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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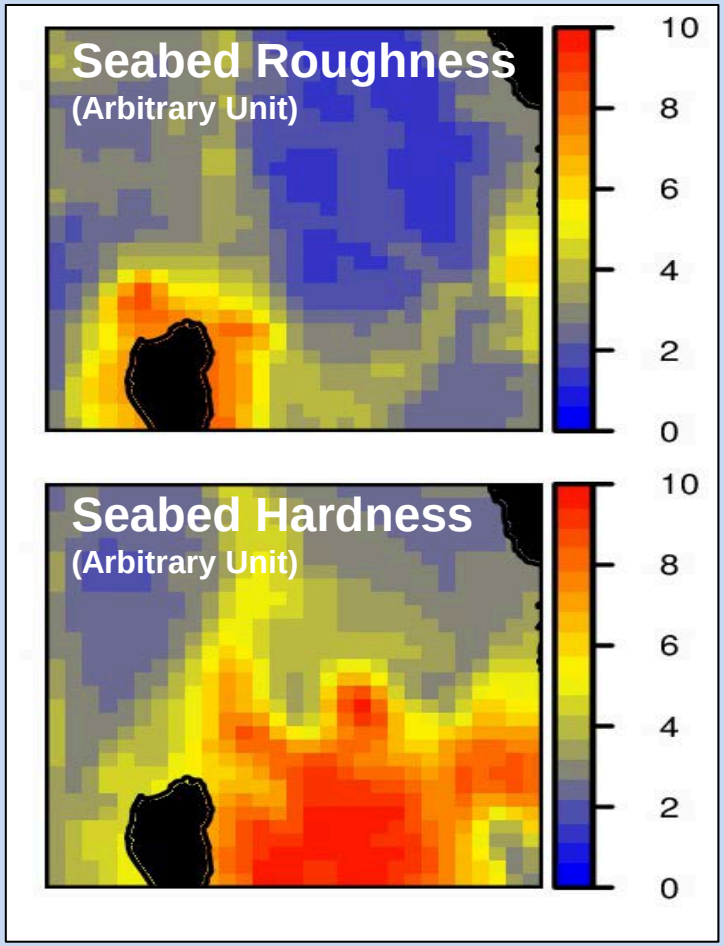
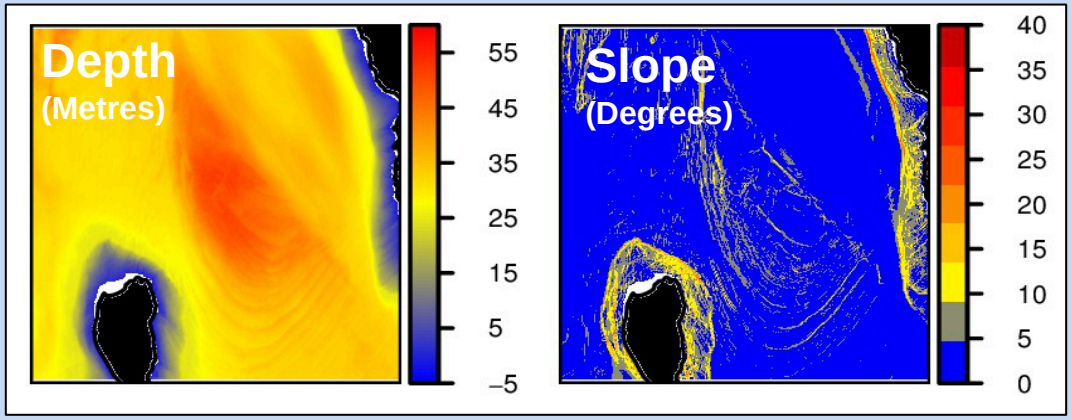
Collision Risks and Spatial Overlap

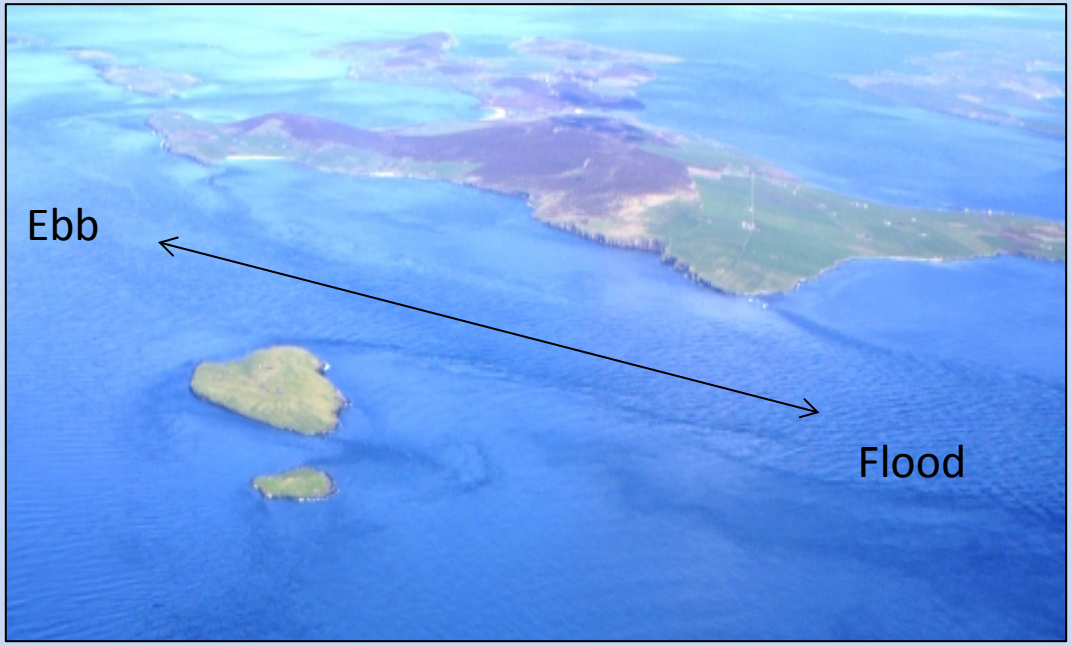
- Impacts of tidal stream turbines on seabird populations unknown.
- Quantifying collision risks between deep diving seabirds and devices prioritised.
- Estimating spatial overlap an essential component of quantifying collision risk
- Understand and predict seabird foraging distributions within the tidal pass habitats favoured for installations

