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# An Atlantic journey: The distribution and fishing pattern of the Madeira deep sea fishery

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## HIGHLIGHTS

- Fishing sets targeting deep water fishes by Madeira fishing fleet were plotted.
- A progressive and wide dispersion of the fishing grounds has been detected.
- Trends in the yields of *Aphanopus* spp. show a steep decline.
- Present results support the need for new resource management strategies.

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## ABSTRACT

The deep sea fishery targeting the black and intermediate scabbardfishes (*Aphanopus* spp.) off the Madeira archipelago represents one of the world long standing exploitations of meso- and bathypelagic fishes. The intensive fishing of the target species caused an overall decrease of more than (51%) in their yields. Fishing vessels had to go further away of the usual fishing grounds, leading to a progressive geographical expansion of the fishery reaching as far as the Southern Azores Seamount Chain and the Canaries Economic Exclusive Zone. Changes in the fishing pattern of the Madeira fleet were also registered along the last decades. Trends of the spatial distribution of the fishing sets and of the fishing pattern exerted by the Madeira fishing fleet in the North-central eastern Atlantic are presented herein and its implications for the conservation of the resource and fishery management are discussed, along with the emergence of new fisheries upon this resource at regional level. Changes in the conservation and management strategies followed so far is urgent and should integrate all fisheries acting upon the resource and take in account the phase of the life cycle it fishes otherwise the sustainability of the exploitation may soon be in danger. Authors propose a prohibition of bottom trawling bellow 200 m deep and a temporary closure of the fishery in some areas.

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## 1. Introduction

The deep sea fishery targeting the black and intermediate scabbardfish (respectively *Aphanopus carbo* Lowe, 1839 and *Aphanopus intermedius* Parin, 1983) off the Madeira archipelago represents one of the world long standing exploitation of meso- and bathypelagic fish species (Biscoito et al., 2011; Delgado et al., 2013). During at least 150 years this fishery continued as an artisanal sustainable activity, but during the last decades of the twenty century the increase of the fishing effort and yields may have

changed this situation. At present it is still one of the most important activities of the Madeira fishing fleet considering both its yields and economic value. Landings in 2017 achieved around 2163 tonnes, which yielded ca 7.6 M€, however this represents a serious decrease since the fishery landings peak in 1998 (4203 ton).

New important regional fisheries at the North-eastern Atlantic also targeting this resource emerged in the 1980's in Sesimbra, off mainland Portugal, using a bottom longline (Set longline- LLS) and *A. carbo* become also an important by-catch for the French deep-sea trawl fishery west of the British Isles (Nakamura and Parin, 1993; ICES, 2012).

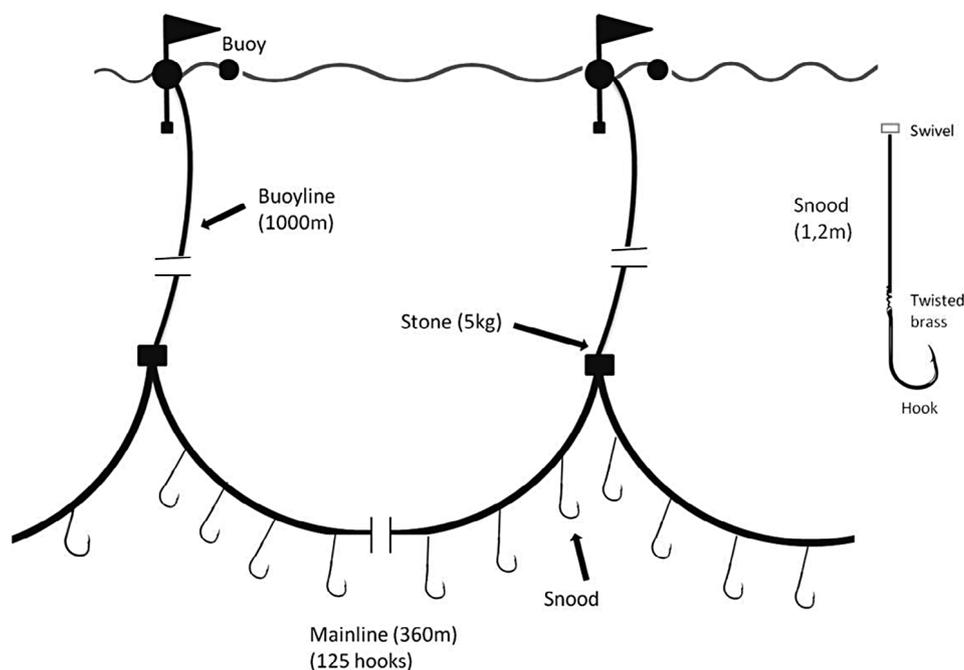
Concerning the target species of these deep water fisheries, catches off Madeira are composed by the sympatric species: *A. carbo* and *A. intermedius* in an 80%:20% ratio. Catches from south i.e. Canaries area, present a higher abundance of the intermediate

