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Cold-water corals landed by bottom longline fisheries in the Azores (north-eastern Atlantic)

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The impact of bottom trawling on cold-water corals (CWC) has been thoroughly studied and shown to be long-lasting; however the effects of bottom longlining on CWC ecosystems have received little attention. The present paper identifies the principal CWC species landed by bottom longlining in Faial (Azores) from 150 to 600 m depth. Data were obtained from a survey of 297 landings during four months coupled with 16 interviews with fishermen. A distinction was made among corals brought on deck directly entangled in the fishing gear (primary by-catch) from corals brought up associated with other larger CWC species or rocks (secondary by-catch). Forty-five (15.5%) of 297 fishing trips surveyed landed coral specimens. The survey recorded 39 different CWC taxa in the by-catch, belonging to five different orders (Scleractinia, Alcyonacea, Antipatharia, Zoanthidea and Anthoathecata). Secondary by-catch included a larger number of species but the total number of corals was in the same order of magnitude for both groups. The taxa most frequently encountered were Leiopathes*spp.,* Errina dabneyi *and* Dendrophyllia sp. *CWC taxa in the by-catch were mostly medium size (10–60 cm), 3-dimensional and branched colonies. Local ecological knowledge of fishermen confirmed that the corals recorded were representative of their past experience and also revealed a general agreement that there has been a decrease of CWC by-catch on traditional fishing grounds. Corals are common by-catch in bottom longline fisheries around the Azores and so conservation measures may be required.*

Keywords: cold-water corals, deep-water fisheries, bottom longline, anthropogenic impact, conservation

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INTRODUCTION

The increasing exploitation of deep-sea resources has brought into attention the urgent need to conserve and manage the deep-sea environment (Morato *et al.*, 2006; Davies *et al.*, 2007). Not only are most deep-water fisheries believed to be unsustainable for the exploited species itself (Sissenwine & Mace, 2007; Norse *et al.*, 2012) but their impact on benthic habitats has also shown to be dramatic (Hall-Spencer *et al.*, 2002; Clark & Koslow, 2007; Edinger *et al.*, 2007a; Waller *et al.*, 2007; Clark & Rowden, 2009). Cold-water corals (CWC) have a worldwide distribution and can be found in a wide variety of deep-water environments such as fjords, continental shelves, island slopes and offshore seamounts (Freiwald *et al.*, 2004). They include colonial anthozoans without symbiont dinoflagellates (e.g. Scleractinia, Antipatharia and Alcyonacea) and calcareous hydrozoans (e.g. Stylasteridae) that often aggregate forming benthic habitats known as coral reefs and coral gardens (Freiwald *et al.*, 2004; Clark *et al.*, 2006; Roberts *et al.*, 2006; Rogers *et al.*, 2007). Reefs are 3-dimensional structures densely built up above the bottom by stony scleractinian corals such as *Lophelia pertusa* or *Madrepora oculata*, whereas coral gardens are formed by dense aggregations of colonies that can be composed of one or more species belonging to one or more coral groups (i.e. Scleractinia, Antipatharia, Alcyonacea and Stylasteridae) (Roberts *et al.*, 2009; OSPAR, 2010).

The ecological importance of such habitats is widely recognized as both types of coral aggregations increase habitat complexity, representing biodiversity rich areas for invertebrates (Jensen & Frederiksen, 1992; Fosså *et al.*, 2002; Buhl-Mortensen & Mortensen, 2005; Le Guilloux *et al.*, 2010; Braga-Henriques *et al.*, 2011) and support a high abundance of fish (Breeze *et al.*, 1997; Husebø *et al.*, 2002; Costello *et al.*, 2005; Edinger *et al.*, 2007b; Söffker *et al.*, 2011). The emergence of data on the biology and life history of CWC revealed extremely slow growth rates and long life spans (e.g. Adkins *et al.*, 2004; Marschal *et al.*, 2004; Andrews *et al.*, 2005; Prouty *et al.*, 2011). While some species' life expectancy is a couple of centuries (Sherwood & Edinger, 2009), others can live more than 4000 years presenting radial growth rates as low as 5 μm year^{-1} (*Leiopathes* sp.: Roark *et al.*, 2009). Such life history characteristics make them particularly sensitive to anthropogenic perturbations and as a result cold-water corals have been included in the lists of vulnerable marine ecosystems (VME) (FAO, 2009), for which conservation constitutes a global priority (Morgan *et al.*, 2005; Hall-Spencer *et al.*, 2009; Clark *et al.*, 2010; Norse *et al.*, 2012).

