FISH and FISHERIES

FISH and FISHERIES, 2011, **12**, 34–50

Overfishing and the Common Fisheries Policy: (un)successful results from TAC regulation?

Sebastián Villasante[1,2], María do Carme García-Negro[2], Fernando González-Laxe[3] & Gonzalo Rodríguez Rodríguez[2]

[1]Karl-Göran Mäler Scholar, The Beijer Institute of Ecological Economics, The Royal Swedish Academy of Sciences, P.O. Box 50005, SE-104 05, Stockholm, Sweden; [2] Fisheries Economics and Natural Resources Research Unit, University of Santiago. Av. Burgo das Nacións s/n. 15782. Santiago de Compostela, A Coruña, Spain; [3] Institute of Maritime Studies. University of A Coruña.Campus de Elviña s/n. 15071. A Coruña, Spain

Abstract

This paper combines official data from 1990–2007 for (i) the Total Allowable Catchs (TACs) recommended by International Council for the Exploration for the Sea (ICES) scientists and the proposed and approved TACs and (ii) biomass, recruitment, catches, fishing effort, and current exploitation rates for all marine populations subjected to TAC regulation. The differences between the fishing quotas and the scientific recommendations provided by the ICES were calculated to be 19% after the first CFP reform (1992–2001) and 21% after the second one (2002–2008). In some species, these differences showed a three-fold increase, in particular those currently considered to be beyond the biological safety limits.

Regarding the most important index of abundance, the results also indicate a biomass and recruitment reduction of ~75–85% of the stocks and 90% of catches, whereas the fishing mortality increased in 35% of stocks. In addition, of all populations analysed under TAC regulation, 20% presents an increase in the current exploitation rate, 17% did not show significant changes, and the remaining 63% presented a reduction between 1990 and 2007. These results could contribute to the recovery of stocks. However, following the methodology used by Worm *et al.* who reported that 6 out of the 10 (60%) marine ecosystems examined showed current exploitation rate values that were significantly higher than those that provide the maximum sustainable yield, this study demonstrates that 86% of the populations regulated by TACs present values higher than exploitation rates that give maximum sustainable yield, following an alarming pattern of exploitation.

Keywords Common Fisheries Policy, global assessment, impact of TAC regulation, overexploitation of fishery resources

Correspondence:
Sebastián Villasante. The Beijer Institute of Ecological Economics, and Fisheries Economics and Natural Resources Research Unit, University of Santiago de Compostela (Spain). Av. Burgo das Nacións s/n. 15782 A Coruña Spain
Tel.: +34 981563100, extn 11671
Fax: +34 981559965
E-mail: sebastian.villasante@beijer.kva.se

Received 25 May 2009
Accepted 4 June 2010

 DOI: 10.1111/j.1467-2979.2010.00373.x

Introduction

In 1970 when the United Kingdom, Norway, Ireland, and Denmark, all of which have substantial fishing waters, were negotiating entry into the European Union (EU), the six original members sped up the development of the Common Fisheries Policy (CFP). After the accession of the United Kingdom, Ireland, and Denmark into the EU, it took almost ten years of intense debate before the EU reached an agreement among its member States about *where*, *who*, and *how* fishery resources could be exploited.

In 1983, an agreement was reached to create the CFP and the fisheries conservation and management scheme was approved in Europe. In this scheme, Total Allowable Catch (TAC) plays the key role in allocating fishing quotas among member States. The last CFP reform (2002–2012) addressed the issue of total allowable catchs total allowable catches (TACs) through Regulation European Commission (EC) N 2369/02, 2370/02, and 2371/02, which recognized the need to maintain the TAC system.

Herein, the success of TACs in relation to their implications for fishery resources is examined in three different ways. First, this paper analyses the scientific recommendations made by the International Council for the Exploration of the Sea (ICES), the quota proposals from the EC, and the quotas approved by the Council for all commercial populations under TAC regulation for which information is available. Second, the status of commercial fish stocks by using catches, fishing mortality, biomass, recruitment, discards, and exploitation rates in relation to the maximum sustainable yield is also investigated. Because the isolated assessment of each of these variables by itself does not guarantee the success or failure of a fisheries policy, a joint assessment of all of them is recommended (Worm *et al.* 2009). Third, this paper assesses the state of stocks based on three indicators recognized by ICES: reproductive biomass and fishing mortality in relation to precautionary limits and fishing mortality as compared to maximum sustainable yield.

Criticism of the TAC regulation: decision-making process, biological, economic, and institutional implications

The implementation of the TAC system has received numerous criticisms by the scientific community because of its rigidity and because of its repercussions in the fishing sector (Pitcher *et al.* 2001). These criticisms include arguments about the negative effects on marine ecosystems in the North Atlantic Ocean (ICES 2007, 2008a), the generation of a considerable volume of illegal fishing (Agnew *et al.* 2009) and discards (European Commission 2007a), and more recently, the need to discuss the analysis of the benefits (Grafton *et al.* 2007; Costello *et al.* 2008; Andersen *et al.* 2009), the limitations on the individual rights (Clark *et al.* 2008; Chu 2009), and the implications of the TAC system on the objectives established for 2015 by the *Johannesburg Plan of Implementation of the World Summit on Sustainable Development* (Froese and Proelβ 2010).

With regard to the decision-making process, practice has shown that fragile commitment agreements have prevailed by simplifying the distribution of resources to a political negotiation (Pitcher *et al.* 2001) without considering the impact that the TAC system may have both on fishery resources and on the fishing industry (Piet *et al.* 2010). First, the TACs tend to stimulate competition among fishermen for access to fishery resources (Pauly and Maclean 2003). Second, scientific recommendations are not taken into account by quota proposals agreed upon by the EC (European Commission 2007a,b,c). Third, quotas initially approved by the Council are revised during the year during which they are valid (European Commission 2008).

From the biological perspective, the last CFP reform (2002–2012) adopted several measures to protect overexploited fishery resources. These include cod (*Gadus morhua*) in the North and Baltic Seas (Regulation No 423/2004) and the Northern hake stock (*Merluccius merluccius*) (Regulation No 811/2004), among others. The implications of TACs on structural measures (Hatcher 2001; Lindebo *et al.* 2002; Surís-Regueiro *et al.* 2003) and on technological efficiency for the European fishing fleet (Villasante and Sumaila 2010) also have been criticized. TACs also have serious consequences for deep-sea fisheries (Villasante 2010) and for fishing grounds in Africa (Sumaila and Vasconcellos 2000) and in South America (Villasante and Sumaila 2008). As consequence, it is clear that deteriorating biodiversity impairs a marine ecosystem's capacity to provide food, maintain water quality, and recover from perturbations (Peterson and Lubchenco 1997; Worm *et al.* 2006). Moreover, TACs have been criticized because of the lack of an adequate governing framework (Mikalsen *et al.* 2007), particularly with regard to recovery plans for stocks (European Commission 2009).

The TAC system has also economic implications. The system's rigidity exacerbates the *race for fish*, encouraging fishermen to consider the convenient harvesting species until they reach an overexploited stage (Hilborn and Walters 1992). Once species are economically profitable, catches usually exceed the quota allocated (European Commission 2008). The TAC system also promotes fleet overcapacity (Gelchu and Pauly 2007), and this is often exacerbated by subsidies (Clark *et al.* 2005; Khan *et al.* 2006). In the field of institutional framework, efficient implementation of TACs is based on the existence of a system to register catches. Monitoring the compliance of fishermen to TACs and application of sanctions to transgressors both depend on the inspection system developed by the EU, and they rely on available staff and the capacity of the legal system employed by each member State (European Court of Auditors 2007). This process has been criticized as being ineffective (European Commission 2009).