Fall Of Warness, Orkney, UK

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



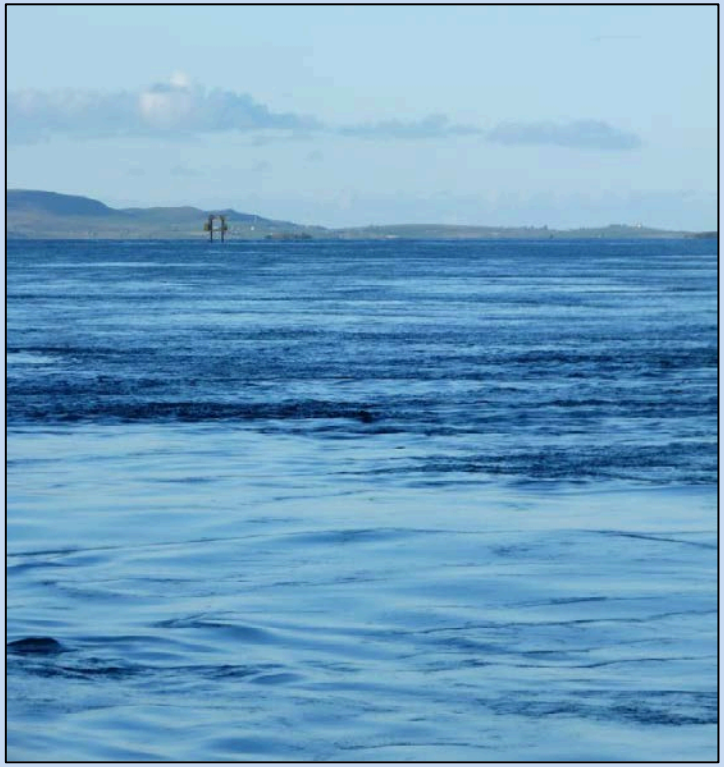




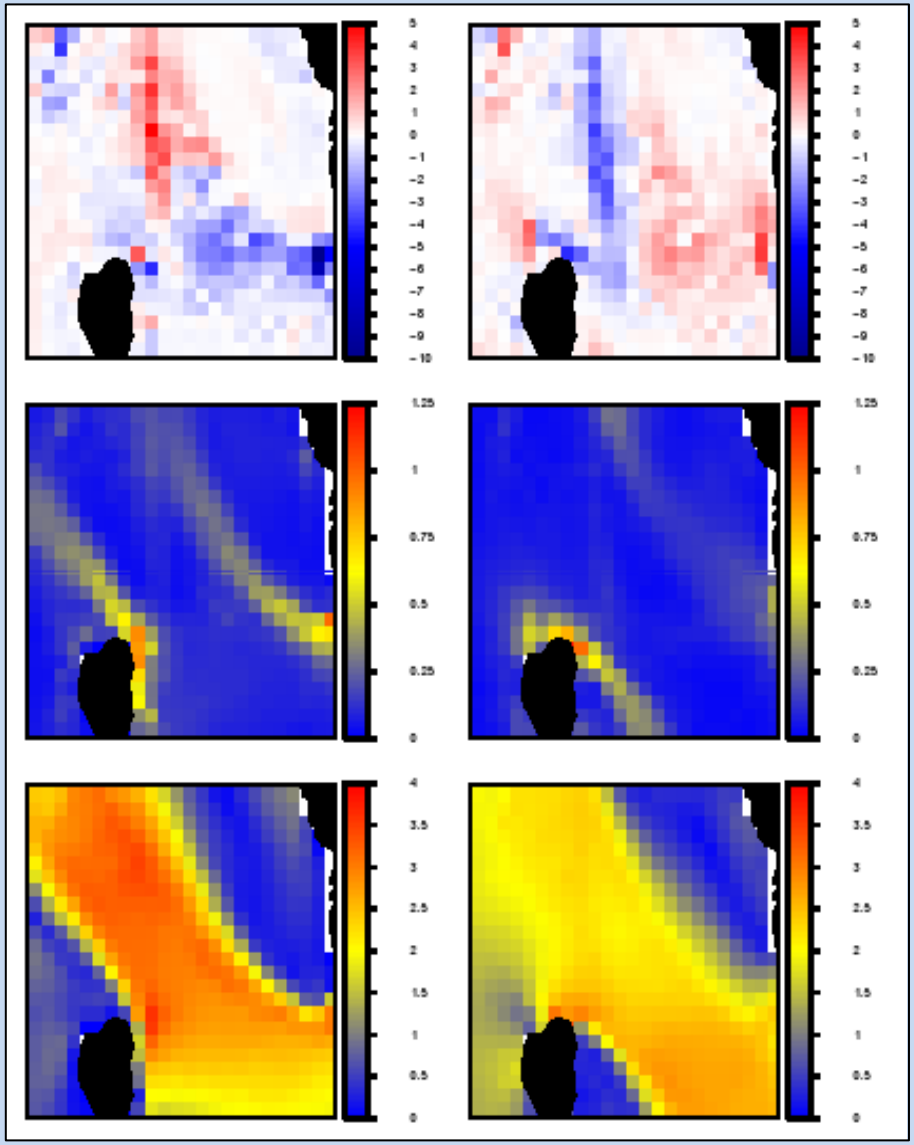
Bathymetry is from multibeam sonar
Seabed characteristics are from echosounder