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Characterizing the impact of human activities is an important step to support conservation policies as addressed by the 2006 United Nations General Assembly Resolution 61/105 on sustainable fisheries. Despite other threats, such as climate change and ocean acidification, deep-sea fisheries are the main cause of species removal and habitat destruction (Caldeira & Wickett, 2003; Freiwald *et al.*, 2004; Guinotte *et al.*, 2006; Roberts *et al.*, 2006). The impact of bottom trawling on VMEs has been thoroughly studied (e.g. Clark & ÓDriscoll, 2003; Shester & Ayers, 2005) and has shown to be long lasting. For example, by-catch of CWC and other sessile megafauna in New Zealand's orange roughy trawling fishery can be as high as 50 t in a single tow (Anderson & Clark, 2003). Seabed video of heavily trawled *Lophelia* reefs off western Ireland revealed entire areas of dead coral rubble with extensive trawl scars on the sediment with little sign of recovery (Hall-Spencer *et al.*, 2002; Söffker *et al.*, 2011). It has been estimated that between 30 and 50% of the Norwegian *Lophelia* reefs have been damaged by trawling (Fössa *et al.*, 2002). On the other hand, the effects of deep-sea bottom traps, drift-nets and longlines are believed to be less dramatic (Chuenpagdee *et al.*, 2003) and have as yet received little attention. However, the area swept during a bottom longline fisheries operation (when the gear is being hauled up) can be comparable with that of demersal trawls and interaction with benthic organisms is believed to be quite high (Welsford & Kilpatrick, 2008). Furthermore, bottom longlining allows fishing on rocky grounds that are inaccessible for trawling. There is now growing concern surrounding the CWC by-catch of commercial bottom longline fishery from the Hatton Bank in the north-east Atlantic (Dúran-Muñoz *et al.*, 2011) and from the Ross Sea (Parker & Bowden, 2009).

This study is an initial assessment of the level of interaction between bottom longlining and VMEs in the Azores that will provide baseline information for their conservation. The Azorean fishing industry is an interesting case study due to the type and scale of the operations (Carvalho *et al.*, 2011). Taking into consideration that bottom-trawling and other 'deep water nets' (gillnet, entangling net or trammel net) have been forbidden in the Azores since 2005 (EC 1568/2005), bottom fisheries are now limited to handlines and longlines. Moreover, there is a good and efficient communication flow and a strong collaborative work between the fishermen of this small community-based fishery with the local scientific community and the Regional Authorities (Morato *et al.*, 2010), allowing us to obtain relatively reliable fisheries data.

In this paper we have studied the cold-water coral by-catch in the Azores based on data from the bottom longline fishing as well as from fishermeńs local ecological knowledge. Specific aims were to provide a list of impacted coral species and to estimate their catch frequency by surveying commercial landings. We also investigated the interaction between caught species and colony morphology.

MATERIALS AND METHODS

The fishery

A portion of the longline fishing fleet was surveyed in Horta harbour on the island of Faial, Azores to identify the corals landed, to estimate their catch frequency and to relate the catchability with their own morphology (Figure 1). This multi-species fishery uses mainly small vessels (<14 m) operating on the rocky island's slopes and on seamounts down to ~600 m (Santos *et al.*, 1995; Morato *et al.*, 2001). A typical longline fishing trip lasts for 3 to 5 days, during which 2 to 4 fishing sets are completed (see details in Pinho & Menezes, 2006; Silva & Pinho, 2007). The bottom longlines used normally have a stone/float configuration, with ~4000–7000 J-type hooks number 9 per skate mounted on 40 cm branch-lines at ~1 m intervals and baited with pieces of salted sardine. Line settings usually start before sunrise having a soak time of 2–4 hours. Fishing is concentrated mainly around the island of Faial and on the complex of seamounts to the south-west of the island (Figure 1). Surveys were conducted between March and June 2007, during commercial landings. Fishermen were asked about the fishing operation and requested to bring all coral colonies caught during their fishing trips. Of 93 fishing vessels operating in this area during that period, 39 (41%) were surveyed and 8 (21%) brought corals to the harbour. A total of 297 fishing trips were surveyed from which 52 (15.5%) landed coral specimens.

