Mapping cetacean distributions in NW European Seas

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University of Bangor & Sea Watch Foundation
**MERP Consortia**

- **£5m, 5 year research programme**
- Funded by the Natural Environment Research Council (NERC) and Department for Environment, Food and Rural Affairs
- Addressing key knowledge gaps in marine ecosystem research
- Involving over 50 UK scientists from 12 research organisations
- Broad and appropriate range of skills
Summary of Work

• Collation of dedicated seabird & cetacean surveys across NW European seas
• Standardisation across surveys by estimating effective strip width and g(0)
• Ecologically informed habitat modelling using environmental variables believed to influence distributions
• Density surface maps with abundance estimates at 10 km & monthly resolution between 1985 and 2017
Thanks to the many organisations contributing data
Data Collation

- 40 main data sources from 11 countries
- 2.6 million km of surveys
- Aerial, digital & vessel effort-based data from 1979 to 2017
- Data used only where sufficient information on survey protocols existed plus variables affecting detection rates
- Cleaned & processed into single spreadsheet
Habitat Modelling: GLM-GEE in a hurdle-model framework

**GLM**
- Linear or quadratic terms
- Identify functional relationships
- Avoid overfitting relationships

**GEE**
- Survey source/month as the correlation structure
- Spatial and temporal autocorrelation
- Accounting further for differences among surveys

**Hurdle-Model**
- Presence-absence and count model
- Reduces problems with zero inflation and overdispersion
- Use knowledge of scale-dependent associations
## Standardisation

**Summary of esw and g(0) calculations across explanatory variables.**

DOL = Bottlenose Dolphin, Common Dolphin, Striped Dolphin, White-Beaked Dolphin, Atlantic White-Sided Dolphin  
GOB = Killer Whale, Long-finned Pilot Whale, Risso’s Dolphin, MIN= Minke Whale, POR = Harbour Porpoise, FIN = Fin Whale

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<th>STRIP</th>
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Incorporating Environmental Data

Coarse-scale processes likely to influence prey communities and abundances

- Primary Productivity
- Sea Surface Temperature
- Stratification
- Depth

Finer-scale processes likely to influence prey availability

- Tidal Fronts
- Current Speed
- Eddy Potential
- Seabed Roughness
Functional Relationships – Bottlenose Dolphin

a) Coastal

- Strong positive relationship with annual productivity
- Strong negative relationship with current speed

b) Offshore

- No relationship with productivity or temperature
- Strong positive relationship with current speed & seabed roughness
Spatial Patterns – Cetaceans

1.2 million individuals
Spatial Patterns - Seabirds

6.4 million individuals
Monthly Trends: Harbour Porpoise
Monthly Trends: Risso’s Dolphin
Monthly Trends: Long-finned Pilot Whale
Inshore-Offshore Movements: Common Dolphin

- % deviation from the annual mean for each month of the year
- Red denotes positive and blue negative deviations
- Results show a movement towards the shelf edge west of Ireland and into the Bay of Biscay between Dec & May
Long-term Trends in Harbour Porpoise Distribution

Phocoena phocoena

88-97

98-07

08-17
Seasonal Patterns: Cetaceans

- Bottlenose Dolphin
- Common Dolphin
- Fin Whale
- Harbour Porpoise
- Killer Whale
- Minke Whale
- Pilot Whale
- Rissos Dolphin
- Sperm Whale
- Striped Dolphin
- White Beaked Dolphin
- White Sided Dolphin
Annual Patterns: Cetaceans
Seasonal Patterns: Harbour Porpoise

Celtic Seas

North Sea
Harbour Porpoise Movements

Source: Nielsen et al., 2018
Future Impact and Policy Relevance

- Density surface mapping, abundance estimates, population trends (for Marine Strategy Framework Directive)
- Identification of persistent species density hotspots (for Marine Protected Areas)
- Identification of areas of high biodiversity & biomass (for Ecologically or Biologically Significant Areas & Key Biodiversity Areas)
- Risk mapping (for marine spatial planning & ecosystem services)
How can the evidence be used? – MSFD indicators

- M4: Abundance at the relevant temporal scale of cetacean species regularly present

- Large-scale synoptic surveys are currently every 11 years due to resource constraints but this limits ability to determine trends

- Gap filling with spatio-temporal trends from high intensity studies

Sources: MERP Project; Hammond et al., 2017: SCANS III Report
How can the evidence be used? - Marine Protected Areas

- Consideration of density surfaces over large-scale can identify hotspots beyond national boundaries – see, for example, area west of Denmark
Species Diversity, Biomass & Abundance

a) Seasonal modelled relationships for cetacean communities

b) Physical & oceanographic features, prey resources

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<tr>
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No. of spp.

Biomass

Abund.
Collating Prey Data

Harbour Porpoise diet in NW Europe (by weight)
Modelling of monthly prey distributions: *Herring*
Modelling of monthly prey distributions: Sprat
Collating Prey Data

Temporal trends in fish spawning biomass

- **Sprat**
  - SSB (millions of tonnes) vs. Year
  - Data from 1960 to 2020

- **Cod**
  - SSB (millions of tonnes) vs. Year
  - Data from 1960 to 2020

- **Mackerel**
  - SSB (millions of tonnes) vs. Year
  - Data from 1960 to 2020
Collating Prey Data

Temporal trends in fish spawning biomass

**Herring**

**Whiting**

**Sandeel**
Risk Mapping: Common Dolphins & Trawling

Main Risk Areas
- Channel Western Approaches
- Northwest France
- Northwest Spain
Risk Mapping: Harbour Porpoise & Static Gillnets

Main Risk Areas
- West of Norway & Denmark
- Southwestern North Sea
- Eastern English Channel
- Celtic Sea & SW Approaches
Risk Mapping: Fin Whales & Shipping

Main Risk Areas/times
- Western Bay of Biscay
- North-West Spain
- Mainly Jul-Dec
Products

- New distribution maps for all the major cetacean & seabird species in NW European seas
- Modelled density surface plots & abundance estimates by month and by year from 1985-2017
- Modelled outputs of cetacean & seabird habitat preferences
- Identification of diversity, biomass & density hotspots in NW European seas
- Risk maps for potential impacts of different human pressures
Looking Forward

• Incorporate new cetacean & seabird survey data
• Refine models, incorporating more prey information
• Refine plots of human pressures
• Refine vulnerability & sensitivity indices
• Develop cumulative pressure risk maps
• Predict responses to climate change