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Trophic ecology of black scabbardfish, *Aphanopus carbo* in the NE Atlantic—Assessment through stomach content and stable isotope analyses

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ABSTRACT

The black scabbardfish is a deep water species of high commercial interest in the NE Atlantic. Specimens were collected from commercial trawls to the west of the British Isles and from longliners operating near Madeira between September 2008 and May 2010. Stomach content analysis was confined to samples from the northern area, because of a high number of empty stomachs from Madeira. Stable isotope analyses identified that black scabbardfish feeds on species with epipelagic and benthopelagic affinities. For the west of British Isles, the δN values were significantly different between seasons suggesting a change in the diet throughout the year. Black scabbardfish have higher δN and δC values compared with other co-occurring benthopelagic feeders and lower nitrogen values than the true benthic predators and/or scavengers. Comparison with stable isotope analysis in samples from Madeira indicated that black scabbardfish feed at a similar trophic level and has the same trophic niche width in both areas, assuming similar baseline isotope compositions. The diet in the northern area comprised fish (68% N), crustaceans (22% N) and cephalopods (15% N) with blue whiting (*Micromesistius poutassou*) constituting 40% of the prey. Seasonal shift in diet was observed, with a predominance of blue whiting (70%) in the first quarter of the year, shifting to a more diverse diet in the remainder of the year. These results indicate that the diet of black scabbardfish is closely linked with the seasonal migration of blue whiting and that they likely select prey in proportion to availability. This study demonstrates that the combined used of both methods can elucidate the trophic ecology of black scabbardfish, in situations where conventional methods alone provide insufficient data.

1. Introduction

The black scabbardfish (*Aphanopus carbo* Lowe, 1839) is a deep water fish, belonging to the family Trichiuridae. This species has a world-wide distribution, with records in the Atlantic from Iceland (Magnússon and Magnússon, 1995) to the Canary Islands (Uiblein et al., 1996), including the islands of Madeira, Azores and numerous submarine banks and seamounts (Zilanov and Shepel, 1975; Nakamura and Parin, 1993; Morales-Nin and Sena-Carvalho, 1996; Vinnichenko et al., 2005; Pajuelo et al., 2008). It belongs to the benthopelagic category of deep-water fishes, living close to the bottom along the continental slope (Nakamura and Parin, 1993; Gordon, 2001; Bordalo-Machado and Figueiredo, 2008) and occurs at depths between 200 m in the British Isles (Tucker, 1956; Bordalo-Machado et al., 2001; Bordalo-Machado and Figueiredo, 2008) to 1800 m in the south of Madeira, being more commonly found between 800 and 1200 m (Bordalo-Machado et al., 2001).

Black scabbardfish is an economically important deep water species that has been exploited in the eastern Atlantic, off the Madeira Islands, for centuries (Haedrich et al., 2001). Since 1983, the exploitation of black scabbardfish expanded to the Portuguese continental waters (Martins et al., 1989; Bordalo-Machado and Figueiredo, 2008). In the north of Europe, the species has been captured around the British Isles (ICES Subareas V, VI and VII) and Iceland (ICES Subarea Va), mainly by French, Icelandic and Spanish trawlers (ICES, 2011) since the early 1990s (ICES, 2008).

Despite the wide distribution and commercial interest in black scabbardfish, biological studies are relatively sparse and have concentrated on distribution (Zilanov and Shepel, 1975; Piotrovskiy, 1981; Mauchline and Gordon, 1984c; Nakamura and Parin, 1993; Magnússon and Magnússon, 1995; Uiblein et al., 1996; Vinnichenko et al., 2005), anatomy (Bone, 1971), age and growth (Morales-Nin and Sena-Carvalho, 1996; Morales-Nin et al., 2002;

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Pajuelo et al., 2008; Vieira et al., 2009) and reproduction (Bordalo-Machado et al., 2001; Figueiredo et al., 2003; Pajuelo et al., 2008; Ribeiro Santos et al., 2013). The available information on the diet of black scabbardfish is confined to general comments on the stomachs contents from specimens collected from the Hatton Bank (Du Buit, 1978), the Rockall Trough (Mauchline and Gordon, 1984c), west of the British isles (Zilanov and Shepel, 1975) and Portugal (Santos, 2000), but without any detailed description or interpretation. Overall, detailed diet studies of deep water species are very limited and scarce due to the difficulty of collecting samples and high rate of stomach eversion.

