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Sustainability of deep-sea fish species under the European Union Common Fisheries Policy

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ABSTRACT

The historical expansion of fishing industries into the deep sea has been described at the global level, but corresponding patterns are less well known at other geographical scales. The International Council for the Exploration of the Sea (ICES) has stated that most deep-sea species exploited by European fishing industries are harvested outside safe biological limits. As a result, the European Union commenced regulating exploitation of deep-sea stocks with total allowable catches (TACs). These regulations have been operational since 2002, but no detailed overview of their effectiveness is hitherto available. The objectives of this paper are: 1) to analyse changes in mean depth of fishing of the EU fleet before (1950–1982) and after (1983–2006) the adoption of the Common Fisheries Policy (CFP), 2) to analyse the degree to which the European Council follows scientific advice on sustainable catches provided by ICES and 3) to investigate the degree to which the fishing industry complies with agreed catch limits. Our results indicate that the EU fleet has experienced a bathymetric expansion by an average of 78 m depth for the 1950–2006 period, or almost twice the value (42 m) previously reported for the global fleet. This pattern of expansion towards deep-sea fishing grounds has not changed under the CFP. Additionally, the paper demonstrates that the mean longevity of species caught by the EU fleet increased with depth, from about 13 years for shallow water species to about 25 years for intermediate species and about 60 years for deep-sea species. Thus, fishing deeper means fishing for increasingly long-lived and vulnerable species. This study also shows that approved TACs for deep-sea fish stocks did not follow scientific advice. Scientifically proposed TAC levels were not respected in about 60% of the cases investigated and these approved TACs were not complied. Member States exceeded agreed quotas in about 50% of the cases during the 2002–2011 period. Reported catches were on average 3.5 times greater than approved for deep-sea species, but in some cases catches even 10–28 times higher than agreed. The identified pattern that Member States fail to respect approved quotas indicate a lack of incentives to comply, likely as a consequence of limited enforcement and sanctioning mechanisms. Ensuring long-term

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sustainability of deep-sea stocks is urgently needed but requires dramatic change to the existing management system.

1. Introduction

Wild-caught fish represents a global commodity subject to an increasing demand (FAO, 2010). However, overexploitation of many near shore and easily accessible stocks (FAO, 2010; Garcia and Rosenberg, 2010) has resulted in negative effects on coastal marine ecosystems (Hilborn et al., 2003; Gelcich et al., 2010), including a decline in marine biodiversity (Myers and Worm, 2005). The effects of overfishing have been evident for many long-lived, late-reproducing predatory fish species at higher trophic levels (Christensen et al., 2003), which may serve critical functions in marine ecosystems (MEA, 2005; Cheung et al., 2007). However, many of the negative ecosystem effects of overfishing only become apparent years or decades later (Jackson et al., 2001).

Fishing activities are primarily driven by profit (Sethi et al., 2010) and fisheries operating with highly mobile vessels are able to adapt to local or regional stock collapses (Berkes et al., 2006). The depletion of traditional fish stocks on continental shelves and the development of new technologies have spurred an expansion of fisheries towards the deep sea in search of new fishing grounds and commercial opportunities (Gordon, 2001; Piñeiro and Bañón, 2001; Morato et al., 2006; Norse et al., 2012). This development also represents a fisheries expansion to beyond the 200 nautical mile zone (the High Seas), where governance arrangements and the prospects for monitoring compliance are less well developed (Worm and Vanderzwaag, 2007).

The deep sea is considered to start below the epipelagic zone (200 m and beyond), where sunlight no longer penetrates (Herring, 2002) and the animal communities differ significantly from those on the continental shelf (Joubin, 1922; Bruun, 1957). However, it has become accepted that deep-sea fish species are considered to be those living deeper than ~400–500 m (Koslow et al., 2000; ICES, 2007). Many deep-sea species are characterised by high longevity (~100 years), slow growth, low fecundity, late maturity (~15–25 years), intermittent recruitment and high vulnerability to fishing and environmental changes (Koslow et al., 2000; Morato et al., 2006; Drazen and Haedrich, 2012). Additionally, deep-sea fisheries may seriously threaten fragile deep-water ecosystems such as those made up of cold water coral colonies, which can be as much as 1,800 to 4,200 years old and representing important sources of biodiversity (Druffel et al., 1995; Pandolfi et al., 2003; Roark et al., 2009). Deep-sea coral reefs have been dated to be 9,000 to almost 11,000 years old (Hovland and Mortensen, 1999; Frank et al., 2005).