Material and methods

There are several ways to evaluate the status of fishery resources, but each has its limitations and a different range of uncertainties (Hilborn *et al.* 2003; Worm *et al.* 2006). As regards catches, official statistics often are not very reliable for two main reasons. First, official catches only reflect part of the the number of fish extracted from the sea, because statistics on landings show quantities of marketed fish, and do not include the volume discards and illegal, unreported and unregulated catches (Zeller *et al.* 2006). Second, the collection of fishing statistics is conditioned by problems related to the heterogeneous origin of the different fishing sectors and to the different treatment given to the sector depending on the importance of each member State (Schwach *et al.* 2007).

For this reason, this paper analyses all available data types (catches, fishing mortality, biomass, recruitment, discards and exploitation rates in relation to maximum sustainable yield) in order to unify the understanding of the global status of marine ecosystems. All these public indicators are examined because ICES is the international organization responsible for gathering scientific data to assess the situation of stocks in European fishing grounds. In doing so, ICES selected such indicators so that it could provide advice about the appropriate exploitation rate for each species (ICES 2008a). In addition, the relationships among the chosen parameters are robust from the scientific point of view. An increasing exploitation rate (fishing mortality) causes a decline in abundance (biomass), and profits (catches) and the recruitment of the stock at such low abundance may be severely limited (Walters and Martell 2004; Beddington *et al.* 2007).

ICES assessment of marine populations

The scientific data gathered by ICES for ~150 fish and shellfish stocks in European waters are based on research conducted in the member States (ICES 2006, 2007, 2008a). The quality of the fish assessments is closely linked to the quality of the fisheries data, and the stock assessments conducted by ICES use the best possible estimates of the total catch. Stock assessment models mainly use stock production models, catch-at-age data, Bayesian models, and additional information includes research survey indicators or catch rates (ICES 2007). ICES attempts to identify the main factors contributing to the total catches using stock assessment models by evaluating, when available, the following data: recorded landings, recorded catches based on a stock basis, biomass, fishing mortality, catch per unit effort, recruitment, and discards. This study includes all of these parameters except catch per unit effort.

Although this index is commonly used in stock assessment as an indicator of stock abundance (ICES 2006, 2007, 2008a), Hilborn and Walters (1992) and Walters and Martell (2004) asserted that its use is one of the main causes of dangerously misleading overestimates of abundance. Firstly, catch per unit effort is not an index that is proportional to abundance. Secondly, fishermen usually harvest smaller fish as soon as the abundance of large predators declines. However, this exploitation pattern can help prevent the catch per unit effort from declining, thereby making it appear to a scientific observer that abundance must still be healthy because plenty of small fish are still being harvested (Walters and Martell 2004; Beddington *et al.* 2007).

ICES scientific recommendations, quota proposals, and approved quotas

In this study, 40 marine populations that were subjected to TAC regulation under the CFP in European waters for the 1990–2007 period are analysed. For the first time, this paper examines how the TACs recommended in the original ICES scientific reports were distorted by the time they were proposed and finally approved as quotas and how this process affected the trends and status of the stocks.

Catches, fishing mortality, recruitment, biomass, discards, and exploitation rates

The analysis described above is reinforced with a second level of assessment that involved examining catches, fishing mortality, recruitment, biomass, and discards. In addition, in the event that information regarding some of the parameters commonly used to evaluate TAC-regulated stocks (B_{lim}, B_{pa}, F_{lim}, F_{pa}, F_{mg}, and F_y) was not available, current exploitation rate ($U_{current}$) for all species subject to TAC regulation is calculated. Here, the evolution of the $U_{current}$, the exploitation rate that allows the maximum sustainable yield (U_{mmsy}), and the exploitation rate limits necessary to ensure stock conservation in the long term ($U_{conserve}$) are also presented (Worm *et al.* 2009).

Three sustainability indicators in relation to the maximum sustainable yield

In the third level of analysis, three sustainability indicators recognized by ICES for 45 stocks under TAC regulation are evaluated: reproductive biomass and fishing mortality in relation to precautionary limits, and fishing mortality as compared to maximum sustainable yield.

Step-by-step approach

Here the development of the global assessment for all commercial stocks under TAC regulation is presented:

1. A temporal series to combine scientific recommendations of ICES, quota proposals of the EC, and quotas annually approved by the Council is constructed. The information was gathered from ICES reports and European fisheries law. For example, data about quota proposals were gathered from the Proposal for a Council Regulation [COM (2006) 774], and information about quotas approved were found in Council Regulation (EC) No 41/2006. This exhaustive compilation allowed us to conduct a comparative analysis of the differences between ICES recommendations and approved quotas in order to determine whether the decision-making process did or did not follow the ICES recommendations.
2. Species covered are all those commercial fishery populations under TAC regulation (See Table S1), and ICES areas covered by this work were all in EU areas where quotas were granted for European vessels (Table S2).
3. All information related to catches, fishing mortality, recruitment, biomass, discards, and B_{lim}, B_{pa}, F_{lim}, F_{pa}, and F_{mgt}, and F_y are also collected from ICES reports to determine whether all of these variables and parameters were measured by ICES (Table S3). Because ICES does not provide data for all of these parameters, $U_{current}$, U_{mmsy}, and $U_{conserve}$ (Worm *et al.* 2009) for all marine populations under the TAC regulation are calculated.
4. In the process of identifying and selecting species, this paper includes: (i) areas of evaluation and attribution of different quotas, and (ii) those populations for which the TAC assigned by the EC did not exceed 5000 tonnes from 1986 to 2008. However, those populations for which the ICES did not have at least one of the scientific variables (TAC recommendation by ICES, catches, fishing mortality, recruitment, biomass, and discards), or those for which we could not compare the evaluation of a stock with the quotas are excluded from the analysis. Finally, deep-sea species quotas, the fishing species quotas for the European fleet in third-country waters and in international waters, and the species quotas granted to foreign fishing fleets (Norway, Russian Federation, etc.) in European waters are also excluded. The resulting data included 465 668 values, which were integrated and incorporated manually into *Microsoft Excel*.

Results and discussion

Impact of the TAC regulation (I): relationships among scientific recommendations, proposals, and approved quotas for commercial populations

Pelagic species

European anchovy (Engrasulius engrasulius). Anchovy is a short-lived species whose recruitment strongly depends on environmental and oceanographic factors (Motos *et al.* 1996). Between 1990 and 2005, the TACs for anchovy in ICES area VIII the first area fluctuated around 30 000 tonnes. Subsequently, due to very low recruitment in 2004 and to the inefficient application of the TACs, the biomass suffered a severe decline until its collapse, which forced the closure of this fishery (European Commission 2007b). Regarding the quotas, scientific recommendations were not respected by the EC's proposal. Similarly, quotas approved by the Council did not follow scientific recommendations of ICES. The approved quotas were higher by 143.9 (1990) and 200% (2004) than the proposed quotas. As a consequence, catches dropped by 96.7% in the 1990–2005 period due to the decline of the stock (Table S4).

Atlantic herring (Harengus harengus). Herring populations represent an adequate sample for assessing the TAC regulation as a conservation policy because of the long statistical series available for this species. Partially due to environmental factors that commonly affect the behaviour of this species (Hilborn and Walters 1992), the stock's biomass declined in area VIa (58.1%) in the 1990–2007 period, thus causing a decrease in landings (33.6%) due to the increase in fishing mortality (18.8%). Moreover, quotas proposed by the EC have not always respected scientific recommendations, and quotas approved by the Council exceeded year after year those proposed by the EC.

Scientists do not know the real situation for the herring biomass in area VIIj, although it is estimated to be at a low level following an important decline between 1990 and 2002. The present situation is a consequence of the approval of quotas that systematically exceeded the volumes proposed by scientists.

Moreover, quotas approved by the Council often were higher than those proposed by the EC.

Demersal species

Atlantic cod (Gadus morhua). The cod population from the Baltic Sea (IIIbcd) is composed of subpopulations from subdivisions 22–24 and 25–32. This is a resource with narrow trophic relations with other species; cod prey on pelagic species such as European sprat and herring. Consequently, evolution of the cod stock determines the fishing mortality of such species. Biomass and landings in both areas declined by 36.6 and 56.3% due to high fishing mortality, and discards continue to be substantially high in area 22–24 (Table S4) (Fig. 1).