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**Fig. 1.** Fishing gear: drifting longline (LLD) used in the water column. Usually set targeting the depth layer between 800 to 1300 m deep.

scabbard fish, whereas catches north of Madeira made by the Sesimbra fishery, off Portugal mainland, are solely constituted by the black scabbard fish (Biscoito et al., 2011). These fisheries present a by-catch mainly constituted by deep water sharks. In Madeira this by-catch usually represents around 5% of total catches in number (Severino et al., 2009; Veiga et al., 2013).

Farias et al. (2013) proposed a distribution and hypothetical migratory cycle of *A. carbo* in the northeast Atlantic. Authors state that spawning of black scabbard fish occurs around Madeira and the Canary Archipelagos during the last quarter of the year. According to their migratory hypothesis, eggs, larvae, and possibly juveniles move north to areas from south of Icelandic and Faroe Islands to the west of the British Isles where they remain for some years to feed and grow. Then, they move south to the area off mainland Portugal, where they reach the size of first maturity but do not reproduce, and later move further south to the spawning grounds. Apparently *A. intermedius* distributes southward, being a subtropical and tropical species in the Atlantic Ocean, with Madeira, Azores and the Canaries being the superposition area of both species (Parin, 1990; Biscoito et al., 2011).

The fishing gear used by the Madeira fleet for the capture of these deep sea fishes is a drifting long line (Fig. 1) usually set well above the bottom, in the water layer between 800 and 1300 m deep (Morales-Nin and Sena-Carvalho, 1996). The fishing gear used in this way does not contact the seafloor, causing no damage to its vulnerable ecosystems.

Nevertheless, the intensive fishing of the target species caused a decrease in their relative abundance in the usual fishing grounds, leading to an extensive geographical expansion of the fishery reaching as far as the Southern Azores Seamount Chain and the Canaries Economic Exclusive Zone. Changes in the fishing pattern of the fleet, for example the increase of soak time, were also registered along the last decades. These changes resulted from the need to compensate the notorious reduction of fish available in the usual fishing grounds off the islands of Madeira and Porto Santo.

Yearly trends of the spatial distribution of the fishing sets and of the fishing pattern, such as yields, fishing effort and LPUE, exerted by the Madeira fishing fleet in the North-central eastern Atlantic are presented herein, and its implications for this fishery management are discussed.