The current scientific evidence suggests that many deep-sea fish stocks are being exploited beyond sustainable levels (Koslow et al., 2000; Watson and Morato, 2004; Devine et al., 2006; ICES, 2007; Bailey et al., 2009), thus emphasising the need to improve the management of these species (Sadovy and Cheung, 2003; Morato et al., 2006; European Commission, 2007; Bailey et al., 2009; Norse et al., 2012). Some deep-sea fisheries began before basic biological information was available. For example, in the 1960s, there was very limited information on the biology of the Grenadier (*Coryphaenoides rupestris*). Haedrich et al. (2001) plotted the progress of scientific information relative to catches and Total Allowable Catch (TAC) for *C. rupestris* and showed that some of the most important data about the species were gathered long after the stock had collapsed. This illustrates how rapid development of new fisheries can operate at much faster scales than the scientific community or adequate policy making (Berkes et al., 2006).

The historical expansion of global fishing has been described at large scales (FAO, 2008; Morato et al., 2006) but the corresponding patterns are less clear at smaller geographical scales, such as Europe. The European Union (EU) began to show an interest in deep-sea fisheries in 1992, when the International Council for the Exploration of the Sea (ICES) stated that most of the exploited deep-water species were being harvested outside safe biological limits (ICES, 2001). As a result, the EU decided to initiate a gradual but regulated exploitation of such species by establishing a ceiling of effort for four deep-sea fisheries. Given the ineffectiveness of these measures, the European Commission introduced the TAC regulation in 2002 in order to reduce pressure on all stocks in Community waters (Clarke and Patterson, 2003). Although this mechanism has been applied since 2002, ICES does not yet have a systematic and detailed overview of the situation for each deep-water fishery. Data on landings and fishing effort are scarce, and discards remain largely unreported despite their large magnitude (European Commission, 2007).

The objectives of this paper are: 1) to test whether the EU deep sea fishing fleet is fishing deeper than the previously published global trends, by analysing the mean depth and longevity of catches before (1950–1982) and after (1983–2006) the adoption of the Common Fisheries Policy (CFP), 2) to investigate whether EU fisheries decision makers follow scientific advice, and 3) to investigate the degree to which the fishing industry complies with approved quotas, during the 2002–2011 period, under the CFP and the Management Regime specifically designed for deep-sea fish stocks (Council Regulation (EC) No. 2347/2002 referred to as the "Deep-Sea Access Regime").

2. Material and methods

2.1. Expansion of the EU fishing fleet towards deep-sea species

In this study, we investigate whether the EU fishing fleet was fishing deeper-dwelling species by estimating the annual mean depth of fishing for the period 1950 to 2006 as described by Morato et al. (2006). Data on reported catches per species were obtained from *Fishstat*J,[1] and the official database of FAO (2012) for the EU fishing fleets operating in all FAO fishing areas. Countries considered in this study include Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, the Netherlands, Poland, Portugal, Spain, Sweden, and the United Kingdom.[2]

Fishbase was used to estimate the average depth of occurrence, longevity, and habitat (Froese and Pauly, 2012) for most of the 485 species (excluding crustaceans and molluscs) or groups included in the catches statistics. Following the methodology proposed by Morato et al. (2006), the average depth of occurrence for taxa identified at species level in the catches statistics was estimated as the mean of the common depth range or as 1/3 of the total depth range. Depth range is defined as the extreme range reported for

[1] See <http://www.fao.org/fisherand/statistics/software/fishstat>.
[2] Dependent territories are not included in this study.

