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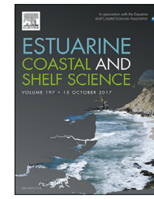

A comparison of acoustic and observed sediment classifications as predictor variables for modelling biotope distributions in Galway Bay, Ireland

Jack P.J. O'Carroll [a, *], Robert Kennedy [a], Lei Ren [b], Stephen Nash [b, c, d], Michael Hartnett [b, c, d], Colin Brown [e]

[a] Ryan Institute, School of Natural Sciences, Zoology, National University of Ireland, Galway, Ireland
[b] College of Engineering & Informatics, National University of Ireland Galway, Ireland
[c] Ryan Institute for Environmental, Marine and Energy Research, National University of Ireland Galway, Ireland
[d] National Centre for Marine and Renewable Energy Ireland (MaREI), National University of Ireland Galway, Ireland
[e] Ryan Institute, National University of Ireland, Galway, Ireland

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ABSTRACT

The INFOMAR (Integrated Mapping For the Sustainable Development of Ireland's Marine Resource) initiative has acoustically mapped and classified a significant proportion of Ireland's Exclusive Economic Zone (EEZ), and is likely to be an important tool in Ireland's efforts to meet the criteria of the MSFD. In this study, open source and relic data were used in combination with new grab survey data to model EUNIS level 4 biotope distributions in Galway Bay, Ireland. The correct prediction rates of two artificial neural networks (ANNs) were compared to assess the effectiveness of acoustic sediment classifications versus sediments that were visually classified by an expert in the field as predictor variables.

To test for autocorrelation between predictor variables the RELATE routine with Spearman rank correlation method was used. Optimal models were derived by iteratively removing predictor variables and comparing the correct prediction rates of each model. The models with the highest correct prediction rates were chosen as optimal. The optimal models each used a combination of salinity (binary; 0 = polyhaline and 1 = euhaline), proximity to reef (binary; 0 = within 50 m and 1 = outside 50 m), depth (continuous; metres) and a sediment descriptor (acoustic or observed) as predictor variables. As the status of benthic habitats is required to be assessed under the MSFD the Ecological Status (ES) of the subtidal sediments of Galway Bay was also assessed using the Infaunal Quality Index.

The ANN that used observed sediment classes as predictor variables could correctly predict the distribution of biotopes 67% of the time, compared to 63% for the ANN using acoustic sediment classes. Acoustic sediment ANN predictions were affected by local sediment heterogeneity, and the lack of a mixed sediment class. The all-round poor performance of ANNs is likely to be a result of the temporally variable and sparsely distributed data within the study area.

1. Introduction

The benthic environment plays a vital role in the structure and functioning of marine ecosystems through the recycling of nutrients, provision of high levels of secondary production and the dispersal and burial of sediments (Snelgrove, 1998). It is also exploited as a natural resource by commercial fishing, hydrocarbon and aggregate extraction, deep sea mining, aquaculture, and tourism industries and is the receiving environment for a range of industrial and agricultural waste products (Halpern et al., 2008, 2015). The importance of a properly functioning benthic ecosystem is reflected in its designation and protection under conservation frameworks (hereinafter referred to as the Directives), such as the Habitats Directive (HD: Council Directive 92/43/EEC), Birds Directive (BD; Council Directive 2009/147/EC), Water Framework Directive (WFD: Council Directive, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD; Council Directive, 2008/56/EC).

* Corresponding author.
E-mail address: jackocarroll1990@gmail.com (J.P.J. O'Carroll).

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The Marine Strategy Framework Directive (MSFD) establishes a framework in which EU Member States (MS) are required to take the necessary measures to achieve or maintain Good Environmental Status (GES) in the marine environment by 2020. The MSFD covers all marine waters from one nautical mile to the outer limits of the Exclusive Economic Zone (EEZ). MSs are required to determine a set of characteristics for Good Environmental Status (GES) for eleven Quality Descriptors, each addressing a critical component of the ocean ecosystem or a form of pertinent human impact. One of the eleven Quality Descriptors of the ocean ecosystem is seafloor integrity. According to the criteria outlined in the MSFD, the integrity of the seafloor must be "at a level that ensures the structure and functions of ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected" (Barry et al., 2013).

In addition to occupying an integral role in the functioning of marine ecosystems, benthic infaunal distributions can be used as bioindicators of environmental conditions (Pearson and Rosenberg, 1978). Their sedentary nature, or limited mobility prevents their evasion of adverse conditions (Wass, 1967). The predictable, functional responses of benthic infauna to disturbance events have been extensively studied and has resulted in species being placed into ecological groups according to their tolerance to stress (Pearson and Rosenberg, 1978; Glémarec and Hily, 1981; Grall and Glémarec, 1997). This qualitative weighting of species allows their distributions to be used as spatial and temporal indicators of disturbance in the benthic environment (Kennedy et al., 2011; Forde et al., 2013; O'Carroll et al., 2016; O'Carroll et al., 2017a,b). This approach to benthic monitoring was most notably adopted and developed in response to the criteria outlined by the WFD (Borja et al., 2000, 2007; Prior et al., 2004; Borja et al., 2007; Muxika et al., 2007; Mackie, 2009; Phillips et al., 2014). Multimetric Indices (MMIs) developed in response to WFD criteria assess the Ecological Status (ES) of a habitat by incorporating metrics that address 'the level of diversity and abundance of invertebrate taxa' and 'the proportion of disturbance sensitive taxa' (Borja et al., 2007). MMIs have been shown to be applicable across large geographical distances (Forde et al., 2013), amenable to modification (Forde et al., 2013, 2015), robust to changes in sampling methodologies (Kennedy et al., 2011) and have the potential to facilitate the standardisation of benthic monitoring outputs across the Directives (Borja et al., 2013; Forde et al., 2015).

