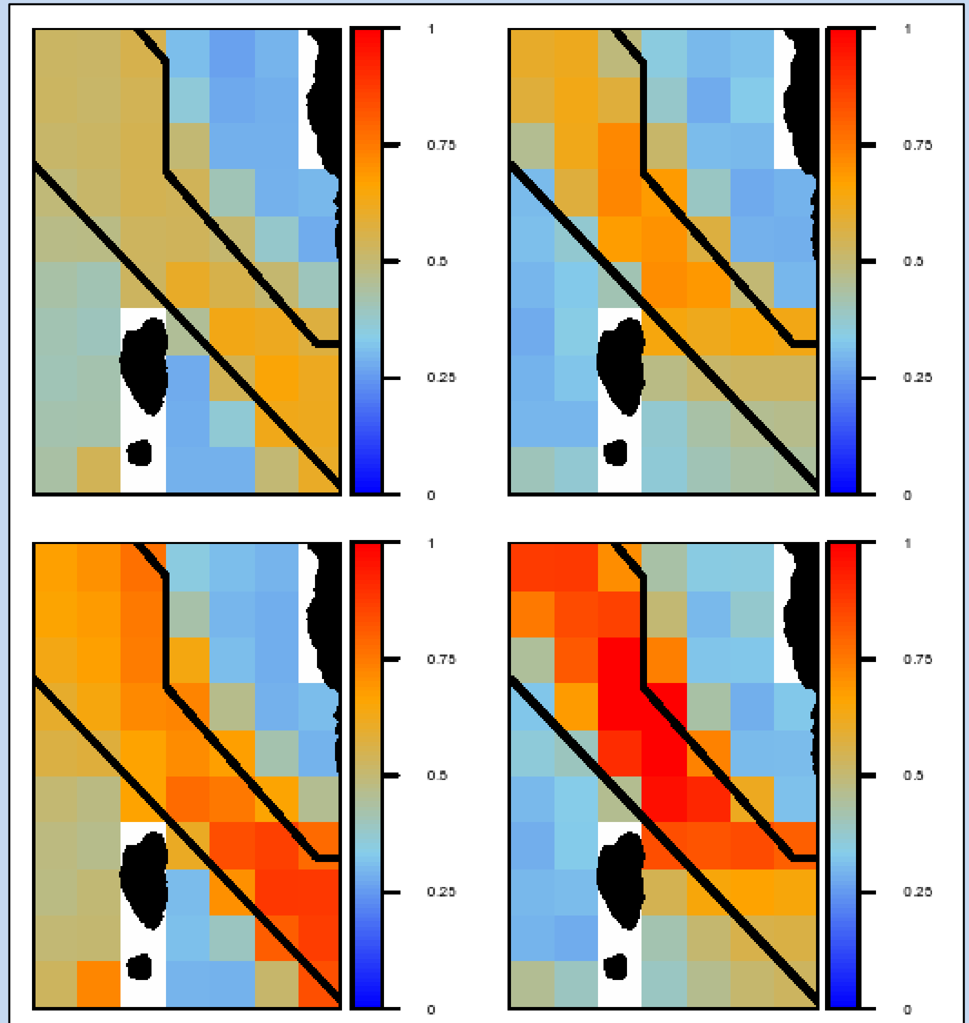
High Spatial Overlap
Increases during spring tides
Increases during ebb tides

