DEEPFISHMAN
Management and Monitoring of Deep-sea Fisheries and Stocks

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Guidelines towards a prototype management and monitoring framework for deep-water fisheries/stocks in the NE Atlantic

1 Introduction and background

Deep-water fisheries occur in all of the world's oceans and in the Mediterranean Sea. They are important to fishers because of their economic value and, in some areas, because they provide an alternative resource when fish/shellfish stocks on the continental shelf and inshore waters have become depleted, or where access has been restricted. Scientific interest in deep-water resources has increased dramatically over the last 10-20 years, as management bodies have sought advice on how to manage deep-water fisheries and ecosystems.

Regional Fisheries Management Organisations (RFMOs) and national management bodies around the world have responded to advice, and to the requirements of the United Nations General Assembly (UNGA) Resolutions 61/105 (UNGA, 2007) and 64/72 (UNGA, 2008) to implement measures to regulate bottom fisheries in accordance with the Precautionary Approach (PA), the Ecosystem Approach (EA) and international law, by introducing, and in some cases strengthening, the management and monitoring of deep-water fisheries. Many have taken into account the FAO International Guidelines for the Management of Deep-water Fisheries (DWFs) in the High Sea (FAO, 2009), which address management factors ranging from an appropriate regulatory framework to the components of a good data collection programme.

The aim of this internal deliverable is to develop a first draft of strategic options for a short- and long-term management and monitoring framework for deep-water stocks, fisheries and ecosystems in the NE Atlantic. In doing so we attempt to pull together the outputs and knowledge gained from a number of sources, including:

- (i) deliverables from the various DEEPFISHMAN Work Packages
- (ii) feedback from a European Commission review (EC, 2009a) of the current EU Deep-sea Access Regime (EC, 2002)
- (iii) the requirements of EU Regulations and developing policy
- (iv) a DEEPFISHMAN review (D2.3) of the management and monitoring regimes applying in the north-west Atlantic, the south-east Atlantic, off Brazil, in the Antarctic, off Australia and New Zealand and in the Mediterranean (Large et al, In press)
- (v) outcomes from consultations with stakeholders in the deep-water fishing industry in the NE Atlantic (Lorance et al, 2011)
- (vi) information on the strengths and weaknesses identified in the existing management and monitoring of DEEPFISHMAN Case Study stocks/fisheries and
- (vii) relevant information from other DEEPFISHMAN Deliverables

Assessment methodologies, biological reference points and harvest control rules (FAO, 1996) are not included in this early draft. These will be addressed as the outcomes from the relevant DEEPFISHMAN studies and deliverables are finalised.

A step-wise approach has been used in the DEEPFISHMAN Consortium to address each of the following topics for (i) EU vessels and (ii) vessels of all nationalities fishing in the Northeast Atlantic Fisheries Commission (NEAFC) Regulatory Area (RA):

Topic 1. Management of deep-water fisheries in the NE Atlantic at the macro-level (TACs, effort, rights-based management etc)

Topic 2. Definition of deep water and deep-water species

Topic 3. Total Allowable Catch (TAC) management: review of the current list of species and the periodicity of TAC reviews

Topic 4. Review of TAC management units taking into account new knowledge of stock structure. Preliminary suggestions for fisheries-based management units

Topic 5. Definition of deep-water fishing effort and Capacity ceilings

Topic 6. Management and monitoring of by-catches, discards and protected, endangered and threatened (PET) species

Topic 7. Spatial and temporal closures and technical measures

Topic 8. EU Data Collection Framework (DCF) and observer sampling plans

Topic 9. Fisheries-independent surveys and monitoring regimes

Topic 10. Management of mixed-fisheries: species/fishery level

Topic 11. Short term and long term management options

Topic 12. Recommendations for further research studies

Under each topic, recommendations are presented. Where the DEEPFISHMAN Consortium cannot arrive at a consensus, this is flagged and the various alternative recommendations and related trade-offs are presented. As agreed at the WP7 Workshop in Bilbao, after each topic has been signed off by the Consortium the draft will be circulated through the Project Coordinator to DG Mare so that the latest outputs may be of use to the ongoing review of the EU Deep-water Access Regime.

2 Results

Topic 1. Options for deep-water fisheries[1] management in the NE Atlantic at the macro-level (TACs, effort, rights-based management etc).

We start with a general review of the economics of commercial deep-water fisheries and how this may impact on the choice of management controls in any future management regime.

The history of most deep-water fisheries is unfortunately quite similar to many other marine fisheries around the world. At first, when harvesting begins, stocks are usually large. Catches are consequently good and fishermen enjoy high returns on their effort and investment, which attracts entry into the fishery and encourages those already taking part to expand their level of operation. Total investments and fishing effort therefore increase. Over time, this expansion, if unchecked by management controls, leads to dwindling stocks and lower catches per unit effort (CPUE). Under open access, equilibrium will not be reached until total revenue equals total costs. As long as profits are positive, new entrants will be attracted to the fishery, while firms will leave the fishery if profits are negative. It should be noted that this adjustment will probably not take place instantaneously. It takes time to build new vessels and fishermen will not leave the fishery immediately in bad years, but may prefer to wait and see if next season will bring a better harvest and/or if others will leave the business first (Anderson, 2004; Anderson and Seijo, 2010). However, given that most deep-water species are long-lived and slow growing, and that some fisheries target fish aggregations, deep-water fishers often exhibit a 'mining strategy' to obtain the maximum short-term financial return at the expense of the long-term sustainability of fisheries and stocks. Trawl fisheries for orange roughy (*Hoplostethus atlanticus*) in the NE Atlantic are a typical example of this extreme form of exploitation.

The general development of open access fisheries (including deep-water fisheries) is more clearly illustrated in Figure 1. Income grows quickly in the beginning when harvests are small, while the corresponding costs grow much slower and almost linearly (in this case). Profit, which is defined as the distance between the two curves, will therefore increase and reaches a maximum at point A, which is defined as the maximum economic yield (MEY) and represents the optimal level of fishing effort, E*. At this level of fishing effort, profits and consequently, the contribution of the fisheries to gross domestic production (GDP), are maximized. The optimal fishing effort E* is less than the effort corresponding to the maximum sustainable yield (MSY) (D). Fishing at effort MEY is, from a sustainability standpoint, more conservative than fishing at effort MSY and consequently, some countries have adopted MEY as a management target (Australia for example (Large et al, In press)).

[1] Noting that management approaches for deep-water ecosystems are addressed later in this Deliverable.

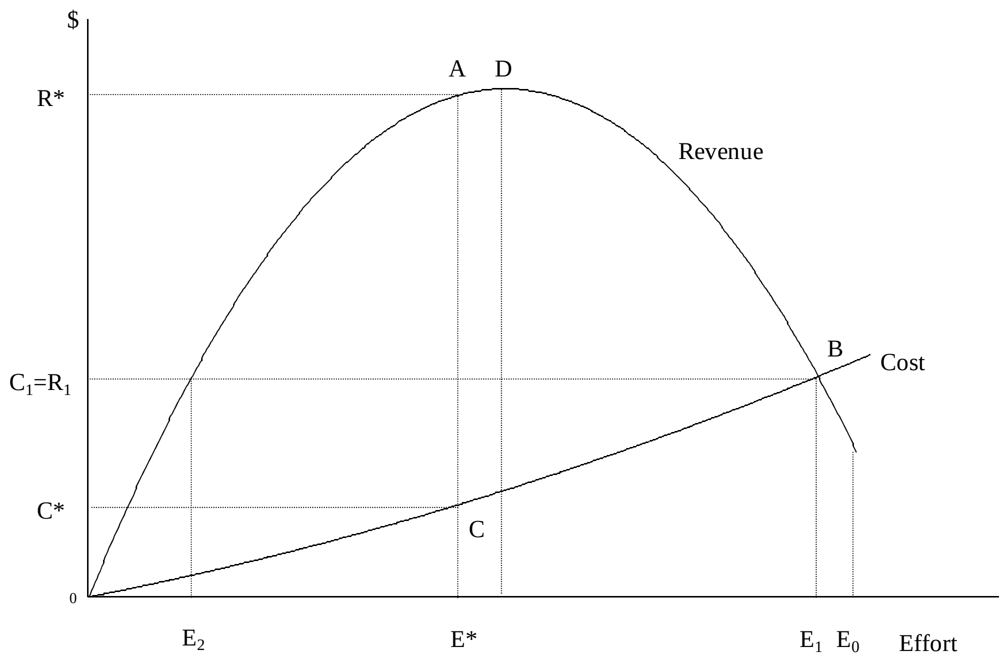

Figure 1. The general relationship between costs and revenue (y axis) and fishing effort (x axis).

Effort beyond E* will lead to declining profits. At point B, where effort equals E1, total revenue equals total costs and there are no profits. There are no incentives to increase effort beyond E1, as costs then always exceed revenues. By contrast, new vessels will enter the fishery if the level of effort falls somewhere between E* and E1 or those already taking part in the fishery intensify their efforts, as profits are then positive. The long-term equilibrium in an open access unregulated fishery can therefore only occur at point E1, irrespective of the size and productivity of the underlying natural resource.

The problems of unregulated fishing can thus be said to manifest themselves as (Arnason, 2009):

- Excessive fishing fleets and effort
- Too small fish stocks
- Little or no profitability and unnecessarily low personal incomes
- Unnecessarily low contribution of the fishing industry to the GDP
- A threat to the sustainability of the fishery

These problems were all evident to various degrees in most deep-water fisheries in the NE Atlantic prior to the introduction of the EU Access Regime in 2002, and subsequent management measures introduced in international waters by NEAFC. Although some progress has been made by these regimes, there remains a strong need for a robust and effective management and monitoring framework for deep-water fisheries, stocks and ecosystems in the NE Atlantic. From an economic point of view, the main objective of management policy should be to induce harvesters to change their level of effort to that corresponding to MEY, but given the commitment by the EU to harvest all fish stocks at fishing levels corresponding to MSY by 2015 (EC, 2006), this must be a primary aim of any proposed new management framework.

It is possible to group the different fisheries management systems in a number of different ways, including biological and economic (Arnason, 2007) and input and output controls (FAO, 2002). Here we do not make any explicit grouping but simply review the various management tools available and highlight their strengths and weaknesses.

Total Allowable Catches (TACs)

TACs are the main management tool in the current EU Deep-water Access Regime and, by definition, these limit the tonnage of fish that may be caught in a defined management area in a specified period of time. A major general weakness of TACs is that the unlanded part of the catch (discards) may be a substantive part of the total catch (Alverson et al, 1994), and if these are not included in TAC monitoring then the TAC effectively becomes a TAL (Total Allowable Landings) and the discarded component of the catch remains unregulated. This is of importance in many mixed-species deep-water trawl fisheries where discards can be high and can include seriously depleted species (e.g., deep-water sharks). A further problem is that almost all discarded deep-water species die due to barotrauma and, in trawl fisheries, abrasion in nets (Connolly and Kelly, 1996; Koslow et al., 2000). Notwithstanding, TACs are attractive to managers because they expedite the allocation of resources between countries in internationally shared fisheries (most deep-water fisheries in the NE Atlantic are of this type). However, NEAFC has used TACs to manage only one species currently listed in the EU Access Regime (orange roughy) and there is currently no TAC in place for this species due to a lack of agreement between Contracting Parties (CPs). TACs are perhaps the only effective management tool for fisheries targeting fish aggregations where catches are variable (depending on trawling success), but potentially extremely high in a very short period of fishing time (thereby rendering effort management to be far less effective for such fisheries).

A major problem with TACs is that they only limit catches in a particular period. They do not address the fundamental economic problems associated with open access fisheries. Thus, setting a TAC does not change the incentives of the fishermen; the race to fish will continue until the TAC has been exhausted. It is, however, likely that the harvesting season will become shorter after the introduction of the TAC. This holds regardless of whether the TAC is set at a national or international level. Setting a total TAC for an international fishery and then a country quota for each of the nations involved will therefore have the same effects as setting a TAC in a purely domestic fishery.

Another major problem with TACs (and output controls in general) is non-compliance (under-reporting or over-reporting; the latter to obtain track record in years preceding the introduction of TAC regulation) or circumvention of regulations (mis-reporting by species or management area). Non-compliance may be a problem in deep-water fisheries because in EU fisheries observers are scientific observers and as such the extent of observer coverage is set following general scientific sampling protocols and not on the basis of compliance protocols (usually requiring 100% observer coverage). However, onboard observations are not the only option to control TACs, as long as they are recognised to be TALs and discarding is permitted. The current EU Access Regime includes a licence scheme and designated ports of landing for deep-water species and these provide another option contributing to the effective control of quantities landed. The situation is worse in international waters where NEAFC only requires observer coverage on vessels fishing in new bottom fishing areas, i.e., outside the existing bottom fishing footprint.

Mis-reporting by species in EU fisheries may be further exacerbated by the small number of deep-water species currently regulated by TAC. As a consequence, some landed species are unregulated. An additional concern is that current EU TACs are allocated to management areas yet the delineation of these areas in many cases is somewhat arbitrary and is not based on robust information on stock identity, which for most species is currently lacking. These concerns are addressed later in this Deliverable.

Management by effort and capacity controls

The control of fishing effort and restrictions on the number of vessels licensed to fish for deep-water species (often both referred to as input control or direct economic restriction) are the second major component of the current EU Deep-water Access Regime. The attempted control of fishing effort is essentially the only macro-level management control in the NEAFC RA. We use the word "attempted" deliberately here since CPs have not agreed a common reference period, thus allowing a CP to select a reference period when fishing levels are high and therefore comply on paper with agreed reductions in fishing effort without any real reduction in the actual amount of effort expended. In a wider RFMO context, the agreement of a common reference period has recently been identified as best practice (TXOTX, In preparation).

In EU waters, deep-water fishing effort is monitored as reported effective effort (kilowatt-fishing days for trawlers, for example; EC, 2002) and for all types of fishing methods in NEAFC waters as aggregate power, aggregate tonnage, fishing days at sea or number of vessels (NEAFC, 2010). Monitoring fishing effort using alternative methods is problematic. Monitoring using VMS data is difficult because although methods have been developed to differentiate steaming from fishing for trawlers (Lee et al. 2010 and literature therein), such methods are not appropriate for vessels using fixed gears and, because of the assumptions made, have only hitherto been applied for trawlers for scientific purposes. The use of observers is also problematic because observer coverage is usually inadequate for real-time effort monitoring and compliance. Notwithstanding, there are also problems with estimates of effective effort for trawlers since information on vessel brake-horsepower can be compromised because engines can be 'de-rated' in a variety of ways (some legal and some illegal) to alter their actual engine power (FAO, 2002).

A major weakness of effort management is that it assumes a constant proportionality over time between fishing effort and fishing mortality (F), but this is rarely the case because of technical improvements in vessel design and fishing gear technology (often referred to collectively as 'technological creep') and skipper ability (Marchal et al. 2007, Eigaard, 2009; Eigaard et al, 2001). The latter is particularly relevant in new and developing deep-water fisheries. Consequently, the only way of attempting the control of effective fishing effort is by extensive regulation of the parameters contributing to technological creep, but this can be administratively difficult, extremely costly and technically challenging. Small changes in fishing gear, such as changes in hook size by longliners and minor changes to trawl design, can have significant impacts on fishing power that are difficult to evaluate without extensive and costly gear trials. Furthermore, observer coverage is usually inadequate for real-time monitoring and compliance.

From an economic standpoint, input restrictions prevent harvesters from choosing the input composition that minimises costs. Time restrictions limit the duration of use of capital assets, (e.g., vessels). Consequently, the capital in question must be used more intensively during the allowed fishing period, and in combination with a higher level of variable inputs (gear, crew, etc.; Anderson, 2004). Costs will therefore increase. Gear restrictions also tend to discourage efforts to increase productivity. However, such restrictions may be a valuable part of a programme designed to slow down the turnover rate of fishing equipment and the potential for technological creep (Anderson, 2004).

It is often argued that fishing effort controls rather than TACs should be applied to mixed species fisheries, as the former may result in fewer discards (if single species TACs are applied, some may become exhausted but fishing may be allowed to continue and these species discarded). However, the relationship between fishing effort and F may be further confounded by changes in catchability. These can be driven by changes in the species-directivity of fishing arising from a range of drivers which can include (i) changes in the depth of fishing, (ii) changes to the design of fishing gears, (iii) changes in the seasonality of fishing (if fish show seasonal aggregating patterns, for example) and (iv) changes in the diurnal pattern of fishing (if fish show diurnal patterns of vertical migration in the water column). The effect of these changes with time will be minimal if the proportion of fishing effort in each category of such factors remains relatively constant from year to year, but if this proportion changes, then the species-specific F generated by fishing effort will change. These factors are often overlooked when effort control is advocated as suitable tool for managing mixed species fisheries.

Measures to control fishing effort often include restrictive licensing to limit the total number of vessels engaged in particular fishery and their fishing power. As discussed further below, fishing licenses may be regarded as constituting a property right, albeit of rather limited quality. When such schemes are introduced they are often inclusive, to reduce initial resistance from fishers, and as a consequence they can include vessels which mostly participate in other fisheries. These vessels constitute a latent fishing capacity, whose effort can expand should there be opportunities/drivers to do so (FAO, 2002). This was likely the case when the EU Deep-sea Access Regime was introduced in 2002. Although there have been enforced reductions in the overall level of EU deep-sea fishing effort, there likely remains substantive latent capacity. A further concern is that measuring and monitoring deep-water fishing effort may have been compromised by a lack of clarity regarding the definition of deep-water species and deep-water fishing (these issues are discussed later in this Deliverable).

Indirect fisheries management[2]

Indirect fisheries management (sometimes referred to as economic fisheries management) aims at changing the incentives of fishermen. This can either be done by taxing the industry or by establishing a rights-based management system. The former and its opposite, the provision of subsidies, will be addressed later when this Deliverable is finalised.

Property rights-based approaches to fisheries management attempt to eliminate the common property problem by establishing private property rights over the fish stocks. Since a major source of the economic problems in fisheries is the absence of property rights, this approach should be in principle successful in securing full economic benefits from the fishery. However, this approach is likely to be more effective in single nation fisheries and multi-nation fisheries where fisheries management has been delegated to a single management body (EU fisheries, for example), but is likely problematic in high-seas international fisheries such as those occurring in the NEAFC RA because of the number of CPs involved in fisheries and the fact that the method of allocation of CP quotas is a CP responsibility.

Rights-based management has the following benefits for the stocks and fisheries themselves:

- An effective system reduces the need for fishery management insofar as users are identified
- Fishers and fishing communities can better plan their resource harvesting, with users better able to maximise the value of the output within a conservation framework and to adapt to changing conditions
- Right-based systems can be adjusted to promote (or favour) certain gear types or fishing practices
- Long-term conservation measures become more compatible with fishers' long-term interests and may encourage adoption of a conservation ethic and responsible fishing practices
- Reduced number of fishermen and vessels
- Increased output per unit of effort
- Improved access to capital markets
- Market-orientated production leads to better quality products and a more stable level of production which increased revenue
- Lower variable costs
- Higher profits

[2] Parts of this section are taken from Arnason (2007).

- More emphasis on safety and security as there is no need to fish in bad weather

It is important to realise that the effectiveness of rights-based regimes depends crucially on the quality of the property right in question. A property right specifies the rights someone (the owner) has with regard to something (the property). A property right generally consists of a bundle of rights or characteristics (Alchian, 1965; Demsetz, 1967). Ownership of property yields the owner the power to manage his resource (like a farmer manages his land), dispose of it (sell, lease or bequeath), and enjoy its yield (crop, rent or royalty income). The number of distinguishable characteristics that make up any given property right may be high. According to Scott (1989, 2000) the most crucial property rights characteristics are security, exclusivity, permanence and transferability. A property right may be challenged by other individuals, institutes or the government. Security here refers to the ability of the owner to withstand these challenges and retain his property right. It is perhaps best thought of as the probability that the owner will be able to hold on to his property right. Exclusivity refers to the ability of the owner to utilize and manage his property without outside interference and to exclude others from doing the same. The right of a fisherman to go out fishing has exclusivity that diminishes with the number of other fishermen holding the same right. It should be noted that enforceability, i.e. the ability to enforce the exclusive right, is an important aspect of exclusivity. Permanence refers to the duration of the property right. This can range from zero, in which case the property right is worth nothing, to infinite duration. Leases are examples of property rights of a finite duration. Transferability refers to the ability to transfer a property right to someone else. For any scarce (valuable) resource, this characteristic is economically important because it facilitates the optimal allocation of the resource between competing uses. An important feature of transferability is divisibility, i.e., the ability to subdivide the property right into smaller parts for the purpose of transfer. Perfect transferability implies both no restrictions on transfers and perfect divisibility. We now turn to discussing the various forms of property rights systems which include (i) fishing licences, (ii) sole ownership, (iii) territorial use rights in fisheries (TURFs), (iv) individual catch quotas (ITQs), and (v) community fishing rights (CFRs) (Arnason, 2007).

Fishing licences, i.e. the right to conduct fishing, constitute a property right. However, this property right is quite far removed from the source of the common property problem, namely the fish stocks and to harvest from them. As a result, licence holders may still be forced to compete for shares in the catch with the resulting use of excessive fishing effort and capital. Therefore, fishing licences, even when their issue is very restrictive, are not capable of significantly remedying the common property problem and the economic consequences of the race to fish.

Sole ownership, is where one agent (individual or firm) is awarded the exclusive ownership over a resource or part thereof. By definition, sole ownership eliminates the common property problem. Consequently, the fishery should reach full economic efficiency. Although theoretically quite appealing, this arrangement cannot really be regarded as very practical, as the creation of this kind of monopoly would doubtless meet stiff resistance from excluded potential owners.

Territorial use rights (TURFs) in fisheries consist of the allocation of a specified area of the ocean and the associated seabed to a single owner (user). Being similar to a property right in a farm, the owner will have every incentive to husband his TURF efficiently. Consequently, this arrangement works very well for relatively sedentary fish stocks, i.e. those that remain within the confines of the TURF. In fact, under those circumstances, TURFs are virtually the same as sole ownership and should lead to full economic efficiency. For relatively migratory stocks, i.e. stocks that periodically migrate in and out of the TURF area, the effectiveness of TURFs is much reduced. Indeed, the indications are that a stock does not have to spend much time outside the TURF area for its beneficial effects to be nullified. TURFs have been found to be very effective when applied to species that do not move much such as certain types of shellfish.

Individual harvest quotas have been widely applied around the world with a fair degree of success. These are quotas that are issued to specified identities which can be fishing sectors, fishing communities or individual fishers. Harvest rights can be allocated to individual fishers on an annual basis as individual quotas or as rights to harvest annually a specified proportion of the resource (i.e., a fraction of the TAC). The latter can be in the form of individual transferable quotas (ITQs) which can be permanently bought and sold among fishers or as individual non-transferable quotas (INTQs) which are not permanently transferable. ITQs systems are applied in New Zealand, Iceland, Australia, Canada, United States, Chile, Peru and South Africa. As an example, under the ITQ system in Iceland, vessels are allocated permanent quota shares. Once the TAC for each species has been set, the seasonal quotas (annual catch entitlements, ACEs) are calculated as the product of the TAC and the quota share.

Benefits of individual fishing rights are that they allow a fisher to plan his fishing activity taking accord of his involvement in other fisheries and the needs of markets, thus avoiding the 'race to fish' each year, so that individual harvests can be taken at a lower cost with less incentive for over-capitalisation, which can occur with other types of management regime. According to standard economic theory, barring market imperfections, introducing an ITQ management system into a fishery should, through time, make it possible for a fishery to automatically reach a point of maximum profits (i.e. net economic benefits). This will be done in two ways. Firstly, by securing rights to a certain quantity of harvest[3] and enabling the holder to take this harvest in the economically most efficient way. Secondly, by facilitating quota trades. Given quota tradability, there will be a tendency for only the most efficient fishing firms to operate in the fishery. The less efficient firms will simply find it to their advantage to sell their quota and leave the fishery. Thus, under an ITQ system, there will be a convergence to the optimal use of overall fishing capital and fishing effort, and to the most efficient fishing firms operating in the fishery. This prediction has been verified in numerous empirical studies of actual ITQ fisheries. It follows, that an INTQ system, where trades are not permitted, will not be able to deliver the same results. It is important to realise however, that the ITQ system will not automatically lead to full efficiency in fisheries. For this, the level of TAC over time must be optimal and this is extremely difficult to achieve in data-poor fisheries.

One of the most visible outcomes of an ITQ system is the quota price, i.e. the price by which quotas are traded. This price, just as any other market price, represents the value of the marginal fish to society as a whole. At the same time, it represents a cost to the user of the quota. Thus, the quota price, can act as a deterrent to harvesting. Furthermore, it has been theoretically shown that the quota price is maximized along the profit maximizing path of the fishery. Thus, the quota price contains crucial and very visible information about the optimality of the TAC or lack thereof. Thus, if the quota price rises in response to a particular TAC setting, this indicates that the TAC was in the right direction and vice versa. In this way, the quota price can serve as guidance to the TAC setting authority (Arnason, 1990). Further, Newell et al (2005) have shown that in terms of trends in market activity, price dispersion and the fundamentals determining quota prices, ITQs management systems can be effective instruments for efficient fisheries management.