Coral sampling and morphological classification

Surveys were conducted between March and June 2007, during commercial landings operations. Fishermen were asked about the fishing operation and requested to bring all coral colonies caught during their fishing trips. A total of 297 fishing trips were surveyed from which 52 (15.5%) landed coral specimens. However, only a small fraction of the fleet (~5 vessels) cooperated regularly. Most vessels landed cold water corals only occasionally, often keeping just the most attractive colonies (i.e. antipatharians or selected gorgonians) discarding the others at sea. Upon collection, landed coral samples were photographed and identified to the lowest taxonomic level possible, following Grasshoff (1977, 1979, 1981, 1986), Zibrowius (1980), Bayer (1981), Zibrowius & Cairns (1992) and Brito & Ocaña (2004).

The by-catch was classified into two groups based on how the colonies were brought up to deck: (1) 'primary by-catch' is referred to coral colonies that were directly entangled in the fishing gear; and (2) 'secondary by-catch' for coral colonies that were brought to deck associated with a substrate which got entangled within the fishing gear (e.g. on other corals, rocks or objects). Entire colonies of primary by-catch corals were weighed and their length, width and height measured to 0.1 g and 1 mm, respectively (Figure 2). Species were classified into morphological categories based on their maximum size (small, medium or large), structure (3-dimensional versus 2-dimensional) and whether branched or not (see Table 1 for classification criteria). Height determined the 3-dimensional extent of a colony (Figure 2B).

Local ecological knowledge

Short interviews were conducted with 16 captains (17%) in order to perceive the distribution of different taxa of corals in the study area. All the captains of the fishing vessels that collaborated frequently with the sampling were interviewed, as well as other captains that know the study area well. They

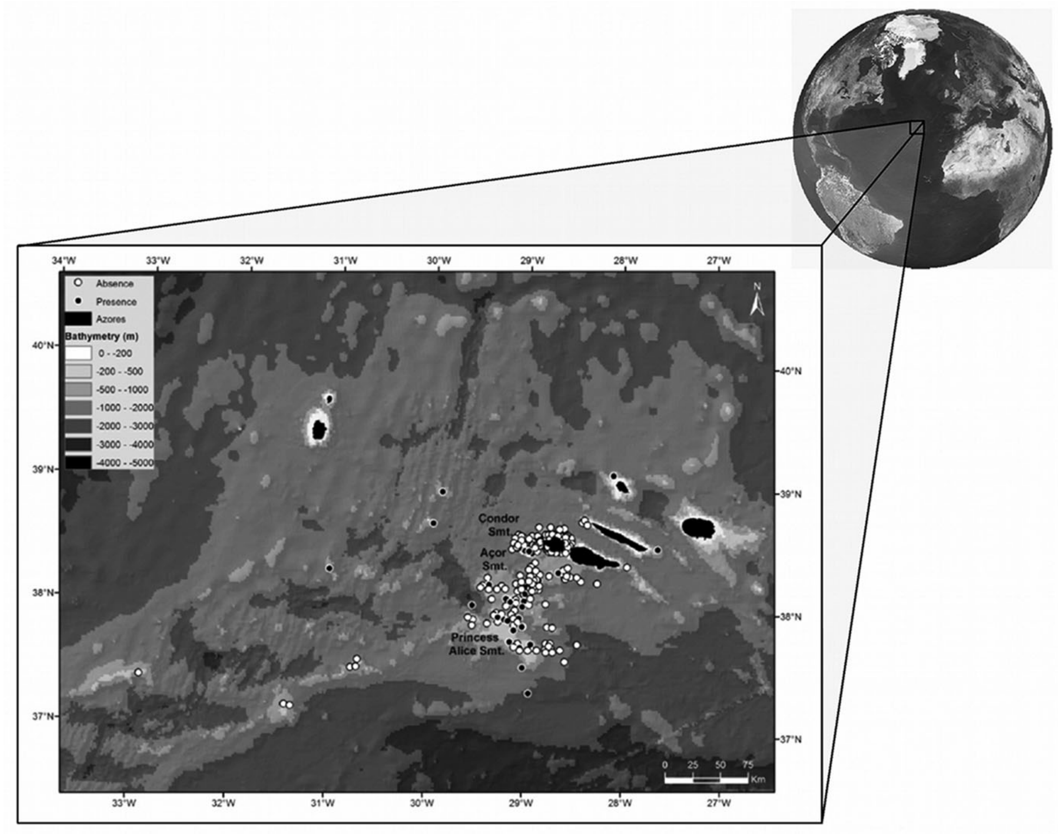

Fig. 1. Location of the fishing sets covered by the present study. ●, fishing position with corals by-catch; ○, fishing position without coral by-catch reported.

