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History, effort distribution and landings in an artisanal bottom longline fishery: An empirical study from the North Atlantic Ocean

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ABSTRACT

Commercial fishing data were used to reconstruct historical spatio-temporal patterns of fishing effort and landings in the bottom longline fishery of the Azores. Key events during an important 15-year period were charted, through fisher interviews together with GIS analysis. While effort distribution varied over time, the prevailing pattern was a shift in focus from eastern to western areas and from shelf/slope to offshore banks and seamounts in response to policy measures (e.g. banning bottom longline inside 3 NM, public aids for modernization of the fleet) and reduced fishing yields. Areas 12–50 NM from shore represented the most vital fishing grounds in terms of fishing effort and production. Declining landings of the major demersal species, in recent years, indicate that present catch levels are not sustainable and further measures need to be taken in order to sustain fisheries resources. Knowledge of fleet behavior and the distribution of fishing effort, particularly in patchy environments, provide valuable insights into the impacts of past management decisions and help predict the outcome of new policies both in this region and elsewhere.

1. Introduction

A fishery's impact on its own resources is determined in large part by the distribution of fishing effort and the type of habitat where the effort occurs. Monitoring and quantifying changes in fishing effort is crucial for effective fisheries management [11]. The distribution of fishing activities depends on each fishing unit's response to management measures and market conditions, as well as fish abundance and distribution [2]. Effort information is needed to understand changes in fisheries production, and to regulate fishing efficiency to maximize profit and minimize overfishing [4]. One of the more common methods used by researchers in small-scale and industrial fisheries is the use of fisher interview data to quantify effort and gather information on catch composition per fishing trip, number of trips, vessels and effort spatial distribution [8,18,19,11]. The use of GIS applications to allocate fishing effort on the basis of interviews constitutes a powerful tool that helps decision makers to evaluate decisions taken and to assess the effectiveness of policy changes [5]. Such tools can be particularly useful in systems where fish populations are distributed heterogeneously in space and fishing vessels tend to move back and forth between different patches in order to maximize profit opportunities [23].

The spatial distribution of fishing effort of demersal fisheries in the Azores region was, until now, scarcely studied. Until the early 1980s, the fishing fleet was predominantly involved in small-scale fishing, which operated mainly on the shelf and slope of the islands [13,24]. In 1985, with the adhesion of Portugal to the European Economic Community (EEC), the archipelago of the Azores, as an outermost region, received a large amount of public subsidies, which permitted the modernization of the fleet and the introduction of larger vessels built from modern materials and equipped with highly technological equipment such as sonar and radar, with enlarged storage capacity and autonomy [7,22]. At the same time, the use of gears such as the bottom longline were widespread, enabling the expansion of the fleet to the deepest ocean layers (400–700 m) and led to an increase in demersal fishing effort [12].

Presently, fishing activities are of great importance to the Azores' economy with emphasis on demersal species, which represent more than 50% of the total annual value landed in the region [20,6]. Azorean fisheries are characteristically small-scale and artisanal with 89.7% of the fishing vessels being small, open- or closed-deck boats (length < 12 m), mainly operating nearby the islands [7,14]. The remaining fleet is composed of larger vessels

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(12–31 m) that operate mostly between 3 and 200 nautical miles (NM) from shore [20,7,14]. The largest part of the fishing fleet, approximately 87%, is multispecies and multigear [20], mostly equipped with handlines and bottom longlines.

The blackspot seabream (*Pagellus bogaraveo*) is the main species targeted by the Azorean bottom longline fishery; however, the fishery also directs its effort to a great number of other demersal species such as wreckfish (*Polyprion americanus*), bluemouth rockfish (*Helicolenus dactylopterus*), forkbeard (*Phycis phycis*), conger eel (*Conger conger*), and alfonsinos (*Beryx splendens* and *Beryx decadactylus*), species that typically occur down to depths of 700 m on island slopes and seamounts [13].

The Azores Exclusive Economic Zone (EEZ) covers an area of approximately 1000,000 km^2, and average depth is approximately 3000 m. Since only about 1% of the EEZ has depths of less than 600 m [13], the area available for demersal fishing very limited and dispersed. As in other volcanic archipelagos, the fish populations are distributed across a set of spatially discrete habitats or patches, constituting metapopulations [23]. Archipelagos with this type of habitat discontinuity present different levels of connectivity between patches, which increases the complexity of biological interactions and processes [23]. Particularly, the Azorean offshore patches are dependent on annual replacement of recruits from: (i) Azorean inshore nurseries (e.g. blackspot seabream; bluejack mackerel, *Trachurus picturatus* [13,21]), (ii) distant regions such as the American east coast (e.g. wreckfish; [14]) and (iii) from each seamount itself or adjacent seamounts and slopes (e.g. bluemouth rockfish). Demersal fish populations in remote and isolated offshore patches are thought to receive less biomass and fewer recruits from other patches [23], making them more vulnerable to fishing, especially when the species' life histories present characteristics of late maturation, slower growth, and little capacity for egg and larval dispersion [15].