Disadvantages of individual harvest quotas are broadly similar to those for catch controls in general and include incentivising under-reporting, dumping, discarding and high-grading (thereby allowing a fisher to directly increase the value of landings and consequently maximise the profit obtained from the corresponding quota). However, a possible deterrent to these practices, at least for ITQs and INTQs, is that these systems should encourage fishers to have a longer term view regarding the conservation of stocks and the sustainability of fisheries, because they actually own the catching rights. In the ITQ system applied in New Zealand (where discarding is banned) there is some

[3] Defined as a share in whatever TAC is set.

flexibility in annual catch-quota balancing provided by a carry-over allowance and the payment of a landing tax, the deemed value, for every fish landed above quota (Marchal et al, 2009). If ITQs are introduced in the EU, such a system may be appropriate.

Community fishing rights (CFRs), where exclusive harvesting rights are given to a community (e.g. group of fishermen, village, municipality etc.). These exclusive rights may apply to the whole fishery or a certain share of it, in the form of a community fishing quota for example. With this exclusive asset in hand, the hope is that the group will somehow find a way to manage it efficiently. Fundamentally, this belief rests on the argument that if property rights are clearly defined and bargaining and enforcement costs sufficiently low, then there is good reason to expect the parties involved to come to a mutually beneficial conclusion. In the case of fisheries the mutually beneficial conclusion would be the introduction of efficient fisheries management. The main disadvantage of CFRs as a way toward good fisheries management is that this simply may not happen. It is important to realise that CFRs do not constitute a fisheries management system. They merely represent devolution of the fisheries management authority from a higher level to a lower level. The community will still have to deal with the problem of designing and implementing a good fisheries management system.

The fisheries management developed by a community will depend on various factors including the decision making process, group dynamics and coherence. To increase the probability of success, it is imperative that (i) the rights allocated to the communities should be as high quality as possible, (ii) the communities have the ability to exclude new members, (iii) the communities should consist of as homogenous group of fishermen as possible and (iv) the communities should, if at all possible, be set-up so that each member's pay-off is an increasing function of the aggregate pay-off. If these four conditions are met, there is a high probability that the fisheries community will manage its rights in an efficient manner. Other advantages of CFRs are that they are often socially acceptable and facilitate effective enforcement of fisheries management rules on the basis of social and physical proximity and social group pressure. Obviously for this latter advantage to be effective, the group or community in question has to be reasonably small and socially coherent.

Although, in most cases, it would be overly optimistic to expect a speedy resolution to the fisheries management problem on the basis of CFRs, the allocation of exclusive fisheries property rights to communities may actually be the best option in many situations where the implementation of individual quota property rights are simply not feasible. This actually seems to be the case in many fisheries in the world, not least in many artisanal types of fisheries where there are a great number of participants and little social infrastructure. In addition, the devolution of fisheries management authority to communities may, in many cases, remove a thorny problem from the higher authority and thus be politically attractive.

Regarding the macro-management of deep-water stocks and fisheries in the NE Atlantic, the use of CFRs is unlikely to be appropriate given the spatial extent of most stocks. Possible exceptions include the artisanal fisheries for black scabbardfish (*Aphanopus carbo*) off Portugal (ICES Sub-area IX) and for blackspot seabream (*Pagellus bogaraveo*) in the Straits of Gibraltar. However, both species are likely to be highly migratory (particularly black scabbardfish) and therefore any allocated CFRs may have to be embedded in a broader-based management system.

Views on macro-management regimes by participants attending/contributing to DEEPFISHMAN Stakeholder Workshops[4]

An important outcome of the stakeholder consultations was that the diversity of situations of deep-water fisheries was reflected in the diversity of opinions on suitable management measures (Lorance et al, 2011). A "one size fits all" approach was not seen as satisfactory. A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis (Horn et al, 1994) suggested that no single management tool was sufficient. Questionnaires and cognitive maps (Özesmi and Özesmi, 2003; Prigent et al., 2008) supported this view and further suggested that a different combination of management measures may be suitable at fishery/regional levels. The SWOT analysis identified TACs and effort regulation as the macro-management measures potentially applicable to deep-water fisheries. Stakeholders, expressing their views by questionnaire, were dissatisfied overall with current fisheries management. Around 50% of responses suggested that TACs, effort control and licenses should be changed to varying degrees, ranging from radical to minor adjustments. However, the favoured method of implementation was self-management by fishers.

Summary and conclusions of the DEEPFISMAN review of 0

- *From an economic point of view, the main objective of management policy should be to induce harvesters to change their level of effort to that corresponding to MEY, but given the commitment by the EU to harvest all fish stocks at fishing levels corresponding to MSY by 2015 (EC, 2006), this must be a primary aim of any proposed new management framework.*

- *The agreement of a common reference period has recently been identified as best practice (TXOTX, in prep.). This is in relation to a wider RFMO context, to address the fact that CPs have not agreed a common reference period, thus allowing a CP to select a reference period when fishing levels are high and therefore comply on paper with agreed reductions in fishing effort without any real reduction in the actual amount of effort expended.*

- *Fishing licences, even when their issue is very restrictive, are not capable of significantly remedying the common property problem and the economic consequences of the race to fish.*

- *Sole ownership arrangements cannot be regarded as very practical, as the creation of this kind of monopoly would meet stiff resistance from excluded potential owners.*

- *Territorial use rights (TURFs) have been found to be very effective when applied to species that do not move much such as certain types of shellfish.*

- *Individual transferable harvest quotas (ITQs) can be effective instruments for efficient fisheries management.*

- *The use of community fishing rights (CFRs)* for *macro-management of deep-water stocks and fisheries in the NE Atlantic is unlikely to be appropriate given the spatial extent of most stocks, therefore any allocated CFRs may have to be embedded in a broader-based management system.*

[4] Participants/contributors included fishers from (i) the French mixed deep-water trawl fishery in the NE Atlantic, (ii) the Spanish and Portuguese trawl fishery for Greenland halibut (*Reinhardtius hippoglossoides*) in the NAFO RA and (iii) the artisanal longline fisheries for black scabbardfish off Portugal and blackspot seabream in Greek Ionian waters and in the strait of Gibraltar. Consequently the views expressed may not be representative of all deep-water fisheries in the NE Atlantic or individuals within these fisheries.

Recommendations by the DEEPFISHMAN Consortium

- *DEEPFISHMAN recommends that EU vessels fishing for deep-water species[5] in EU waters and in international waters of the NEAFC RA continue to be managed by TACs and effort/licensing.*

- *Notwithstanding, DEEPFISHMAN recommends that the TAC and effort regimes currently incorporated in the EU Access Regime should be substantially revised in content and scope and this is addressed later in this Deliverable.*

- *Consistent with proposed CFP reforms (EC COM, 2011), DEEPFISHMAN recommends the introduction of a system of transferable fishing rights (preferably ITQs) for EU vessels having deep-water licences. Distributed by Member States, the concessions will grant their owner an entitlement to a share of the national fishing opportunity for each year. Operators will be able to lease or trade their shares. This will give the fishing industry a long-term perspective, more flexibility and greater accountability, while at the same time reducing over-capacity.*

  In making this recommendation the Consortium assumes that ITQs will be tradable between fishers in different Member States, subject to the principle of overall relative stability (which we assume will remain in the reformed CFP).

- *DEEPFISHMAN recommends that TACs be evaluated using management strategy evaluation (MSE) for all three DEEPFISHMAN Case Study stocks[6] to be investigated (Diez et al., in prep). Diez et al. (in prep) suggest that the effort management could be used as an alternative management mechanisms for beaked redfish (Sebastes mentella) and blackspot seabream but not for blue ling, as effort control is considered poorly effective for an aggregating species. However, as result of the protection areas introduced for spawning aggregations of blue ling (Large et al, 2010) in EU waters (EC, 2009b), it is very likely that much of the F expended on this stock occurs in the mixed trawl demersal fishery outside the spawning season when the species is disaggregated. Consequently DEEPFISHMAN recommends that effort control also be included in MSE studies of this stock.*

- *DEEPFISHMAN recommends that vessels of all nationalities fishing for deep-water species in international waters of the NEAFC RA should continue to be managed by TACs and effort control. However, these regimes should be revised and considerably strengthened as described later in this Deliverable.*

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[5] To be defined below in the section on definition of deep-water species and fishing.

[6] Beaked redfish in ICES Sub-areas I and II; blue ling in ICES areas Vb,VI,VII and XIIb and blackspot seabream in Sub area IX.

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Topic 2. Definition of deep water and deep-water species

At present there is not an agreed world-wide definition of 'deep water'. Deep water is defined by the United Nations (UN) Food and Agriculture Organisation (FAO) as all depths >200 m. In the NE Atlantic, ICES in 2005 advised an identical definition (>200 m) corresponding with sea areas beyond the edge of the continental shelves (ICES, 2005). Justification for a depth limit may be sought through understanding environmental, bathymetric and oceanographic considerations (Dye, 2010). The major difference between deep and shallow environments is found at the offshore edge of the continental shelf, where the seafloor transitions to continental slope at the continental shelf break and is characterised by a markedly increased slope toward the deep ocean bottom. The shelf may break at a depth as shallow as 20 m or as deep as 550 m; the worldwide average depth is 133 m. In European waters it is usually considered to be at about 200 m.

Light and productivity zones in the ocean provide a classification of the water column (Figure 2). In the euphotic zone light is available for photosynthesis to the depth of the 'compensation level', below which there is no net primary production as the reduction in light means that oxygen production and consumption by photosynthesis and respiration balance. The light at this depth is about 1% of that of the surface. For the clearest oceanic waters this depth can be 110 m. Some of the light towards the green and blue end of the spectrum can penetrate deeper but does not support net growth. This can reach as deep as 1000 m but is generally considered to extend to around 200-500 m and is called the dysphotic zone. The aphotic zone below 200-500 m is dark.

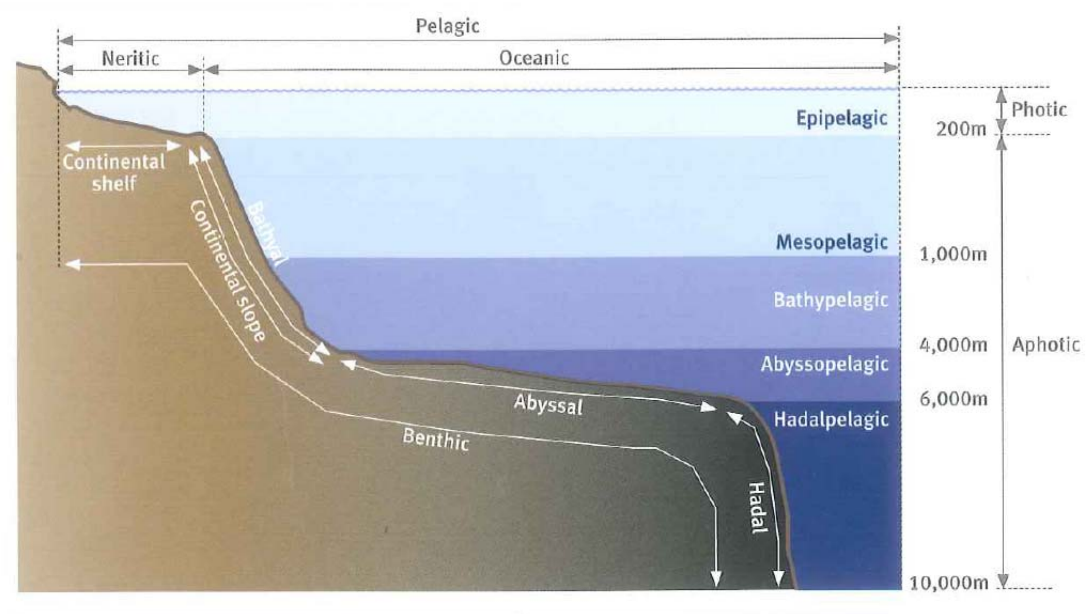

Figure 2. Graphic definition of the different zones in the ocean.

None of the environmental/bathymetric/oceanographic arguments provide a strong rationale for either 200 m or 400 m as a set depth for the upper boundary of 'deep water'. Good arguments could be made for setting it at as shallow as 100 m or as deep as 1000 m. The logical choice in this case is to opt for the shallower of the two limits, which has the benefit of fitting best the short-hand oceanographic use of the 200 m contour as the limit between shelf seas and oceanic waters (Dye, 2010). DEEPFISHMAN recommends that in the NE Atlantic deep water be defined as waters where the depth is >200 m; this is consistent with the FAO definition applied globally in all of the world's oceans.

The lack of an agreed definition of 'deep water' has perhaps contributed to a lack of a common definition of deep-water species across the various management bodies that manage deep-water fisheries and ecosystems around the world (Large et al, in press). This, and the fact that some species are distributed on continental shelves as well as in much deeper waters (Hake, greater forkbeard, blackbelly rosefish, anglerfishes, for example), has likely contributed to problems regarding developing an agreed definition of deep-water species. Furthermore, alternative identification criteria such as the use of life history characteristics are problematic because not all species are slow-growing and long-lived. Alfonsino (*Beryx splendens*) and black scabbardfish (*Aphanopus carbo*) are two examples of species found entirely at depths >200 m but have a maximum age of only 17 years (FAO, 2005) and around 12 years (Pajuelo et al. 2008), respectively.

All of these issues have resulted in advisory and management bodies having difficulty in defining deep-water species for management and monitoring purposes. ICES uses the term deep-water fisheries for those fisheries that occur in depths >400 m (ICES, 2005). In New Zealand, deep-water species are defined very broadly and include species found deeper than 600 m such as orange roughy (*Hoplostethus atlanticus*), oreos (*Allocyttus niger*, *A. verrucosus*, *Pseudocyttus maculatus*), black cardinalfish (*Epigonus telescopus*), alfonsino (*Beryx splendens* and *Beryx decadactylus*), other species generally distributed between 200 and 600 m including pink cusk-eel (*Genypterus blacodes*), hoki (*Macruronus novaezelandiae*) and hake (*Merluccius australia*), and deep-water crabs which can be found at varying depths down to 1500 m. In the current EU Access Regime (EC, 2002), the rationale used for identifying deep-water species in the NE Atlantic is not clearly defined. The EU Scientific, Technical and Economic Committee for Fisheries (STECF) in 2010 recognised that discussions regarding the definition of deep-water species were ongoing (STECF, 2010), but has since not yet developed a final definition.

From the arguments presented above, it is evident that the use of a simple depth limit and/or life history characteristic as distinguishing criteria for the definition of deep sea will be flawed, so an alternative definition is required for management (and monitoring) purposes. A pragmatic way forward may be to define deep-water species on the basis of the relative proportionality of species biomass in 'deep' and shallow' waters. Deep-water species would be defined as those where more than 50% of the adult biomass occurs at depths greater than >200 m[7]. However due to a general lack of large-scale fisheries-independent survey data in most areas of the NE Atlantic, information on the depth distribution of species biomass is confined to localised areas where surveys have taken place, such as areas of the Rockall Trough to the west of Scotland (Basson et al, 2002), along the coasts of Norway including Spitsbergen, around the Faroes, Iceland and Greenland. In the absence of information on the depth distribution of species biomass along the European continental slope the only proxies available are differences in abundance as indicated by comparisons of time-series data of catch per-unit-effort (CPUE), landings per-unit-effort (LPUE) and landings from commercial vessels fishing in 'shallow' and 'deep' water, all of which are extremely coarse indicators likely to be confounded by a range of factors including differences in types of fishing gear (trawl design, for example) and in the species-directivity of fishing activity. Notwithstanding, these data, in combination with information on the minimum and maximum depth of distribution, provide most of the information available to inform on the depth distribution of most species likely to considered as potential deep-water species in NE Atlantic.

DEEPFISHMAN recommends that in the NE Atlantic deep-water species be defined as those which spend a significant part of their life-cycle at depths >200 m. More practically, this can be defined by >50% of adult biomass located at depths >200 m, or by >50% of expected lifetime spent at depths >200 m. Information on the depth distribution of species biomass should, where possible, be

[7] This is consistent with the FAO depth definition and contrasts with the depth limit of >400 m provisionally used by STECF (2010).

sourced from available fisheries-independent survey data and, in the absence of these, time series abundance and landings data from commercial vessels and available information on the maximum and minimum depth range of species distribution. DEEPFISHMAN recommends that where ICES rectangles straddle the 200 m depth contour, commercial CPUE, LPUE and catch data should be allocated as 'deep' where more than 50% of the area of the rectangle has a depth >200 m.

Such a definition would support the continued inclusion of almost all of the 46 species listed in Annexes I and II of the current EU Access Regime. Only conger eel (*Conger conger*) and Norway redfish (*Sebastes viviparus*) would be excluded. Although conger eel is found in the NE Atlantic at depths down to around 650 m (Cohen et al., 1990), based on ICES catch statistics (ICES, 2011a) the majority of landings are taken in areas where the depth is considerably <200 m. This species reproduces in deep water and thus may be mostly found at greater depths when spawning. Norway redfish is found mostly at depths <150 m although it can be found at depths up to 760 m (Froese and Pauly, 2005). Species such as ling (*Molva molva*), hake (*Merluccius merluccius*), megrim (*Lepidorhombus* spp.) and anglerfish (*Lophius* spp.) would continue to be excluded as time-series landings data suggest that these species are most abundant at depths <200 m. However, using the definition above, species such as tusk (*Brosme brosme*), Greenland halibut (*Reinhardtius hippoglossoides*), beaked redfish and blue whiting (*Micromesistius poutassou*) would qualify for inclusion as most of the adult biomass of these species is found at depths >200 m.

The inclusion of blue whiting in deep-water species is particularly relevant to the ecosystem approach as this species is a key in the trophic flow towards deep-water piscivorous species (Howell et al., 2009; Blanchard et al., in prep). Blue whiting, is a mesopelagic species that occurs in large schools at depths ranging between 300 and 600 m (ICES, 2011b) and fisheries for this species often take greater argentine (currently an Annex I species) as a by-catch. However, blue whiting is fished with pelagic trawls, so that fisheries do not qualify for the FAO criteria that fishing gears are in contact with the bottom. Blue whiting is also a large straddling stock, which management includes other considerations such as apportionment on fishing opportunities between EU and non-EU fleets. As a consequence, blue whiting needs to be taken into account in deep-water ecosystem assessment and management as done is current ecosystem modelling (Howell et al., 2009; Blanchard et al., in prep). These ecosytem models, allow to appraise to which extend natural and fishery induced variations in the biomass of blue whiting affect stocks of benthopelagic fish. The management of blue whiting should take into account this ecosystem effect, in an objective "to leave out in the sea a sufficient blue whiting biomass for its predators".

Based upon the above definition, the inclusion of some species usually considered deep-water may be questioned. For example, red sea bream (*Pagellus bogaraveo*) is distributed down to at least 700 m, but more than 50% of the stock biomass may be at depths <200 m (Morato et al., 2001). However, this may vary with area and much of the biomass in 'shallow' waters may comprise juveniles and only be present on a seasonal basis. In the strait of Gibraltar, adults are usually found at depths between 200 and 700 m (Gil, 2010) and this supports the continued inclusion of this stock in deep-water management and monitoring regulations.

Lastly, the 200 m criterion may not apply properly in all areas. It was tested for the West of the British Isles, Celtic Sea and Bay of Biscay, all areas where the shelf is rather wide.The relative distribution of teh biomass may be different in areas on norrow shelf such a the West of Iberia, where further testing should be carried out.

Licensing specifically applies to the 24 species listed in Annex I. Reporting of catch and effort information is also required for the further 22 species listed in Annex II (noting that these can be landed by non-licensed vessels). From a licensing standpoint, the rationale for the selection of only 24 species is not defined but presumably, these were considered to comprise the most commercially important species. Many of the species listed in Annex II are by-catch species, however several commercially important deep-water species are included such as blackspot seabream (for which there are EU TACs), deep-water red crab (*Chaceon affinis*) and wreckfish (*Polyprion americanus*). Furthermore, there is trend in deep-water fisheries for previously discarded by-catch species to become marketable and therefore landed. A recent example is the previously discarded common mora (*Mora moro*) which is now landed in Spain. This trend may become more prevalent if regulations regarding the landing of discards are introduced (see later in this Deliverable). DEEPFISHMAN recommends that for licensing purposes the species listed in Annex I and II be combined, that conger eel and Norway redfish be deleted and Greenland halibut[8], tusk and beaked redfish be included.

It is important that licensed species are aligned with the UNGA Resolutions 61/105 and 64/72 concerning the protection of vulnerable marine ecosystems (VMEs) and the long-term sustainability of deep-sea fish stocks. An important consideration is whether the species should include fish species and benthic fauna (sessile or mobile) that are normally discarded as an unwanted by-catch. DEEPFISMAN is of the view that all species listed should be subject to the monitoring of catches (as well as landings) and biological sampling, in both cases where observer coverage allows (see later in the Deliverable). Fish species included in the proposed list that demonstrate the characteristics of VME components (including protected, endangered and threatened species, slow growth, long-lived and late age of maturity (FAO, 2009)) include several of the listed species of sharks (specify which are PET species), orange roughy, roundnose grenadier, beaked redfish and some of the sharks (the leafscale gulper shark and the Portuguese dogfish for example). Other VME components and indicator species, such as corals and sponges are not included as these are not landed commercially and their management and monitoring is addressed later in the Deliverable.

A proposed list of species for consideration in the review of the EU Deep-sea Access Regime is attached as Annex 1.

The issue as to whether the EU licensing scheme should be applied to all EU deep-water fishing in the NE Atlantic (as it is at present) or whether separate licensing schemes should be introduced for individual fisheries is addressed later in this Deliverable.

Regarding the list of deep-water species used for management purposes by NEAFC (NEAFC, 2011), the definition used to identify these species is unclear but the list appears to be largely based on those species listed in Annex I and II of the EU Access Regime. The only differences in the NEAFC list are that tusk, ling and Greenland halibut are included. Taking into account the definition recommended above, DEEPFISHMAN recommends that tusk and Greenland halibut continue to be included, that beaked redfish is added, and that ling, conger eel and Norway redfish be removed.

Summary and conclusions of the DEEPFISHMAN review of Topic 2

- *The lack of an agreed definition of 'deep water' has contributed to a lack of a common definition of deep-water species across the various management bodies that manage deep-water fisheries and ecosystems around the world. This has resulted in advisory and management bodies having difficulty in defining deep-water species for management and monitoring purposes. Discussions regarding the definition of deep-water species were ongoing*

- *Licensing specifically applies to the 24 species listed in Annex I. Reporting of catch and effort information is also required for the further 22 species listed in Annex II (noting that these can be landed by non-licensed vessels). Many of the species listed in Annex II are by-catch species, however several commercially important deep-water species are included.*

[8] Noting that Greenland halibut was included in Article 3 the licensing regime in 2011 (EC, 2011).

DEEPFISMAN is of the view that all species listed should be subject to the monitoring of catches (as well as landings) and biological sampling.

Recommendations by the DEEPFISHMAN Consortium

- *DEEPFISHMAN recommends that in the NE Atlantic deep water be defined as waters where the depth is >200 m; this is consistent with the FAO definition applied globally in all of the world's oceans.*

- *DEEPFISHMAN recommends that in the NE Atlantic deep-water species be defined as those which spend a significant part of their life-cycle at depths >200 m. More practically, this can be defined by >50% of adult biomass located at depths >200 m, or by >50% of expected lifetime spent at depths >200 m. Information on the depth distribution of species biomass should, where possible, be sourced from available fisheries-independent survey data and, in the absence of these, time series abundance and landings data from commercial vessels and available information on the maximum and minimum depth range of species distribution. In areas of narrow shelf, this rule may need some adjustment.*

- *DEEPFISHMAN recommends that where ICES rectangles straddle the 200 m depth contour, commercial CPUE, LPUE and catch data should be allocated as 'deep' where more than 50% of the area of the rectangle has a depth >200 m. More accurate allocation based e.g. on VMS and match of landings and VMS data should de done wherever possible.*

- *DEEPFISHMAN recommends that for EU deep-sea licensing purposes the species listed in Annex I and II be combined, that conger eel and Norway redfish be deleted and Greenland halibut, tusk and beaked redfish be included.*

- *DEEPFISHMAN recommends that tusk and Greenland halibut continue to be included in species treated as deep-sea by NEAFC, that beaked redfish is added, and that ling, conger eel and Norway redfish be removed.*

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STECF, 2010. 33rd Plenary Meeting Report of the Scientific, Technical and Economic Committee for Fisheries (plen-10-01) plenary meeting, 26-30 April 2010, Norwich. Edited by J. Casey & H. Dörner.