The biomass of the cod stock from area VIIa (Celtic Sea) decreased by 82.7% during 1990–2007 due to a 26.4% increase in fishing mortality between 1990 and 2002. The TAC has not been satisfactory because scientific recommendations have not been followed. Rates of discarding also were considerable at times in small-mesh demersal fisheries. The large fishing effort of *Nephrops* vessels in the Irish Sea can result in a substantial quantity of discards of cod by the fleet (ICES 2006, 2007, 2008a) (Table S5).

For the cod stock from area VIIe-k, decreasing trends in biomass (71.6%) and landings (74%) have been observed. In neither case have proposals from the EC respected ICES recommendations, and quotas have always been higher than such recommendations. The cod population from Kattegat has shown a remarkable biomass reduction (74%) and decrease in landings (89.8%). Furthermore, its high fishing mortality has barely been reduced since 1990, and the current level of fishing mortality remains unknown. In this case, scientific advice was not followed and catches were higher than quotas. Moreover, a serious problem with discarded catches persists, and discards are estimated to be at ~100% of official catches (ICES 2006, 2007, 2008a).

European hake (Merluccius merluccius). Hake often is exploited jointly along with Norway lobster, turbot, anglerfish, sole, pouting, conger, and cephalopods in ICES areas IIa, IV, VI, VII, and VIIIabd (Northern stock) and in areas VIIIc and IXa (Southern stock). For the Northern stock, the slight increase in its biomass (6.4%) seems to be linked to a reduction in fishing mortality (31.5%) in the 1990–2007 period. This has led to an improvement in the stock, but it has not prevented a reduction in landings (30.9%) since 1990, partially because the Council has not respected the EC's proposals (with the exception of 2005–2007). Discards of juvenile hake can be substantial in some areas and fleets (Table S5) (Fig. 2).

The Southern hake stock exhibited an increase in fishing mortality (39%) between 1990 and 2005,

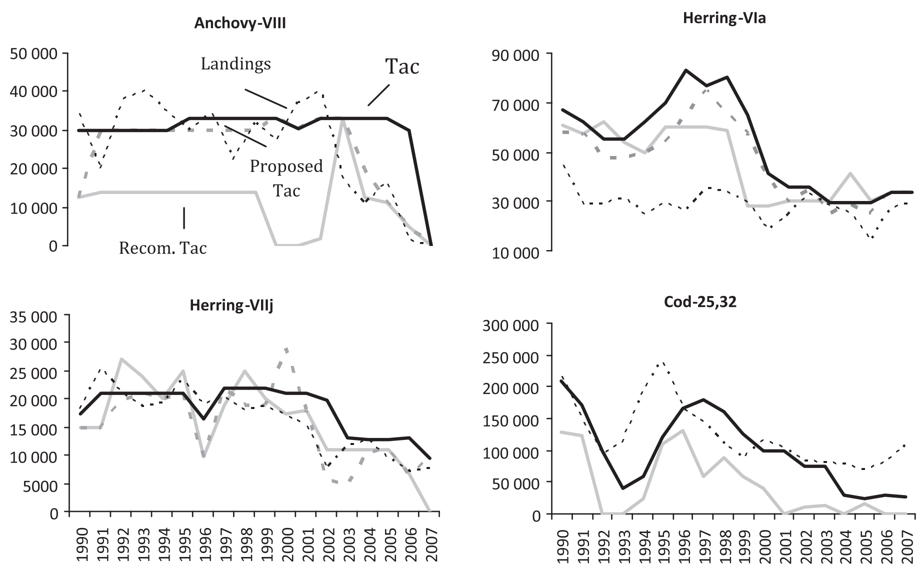

Figure 1 Impact of the TACs determining by analyzing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (or landings), and discards for: Anchovy in area VIII; Herring in area VIa-North; Herring in area VIj-Celtic Sea; Cod in area IIIbcd (22–24, 25–32)-Baltic Sea. Source: own elaboration from ICES (2006, 2007, 2008) and EU fisheries law.

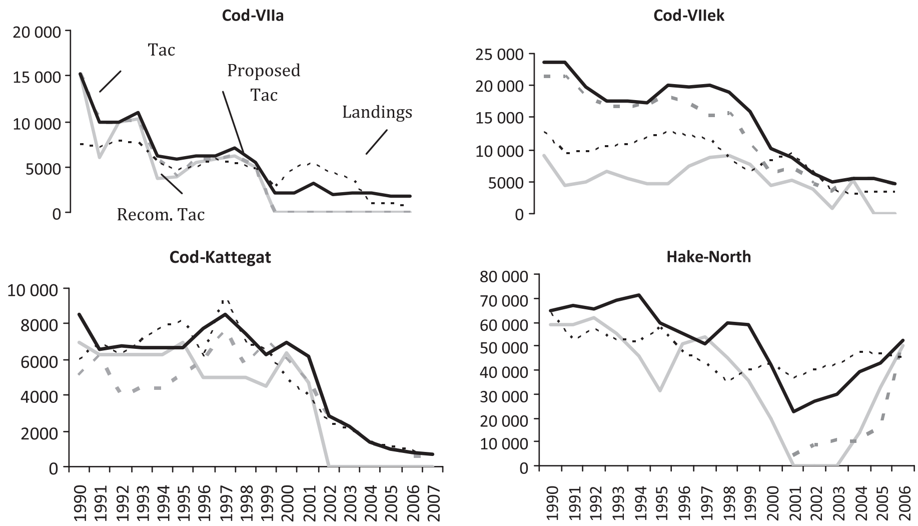

Figure 2 Impact of the TACs determining by analyzing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (or landings), and discards for: Cod in area VIIa; Cod in area VIIek; Cod in area IIIa; Hake Northern stock. Source: own elaboration from (ICES, 2006, 2007, 2008) and EU fisheries law.

causing a reduction of the biomass (23.7%) and catches (37.8%) (Table S6). Scientific recommendations seldom were followed in the proposals by the EC, and quotas approved by the Council exceeded scientific recommendations in most years. Furthermore, hake just below the minimum landing size suffer a high discard rate. Preliminary discard estimates are approximately 3000 tonnes in 2007, representing approximately 20% of total landings (ICES 2006, 2007, 2008a).

Megrim (Lepidorhombus boscii and Lepidorhombus whiffiagonis). The population of megrim in area VIIIc (Western Scotland) exhibited declines in biomass (25.8%), fishing mortality (54.3%), and landings (58.6%) in the 1990–2007 period. The fishing effort decline was a consequence of the decommissioning of 96 Scottish trawling vessels between 2001 and 2004. Quotas approved in the majority of years exceeded scientific recommendations, and only in four cases did EC proposals coincide with quotas adopted by the Council (ICES 2006, 2007, 2008a, 2008b).

European plaice (Pleuronectes platessa). The plaice population from area VIIe (Western Scotland) showed an increase in fishing mortality (12.6%) and biomass constantly decreased (65.8%) in the 1990–2007 period, thus causing an important reduction in landings (52%). Although catches have been kept below the volumes suggested by ICES, Community officers systematically ignored scientific recommendations when adopting TACs. The stock from area IV (North Sea) decreased in biomass (43.1%) and catches (66.2%) due to the high fishing mortality, which remained stable during the study period (although it has been reduced in the last few years). Quotas established have not always respected scientific recommendations, and in 2004 and 2005 the quotas were exceeded by catches. Following these poor results, an annual restriction zone was approved in 1995, and this has had a positive effect on recruitment and may have favoured a reduction in discards (Grift *et al.* 2004) (Table S6).

