Modelling the impact of recreational activities to inform management of Marine Protected Areas

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Summary

Recreational use of the UK's coast is increasing and can be detrimental to marine habitats and species. Marine Protected Areas (MPAs) have been established to protect sensitive features, but recreational activities remain largely unregulated although management options exist. Multi-criteria evaluation of spatial data predicted the distribution and intensity of recreational activities and their potential impact on MPA features on the UK's north-east coast. Stakeholder validation showed that this method reliably identified hotspots of high intensity activity and highlighted vulnerable areas where pressures and features co-occur. This rapid, repeatable method has considerable potential as a decision-support tool to target management effectively.

KEYWORDS: Marine Protected Areas; Multi-Criteria Evaluation; Marine Spatial Planning; Recreational Disturbance

1. Introduction

Recreational use of the UK's coast is increasing; an estimated 271 million recreational visits are made to the English coast each year (Elliott *et al.*, 2018), 16.3 million people participated in water-based recreation in the UK in 2017 (Arkenford *et al.*, 2018) and a footpath around the entire English coast will be complete by 2020 (Natural England, 2013). Recreational activities and increased coastal access may be detrimental to temperate marine habitats and species, particularly birds (Liley *et al.*, 2015; Natural England, 2015). Despite the UK's emerging network of Marine Protected Areas (MPAs), recreational activities remain largely unregulated, but there are options for management ranging from voluntary codes of conduct to legal enforcement (Liley *et al.*, 2012; Fenn and Bosley, 2016). Effective management must be underpinned by reliable information on the distribution of activities and sensitive features (Roberts, 2017). This study evaluates regional-scale GIS modelling as a means of understanding the distribution and intensity of recreational activities and their potential impact on MPA features.

2. Methods

2.1. Study site

The study area covers south-east Scotland and north-east England, comprising the Berwickshire and North Northumberland Coast Special Area of Conservation (SAC), Coquet to St Mary's Island Marine Conservation Zone (MCZ) and Berwick to St Mary's recommended MCZ (**Figure 1**). The area's diverse coastal habitats support rich marine life and thousands of breeding and over-wintering seabirds.

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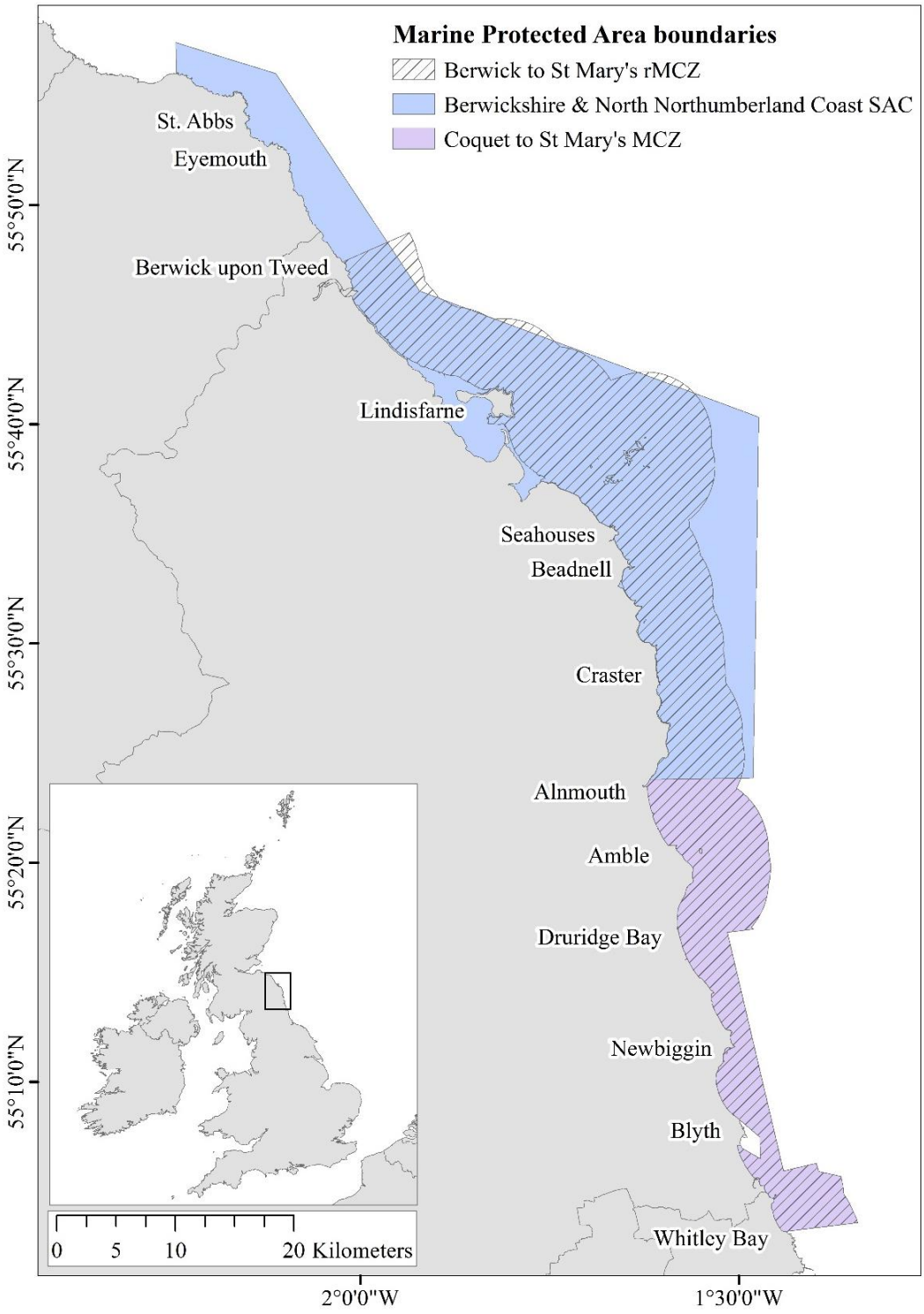