Table 1. Morphological criteria adopted to classify coral colonies by size, structure and branching categories.

Category	Denomination	Description
Size	Little	Between 0 and 10 cm of total lenght
	Medium	Between 10 and 60 cm of total lenght
	Big	More than 60 cm of total lenght
Structure	2D	Flat colony, only with 2 dimensions (lenght and width)
	3D	Tridimensional colony: with lenght, width and height
Branch	Simple	Without branches
	Branched	With branches

were asked to recognize various coral species (using a photo catalogue for reference) and identify on a map the areas where: (1) they normally fish; and (2) they have captured most CWC. They were also asked to express their views on eventual shifts in coral abundance over their fishing career.

RESULTS

Cold-water corals landed

A total of 205 specimens belonging to 39 different taxa (25 to species level) were landed during this survey (Table 2). The species belonged to five different orders (Alcyonacea, Antipatharia, Scleractinia, Zoanthidea and Anthoathecata) and were caught between 158 and 594 m (Table 2; Figure 3). Gorgonians (order Alcyonacea) were the most diverse and abundant group, followed by stony corals (order Scleractinia), hydrocorals (order Anthoathecata), black corals (order Antipatharia) and finally colonial anenomes (order Zoanthidea).

Eighteen taxa were recorded as primary by-catch (directly entangled by the longline) whilst 21 species were classified as secondary by-catch (Table 2). Despite a lower species diversity, there were more colonies in the primary by-catch group compared to the secondary by-catch group (N = 113 versus 92). The stylasterid *Errina dabneyi*, the large antipatharian *Leiopathes* spp., and the alcyonean *Callogorgia verticillata*, were the most abundant primary by-catch species (representing 24.8%, 23% and 10.6% of the total number of colonies within the primary by-catch group, respectively). The remaining fraction of the primary by-catch group was composed of *Paracalyptrophora josephinae*, *Viminella flagellum* and *Acanthogorgia armata* (representing 7%, 7% and 6.1 %, respectively). The most abundant taxa of the secondary by-catch group were the scleractinians *Caryophyllia cyathus* and *Dendrophyllia* sp. (7.8% and 12.2% of the colonies, respectively). *Caryophyllia* spp. was also well represented (3.9%) as an epizoan on damaged branches of other corals (mainly *Leiopathes* spp.) or solitarily fixed to bottom rock crusts. Additionally fishermen often bought to deck entangled bathyal rock crusts or dead fragments of corals colonized by various species such as *Alcyonium* spp., *Anthomasthus agaricus*, *Thouarella* spp. and *Bebryce mollis*.

Most of the CWC by-catch was originated from 200 to 400 m depth (Figure 3). However, some species like

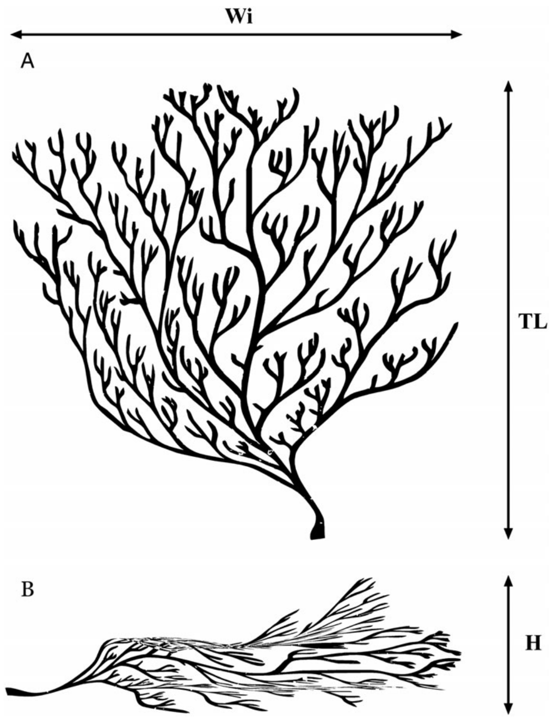

Fig. 2. Morphometric measurements (cm) made on deep-water corals colonies sampled. (A) Total length (TL) and colony width (Wi); (B) coral height (H).