**Black Lines = Turbine Area**

Flood | Ebb

Neap

Spring



# Predicted Distributions

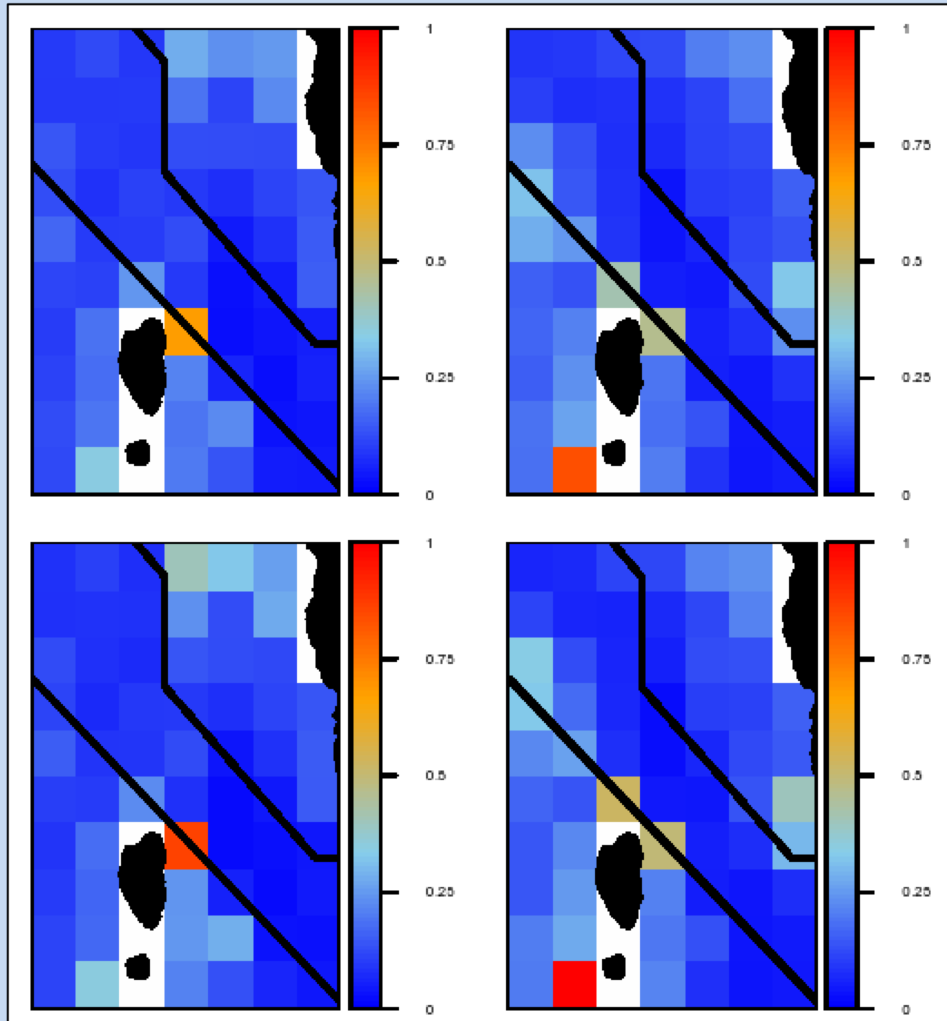
## Black Guillemot (Summer)

Low Spatial Overlap

**Black Lines = Turbine Area**

Flood

Ebb




Neap

Spring

# Predicted Distributions

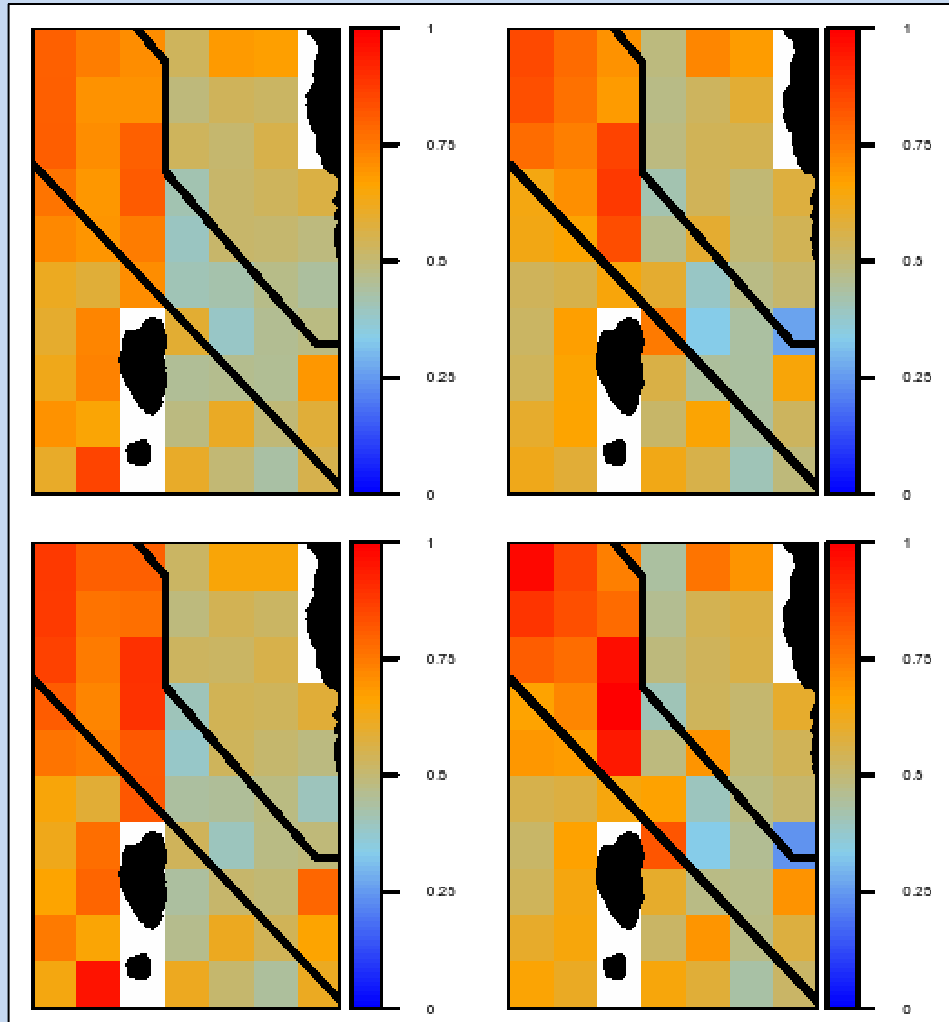
## Black Guillemot (Winter)

