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A spatial multivariate approach to understand what controls species catch composition in small-scale fisheries

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ABSTRACT

Many multivariate methods have been applied to small-scale fishery data in an attempt to distinguish factors that characterize the fishing activity and influence catch composition. While such approaches are important, they are still incomplete for including the spatial structuring in the analysis, a non-random fundamental and functional component of the ecosystem. This study fills this gap by identifying, describing, and quantifying factors that influence the fleet type of tropical small-scale fisheries using a multivariate spatial approach. The example data came from two Brazilian States where two main fleets, open water canoes and motorized boats, operate. Different complex combinations of fishing, environmental and spatial factors affect the structure of the fish catch composition of each fleet. Motorized boats showed strong spatially-structured species catch composition in comparison with open water canoes. Similar environmental factors, such as type of the seabed and depth, but different fishing variables (gear vs crew size), affected the species catch composition of these vessel categories. Despite some overlap, each fleet focuses on a relatively distinct set of species groups and exploits habitats at different spatial scales. These results suggest that different sets of regulations should be considered for each fleet type within a specific spatial scale. It also shows that multi-species models that aggregate groups of species is a more efficient alternative than single-species assessment models for small-scale fisheries, as these are multi-specific and multi-gear, with scattered landing harbors, features that make such fisheries a complex challenge for management.

1. Introduction

Marine fisheries worldwide are characterized by the coexistence of small-scale fisheries with large-scale or industrial fisheries (Panayotou, 1982). Such coexistence is limited however to the wider notion of sharing the oceans, as the two kinds of fisheries differ in all other regards, besides the scale of operations, such as technology used, degree of capital investment and employment generation (Ruttan et al., 2000). Nevertheless, data collection systems and public policies on fisheries have focused almost exclusively on the industrialized fishing sector, presumably because it is easier to monitor and collect more data at large scale.

However, after more than three decades of intense fisheries development, it is estimated that small-scale fisheries still account for more than 90% of the world's capture fisheries and fish workers, and supply around 50% of all global fish catches, inland fisheries included (Béné, 2005; FAO, 2012). Such fisheries provide a valuable source of animal protein for billions of people worldwide and often underpin local economies in coastal, lake and river-side communities (www.fao.org/cofi/en). Despite their importance, many small-scale fishing communities continue to be marginalized and this has led to policies that inadvertently undermine their ability to adapt to global change processes, such as urbanization, globalization and climate change (Béné and Friend, 2011). Thus, there is an urgent need to fully understand the dynamics of small-scale fisheries and explore the factors that drive the activity.

In particular, small-scale fisheries, especially the ones taking place in tropical countries, capture multiple species using various fleets and gear types across multiple landing stations. Consequently, traditional management options based on single-species assessments can be challenging to implement (Lucena et al., 2002). The Ecosystem Approach to Fisheries Management (EAFM) could

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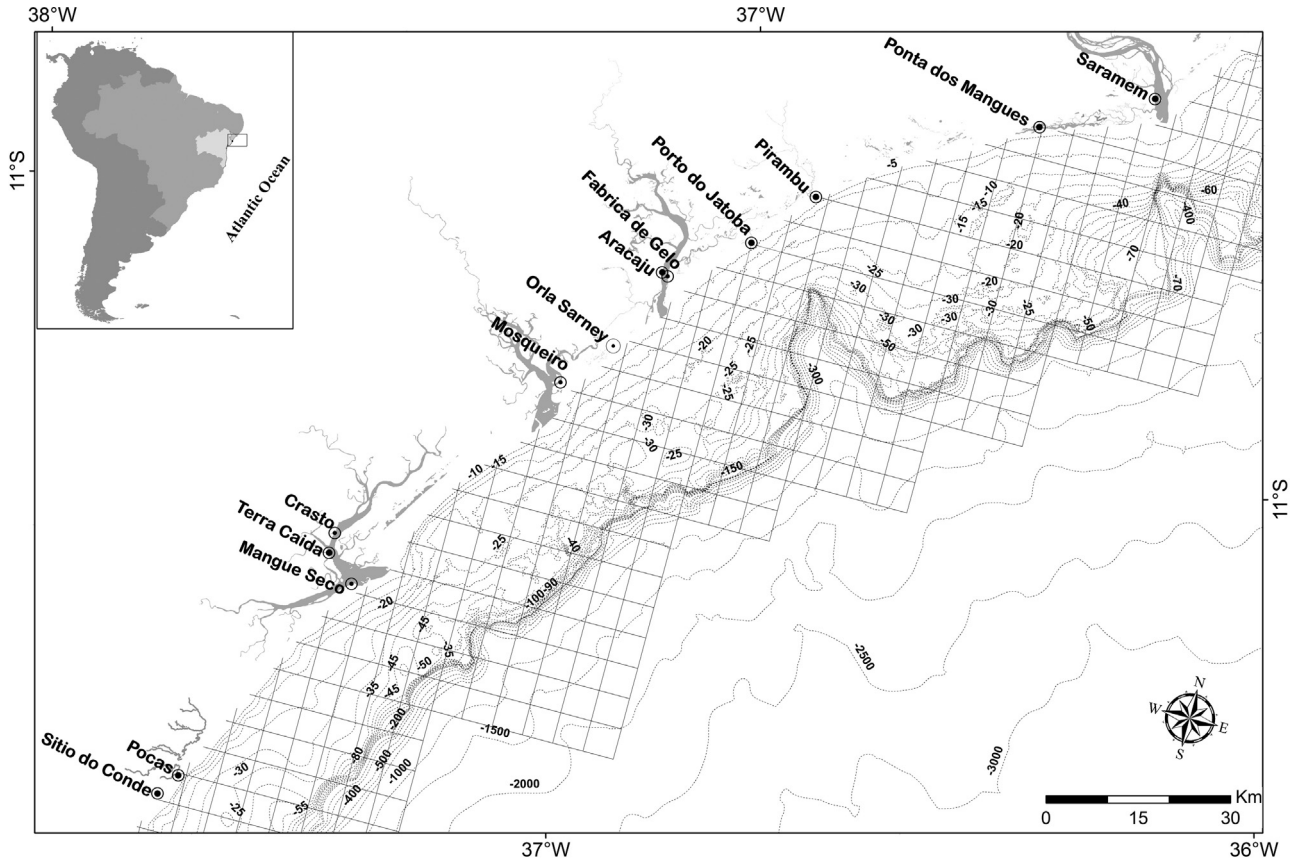