Fall Of Warness, Orkney, UK

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

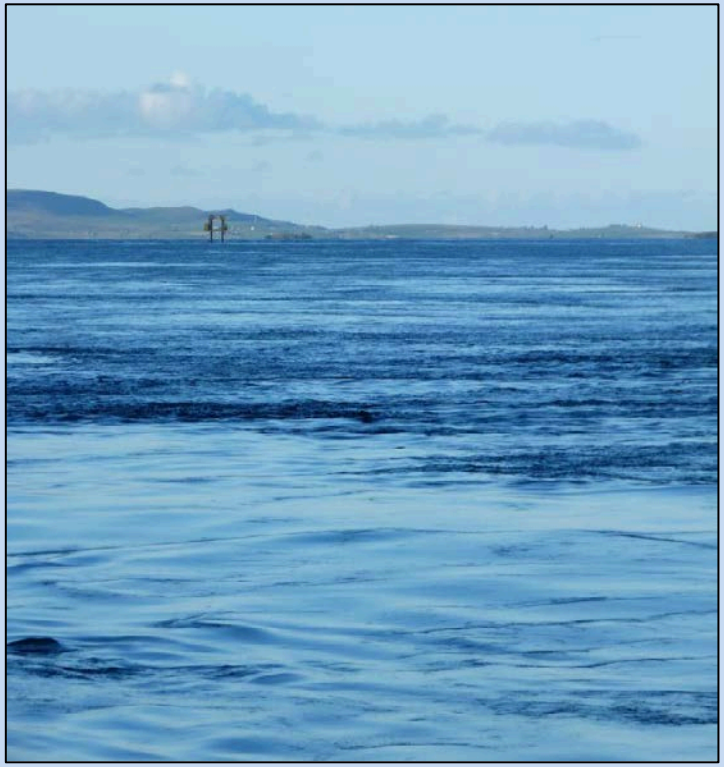


FVCOM 3D Hydrodynamic Model Outputs →

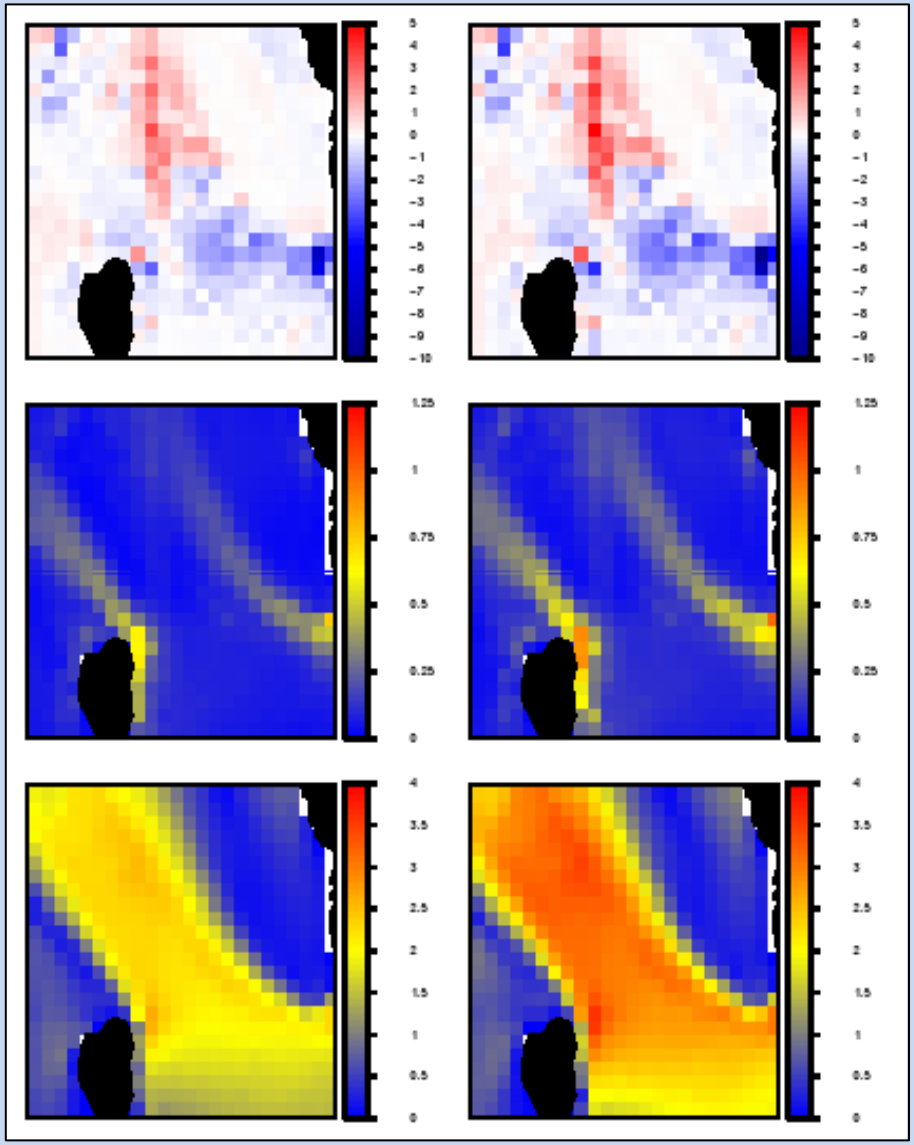


Fall Of Warness, Orkney, UK

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

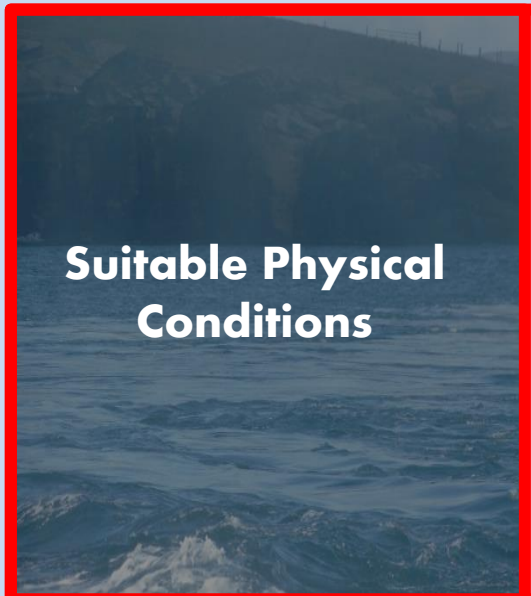


FVCOM 3D Hydrodynamic Model Outputs



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

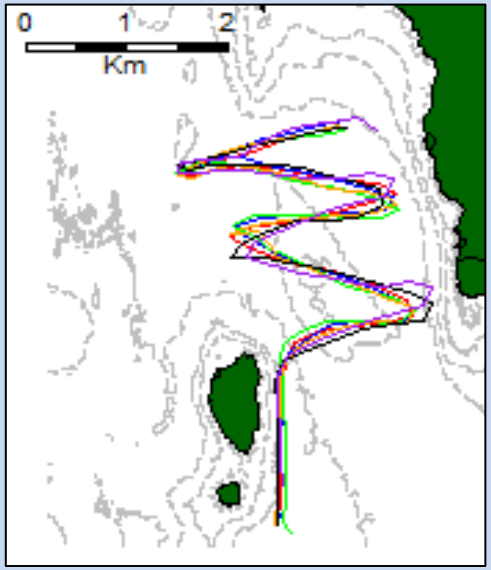
May and October

2012 and 2013

Zigzag route against currents

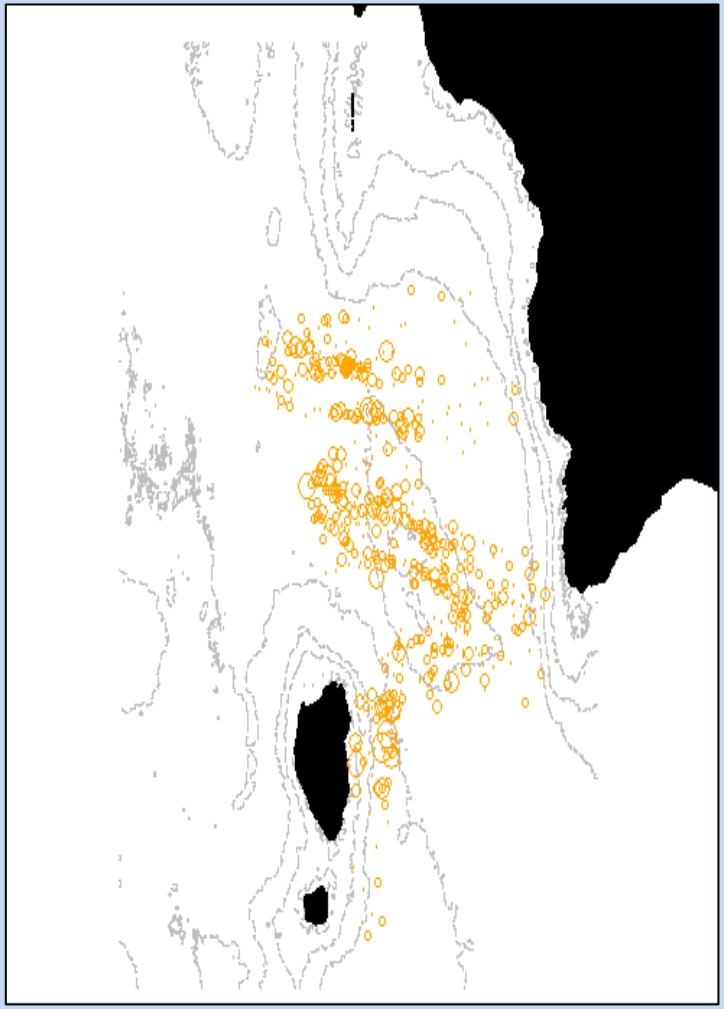
Only seabirds upon the sea surface recorded