Moderate Spatial Overlap

**Black Lines = Turbine Area**

Flood

Ebb




Neap

Spring

# Predicted Distributions

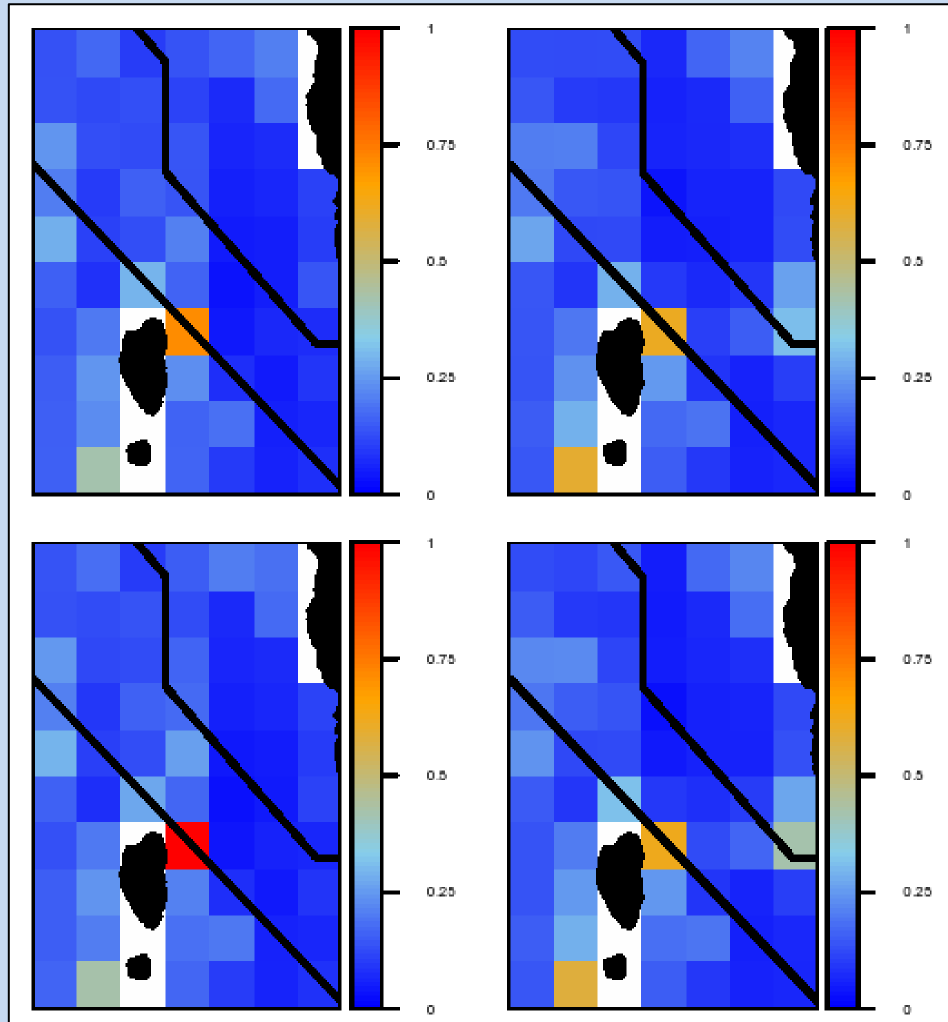
## European Shag (Summer)