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juveniles and adults (but not larvae), while common depth is the range where adults are most often found. For those taxa not reported to species level, the average for the genus or family was calculated using the most likely species.

By combining this information, the temporal series of mean depth of the catch in all FAO areas where the EU fleet operated from 1950 to 2006 was calculated for all fish, bottom fish only, and for fish species with a mean depth of occurrence greater than 400 m. Additionally, we estimated the mean longevity of fish reported by the EU fleet as a function of depth of occurrence of those species.

2.2. Expansion of the EU fishing fleet towards deep-sea species before and under the Common Fisheries Policy

To establish a relationship between depth and longevity of the catch for the periods before and after the implementation of the CFP, we analysed differences between the mean depth and longevity of catches during both periods. Additionally, we allocated countries to four categories or scenarios determined by the average depth and longevity of the catch observed before the CFP (1950–1982) and under the CFP (1983–2006). The four categories are:

- *Fishing shallower for short-lived species* (SS). A given country in this category is fishing shallower than the average and for shorter-lived species than the average.
- *Fishing shallower for long-lived species* (SL). A given country in this category is fishing shallower than the average and for longer-lived species than the average.
- *Fishing deeper for short-lived species* (DS). A given country in this category is fishing deeper than the average and for shorter-lived species than the average.
- *Fishing deeper for long-lived species* (DL). A given country in this category is fishing deeper than the average and for longer-lived species than the average.

2.3. Comparing proposed TACs with approved and reported catches

Da Rocha et al. (2012) investigated the level of compliance in pelagic and demersal species under TAC regulation, in particular the level of compliance in two of the most important commercial species being managed under recovery plans, the European hake (*Merluccius merluccius*) and the Atlantic cod (*Gadus morhua*). They concluded that while TACs proposed by scientific officers are often similar to TACs approved by the Commission, the reported catches are mostly higher than the approved TAC.

Here, the degree to which the Council followed the scientific advice and industry respected the agreed-to catch limits of deep-sea fish stocks were analysed. This was done by comparing approved TACs to the reported catches or landings (hereafter, catches, excluding discards and illegal, unreported and unregulated catches).

In order to achieve these objectives, data were collected from approved quotas by the Council, and catches for 27 deep-sea species (See TS1 of the Supplementary Material for detailed information for each species and ICES area) that were subjected to TAC regulation[3] under the CFP in European waters for the 2002–2011 period. This information was gathered from ICES reports and European fisheries legislation (ICES, 2001; 2007, 2008; 2011). (See TS2 on the steps for setting a quota for European Union fish stocks in ICES areas). TACs for species caught by the EU fleet in non-EU waters and in international waters, as well as TACs granted to foreign fishing fleets were excluded from this analysis.

3. Results and discussion

3.1. The expansion of the EU fishing fleet towards deep-sea species

Our analyses show that the average depth of the catch increased continuously between 1950 and 2006 (Fig. 1), revealing a trend of fishing for deeper water species. During this period there was a 78-m increase in the average depth of bottom catches by the EU fleet, from 163 m in the 1950s to 242 m in 2006, at a rate of 15 m per decade. Even if all species (pelagic, bottom and deep water) are included, a significant shift towards greater depths was observed with an increase in average depth of fishing of about 59 m (from 137 m in the 1950s to 196 m in 2006). When presenting the results for deep-sea species only, our analysis shows an increase in the average depth of catches in the same period of about 128 m (from 407 m in 1950 to 535 in 2006).

Fishing deeper water species means fishing for increasingly longer-lived and thus more vulnerable species (Fig. 2). The mean longevity of species reported by the EU fleet catch increased with depth from about 13 years for shallow water species to about 25 years for intermediate species and about 60 years for deep-sea species.