Positions calculated to an estimated accuracy of several hundred metres



Seabird Distributions

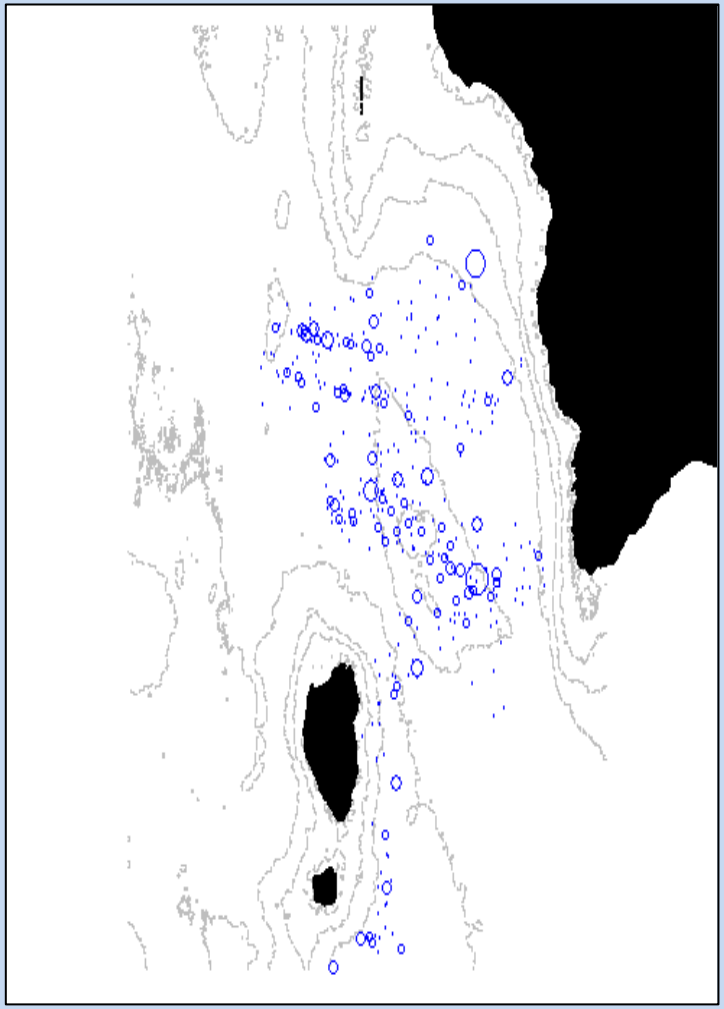
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



Atlantic Puffin *Fratercula arctica*
Feed primarily within water column
Present during May

Seabird Distributions

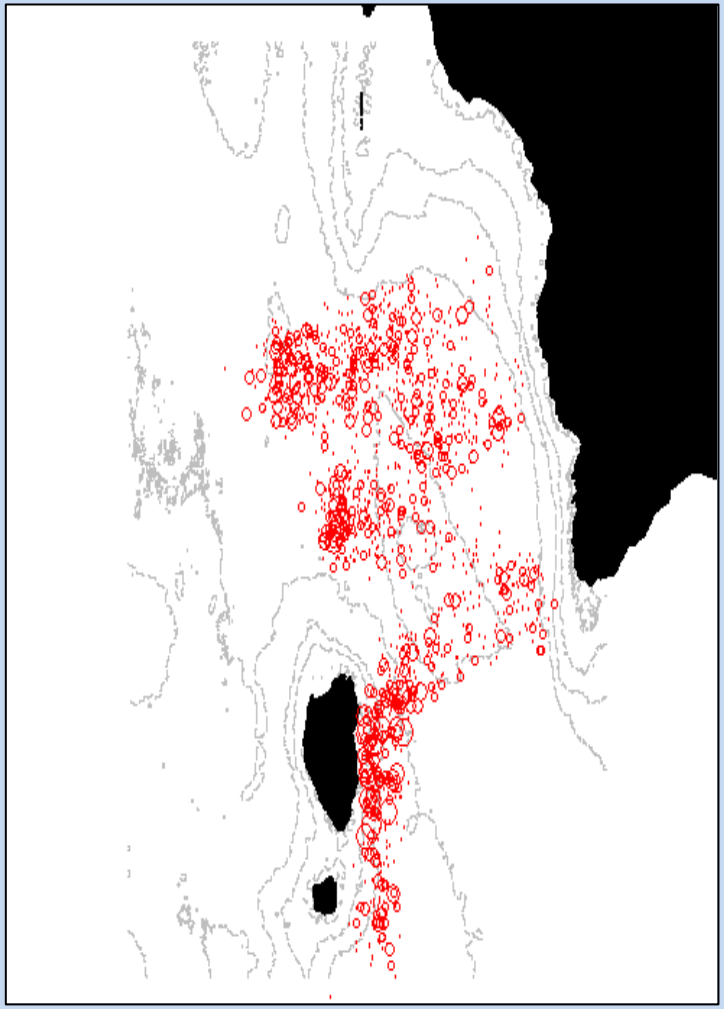
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



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

Seabird Distributions

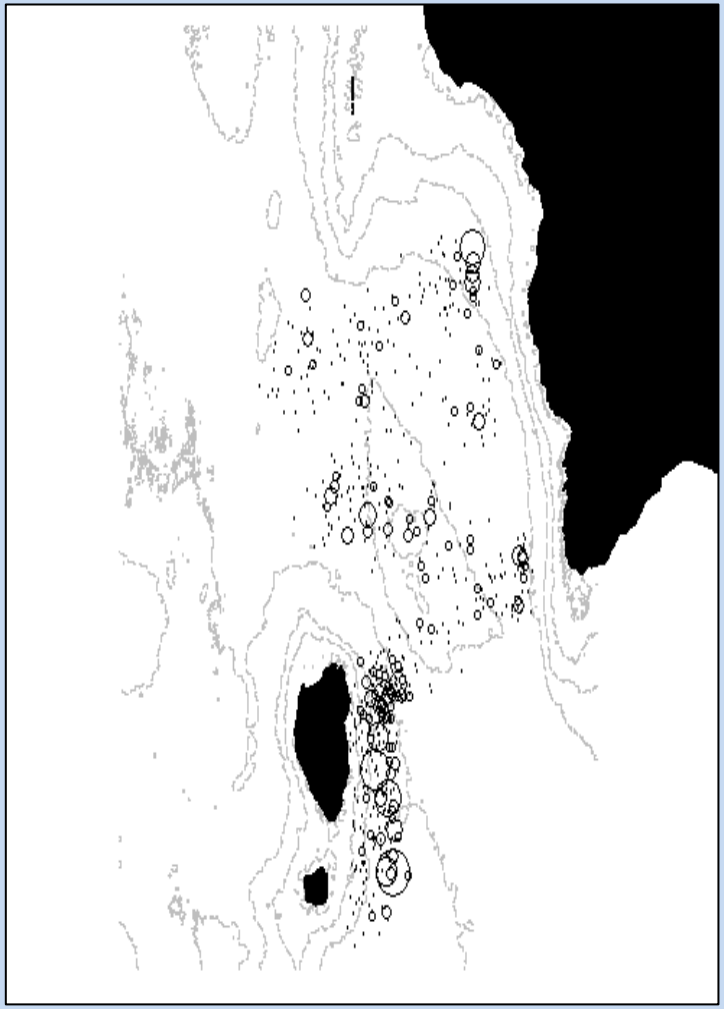
4 Abundant Deep Diving Species
Behavioural Differences
Ecological Differences