Low Spatial Overlap

**Black Lines = Turbine Area**

Flood

Ebb




Neap

Spring

# Predicted Distributions

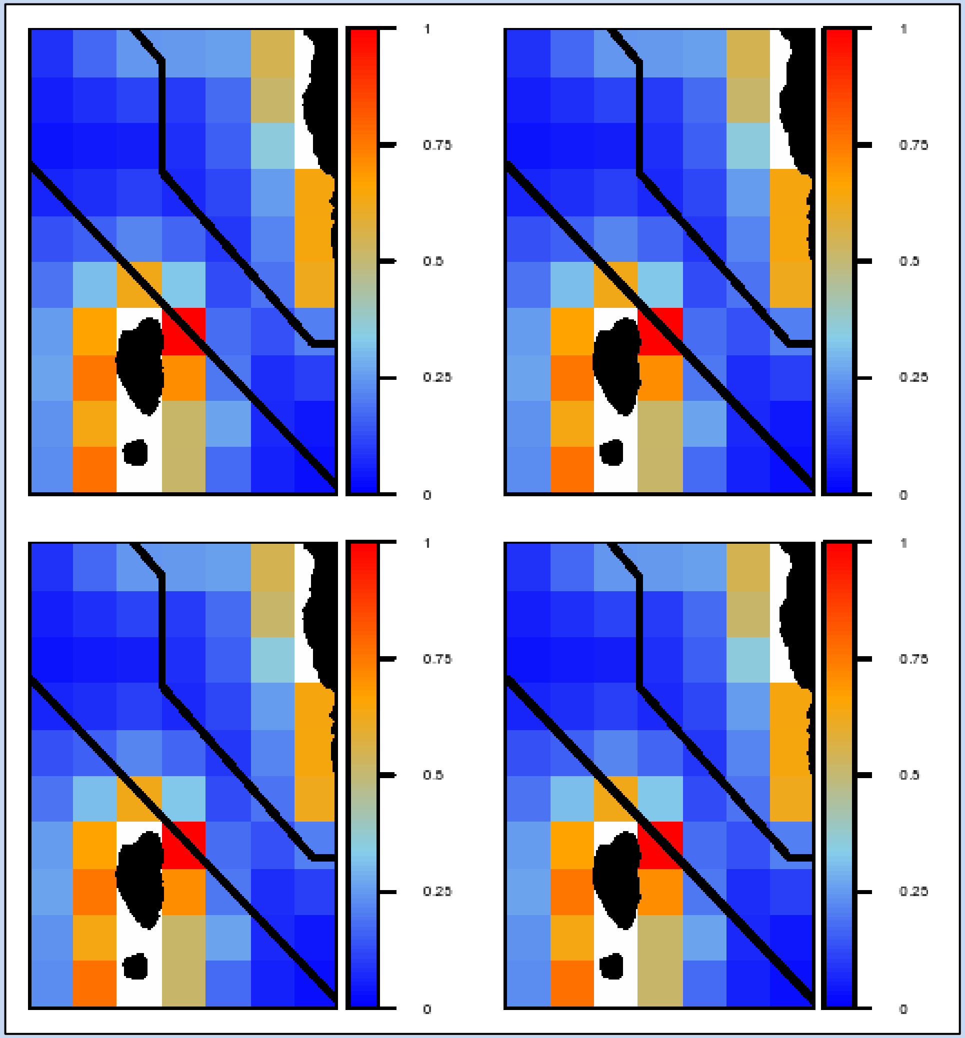
## European Shag (Winter)

Low Spatial Overlap

**Black Lines = Turbine Area**

Flood

Ebb




Neap

Spring

# Conclusions

**Differences in associations among species and within species over time.**

**Several ecological explanations relating to resource competition and foraging behaviours**

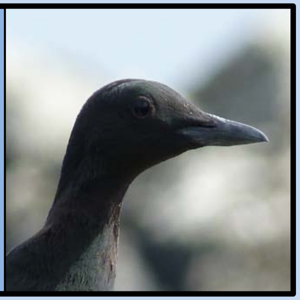
**However, results highlight which and when species are most likely to forage near tidal stream turbines.**

**Quantitative measures enable predictions of spatial overlap at population levels**

**Atlantic Puffin**
*Summer Resident*
*High Spatial Overlap*
*Increases in Ebb and Spring Tides*

**Common Guillemot**
*Summer Resident*
*High Spatial Overlap*
*Increases in Ebb and Spring Tides*

**Black Guillemot**
*Summer and Winter Resident*
*Moderate Spatial Overlap in Winter*



**European Shag**
*Summer and Winter Resident*
*Low Spatial Overlap*

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