Topic 3. Total Allowable Catch (TAC) management: review of the current list of species and the periodicity of TAC reviews

The EU introduced TACs for deep-water species in 2003 (EC, 2002). These TACs are reviewed biennially taking into consideration the ICES biennial advice for deep-water stocks. From an administrative standpoint, the TACs are documented in a stand-alone regulation separate to the general TAC regulation applying to most other stocks in EU waters, although due to operational needs since 2003, some deep-water species and stocks have been transferred to the general TAC regulation, greater argentine (*Argentina silus*) and blue ling in VI and VII for example. TACs are currently applied to the deep-water species listed in the current Access Regime (Table 1).

Table 1. Deep-water species listed in the current Access Regime.

Species	EU TAC Regulation[9]
Black scabbardfish	Deep-water
Alfonsino (*Beryx* spp.)	Deep-water
Roundnose grenadier	Deep-water
Orange roughy	Deep-water
Blue ling	Deep-water and General[10]
Blackspot seabream	Deep-water
Forkbeards (*Phycis* spp.)	Deep-water
Deep-water sharks[11]	Deep-water
Greater silver smelt	General

All 24 species (including the 17 shark species) listed in Annex I of the Access Regime are managed by EU TACs, however, in the 22 species currently listed in Annex II, only blackspot seabream is managed by TAC. As a consequence some landed species are currently unregulated.

Under Topic 2 (above), recommendations were made to revise the deep-water species listed under the Access Regime and to combine Annexes I and II for licensing purposes. Given that mis-reporting by species in EU fisheries may be further exacerbated by the small number of deep-water species currently regulated by TAC (EC, 2007), it is appropriate that the list of deep-water species managed by EU TAC should be revised and expanded. However, not all the species currently listed in Annex II are landed commercially and some are landed sporadically in quantities too small to make it feasible to set TACs (EC, 2007). Based on ICES landings statistics (ICES, 2011), DEEPFISHMAN recommends that EU TACs be introduced for the following:

- Common Mora (*Mora moro*) and the Moridae
- Rabbitfish (*Chimaera monstrosa* and *Hydrolagus* spp.)
- Baird's smoothhead (*Alepocephalus rostratus*)
- Wreckfish (*Polyprion americanus*)
- Bluemouth (Bluemouth redfish) (*Helicolenus dactylopterus*)
- Silver scabbardfish (*Lepidopus caudatus*)
- Black (deep-water) cardinal fish (*Epigonus telescopus*)
- Deep-water red crab (*Chaceon* (*Geryon*) spp.)

[9] These currently comprise Council Regulation (EU) No 1225/2010 of 13 December 2010 fixing for 2011 and 2012 the fishing opportunities for EU vessels for fish stocks of certain deep-sea fish species and Council Regulation (EU) No ?/2012 of ? January 2012 fixing for 2012 the fishing opportunities for certain fish stocks and groups of fish stocks, applicable in EU waters and, for EU vessels, in waters where catch limitations are required.

[10] Blue ling in EU and international waters of ICES Sub-areas VI and VII.

[11] Comprises the 17 species of deep-water shark listed in Annex 1 of the EU Access Regime.

However, considering the move toward a demand for more quantitative assessment, it should be noted that quantitative assessment of these species will not be feasible. Therefore, on an area basis, an alternative option is to assess to contribution of the landings of these species to total landings of deep-water species. Where they are only a small bycatch, setting the effort ceiling at level in line with the exploitation of the main target species may be asufficient option. This might prevent changes in the targeting toward these currently bycatch species, if ever it was regionally possible, for deep-sea fishing vessels to start targeting these previously bycatch species.

Greenland halibut and tusk, recommended for inclusion in the species remit for EU deep-water licensing purposes are currently managed by EU TACs and are included in the EU general TAC and quota regulation. However, redfish (*Sebastes* spp.) is managed as a generic TAC and DEEPFISHMAN recommends that consideration be given to allocating a specific EU TAC to beaked redfish (*Sebastes mentella*).

To include all deep-water species managed by EU TACs in the EU deep-water TAC and quota regulation would improve clarity and transparency but may require some harmonisation with ICES regarding the frequency of ICES advice, which in turn may be dependent on the revision of the species remit of ICES WGDEEP.

Of the species proposed above for EU TAC and quota regulation, only beaked redfish and orange roughy are currently managed by TAC in the NEAFC RA (NEAFC, 2011). DEEPFISHMAN recommends that the historical landings data for the NEAFC RA be evaluated to determine the scale and extent of landings of the species proposed for EU TAC regulation. Taking this information into consideration, and the potential for mis-reporting by species in unregulated fisheries, DEEPFISHMAN recommends that the deep-water species managed by TACs in the NEAFC RA be revised as appropriate.

Understandably, fisheries managers (both in the EU and at NEAFC), Regional Advisory Councils (RACs) and fishers are likely to be concerned about the administrative and operational overhead of increasing the number of species managed by TACs and quotas, however the extent of this overhead will depend, to a large extent, on the frequency of scientific advice and related reviews of TACs and the implementation of long-term management plans. ICES will shortly (March 2012) be holding a Workshop on the Frequency of Assessments (WKFREQ), which will also address the frequency of ICES advice. The outputs from this workshop will be taken into consideration in later drafts of this deliverable, however at this time it is useful to develop suggested changes to the frequency of reviews of EU (and NEAFC) TACs taking into account the life history characteristics of individual species, perceived stock dynamics, and the likely recovery rates of severely depleted stocks.

Of the species currently managed by EU TACs, orange roughy and deep-water sharks (especially Portuguese dogfish (*Centroscymnus coelolepis*) and leafscale gulper shark (*Centrophorus squamosus*) are particularly long-lived and slow growing, are seriously depleted in several stock areas and because of their life history characteristics their recovery is likely to be slow. Orange roughy is extremely long-lived (maximum recorded age 187 years (Nolan, 2004)) and slow-growing/late maturing (age 30-40 years (Nolan, 2004)) and little is known about recruitment which is likely episodic, possibly on a decadal scale. The two stocks of orange roughy of major interest to EU vessels are those in ICES Sub-areas VI and VII. The ICES advice for all stocks of orange roughy in the NE Atlantic is for no directed fishing (ICES, 2010), and has implemented, in response the EU, a zero TAC for all areas of the NE Atlantic (EC, 2010). New information on orange roughy is collated on an annual basis by ICES WGDEEP and ICES currently gives advice on these stocks biennially in advance of EU reviews of deep-water TACs. Given the above mentioned biological characteristics and stock dynamics, the current status of stocks and the current ICES advice, DEEPFISHMAN recommends that EU TACs for orange roughy be reviewed every five years.

A similar argument can be put forward for Portuguese dogfish and leafscale gulper shark and most of the other 15 species sharks which collectively are managed by a generic TAC for 'deep-water sharks' (see above). Portuguese dogfish and leafscale gulper shark (maximum age 70 years (Clarke et al, 2002)) are both considered to be long-lived species and are seriously depleted (ICES, 2010). The current ICES advice for deep-water sharks is for no directed fishing and EU TACs are currently set to zero (EC, 2010). DEEPFISHMAN recommends that EU TACs for deep-water sharks be reviewed every five years.

Roundnose grenadier (*Coryphaenoides rupestris*) (maximum age 60 (Kelly et al., 1997)) and beaked redfish (maximum age 75 years (ICES, 2010)) are also relatively long-lived and slow-growing, consequently the stock dynamics of these species likely operate relatively slowly. DEEPFISHMAN recommends that EU TACs for these species be reviewed on a triennial basis.

For all other existing and proposed deep-water species, DEEPFISHMAN recommends that EU TACs be reviewed biennially, except where long-term management plans are in place (see later in this deliverable).

As described above, the only deep-water species managed by TAC in the NEAFC RA are beaked redfish and orange roughy, and at present there is no agreement between Contracting Parties on the TAC for orange roughy. Given the problems encountered with this species it could be argued that it would be inappropriate for operational reasons to expand the species coverage of TACs and to make recommendations on the frequency of their review. Notwithstanding, it can be counter-argued that this should not be an excuse for not trying to attain best practice in the NEAFC RA by introducing management measures that take account of the life history characteristics of individual species, their perceived stock dynamics and the likely recovery rates of severely depleted stocks. DEEPFISHMAN recommends that if the range of deep-water species managed by TAC in the NEAFC RA is expanded, consideration should be given to reviewing these TACs with the same frequency as recommended above for EU TACs.

In identifying those species to be managed by TAC (whether by the EU or by NEAFC), in some areas where mixed-species fisheries exist, consideration should also be given to multispecies TACs (and possibly greater reliance on effort management and/or management at the fisheries level). These subjects are explored later in the deliverable.

It must be emphasized that the above proposed TAC regimens should be flexible, so that if new information becomes available on the status of stocks implying a change in the perceived level of stock or F used as a basis for ICES advice, then the EU and NEAFC TACs should be reviewed on an ad hoc basis.

Summary and conclusions of the DEEPFISHMAN review of 0

- *It is appropriate that deep-water species listed in Annexes I and II of the Access Regime managed by EU TAC should be revised and expanded. However, not all the species currently listed in Annex II are landed commercially and some are landed sporadically in quantities too small to make it feasible to set TACs.. Some landed species are also currently unregulated.*
- *TAC and quota regulation would improve clarity and transparency but may require some harmonisation with ICES regarding the frequency of ICES advice*

Recommendations by the DEEPFISHMAN Consortium

DEEPFISHMAN recommends that EU TACs be introduced for the following:

- *Common Mora (*Mora moro*) and the Moridae*

- *Rabbitfish (*Chimaera monstrosa *and* Hydrolagus *spp.)*
- *Baird's smoothhead (*Alepocephalus rostratus*)*
- *Wreckfish (*Polyprion americanus*)*
- *Bluemouth (Bluemouth redfish) (*Helicolenus dactylopterus*)*
- *Silver scabbardfish (*Lepidopus caudatus*)*
- *Black (deep-water) cardinal fish (*Epigonus telescopus*)*
- *Deep-water red crab (*Chaceon (Geryon*) spp.)*

- *DEEPFISHMAN recommends that consideration be given to allocating a specific EU TAC to beaked redfish (*Sebastes mentella*).*

- *DEEPFISHMAN recommends that the historical landings data for the NEAFC RA be evaluated to determine the scale and extent of landings of the species proposed for EU TAC regulation.*

- *DEEPFISHMAN recommends that the deep-water species managed by TACs in the NEAFC RA be revised as appropriate.*

- *DEEPFISHMAN recommends that EU TACs for orange roughy be reviewed every five years.*

- *DEEPFISHMAN recommends that EU TACs for deep-water sharks be reviewed every five years.*

- *DEEPFISHMAN recommends that EU TACs for Roundnose grenadier and beaked redfish these species be reviewed on a triennial basis.*

- *For all other existing and proposed deep-water species, DEEPFISHMAN recommends that EU TACs be reviewed biennially, except where long-term management plans are in place.*

- *DEEPFISHMAN recommends that if the range of deep-water species managed by TAC in the NEAFC RA is expanded, consideration should be given to reviewing these TACs with the same frequency as recommended above for EU TACs.*

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Topic 4. Review of TAC management units taking into account known information on stock structure

The currently accepted definition of a stock in fisheries science, is that of Begg et al. (1999), "…[a "stock"] describes characteristics of semi-discrete groups of fish with some definable attributes which are of interest to fishery managers".

In an ideal world, stock units used for fisheries assessment and management purposes would be self contained and spatially discrete. However, for many species, and not specifically deep-sea species, the scientific basis underlying stock definitions has been rather loose. In the case of deep-sea species, the criteria used to identify stocks is based on either theoretical considerations on the mixing of populations in relation to the hydrological and geological characteristics of fishing grounds (e.g. direction of currents, natural barriers, fish ecology), or comparison of trends in catch rates, or consistency with management units which set out specific access rights to deep sea stocks in accordance with Council Regulation (EC) No. 2347/2002 establishing TAC fishery management units. This has tended to result in the definition of deep-sea stock assessment units which may not actually correspond to biological populations.

For effective fisheries management there is therefore a need to spatially match (i) the extent of the target population or stock (defined by its actual spatial and temporal dynamics), (ii) the defined ICES stock assessment unit, and (iii) the corresponding EC fishery TAC management unit. However, for deep-sea stocks, discrepancies occur between these stock related spatial categories.

To overcome some of these differences, a workshop on stock discrimination was organised by ICES in 2007 (ICES, 2007). The workshop evaluated techniques that could be used for stock discrimination in deep-water species and examined the available information to identify stock units in the ICES area. The results of the workshop, and more recent studies on stock structure and life histories, are summarise below and then compared to the present EC management units defined by Council Regulation (EC) No. 1359/2008 in Table 2, to highlight any potential mismatches between stock assessment and TAC management units.

Ling (*Molva molva*)

Ling is not a deep-water species in the sesne of the EU regulation 2347/2002. DEEPFISHMAN treats it as not deep-water (see topic 2). Ling is however analysed in this section as a species under the remit of ICES WGDEEP and because it has some common ecological and commercial characteristic with deep-water species. The knowledge of the abundance and fisheries is also limited in several areas because it is mainly a bycatch, while in other areas significant targetted fishing occurs. There is currently no evidence of genetically distinct populations of ling within the ICES area. Differences in trends in CPUE per area were identified by Bergstad & Hareide (1996). ICES (2012a) shows an overall trend of increasing CPUE in Nordic (Barents, Faroese and Icelandic Seas) and EU waters. However, there are also inversed trends in adjacent areas such as VIa, stable or decreasing over 1999-2011, and VIb clearly increasing over the same period. The increase in CPUE in most areas may reflect a reduction of fishing effort and may not be informative in terms of stock structure. Therefore, the view expressed in ICES (2007) that "ling found at widely separated fishing grounds may be sufficiently isolated to be considered as separate assessment and management units, i.e. stocks, between which exchange of individuals is limited and has little effect on the structure and dynamics of each unit. Current ICES advice is that Iceland (Va), the Norwegian Coast (II), and the Faroes and Faroe Bank (Vb) have separate stocks, but that the existence of distinguishable stocks along the continental shelf west and north of the British Isles and the northern North Sea (Subareas IV, VI, VII and VIII) is less probable" cannot be further decided. Some microsatellite loci have been developed for ling (Ring et al., 2009) but have not been used yet for population identity. Other studies such as further analyses of CPUE trends and mean length might have been limited by fishery data availability. Ling is also a by-catch in several trawl fisheries and a target of longline fisheries. Although CPUEs derived from longlining are probably more sensitive to non-abundance factors (e.g. behaviour, selectivity) than CPUEs derived from trawling (Løkkeborg, 1994), comparative analyses of CPUE trends may be the best option to evaluate to what extent ling in different areas forms distinct dynamic populations.

Available evidence on ling stock discrimination is not sufficient to suggest changes to current ICES interpretation of the stock structure. Two types of studies may provide some progress: (i) analysis of fishery data (primarily trends in CPUEs and mean length) and (ii) genetics studies.

Blue ling (*Molva dypterygia*)

Biological investigations in the early 1980s suggested that at least two adult stock components were found within the area, a northern stock in Subarea XIV and Division Va with a small component in Vb, and a southern stock in Subarea VI and adjacent waters in Division Vb and VII. However, the observation of spawning aggregations in each of these areas and elsewhere suggest further stock separation. This was supported by reports of differences in length and age structures between areas as well as in growth and maturity. Egg and larval data from early studies also suggest the existence of many spawning grounds. The conclusion is that stock structure is uncertain within the areas under consideration. One problem with this definition is that juvenile blue ling of 0 to 5 years are not observed to the west of the British Isles. Some small blue ling occur in Faroese waters but do not seem to be at a level of abundance susceptible to support the recruitment (mainly between 7 and 9 years of age) of the adult stock blue ling exploited in Vb, VI and VII. Juvenile blue ling are seldom caught on the Scottish shelf. Very small blue ling, possibly of group zero, have only been observed off the coast of Iceland where they are caught in an Icelandic survey for Norway lobster (*Nephrops norvegicus*) (Gudmundur Thordarson, MRI, Iceland, pers. comm.). At least to the west of Scotland, it is considered that such small blue ling could not have passed unnoticed if it existed owing to the number and diversity of fisheries and scientific surveys. The Icelandic groundfish survey in spring catches blue ling from 20 cm and occasionally less, and commercial landings included fish from about 50 cm (ICES 2012a). There are no reasons that would make small blue ling catchable by scientific and commercial gears in Icelandic waters and not in Scottish and Faroese waters. Therefore, an alternative option could be that the bulk of blue ling occurring in the NE Atlantic come from nursery grounds located in Icelandic waters. The previously reported difference in growth and maturity may have several explanations, such as difference in age readings (there are no published successful intercalibration trials for this species) or different size range present in different areas, with possibly some relationship between the distance travelled during migration and size (i.e. faster growing individuals could migrate further away). Also, the proportion-at-age of mature individuals cannot be similar in all areas, just because to the west of Scotland no immature blue ling are caught.

It is recommended that the current practise of separating blue ling into a northern stock (Division Va and Subarea XIV) and a southern stock (Divisions Vb &XIIb, Subareas VI, VII) is continued until information from DNA microsatellite studies is available. The stock structure should then be reviewed. Future research should aim at developing Msat DNA primers, as genetic analysis has proven very informative in detecting potential population structure in other marine fish species such as Atlantic cod and Greenland halibut. Based upon the continuity of bathymetric features, blue ling from the western Hatton Bank is likely to be similar to those from the northern Hatton Bank (VIb). Therefore, including ICES Division XIIb in the assessment unit Vb, VI and VII could be considered. However, because of the much lesser abundance of blue ling on the Hatton Bank, this should not have a big impact on stock modelling.

In ICES subareas VIII and IX, blue ling does not occur and actual catches reported as blue ling are formed of the Spanish ling (*Molva macrophthalma*), mainly a by-catch species of other fisheries. A small TAC should be set for Spanish ling in these areas in order to allow vessels to land small by-catch of Spanish ling. A zero TAC should be set for blue ling in these Subareas in order to prevent misreporting.

On this basis the following assessment and management units should apply: Division Va and Subarea XIV (Iceland and Reykjanes ridge), Division Vb and XIIb and Subareas VI and VII (Faroes, Hatton, Rockall and Celtic shelf); all other areas were blue ling occurs I, II, IIIa, IVa, XIIa and XIIc. The latter grouping is a combination of isolated fishing grounds with rather small catch in recent years and these areas are grouped due to lack of data. Lastly a zero TAC should be set to prevent misreporting in areas VIII and IX where blue ling does not occur.

Tusk (*Brosme brosme*)

Adult tusk and tusk eggs have been found in all parts of the distribution area, but the banks to the west and north of Scotland, around the Faroes and off Iceland. The shelf edge along mid and north Norway seems to be the most important spawning areas (Magnússon et al. 1997). Nothing is known about migrations within the area of distribution. It is noteworthy that although studies of enzyme and haemoglobin frequencies showed no geographical structure, indicating that tusk in all areas of the north-east Atlantic, belong to the same gene pool (Bergstad and Hareide, 1996), a more recent Norwegian molecular genetics study examined the population structure of tusk using microsatellite DNA (Knutsen et al, 2009). This study demonstrated for the first time geographical heterogeneity within the ICES area such that the Rockall tusk appears to have a separate identity from that of the mid-Atlantic ridge. This study suggests that gene flow in tusk is limited by bathymetric barriers, a result which tends to support the appropriateness of inferring stock structure from basin-wide bathymetry. However, the role of this factor may be expected to vary between species depending on eggs buoyancy and larval stages duration, for example. Knutsen et al. (2009) did not include samples from the Hatton Bank in their study. As they found that bathymetry was the main factor for population distribution, it seems consistent to expect that tusk from the Hatton Bank is closer to tusk from the Rockall Bank.

Based upon the Norwegian genetic study, the following tusk stock assessment units currently used by ICES could be refined as Icelandic and East Greenland waters (Division Va and XIVb2), Mid Atlantic Ridge (Divisions XIVb1, XIIa and XIIc), Rockall and Hatton (Division VIb and XIIb), Norwegian Sea and Barents Sea (Subareas I and II) and all other areas (IVa,Vb, VIa, VII,…).

Greater silver smelt

The current ICES structure for greater silver smelt is that ICES Subareas I, II, IV, VI, VII, VIII, IX, X, XII and XIV and Divisions IIIa and Vb, are treated as a single assessment unit. Only the greater argentine around Iceland (Division Va) is treated as a separate assessment unit. During a benchmark meeting, ICES acknowledged that there was considerable uncertainty over stock structure in the northeast Atlantic and recommended a further appraisal of the oceanographic conditions, genetic characteristics, morphometric and meristic characteristics (ICES 2010b). There is no scientific data in support of the split between Va and all other areas in the NE Atlantic. As a large stock of a predominantly pelagic and migratory species, population units of greater silver smelt can be expected to be panmictic over wide areas.

Blue whiting

Blue whiting (*Micromesistius poutassou*) is considered in this section because it is a mesopelagic species, which is trophically crucial to benthopelagic deep-water fish. A large panmictic population is also the consensus view of blue whiting, where an ICES benchmark group decided to recommend assessment of blue whiting in ICES Subareas I–IX, XII and XIV as a single stock for assessment purposes (ICES 2012b). This decision was based on a thorough review of the best available science and considered that population structure suggested by some genetic and larval growth studies did not provide support to treat blue whiting in the NE Atlantic as several stocks. This underscores the notion that population genetic studies may not provide unambiguous results. Depending on the number of loci used and the number of cohorts, ages, years, sampling locations and seasons, and more generally overall samples size, different results may be obtained. Some genetic analyses suggest some genetic difference on the large spawning grounds located to the West of the British Isles. But migrations and changes over time of the spatial distribution of spawning do to allow considering this as evidence on separated stocks.

Orange roughy (*Hoplostethus atlanticus*)

The fishing grounds so far discovered in the North Atlantic have appeared to support relatively small aggregations of fish, usually associated with seamounts and other topographical features. There is no indication that aggregations that were depleted, particularly on the Hebrides Terrace Seamount, rebuilt, although significant orange roughy biomass occurs in other areas. The existing biomass of orange roughy is reflected by an acoustic survey carried out in 2005 on 7 seamounts on the slope of the Porcupine Bank, in Irish waters. The survey provided an estimated biomass of 19000 tonnes for the Porcupine Bank (ICES 2006). However, this estimate had a high level of uncertainty (CV of 60%), so management cannot rely on it. Video observations on the Bay of Biscay, Celtic Sea and west Porcupine slope also reveal the occurrence of orange roughy. It should be noted that recent video observations carried out as part of CoralFISH did not target orange roughy, so that the observation of it in most video transects suggests that it is quite frequent both on the Porcupine slope and in other areas. This suggest that although some local aggregations were depleted by fishing, the current population represents a significant biomass, which may be more that the total cmulated landings since 1990 considering the 19,000 tonnes estimates on the Porcupine slope alone.

Therefore, as the current total biomass may be more than 50% of the unexploited biomass, the absence of a rebuilding of depleted aggregations may suggest that there is little or no exchange between different aggregations of orange roughy, which should then be regarded as dynamically separated units to which fish recruit from juvenile areas. In other words, aggregations of adult fish would be mainly renewed by immigration of juveniles but adult fish would remain part of the same aggregations during all their life, or at least during a long time. As a consequence, there might not be separated genetic populations. This view is supported by several genetic studies having not found genetic structuring in orange roughy at ocean-basin scale (see Varela et al. 2012 and literature therein). As these authors report "this does not necessarily mean that populations are demographically connected" and they hypothesised three options for the observed results: (i) panmixia, (ii) recent differentiation that is undetected with mitochondrial markers, and (iii) few migrants per generation that maintain genetic connectivity, but not necessarily demographic connectivity. The view that adult aggregations are demographically distinct is supported by studies based on morphometrics, otolith microchemistry, and parasites that have found differences between locations within oceanic regions. There are however seasonal migrations between spawning aggregations and flat grounds where both juveniles and adult fish occur (Shepard and Rogan, 2006).

At the spatial scale of current management units, TACs would not prevent sequential depletion of local aggregations. These local aggregations do not represent genetic populations, but their sequential depletion implies a risk to the overall population. A secure way to manage orange roughy fisheries would be to assess the biomass of every aggregation and allow a sustainable catch from it. There is no known appropriate method to assess reliably the biomass of the small aggregations that occur in the NE Atlantic. Therefore the management at the scale of every aggregation is not currently achievable.

DEEPFISHMAN considers that management of sustainable orange roughy fishery could only be done at the scale of every small aggregation. In each aggregation a fishing mortality not exceeding that producing MSY, i.e. F between 0.04 and 0.05 should be applied to keep the biomass of every aggregation at or above a BMSY level. The techniques to assess the biomass of every aggregation in order to set the catch level associated with the target (below or equal to FMSY) remain to be defined. In the current technological context, the small aggregations of orange roughy that occur in the NE Atlantic cannot be managed sustainably.