Black Guillemot *Cepphus grylle*
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

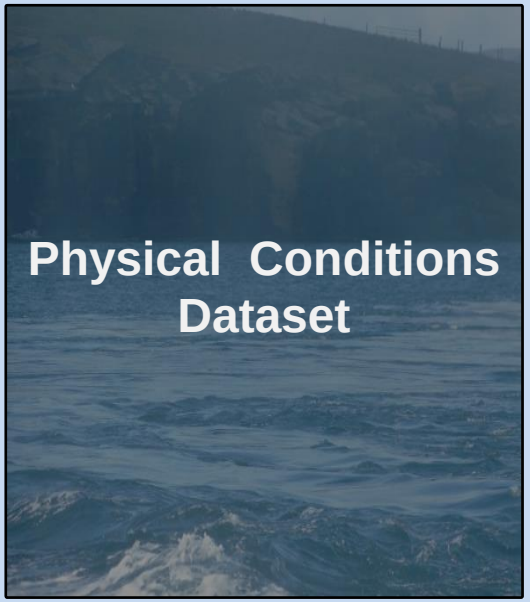
Seabird Abundances
Atlantic Puffin (May)
Black Guillemot (May, Oct)
Common Guillemot (May)
European Shag (May, Oct)

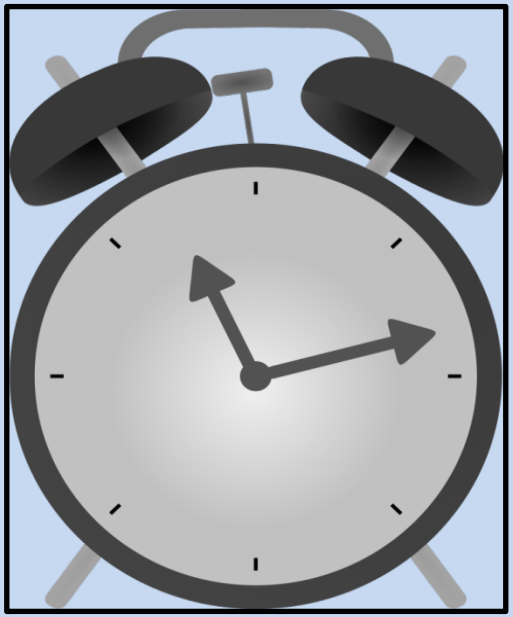
Environmental Variables
Speed
Turbulence
Upward Currents
Seabed (Roughness/Hardness)

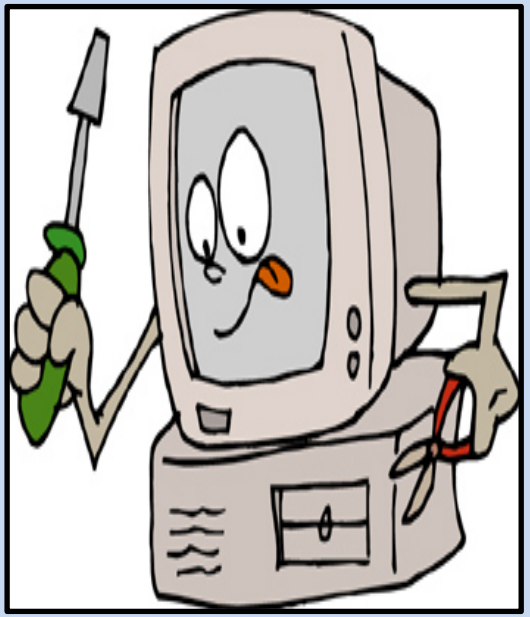
Random Variables
DateTime

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

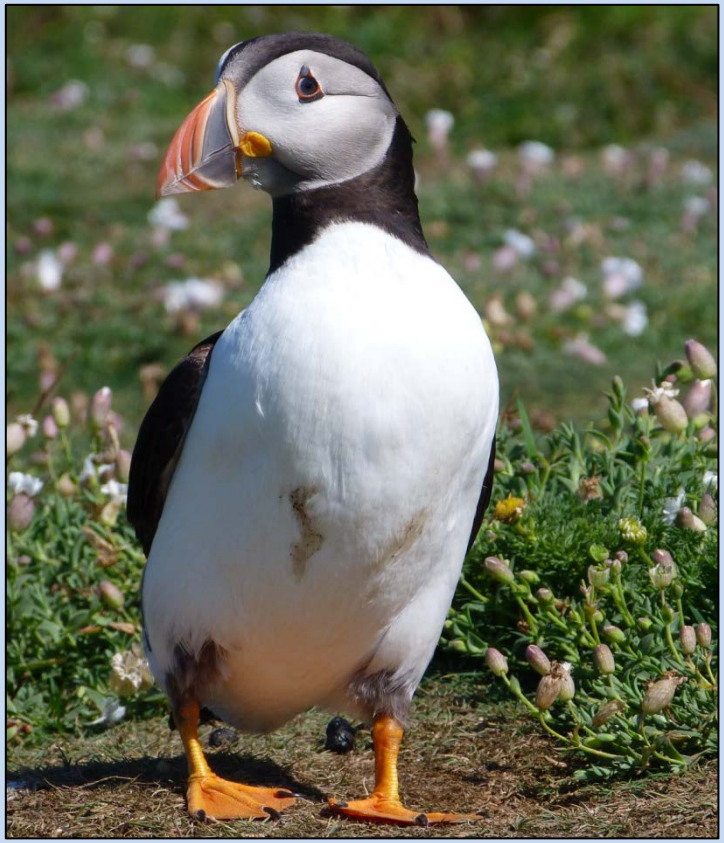
Season	Species	Speed	Turbulence	Upwelling	Substrate
Summer	Atlantic Puffin	Positive	Positive		
Summer	Common Guillemot	Positive			
Summer	Black Guillemot	Negative	Positive	Downwelling	Soft/Rough
Winter	Black Guillemot	Positive		Neither	Soft/Rough
Summer	European Shag			Downwelling	Soft/Rough
Winter	European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