Figure 1 Study site and boundaries of Marine Protected Areas

2.1. Species case study

Common Eider (*Somateria mollissima*) is presented as a case study to demonstrate methods and outputs. The study area supports nationally important numbers of Common Eider all year round, but populations are declining (Coulson, 2010). The Farne Islands, Coquet Island and Lindisfarne support breeding colonies, while the wider area provides important habitat for foraging, preening, bathing and displaying. Common Eider are a designated feature of Lindisfarne Special Protection Area (SPA) and Berwick to St Mary's rMCZ.

2.2. GIS modelling

A grid of 0.25km^2 hexagons covering the study area was created in ArcGIS v10.5. The distribution and intensity of recreational activities were predicted using multi-criteria evaluation (MCE) in Arc ModelBuilder to interpret spatial data on factors likely to influence each activity. Pressure maps were created by combining the predicted intensity values of all activities known to generate a specific pressure based on existing activity-pressure-feature matrices (ICG-C, 2011; Tyler-Walters *et al.*, 2018) (**Table 1**). Sensitivity maps for designated features of MPAs were produced using spatial data on species, habitats and other ecological factors. Predicted pressure and sensitivity values were combined based on the same activity-pressure-feature matrices to create vulnerability maps, highlighting where sensitive features are at greatest risk from recreational disturbance.

Table 1 Matrix of activities and pressures known to have a negative impact on Common Eider

Activity \ **Pressure**	Above water noise	Collision below water	Introduction of light	Litter	Removal of non-target species	Visual disturbance
Beach leisure	low			low		low
Coasteering	medium					medium
Dog walking	high			low	low	high
Firework displays	low			low		low
Horse riding	high			low		high
Motorised and non-motorised land craft	medium			low		medium
Non-motorised water craft	low			low		low
Powerboating/sailing with an engine: *(launching, recovery, participation)*	low	low	low	low		low
Powerboating/sailing with an engine: *(mooring and/or anchoring)*	low		low	low		low
Sailing without an engine: *(launching, recovery, participation)*	low	low	low	low		low
Sailing without an engine: *(mooring and/or anchoring)*	low		low	low		low
SCUBA diving	low	low	low	low		low
Wildfowling	high			low		high
Wildlife watching from a boat	medium					medium
Wildlife watching on land	medium					medium

2.3. Stakeholder input

Methods and maps were presented to regional stakeholders working in research, marine management, conservation, local government, tourism and recreation at a workshop in November 2018. Choice of input data, selection of influencing factors and weighting of criteria used in the models were refined based on stakeholder feedback.

3. Results

Validation by stakeholders determined that these methods reliably predicted the distribution and intensity of recreational activities in the study area. Areas where Common Eider may be particularly vulnerable to impact from recreational activities were identified as Amble, Beadnell, Seahouses and the south coast of Lindisfarne (**Figure 2**).