Fig. 1. Map of the study area. Feature on the coast of Brazil the states of Sergipe and the North Bahia showing the sampled harbors along the coast and the rivers, from the North to the South: São Francisco, Japaratuba, Sergipe, Vaza-Baris, Real-Piauí and Itapicuru. In the marine area the depth contours in meters and the spatial grid used for data analysis.

be a viable alternative to this type of situation, as it recognizes that fisheries are embedded into the environment, and fish species are related to each other, not being harvested independently (Jennings et al., 2001; Gascuel et al., 2012). Some of the mandatory requirements for the implementation of the EAFM are the identification and quantification of factors influencing the dynamics of fishing activities and the structure of the fish community (http://www.fao.org/fishery/topic/13261/en).

Several studies have tried to characterize the fleet dynamics of small-scale fisheries by analyzing catch composition using multivariate methods (e.g., Pelletier and Ferraris, 2000; Frédou et al., 2006; Cetra and Petrere, 2014). Such techniques help obtain an integrated picture of the structure of the system, the factors that characterize the fishing activity and influence catch composition, and the species that drive fishing dynamics (Frédou et al., 2006). While such approach is important, it is still incomplete if it ignoring spatial structuring of species communities, a fundamental non-random functional component of the ecosystem. Spatial structuring affects species distribution either because biotic processes such as growth, mortality or predation can only occur under certain spatial conditions and/or because species distribution are shaped by other spatially-structured data (Legendre and Legendre, 1998).

However, spatially structured data are seldom incorporated into catch composition analyses for multi-species fisheries, especially marine fisheries (Erisman et al., 2011). This study fills this gap by identifying, describing, and quantifying factors that influence tropical small-scale fisheries in Brazil, using a spatial multivariate approach to understand catch composition as an outcome of the environment, fishing factors and space.

Identifying this sort of baseline for small-scale fisheries could be a critical step to implement marine tropical fisheries management measures that are more likely to succeed. In particular, understanding how and if the spatial scale influences fishing activities and the fish catch composition will help to determine the proper spatial scale for management, and evaluate how different conservation policies may affect fishing economies.

2. Material and methods

2.1. Background

In Brazil, as in other coastal developing countries, small-scale fisheries play a unique role of biological, economic and social relevance. Nevertheless, worldwide, such fisheries have also been disregarded by uniform official measures applied over entire countries, ignoring cultural, social and environmental local differences. For instance, Brazil is everything but uniform when it comes to fisheries, especially given its more than 8000 km of coastline, with large estuaries and a continental shelf that varies widely. Such breadth in coastline and habitat implies a high degree of heterogeneity. In the Brazilian northeast, for example, small-scale fisheries can comprise up to 90% of the catch, a figure that varies from year to year, depending on many economic and social factors.

2.2. Study area

This study was based on information from fisheries that took place on the continental shelf of the states of Sergipe and the north-