Predicted Distributions

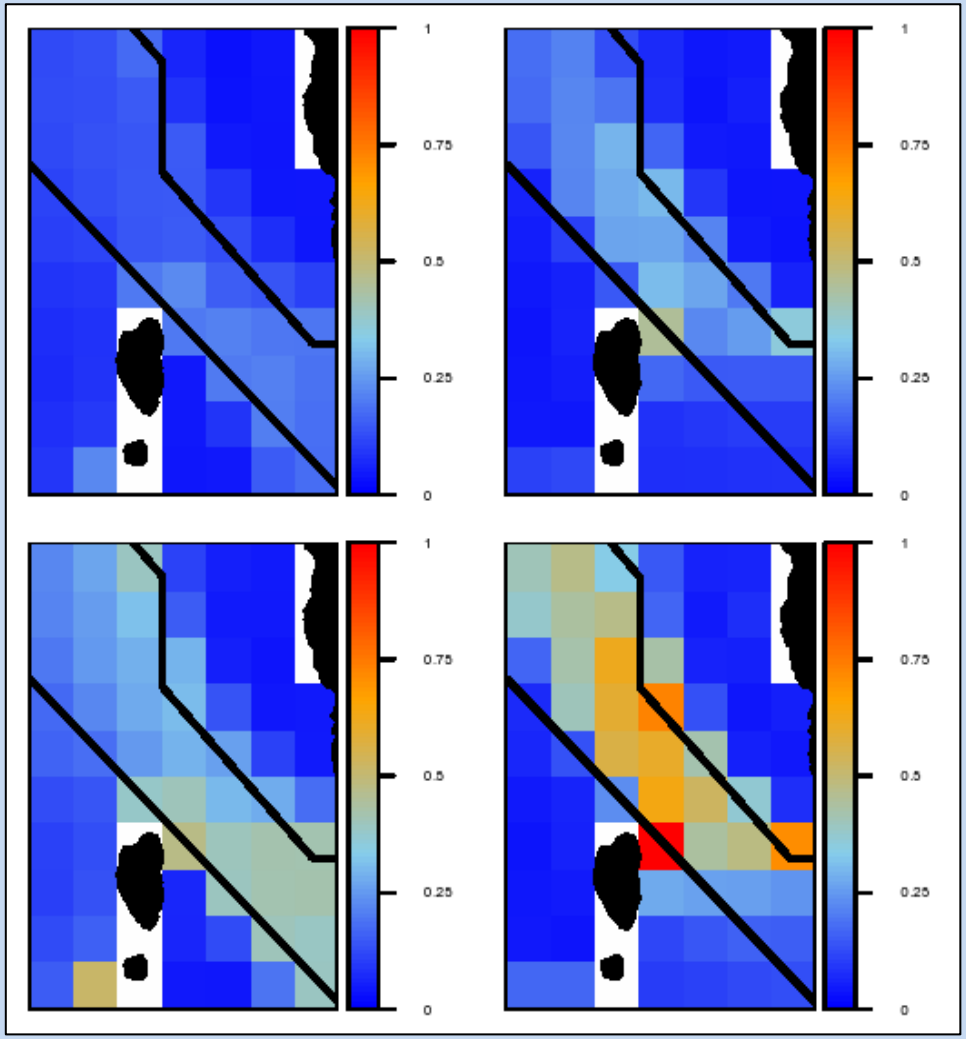
Atlantic Puffin (Summer)

High Spatial Overlap
Increases during spring tides
Increases during ebb tides

Black Lines = Turbine Area



Flood | Ebb

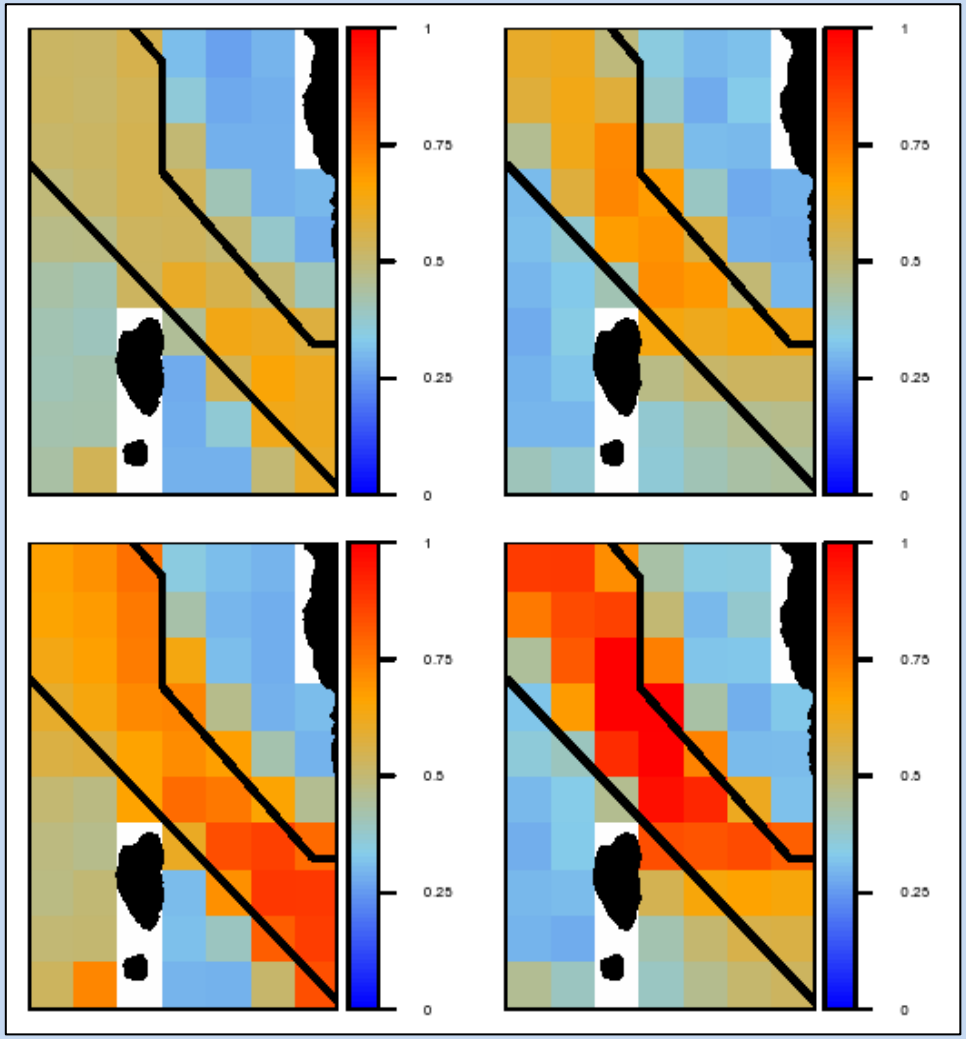


Predicted Distributions

Common Guillemot (Summer)

