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Geospatial assessment of fishing quality considering environmental and angler-related factors

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ABSTRACT

Increased efforts to analyze the spatial and human dimensions of anglers are necessary to improve fisheries management. Fishing quality is considered to be important in angler site choice. This paper provides a geospatial framework for assessing and mapping fishing quality in recreational fisheries. The framework relies on three main components: 1) experimental angling records for calculating fishing quality metrics, 2) spatial modeling for making predictions at unsampled locations, and 3) angler preference information for generating an integrated fishing quality index. We applied this framework to a mixed-species recreational fishery in a marine temperate ecosystem dominated by seagrass in Palma Bay (NW Mediterranean). We calculated different fishing quality metrics (i.e., catch per unit effort, yield per unit effort, mean fish size, price per unit effort, and fish diversity) using fishery-independent experimental surveys. We then used regression models (Generalized Linear Mixed Models) to predict and map these metrics based on environmental and angler-related variables. Lastly, we combined Geographic Information System (GIS) and Multi-criteria Analysis (MCA) to integrate all metrics into a single index, considering alternative consumptive orientation profiles (ie., generic, consumptive and trophy anglers). Our results demonstrate that spatially explicit environmental variables (i.e., slope, bathymetry, benthic habitat and coastal protection) can predict the spatial distribution of fishing quality metrics. In addition, we found a significant effect of a marine protected area (MPA) on price, providing insight into the role of partial protection for recreational fisheries management. Mapping and modeling fishing quality will increase our understanding of angler site choice and the factors underlying spatial patterns in the fishing effort. The geospatial framework presented here can be used to inform ecosystem-based fisheries management.

1. Introduction

Relative to the effects of commercial fishing, the potential impacts of recreational fisheries on fish stocks have traditionally been considered negligible (Cooke and Cowx, 2004; Cooke and Cowx, 2006; Post and Parkinson, 2012). However, recent studies found that for particular species recreational catches can be comparable to commercial landings (eg., Coleman et al., 2004; Veiga et al., 2010; Zeller et al., 2008). Consequently, it has been clearly established that recreational catches should be considered in fisheries management (Coleman et al., 2004; Ihde et al., 2011; Lewin et al., 2006).

Ecosystem-based management of nearshore ecosystems depends on an understanding of fine-scale patterns of exploitation (Crowder et al., 2008; Parnell et al., 2010). In particular, spatial information regarding fishing effort and fishery resources is important for understanding fisherman behaviour and for supporting fisheries management (Fenichel et al., 2012; Hunt et al., 2011; Post and Parkinson, 2012). However, spatial dimensions have only recently been considered in recreational fisheries science (Parnell et al., 2010), primarily in the field of overexploitation risk in freshwater ecosystems (Hunt et al., 2011; Post et al., 2008; Post et al., 2002).

A greater understanding of the processes governing angler site choice can provide new insights into the spatial distribution of recreational fishing effort. In contrast to commercial fishermen who tend to focus on optimizing economic gains, recreational anglers have a more complex suite of motivations (Johnston et al., 2010). Hunt (2005) proposed that six general attributes affect a recreational fisher's site selection, maximizing personal utility: cost, fishing quality, environmental quality, facility development, encounters with other anglers, and regulations. Fishing quality and catch-related variables play a major role in the site selections of anglers and fishermen in general (e.g., Arlinghaus, 2006; Kyle et al., 2007; Spencer and Spangler, 1992). Although anglers are a heterogeneous group, the catch-related expectation is the primary criterion in an angler's choice of site and is of paramount importance to anglers (Arlinghaus, 2006; Matlock et al., 1988; Schramm et al., 2003).

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The relative importance of fishery attributes varies widely among angler types (Johnston et al., 2010; Johnston et al., 2013; Kyle et al., 2007). Thus, the characterization of multiple fishing quality metrics can allow angler preferences to be incorporated into integrated fisheries-management models. The most commonly used metrics include catch rate standardized by effort (number of fish or biomass per unit of time, e.g., Hunt et al., 2011; Post and Parkinson, 2012; Post et al., 2008; Schramm et al., 2003), fish size (Hunt, 2005; Kyle et al., 2007; Oh et al., 2005), and fish diversity or preferred species (Finn and Loomis, 2001; Smith et al., 2012). A major hurdle to assessing fishing quality is limited data. Inference from interviews may be a solution (reviewed in Hunt, 2005), although this method may be prone to bias (Steffe and Murphy, 2010). Alternatively, model prediction using independent-fishery data (i.e., data obtained from research surveys or scientific stock assessment) and potentially explanatory variables may overcome this limitation (Heermann et al., 2013). Previous studies have focused on angler-related biotic and abiotic factors influencing fish catchability (Englin and Lambert, 1995; Heermann et al., 2013; Kuparinen et al., 2010; Smith et al., 1993). Moreover, the indirect effects of management measures that enhance abundance should also be taken into account when assessing fishing quality. For example, spatial management measures such as marine protected areas (MPAs) can also affect fishing quality (Alós and Arlinghaus, 2013). In addition, model prediction using spatial covariates could be used to predict fishing quality at unsampled locations with combination of Geographic Information Systems (GIS). However, studies addressing the spatial variability of fishing quality in recreational fisheries, particularly in open marine waters, are lacking.