## 2. Material and methods

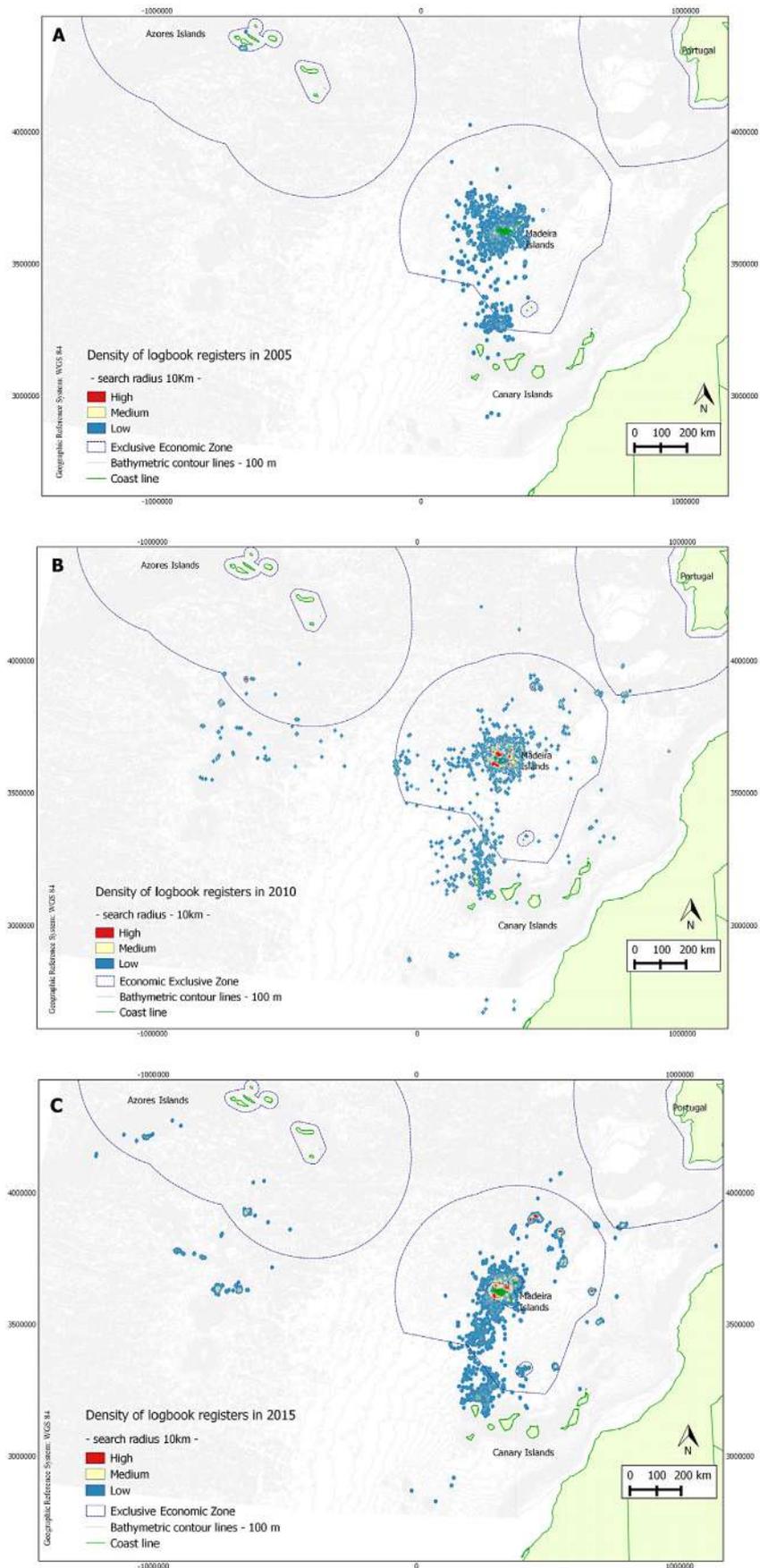
Data (fishing set positions) was collected from paper (2005–2012) and electronic logbook registers (2013–2015). Density maps were estimated with the Heatmap plug-in, a Quantum GIS 2.2 utility, that use Kernel Density Estimation to create a density raster output, defining a circular neighbourhood, a search radius of 10 km, based on the number of points in a location within the data extent (Caddy and Carocci, 1999; Riolo, 2004; QGIS, 2014).

Yields and fishing effort data were obtained from the electronic and paper logbooks and sales notes from the Data Collection Framework database of the Regional Directorate of Fisheries of Madeira.

## 3. Results

The deep sea fishery carried out by vessels of Madeira, has undergone considerable geographic expansion in recent decades in the North-central Eastern Atlantic (Fig. 2(A)–(C)). The fishery which was traditionally concentrated mostly off the islands of Madeira and Porto Santo, from 2005 onwards initiated a process of expansion looking for new fishing grounds. Progressively, fishing grounds located in international waters SE of the Azores, off the Canaries and the “rediscovery” of the seamounts within the Madeira EEZ which were frequently fished in the 1980–1990’s, became indispensable for this fishery. Recently agreements with the Azores and the Canaries have been made to allow the fleet access to those areas.