High Spatial Overlap
Increases during spring tides
Increases during ebb tides

Black Lines = Turbine Area



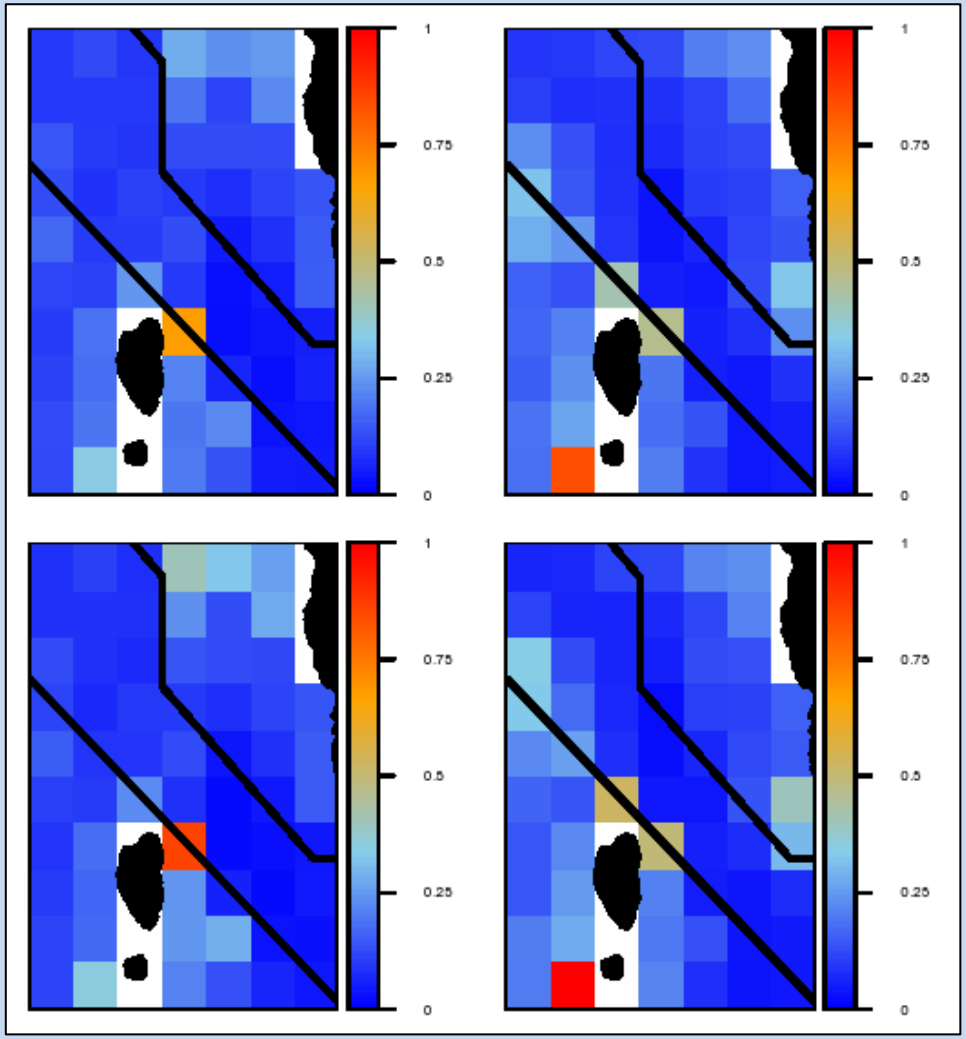
Predicted Distributions

Black Guillemot (Summer)

Low Spatial Overlap

Black Lines = Turbine Area

Flood | Ebb



Neap

Spring

Predicted Distributions

Black Guillemot (Winter)

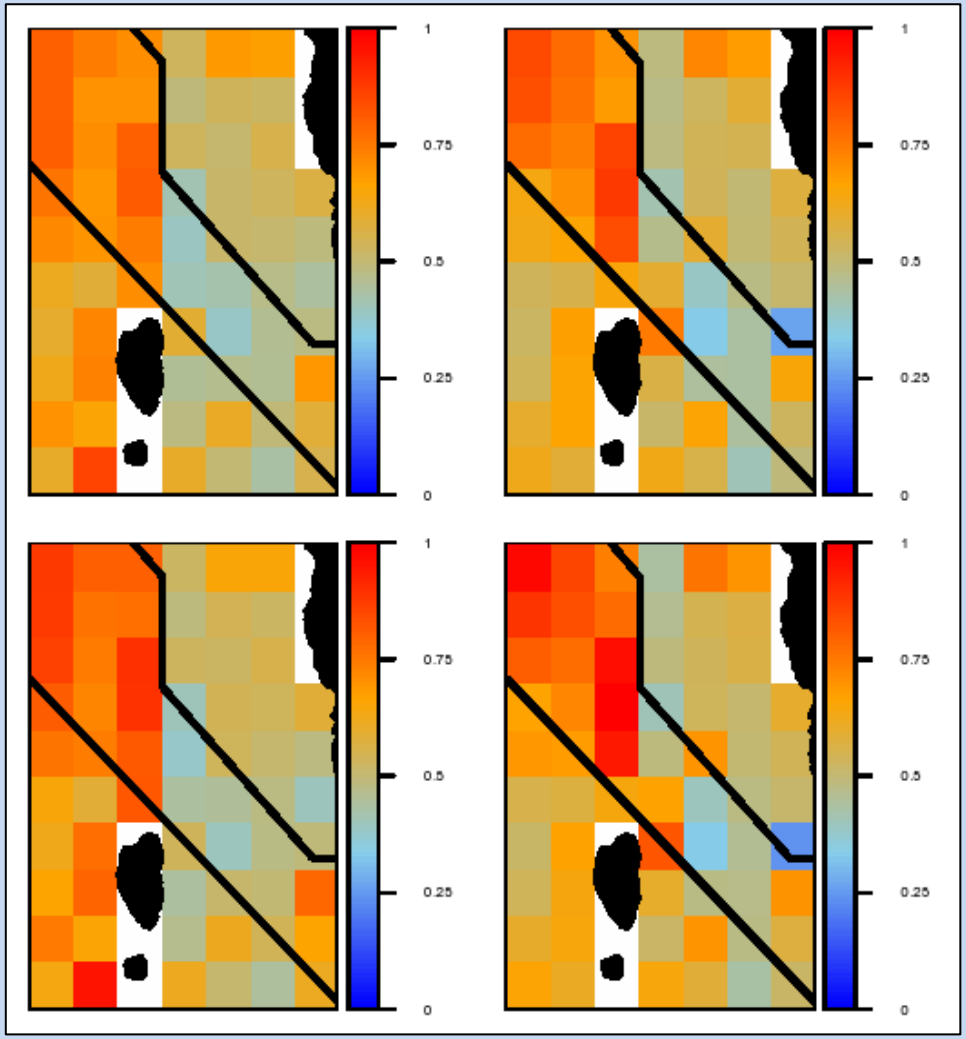
Moderate Spatial Overlap

Black Lines = Turbine Area

Flood | Ebb

Neap

Spring



Predicted Distributions

European Shag (Summer)