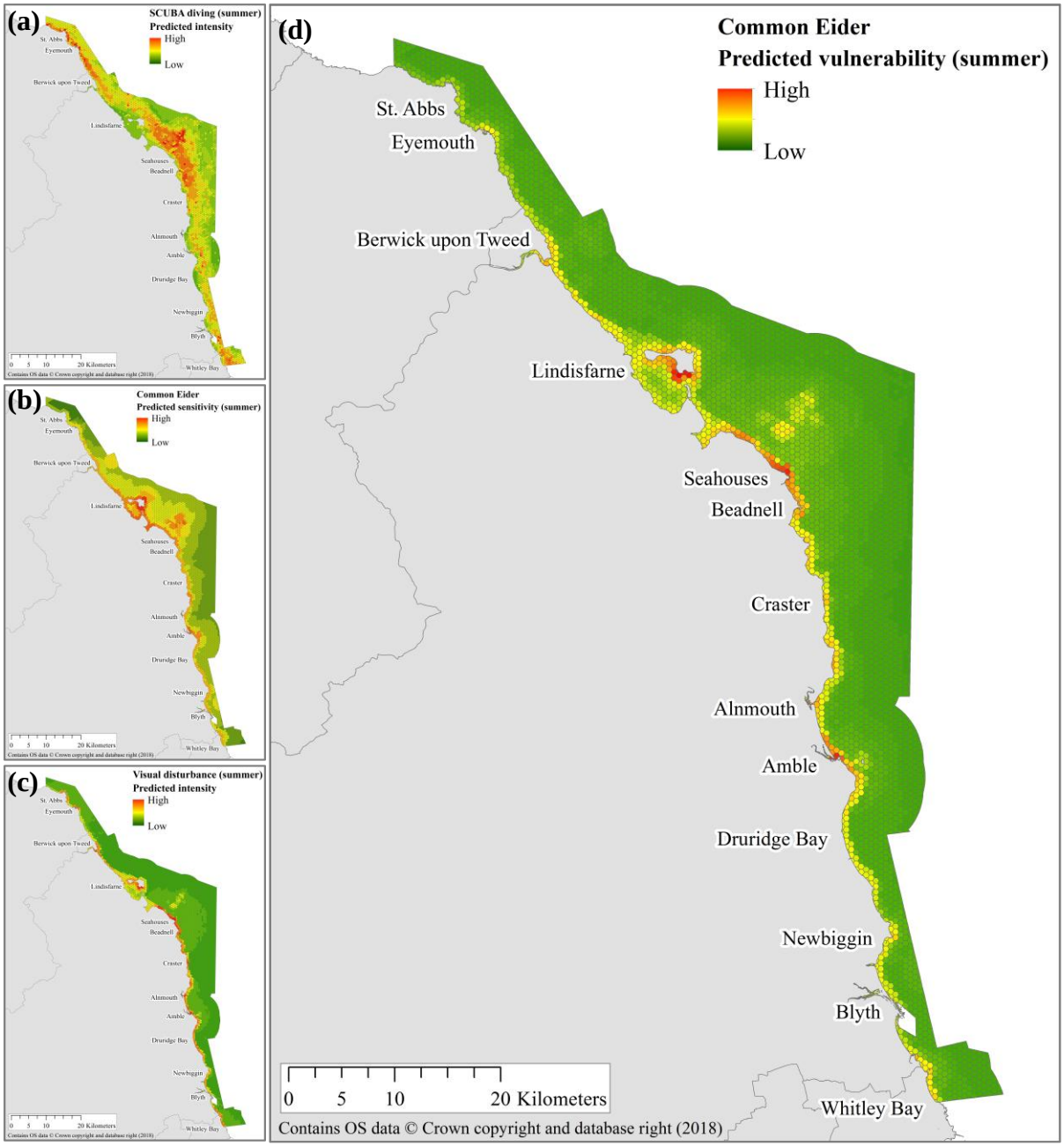

Figure 2 (a) Recreational activity map example – predicted intensity of SCUBA diving (summer) based on seabed depth, habitat type, topography, shipwrecks, dive charter operations and boat launch facilities
(b) Sensitivity map for Common Eider
(c) Pressure map example – predicted intensity of visual disturbance (summer)
(d) Predicted vulnerability of Common Eider to disturbance from recreational activities (summer)

4. Discussion

MCE has previously been used to predict the distribution and intensity of marine and coastal recreation (MMO, 2014) but the present study develops MCE methods at higher spatial resolution and is the first to predict not only the distribution of recreational activities but also their consequent pressures and likely impacts on sensitive features.

4.1. Limitations and recommendations

Open access datasets were used where possible, but some datasets were edited to correct errors or fill gaps, while others were digitised manually for the project, which may introduce subjectivity and reduce repeatability. The temporal resolution of maps was limited to 'summer' and 'winter' but future research could adapt these models to finer temporal scales. Activity intensity values are relative not absolute, but further research could establish equivalent real values e.g. number of participants/duration of activity. Methods were developed in ArcGIS because this software is used by the project funders who wish to adopt these methods for marine management, but future research could develop applications using free open source software to enable wider uptake.

4.2. Implications for management

MCE is a rapid, repeatable method which can be refined as new or better data become available. It reliably identified 'hotspots' where recreational activities occur at high intensity or in combination. This method has considerable potential as a decision-support tool to aid marine management and conservation, for example identifying where species or habitats may be most vulnerable to recreational disturbance, and providing additional evidence to target management of recreational activities at sensitive locations, particularly during bird breeding seasons.

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Biographies

Dr Paula Lightfoot completed her PhD at Newcastle University in 2018 on object-based image analysis of multi-resolution remote sensing data for temperate marine habitat mapping and change detection. Her post-doctoral research develops and evaluates GIS methods for predicting distribution, intensity and potential impact of recreational activities in MPAs.

Dr Catherine Scott, Marine Lead Adviser at Natural England, has many years' experience in marine research and public service, and has collaborated closely with Dr Clare Fitzsimmons since 2009 to develop and deliver highly successful research projects with beneficial outcomes for evidence-based marine management and conservation in the North Sea.

Senior Lecturer Dr Clare Fitzsimmons' background in environmental research and commercial experience in defence and marine consultancy gives her unique analytical skills and expertise in applying novel techniques to marine environmental issues. A common theme of her wide-ranging research is analysis of complex systems and application to marine governance, primarily investigating human interactions with ecological systems.