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Research article

Heterogeneous public and local knowledge provides a qualitative indicator of coastal use by marine recreational fishers

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ABSTRACT

Marine recreational fishing (MRF) benefits individuals and economies, but can also impact fish stocks and associated ecosystems. Fish are an important resource providing direct economic benefit through commercial and recreational exploitation, and more esoteric ecosystem services. It is important to consider recreational fishing in marine spatial planning, but spatial information on coastal utilisation for MRF is frequently lacking. Public sources of local knowledge were reviewed and the frequency of unique references to sites extracted. Sites were georeferenced using a gazetteer compiled from the Ordnance Survey and United Kingdom Hydrographic Office named sea features gazetteer and local knowledge sources. Recreational fishing site densities were calculated across 2700 km of coastline and this proxy indicator of coastal utilisation validated against two independent surveys using permutative Monte Carlo sampling to control for sparse and non-independent data. Site density had fair agreement with independent surveys, but standardization by shore length reduced this agreement. Applying a 3 by 3 box filter convolution to the spatial layers improved the agreement between local knowledge derived predictions of activity and those of directed surveys, and permutation testing showed that agreement did not arise as a result of the convolution itself. High and low activity areas were more accurately predicted than areas of intermediate activity. Site density derived from heterogeneous participant and local knowledge can produce qualitative predictions of where recreational fishers fish, and applying a convolution can improve the predictive power of data so derived. However, this approach will be subject to unquantifiable bias and may fail to identify areas highly valued by marine recreational fishers. Thus it should be used in conjunction with other information in decision making and may be best suited to inform the early stage sampling design of on-site surveys or to complement other data sets in mapping areas of importance to recreational fishers.

1. Introduction

Coastal and marine spatial planning (MSP) frameworks have become an integral tool in the governance of marine and coastal resources in the European Union, America and many other nations (e.g. European Commission, 2014; MaPP, 2016; The White House, 2010; Vince, 2014). In Europe, the European Parliament has adopted Directive 2014/89/EU to create a common framework for maritime spatial planning (European Commission, 2014) and the USA has adopted the National Policy for the Stewardship of the Ocean, Our Coasts, and the Great Lakes of USA (The White House, 2010). MSP aspires to achieve the equitable allocation of marine and coastal resources where stakeholder activities are potentially in conflict. The aim of using the MSP framework is to ensure that benefit maximisation occurs now and in the future and is considered a vital component of ecosystem-based management (Douvere, 2008; Environmental Law Institute, 2009).

Fisheries are an important marine resource used by humans for both food production and recreation. For this reason, MSP should evaluate the interaction among those marine and coastal stakeholder activities that might impact marine fisheries. Historically, marine recreational fishing (MRF) was considered to have negligible impact on fisheries hence recreational harvests have been omitted from stock assessments of commercially important species. This orthodoxy has changed and contemporary research has demonstrated the potentially large numbers of fish caught by recreational fishers (Coleman et al., 2004; Hyder et al., 2018; Post et al., 2002) and the possible ecosystem and environmental

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effects associated with MRF (Hyder et al., 2017; Lewin et al., 2006; O'Toole et al., 2009). For these reasons, there is increasing interest in trying to include MRF data in stock assessments (e.g. Eero et al., 2014; Hyder et al., 2017; ICES, 2017a).

It has been suggested that unaccounted recreational harvest can impede stock recovery in managed fisheries (Maggs et al., 2016; Sherwood and Grabowski, 2016). Conversely, research has identified the benefits of MRF to economies at national and local levels (Brown et al., 2013; Donnelley et al., 2009; Gartner et al., 2002; Herfaut et al., 2012; Roberts et al., 2017) and in health and wellbeing (Brown et al., 2012; Gartner et al., 2002; Griffiths et al., 2016; Lawrence et al., 2007) Balancing the interests of marine recreational fishers (MRFs) with ecological considerations and other marine stakeholders is therefore an important aspect of MSP. The potential importance of the sector has been recognised, with recreationally important stocks protected from commercial exploitation to assure the quality of recreational fishing (e.g. Irish Parliament, 2006; Isle of Man Government, 2016; Maine Department of Marine Resources, 2016).

Despite the importance of MRF, many countries do not undertake regular assessments of recreational fishing activity. For example, only four European member states have recreational mortality estimates for European sea bass (*Dicentrarchus labrax*, henceforth sea bass) (Hyder et al., 2018; ICES, 2017a). This is despite evidence that recreational sea bass catches can be significant (Armstrong et al., 2013a; Herfaut et al., 2010; Rocklin et al., 2014; van der Hammen and de Graaf, 2015), concerns over stock health, and lack of data for stock assessment (ICES, 2017b, 2017c). Moreover surveys to estimate MRF effort and catch at a national level tend not to provide the level of sampling needed to produce detailed information on the spatial distribution of activity (Armstrong et al., 2013a).