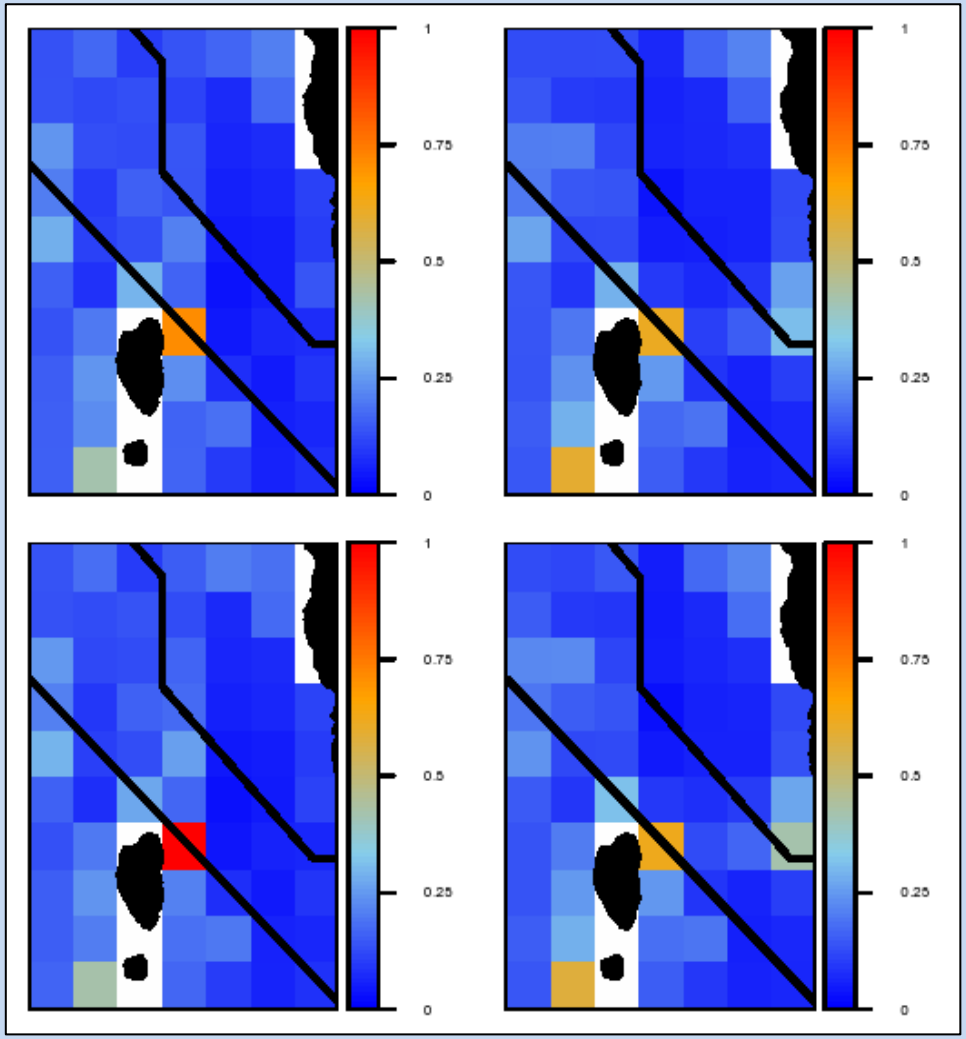
Low Spatial Overlap

Black Lines = Turbine Area

Flood | Ebb

Neap

Spring

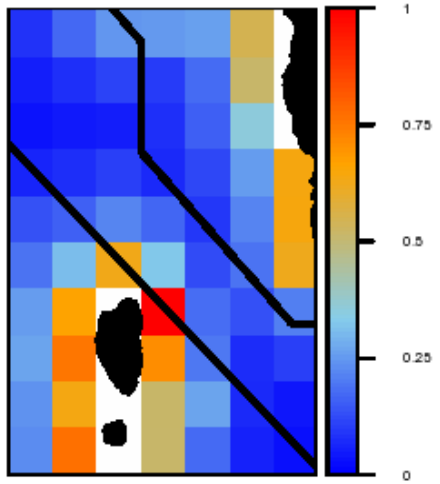
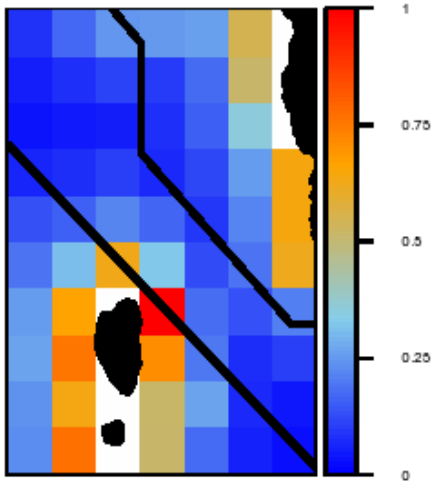
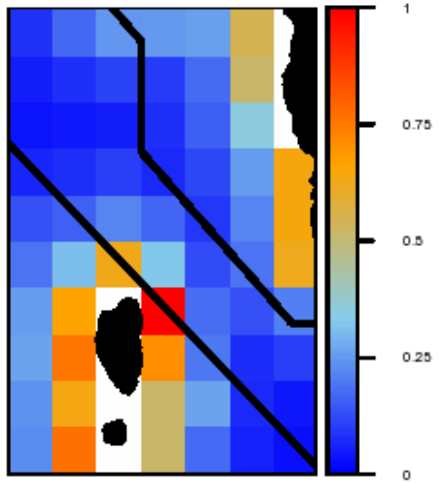
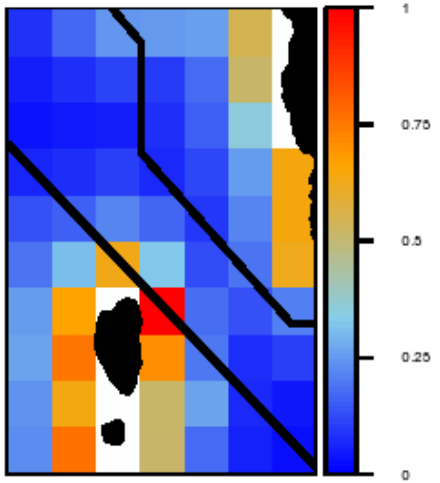


Predicted Distributions

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

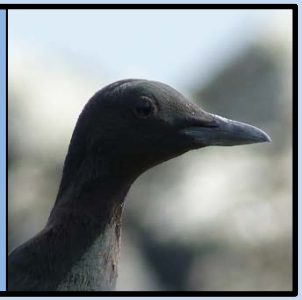
However, results highlight which and when species are most likely to forage near tidal stream turbines.

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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