Roundnose grenadier (*Coryphaenoides rupestris*)

ICES WGDEEP has in the past proposed four assessment units of roundnose grenadier in the NE Atlantic: Skagerrak (IIIa), the Faroe-Hatton area, Celtic sea (Divisions Vb and XIIb, Subareas VI, VII), the Mid-Atlantic Ridge 'MAR' (Divisions Xb, XIIc, Subdivisions Va1, XIIa1, XIVb1), and all other areas (Subareas I, II, IV, VIII, IX, Division XIVa, Subdivisions Va2, XIVb2).

This perception was based on what are believed to be natural restrictions to the dispersal of all life stages. The Wyville-Thomson Ridge may separate populations further south on the banks and slopes off the British Isles and Europe from those distributed to the north along Norway and in Skagerrak. Considering the general water circulation in the north Atlantic, populations from the Icelandic slope may be separated from those distributed to the west of the British Isles.

Recent genetic studies confirmed this view with a main difference in population in the Atlantic found on the mid-Atlantic Ridge at the Charlie-Gibbs Fracture Zone, and with little genetic structuring between the West of Scotland and Bay of Biscay (White et al., 2010). Otolith microchemistry confirmed that the mid-Atlantic Ridge, West of British Isles and Skagerrak (ICES IIIa) from 3 distinct population units (Longmore et al. 2011).

The management units currently in use seem appropriate for roundnose grenadier. Some structuring at smaller scale may exist (White et al. 2010). The same authors suggested depth structuring, while Longmore et al. (2011) showed that individuals migrate to deeper habitat with age, which was already visible from size distribution per depth (Mauchline and Gordon, 1984; Lorance et al., 2008). Therefore structuring within the 3 main populations is doubtful. Weak structuring may exist and in terms of science in support of management, it should not be regarded as a question specific to roundnose grenadier, but as a general question of how genetic diversity is maintained under demographically sustainable fishing. In other words, the question is to assess how spatial population genetic structure is conserved in a stock management unit exploited in line with the current policies (e.g. the PCP, MSFD in the European Union).

DEEPFISHMAN recommends that current stock definition is kept. As for most exploited species, further population structure monitoring and research is needed to evaluate whether the objective of maintenance of the genetic diversity are secured.

Black scabbard fish (*Aphanopus carbo*)

This species is distributed on both sides of the north Atlantic and on seamounts and ridges south to about 30°N. It occurs only sporadically north of the Scotland-Iceland- Greenland ridges. Juveniles are presumed mesopelagic and adults are benthopelagic. Its life cycle is not completed in just one area and either small or large scale migrations occur seasonally. It has been suggested that fish caught to the west of the British Isles are pre-adults that migrate south and this has been supported by recent work by Longmore et al. (2010). This, in combination with results from morphometric and stable isotopes (Longmore et al. 2010), suggest that black scabbardfish from the west of the British

Isles, west Portugal and Madeira may form one single panmitic population. The size distribution and maturity stages of commercial catch are consistent with this assumption of one single population unit with an ontogenic migration throughout the NE Atlantic. It is noteworthy that the assumed population migration extends to the central east Atlantic for spawning around Madeira. Lastly, this population structuring remains unconfirmed and some studies are on-going.

Nevertheless, for stock assessment and fishery advice, ICES currently considers three assessment units, namely (i) northern (Divisions Vb and XIIb and Subareas VI and VII), (ii) southern (Subareas VIII and IX), and (iii) all other areas (Divisions IIIa and Va Subareas I, II, IV, X, and XIV). Amongst the latter areas, the species occurs at a significant abundance level only in ICES Subarea X, Azorean area.

Although the main assumption has been for one single population in the NE Atlantic since the 1990s, stock assessment efforts have focused on smaller regions primarily because of fisheries of different types of fisheries (mixed trawl fishery to the west of the British Isles and longlines fisheries in southern areas) spatially separated by areas where the species is not exploited. Within DEEPFISHMAN, development of new assessment methods have included the development of CPUE standardisation to derive stock abundance indices for black scabbardfish in northern areas and a state-space model of the dynamic in ICES Division IXa. Although they are applied to parts of the spatial distribution of the population, these approaches treat black scabbardfish as one single population with abundance indices for the northern areas used as input in the modelling for the southern area. In the northern area only pre-adult fish occur, a population dynamic model would not be pertinent and the appropriate assessment and management can be based upon abundance and mean length trends, with indicators based upon both fishery and survey data. Owing to the availability of data from the onset of the fishery, there are options for using CPUE-based reference points and HCR (Little et al., 2011), but such an approach is not currently implemented in fisheries management in the NE Atlantic. The effect of the northern fishery on the adult population is taken into account through the integration of abundance indices from the northern area into the model of the southern area. In other words, although this model is used to assess the population stage in ICES Division IXa, it explicitly integrates the more complete life cycle. Therefore the current assessment and management unit allows for pertinent stock assessment and management of black scabbardfish.

DEEPFISHMAN recommends that further stock identity and migration studies are carried out to confirm or reject to current understanding of the stock and migration (which is already on-going).

Blackspot seabream (*Pagellus bogaraveo*)

ICES considered three different components for this species, namely (i) Areas VI, VII, and VIII, (ii) Area IX, and (iii) Area X (Azores region), (ICES, 1996; 1998a). The interrelationships of the (blackspot) seabream from Areas VI, VII, and VIII, and the northern part of Area IXa, and their migratory movements within these areas have been observed by tagging methods (Gueguen, 1974). However, there is no evidence of movement to the southern part of IXa where the main fishery currently occurs. In addition, recent studies show that there are no genetic differences between populations from different ecosystems within the Azores region (east, central and west group of Islands, and Princesa Alice bank) but there are genetic differences between Azores (ICES Area Xa2) and mainland Portugal (ICES Area IXa) (Stockley et al., 2005). These results, combined with the known distribution of the species by depth, suggest that Area X component of this stock can effectively be considered as a separate assessment unit. Available information, particularly from genetics and tagging studies, seems to support the current assumption of three assessment units, namely (i) VI–VIII, (ii) IX and (iii) X.

The current assessment and management area seem appropriate.

Greater forkbeard (*Phycis blennoides*) in all ecoregion

The Greater forkbeard is a gadoid fish which is widely distributed in the north-eastern Atlantic from Norway and Iceland to Cape Blanc in West Africa and the Mediterranean (Svetovidov, 1986). It is distributed along the continental shelf and slope in depths ranging between 60 and 800 m, but recent observations on board of commercial longliners and research survey vessels extend the depth range to below 1000 m.

ICES currently consider greater forkbeard as a single stock for the entire ICES area, but it is likely that the stock structure is more complex. However further studies are required to justify a change to the current assumption. Nevertheless, ICES has for assessment purposes split the stock into four different components according to the importance of the catches and their geographical distribution. The separation is for practical purposes only and does not pre-suppose that there are four different stocks of Greater forkbeard. The following assessment areas are used: (i) subareas I, II, III, IV and V, (ii)subareas VI, VII and XII (Hatton Bank), (iii) subareas VIII and IX, and (iv) subarea X (Azorean region). The presumption of some population structuring in greater forkbeard is primarily supported by the occurrence of juvenile fish on the shelf in several areas, suggesting several nurseries. As greater forkbeard is mainly a by-catch of deep-water and shelf fishery and is not presumed to be a vulnerable species, it may not be a priority for stock structure studies. Trends in fishery-dependent and survey indicators seem to be the most appropriate way forward for assessment of this species.

Alfonsinos/Golden Eye perch (*Beryx* spp.) in all ecoregions

The Alfonsinos (*Beryx* spp.) are deep-water species that occur throughout the world's tropical and temperate waters, in depths from 25 to 1300 m. Genetic studies suggest one single genetic population for both *Beryx splendens* and *Beryx decadactylus* (Hoarau and Borsa, 2000; Friess and Sedberry, 2011). These species are caught as small by-catch in most regions of the northeast Atlantic with some targeted fisheries in the Azores (ICES Subarea X), to the west of Portugal (ICES division IXa) and to a lesser extend in the southern Bay of Biscay (ICES Division VIIIc). The absence of genetic structuring in these species might derive from their extended pelagic larval duration (Lehodey and Grandperrin, 1996; Lehodey et al., 1997, Akimoto et al., 2006). Therefore recruitment to individual locations/seamounts comes from the basin-scale population of spawners. This life strategy is likely to buffer these species against loss of genetic components. In terms of fisheries management, the important issues are to maintain the basin-scale spawner population to levels where recruitment is not impaired and to exploit at a level producing MSY at local scale. The achievement of the latter objective should ensure the first. It is unknown whether local and/or sequential depletion, i.e. at seamounts scale in areas such as the Azores, is likely and can be detected. This might depend on the detail in the way fisheries are operated. However, there is little doubt that monitoring and assessing these species at smaller scale than the whole NE Atlantic is advisable. Therefore, it can be recommended to define 3 assessment and management areas: (i) ICES subarea X, (ii) ICES division VIIIc and IXa, and (iii) all other areas. The latter stands for areas where these species appear in fisheries as minor by-catch only.

Leafscale guper sharks (*Centrophorus squamosus*), Portuguese dogfish (*Centroscymnus coelolepis*) and other deep-water sharks

The current management units considered for deep-water sharks are: (i) the western European slope and Banks (ICES Subareas V, VI, VII, VIII and IX), (ii) the Azorean area and southern Mid-Atlantic ridge (ICES Subarea X), and (iii) the Northern Mid-Atlantic ridge (ICES Subarea XII). Because of lack of reporting of fisheries landings by species, TACs for each of these areas have been applied to all deep-water sharks confounded and have been driven to zero from year 2010, as a result of assessments that abundance was strongly declining.

These species are still caught and discarded in both trawl and longline fisheries in all areas. The current catch might however be overall much smaller that past catches owing to (i) the closure of target fishery, (ii) the incentive to mix-fisheries to avoid fishing locations where the shark by-catch is highest, because this by-catch is no longer marketable, and (iii) the overall drop in fishing effort in deep-water fishery, at least in the EU.

In ICES subareas V, VI, VII and VIII, fisheries have mainly landed *Centrophorus squamosus* and *Centroscymnus coelolepis*, in ICES subarea X the kitefin shark (*Dalatias licha*) may have been the main target. A number of other sharks have been caught and some, in particular birdbeak dogfishes (*Deania* spp.) have been landed in some areas. *Deania* spp. and *D. licha* occur throughout the NE Atlantic but *D. licha* is mostly abundant in the Azorean area (ICES Division X), where it has been subject to commercial fishery. This fishery is now closed through the 0 TAC for all deep-sea sharks.

The population structure of deep-water sharks might be species specific and may strongly differ from that of deep-water bony fishes because of the absence of larval stage, the high swimming capabilities of sharks and their large size. Genetic studies suggest that there is no genetic population structuring in the NE Atlantic for *C. squamosus* and *C. coelolepis* (Verissimo et al., 2011, 2012) so that the management by large areas is appropriate. It is not known if the common genetic population at the NE Atlantic scale encompasses one or several demographic populations. The stock structures of the kitefin shark and bordbeak dogfishes are unknown.

Because of the difficulties in assessing quantitatively elasmobranch populations it is unlikely that some population dynamic modelling can be achieved in the absence of (i) fisheries landing data (that usually helps raising population models to the absolute population size), and (ii) age composition. Therefore, the monitoring and management of deep-water sharks should be carried out using populations indicators derived from surveys and on-board observations. Monitoring and management are required to assess whether sharks populations recover under the current fishing pressure, and to take management actions if not. The most appropriate option could be to monitor abundance of sharks and manage fisheries at scale corresponding to the area of distribution of the main deep-water fisheries.

Table 2. Management units and stock assessment units of NE Atlantic deep-water stocks (shaded rows relate to species of deep-sea sharks for which there is no directed fishery permitted, and as such are assessed as by-catch only up to 10% of 2009 quotas). The current management units were taken from the council regulation (EC) No 1225/2010 of 13 December 2010 fixing for 2011 and 2012 the fishing opportunities for Community fishing vessels for certain deep-sea fish stocks and council regulation (EU) No 44/2012 of 17 January 2012 fixing for 2012 the fishing opportunities available in EU waters and, to EU vessels, in certain non-EU waters for certain fish stocks and groups of fish stocks which are subject to international negotiations or agreements. Assessment units were taken from ICES (2012a). Match column blank when there is not assessment (e.g. minor by-catch fishery).

Species	EC Management units	ICES Assessment units	Match	Comment	Recommendation
Roundnose grenadier	EU and international waters of: Vb, VI, VII (RNG/5B67-)	Faroe-Hatton area, Celtic sea (Divisions Vb and XIIb, Subareas VI, VII)	No	Advice for landings in are given separately for: - Vb, VI and VII - XIIb are given	Add XIIb to these areas
	VIII, IX, X, XII and XIV (RNG/8X14-)	Mid-Atlantic Ridge 'MAR' (Divisions Xb, XIIc, Subdivisions Va1, XIIa1, XIVb1)	No	EU TAC mostly exploited in XIIb and set according to advice for Divisions Vb and XIIb, Subareas VI, VII (see above). Minor EU fisheries in other areas	Separate XIIb (Western Hatton) from other areas in management unit and merge it with Vb, VI and VII
	III (RNG/03-)	Division IIIa	Yes		
	I, II, IV (RNG/124-)	All other areas (Subareas I, II, IV, VIII, IX, Division XIVa, Subdivisions Va2, XIVb2)		Small fisheries in all areas	
Black scabbardfish	EU and international waters of: I, II, III and IV (BSF/1234)	Other areas (Divisions IIIa and Va Subareas I, II, IV, X, and XIV)		Minor TAC set to prevent misreporting	
	V, VI, VII and XII (BSF/56712-)	Northern (Divisions Vb and XIIb and Subareas VI and VII)	No	In subarea XII, landings out of XIIb are minor	Separate XIIb (Western Hatton) from other area (Mid-Atlantic ridge) in management unit
	VIII, IX and X (BSF/8910-)	Southern (Subareas VIII and IX) Other areas (Divisions IIIa and Va Subareas I, II, IV, X, and XIV)	No	Most of the fishery in VIII and IX occur in IXa and in other areas in X, both are Portuguese	Split the management area in: - X - VIII and IX
	CECAF 34.1.2 (BSF/C3412-)	Not an ICES area		CECAF area 34.1.2 covers Madeira and Canaries, not appropriate to managed the assume spawning area around Madeira	
Greater forkbeard	EU and international waters of: I, II, III, IV (GFB/1234-)	Entire ICES Area	No	Recommended assessment from indicator trends by area	No change
	V, VI and VII (GFB/567-)	Entire ICES Area	No		
	VIII, IX (GFB/89-)	Entire ICES Area	No		
	X, XII (GFB/1012-)	Entire ICES Area	No		
Alfonsinos	EU and international waters of: III,IV, V, VI, VII, VIII, IX, X, XII and XIV (ALF/3X14-)	Entire ICES Area	Yes	Recommended monitoring and assessment from indicator trends by area	Split management areas as: -VIIIc and IXa X Other areas

Species	EC Management units	ICES Assessment units	Match	Comment	Recommendation
Orange roughy	EU and international waters of: VI (ORY/06-)	Northern (Subarea VI)	Yes	No current method for reliable monitoring	
	VII (ORY/07-)	Southern (Subarea VII)	Yes	No current method for reliable monitoring	
	I, II, III, IV, V, VIII, IX, X, XII and XIV (ORY1CX14C)	All other areas (Subareas X, XI, Vb, Va and XIV)	Yes	No current method for reliable monitoring	
Blue ling	Icelandic stock	Iceland and Reykjanes ridge (Subdivisions Va and XIV)	No	Catches in these areas are from Iceland and Faroe, management is under the jurisdiction of Iceland and relies upon effort ceiling	
	EU waters and international waters of Vb, VI, VII (BLI/5B67-)	Faroes Rockall and Celtic shelf (Division Vb and Subareas VI, and VII)	Yes	TAC applies to EU waters, ICES advice covers the full Vb area. The scientific recommendation for catch is treated by managers in the EU-Faroes Islands negotiation	Add Division XIIb to the management area
	II, and IV (BLI.24-)	All other regions (Subdivisions I, II, IIIa, IVa, VIII, IX, and XII)		Small TAC to manage small by-catch	Management area appropriate
	III (BLI/03-)	All other regions (Subdivisions I, II, IIIa, IVa, VIII, IX, and XII)		Small TAC to manage small by-catch	Management area appropriate
Red seabream	EU and international waters of: VI, VII and VIII (SBR/678-)	(Subareas VI, VII, VIII)	Yes		
	IX (SBR/09-)	(Subarea IX)	Yes		
	X (SBR/10-)	Azores (Subarea X)	Yes		
Portuguese dogfish	Community waters and waters not under the sovereignty or jurisdiction of third countries of V, VI, VII, VIII and IX (DWS/56789-)	One single assessment unit in the northeast Atlantic		Probably one single population unit in the NE Atlantic. TAC (currently 0) applies to all deep-sea sharks	Management area appropriate under the current regime of closed fishery
	Community waters and waters not under the sovereignty or jurisdiction of third countries of XII (DWS/12-)	One single assessment unit in the northeast Atlantic		Probably one single population unit in the NE Atlantic. TAC (currently 0) applies to all deep-sea sharks	Management area appropriate under the current regime of closed fishery
Leafscale gulper shark	Community waters and waters not under the sovereignty or jurisdiction of third countries of V, VI, VII, VIII and IX (DWS/56789-)	One single assessment unit in the northeast Atlantic		Probably one single population unit in the NE Atlantic. TAC (currently 0) applies to all deep-sea sharks	Management area appropriate under the current regime of closed fishery
	Community waters and waters not under the sovereignty or jurisdiction of third countries of XII (DWS/12-)	One single assessment unit in the northeast Atlantic		Probably one single population unit in the NE Atlantic. TAC (currently 0) applies to all deep-sea sharks	Management area appropriate under the current regime of closed fishery

Species	EC Management units	ICES Assessment units	Match	Comment	Recommendation
Kitefin shark	EU and international waters of X (DWS/10-)	One single assessment unit in the northeast Atlantic		Species occur at low density out of Azorean area (ICES Subarea X), where landings records back to 1972 exist (ICES 2011). TAC (currently 0) applies to all deep-sea sharks	Management and assessment area appropriate
Birdbeak sharks	Community waters and waters not under the sovereignty or jurisdiction of third countries of XII (DWS/12-)	No assessment		Birdbeak sharks are explicitly mentioned for the management area XII only, however. TAC (currently 0) applies to all deep-sea sharks in all areas	Management and assessment area appropriate

Summary and conclusions of the DEEPFISHMAN review of 0

- *DEEPFISHMAN examined available evidence on ling stock discrimination and concluded that available information is not sufficient to suggest changes to current ICES interpretation of the stock structure*
- *Blue ling stock structure is uncertain within the areas under consideration*
- *Based upon the Norwegian genetic study, the following tusk stock assessment units currently used by ICES could be refined as Icelandic and East Greenland waters (Division Va and XIVb2), Mid Atlantic Ridge (Divisions XIVb1, XIIa and XIIc), Rockall and Hatton (Division VIb and XIIb), Norwegian Sea and Barents Sea (Subareas I and II) and all other areas (IVa,Vb, VIa, VII,…).*
- *At the spatial scale of current management units, TACs of orange roughy would not prevent sequential depletion of local aggregations. These local aggregations do not represent genetic populations, but their sequential depletion implies a risk to the overall population. A secure way to manage orange roughy fisheries would be to assess the biomass of every aggregation and allow a sustainable catch from it. There is no known appropriate method to assess reliably the biomass of the small aggregations that occur in the NE Atlantic. In the current technological context, the small aggregations of orange roughy that occur in the NE Atlantic cannot be managed sustainably*
- *The management units for roundnose grenadier currently in use seem appropriate*
- *The current assessment and management area for blackspot seabream seem appropriate*
- *As greater forkbeard is mainly a by-catch of deep-water and shelf fishery and is not presumed to be a vulnerable species, it may not be a priority for stock structure studies. The important issues in its management are to maintain the basin-scale spawner population to levels where recruitment is not impaired and to exploit at a level producing MSY at local scale*
- *Because of the difficulties in assessing quantitatively elasmobranch populations it is unlikely that some population dynamic modelling can be achieved in the absence of (i) fisheries landing data (that usually helps raising population models to the absolute population size), and (ii) age composition. Monitoring and management are required to assess whether sharks populations recover under the current fishing pressure, and to take management actions if not*

Recommendations by the DEEPFISHMAN Consortium

- *DEEPFISHMAN recommends that comparative analyses of CPUE trends may be the best option to evaluate to what extent ling in different areas forms distinct dynamic populations*
- *DEEPFISHMAN recommends that the current practise of separating blue ling into a northern stock (Division Va and Subarea XIV) and a southern stock (Divisions Vb &XIIb, Subareas VI, VII) is continued until information from DNA microsatellite studies is available. The stock structure should then be reviewed. Future research should aim at developing Msat DNA primers. A small TAC should be set for Spanish ling in order to allow vessels to land small by-catch of Spanish ling. A zero TAC should be set for blue ling in order to prevent misreporting. Lastly a zero TAC should be set to prevent misreporting in areas VIII and IX where blue ling does not occur*

- *Management of orange roughy at the scale of every aggregation is not currently achievable. DEEPFISHMAN considers that management of sustainable orange roughy fishery could only be done at the scale of every small aggregation*

- *DEEPFISHMAN recommensd that current stock definitionof roundnose grenadier is kept. As for most exploited species, further population structure monitoring and research is needed to evaluate whether the objective of maintenance of the genetic diversity are secured*

- *DEEPFISHMAN recommends that current stock definition of black scabbard is kept. As for most exploited species, further population structure monitoring and research is needed to evaluate whether the objective of maintenance of the genetic diversity are secured*

- *Trends in fishery-dependent and survey indicators seem to be the most appropriate way forward for assessment of greater forkbeard*

- *Monitoring and assessing alfonsinos/golden eye perch at smaller scale than the whole NE Atlantic is advisable. DEEPFISHMAN recommends 3 assessment and management areas: (i) ICES subarea X, (ii) ICES division VIIIc and IXa, and (iii) all other areas*

- *DEEPFISHMAN recommends that the monitoring and management of deep-water sharks should be carried out using populations indicators derived from surveys and on-board observations. The most appropriate option could be to monitor abundance of sharks and manage fisheries at scale corresponding to the area of distribution of the main deep-water fisheries*

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Topic 5. Definition of deep-water fishing effort and capcity ceilings

Background

Depending on the case study fishery, defining deep-water fishing may be straightforward or not. Furthermore, within a multispecies deep-water fishery, there may be some need to allocate effort to individual species. Within DEEPFISHMAN case studies there are mono-species fisheries where all effort is clearly directed at catching the target species. For example, the black scabbardfish fishery in Portuguese waters (Table 2) targets a deep sea fish species as defined by Annex I of EU regulation 2347/2002, so the fishing effort for this fishery can be clearly defined as deep-water effort. However, not all fisheries operating in the deep-sea (>200 m) are targeting deep-sea species (see Topic 2).

Definition of deep-water fishing effort in the regulation

EU waters

In EU waters and for EU vessels fishing in international waters, the Regulation (EC) No 2347/2002 includes one article on effort restriction (Article 4). However, this article addresses the aspects of global fleet volume and power, i.e. fleet capacity, rather than fishing effort. For example, under the heading of effort restriction, it is capacity (defined by total fleet power and volume) that is regulated. This regulation obliges all vessels that capture more than 10 tonnes of deep-sea species in a year to have a deep-sea fishing permit, but vessels are allowed to land up to 100 kg per fishing trip without a permit. The total capacity of vessels holding deep-sea fishing permits was restricted to the aggregate capacity of the vessels that fished more than 10 tonnes of deep-sea species in any of the years 1998, 1999, 2000 (2000-2003 for the new Member States).

However, this cap on national fleet volume and power has been further used to reduce allowed effort from the annual TAC regulation. For 2008 (Council Regulation (EC) No 40/2008), the fishing effort, measured in kilowatt days absent from port by vessels holding deep-sea fishing permits, was limited to 75% of the average annual fishing effort deployed by the vessels of the Member State concerned in 2003, on trips when deep-sea fishing permits were held and/or deep-sea species, as listed in Annexes I and II to Regulation (EC) No 2347/2002, were caught. This limitation applies only to fishing trips on which more than 100 kg of deep-sea species, other than greater silver smelt, were caught. In subsequent years the fishing effort was limited to 65% of the 2003 level (Council Regulations No 43/2009, No 23/2010, 57/2011, 44/2012). These regulations actually set quotas of fishing effort per member states.

International waters based on FAO guidelines and UNGA resolutions

The FAO guidelines developed to implement the United Nations General Assembly (UNGA) Resolution 61/105 (FAO, 2009) defined deep-sea fisheries as those where (i) the total catch (everything brought up by the gear) includes species that can sustain only low exploitation rates, and/or suffer incidental mortality; and/or (ii) the fishing gear is likely to contact the seafloor. The references to fishing effort made in the guidelines are given and commented on below.