While Morato et al. (2006) reported a worldwide increase of 42 m in mean depth for fishing bottom species between 1950 and 2006, our research reports an increase of 78 m for EU fleets, nearly double that documented for the worldwide fleet. Moreover, the maximum values reported in Morato et al. (2006) for the global trends (145 m in 2001) are slightly lower than the minimum values for the EU fleet (163 m in 1950). If we only consider deep-sea species, results also indicate that the average depth of the catch increased exponentially to 128 m between 1950 and 2006.

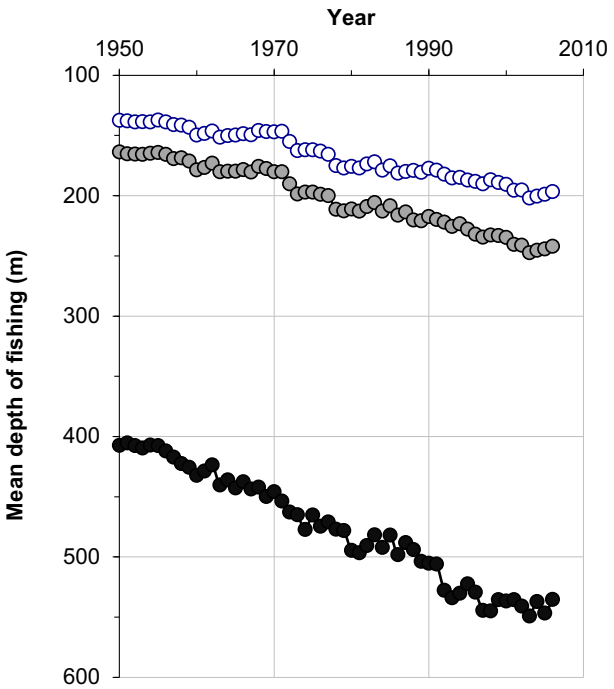

Fig. 1. Trends in the mean depth of catches of the European Union fleet. Mean depth of all fish including pelagic are showed in blue, bottom fish only in grey and deep-sea species in black. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

[3] For example the Proposal for a Council Regulation fixing for 2009 and 2010 the fishing opportunities for Community fishing vessels for certain deep-sea fish stocks. COM (2008) 595, and the Council Regulation (EC) No 1359/2008 of 28 November 2008 fixing for 2009 and 2010 the fishing opportunities for Community fishing vessels for certain deep-sea fish stocks.

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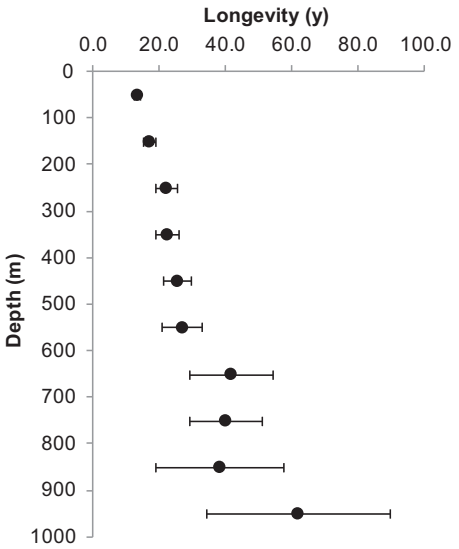

Fig. 2. Trend of mean (±SE) longevity of the European Union bottom marine fisheries catch by 100 m depth strata.

The increase in average depth of catches has largely been made possible through technological developments, allowing fleets to increase their fishing capacity. For example, Villasante (2010) reported an increase in the total fishing capacity of the EU deep-sea fleet by 34–44% between 1990 and 2006. Since then, according to data from *Eurostat*,[4] the fishing capacity of the deep-sea fleet has increased by about 3% until 2010.

The bathymetric expansion of the EU fleets can be seen in all oceans (except for the Central Pacific FAO areas), but it is particularly important in the Southern Ocean (FAO areas 45-81-88), where there was a more than 451 m increase in the average depth of catches between 1950 and 2006 (Fig. 3).