Acanthogorgia armata, *Callogorgia verticillata* and *Leiopathes* spp. were caught as deep as 600 m.

Morphological classification

Most of the coral samples were complete colonies, while 28% were damaged or fragments. The morphological classification of the various taxa caught with bottom longline (Table 2) revealed a higher number of 'small' corals (22 out of the total 39) that comprised all the zoanthids and scleractinians but also 12 species of gorgonians (Alcyonacea). However, the number of individuals was comparable to the two other size-groups (small = 72; medium = 79; large = 54). Most of these 'small' taxa belonged to the secondary by-catch group whilst primary by-catch comprised mostly medium and large coral size-groups. Large corals were represented by only four taxa (3 Alcyonacea and 1 Antipatharia) while the medium size groups included 13 different taxa. Corals with a 3-dimensional morphology represented 75.1% of the specimens caught and comprised 26 taxa, covering four orders except Zoanthidea. Even though the number of taxa of branched and unbranched corals was almost similar, branched corals were much more abundant in the by-catch (69.3%). The most common combination of these three morphological characteristics was colonies being medium, 3-dimensional and branched with 32% of the specimens belonging to that group.

Local ecological knowledge

According to the local fishermen corals are commonly caught in the haul of the bottom longline fishing in most of the fished seamounts, namely in Princess Alice, Condor, Açores, Baixo de S. Mateus, Alcatraz do Norte, Ferradura, Voador and Gigante (Figure 1). Fishermen reported low occurrence of CWC by-catch in island slopes. The majority of the fishermen recognized most species in the catalogue and mentioned that colonies of the families Elliselidae, Pleuxaridae and Leiopathidae, which include *V. flagellum*, *Dentomuricea* sp., and *Leiopathes* spp., respectively, are frequently or very frequently caught by fishing lines (Figure 4). Species of other families like Coralliidae, Flabellidae Gerardiidae and Isidiidae were in general not recognized or reported as rarely caught. All fishermen noticed a decrease in the accidental capture of cold-water corals over the years.

DISCUSSION

The Azores Region shows a high diversity of CWC of about 150 species from 25 m down to 3250 m deep (DOP/UAz, unpublished database) when compared to other parts of the north-east Atlantic (Brito & Ocaña, 2004; Hall-Spencer *et al.*, 2007). Thirty-nine different taxa of anthozoans and hydrozoans were recorded from longline by-catch, representing 26% of currently known CWC. These taxa were by-caught at all depths surveyed in this study. The most abundant species composing the primary by-catch were the antipatharian, *Leiopathes* spp., the stylasterid, *Errina dabneyi* and the gorgonians, *Callogorgia verticillata*, *Acanthogorgia armata*, *Paracalyptrophora josephinae* and *Viminella flagellum*. Most of these species are important habitat builders in the region. However it is important to take into account that due to the selection of by-caught corals by the fishermen this may not reflect the real abundance of species by-caught in longline activities. In addition, those species have been previously reported to be important components of bathyal coral gardens as is the case of Condor seamounts (Tempera *et al.*, in press). They are large and complex structured colonies that are easily entangled on fishing lines. Inquiries made to the fishermen confirmed recognition of these species to be the main recognizable CWC primary by-catch and taxa in this part of the Archipelago. It should be noted that some species such as the black coral *Leiopathes* spp., one of the most common species in this study, has extremely slow growth rates and can span for thousands of years (Roark *et al.*, 2009) and therefore has very low recovery capacity.

The list of species also included a large number of individuals which did not get directly hooked, but, were found on rocks, crusts or dead corals brought up by the fishing gear (secondary by-catch). This group included small, solitary or colonial species but also epibionts living on other corals such as the recently described *Isozoanthus primnoidus*, a zoanthid parasitic to the gorgonian *Callogorgia verticillata* (Carreiro-Silva *et al.*, 2011). The most abundant associated species were the stony corals (order Scleractinia) represented by one small to medium size species of the genus *Dendrophyllia* and various species of the genus *Caryophyllia*. Even though they are not directly entangled in the fishing line, the settlement preference of these smaller species makes them also vulnerable to bottom longline. In the future, it will be important to carefully assess this secondary by-catch group as it may represent an important fraction of the species affected by the fishing gear.