In the section titled 'Identifying vulnerable marine ecosystems and assessing significant adverse impacts', article 47 of the guidance states that "*Flag States and regional fisheries management organizations and arrangements (RFMO/As) should conduct assessments to establish if deep-sea fishing activities are likely to produce significant adverse impacts in a given area. Such an impact assessment should address, inter alia: type(s) of fishing conducted or contemplated, including vessels and gear types, fishing areas, target and potential by-catch species, fishing effort levels and duration of fishing (harvesting plan)*".

In the section ‘Enforcement and compliance’ of the guidance, article 54 states that “*Monitoring, control and surveillance programmes may include, inter alia [...] better assessments of fishing effort by gear*”. Effort estimation is presented here as one option for enforcement and compliance, but does not seem to be a mandatory component.

In the section ‘Management and conservation tools’ of the guidance, article 63 states that “*until a functioning regulatory framework is developed to prevent significant adverse impacts on VMEs and to ensure the long-term sustainability of deep-sea fisheries, conservation and management measures should include, at a minimum[...] refraining from expanding the level or spatial extent of effort of vessels involved in deep-sea fisheries and reducing the effort in specific fisheries, as necessary, to the nominal levels needed to provide information for assessing the fishery and obtaining relevant habitat and ecosystem*”. The essential point in this article is that effort should not be allowed to increase before it is shown to be sustainable at ecosystem level, in particular in terms of significant adverse impact on VMEs.

Article 65 states that “*Precautionary conservation and management measures, including catch and effort controls, are essential during the exploratory phase of a deep-sea fishery, and should be a major component of the management of an established deep-sea fishery. [...] Implementation of a precautionary approach to sustainable exploitation of deep-sea fisheries should include the following measures:*

i. *precautionary effort limits, particularly where reliable assessments of sustainable exploitation rates of target and main by-catch species are not available*

v. *comprehensive monitoring of all fishing effort, capture of all species and interactions with VMEs*”.

In this article of the guidance, effort is presented as an opportunity for a precautionary approach. In fisheries management, effort has often been used in cases where the stock(s) dynamics are not quantitatively known, i.e. the case refered to in point i. (above), but where exploited stock(s) were considered to have sustained a given level of effort for a long period. In such situations, it may not be known if the effort levels correspond to MSY or any other management objective, it is only empirically assumed that it is sustainable. This seems hardly applicable in the exploratory phase of a fishery were sustainable levels of effort are likely to be completely unknown. It may apply in some long-standing deep-water fisheries, such as the black scabbardfish fishery in Madeira, which has operated for over a century (Leite, 1988) without apparent impact on the population. However, there is no such long-standing fishery with apparent stable population dynamics in the DEEPFISHMAN case studies. Point v. of article 65 (above), claims for accurate effort monitoring and all fishery science experience reveals the importance of accurate stock data to support fish stock and ecosystem assessments.

Articles 70 and 71 recommend that “*States and RFMO/As should [...] adopt conservation and management measures to achieve long-term conservation and sustainable use of deep-sea fish stocks, ensure adequate protection and prevent significant adverse impacts on VMEs. These measures should be developed on a case-by-case basis and take into account the distribution ranges of the ecosystems concerned*”. Conservation and management measures applicable to these fisheries may include “*(i) effort controls and/or catch controls*”. In other words, with respect to article 70 and 71, managing effort is only one option for deep-sea fisheries, but other management approaches may be preferred. Lastly, article 72 specifies that effort management may not be effective for the protection of VMEs.

Overall, the guidelines do not make strong prescriptions about how deep-water fishing effort should be defined, collected and managed. They clearly state that effort should be properly monitored, which suggest the view that accurate effort data are essential to stock, fisheries and ecosystem assessment, they do make effort management mandatory, and they point out that spatial management of effort is an effective tool for VMEs protection.

Effectiveness of effort regulation

Effort estimations and management in EU waters

In EU waters and for EU fleets in international waters, the levels of fishing effort have been reviewed yearly by STECF since 2008. Time-series data records of effort (as defined in council regulation (EC) No 40/2008) have been compiled back to 2000. STECF observed a declining trend in effort (Figure 3). The bulk of the deep-water fishing effort for EU fleets is expended in Subareas VI and VII. There are anecdotal reports that year 2002 was the year of highest reporting of effort ever, as vessels were building up track records. However, ignoring year 2002, the overall deep-water fishing effort in all these areas combined, declined from more than 30 million kW fishing days in 2000-2004 to 12 million kW fishing days in 2010.

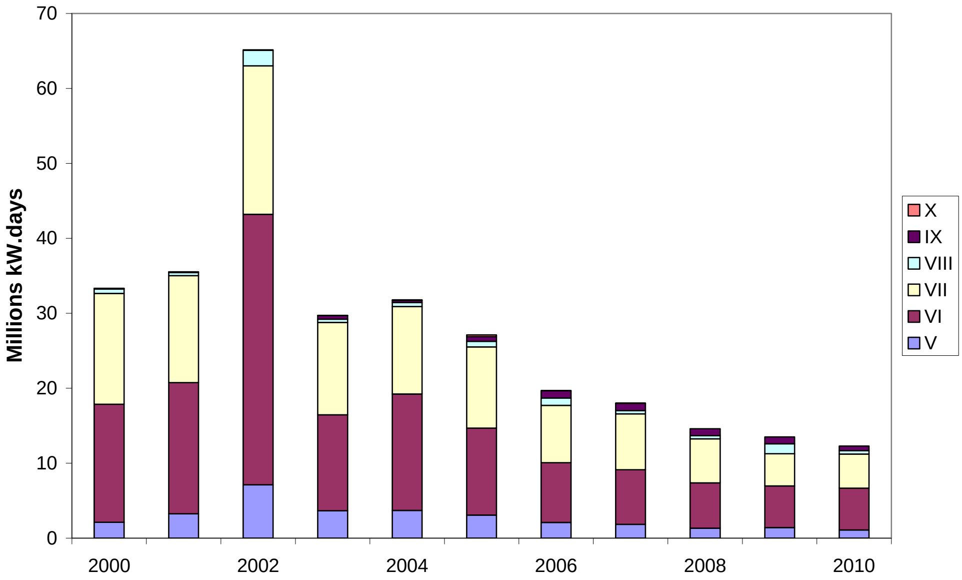

Figure 3. Deep-water fishing effort from EU vessels in Atlantic EU and non-EU waters of ICES Subareas V-X (from STECF 2011 data).

The contribution of the EU effort regulations to the driving of this effort reduction over the 2000s is debatable, because the level of effort in 2010 was 41% of 2003 effort, i.e. much less than the allowed 65%. Effort was reduced more than required, and it is then likely that the observed effort reduction was driven by the decreasing TACs. All allowed effort was not spent because quotas were caught with lesser effort.

In addition, an assessment of fishing effort from an analysis of UK VMS data for all fishing vessels operating in ICES Areas VI and VII, reveals a very clear decreasing trend in fishing activity at depths >800m (Figure 4). Also, it can be seen that most deep water fishing effort (e.g. > 200m) is concentrated at depths between 200 – 800 m and therefore potentially overlaps significantly with fisheries targetting non deep water species such as monk fish and hake. This has significant implications for managing bottom trawling activities in relation to the protection of deep sea VMEs as many VMEs in the North east Atlantic (e.g. coral and sponge biogenic reef) are located within this depth range.

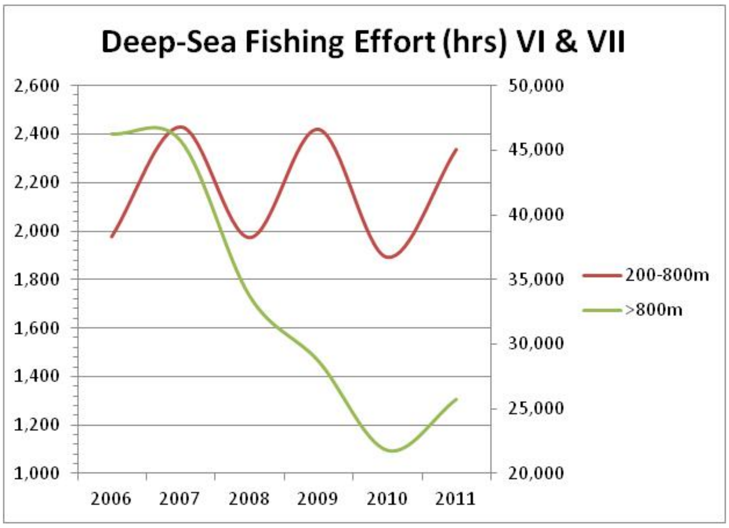

Figure 4. Deep water fishing effort (total hours fished) for all vessels operating in UK waters in ICES Areas VI and VII for water depths 200 – 800m and >800m.

Effort estimation required for monitoring potential siginificant adverse impacts of deep-water habitats and species

Topic 2, highlighted that the habitat and stock specific attributes which define deep-sea habitat are depths >200 m and for stocks which support more than 50% of the biomass at depths >200 m. For management and conservation purposes, deep waters (>200 m) are those where VME monitoring and management is required, and deep-species are defined as populations/stock that can only sustain low exploitation levels.

The total effort estimated in the previous section (in part) has been sufficiently spatially resolved using VMS data to assess the total area of sea-bed actually fished at different depths. This is show in Figure 5 and summarised in Table 3.

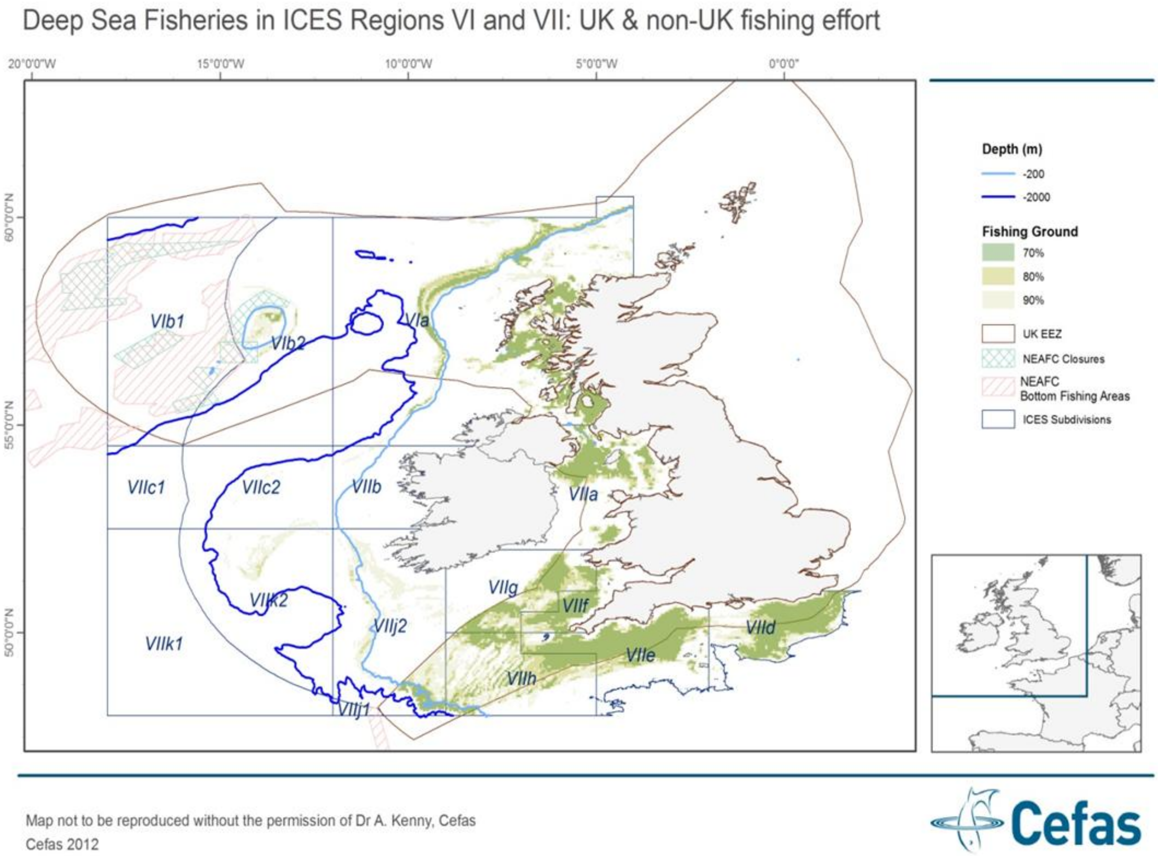

Figure 5. Fishing activity (effort) derived from VMS data for all fishing vessels operating in UK waters corresponding to ICES Areas VI and VII averaged between 2006 and 2011. The map shows the spatial extent of fishing corresponding of 70%, 80% and 90% of the fishing effort.

Table 3. Summary of the total fishable area for different depth strata in relation to the actual area fished as an average for years 2006 to 2011. For UK sector in ICES Areas VI and VII for all fishing vessels.`

	Total Fishable Area (km^2)	Area of 90% Effort (km^2)	% of fishable area actively fished
<200m	463,324.56	186,550.09	40
200 - 800m	146,441.38	29,593.78	20
800 - 2000m	235,222.17	2,828.88	1

The fishing effort data presented above can also be standardised against total area to provide an estimate of fishing pressure, that is the total hours fished on average per km^2 (Figure 6).

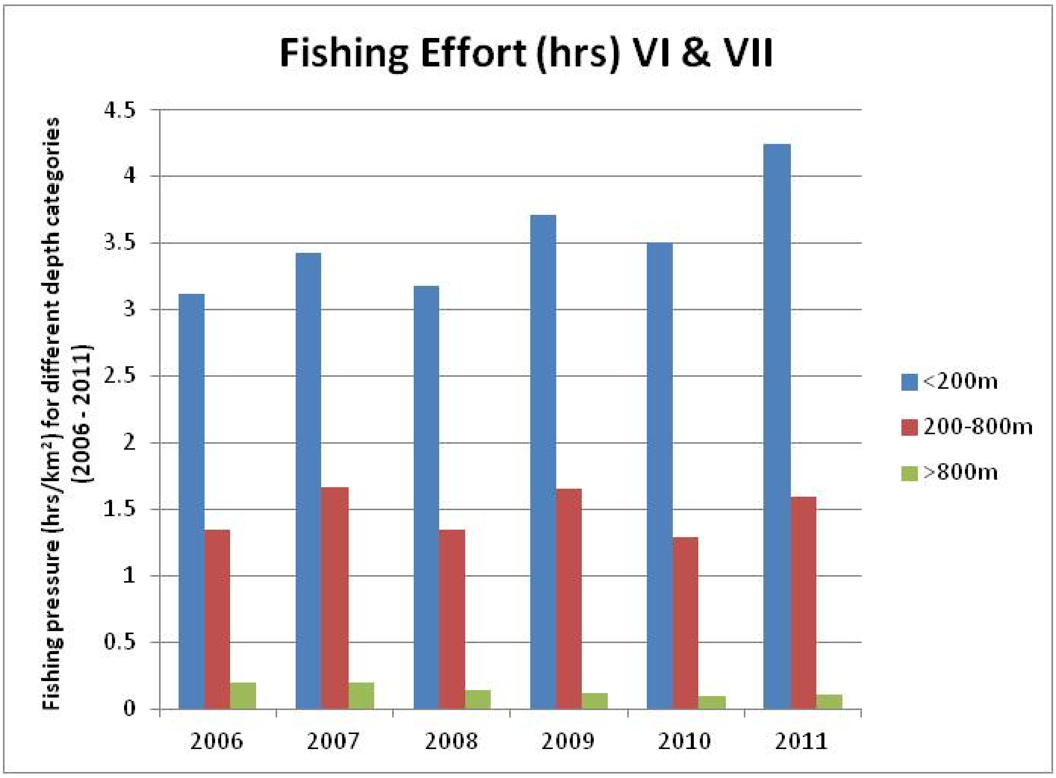

Figure 6. Deep water fishing pressure (total hours fished per km^2) for all vessels operating in UK waters in ICES Areas VI and VII for water depths <200m, 200 – 800m and >800m.

A similar pattern of fishing activity has been shown for the French mixed fishery to the West of the British Isles (Figure 7).

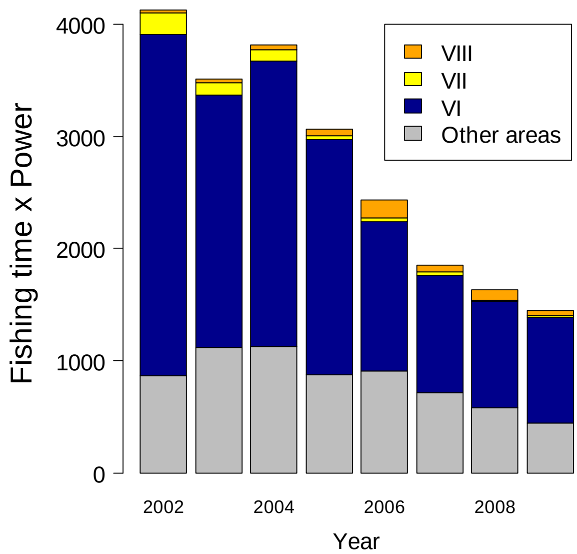

Figure 7. French licensed deep-water fishing fleet 2002-2009. Fishing effort on seafloor deeper than 800 m by ICES subarea in kW days fishing.

Effort estimations and management in international waters

The fishing industry has pointed out that generally (i) experience shows that fishing effort in deep-sea fisheries can expand rapidly, though this is not always the case, (ii) information from the start of a fishery is essential for effective management, (iii) good cooperation with the fishing industry allows for a system of rapid flow of information to be established, and (iv) technical creep increases the overall effective fishing effort (FAO 2008). The latter point has major consequences for stock assessment and it has been suggested that detailed technical data collection could allow improving the relationship between estimated fishing effort and fishing mortality (Marchal et al. 2007).

The industry that operates in international waters showed a preference for quotas as an efficient effort control management tool, but recognised that quotas, like all management tools, have weaknesses and require effective enforcement to work (FAO, 2008). It was unclear which weaknesses were meant, however, the effect of technical creep (Marchal et al., 2007) can be identified as one weakness. There are other case were effort is difficult to estimate. VMS data allow for an accurate estimation but they are not always available. For example, for the blackspot sea bream fishery in the Strait of Gibraltar, which is operated by small vessels not equipped with VMS, effort is estimated from the number of sales events, but this does not provide an appropriate effort estimate because some fishing trips do not generate a sale event when the catch is null or too small.

Summary and conclusions of the DEEPFISHMAN review of 0

- *The FAO guidelines do not make strong prescriptions about how deep-water fishing effort should be defined, collected and managed. They clearly state, however, that effort should be properly monitored, which suggest the view that accurate effort data are essential to stock, fisheries and ecosystem assessment. The guidelines do make effort management mandatory, and they point out that spatial management of effort is an effective tool for VME protection*
- *Deepfishman results show that a relatively small proportion of the total fishable area is actually fished in the deep sea. Results show that typically only 20% of fishable area at depths between 200 and 800m is actively fished whereas at depths >800m this figure is substantially redcued to 1%. By comparison results for shalf areas <200m in depth show that typically 40% of the fishable area is actively fished.*
- *Deepfishman results show that fishing effort at depths >800m has been in significant decline since 2006.*

Recommendations by the DEEPFISHMAN consortium

- *DEEPFISHMAN recommends that deep-water fishing effort is estimated from VMS data as this allows an accurate tracking on fishing effort by depth. Effort management may not be required if an effective catch management is in place. In EU waters in recent years, the management of landings through TACs and quotas has probably been effective and allowed effort was not all used. However, even if it is not a management tool, an accurate monitoring of effort is essential, as accurate effort data are essential to both stock and ecosystem assessment*

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Topic 6. Management and monitoring of by-catches, discards and protected, endangered and threatened (PET) species

PET species taken into consideration

Protected, Endangered and Threatened (PET) species are marine species which are impacted or presumed impacted by deep-water fishing. PET deep-water species that are threatened by other human activities but not by fishing will not be considered here, as deep-water fisheries management would not be beneficial to these species. Similarly, threats other than fishing may be mentioned in this section but will not be treated in detail, as these cannot be solved by fisheries management. For example, it is now well understood that ocean acidification is a major component of global change with likely adverse impacts on marine ecosystem (Guinotte and Fabry, 2008) and probably already on-going (Maier et al., 2012). Cold water corals and all other organisms that build skeletons, shells, and tests of biogenic calcium carbonate will be impacted because their carbonate budget will change, but acidification can only be tackled by reducing the global release of $C0_2$; fisheries management will have no effect on it.

Presumed and reported threat of deep-water fisheries to mobile species has been reviewed for marine mammals, sea turtles, seabirds and deep-water fish.

Invertebrates

Globally, 130 species from phyla other than Chordata occurring in deep benthic habitats have been assessed by IUCN. All but one, the Cape Verde spiny lobster (*Palinurus charlestoni*), were deemed to be of least concern (LC) or data deficient (DD). However, most of the assessed species are mobile crustaceans (mostly decapods) and cephalopods. In the sessile deep-water fauna, only five Scleractinian coral species endemic from the Galapagos have been assessed by IUCN.

OSPAR has defined a list of threatened and declining habitats and species. The threat of declining deep-sea habitats is shown in Table 4. It is unclear whether the list matches habitat classification such as EUNIS. Nevertheless, the considerations for fisheries management are (i) whether interaction with and impact on these threatened habitat occurs, (ii) how these interaction/impacts are recorded/monitored, and (iii) how the protection of these threatened habitats can be addressed.

Table 4. Threatened or declining deep-sea habitat (OSPAR Commission 2008).

Habitats	OSPAR Regions where the habitat occurs[a]	OSPAR Regions where such habitats are under threat and/or in decline
Carbonate mounds	I, V	
Coral Gardens	I, II, III, IV, V	All where they occur
Deep-sea sponge aggregations	I, III, IV, V	All where they occur
Lophelia pertusa reefs	All	All where they occur
Oceanic ridges with hydrothermal vents/fields	I, V	V
Seamounts	I, IV, V	All where they occur
Sea-pen and burrowing megafauna communities	I, II, III, IV	II, III

[a] Regions are I: Arctic waters, II: Greater North Sea, III: Celtic Seas, IV: Bay of Biscay and Iberian Coast, V: Wider (i.e. mostly deep) Atlantic

The coral species *Caryophyllia* spp., *Lophelia pertusa*, *Dendrophyllia cornigera*, *Dendrophyllia ramea* and *Madrepora oculata* are included in the Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Invertebrates and habitats considered as PET are all sessile fauna and are therefore considered further under Topic 7, Spatial and temporal closures and technical measures. The present topic will focus on mobile vertebrate species, benthic VMEs will however be considered in terms of review of impacts of case study fisheries.

Marine mammals, seabirds and turtles

All marine mammals and seabirds were considered is this analysis although not all species are either threatened or protected. Turtles occurring in the NE Atlantic are all PET species.

Fish

The review of fish was restricted to species corresponding to the criterion defined in Topic 2 (Definition of deep water and deep-water species), i.e. deep-water species are those with more than 50% of their biomass distributed deeper than 200 m.

In the IUCN redlist[12], a search was done applying the following criteria:

- taxonomic groups: Cephalaspidomorphi (Chimaeras) or Chondrichthyes (Sharks and rays)
- habitat: marine deep benthic
- location: Atlantic northeast and northwest
- IUCN assessment: EX, EW, CR, EN, VU, LR/cd, NT or LR/nt

This search returned 19 species, some of which were not taken into account because either (i) they are unknown to be impacted by deep-water fishery, (ii) they are oceanic species so that their habitat is the open water rather than the benthopelagic domain, or (iii) they are rare in the north Atlantic and more abundant in other areas. For example, tropical and sub-tropical species are not likely to be significantly impacted by north-Atlantic deep-water fisheries because the fraction of their populations distributed in the North Atlantic is small. The species left out based on these criteria are *Carcharhinus falciformis*, *Manta birostris*, *Odontaspis ferox* and *Sphyrna lewini*. Further, the species *Leucoraja fullonica*, *Leucoraja ocellata*, *Mustelus mustelus*, *Raja clavata* were also extracted by the from the search results because they are not deep-water species under the DEEPFISHMAN definition.

A resulting list of 11 deep-water PET species was obtained from IUCN criteria (Table 5). With the same taxonomic, habitat and location criteria but with an additional data deficient (DD) criterion, fourteen Cephalaspidomorphi or Chondrichthyes were found, including *Hydrolagus lusitanicus*, *Neoraja iberica*, *Oxynotus paradoxus*, *Rajella kukujevi*, *Scymnodon ringens*, *Somniosus rostratus*, *Squalus blainville*. Similarly, 22 species were returned as least concern (LC).

