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Coastal community CPUE standardization in the Galician Small-Scale Fishery (southeastern Atlantic shelf) from 1999 to 2013 using on board observer data

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Small-scale fisheries (SSFs) are usually under-attended despite being a large contributor to global catches, and of relevance for local economies and society. This is in part due to the paucity of appropriate information preventing the assessment and management of key species. This work presents catch per unit effort (CPUE) standardization for thirteen species, eleven fishes and two invertebrates, caught by the SSF operating off the Galician coast (NW Spain) during 1999–2013. Using catch and effort data obtained from on board observers, we estimated trends in relative abundance for each species and related the variability in catches with operational, temporal, spatial and environmental variables. Generalized linear models were fit to data to standardize catch rates. The results showed that, in general, abundance remained relatively stable over the 15-year period for the whole set of species. Some species depicted marked seasonal cycles likely related to species' catchability. Temperature was revealed as an indicator of habitat preference in several species, and the excess zeroes in the catch in zero-inflated formulations were generally related to deeper operations. This study provides comprehensive information on abundance dynamics of several data-limited species fished by a SSF operating in the southern European Atlantic shelf.

Introduction

SSFs are large contributors to worldwide fish catches, food supplies and security, and they provide employment to the largest number of fishermen (Chuenpagdee and Pauly, 2008). Despite its importance, SSFs have been traditionally under-attended and marginalized in national and international policies (Macfadyen *et al*., 2011). In general, most of the SSFs worldwide are not formally assessed due to a lack of appropriate data which prevents the evaluation of the status and productivity of those fish stocks mainly in developing countries but also in industrialized ones (Costello *et al*., 2012). Conventional assessment methods require adequate scientific monitoring, historical catch records and basic biological information. Yet, all these requirements are not always satisfied thus different approaches are frequently used to evaluate stock status, estimate overfishing thresholds and set catch limits (Carruthers *et al*., 2014). Fishery-independent indices of abundance are crucial during the management procedure. However, when these are not available the construction of stock indices of abundance must be based on fishery-dependent data (Campbell, 2015) such as catch and effort information obtained from fishery observers onboard commercial vessels.

Galician waters are located at the northern boundary of the Iberia-Canary Current upwelling system and, this area is one of the main fishing regions in Spain and Europe (Freire and García-Allut, 2000) counting a large fleet of around 4000 small-scale fishing boats. Despite these figures, the dynamics of this multi-gear artisanal fleet and the composition and status of the targeted species are poorly known. In this paper we applied a series of generalized linear models to standardize catch and effort data collected by fishery observers for a number of species harvested by the multi-gear SSF operating off the Galician coast. Catches and effort were modeled as a function of operational, spatial, temporal and environmental data, and standardized trends in relative abundance were estimated for the period 1999 to 2013 as a first attempt to evaluate the population trend for the species in the southern European Atlantic shelf.

Material and Methods

Fishery observers' data: Catch and operational data were collected by observers working on the artisanal fishing sampling program run by the Unidade Técnica de Pesca de Baixura (UTPB, Technical Unit of Artisanal Fisheries) of the Xunta de Galicia (Galician autonomous government). The sampling program monitors fishing vessels randomly selected from within the artisanal fishing fleet covering the full set of multiple gears used in Galician waters. For each haul, observers recorded the number, weight and total length of the specimens caught (Alonso-Fernández *et al*., 2014). Observers also recorded a suite of operational variables that could affect catch rates: gear type and size, average gear depth, soak time, and gross registered tonnage. In addition, seafloor type was also recorded based on

traditional fishermen knowledge, and each haul was geo-referenced.

Environmental data: To evaluate the role of environmental conditions as an indicator of habitat preference we compiled data on sea surface temperature (SST, in ºC) from a combination of satellite and in situ measurements (http://www.esrl.noaa.gov/psd/). Each haul was assigned the SST data from the grid cell in which the given haul falls in. At the latitude of our study site temperature shows strong seasonality, thus, before using that variable as a predictor in the models, it was deseasonalized and detrended using generalized additive models (Alonso-Fernández *et al*., 2014).

Statistical analyses: Here, we standardized the catch rates for each species by modeling the number caught (N) per operation (i.e. per haul i) using generalized linear models (GLMs) and zero-inflated models (e.g. Brodziak and Walsh, 2013). Fishing effort was included in the standardization models through the use of an offset, and count data regression models were compared using the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), and the log-Likelihood (Campbell, 2015).

Results and Discussion

Most species were fished by multiple gears, however, for the modeling purposes we used only those that had the better spatiotemporal coverage and were more efficient. This resulted in gillnets for most species (sea bream, ballan wrasse, spider crab, red mullet, flounder, pollack, undulate ray, spotted catfish, sole and pouting), and creels for conger and octopus, and hooks for sea bass. Model selection favored GLMs with negative binomial distribution only for conger, octopus and sole, while a zero inflated model was more optimal for the other species. An excess of zero counts is a common feature in standardization of catch rates (e.g. Brodziak and Walsh, 2013). For all species it was apparent a seasonal trend in abundance concurring with known species' biological annual cycles (e.g. pollack, Alonso-Fernández *et al*., 2014; octopus, Otero *et al*., 2007; ballan wrasse, Villegas-Ríos *et al*., 2014). In addition, SST was related to sea bass, spider crab, red mullet, octopus, flounder, and sole. Moreover, models revealed different species-specific affinities for the type of seafloor. For instance, red mullet was more abundant in mixed seafloors, and flounder, sole and undulate ray peaked in soft seafloors, while the other species' abundance were mostly related to hard seafloors. Environmental relationships, SST and seafloor, agree with current biological knowledge for the species in the study area. Finally, in general, predicted abundance remained relatively stable over the 15-year period for most species. Moreover, temporal trends, with the exception of octopus, showed little correlation with official landings suggesting that publicly available figures for these species in this region are actually a mix between catches of artisanal origin and other fleets.

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