The plaice population from area VIIa (Celtic Sea) showed an increase in biomass (33.3%) and a significant reduction in fishing mortality (98.5%) in the period analysed. This is one of the few populations for which the TAC system has worked relatively satisfactorily. However, this situation has not prevented a reduction in landings (75%) and an increase of discards. At present, protection measures are linked to the cod recovery plan. As for the TACs, they show a declining trend (64.7%). This has partially allowed compliance with scientific recommendations, although quotas have exceeded the EC's proposals. The high level of discarding (up to 80% by number) indicates a mismatch between the minimum landing size and the mesh size of the gear being used (Table S7) (ICES 2006, 2007, 2008) (Fig. 3).

Common sole (Solea solea). This species is exploited in area IV (North Sea) in a mixed fishery of trawler vessels that also harvest plaice and other flat fish. Scientific assessments indicate a direct

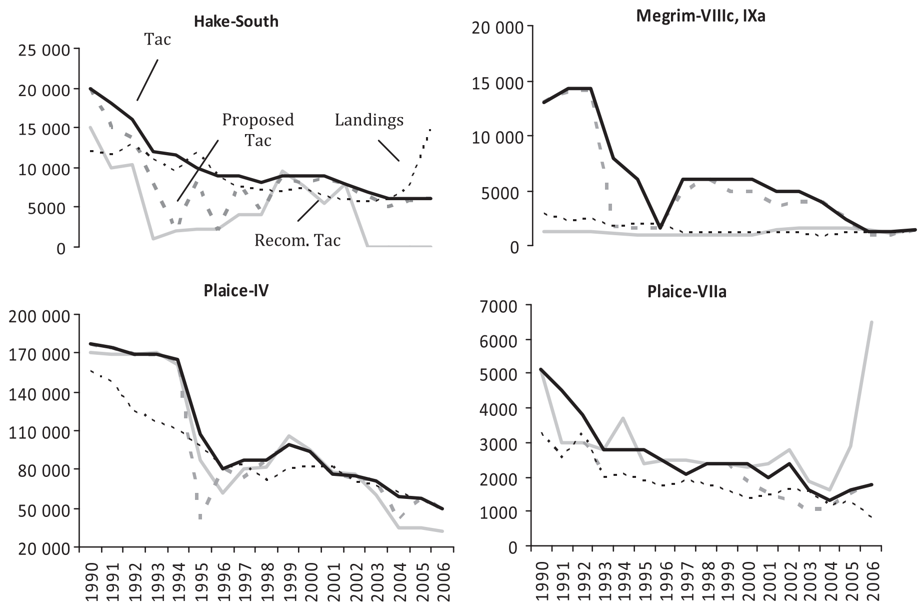

Figure 3 Impact of the TACs determining by analyzing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (or landings), and discards for: Hake Southern stock; Megrim in areas VIIIc, IX, X; Plaice in area VIIe; Plaice in area IV. Source: own elaboration from (ICES, 2006, 2007, 2008) and EU fisheries law.

relationship between the strong biomass decline (78.7%) and the maintenance of fishing mortality levels ($F = \sim 0.45$). As consequence, a decline in catches was observed (48.4%) in the 1990–2007 period. The reduction of TACs between 1990 and 2007 (40%), limitations on fishing effort, and the increase in fuel prices caused most of the fishing effort to be focused in the southern area of the North Sea, where most of the juvenile plaice population can be found. Recommended quotas were not respected and they were exceeded. The combination of a change in fishing pattern and the spatial distribution of juvenile plaice has led to an apparent increase in discarding of plaice (ICES 2006, 2007, 2008).

The sole stock from area VIIfg (Celtic Sea) experienced an increase in biomass (34.7%) and lower fishing mortality (50%) and catches (18.1%), which have allowed this stock to reach levels that make it possible to ensure this fishery's economic profitability and stock conservation. As a result, the TACs have worked in a reasonably good manner, as there was no difference between recommendations and approved quotas despite the quota reduction (33.3%).The biomass of the sole stock from area VIIIabd (Bay of Biscay) decreased by 9.7% due to the constant fishing mortality levels over time. This has caused a reduction in catches (28.8%). The restrictive TACs have been exceeded by catches during almost the entire period examined (Table S7) (ICES 2006, 2007, 2008) (Fig. 4).

Whiting (Merlangius merlangius). The whiting stock from area VIIe-k has maintained a relatively stable biomass in recent years; it also has experienced an important reduction in fishing mortality (30.2%). However, recent biomass and mortality estimations are uncertain because of the non-inclusion of a high volume of discards and because of decreasing recruitment. Moreover, the under reporting of haddock catches is an important problem; haddock are sometimes declared to be whiting when restrictive quotas for haddock have been adopted (Table S8) (ICES 2006, 2007, 2008).

Benthic species

Norway lobster (Nephrops norvegicus). The two Norway lobster populations examined herein are those from areas VIIIab (Bay of Biscay) and VIIIc (Northwestern Bay of Biscay). The Norway lobster stock from area VIIIab has been tolerating well the level of exploitation in recent years. Although biomass has been maintained at acceptable levels, fishing mortality remains high, especially for individuals of small size. A decrease in catches (11.2%)

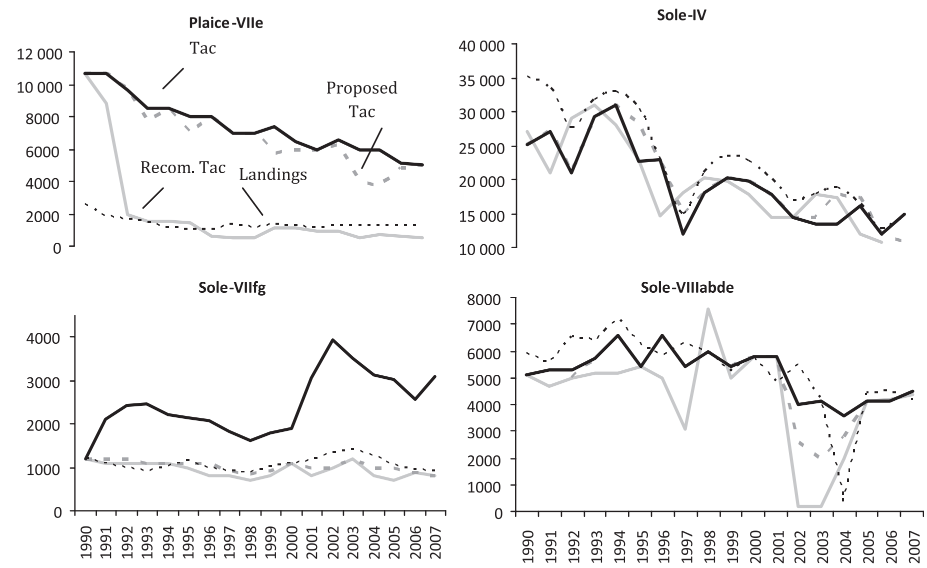

Figure 4 Impact of the TACs determining by analyzing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (or landings), and discards for: Plaice in area VIIa; Sole in area IV; Sole in area VIIfg; Sole in area VIIIabd. Source: own elaboration from (ICES, 2006, 2007, 2008) and EU fisheries law.

was observed, and even so they still exceeded the TACs. As a result, the TACs have been reduced by almost half since 1990; however, they still exceeded ICES recommendations. Finally, the estimates of discards are another important source of uncertainty. The average weight of discards per year in the period 1987–2007 was about 1700 tonnes, whereas discards between 2003 and 2007 reached a higher level (2760 tonnes), corresponding to 57–79% in number (ICES 2006, 2007, 2008).

The Norway lobster population from area VIIIc showed very low biomass levels due to the stable level of fishing mortality over time. As a result, catches have significantly diminished (50%) in the time examined. ICES recommendations were not followed and the Council approved quotas that were twice those recommended by scientists. A recovery plan for southern hake and Norway lobster has been in force since the end of January 2006, with the goals of rebuilding the stocks within 10 years and reducing by 10% the fishing mortality relative to the previous year (Council Regulation (EC) No. 2166/2005) (Table S8) (Fig. 5).