However, as the above search did not extract all species assessed by IUCN, for example *Centrophorus squamosus* and *Centroscymnus coelolepis*, additional searches were made to collect all deep-water species based on the DEEPFISHMAN definition. The final list of Cephalaspidomorphi and Chondrichthyes with populations in the North-Atlantic, which have been assessed in the threatened categories (EX, EW, CR, EN, VU) is given in Table 5. No deep-water benthopelagic bony fish species were found in the threatened categories of IUCN.

[12] URL: http://www.iucnredlist.org

Table 5. Deep-water fish occurring in the North Atlantic taken into account for impacts of North Atlantic deep-water fisheries on PET species.

Species	Group	Assessment (Agency)
Amblyraja radiata	Ray	VU (IUCN)
Bathyraja spinicauda	Ray	NT (IUCN)
Centrophorus lusitanicus	Shark	VU (IUCN)
Centrophorus granulosus	Shark	Declining (OSPAR)
Centrophorus squamosus	Shark	VU (IUCN), Declining (OSPAR)
Centroscymnus coelolepis	Shark	NT (IUCN), Declining (OSPAR)
Chimaera monstrosa	Chimera	NT (IUCN)
Chlamydoselachus anguineus	Shark	NT (IUCN)
Dalatias licha	Shark	NT (IUCN)
Dipturus batis	ray	Declining (OSPAR)
Dipturus laevis	Ray	EN (IUCN)
Dipturus nidarosienis	Ray	NT (IUCN)
Dipturus oxyrinchus	Ray	NT (IUCN)
Galeus atlanticus	Shark	NT (IUCN)
Hexanchs griseus	Shark	NT (IUCN)
Hydrolagus mirabilis	Chimera	NT (IUCN)
Leucoraja circularis	Ray	VU (IUCN)
Oxynotus centrina	Shark	VU (IUCN)
Rostroraja alba	Ray	EN (IUCN) , Declining (OSPAR)
Squalus acanthias	Shark	CR (IUCN), Declining (OSPAR)
Squatina squatina	Shark	CR (IUCN) , Declining (OSPAR)
Hoplostethus atlanticus	Actynopterygian	Declining (OSPAR)

In addition to species assessed by IUCN, deep-water fish assessed as declining by OSPAR were considered PET fish species (Table 5). OSPAR PET fish species include 5 sharks, 2 rays and one bony fish (OPSAR Commission 2008). The list of PET fish species obtained in Table 5 is in line with DEEPFISHMAN experts' knowledge and with ICES assessments. However, it should be kept in mind that there are no quantitative assessments of the abundance of these species. For example, the biomass of orange roughy in the NE Atlantic clearly decreased in the 1990s and 2000s, but there is still significant biomass in some areas including the slope of the Bay of Biscay and Porcupine Bank, and under the current fishery ban it is likely that these species is no longer threatened (Dransfeld et al., 2012).

PET species impacted by DEEPFISHMAN case study deep-water fisheries

PET species are monitored in fishery surveys where all species caught are usually identified to species level. Data for all species is standardised (e.g., ICES coordinated or EU data collection framework (DCF) funded datasets include number, weight and length distribution per species). As a result, such datasets include accurate PET data, but as PET species occur by definition in low numbers, the amount of data is usually limited. PET species may also be part of the data collection specification of the on-board observation scheme. For example, the French on-board observation sampling plan includes estimating number and weight of all species caught. Measurements are also required for all species but for practical reasons, only a subset of species is measured at every haul. Species identification by on-board observers, where data are collected by one single observer on board a fishing vessel is less reliable for identification of rare species than dedicated survey identifications, but they provide a larger amount of data.

Table 6. Impact of DEEPFISHMAN case study fisheries on PET species, based on DEEPFISHMAN CS reports and other DEEPFISHMAN data and reports.

Case study	PET species	Data collection	Status (assessment organisation)	Impact	Mitigation
1a Orange roughy, Namibia (fishery currently closed)	Coral and sponges known to occur, no other record of PET species in fishery and on-board observation data	On-board observers trained to collect catch information on corals and sponges, PET species, seabirds, marine mammals and turtles	Coral and sponges: unknown	VMEs including coral and sponges where impacted mainly at the start of the fishery	Fishery under moratorium
1b Orange roughy west of the British Isles (fishery currently closed)	No known catch of marine mammal, turtle and seabirds. Interaction with VMEs known to occur. Fish species in table 1 were by-catch of the fishery with the exception of *Centrophorus lusitanicus* and *C. granulosus*, not occurring in the area		Deep-water sharks assessed at low level (ICES 2011)		Deep water gillnetting for deep water sharks have been banned in EU waters since 2006. Retrieval surveys for lost gillnets have been conducted in 2005-2008
1c Blue ling West of the British Isles	No known catch of marine mammal, turtle and seabirds. By-catch of other fish species smaller in the targeted blue ling fishery than in the mix deep-water fishery	Incidental catch of marine mammal, turtle and seabirds are part of on-board observation plans. By-catch of fish species varying by country, include all species for some fleets	Deep-water sharks assessed at low level (ICES 2011)	The by-catch of sharks depend upon the way the fishery is operated it is lower when blue ling aggregation are targeted than when blue ling is a by-catch of a mix fishery	
2 Mix-trawl fishery to the west of the British Isles	No known catch of marine mammal, turtle and seabirds. By-catch of several species of sharks. Sharks were commercial before TACs were set to 0 in 2010. Impact on VMEs may have been significant but are considered to be decreasing because of the reduced effort and are fished (footprint, see section on VME and footprint). The fishery is mainly developed on sedimentary bottoms.	Incidental catch of marine mammal, turtle and seabirds are part of on-board observation plans. By-catch of fish species varying by country, include all species for the French fleet	Deep-water sharks assessed at low level (ICES 2011)		Ban on deep-water gillnetting, 0 TAC for deep-water sharks, decreasing TAC for the main target species and decreasing effort have reduce the mortality of sharks. The impact on orange roughy has been reduced (Dransfeld, 2012). NEAFC ban on deep-water nets below 200 m from the 1st February 2006.

Case study	PET species	Data collection	Status (assessment organisation)	Impact	Mitigation
3a Red Sea bream	Gibraltar: No known interaction with PET species Bay of Biscay: currently a minor by-catch fishery				Not relevant
3b Red Sea bream, Greek waters	By-catch of dolphins and turtles or in the trawling fleet				MPA established for sea turtles and monk seals in Zakynthos island
3c Black scabbardfish in IXa	No interaction with turtles and seabirds. Some depredation of the catch of the target species by marine mammals. No by-catch of mammals. By-catch of deep-water sharks (Farias et al., 2009)		Deep-water sharks assessed at low level (ICES 2011)		None
4a Beaked redfish in the Norwegian se	*Sebastes mentella* and *S. marinus* are on the Norwegian redlist (Kålås et al., 2006) (http://www.biodiversity.no/). *S. mentella* is classified as vulnerable (a high risk of extinction, i.e. 10% probability of extinction within 100 years) category A3 (i.e. projected or suspected population reduction during the coming 10 years or 3 generations). By-catch level of seabirds and mammals are presumed low but the quality of reporting is poor. No by-catch of turtles	Total catch, incl. discards and PET should be reported by species, live weight and/or numbers			Not relevant
4b Beaked redfish, Irminger Sea	No reported by-catch of PET species	Total catch, including discards and PET species is reported by species (weight and/or numbers)			Not relevant
5 Greenland Halibut in NAFO area	Interaction with VMEs Incidental catch of cetaceans and pinnipeds in trawl and gillnet fisheries (Lens, 1997) By-catch of deep-water sharks				No

Table 7. Description of data and knowledge of discards by fishery.

DEEPFISHMAN case study	Data	Discard of the target species	Other main species discarded	Comment
1a Orange roughy, Namibia (fishery currently closed)	Little data, expert knowledge suggest discards can be important	Minor	Unknown	
1b Orange roughy west of the British Isles (fishery currently closed)		Minor	*Alepocephalus bairdii* *Coryphaenoides rupestris* *Centroselachus crepidaer* *Centrophorus squamosus*	Discard smaller in the targeted fishery on seamount
1c Blue ling West of the British Isles	On board observation 2004-2011	Minor	Small	
2 Mix-trawl fishery to the west of the British Isles	On board observation 2004-2011	Roundnose grenadier (~20%) All deep-water sharks since the ban of landings	*Alepocephalus bairdii* Macrourids, deep-water sharks	
3a Red Sea bream		None of minor	Gibraltar: none	Bay of Biscay: red sea bream is mainly a by-catch of other fisheries
3b Red Sea bream		None of minor		
3c Black scabbardfish in IXa		None of minor	Deep-water sharks	
4a Beaked redfish	No discard data (discard ban?)			Lack of information on discards and misreporting
4b Beaked redfish, Irminger Sea	Data limited to the target species	Discards lower than 5% of landings	Species composition of discarded catch unknown	
5 Greenland Halibut in NAFO area		Less than 0.5%.	Grenadier (*Macrourus berglax*?). Reported total discards around 2.8% of the total catch	Discards level seem low for a trawl fishery

Most deep-water fisheries studied as DEEPFISHMAN case studies can be considered having no direct impact on marine mammals, turtles and seabirds. Indirect impacts, i.e. through the food web are unknown, and not likely significant as deep-water organisms are only a minor part of the food of marine mammals, turtles and seabirds. In most of these fisheries, observations of marine mammals, seabirds and turtles are part of the training and data collection of on-board observers. These animals are sighted (at least mammals and seabirds) but, in most fisheries, no records of by-catch have occurred.

Two exceptions can be identified with the red sea bream fishery in Greek waters and the fishery for Greenland halibut in the NAFO area.

There are records of by-catch of dolphins and turtles in the red sea bream fishery in Greek waters. However, for most of the vessels involved, red sea bream is a by-catch of a mix fishery with either static or towed gears. Therefore the by-catch of dolphins and turtles needs to be addressed in the larger context of these mix-fisheries and no particular deep-water fishing management measure can be of interest in this respect.

In the Greenland halibut and gillnet fisheries in the NAFO area, incidental catches have been reported in the early 1990s (Lens, 1997; Benjamins, 2007). In gillnet fisheries, the by-catch seem to be much more frequent in coastal fisheries (Benjamins, 2007) than in deeper waters fisheries. In the trawl fishery, based on dedicated on-board observation in 1993-94, 0.27% were estimated to catch mammals, mostly 1 individual, 73.8% of this mortality corresponded to seals. This was considered a low mortality (Lens, 1997). Sperm whales (*Physester macrocephalus*) have been observed from Greenland halibut trawlers and were speculated to feed on preys escaping from hauled trawls but no by-catch was reported (Karpouzli and Leaper, 2004). There are no recent data available from ongoing onboard observation programmes in the NAFO Greenland halibut fishery.

Marine mammals are reported to generate some depredation in longline fisheries. In DEEPFISHMAN case studies, this has been anecdotally reported in the black scabbardfish fishery to the southwest of Portugal. This is also known to occur in Patagonian toothfish (*Dissostichus eleginoides*) fisheries in southern oceans and in some Greenland halibut fisheries (Yano and Dahlheim, 1995; Goetz et al., 2011). These depredations do not generate catch or mortality of mammals.

By-catch and depredation also occur with seabirds and are a conservation problem. Mitigation measures to avoid seabird catch have been developed (e.g. Ryan and Watkins, 2002), interactions with seabirds do not seem to occur to any significant level in DEEPFISHMAN case study fisheries nor in deep-water fisheries of the NE Atlantic.

Overall, the main impact on PET species appears to be the by-catch of deep-water sharks. The Portuguese dogfish (*Centroscymnus coelolepis*), leafscale gulper sharks (*Centrophorus squamosus*) and kitefin shark (*Dalatias licha*) are considered at a very low level, although not quantitatively estimated in either absolute or relative terms (ICES 2010). Available survey indices suggest a decline of these species since the early 1990s. It is not known if the current management (ban of deep-water net, 0 TACs and overall reduction in deep-water fishing effort) has been sufficient to halt the decline. The fishing mortality should however be well below the level from 2006 when there was significant targeted fisheries for deep-water sharks. The status of other deep-water sharks is likely to be similar to that of these three species. For example, the ban of nets (gillnets, entangling nets and trammel nets) in ICES Divisions VI a, b and VII b, c, j, k and Subarea XII at depth deeper than 200 m in 2006, mainly aimed at protecting sharks. In other words, management actions have been taken to protect deep-water sharks in the NE Atlantic both EU and international waters.

Due to the paucity of available assessment data, the status of deep-water sharks stocks is unknown. This is unlikely to improve quickly and it is worth noting here that the population status of most demersal elasmobranchs is also poorly known. Deep-water sharks remain a subject of concern and reducing their by-catch should be considered. One possible option for reducing deep-water shark by-catch is spatial management. In this respect, in the blue ling fishery it has been shown that deep-water shark by-catch is lower when blue ling aggregations are targeted than when fishing on more dispersed blue ling. As long as blue ling is now quantitatively assessed using methods developed in DEEPFISHMAN (ICES 2012) and that there is no longer a concern of stock collapse for blue ling, the management of blue ling fishery should aim at (i) limit the fishing mortality of blue ling to MSY based levels, and (ii) allow the catch to be taken in conditions where shark by-catch are the lowest. This may imply releasing the closed areas for blue ling spawning protection. There are no other clear spatio-temporal management options for reducing shark by-catch in DEEPFISHMAN case studies. There is also anecdotal information that the level of shark by-catch in longline fishery for black scabbardfish varies spatially, but the amount of on-board observation is too low for a quantitative estimate of this.

Spatial patterns of discards – example of one fishery with discard data

This section is based upon data from on-board observations of the French deep-water trawl fishery to the West of the British Isles.

Spatial patterns in sharks catches

All deep-water sharks caught are now discarded as a result of the 0 TAC. In line with the main concern with PET species, the spatial pattern in the shark catches were analysed. French onboard observations from 2004 to 2011 were used. All shark catches were considered, i.e. landings and discards, as these can represent the amount now discarded. The catch of the 5 main shark species caught did not show clear spatial patterns (Figure 8), which can be expected, as no scientific analysis of the deep-water fish community has suggested the existence of areas with clearly higher or lower shark abundance.

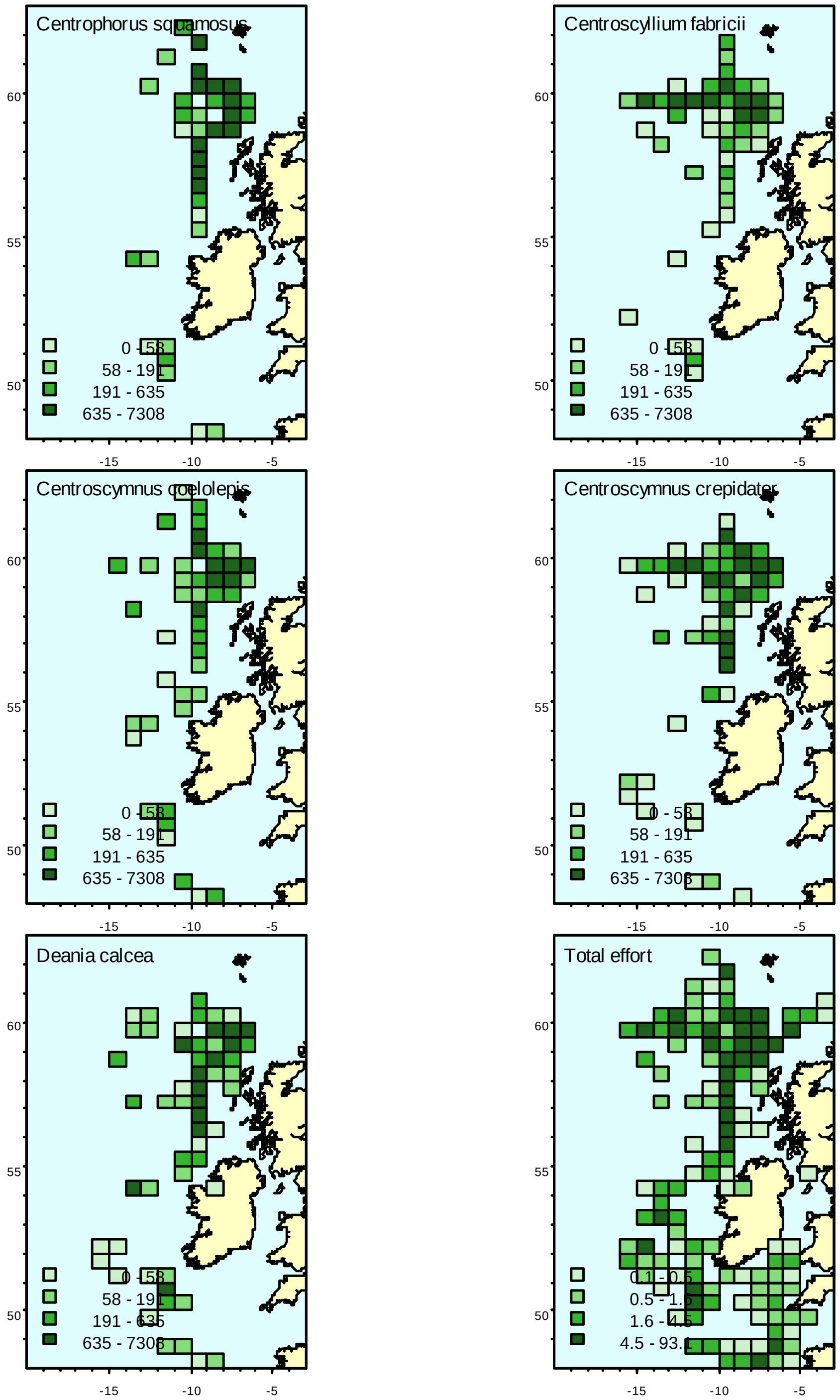

Figure 8. Spatial distribution of the catch of the 5 most abundant shark species and fishing effort in French onboard observations of the deep-water trawling fleet, all years 2004-2011 combined.

For one shark species, the Greenland shark *Somniosus microcephalus*, a clear spatial pattern was found with catches occurring in the north of the fishing area of the fleet by 60° north and not further south (Figure 9). This shark species is currently not considered as a PET species as it is categorised near threatened in the IUCN redlist. The species is also caught on the shelf and at the coast. It seems to be landed or discarded by a number of fisheries in unknown amounts (ICES 2010). The by-catch in deep-water fisheries might therefore be only a small proportion of the fishing mortality of this species. However this example suggests that spatial patterns can be found for some species and may allow managing the amount discarded. In the case at hand, the catch represented 24 individuals caught 24 different hauls in a total of >2700 observed hauls. Due to the low occurrence of these catches, further analyses are not possible on the set of observed hauls, and only data from skippers could be use to assess more accurately other factors (e.g. depth, season) for the catch of these species.

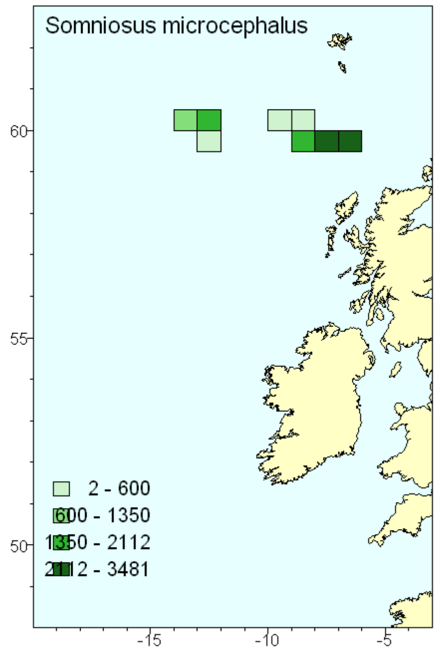

Figure 9. Spatial distribution of the catch of Greenland shark (*Somniosus microcephalus*) in French onboard observations of the deep-water trawling fleet, all years 2004-2011 combined.

Spatial patterns in total discards

Similar to sharks, the spatial patterns in total discards was investigated at the scale of ICES statistical rectangles (1° in longtitude x 30' in latitude). These did not show strong patterns that could be used for management purposes (Figure 10). Slight variations may be related to target species and depth fished per area, as it was shown that the rate of discards (proportion of the total catch that is discarded) varied according to the target species.

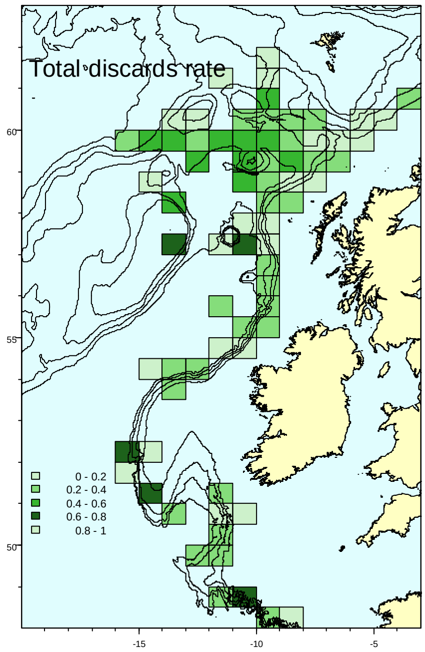

Figure 10. Spatial distribution of the discard rate (discard/total catch in weight) by ICES rectangle, from French onboard observations of the deep-water trawling fleet, all years 2004-2011 combined.

It was previously shown, that CPUEs of other species vary according to the target species. In the first years of the French onboard observations of the deep-water fleet, the target species was indicated by the skipper. The CPUE of black scabbardfish, roundnose grenadier and sharks were estimated depending on depth and the target species (Figure 11Figure 12Figure 13). Target species were defined as four categories roundnose grenadier, black scabbardfish, blue ling and 'deep-water species'. The latter category stands for a mix of several species being expected for the haul. It is trivial that the target of one particular species is higher when this species is targeted. More interestingly this data show the variation of catch rates per depth and that catch of other species is minimal when blue ling is targeted. Therefore there is probably more opportunity to manage the amount discarded by managing how species are targeted and which depth is fished than by using a spatial approach.

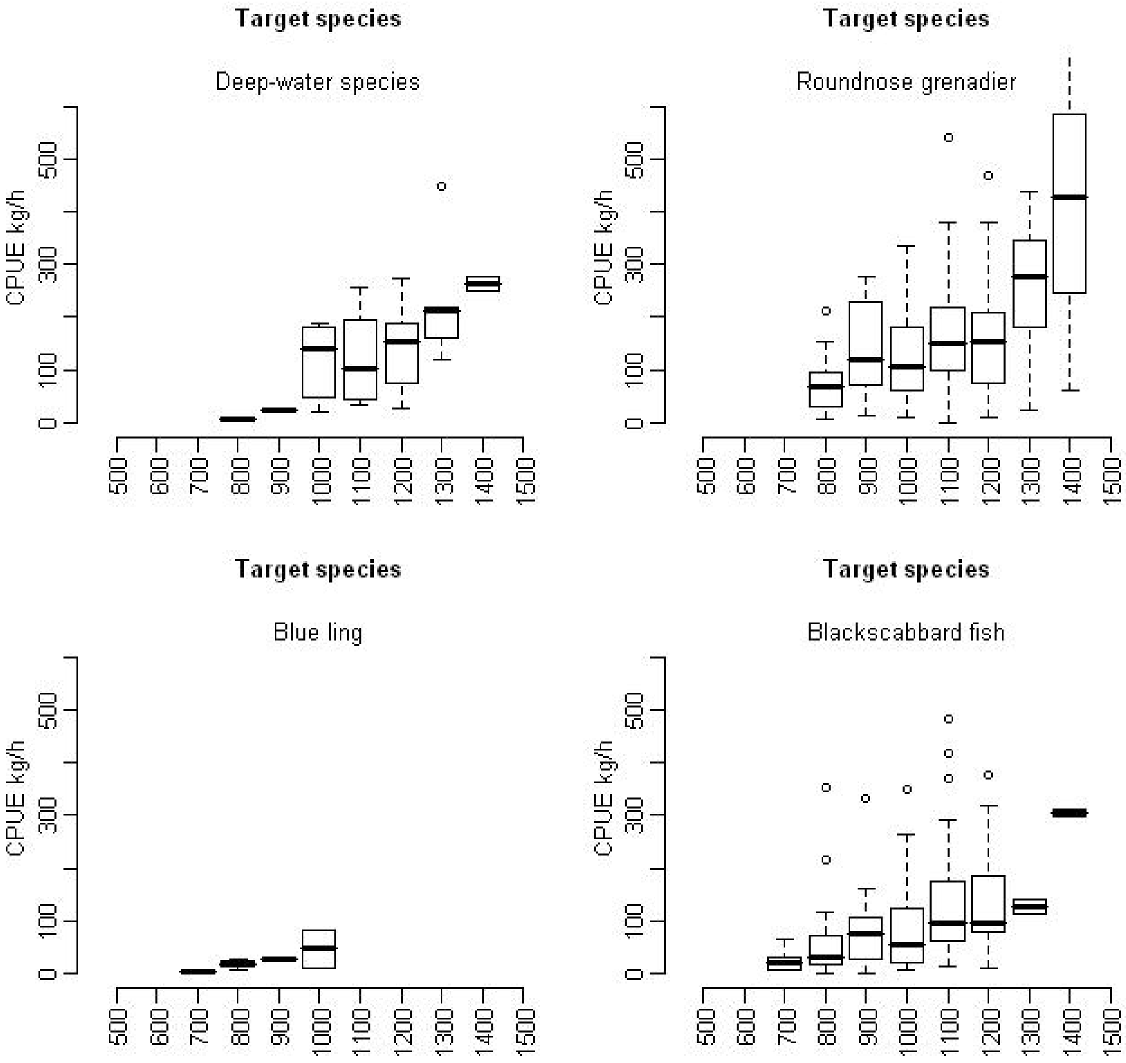

Figure 11. Observed CPUE (kg/h; landings and discards combined) of roundnose grenadier when targeting 'deep-water species', roundnose grenadier, blue ling and black scabbardfish.

