Predictive substratum modelling for juvenile gadoid distribution and abundance

Sophie. A. M. Elliott (1), Alessandro. D. Sabatino (2), Michael. R. Heath (2), William. R. Turrell (3) and David. M. Bailey (1)

(1) Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow, UK; (2) Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK; (3) Marine Scotland Science, Aberdeen, UK. Presenter contact details: S.Elliott.1@research.gla.ac.uk, Phone +44 141 330 8080.

Summary

Successful spatial management of species and their habitats requires a good understanding of their distribution. Coastal areas are proposed to be of particular importance for juvenile demersal fish recruitment. However, in many cases the distribution of seabed types and their role for species are poorly understood. Data on fish relative abundance, size and substratum type were collected using Stereo Baited Remote Underwater Video cameras (SBRUV). A multinomial model was used to predict and map substrata around a recently designated Marine Protected Area (MPA) in the Firth of Clyde, west of Scotland. The predicted substratum map was used to understand the relationship between seabed type and extent and gadoid distribution. The multinomial model performed well with an area under the curve (AUC) score of 0.87. Substratum type and heterogeneity had varying effects on gadoid relative abundance. Atlantic cod (*Gadus morhua*) was associated with relatively more rugose and heterogeneous substrata than haddock *(Melanogrammus aeglefinus)* or whiting (*Merlangius merlangus*).

Introduction

Fishing and other anthropogenic pressures have led to declines in many fish species and modification of the seafloor (Worm et al. 2006). As a result, much effort has been placed on identifying spatial management mechanisms to protect, sustain and recover species and seabed types (Seitz et al. 2014). Use of spatial management mechanisms requires knowledge of the distribution and extent of vulnerable features to draw up management boundaries. However, in many cases the distribution of species and their habitats are not well understood (Seitz et al. 2014). Understanding juvenile fish habitat is thought to be of particular importance since cohort size of marine fish may be determined during their first year (Myers & Cadigan, 1993). Predictive substratum mapping was undertaken within South Arran MPA using ground-truthed data to understand effects of substratum extent and heterogeneity on gadoid distribution (Figure 1).

Materials and methods

Data were collected from June to September 2013 and 2014 around South Arran MPA using SBRUVs. Substratum categories included: mud, sand, gravel-pebble with algae, boulder-cobbles covered in algae and seagrass. Variables used to predict the distribution of substrata included maximum tidal flow (Sabatino et al. in prep.), wave fetch (Burrows et al. 2008), depth, distance from shore and geological information (BGS, 2013 using: EDINA Geology Digimap Service). Multinomial regression analysis was used to predict substratum type. Model accuracy was tested on 25% of the dataset, running a confusion matrix and AUC calculations.

Using environmental point data at a 400-600 m resolution, presence of substrata was predicted over the study area. Substrata heterogeneity was calculated using the point predictions within a 1000 m radius around the SBRUV data collection points to determine Hill number diversity indices effects. Substratum extent within the 1000 m radius was calculated by creating polygons from the substratum predictions. Negative binomial generalised linear mixed models using substratum type, heterogeneity and extent were used to understand gadoid relative abundance and distribution.

Results and Discussion

Evaluation of the multinomial model using the validation dataset indicated good predictive power (AUC scores of 0.88) and a correct classification of 61%. Correct classification for seagrass was 100%, followed by mud with 89%. Gravel, sand and boulder correct classification varied between 70% and 68%. *M. merlangus* and *M. aeglefinus* were observed in significantly higher abundance in sand and mud substrata. A significantly higher abundance of *G. morhua* was observed in gravel-pebble substratum and areas of increased substratum heterogeneity. Significant differences in gadoid lengths were observed with *G. morhua* smaller (mean = 82.01 mm, S.D. = 28.05 mm) than *M. aeglefinus* or *M. merlangus* (mean = 120.16 mm and 139.92, S.D. = 30.53 mm and 43.18 mm).

Mixed gravel substratum type may provide sufficient refuge, camouflage and food availability for juvenile *G. morhua* relative to their size. Lack of recovery in most west coast *G. morhua* stocks have been observed even though fisheries management measures have been introduced to restore stocks (Fernandes & Cook 2013). Understanding the extent and distribution of vulnerable substrata can support spatial management advice to reduce anthropogenic impacts. By combining the predictive map with gadoid relative abundance, a better understanding of the role of substrata has been achieved. Results from this study could also provide MPA and fisheries management and monitoring advice, supporting a more ecosystem-based management.

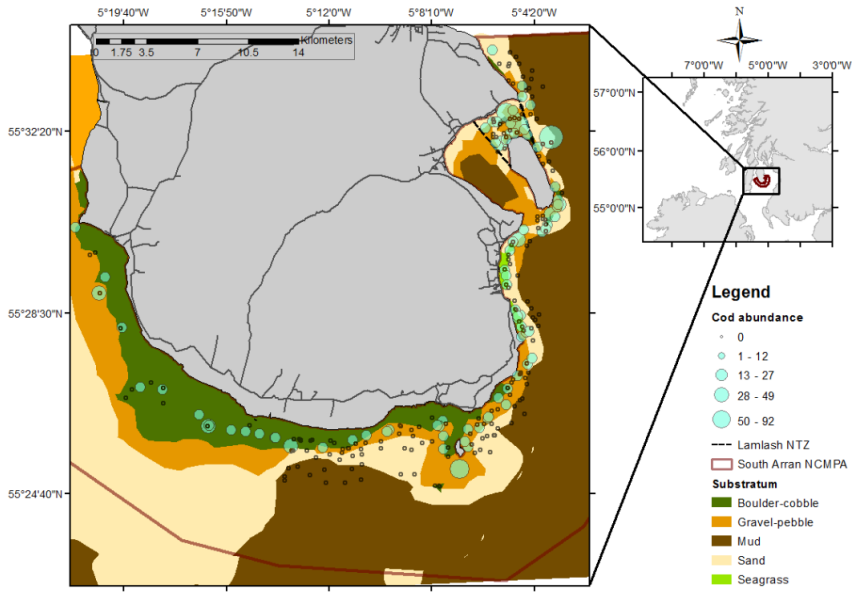

Figure 1. Predictive substratum maps with the relative abundance of *G. morhua* sampled around South Arran MPA, west coast of Scotland.

References

Burrows, M., Harvey, R. & Robb, L. 2008. Wave exposure indices from digital coastlines and the prediction of rocky shore community structure. Marine Ecology Progress Series, 353, pp.1–12.

Fernandes, P.G. & Cook, R.M., 2013. Reversal of Fish Stock Decline in the Northeast Atlantic. Current biology, 23(15), pp.1432 – 1437.

Myers, R. A. & Cadigan, N. G. 1993. Density dependent juvenile mortality in marine demersal fish. Canadian Journal of Fisheries and Aquatic Sciences 50, 1576–1590.

Sabatino, A.D. Heath, M. R., Hills, A., O'Hara, R. B. Modelling surges in the Clyde Sea and the North Channel. pp.1–39.

Seitz, R. D., Wennhage, H., Bergström, U., Lipcius, R. N. & Ysebaert, T. 2014. Ecological value of coastal habitats for commercially and ecologically important species. ICES Journal of Marine Science 71, 648-655.

Worm, B., Barbier, E., Beaumont, N., Duffy, J., Folke, C., Halpern, B., Jackson, S., Lotze H., Micheli, F., Palumbi, S., Sala, E., Selkow, K., Stachowicz, J & Watson, R. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science, 314, 787–90.