In summary, the ICES scientific recommendations were not followed for any of the analysed species. The differences observed between the scientific recommendations and the quotas occurred within the evaluation period between 1990 and 2007. This inconsistency was observed in 11 of the 12 years included in the analysis for cod (VIIj) and plaice (VIIe), in 10 of the 12 years for southern hake and Norway lobster (area VIIIc), and in 9 of the 12 years studied for cod (Kattegat and VIIa), among others. Differences between the proposed quotas and those approved by the Council existed for all of the species studied. The most significant differences were observed for the anchovy stock (66% in 2003 and 200% in 2004 in area VIII) two years before the closure of the fishery, for cod (77.4% in area IIIbcd during the year 2000), for sole (105% in area VIIIabd in 2003), and for plaice (62.1% in area VIIe and 44% in area IV in 2004).

In addition, the differences between the quotas or TACs and the scientific recommendations were around 19% after the first CFP reform (1992–2001) and increased to 21% after the second fisheries reform (2002–2008). During this last period, the difference in the fishing quotas with respect to the scientific recommendations affected 70% of the populations. This difference between quotas and scientific recommendations increased approximately two or three-fold during the second period and affected species that until then were still outside the limits of biological safety and that are presently included in a species recovery plan (i.e., cod, VIIa, Kattegat, 22–24, 25–29,32) (Fig. 6).

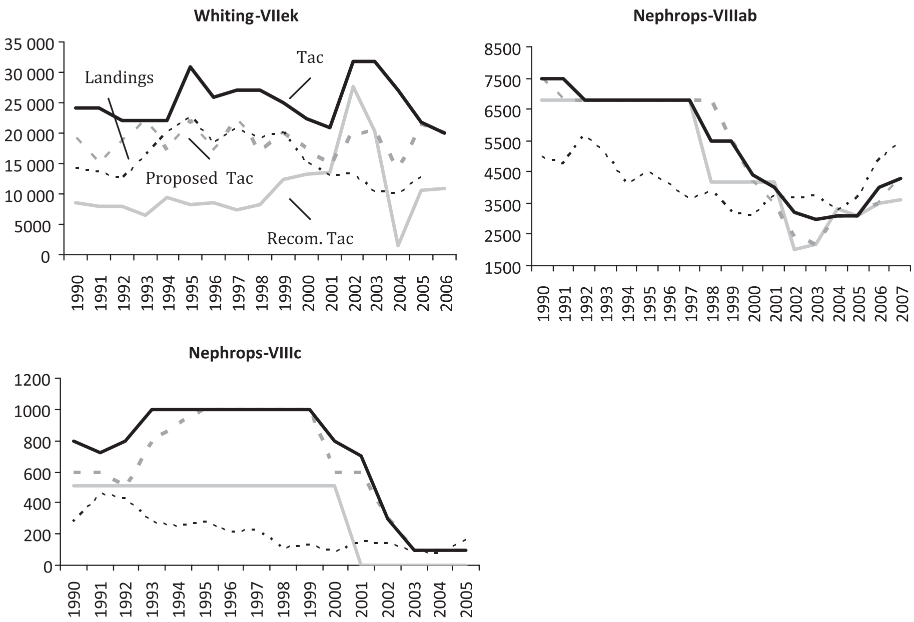

Figure 5 Impact of the TACs determining by analyzing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (or landings), and discards for: Whiting in area VIIe-k; Norway lobster in area VIIIab; Norway lobster in area VIIIc. Source: own elaboration from [3–5] and EU fisheries law.

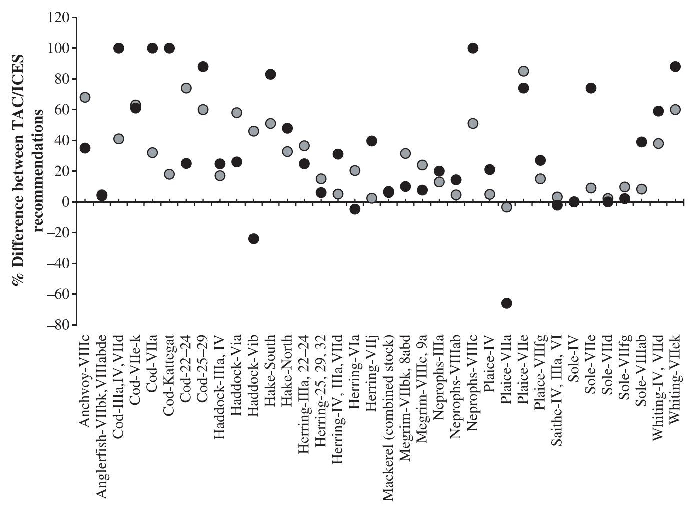

Figure 6 Differences between TACs and ICES recommendations in the 1992–2001 (grey) and 2002–2008 (black) periods. Source: own elaboration from ICES (2006, 2007, 2008) and European fisheries law.

Impact of the TAC regulation (II): relationships among catches, fishing mortality, recruitment, biomass and exploitation rates

In this section, a second assessment of the success of the TACs system was conducted. The five most revealing indexes from a practical point of view were examined: catches, fishing mortality, recruitment, biomass, and exploitation rate in relation to maximum sustainable yield for all species subjected to the TACs for which ICES scientific information was available.

The dynamics of catches

Available data for the 40 populations examined indicate that 36 (90%) of them suffered a decrease in catches. The sharpest falls were found in the following populations: anchovy (VIII), cod (Kattegat, Skagerrat, VIIe–k, VIa, VIIa, and subdivisions 25–32), haddock (IIIa, IV, and VIb), herring (VIa, and subdivisions 22–24), Norway pout (IV, and IIIa), plaice (IV, VIIa, and VIIfg), and saithe (IV, IIIa, and VI). Two stocks did not show significant changes, and the remaining two populations increased their volume of catches. Using this variable as an indicator of the success of the TAC system, a strong decline in catches for 90% of the populations was observed (Table S9).

Fishing mortality

Of the 40 populations under TAC regulation, 11 (28%) of them experienced an increase in fishing mortality during the 1986–2007 period. Cod (VIIa), haddock (VIa), hake (Northern and Southern stocks), herring (subdivisions 22–24), and megrim (VII, and VIIIab) presented the most significant changes. Three populations (8%) presented almost no change [cod (Kattegat) and mackerel and sole (VIId)], and 26 (65%) exhibited a decline in fishing mortality (Table S9).

Recruitment

Recruitment is, by definition, highly variable, and the main problem for scientists is establishing whether size variation of a given stock is due to environmental alterations of the ecosystem, to fishing mortality, or to a combination of both (Hilborn and Walters 1992). Environmental factors and climate change (Bakun *et al.* 1982; Hilborn and Walters 1992), which are increasingly predictable under current bioclimate envelop models, have an important influence on the evolution of a stock (Allison *et al.* 2009; Cheung *et al.* 2009). Thus, marine ecosystems do not guarantee recruitment success from one year to the next, nor do marine ecosystems guarantee stability of populations from one decade to the next (Folke *et al.* 2007). The reason for that if recruitment increases, so will catches, but if recruitment fluctuates, catches will follow that same trend. Here this relationship is investigated by indicating trends in biomass and recruitment for the 40 populations under study. The recruitment of 30 stocks (75%) decreased considerably from 1986 to 2007, 7 (18%) populations presented an increase (e.g. anglerfish in VIIbk and VIIIabde; mackerel; and megrim in VII and VIIIabd), and the remaining 5% showed no changes (Table S10).

Spawning stock biomass

In the 1986–2007 period, 27 out the 40 fish populations (68%) for which scientific information was available exhibited a declining trend in spawning stock biomass. Only 10 (25%) populations experienced an increase (e.g. anglerfish in VIIbk and VIIIabde; herring in IV, IIIa, and VIId; and saithe in IV, IIIa and VI, among others), and 5% showed no significant changes (Table S10) (Fig. 7).