Directed surveys to assess catch frequently use on-site access point or roving creel methodologies to assess catch (Guthrie, 1991; National Reseach Council, 2006; Pollock et al., 1997). Random sampling is frequently achieved by including location (site) as a randomly sampled component, yet the sampling frame of sites will not represent 100% spatial coverage of the entire coastline or all access points. Expert knowledge and pre-survey scoping can be used to create a sampling frame (e.g. Armstrong et al., 2013a) where activity is known to occur and this may include proportionate sampling based on expected site popularity. The development of site sampling frames is improved by considering all available data sources prior to the finalisation of the sampling regime.

In the absence of directed surveys, several methods have been used to assess MRF activity in data poor fisheries. Self-selecting and non-randomised surveys are commonly employed (e.g. McMinn, 2013; Aron et al., 2014; Drew Associates Ltd., 2004; Goudge et al., 2009, 2010). However, spatial coverage is limited by the spatial distribution and number of volunteers, or by site selection criteria. Expert and local knowledge are an important information source (Hind, 2015, 2014; Johannes et al., 2000) and can be the best available information in emerging and artisanal fisheries (e.g. Deepananda et al., 2016; Stange, 2016). The past decade has seen an increase in engagement between recreational fishers and researchers as co-management is increasingly recognised as being important for long-term and effective management (review Linke and Bruckmeier, 2015). Smartphones and social media provide a means of both delivering and promoting software which allow recreational fishers to record catch and other fisheries observations which can be used by scientists involved in fisheries research (review Venturelli et al., 2017) and co-management approaches.

MRF records can be used to derive trends in stock status and MRF activity levels (Barbini et al., 2015; Bennett et al., 1994; Gartside et al., 1999; Richardson et al., 2006). However, accessible data repositories tend to be held by MRF clubs or hobbyist magazines that are unrepresentative of overall activity when considered in isolation. It is apparent that heterogeneous data sources exist from which fisheries data can be derived, but spatial coverage will be limited according to the spatial distribution of clubs and other contributory sources. By combining multiple sources, it is expected that detailed maps of the relative levels of spatial activity could be produced which can be used to inform management and the marine spatial planning process where data is lacking.

Here we use a case-study of a data poor recreational fishery (Wales, United Kingdom) to show how heterogeneous knowledge sources can be used to produce spatial indicators of shore use by MRFs for the purposes of marine spatial planning (see UK Marine Policy Statement), or in other information gathering exercises. We compare several proxy measures for coastal utilisation by MRFs and validate their performance against two independent directed surveys. The best performing activity proxy is further analysed using novel permutative Monte Carlo sampling to determine the suitability of the proxy as an indicator of coastal utilisation.

2. Methods

2.1. Scope

The scope of the present study was recreational fishing on the coastline of Wales, UK. This article's definition of recreational fishing accords with that of Pawson et al. (2008). Only fishing with rod and line (angling) was considered as this method dominates activity in England (Armstrong et al., 2013a) and there were no instances of other fishing methods recorded in the literature. Much of the 2740 km of Welsh coastline was accessible to MRFs. The term public and local knowledge refers to all publicly available sources in which spatial data on coastal use by MRFs was published. Local knowledge means locale specific information published by fishers with respect to MRF activity.

The Welsh Government is responsible for the management of its waters and has obligations to report harvest estimates of some recreational catches under the European Union's multi-annual programme for data collection (EU Decision 2016/1251). Obligations also exist concerning equitable and optimal use of marine resources and good management of the marine environment under the Marine and Coastal Access Act 2009 (UK Parliament, 2009) and the Welsh Government are currently committed to producing the Welsh National Marine Plan (Welsh Government, 2017) under EU directive 2014/89/EU to establish a framework for maritime spatial planning.

2.2. Source identification and data acquisition

Sources recording MRF sites were classified as sea angling literature, social media used by MRFs, government related assessments and academic research. The www.google.co.uk search engine was used in October 2014 to identify angling literature, social media, and government commissioned assessments which may detail sites of MRF activity. The Google search terms were *(Wales OR Welsh) AND (angling OR fishing) AND (sea OR marine)*. The scientific literature was searched using Google Scholar (scholar.google.co.uk), Web of Science (apps.webofknowledge.com) and ProQuest (search.proquest.com) using logically equivalent search terms. All relevant sources were recorded (online Appendix A). Sources were reviewed for the presence of sites used by MRFs in Wales. Some data sources only had partial coverage of Wales (e.g. some were dedicated to fishing in Pembrokeshire in South Wales). It was expected that the number of sources covering a spatial area (*coverage count*) would need to be accounted for in activity estimates, hence coverage extents were created during geoprocessing so the number of contributing sources at any point were known. All data were anonymised and stored in an encrypted Microsoft SQL Server database (Microsoft, 2008).

2.3. Georeferencing and geoprocessing

To determine the geographical coordinates of MRF sites found in