Some of the traditional Azorean fishing grounds are presently subject to intense exploitation rates that are unlikely to be sustainable in the medium and long term [20]. The current differences found in catch rate and biodiversity in different areas of Azores are, in many cases, a consequence of past exploitation [14]. Therefore, the objective of this study was to reconstruct the history of the Azorean bottom longline fishery from 1998 to 2012, in terms of distribution of fishing effort, derived through interpolation of information provided by fishermen, together with landings data acquired through in situ sampling. By examining and understanding the consequences of past management actions, it is hoped that this study will provide valuable information on the nature of artisanal fisheries and reveal their dynamics in a patchy environment, and in this way inform and/or support future management strategies and policies both in this region and elsewhere.

2. Materials and methods

The Azores Archipelago consists of nine isolated islands located in the Northeastern Atlantic (Fig. 1). These volcanic islands are distributed in three groups over an area of 600 km^2 with an orientation WNW–ESE and a coastline of 790 km [13]. In recent years, a total of 63 large and 398 small seamount-like features were identified in the region [16], however, only a few of these are relevant to bottom longline fisheries since many are too deep or too small.

The bottom longline gear is locally known as "stone-buoy longline". It is characterized by a series of buoys spaced 74 m apart that permit the gear to float above the seabed, alternating with stones that anchor the gear. The bottom longline is composed of several units and each unit is approximately 37 m long, known as a 'quarter-skate' and contains 25 to 30 J-type, no. 9 hooks, usually baited with "chopped salted sardine" [13].

2.1. Data collection

Fishing effort data were collected during the period of 1998–2012 as part of the mandate of the Data Collection Framework (DCF). Sampling was designed to cover the main ports of the archipelago and was performed by clerks who carried out standardized interviews ($n=6253$) with the captains of the bottom longline vessels on a daily basis during the landing period. The interviews provided information on fishing effort and fishing operation, namely: the number of hauls, fishing gear, fishing hours, bait type, no. of hooks, fishing depths, crew number, and fishing locations on a pre-defined spatial grid of 10×10 NM [14]. Sampling focused on the four main islands (Faial, Pico, Terceira and São Miguel Island), which represented around 98% of the Azorean bottom longline landings. Data were pooled by island/port, since the importance of bottom longlines differed among the islands/ports, in terms of landings and effort, and since the spatial distribution of the fleet among those ports was heterogeneous. The DCF data covered 22% of the landings corresponding to about 25% in weight of the demersal fish landed in the monitored ports. Official data on landings weight per species, date, landing ports, boat name and fishing gears were attained from the database kept by the Department of Oceanography and Fisheries, University of the Azores (DOP).

In terms of catch composition, six principal taxa were considered: bluemouth rockfish, conger eel, forkbeard, blackspot seabream, wreckfish, alfonsinos, and "others". The category "others" included all species for which overall landings were $\leq 3\%$ of the total. For the group "others" landings were proportioned over all statistical squares in which fishing was reported to have taken place, according to the estimated associated effort.

2.2. Spatial distribution of fishing effort and landings

To calculate the spatial distribution of landings and fishing effort from the bottom longline fleet several steps were taken. Effort per 10×10 NM grid square was estimated from information given by fishermen during the interviews. The number of hooks per trip was divided by the number of areas fished per trip to obtain a typical effort index for each square of the mapped grid, since absolute effort per longline set was unknown. Bottom longline landings were pooled by island/port and year, and weighted by the per-square effort index to obtain an estimate of the landings and effort per square. Landings per taxa per square were calculated by first identifying the squares in which each taxa could potentially have been captured, considering knowledge of the typical depth ranges for each species group provided by Menezes et al. [13], and applying this ratio to the total official landings by bottom longlines from the Lotaçor S.A./DOP databases, for the given island/port and year. Total outputs for each island were then summed to obtain the spatial distribution of annual fishing effort and landings. The landings (total and per species) and effort spatial distribution were plotted and calculated using GIS (ArcView 9.3) in relation to (a) distance from the island shore (0–12 NM, 12–50 NM, 50–100 NM and 100–200 NM) and (b) per area (coast and island slope, eastern banks, central banks, Mid-Atlantic Ridge (M.A.R.) banks, and Great south banks (see Fig. 1). Further, the area in km^2 (see Fig. 2) of fishing grounds at a depth of ≤ 600 m, in relation to distance from the islands shore (0–12 NM, 12–50 NM, 50–100 NM and 100–200 NM), was estimated in order to calculate the catch rates per area (kg/km^2). These calculations were performed using GIS (ArcView 9.3) tools together with bathymetric data from Smith and Sandwell [25].