The exploitation rate ($U_{current}$) and the maximum sustainable yield (U_{mmsy})

Between 1990 and 2007, only 20% of marine populations subject to TAC regulation exhibited an increase in the $U_{current}$, 17% did not show significant changes, and the remaining 63% presented a reduction. However, following the methodology used by Worm *et al.* (2009) who observed $U_{current}$ values that were significantly higher than the U_{mmsy} in 6 of the 10 (60%) ecosystems examined, the present study demonstrates that 86% of the populations regulated by TACs continue to follow an alarming exploitation pattern. The only populations reaching the U_{mmsy} values were megrim (2003–2005), Norway pout (2005, 2007), plaice (2006–2007), and sardine (2006) (See, in detail, Figure S1).

Impact of the TAC regulation (III): precautionary limits and the state of stocks

ICES provides scientific information related to the precautionary principle following a number of international agreements and codes of practice. Some of these are the 1992 *UN Conference on the Environment and Development* (UNCED), *Agenda 21*, the *United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks* (the 1995 Fish Stocks Agreement), the *Code of Conduct for Responsible Fisheries*, the *Convention on Biologic Biodiversity*, the *Jakarta Mandate*, the 2002 *Johannesburg World Summit on Sustainable Development*, and the *UN Framework on Climate Change*.

The precautionary principle was recognized in the 1995 Fish Stocks Agreement as follows: *'States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures'* (United Nations 1995). For ICES, the precautionary principle implies, in practice, the

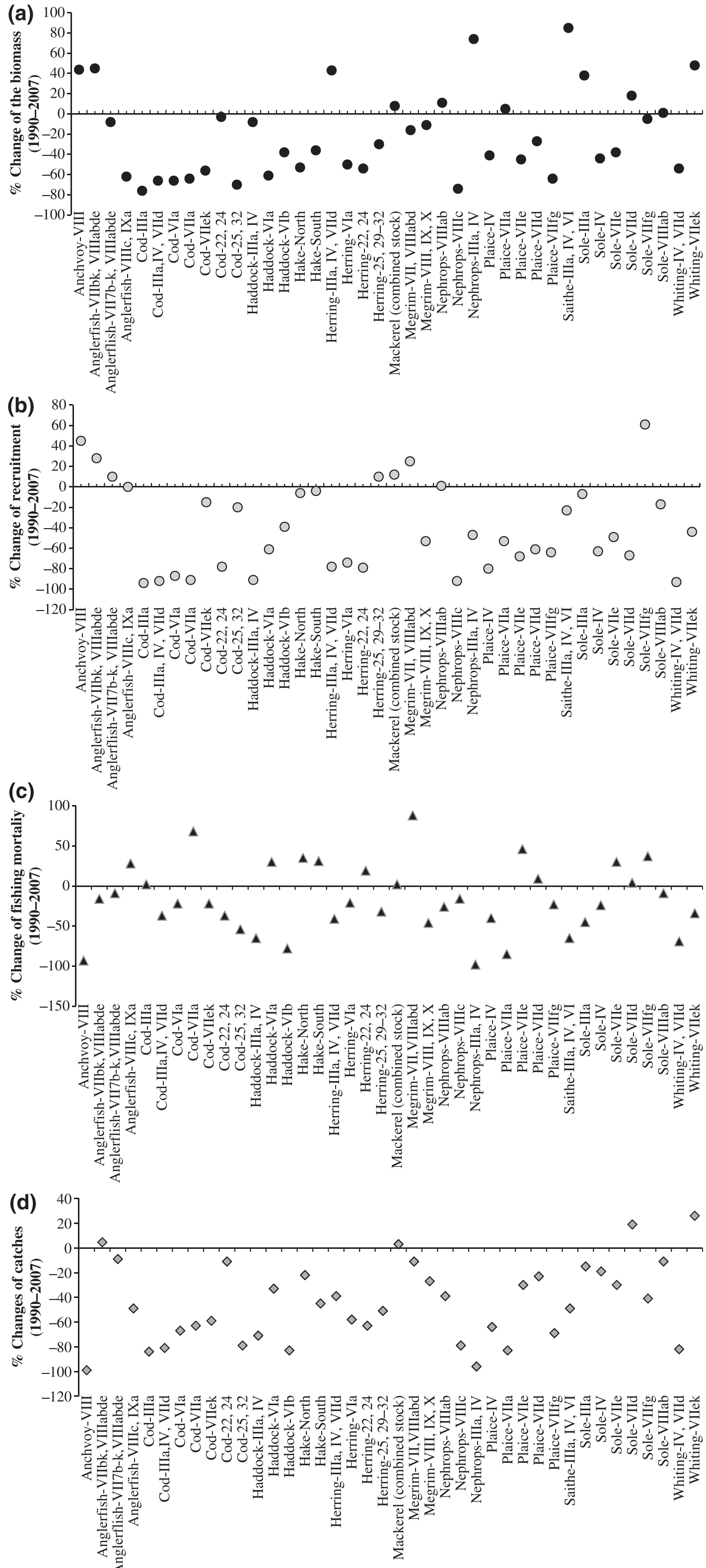

Figure 7 Changes in (a) biomass, (b) recruitment, (c) fishing mortality and (d) catches of all EU marine populations under TAC regulation. Source: own elaboration from ICES (2006, 2007, 2008) and European fisheries law.

determination of a dual system of conservation limits (limit reference points), and a number of precautionary reference points that represent the uncertainty of the present and future scientific knowledge about populations.

Classification of commercial populations

Currently, ICES classifies populations according to their reproductive biomass and fishing mortality (ICES 2006, 2007, 2008a): (i) regarding their reproductive biomass: a) populations '*with total reproducing capacity*', equivalent to the previous category '*within the safety biological limits*', and b) populations '*in risk of having a reduced reproducing capacity*' or '*suffering a reduced reproducing capacity*', which are expressions similar to populations '*outside the safety biological limits*'; and (ii) regarding fishing mortality: a) populations '*sustainably harvested*', equivalent to '*harvested within the safety biological limits*' and b) populations '*harvested outside precautionary limits*', equivalent to populations that are '*harvested outside the safety biological limits*'. For all of these populations, data on at least one of these variables was available and reference points were defined by ICES.

For the spawning stock biomass, the term *acceptable* means that a stock is in a healthy state and above the minimum recommended biomass level. An *increased risk* happens when a stock is below the minimum level recommended. Stocks included into this group cannot be classified as collapsed yet, but the volume of adult fish has fallen to such an extent that production is at risk of suffering a decline. *Reduced reproductive capacity* means that a stock is depleted and is therefore unlikely to be as productive in the marine ecosystem as it potentially could be. This means that current fishing pressure needs to be reduced to more sustainable levels to give the stock a chance to rebuild.

The second variable is the relationship between fishing mortality and precautionary limits. This is a measure of the fishing pressure on a fish stock and whether it is above or below the maximum level recommended by ICES scientists. This indicator is determined by the following categories: *acceptable*, *increasing risk*, and *harvested unsustainable*. *Acceptable* means that the stock is being fished in a sustainable way, and *increasing risk* indicates that fishing pressure is over the level recommended by scientists and if it is not reduced it could lead to depletion of the stock in the future. *Harvested unsustainable* refers to a situation in which fishing pressure is considerably over the recommended level. Stocks included in this category continue to be exploited at the same level, and their collapse is probable, if not already a reality.

The third variable involves fishing mortality as compared to the highest yield of a stock. The three categories for this variable are as follows: *below target* (there is still a margin for increasing fishing effort); *appropriate* (the level of fishing pressure is adequate to reach the maximum yield in the long term); and *overfished* (fishing pressure is too high).

Current state of fish stocks and the precautionary principle

Different possible assessments can be extracted from the scientific advice provided by ICES. First consider the relationship between reproductive biomass and the precautionary limits: There are 8 stocks with *reduced reproductive capacity*, 16 stocks with *full reproductive capacity*, 9 stocks with an *increasing risk*, and 12 that are *not defined* or *unknown*. Second, 4 stocks are exploited in an *unsustainable* way, 17 are exploited in a *sustainable* way, the situation for 16 of them is *not defined* or *unknown*, and the number of stocks in a *risky situation* is 8 (ICES 2006, 2007, 2008a) (Fig. 8).