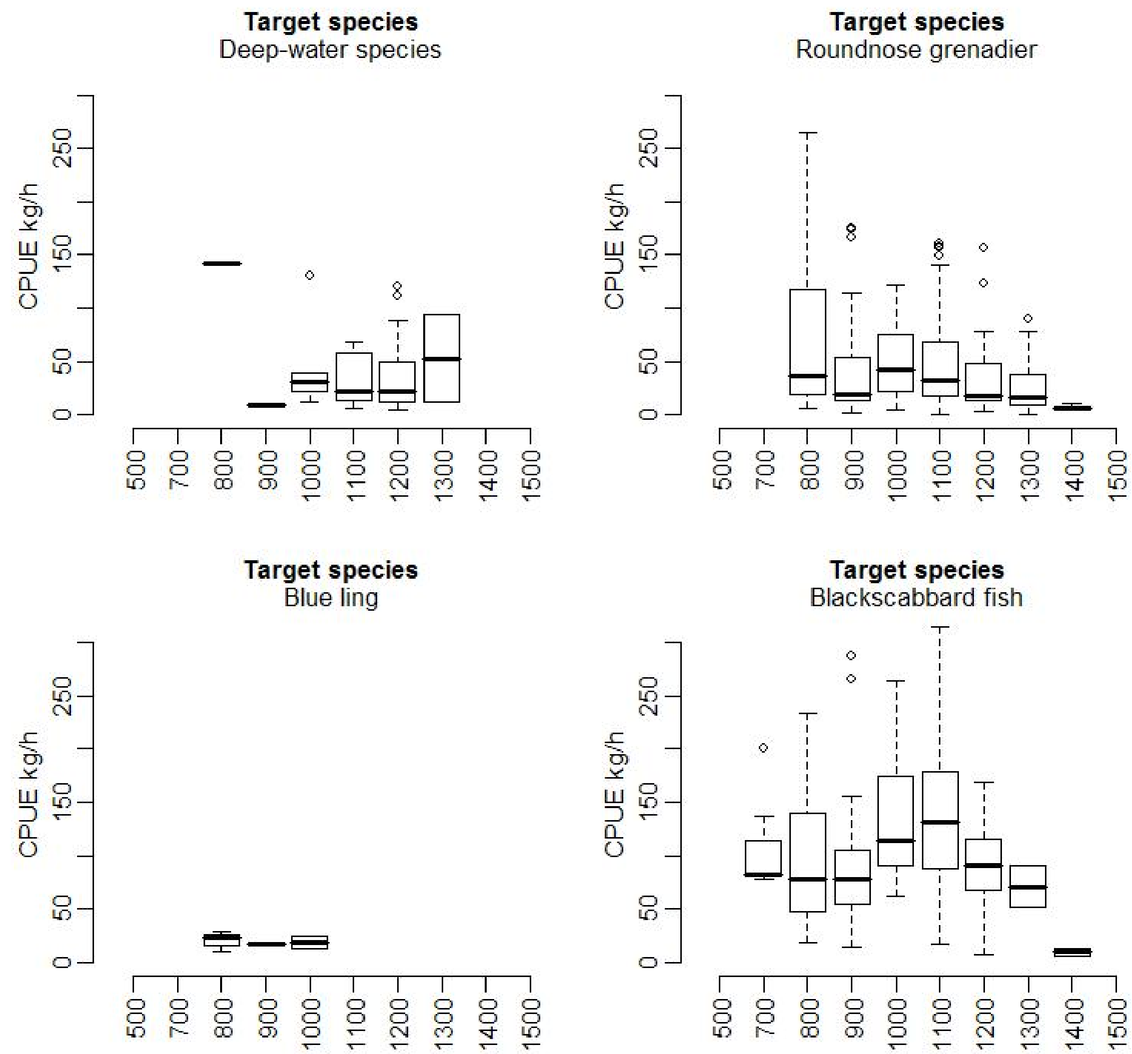

Figure 12. Observed CPUE (kg/h; landings and discards combined) of black scabbardfish when targeting 'deep-water species', roundnose grenadier, blue ling and black scabbardfish

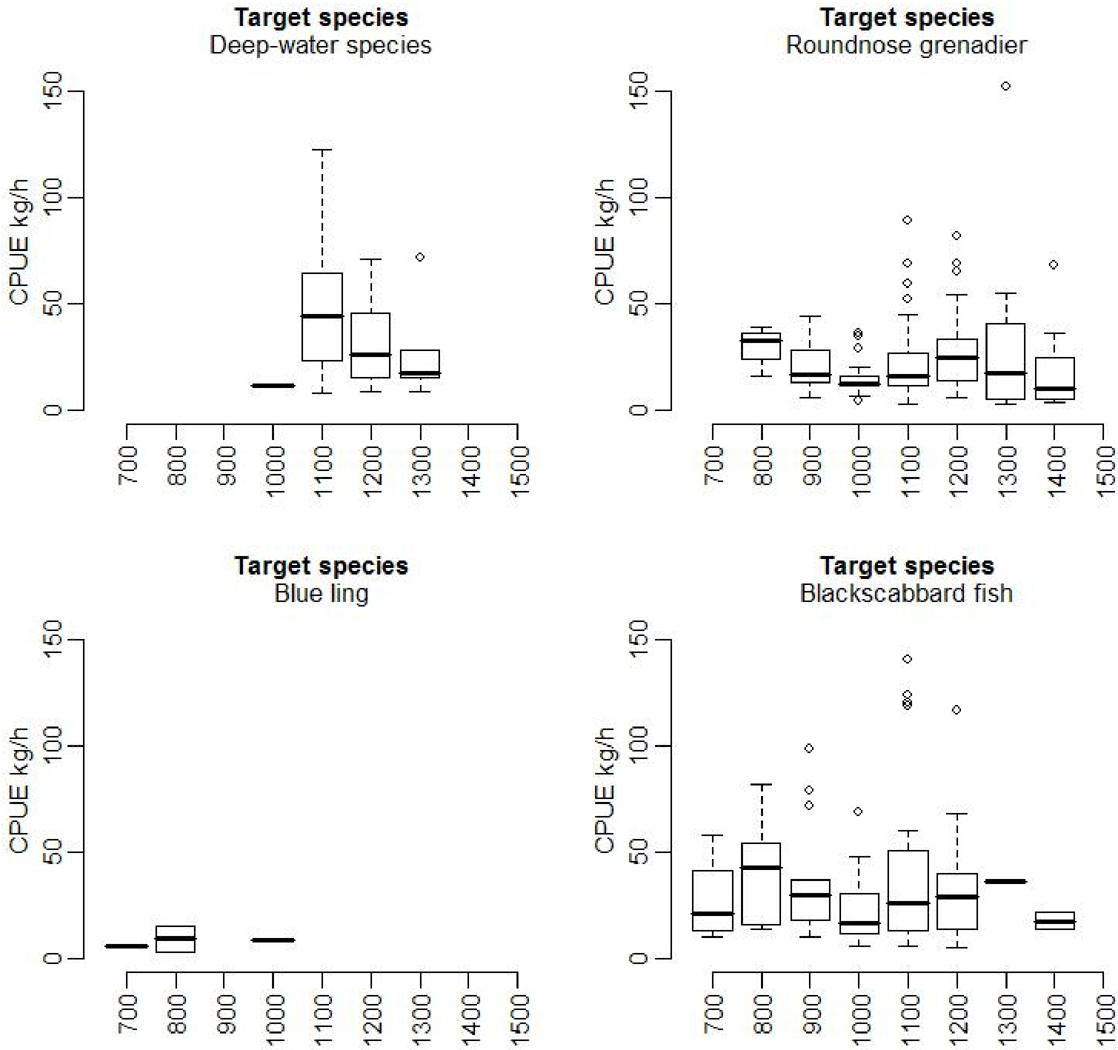

Figure 13. Observed CPUE (kg/h; landings and discards combined) of deep-water sharks when targeting 'deep-water species', roundnose grenadier, blue ling and black scabbardfish.

Summary and conclusions of the DEEPFISHMAN review of 0

- *Mobile PET species to consider for deep-sea fisheries are primarily deep-water sharks. There is no known singificant impact of deep-sea fisheries in the North-East Atlantic to marine mammals, seabirds and marine turtles.*
- *Fixed species are be addressed primarily in terms of VMEs and spatial management*
- *Due to the paucity of available assessment data, the status of deep-water sharks stocks is unknown. This is unlikely to improve quickly and the population status of most demersal elasmobranchs is poorly known. Deep-water sharks remain a subject of concern and reducing their by-catch should be considered. However, some fishing activities targetting deep-sea sharks have been halted as a consequence of the ban of deep-sea sharks landings. Bycatch in other fisheries are reduced owing to the reduced fishing effort since 2003 (see topic 5)*

- *Spatial patterns in total discards did not show strong patterns that could be used for management purposes. However, the rate of discards (proportion of the total catch that is discarded) varied according to the target species. There may be more opportunity to manage the amount discarded by managing how species are targeted and which depth is fished than by using a spatial approach*

Recommendations by the DEEPFISHMAN consortium

- *Further work is needed on deep-sea shark assessment. The ban of fisheries have reduce available data. Trends-based assesment from survey and on-board observation indicators, have been investigated in DEEPFISHMAN and are the main current way forward for assessing the status of deep-sea sharks. These have the potential to provide relative quantitative trends but no absolute assessment.*

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Topic 7. Spatial and temporal closures and technical measures

In offshore areas relevant to deep-sea ecosystems the spatial and temporal technical measures to establish Marine Protected Areas (MPAs) are broadly divided into one of two categories to comply with specific policy drivers and regulatory instruments, these are described below.

Habitat and species MPAs

The first category relates to the protection of specific habitats (usually seabed) features which meet stipulated biodiversity and/or conservation criteria, defined by the Habitat Directive (92/43/EEC). The Habitat Directive requires Member States to designate Special Areas of Conservation (SACs) to protect some of the most threatened habitats and species across Europe. The sites designated under the Habitat Directive contribute to a Europe-wide network of nature conservation protected areas known as Natura 2000 sites. In addition, the Marine Strategy Framework Directive (2008/56/EC) requires Member States to put measures in place to achieve or maintain good environmental status in their waters by 2020. Under the Directive a coherent and representative network of MPAs should be established by 2016. Furthermore (non-statutory) regulations apply under the United Nations (UN CBD Resolutions), Regional Fisheries Management Organisation (NEAFC) and Regional Seas Convention (OSPAR), all of which are responsible for designating sites supporting significant habitat and biodiversity features. However, it should be noted that not all types of MPA have the same status in terms of protecting a habitat or biodiversity from human impacts (including fishing), with the result that biodiversity hotspots can be subject to multiple designations to ensure added levels of protection. The various MPA designation types, their corresponding policy driver and their legal status are summarised in Table 8.

Table 8. Offshore habitat and species designated MPAs relevant to the NE Atlantic designed to protect habitats and biodiversity from human activities including fishing activities. Note, not all MPAs will result in a closure to all types of fishing activity.

Policy Driver	Offshore MPA types	Status
UN CBD	Ecologically, Biologically Sensitive Areas (EBSAs). Global	Non legally binding, but mandatory for CPs
EC Habitat Directive	Natura 2000 sites also known as Special Areas of Conservation (SACs). Regional EU EEZs	Legally binding.
EC Marine Strategy Directive	Marine Conservation Zones (MCZs). Regional EU EEZs	Legally binding
OSPAR Convention	Marine Protected Areas (MPAs)	Non legally binding, but mandatory for CPs
NEAFC	Vulnerable Marine Ecosystems (VME)	Non legally binding, but mandatory for CPs

Habitat and species MPAs are identified by evaluating candidate areas against a set of criteria including uniqueness, aggregation, fitness consequences, and naturalness. Uniqueness refers to the rarity of a particular area, both its physical structure and associated fauna (canyons, highly topographically complex areas). Aggregation here refers to areas where species of significance to the encompassing ecoregion aggregate more than in other areas. Fitness consequences of an area relates to the degree to which the area is essential to the overall dynamics of significant species (spawning, juvenile rearing, adult refugia ,etc.). Finally, naturalness refers to the degree to which the candidate area has been subjected to human activities over its history. Evaluation of candidate areas can occur only within the context of an encompassing ecoregion or biogeographic zone, that is, candidate areas can only be ranked in significance relative to other areas within the boundaries of an encompassing zone.

The schematic presented in Figure 14 gives a simple pictorial overview of these concepts which also includes the implicit notions of recoverability and vulnerability. From this, it is apparent that candidate areas that rank high in terms of the evaluation criteria are highly vulnerable to perturbation and have inherently low recoverability. Such areas would receive the highest relative rankings, and would require the highest degree of risk aversion relative to human activities. Areas that score low on the evaluation criterion scale, or are not vulnerable and show high recoverability potential, would receive a lower overall MPA ranking. Examples of areas that would receive high scores include aggregations of hard corals or other highly structured communities in areas of low natural perturbation and growth potential. Areas that score low include populations that inhabit highly energetic areas with high growth potential.

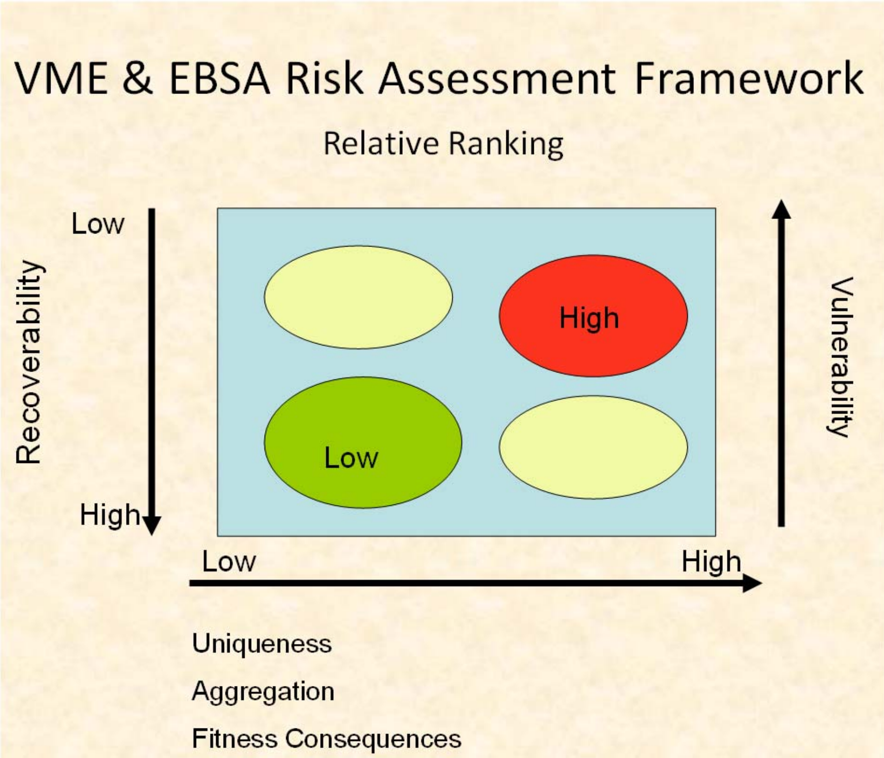

Figure 14. Criteria for identifying and ranking MPAs.

Fisheries MPAs

The second category of spatial and temporal technical measures relates to the sustainability and conservation of fish stocks and fisheries in compliance with the Common Fisheries Policy (CFP Regulation, 2371/2002), and for the high seas the NEAFC scheme of control and enforcement regulations[13]. The CFP regulations apply to all fisheries operating within the EU Member State EEZs and to EU fleets operating in the high seas. The CFP provides for the establishment of zones and/or periods in which fishing activities are prohibited or restricted, as well as specific measures to reduce the environmental impacts of fishing, such as modifications to bottom fishing gear types and practices. The basic regulation does not require Member States to develop MPAs, but rather puts in place a legal framework through which fisheries MPAs could be established in order to protect and sustain important fisheries. Furthermore, the management of fisheries and the protection of fish stocks in high seas areas (outside of EU EEZ CFP jurisdiction) becomes the responsibility of NEAFC for the NE Atlantic.

[13] URL: http://www.neafc.org/system/files/NEAFC_Scheme_of_Control_and_Enforcement_2011 _a4_dbl_sided_plus_annex12_a.pdf

In the context of fisheries MPAs there are three main types of closure to fishing activities; namely:

i. ‘Closed areas’ (or fisheries boxes) which are conditionally closed either permanently or seasonally, depending on certain fishing gear or vessel size, or for a certain target species, usually for the purpose of fish stock management or recovery from targeted exploitation such as the seasonal closures to protect spawning aggregations of fish
ii. ‘No-take zones’ which are areas that are unconditionally temporarily or permanently closed to all fishing activities (not just some gear types) to protect fish stocks and/or natural habitats
iii. ‘Real-time closures’ (RTCs) which are a relatively recent development in fisheries, requiring high volumes of data to be processed quickly to inform management decisions. They can be targeted at specific areas, for example, to protect areas of high abundance, areas where juveniles comprise a higher than average proportion of the catch or areas where catch composition is likely to result in high levels of discards. RTCs enjoy greater confidence from the fishing industry as they are seen to be more responsive to conditions ‘on the ground’; however, their effectiveness is difficult to measure

In all cases, the deep-sea fisheries MPAs are conditional ‘closed areas’ which include seasonal closures for blue ling. Fisheries on blue ling in ICES Areas Vb, VI, VII, and XIIb have mostly targeted spawning aggregations. ICES has repeatedly advised that blue ling is susceptible to sequential depletion of spawning aggregations and that closed areas to protect spawning aggregations should be maintained and expanded where appropriate. However, the documented cases of sequential depletion of blue ling spawning aggregations are limited. The depletion of one spawning aggregation within a few years in Icelandic waters was described by Magnússon and Magnússon (1995) and blue ling is an aggregating species at spawning. In EU waters, there is no evidence that sequential depletion (i.e. a process where a fishery depleted the abundance is a location and then finds new fishing grounds) occured. A continuous state space model suggested sequential depletion did not happen during the past decade (Augustin et al., in press), what did happen was an overall population decrease untill 2004 (ICES 2012; Trenkel et al., in press). Nevertheless, to prevent depletion temporal closures have been set. Although a process of sequential depletion of spawning aggregations may not be involved, limiting fishing in seasons and areas where the stock have the higher catchability was appropriate, in particular as long as ther was no absolute biomass estimate before 2012. Information from a range of sources, including fishers, was analysed, and five main spawning areas are identified: (i) along the continental slope northwest of Scotland (ICES Division VIa), (ii) on, around, and northwest of Rosemary Bank (VIa), (iii) on the southern and southwestern margins of Lousy Bank (Vb), (iv) on the northeastern margins of Hatton Bank (VIb), and (v) along the eastern and southern margins of Hatton Bank (VIb). From the information available, it was suggested that, for management purposes, peak spawning be considered to take place at depths of 730-1100 m between March and May inclusive in VIa and Vb, and during March and April in VIb. Based largely on this information, the European Commission (EC) introduced in 2009 protection areas for spawning aggregations of southern blue ling in EU waters within ICES Division VIa.

A map showing all the MPAs areas in the NE Atlantic (as of 2010) is shown in Figure 15.

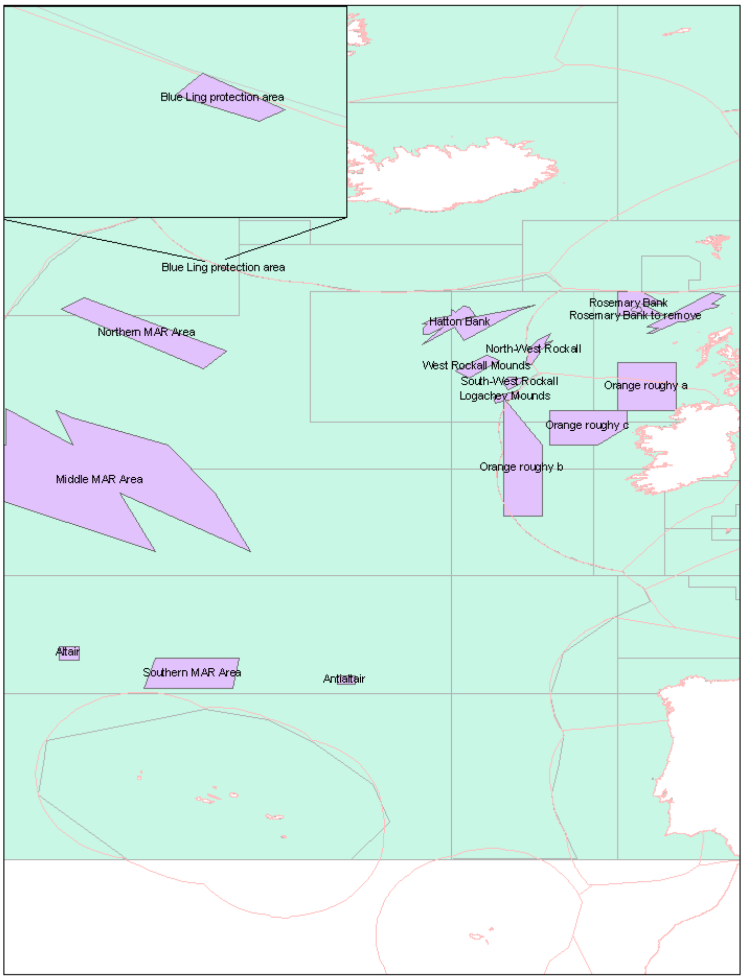

Figure 15. Orange roughy protection areas to the west of the British Isles, blue ling protection areas on Rosemary Bank and the continental slope to the NW of Scotland and to the SW of Iceland (enlarged), coral protection areas on the Rockall and Hatton Banks, and VME protection areas on the Mid-Atlantic Ridge (MAR). The area treated as the NE Atlantic is shown in pale blue. (Note this is not current as several areas are no longer applicable such as the Orange Roughy box).

A detailed assessment was made of the impact of restricting fishing activity directed towards blue ling in the vicinity of the Rosemary Bank and continental slope protection areas (Figure 16) during the annual spawning period. This included analyses of monthly landings data (2002-2010) aggregated by ICES rectangle and the use of high-resolution VMS data to estimate the apportionment of blue ling landings inside and outside the protection areas, both before and after closure implementation in January 2009. Details of the methods used to apportion fishing activity to VMS data points are given in Jennings and Lee (2012) and Lee et al. (2010), and limitations to the apportionment of landings data with respect to the blue ling closures are discussed in Posen et al. (2012). In summary, certain assumptions must be made regarding vessel fishing activity at any specific location, leading to uncertainty in estimating landings in the vicinity of protection area boundaries, hence uncertainty in the precise spatial apportionment of those landings.