Our results support the widespread view that CWC communities are important components of the seamount

Table 2. Coral taxa caught by the bottom longline fishery in the Azores (March–July 2007). Total number of colonies (N), frequency in the landings (F (%) of total surveys), mean length (cm), mean width (cm), mean height (cm), morphological classification (MC: see Table 1) and fishing depth are presented. Standard deviations of the means are also shown.

Taxa	N	F (%)	Length (cm)	Width (cm)	Height (cm)	MC	Depth (m)
Hydrocorals							
Stylasteridae (Gray, 1847)	1	0,3	–	–	–	M, 3D, UB	269
Errina atlantica (Hickson, 1912)	2	0,7	–	–	–	M, 3D, B	329–365
Errina dabneyi (Pourtalès, 1871)	21	7,1	17.7 ± 10	13.8 ± 4.1	6.2 ± 1.7	M, 3D, B	192–402
Errina sp. (Gray, 1835)	7	2,4	10.1 ± 3.1	14.6 ± 0.1	4.7 ± 0.6	M, 3D, B	351
Stolon corals							
Clavularia sp. (Blainville, 1830)*	1	0,3	–	–	–	S, 3D, UB	435
Gorgonian corals							
Schizophytum echinatum (Studer, 1891)*	1	0,3	–	–	–	S, 3D, UB	292
Alcyonidae (Lamouroux, 1812)*	1	0,3	–	–	–	S, 3D, UB	293
Alcyonium cf. *maristenebrosi* (Stiasny, 1837)*	3	1,0	–	–	–	S, 3D, UB	249–365
Alcyonium cf. *rubrum* (Stokvis & van Ofwegen, 2007)*	3	1,0	–	–	–	S, 3D, UB	249–365
Anthomastus cf. agaricus (Studer, 1890)*	1	0,3	–	–	–	S, 3D, UB	238–329
Acanthogorgia armata (Verrill, 1878)	7	2,4	23.8 ± 4.2	33.6 ± 2.2	9.5 ± 4.4	M, 3D, B	256–468
Acanthogorgia hirsuta (Gray, 1857)	1	0,3	–	–	–	M, 3D, B	256–384
Viminella flagellum (Johnson, 1863)	8	2,7	42.5 ± 43.3	1	-	L, 2D, UB	168–366
Plexauridae (Gray, 1859)	1	0,3	–	–	–	M, 2D, B	220–366
Muriceides cf. *paucituberculata* (M arion, 1882)*	1	0,3	–	–	–	S, 2D, UB	293
Bebryce mollis (Philippi, 1842)*	10	3,4	–	–	–	S, 3D, B	183–366
Dentomuricea sp. (Grasshoff, 1977)	5	1,7	31.2 ± 24.9	18.1 ± 13.9	4 ± 2	M, 2D, B	220–402
Dentomuricea meteor (Grasshoff, 1977)	2	0,7	46.8 ± 23.4	30.5 ± 12.3	4.2 ± 2.3	M, 2D, B	238–243
Placogorgia terceira (Grasshoff, 1977)	2	0,7	16.3	25.8	2	M, 2D, B	238–318
Swiftia rosea (Grieg, 1887)	1	0,3	–	–	–	S, 2D, UB	307
Villogorgia bebrycoides (Koch, 1887)*	2	0,7	2.3 ± 0.9	2.9 ± 0.4	1.1 ± 0.1	S, 2D, B	219–384
Callogorgia verticillata (Pallas, 1766)	12	4,0	121.9 ± 31.8	85.5 ± 21.3	7.6 ± 5.4	L, 2D, B	168–594
Candidella imbucata (Johnson, 1862)	2	0,7	21.4 ± 2.8	12.9 ± 5.4	7.2 ± 7.1	S, 3D, B	249–302
Paracalyptrophora josephinae (Lindström, 1877)	8	2,7	65.8 ± 31.6	53 ± 27.3	8.3 ± 5.8	L, 2D, B	220–384
Thouarella sp. (Gray, 1870)*	2	0,7	–	–	–	S, 2D, B	384
Black corals							
Antip atharia	3	1,0	–	–	–	M, 3D, B	329–365
Leiopathes spp. (Haime, 1849)	26	8,8	78.7 ± 58	62 ± 47.8	31.1 ± 24	L, 3D, B	183–512
Stony corals							
Scleractinia	4	1,3	–	–	–	S, 3D, UB	183–366
Anomocora fecunda (Pourtalès, 1871)*	1	0,3	–	–	–	S, 3D, UB	329–365
Caryophyllia sp. (Lamarck, 1801)*	8	2,7	–	–	–	S, 3D, UB	201–329
Caryophyllia cyathus (Ellis & Solander, 1786)*	16	5,4	–	–	–	S, 3D, UB	220–377
Caryophyllia foresti (Zibrowius, 1980)*	2	0,7	–	–	–	S, 3D, UB	238–329
Coenocyathus cf. *cylindricus* (Milne Edwards & Haime, 1848)*	2	0,7	–	–	–	S, 3D, UB	238–293
Javania cailleti (Duchassaing & Michelotti, 1864)*	2	0,7	–	–	–	S, 3D, B	201
Dendrophyllia sp. (de Blainville, 1830)*	25	8,4	–	–	–	M, 3D, B	146–366
Dendrophyllia cornigera (Lamarck, 1816)*	2	0,7	–	–	–	L, 3D, B	377
Stenocyathus vermiformis (Pourtalès, 1868)*	2	0,7	–	–	–	S, 3D, UB	229–384
Zoanthids							
Epizoanthus sp. (Gray, 1867)*	5	1,7	–	–	–	S, 3D, B	307–435
Isozoanthus primnoidus (Carreiro-Silva, Braga-Henriques, Sampaio, de Matos, Porteiro & Ocaña, 2011)*	2	0,7	–	–	–	S, 3D, B	418