In this work, we provide a general framework for assessing the spatial distribution of fishing quality using a correlation approach. We demonstrate its application using as a case study of a mixed-species recreational fishery in Palma Bay (NW Mediterranean). We calculate five fishing quality metrics (i.e., catch per unit effort, yield per unit effort, mean fish size, price per unit effort, and fish diversity) and evaluate the predictive power of environmental and angler-related variables using a spatially explicit modeling approach. Then, we integrate the five fishing quality metrics into a single index based on three simulated scenarios of angler profiles. Alternative angler preferences to fishing quality metrics are evaluated in a spatially explicit manner through the combination

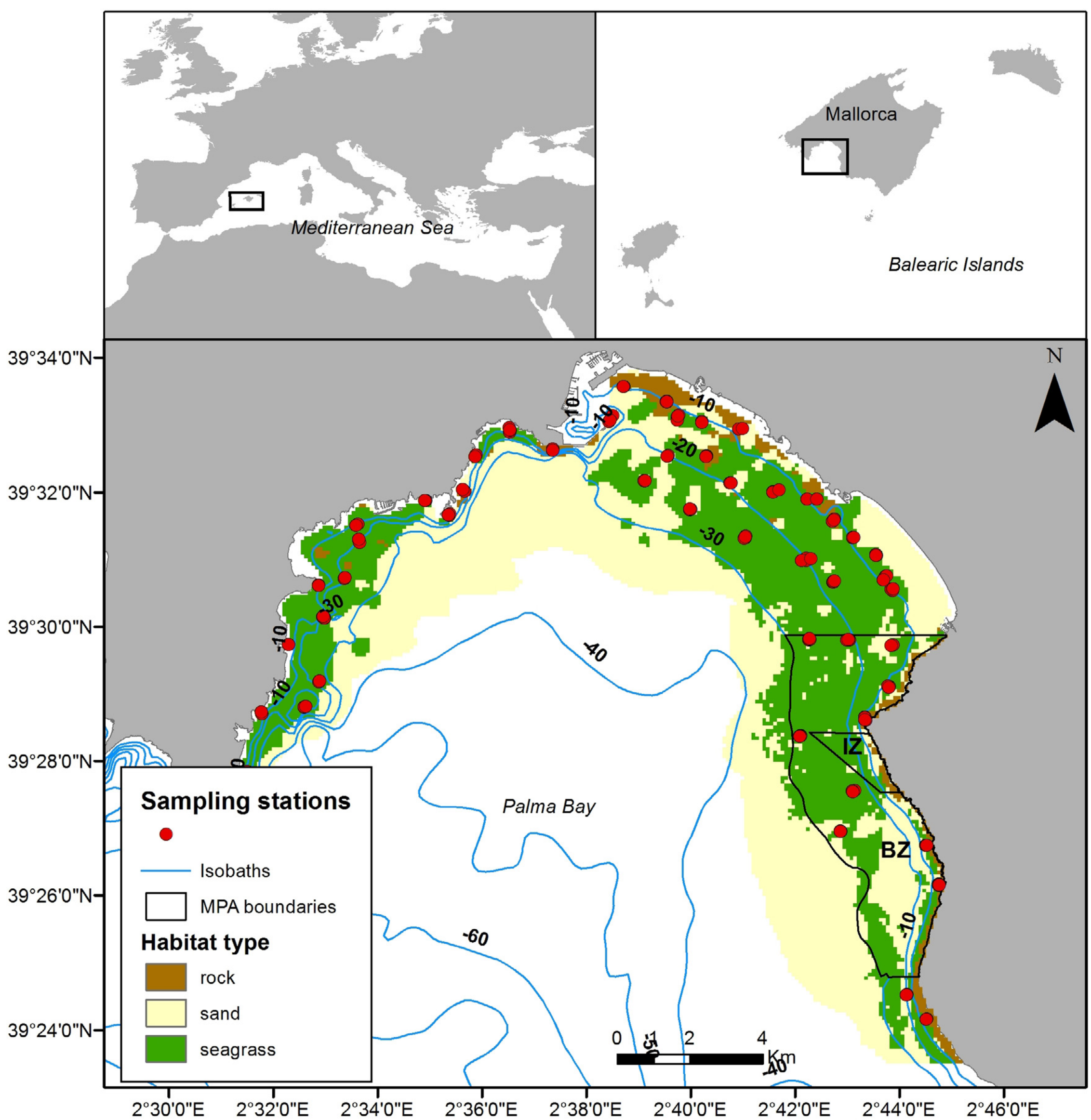

Fig. 1. Study area and sampling locations with map of habitat type. MPA boundaries represent the Integral Zone (IZ) and the Buffer Zone (BZ).