Third, 33 populations are *overfished or overexploited* (and in 6 of them the fishing effort level is not known or not defined), 3 are *underexploited*, and the remaining 3 are *appropriate*. According to the application of the precautionary, this exploitation pattern requires the adoption of protection measures to ensure sustainable levels in future years (Table S11).

Conclusions

Using the main available indicators of abundance, this work demonstrates that the TAC system implemented by the CFP has not been successful in the conservation of stocks. The use of the TAC system reflects the prevalence of a decision-making process of a predominantly political nature that fails to include an evaluation of its potential impact and that fails to consider the interests of stakeholders affected by these decisions.

If the original objective of the CFP was to '*ensure exploitation of living aquatic resources that provides sustainable economic, environmental and social conditions*' (Council Regulation (CE) No. 2371/2002), then the results of its application revolve around a

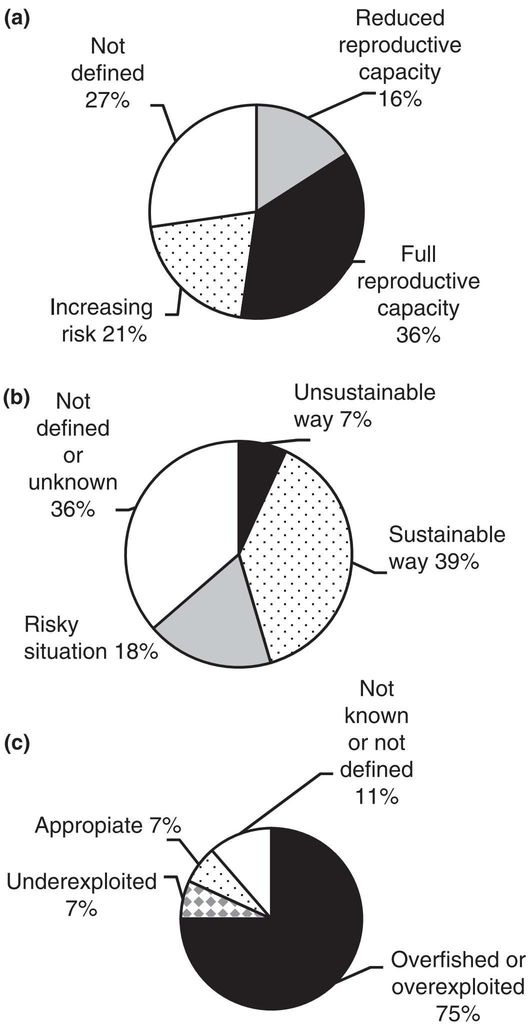

Figure 8 Current status of commercial populations under TAC regulation in relation to precautionary principle. Source: own elaboration from ICES (2006, 2007, 2008).

political rationale more than a *scientific rationale*, given the fact that most of the scientific recommendations were not followed. Beyond the objectives proposed by the EC and described in Regulations No 170/83, 3092/92, 2369/02, 2370/02, and 2371/02 concerning conservation efforts, the results obtained are clearly a reflection of political compromise over time. This prioritization of political agreements over the objectives established by the CFP has only reinforced a general tendency towards the unsustainability of fishery resources in Europe (European Commission 2008, 2009). The increase of technological efficiency (Villasante and Sumaila 2010) and the inefficiency of the regulations concerning the restructuring of the European fleet (Villasante 2010), together with the results presented in this study, emphasize the need for the inclusion by the EC of serious measures for the reduction of the levels of exploitation in the next CFP reform.

Acknowledgements

The authors would like to thank the European Documentation Centre of the University of Santiago de Compostela (Spain) for its contribution to the search and gathering of information. We thank the secretary of ICES who generously answered all of our requests during this research. An earlier version of this paper was presented at the 5th World Fisheries Congress, Yokohama, Japan, October 9–25th, thanks to the financial support of the American Fisheries Society. Sebastian Villasante acknowledges Dr. Rainer Froese (Leibniz Institute of Marine Sciences, Germany) for his advice about some of the approaches and data employed in this study. The author is also grateful for the financial support of the Latin American and Caribbean Environmental Economics Program (LACEEP), supported by the Swedish International Cooperation Development Agency (SIDA), the International Development Research Center (IDRC), and The Beijer Institute of Ecological Economics (The Royal Swedish Academy of Sciences).

Author contributions

Conceived and designed the methodology: SV. Gathering information and data: SV, MCGN, FGL, GRR. Analysed and validated the data: SV, MCGN, FGL, GRR. Wrote the paper: SV.

References

Agnew, D., Pearce, J., Pramod, G., Watson, R., Beddington, J.R. and Pitcher, T.J. (2009) Estimating the worldwide extent of illegal fishing. *PLoS ONE* **4**(2), e4570.

Allison, E., Perry, L., Badjeck, M.C. *et al.* (2009) Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries* **1**, 2–19.

Andersen, J.L., Nielsen, M. and Lindebo, E. (2009) Economics gains of liberalising access to fishing quotas within the European Union. *Marine Policy* **33**, 497–503.

Bakun, A., Beyer, J., Pauly, D., Pope, J.G. and Sharp, G.D. (1982) Ocean sciences in relation to living resources. *Canadian Journal of Fisheries and Aquatic Science* **39**, 1059–1070.

Beddington, J.R, Agnew, D.J. and Clark, C.W. (2007) Current problems in the management of marine fisheries. *Science* **22**, 1713–1716.

Cheung, W.L, Lam, V.W., Sarmiento, J.L., Kearney, K., Watson, R. and Pauly, D. (2009) Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* **10**, 235–251.

Chu, C. (2009) Thirty years later: the global growth of ITQs and their influence on stock status in marine fisheries. *Fish and Fisheries* **10**, 217–230.

Clark, C.W, Munro, G.R. and Sumaila, R. (2005) Subsidies, buybacks, and sustainable fisheries. *Journal of Environmental Economics and Management* **50**, 47–58.

Clark, C., Munro, G. and Sumaila, R. (2008) Limits to the privatizations of fishery resources. *Working Paper # 2008-07*. Fisheries Centre, University of British Columbia. 24 pp.

Costello, C., Gaines, Steven D. and Lynham, J. (2008) Can catch shares prevent fisheries collapse? *Science* **321**, 1678–1681.

European Commission (2007a) *Report from the Commission to the Council and the European Parliament on the monitoring of the member States' implementation of the Common Fisheries Policy 2003-2005*. COM (2007) 167 final, European Commission, Brussels, 04.10.2007.

European Commission (2007b) *Communication from the Commission to the Council and the European Parliament on a Policy to Reduce Unwanted By-Catches and Eliminate Discards in European Fisheries*. COM (2007) 136 final, European Commission, Brussels, 03.28. 2007.

European Commission (2007c) *Report of the Scientific, Technical and Economic Committee for fisheries, Evaluation of the Report of the Ad Hoc Working Group on anchovy in the Bay of Biscay*, Ispra, 18-22 June, 2007.

European Commission (2008) *Commission Working document: Reflections on further reform of the Common Fisheries Policy*; 9 p.

European Commission (2009) *Green Paper Reform of the Common Fisheries Policy*, COM (2009) 163 final. Brussels, 04.22.2009.

European Court of Auditors (2007) Special Report No 7/2007 pursuant to Article 248(4) second paragraph, EC, on the control, inspection and sanction systems relating to the rules on conservation of Community fisheries resources. Retrieved from http://www.europarl.europa.eu/activities/committees/publicationsCom.do?language=EN&body=CONT (accessed May 2008).

Folke, C., Pitchard, L., Berkes, F., Colding, J. and Svedin, U. (2007) The problem of fit between ecosystems and institutions: ten years later. *Ecology and Society* **12**, 30.