Overall, this process of expansion of fleets towards deeper waters began in the 1950s and reached a maximum in the 1960s and 1970s with the development of fisheries for species such as Argentine (*Argentine* spp.), black halibut (*Reinhardtius hippoglossoides*), and blue ling (*Molva dypterygia*) among others (CCAMLR, 2011).

3.2. The expansion of the EU fishing fleet under the CFP

Our results show that the EU fisheries expansion towards deep-water fishing grounds has not changed under the CFP. In fact, before the implementation of the CFP (1950–1982) the expansion in terms of mean depth of catches was 60 m, while under the CFP (1983–2006) it continued to expand by over 50 m. In the first case, the bathymetric expansion is documented during the whole period but with particular emphasis during the widespread adoption of the Exclusive Economic Zones (1973–1980). In the second case, the expansion under the CFP is particularly high until the year 1999 when this process started to be lower than previous years.

The behaviour of the EU-18 fishing fleets before and under the CFP is illustrated in Fig. 4. Overall, the number of countries fishing shallower for short-lived species (SS) and fishing shallower for long-lived species (SL) decreased substantially. There was, however, an increase in the number of countries fishing deeper for both short-lived species (DS) and long-lived species (DL) (Fig. 4).

Ukraine is the only one of the 18 countries included in this study to keep both depth and longevity below the average for the EU-18 during both periods (Fig. 5). However, Ukraine (Fig. 5) has moved from a mean longevity of 9 years to 28 years, and from a mean depth of 80 m to almost 360 m. As result, the country experienced a great expansion in both periods. Poland is also included in this scenario but only in the second time period to where it moved from the category SL.

Greece and Italy are included in category DS during both time periods as their mean depth of fishing is higher but the mean longevity of catches is lower than the average of the EU-18. Neither