Stable isotope analysis offers a complementary perspective to investigate the long term view of feeding relationships by accounting for all the sources of energy assimilated during a feeding season and the trophic position of an organism (Iken et al., 2001). The stable nitrogen isotope ratio ($^{15}N/^{14}N$) increases at every step in the food chain, thus indicating trophic level of a species (DeNiro and Epstein, 1981), while the carbon isotope ratio ($^{13}C/^{12}C$) may provide information on nutrient sources (DeNiro and Epstein, 1978; Vander Zanden and Rasmussen, 2001). Benthic and benthopelagic fish may derive nutrients directly from the pelagic food web, or via the benthic food web. The benthic food web pathway contains more trophic steps between primary production and fish production, thus fish supplied with nutrients from the benthic food sources will be relatively isotopically enriched (Iken et al., 2001; Drazen et al., 2008; Doyle et al., 2012). Although detailed interpretation of stable isotope data to infer diet composition is dependent on the knowledge of isotope signatures of the prey species, some inferences about patterns of variation in diet (e.g. ontogenetic variations) can be made in the absence of such information (Stowasser et al., 2009).

Stomach content and stable isotopes analysis have been rarely applied to other deep water fish. The existing studies using both analyses are mainly focused on the dominant families of the deep sea: Macrouridae and Moridae (Mauchline and Gordon, 1984a; Iken et al., 2001; Polunin et al., 2001; Drazen et al., 2008; Stowasser et al., 2009; Bergstad et al., 2010). In the present study, stable isotope analysis, supported by stomach contents analysis, were used to investigate the trophic ecology of black scabbardfish in two areas of the NE Atlantic: west of the British Isles and Madeira. While stomach content analysis provides information on the composition of recent meals, stable isotopes integrate the signatures of different prey consumed over a longer period, and can be used to infer trophic level and discriminate sources of food between the two areas.

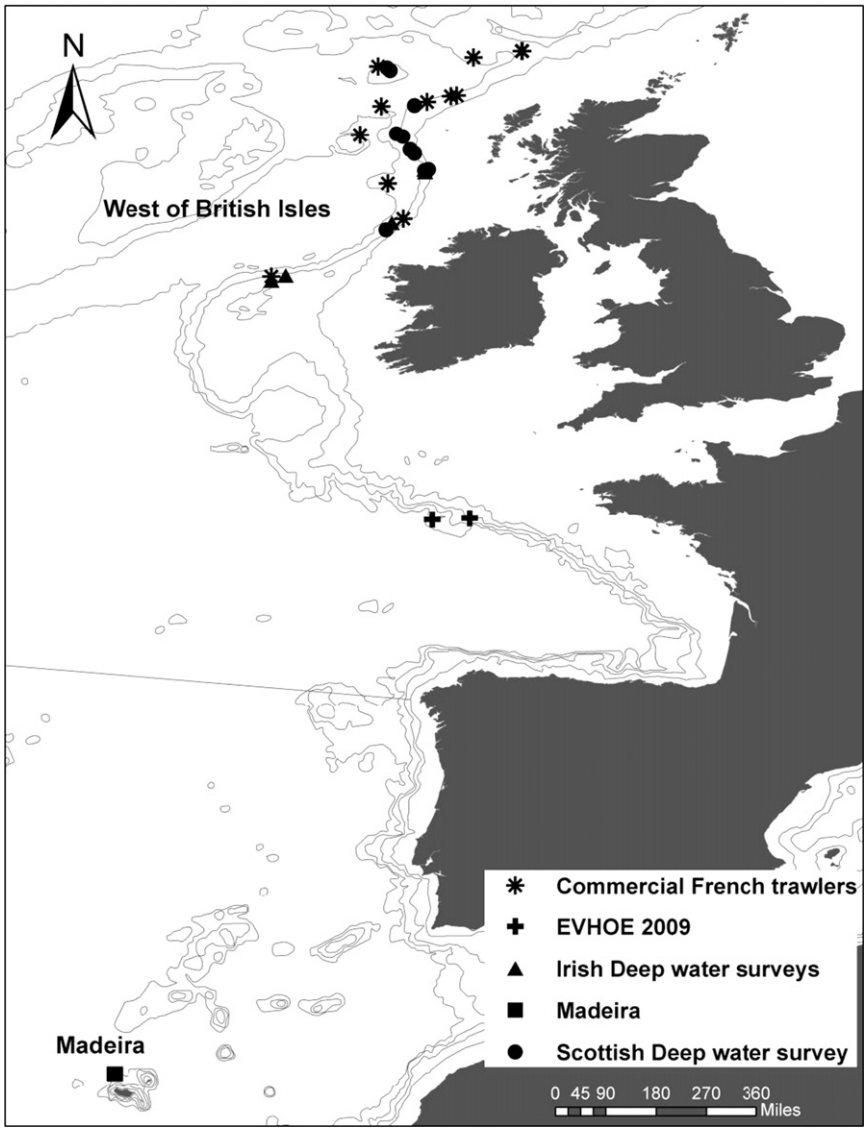

Fig. 1. Map with the locations where the samples of black scabbardfish used for this study were collected.