Froese, R. and Proelβ, A. (2010) Rebuilding fish stocks no later than 2015: will Europe meet the deadline? *Fish and Fisheries* **11**, 194–202.

Gelchu, A. and Pauly, D. (2007) Growth and distribution of port-based global fishing effort within countries' EEZs from 1970 to 1995. *Fisheries Centre Research Reports* **15**, 99.

Grafton, R.Q., Kompas, T. and Hilborn, R. (2007) Economics of overexploitation revisited. *Science* **318**, 1601.

Grift, R. E., Tulp, I., Clarke, L. *et al.* (2004). Assessment of the ecological effects of the Plaice box. Report of the European Commission Expert Working Group to Evaluate the Shetland and Plaice Boxes. Brussels, 121 pp.

Hatcher, A. (2001) *Economics Aspects of European fisheries policies*, CEMARE Report No. 57, United Kingdom, Portsmouth. 14 pp.

Hilborn, R. and Walters, C. (1992) *Quantitative Fisheries Stock Assessment. Choice, dynamics and uncertainty*. Chapman and Hall, New York.

Hilborn, R., Branco, T., Ernst, B. *et al.* (2003) State of the world's fisheries. *Annual Review of Environment and Resources* **28**, 359–99.

International Council for the Exploration of the Sea (ICES) (2006) Report of the ICES Advisory Committee. Copenhagen. Retrieved from http://www.ices.dk/committe/acom/comwork/report/asp/advice.asp (accessed July 2009)

International Council for the Exploration of the Sea (ICES) (2007) Report of the ICES Advisory Committee. Copenhagen. Retrieved from http://www.ices.dk/committe/acom/comwork/report/asp/advice.asp (accessed July 2009)

International Council for the Exploration of the Sea (ICES) (2008a) Report of the ICES Advisory Committee. Copenhagen. Retrieved from http://www.ices.dk/committe/acom/comwork/report/asp/advice.asp (accessed December 209)

International Council for the Exploration of the Sea (ICES) (2008b) Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk, and Megrim, 30 April–6 May 2008 (ICES CM 2008/ACOM:07).

Khan, A.S., Sumaila, R., Watson, R., Munro, G. and Pauly, D. (2006) The nature and magnitude of global non-fuel fisheries subsidies. In *Catching More Bait: A Bottom-Up Re-Estimation of Global Fisheries Subsidies* (eds. U.R. Sumaila and D. Pauly). Fisheries Centre Research, Vancouver. Reports PP. 14, 5–37.

Lindebo, E., Frost, H. and Lokkegaard, J. (2002) *Common Fisheries Policy reform: a new fleet capacity policy*. Fodevareokonimik Institut, Copenhagen.

Mikalsen, K., Hernes, H.K. and Jentoft, S. (2007) Learning on user-groups: the role of civil society in fisheries governance. *Marine Policy* **31**, 201–209.

Motos, L., Uriarte, A. and Valencia, V. (1996) The spawning environment of the Bay of Biscay anchovy (*Engraulis encrasicolus L.*). *Scientia Marina* **60**, 117–140.

Pauly, D. and Maclean, J. (2003) *In a Perfect Ocean: The State Of Fisheries and Ecosystems in the North Atlantic Ocean*. Island Press, Washington D.C.

Peterson, C.H. and Lubchenco, J. (1997) Marine ecosystem services. In *Nature's services: societal dependence on natural ecosystems*, (ed. G.C. Daily) Island Press, Washington DC; 1997, pp. 177–194.

Piet, G.J., van Overzee, H.M. and Pastoors, M.A. (2010) The necessity for response indicators in fisheries management. *ICES Journal of Marine Science* **67**, 559–566.

Pitcher, T.J., Sumaila, R. and Pauly, D. (2001) *Fisheries impacts on North Atlantic ecosystems: evaluations and policy explorations*. Fisheries Centre Research, Vancouver. Report 9, pp 94.

Schwach, V., Bailly, D., Christensen, A.S. *et al.* (2007) Policy and knowledge in fisheries management: a policy brief. *ICES Journal of Marine Science* **64**, 798–803.

Sumaila, R. and Vasconcellos, M. (2000) Simulation of ecological and economic impacts of distant water fleets on Namibian fisheries. *Ecological Economics* **32**, 457–464.

Surís-Regueiro, J.C., Varela-Lafuente, M. and Iglesias-Malvido, C. (2003) Effectiveness of the structural fisheries policy in the European Union. *Marine Policy* **27**, 535–544.

United Nations (UN) (1995) *United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks*. United Nations, New York. A/CONF.164/37.

Villasante, S. (2010) Global assessment of the European Union fishing fleet: an update. *Marine Policy* **34**, 663–670.

Villasante S., Sumaila R. (2010) Estimating the effect of technological efficiency on the European fishing fleet. *Marine Policy* **34**, 720–722.

Villasante, S. and Sumaila, R. (2008) Economics of fisheries management of straddling fish stocks in the Patagonian marine ecosystem. Paper presented to the 5th World Fisheries Congress, Yokohama, Japan, October 20–24th, 23 pp.

Walters, C. and Martell, S. (2004) *Fisheries Ecology and Management*. Princeton University Press, New Jersey.

Worm, B., Barbier, E.B., Beaumont, N. *et al.* (2006) Impacts of biodiversity loss on ocean ecosystem services. *Science* **314**, 787–790.

Worm, B., Hilborn, R., Baum, J.A. *et al.* (2009) Rebuilding Global Fisheries. *Science* **325**, 578–585.

Zeller, D., Booth, S., Davis, G. and Pauly, D. (2006) Re-estimation of small-scale fishery catches for U.S. flag-associated island areas in the western Pacific: the last 50 years. *Fisheries Bulletin* **105**, 266–277.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Exploitation rates (*Ucurrent*) (●) that provide the maximum sustainable yield (*Ummsy*) (◇), and the exploitation rate at which less than 10% of the fished species are predicted to collapse (*Uconserve*) [Minimum (▲) and maximum value (×)] for all marine commercial populations subjected to TAC regulation for the 1990–2007 period.

Table S1. Common and scientific name of commercial populations under TAC regulation of the Common Fisheries Policy.

Table S2. ICES areas included in the gathering of information of quota proposals and quotas approved in the 1990–2007 period.

Table S3. Species and ICES areas regulated by the TAC mechanism that we used to estimate the $U_{current}$, U_{mmsy}, and $U_{conserve}$ included in the analysis.

Table S4. Impact of the TACs determining by analysing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (landings), and discards for: 1–a Anchovy in area VIII; 1–b Herring in area VIa-North; 1–c Herring in area VIj-Celtic Sea; 1–d Cod in area IIIbcd (22–24, 25–32)-Baltic Sea.

Table S5. Impact of the TACs determining by analysing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (landings), and discards for: 2–a Cod in area VIIa; 2–b Cod in area VIIek; 2–c Cod in area IIIa; 2–d Hake Northern stock.

Table S6. Impact of the TACs determining by analysing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (landings), and discards for: 3–a Hake Southern stock; 3–b Megrim in areas VIIIc, IX,X; 3–c Plaice in area VIIe; 3–d Plaice in area IV.

Table S7. Impact of the TACs determining by analysing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (landings), and discards for: 4–a Plaice in area VIIa; 4–b Sole in area IV; 4–c Sole in area VIIfg; 4–d Sole in area VIIIabd.

Table S8. Impact of the TACs determining by analysing relationships among reproductive biomass, fishing mortality, recommended TAC, proposed TAC, approved TAC, catches (landings), and discards for: 5–a Whiting in area VIIe-k; 5–b

Norway lobster in area VIIIab; 5–c Norway lobster in area VIIIc.

Table S9. Evolution of catches (or landings) and fishing mortality of commercial species in European waters.

Table S10. Evolution of reproductive biomass and recruitment of commercial species in European waters.

Table S11. State of the commercial stocks in relation to precautionary limits

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