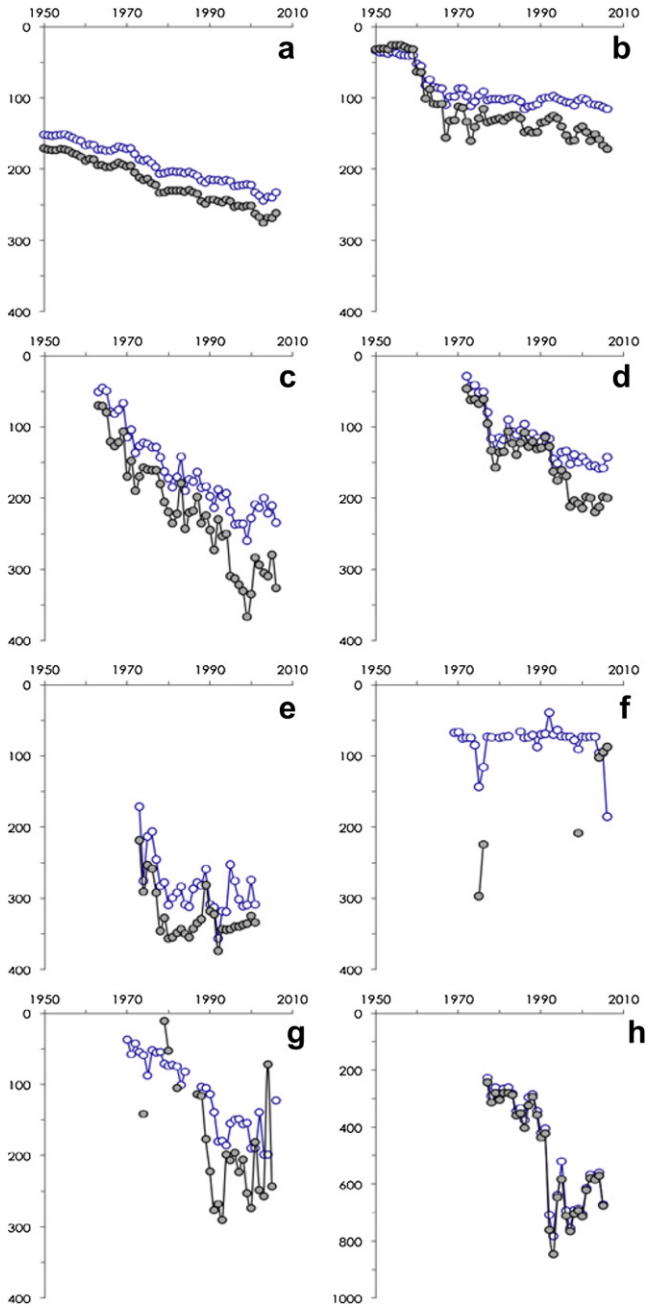

Fig. 3. Trend in the mean depth of catches of the European fishing fleet in different FAO fishing areas during 1950–2006. Mean depth for all habitat (white) and bottom marine species (grey) for: **(a)** North Atlantic Ocean (FAO Areas 21–27) **(b)** North West Central Atlantic (FAO 31), North East Central Atlantic (FAO 34) **(c)** South Western Atlantic (FAO 41), South Eastern Atlantic (FAO 47) **(d)** West Indian Ocean (FAO 51), East Indian Ocean (FAO 57) **(e)** North West Pacific (FAO 61), North East Pacific (FAO 67) **(f)** West Central Pacific (FAO 71), East Central Pacific (FAO 77) **(g)** South West Pacific (FAO 81), South East Pacific (FAO 87) **(h)** Antarctic Atlantic (FAO 48) Antarctic Indian Ocean (FAO 58) and Antarctic Pacific (FAO 88).

[4] See <http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes>.

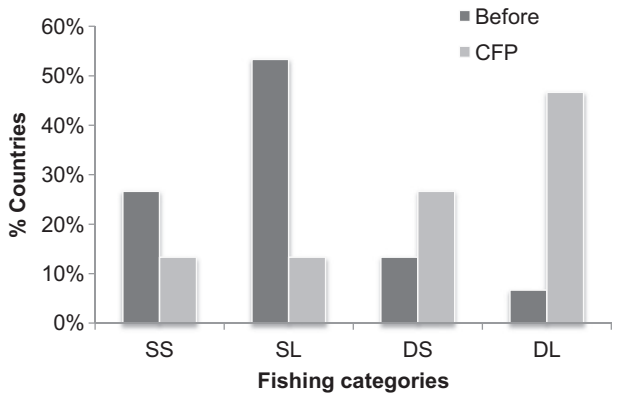

Fig. 4. Behaviour of the EU-18 fishing fleets before and under the CFP. The categories are: SS, fishing shallower for short lived species; SL, fishing shallower for long lived species; DS, fishing deeper for short lived species; and DL fishing deeper for long lived species.

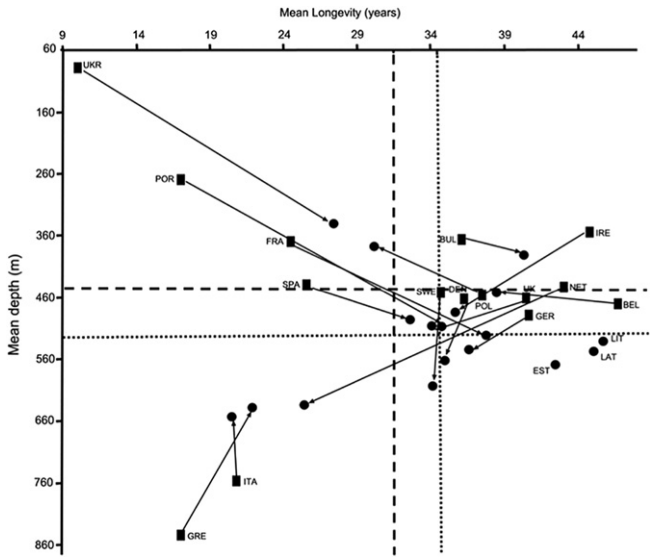

Fig. 5. Trends in the relationship between mean depth of fishing and longevity of the catch for deep-sea species by countries in the EU-12 before the CFP (1950–1982) (■) and for the CFP period (1983–2006) (●) (The dashed line indicates the mean values for the set of all countries in the 1950–1982 period and the dotted line the mean values in the 1983–2006 period).