The spatial scales addressed by the MSFD pose some key problems for benthic mapping and monitoring studies. For example, the Republic of Ireland must gather baseline data for an EEZ of 490,000 km^2. Traditional point source data or Bottom-Up mapping efforts at this spatial scale are prohibitively costly (Buhl-Mortensen et al., 2015) thereby emphasising the need for more time and cost effective mapping techniques. The recent advances in remote sensing technologies have facilitated the extensive use of the Top-Down monitoring approach (Kostylev et al., 2001; Christensen et al., 2009; Mcgonigle et al., 2009; Brown et al., 2011). This approach covers large areas much faster than the Bottom-Up approach as it holds the assumption that distinct topographic features will host distinct biological assemblages (Lafrance et al., 2014). Biological data taken from comparably small proportions of these topographic features (Brown et al., 2002; Solan et al., 2003; Eastwood et al., 2006) are then extrapolated across the feature area so that a biological characterisation can be produced (Buhl-Mortensen et al., 2015). The 'Top Down' approach holds the best potential for mapping benthic habitats at large scales, despite having some inherent limitations within its assumptions (Lafrance et al., 2014).

Using open source and relic data in conjunction with time-efficient survey techniques could significantly reduce costs associated with large scale mapping initiatives (Stephens and Diesing, 2015). Similarly, the use of surrogates for data types that are costly to acquire is also of increasing importance in large scale mapping initiatives (Brown and Blondel, 2009). Broad scale sediment classification commonly results in high resolution data from Particle Size Analysis (PSA) data being placed into several ranked categories based on sediment softness (Long, 2006; Holland and Elmore, 2008; Blott and Pye, 2001). Recent developments in acoustic mapping technologies present new time efficient methods of seafloor data acquisition over large spatial scales (Brown et al., 2011). Acoustic signal derivatives have been successfully used as surrogates for PSA outputs in large scale benthic habitat mapping studies (Ehrhold et al., 2006; Cook et al., 2008; Dolan et al., 2009, Brown and Blondel, 2009; Buhl-Mortensen et al., 2009; Callaway et al., 2009; Dolan et al., 2009; Brown et al., 2011). Using acoustic swathe technologies allows for significant spatial coverage, the challenge facing such mapping studies is obtaining an acceptable amount of representativeness so that the resulting maps are fit for purpose in terms of research, resource management, conservation and spatial planning (Stephens and Diesing, 2015).

The ecosystem approach to the sustainable management of the marine environment requires detailed biological data to be gathered in combination with environmental data. This is a labour and cost intensive task (Buhl-Mortensen et al., 2015) and in response to the criteria of the MSFD, predictive spatial models will be necessary to produce complete coverage of all designated EEZs. Machine learning algorithms or Artificial Neural Networks (ANNs) have become increasingly employed in ecological studies as they can 'learn' complex, non-linear patterns in data to predict an associated value. ANNs have been applied successfully in terrestrial ecology for some years and now are proving to be successful across a range of marine ecological studies (Bradshaw et al., 2002; Wei et al., 2001; Weinert et al., 2016; Watts et al., 2011; Herkül et al., 2017; Gougeon et al., 2017; Stephens and Diesing, 2015). An ANN must first 'learn' the relationship between response and predictor variables in a subset of the area to be mapped. This training dataset must incorporate enough variability so that it is representative of the remainder of the study area. Also, environmental predictor variables must be available for the whole study area if predictions are to be extrapolated across its entirety. The Republic of Ireland's EEZ is well equipped in this regard (Diesing et al., 2009). A significant proportion (125,00 km^2) of which has been acoustically mapped and classified by the Irish National Seabed Survey (now INFOMAR: Integrated Mapping for the Sustainable Development of Ireland's Marine Resources).

As outlined by the MSFD, it is imperative that standard reporting procedures are established so as to facilitate the harmonisation of mapping outputs across the EU. The European Nature Information System (EUNIS) biotope classification (Conor et al., 2004) is a commonly used habitat classification system and also has an associated sediment classification system (Long, 2006). The EUNIS classification system is a pre-existing widely applied framework and has already been employed as a tool for the sustainable management of the marine environment under the HD. Given the familiarity of policy makers with the EUNIS classification scheme it should be considered as one of the optimal tools for standardising MSFD mapping outputs.

In this study, we test the effectiveness of the open source, INFOMAR acoustic sediment classification data as a predictor variable in a spatial model. To do this, we compare the correct prediction rates of two ANNs, one using acoustic sediment classifications, the other using visually classified sediments as the sediment descriptor. We also aim to assess the accuracy of a modelling procedure that uses a majority of open source and relic data, supplemented with some new grab survey data. In doing so