*, indicates secondary by-catch species.

ecosystems in the Azores. So far, dense CWC gardens have only been confirmed in one seamount (Condor Terra: Tempera *et al.*, in press) but their occurrence on other seamounts of the region is thought to be highly likely. Seamounts are amongst the most suitable habitats for suspension feeding CWC as they are areas of strong current regimes with nutrient-rich upwelling and topographic features retaining particles and zooplankton (Genin *et al.*, 1986). Scientific surveys are urgently needed and are being conducted to study the spatial distribution of CWC communities in the Azores to understand if they are overlapping with fishing activities as this will be important for conservation measures.

A consensus amongst the fishermen was that there is a decrease in the abundance of CWC in their by-catch over the years, but time-series of CWC abundance are non-existent, making such affirmation very difficult to support with robust data. However, the need for further research is emphasized in order to understand the current health status of Azorean CWC communities and for the conservation of such VMEs.

Observations of by-catch, alone, underestimates the actual level of interaction and the presented data explains only part of the phenomenon as corals getting damaged by passing gear may not be removed and retained, while others may be

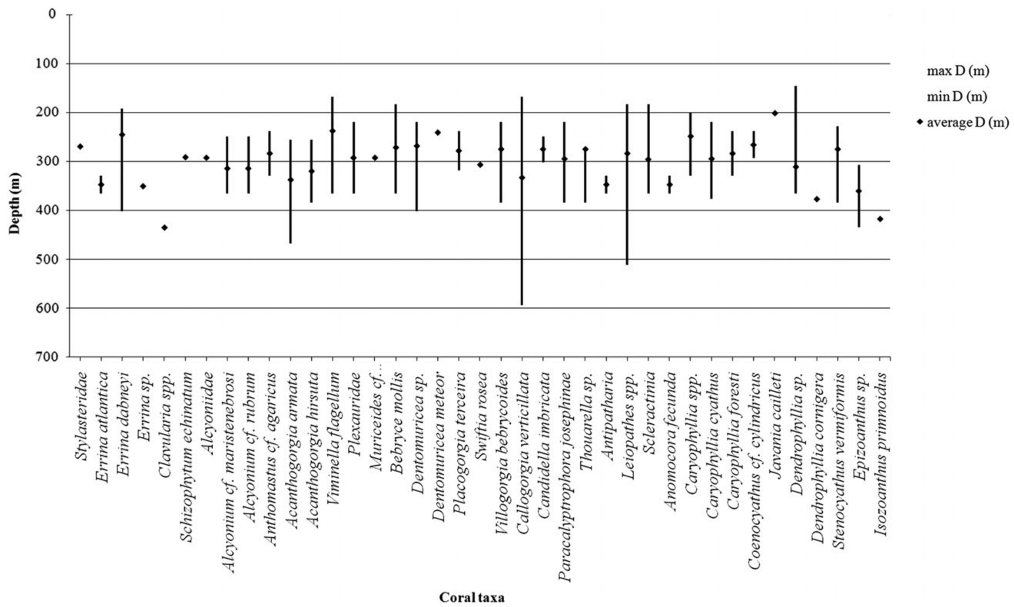

Fig. 3. Vertical distribution of corals caught during this survey (average, maximum and minimum depth in metres).