of these countries showed signs of improvement during the implementation of the CFP. Deep-sea fishing fleets of Spain and the Netherlands are also in this scenario. Spain has moved from SS fishing to DS fishing because there was a tendency for an increased average depth of catches under the CFP. The Spanish fleet reported a catch of 20,144 tonnes in 2010, valued at €47 million, ranking first in the EU-18 (44% of total volume and value of catches) (PEC, 2012). Meanwhile, the Netherlands has moved from Scenario SL to DS, i.e., it tended to increase the mean depth of fishing while decreasing the mean longevity of catches.

Deep-sea fleets of Bulgaria and Ireland are found in category SL, where the mean longevity of catches is greater than the average observed in the fleet of the EU-18. While presenting variations within the same scenario, neither of these countries showed clear signs of change in their fishing practices.

Finally, more than 50% of the EU countries were classified as fishing DL (the category likely to be least sustainable) catching deep-water long-lived species, including: Belgium, Denmark, Estonia, France, Germany, Latvia, Lithuania, Portugal, Sweden, and the United Kingdom. In particular, France and Portugal, representing as much as 45% of the volume (24,500 tonnes) and value (€44.4 million) of catches from across the EU in 2010 (PEC, 2012), showed a clear trend towards fishing deeper for long-lived species. Both of them moved from category SS in the 1950–1982 period to category DL in the 1983–2006 period. In a similar way, other EU countries that have increased their mean depth of the catch during the implementation of the CFP are Denmark, Germany, Sweden, and United Kingdom.

3.3. Comparing proposed TACs with approved TACs and reported catches

Our analysis shows that approved TACs for deep-sea species between 2002 and 2011 exceeded those proposed in 60.3% of the cases, whereas in 36.2% of the cases, the TACs approved were similar to what was proposed. In 3.4% of the cases, TACs approved were lower than those proposed (Fig. 6, left panel). When approved quotas were higher than the proposed values, they were higher by an average of 79%, although quotas up to 8.5 times of the proposed TACs were recorded, e.g., for the stock of Orange roughy (*Hoplostethus atlanticus*) in ICES zones VI and VII. The main fishery for Orange roughy in the Northern Hemisphere moved to zone VII after the collapse of zone VI. This exploitation pattern confirms the process of sequential depletion observed in other commercial fisheries (Hilborn et al., 2003; Berkes et al., 2006) and is indicative

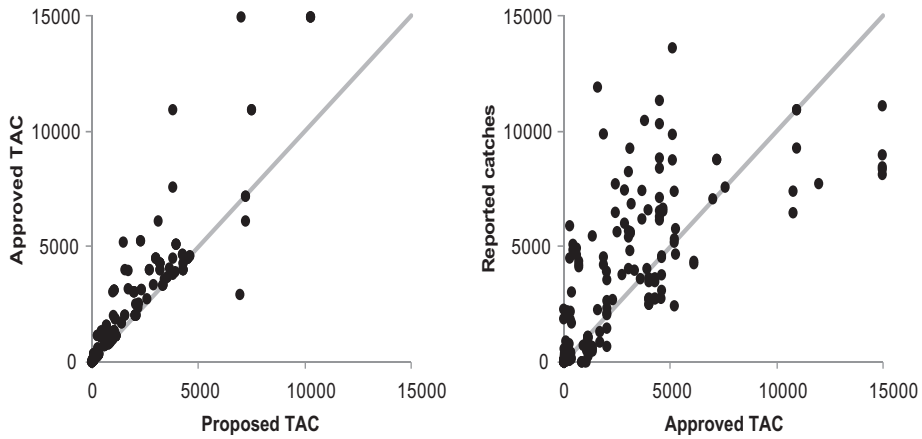

Fig. 6. TAC proposal *vs.* TAC approved (left panel) and TAC approved *vs.* Reported catches (right panel) for European Union deep-sea fish stocks. (Note: The grey line denotes a 1:1 ratio).

of the highly adaptive capacity of mobile fishing fleets (Österblom et al., 2010).