This wide enlargement of the maritime area covered by fishing operations came under the pressure of the notorious decrease of the relative abundance of the resource in the traditional fishing grounds. The search for new fishing grounds was driven by the need to stabilize catches that suffered a severe decline from 2000 onwards. A reasonable stabilization of the yields, fishing effort and LPUE of the fishery was achieved in the last years (Figs. 3–5) but the steep decrease (–51%) of the yields (that are now ca 49% of the 1998 peak) and increase in the cost of each fishing trip led several vessels to leave this activity.



**Fig. 2.** Density plots illustrating the geographical distribution of the fishing sets with catches (A – 2005; B – 2010; C – 2015).

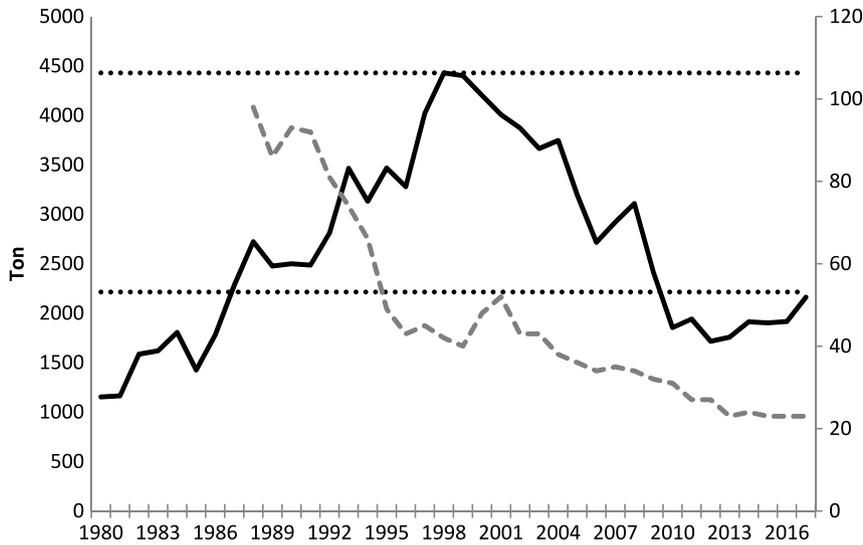


Fig. 3. Yields (bold line) and number of active commercial fishing vessels (dash line). Peak yield (4430 ton), and 50% of the peak yield (2215 ton) represented by the dot lines.

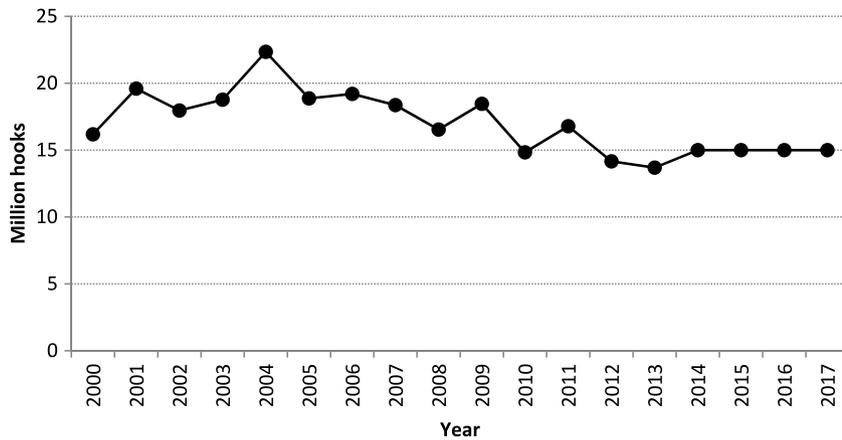


Fig. 4. Yearly accumulated fishing effort, in number of hooks deployed.