caught but are lost in the water column before the gear is returned to the deck of the vessel (Edinger *et al.*, 2007b; Heifetz *et al.*, 2009). Such cases are not insignificant as partial damage due to physical contact with fishing lines may be lethal, as demonstrated for shallower-water anthozoans (Bavestrello *et al.*, 1997; Asoh *et al.*, 2004; Yoshikawa & Asoh 2004). Partially damaged colonies may also be more vulnerable to parasitism by other corals like zoanthids (Carreiro-Silva *et al.*, 2011). Such information on the unseen effects of longlines can only be obtained by complementing by-catch studies with *in situ* observations from remotely operated vehicle surveys (e.g. Heifetz *et al.*, 2009) or with cameras directly fitted onto longlines as recently developed by Kilpatrick *et al.* (2011).

In conclusion, this study showed that VME organisms, particularly cold-water corals are common by-catch components of bottom longline activities in the Azores and that the impact of this fishing gear cannot be negligible. Not only large, branched species get brought up to deck but also small, solitary corals are caught in abundance. These species are strong indicators of the presence of VMEs, thought to be important habitats for many species of invertebrates and fish alike, including some with commercial interest. More research is needed to determine the level of interaction

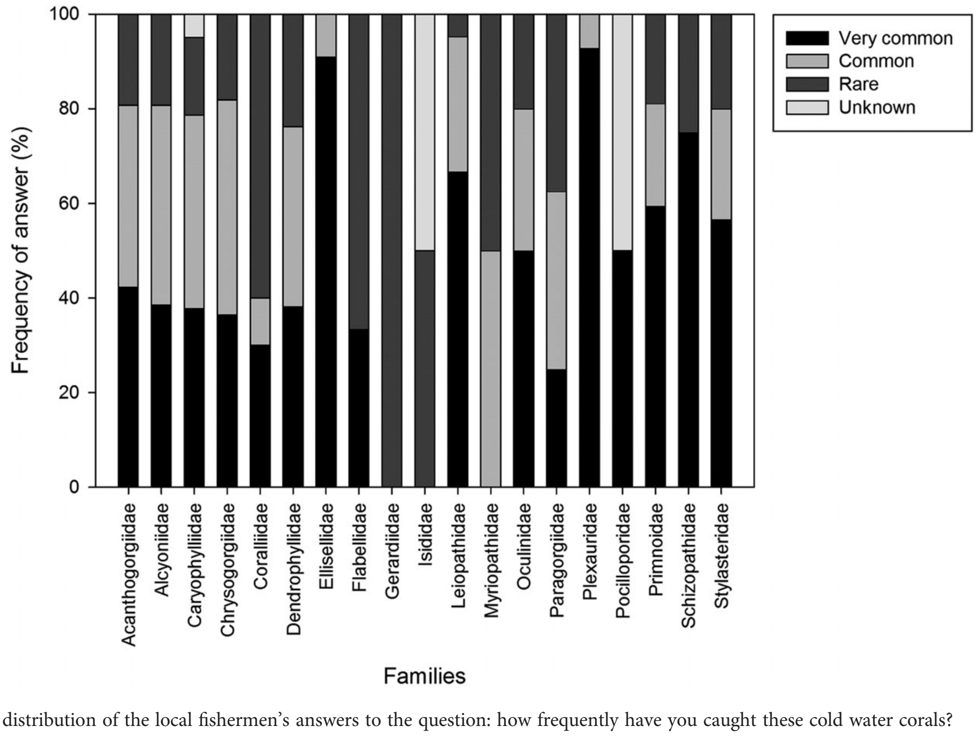

Fig. 4. Frequency distribution of the local fishermen's answers to the question: how frequently have you caught these cold water corals?

between longline activities and those ecosystems, by coupling by-catch reports with *in situ* observations and spatial analysis of fishing effort and CWC distribution.

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