We have also identified the overshooting of deep-sea reported catches in relation to the quotas approved by the European Council. It is important to highlight that TACs for species harvested by the EU fleet in non-EU waters and in international waters, as well as TACs granted to foreign fishing fleets are not included in this study.

Our results showed that reported catches for deep-sea species exceeded proposed TACs in 50.6% of the cases, whereas in 35.5% of the cases the reported catches were lower than the TAC, and in 2.4% of the cases the reported catches exactly matched the TAC (Fig. 6, right panel). In some cases (11.9%) there were no reported catches. Reported catches that exceed the TAC are on average 3.5 times greater than the TACs for deep-sea species during the 2002–2011 period, although in some cases catches were 10–28 times higher than the approved quotas (See also FS1 which shows the relationship between ICES recommended TACs, approved TAC and reported catches).

This phenomenon of non-compliance to agreed quotas has already been shown for both pelagic and demersal species (Piet et al., 2010; Villasante et al. 2011; O'Leary et al., 2011) and for species of high commercial value subject to recovery plans, like cod and hake (Da Rocha et al., 2012). Piet et al. (2010), Villasante et al. (2011), O'Leary et al. (2011) and Da Rocha et al. (2012) stated that enforcement of fisheries management by EU Member States is lax, with cases where actual catches exceeded the agreed amount by more than 100%. Da Rocha et al. (2012) found that although a regular pattern between proposed and approved TACs does not exist, there is a clear pattern of reported catches exceeding approved TACs. As a consequence, there is a distinct lack of enforcement at the level of national fisheries authority, which affects most of the stocks analysed.

4. Conclusions

The lack of success of the CFP has been attributed mainly to the collusion between fisheries managers and industry (Froese, 2011), and the lack of appropriate incentives for achieving sustainability of fishery resources (Österblom et al., 2011). A failure to adapt fishing capacity to existing resources, neglect of scientific advice in decision making and a fishing industry that does not comply with regulations can stimulate feedback mechanisms that create unsustainable social-ecological traps (Österblom et al., 2011). This leads to a decline of fishery resources (EU, 2009; 2011) and reduces marine ecosystem services (MEA, 2005).

With few exceptions, deep-sea fisheries catch a mixture of species, although only one or two of them may be deliberately targeted (ICES, 2011). However, very little is known about the ecosystem effects of deep-sea fisheries, other than the direct damage that can be caused to the habitat by bottom fishing gear (Bett, 2000; Gordon, 2003; Grehan and Unnithan, 2005; Palanques et al., 2006; Pitcher et al., 2007; European Commission, 2007; Armstrong et al., 2008; Althaus et al., 2009; Williams et al., 2010; Auster et al., 2011; Norse et al., 2012). Full compliance with the precautionary approach would thus have required the setting of lower TACs and effort limits, or even the closure of the fisheries (ICES, 2011).

Managing deep-sea species using TACs is challenging because little is known about the spatial structure of deep-sea stocks. The TACs are therefore often set to cover large management areas, partly to prevent the misreporting that could occur if TAC areas were defined more narrowly. Despite the fact that TAC regulations were adopted in 2002, landings and fishing effort data are still poor and discards are largely unreported, even though they may be significant in some fisheries (European Commission, 2007). TAC regulations were first established in 2002 and were applied to seven species in limited areas over the following two years (PEC, 2012). After that, the European Commission annually increased the number of species subjected to TAC regulation in order to improve management of these marine resources, and approved zero TACs for some deep water species. However, given that TACs are higher than EU proposed TACs and Member States do not respect the approved quotas and that Member States do not respect the adopted quotas, it seems urgent that the system implemented so far has to be dramatically improved by changing economic incentives and increasing compliance in order to avoid negative social-ecological consequences of overfishing for decades.

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Appendix A. Supplementary material

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2012.07.033.

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