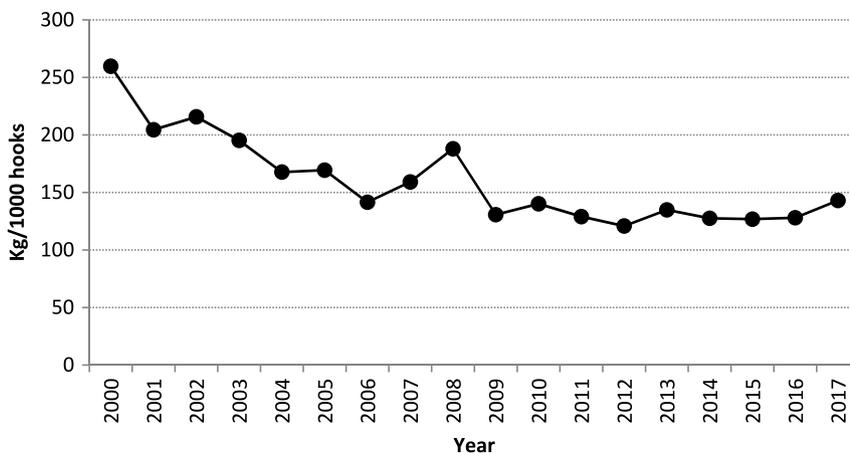


Fig. 5. Yearly trend of the nominal LPUE (kg/1000 hooks).

These changes come also with costs to the security of the activity and quality of the fish, as most fishing trips can last up to about two weeks. Most (96%) of the 23 vessels now in activity are less than 18 m length and have poor conditions to the conservation of the fish on board. The use of ice for the refrigeration of the fish

is sometimes insufficient to maintain its quality, with influence on the sale price or even the discarding of the fish.

The black scabbard fish it is also captured, especially since the 1980's, by trawling in the west of the British Isles, Hatton bank, Faroe Islands and Iceland. These last fisheries capture mostly small

immature fish, less than 100 cm (Magnússon and Magnússon, 1995; Magnússon et al., 2000). According to Gomes (2016) length at maturity is of 108.7 cm in females and 102.9 cm in males, whereas almost only adult specimens are caught by the Madeira fishery. Delgado et al. (2013) reported a mean size of 118.0 TL for *A. carbo* catches off Madeira and specimens were mainly caught between 112 and 120 cm TL.

#### 4. Discussion

Several studies (Farias et al., 2013; Santos et al., 2013) support the migratory hypothesis driven by feeding and reproduction, showing evidence of a single black scabbard fish stock in the North-central Eastern Atlantic. Consequently, there may be a cause effect relationship between the development of these NE Atlantic fisheries and the diminution of the relative abundance of *A. carbo* in the Madeira fishing grounds. This diminution suggested by the long term decrease in the yields and nominal LPUE (Landings per Unit of Effort), was also verified by Gomes (2016) which in a recent work analysing trends in standardized LPUE data of the Madeira fishing fleet, suggests that this fishery may be in a state of hyperstability.

Also, an array of evidences ultimately detected such as the spreading of the fishery to remote areas with increased costs, serious decrease of yields despite the relative maintenance of the yearly accumulated number of hooks deployed (regardless of the important diminution of the number of active fishing vessels), increase of soaking time and long term diminution of nominal LPUE are serious warning signals about the state of exploitation of this resource.

Although in the short term (i.e. in the last 8 years) landings and LPUE are fairly stable and with a tendency of increase in 2017, this stabilization was only achieved at less than 50% of the peak catches. A shift on the management strategies and regulatory measures followed so far (based solely in quotas and capacity limits) is still necessary and should concern and be case specific to all fisheries acting upon the resource, taking in account the phase of the life cycle it fishes (for example the trawl fishery in the North Atlantic catches immature fish conversely in Madeira the fisheries targets the adult spawners) and the fishing methodologies used, otherwise the sustainability of the exploitation may soon be in danger.

#### 5. Conclusion

A complete prohibition of the bottom trawling at depths under 200 m, the higher depth range of the black scabbard vertical distribution according to Pajuelo et al. (2008), in the fishing grounds in the NE Atlantic (e.g. off the west of the British Isles, Hatton bank, Faroe islands and Iceland) and a closure in the spawning area off Madeira and Porto Santo islands during the spawning period (November/December) (Figueiredo et al., 2003; Delgado et al., 2013), should be envisaged by the National and European authorities.

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