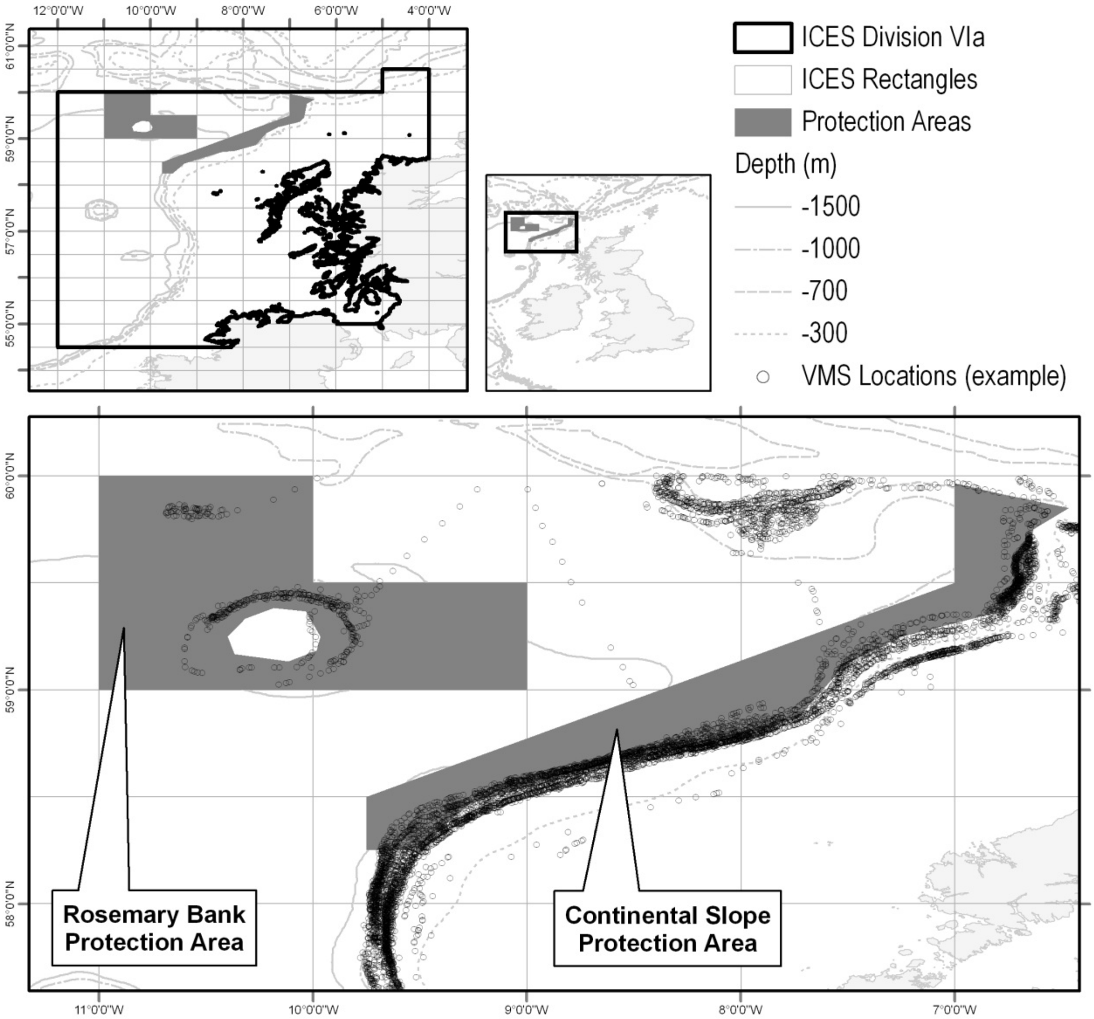

Figure 16. Locations of Rosemary Bank and continental slope protection areas in ICES Division VIa. The lower map gives an example of the spatial distribution of VMS 'pings' representing fishing activity targeted towards blue ling during the annual temporary closure (March-May).

Plots of monthly blue ling landings (Figure 17) from within the Rosemary Bank and continental slope protection areas indicated that, despite an overall reduction in landings over a nine year period, peak fishing activity is still focused on the March-May spawning period. Moreover, there appears to have been a subtle post-regulatory temporal shift towards peak landings in February, immediately prior to the temporary closures of 2009 and 2010.

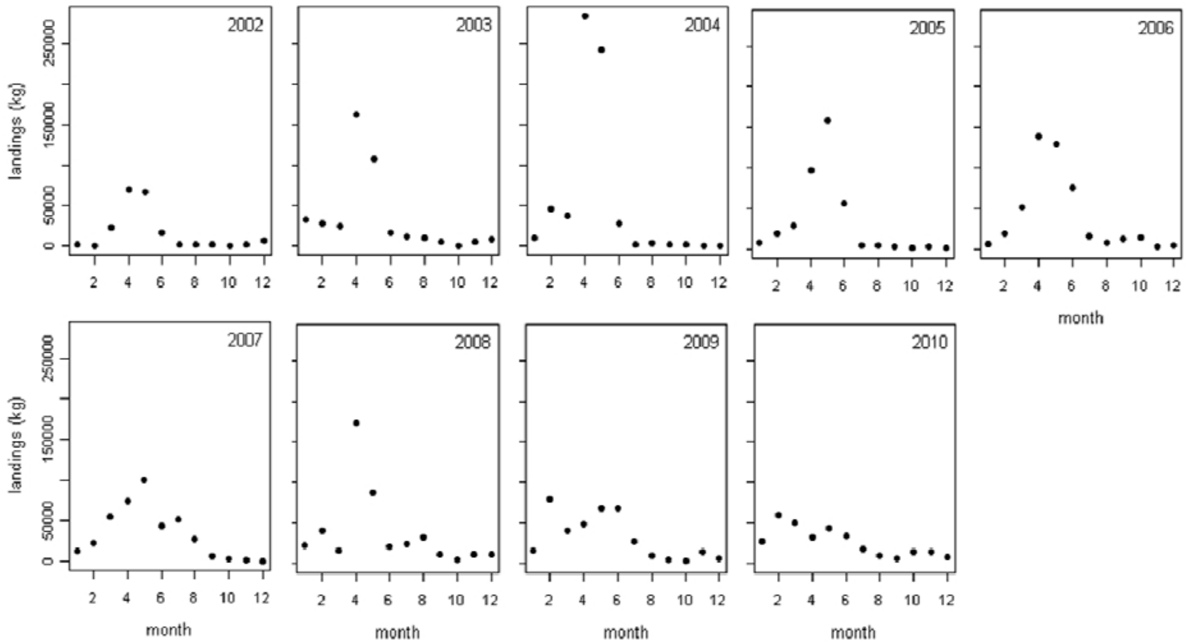

Figure 17. Plots of monthly blue ling landings from within the Rosemary Bank and continental slope protection areas between 2002 and 2010. Closures were implemented in January 2009, therefore the 2009-2010 plots represent landings after closure implementation: it can be seen that peak landings were still focused on and around the closure period during these two years.

The spatial distribution of fishing intensity targeting blue ling (Figure 18) shows annual changes in the focus of fishing activity during the March-May closure period, and captures two pre-regulatory years (2007-2008) and two post-regulatory years (2009-2010). It can be seen that, in general, the most intensive fishing activity is centred around the 750 m depth contour and that annual fluctuations in the regions of highest intensity tend to travel back and forth along this contour. It also appears that in 2009 and 2010, post-implementation of the protection areas, there was a south-westerly shift of fishing intensity along the continental slope protection area to just beyond the most southerly extent of its boundary, still centred on the 750 m depth contour of the continental slope. This suggests that there has been some displacement of blue ling fishing activity arising from implementation of the closures, but the focused activity in this location may indicate that the area immediately beyond this closure boundary is still important for spawning aggregations.

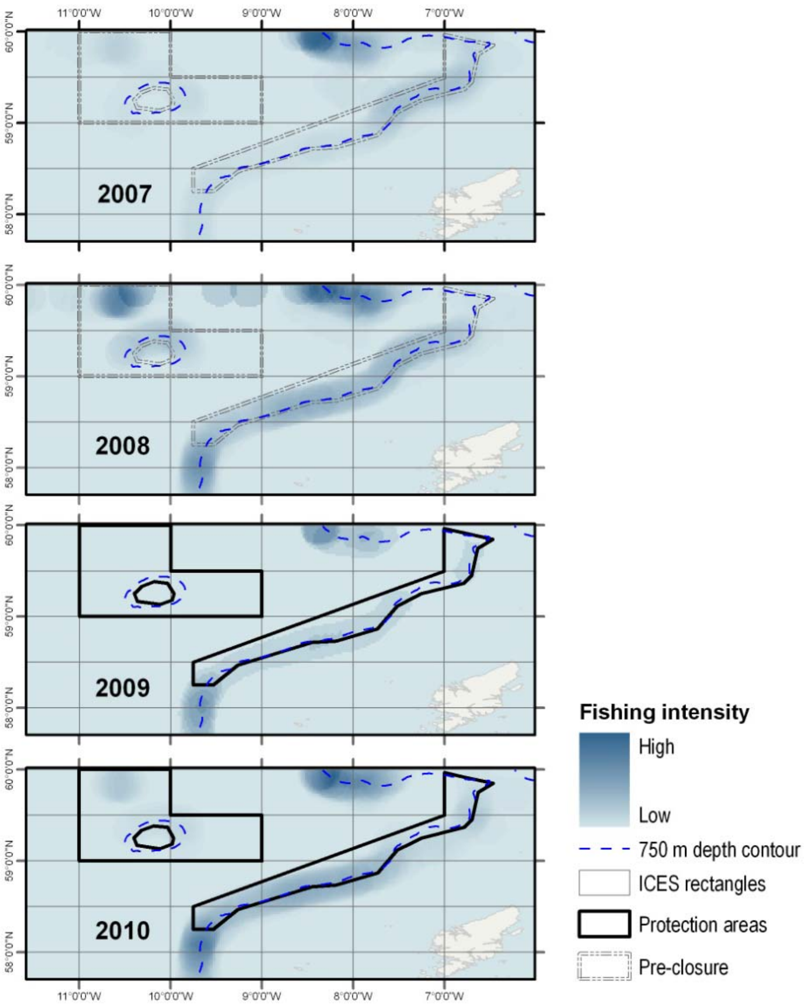

Figure 18. Spatial distribution of fishing intensity targeted towards blue ling during March-May for 2007-2008 (before closure implementation) and 2009-2010 (after closure implementation). Maximum fishing activity tends to follow the 750 m depth contour along the continental slope, and there appears to be some southwards displacement of fishing activity to just outside the continental slope protection boundary after closure implementation.

Without detailed logbook information from all vessels it is difficult to draw firm conclusions regarding the effectiveness of blue ling protection areas in ICES Division VIa, but the continued occurrence of peak landings during the closure period suggests that the regulatory measures are not necessarily having the desired impact. It is also likely that displacement fishing activity is still targeting spawning aggregations of blue ling, but there is insufficient biological evidence to support this hypothesis. However, it is known that fishers habitually return to areas where they have fished successfully in the past and, in this case, the displacement area to the south of the continental slope protection area may be just as vulnerable to stock depletion.

The greatest uncertainty in the analysis relates to the spatial apportionment of landings data and it is recommended that (i) logbook data for all vessels should be made available for scientific analysis of fishing activity to facilitate, amongst other things, evaluation of marine closures, (ii) an increase in VMS signalling frequency in all areas (not just protection areas) would improve the estimation of high-resolution fishing activity, (iii) installation of automatic onboard sensors on fishing gears would assist with assessment and monitoring of actual fishing activity, (iv) more strategic collection of biological data is necessary to support the assessment of spatial and temporal distribution of spawning activity.

Defining the fishing footprint

Fishing vessel position data is now routinely captured by satellite Vessel Monitoring Systems (VMS), with the data being managed by RFMOs and CFP contracting parties within member state EEZs. The provision of this system enables vessel monitoring to be precisely undertaken, making it possible to effectively manage spatially the fishing footprint. Work on VMS data for mixed demersal fishing fleets has shown the spatial coherence of many fishing fleet activities, that is, they tend to fish in the same general areas from one year to the next (Campbell et al., 2011), but the time series of VMS data is limited to the last 5 years. Defining a fishing footprint beyond which no fishing would be allowed, unless supported by an appropriate Environmental Impact Assessment, is possible and would serve to protect as yet unidentified VMEs. Given the relatively high spatial coherence of deep sea fishing activities (e.g. over the last 5 years) such a measure would likely have very little impact on present fishing activities. It has been suggested by Weaver et al. (2011) that the fishing footprint should be based on accurate and verifiable data on the areas actually towed or fished, using, for example, the previous 5 years of VMS data and detailed log-book data. It should also take into consideration information on intensity and frequency of fishing effort.

The overall footprint of the fishing effort within the NEAFC RA and EU EEZs is reasonably well known, and analysis of fishing vessel VMS data for the North Sea and parts of the Western Waters RAC reveals that most of the fishing effort is confined to relatively small areas of the seabed (Figure 19). Indeed, a recent analysis of VMS data in the UK sector reveals that the direct management of fishing footprints, e.g. by defining fishing grounds that exclude existing margins, can disproportionately reduce trawling impacts per unit effort or value (Jennings et al, 2012). The study also concluded that if policy commitments to reduce fishing impacts are required to meet specific targets (e.g. targets for achieving Good Environmental Status (GES) for 'seabed integrity' that result from the Marine Strategy Framework Directive (EC,2008) or 'to reduce to a minimum the impact of fishing on marine ecosystems' (EC, 2007)), then changes to fishery management plans provide an existing and internationally coordinated mechanism that can achieve greater overall reductions in fishing impact than the exclusion of bottom fisheries from MPAs.

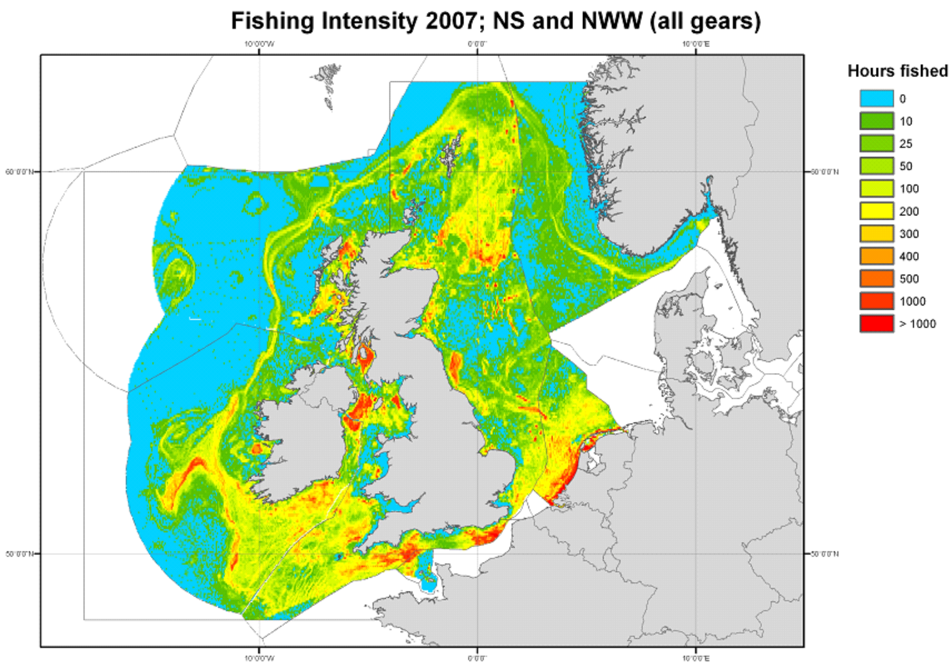

Figure 19. Total hours fished by all gear types in 2007 as calculated from aggregated VMS data for parts of the North Sea and North Western Waters off Ireland and Scotland.

Prototype control measures to manage fisheries ecosystem impacts

The generally understood and, in many cases, observed low resilience of deep sea VMEs highlights the importance of protecting seabed habitat as an integral part of deep-sea fisheries management (Soffker et al. 2011). Indeed, international concern over the impacts of deep sea fishing in both the high seas and EEZs has been the subject of extensive debate by the United Nations General Assembly (UNGA) and other international bodies such as the European Commission (EC) over the past 10 years, a debate which has resulted in the adoption of a series of resolutions by the UNGA to protect deep sea VMEs, the regulation of deep-sea fisheries under the EC 'deep-sea access regime' (Council Regulation 2347/2002), and the implementation of protected areas in the high seas, in EU waters and in EEZs of other countries.

However, progress to protect deep-sea VMEs through designating MPAs, and the reporting of fishery VME encounters with associated move-on-rules, has been considered of limited success in the high seas (Weaver et al., 2011). A more cost effective and ecologically meaningful way of managing the impacts of bottom fishing activities is not by establishing MPAs, but by defining the fishing footprint (Hiddink, 2006; Jennings et al., 2012). Furthermore, the remoteness and scale of deep-sea fisheries make them difficult to monitor cost-effectively. Therefore, a change in the spatial management approach is required, away from an approach which relies entirely on identifying the known presence of VME indicator species (through fishery encounter measures and fishery independent surveys to establish VMEs) to one which relies more on a risk-based approach and defining the fishing footprint. Such an approach would have the advantage of integrating multiple sources of data and evidence from monitoring programmes and predictive habitat models to support an assessment of potential habitat status and risk from bottom fishing activities. It would also provide a basis for targeting ecosystem monitoring and assessment resources more effectively. One possible strategic approach to mapping seabed risk to bottom fishing applicable to the deep sea is outlined in Table 9.

Table 9. Proposed deep seas risk categories of mapped seabed types in fisheries regulatory areas with corresponding management measures.

Seabed Category	Seabed Assessment	Risk Category	Fishing Footprint	Potential Management Measure/Response
1	Areas of known VME (based upon monitoring data)	**High**	Both	Closed to bottom fishing gears
2a	Areas of potential VME (known with low to moderate levels of certainty based upon HSMs)	**Moderate**	Inside	Observer enforced non destructive encounter protocols (e.g. camera systems)
2b	Areas of potential VME (known with low to moderate levels of certainty based upon HSMs)	**High**	Outside	Non invasive low impact survey techniques to be employed before fishing permitted (EIA protocols)
3a	Areas of **no** or low density/biomass VME (based upon monitoring data), which models predict could support VME	**Moderate**	Inside	A proportion of these areas (up to 20% of total predicted extent of VME) should be closed to fishing for potential recovery of seabed functions
3b	Areas of **no** or low density/biomass VME (based upon monitoring data), which models predict could support VME	N/A	Outside	This category essentially provides an evaluation of model reliability (it should be close to zero)
4a	Areas of **no** or low density/biomass VME (based upon monitoring data) which models predict are unlikely to support VME.	**Low**	Inside	Unrestricted bottom trawling
4b	Areas of **no** or low density/biomass VME (based upon monitoring data) which models predict are unlikely to support VME.	**Low**	Outside	Unrestricted bottom trawling
5a	Areas of potential **no** VME (known with low to moderate levels of certainty based upon HSMs)	**Low**	Inside	Unrestricted bottom trawling
5b	Areas of potential **no** VME (known with low to moderate levels of certainty based upon HSMs)	**Moderate**	Outside	Observer enforced non destructive encounter protocols (e.g. camera systems, gear modifications)

Regional maps of these seabed risk categories could be produced with their spatial limits defined by the fishing footprint (see Figure 19). All seabed Category 1 areas should be closed to bottom fishing activities, followed by closing a proportion of the seabed corresponding to Categories 3a which would sustain deep-sea ecosystem function and possibly associated fisheries yield. Finally, all areas corresponding to seabed Categories 4a, 4b & 5a would be unrestricted to bottom fishery activities. However, the precise areal extent to close off for seabed Category 3a is unknown, but under the EC Habitats Directive a minimum of 20% has been suggested as an appropriate area to protect for each designated feature known to occur within a region. Such an approach could ultimately result in an adaptive spatial fisheries management strategy which would allow closed areas to be opened whilst at the same time other open areas would be closed to facilitate their recovery.

The approach suggested in table 9 requires further conceptual work, e.g. defining the vulnerability of the different seabed categories and the level of threat they are exposed to. There is probably a need for more information in table 9, including vulnerability and threat the combinatiion of both given a risk assessment, the risk considered being that of loosing e.g. benthic biodiversity, essential habitat, VMEs. From the definition of seabed categories 4a, 4b, 4c they are primarily categories of low vulnerabilty. Vulnerability would be consideredd here as the inverse of resilience. This could be developped based upon a spatial qualitative "risk analysis" suggested to assess the Environment Status of the Seafloor for the Marine Strategy Framework Directive, taking into account, inter alia: (i) the intensity or severity of the impact at the specific site being affected; (ii) the spatial extent of the impact relative to the availability of the habitat type affected; (iii) the sensitivity/vulnerability vs the resilience of the area to the impact; (iv) the ability of the area to recover from harm and the rate of such recovery; (v) the extent to which ecosystem functions may be altered by the impact; and (vi) where relevant, the timing and duration of the impact relative to the times when the area serves particular functions in the ecosystem (Rice et al., 2012). This approach cannot be finalised before the end of the CoralFISH project in order the integrate the suite of indicators and the HSM model results from this project.

Summary and conclusions of the DEEPFISHMAN review of 0

- *Not all types of MPA have the same status in terms of protecting a habitat or biodiversity from human impacts (including fishing), with the result that biodiversity hotspots can be subject to multiple designations to ensure added levels of protection.*
    - *Habitat and species MPAs are identified by evaluating candidate areas against a set of criteria including uniqueness, aggregation, fitness consequences, and naturalness.*
    - *For fishery MPAs, there are three main types of closure: 'closed areas', 'no-take zones' and 'real-time closures'.*
- VMS data enables vessel monitoring to be precisely undertaken, making it possible to effectively manage spatially the fishing footprint. Work on VMS data for mixed demersal fishing fleets has shown the spatial coherence of many fishing fleet activities
- The remoteness and scale of deep-sea fisheries make them difficult to monitor cost-effectively. Therefore, a change in the spatial management approach is required, away from an approach which relies entirely on identifying the known presence of VME indicator species to one which relies more on a risk based approach and defining the fishing footprint.

Recommendations by the DEEPFISHMAN consortium

- *DEEPFISHMAN recommends priority should be given to fully quantitative and high resolution (spatial and temporal) assessments of both seabed habitat features and fishing pressure (effort), and research should be allocated to increasing our knowledge to fulfil an analysis of the following key elements essential for undertaking an appropriate seabed spatial risk assessment:*
    - *Mapping of actual and predicted VME habitat and VME indicator species distributions and densities*
    - *Mapping of actual fishing effort distribution and intensity in order to define the fishing footprint. VMS data are readily available for the deep-water where mostly large vessels operate, so it is a matter of all flag countries to be obliged to provide data*
    - *Assessment of actual and predicted sensitivity/vulnerability of habitats and species to fishing pressure to determine risk*

- *Assigning the calculated risk to a defined risk category (as outlined above)*
- *An evaluation of uncertainty in the risk*

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Topic 8. EU Data Collection Framework[14] (DCF) and observer sampling plans

Structure of the review

This review gives a background of the new Data Collection Framework (DCF), a summary of its different modules and a review of the DCF in relation to deep-water fisheries. The DCF in its present form will end on 31st December 2013 and will be replaced by a new Regulation, currently under discussion, to cover the period 2014-2020 (EU Multi Annual Programme (MAP) for data collection for 2014-2020).

Background to the DCF

The new European data collection regulation framework (COUNCIL REGULATION (EC) No 199/2008) was set up to establish a Community framework for the collection, management and use of data in the fisheries sector as well as to support scientific advice regarding the Common Fisheries Policy. It is a multi-annual programme and member states are asked to submit national programmes that include:

- multi-annual sampling programmes
- a scheme for at-sea monitoring of commercial and/or recreational fisheries
- a scheme for research surveys-at-sea
- a scheme for management and use of the data for scientific analyses purposes

Multi-annual national sampling programmes cover the sampling plans for biological data following fleet-fishery based sampling including, where appropriate, recreational fisheries. They also include sampling plans for ecosystem data that allows to estimate the impact of the fisheries sector on the marine ecosystem and that contributes to monitoring the state of the marine ecosystem. In addition, it contains sampling plans for socio-economic data with the aim to permit the economic situation of the fisheries sector to be assessed as well as its performance over time to be analysed, and impact assessments of measures undertaken, or proposed to be carried out.

The Community programme is comprised of several modules. The first module deals with the evaluation of the fishing sector and includes sections on the collection of economic, biological and transversal variables as well as research surveys at sea. The second module covers the evaluation of the economic situation of the aquaculture and processing industry sectors, whilst the third module deals with the evaluation of the effects of the fishing sector on the marine ecosystem. The fourth module is for data management and usage of data covered by the DCF.

In this review, only modules related to the capture of deep-water fisheries are covered, the sections relating to the aquaculture and processing industry and data management are not described in any further detail.

There are several legislative documents that cover the Data Collection Framework:

- COMMISSION REGULATION (EC) No 199/2008 is the actual regulation
- COMMISSION REGULATION (EC) No 665/2008 lays down the detailed rules for the application of Council Regulation (EC) No 199/2008
- Commission Decision 2008/949/EC and Commission Decision (2009)10121 contain the actual definition of the multiannual community programmes with all their specifications, variables

[14] Council Regulation (EC) 199/2008, Commission Regulation (EC) 665/2008, Commission Decision 2008/949/EC and Commission Decision (C)2009/10121.

to be sampled and sampling targets for the period 2009-2010 and period 2011-2013 respectively

Overview of the DCF sections and their relevance to the deep-water fishing sector

Module 1: evaluation of the fishing sector

Economic variables. Economic variables that need to be collected for active vessels of the Community Fishing Fleet Register are shown in Appendix VI of 2008/949/EC and 2009/10121(C), and include the following variables: income, personal cost, energy cost, repair and maintenance cost, other operational cost, capital costs, capital value, investments, financial position, employment, fleet details, effort levels, number of fishing enterprises and production value per species. Transversable variables are also collected which include capacity, effort and landings and are further described below.

Economic variables are collected at fleet segment level whereby the fleets are segmented by active gear (e.g. beam trawler), passive gear (e.g. hooks, drift, pots) or the polyvalent category. The fleets are further segmented by supra region (e.g. ICES area), and vessels are split into six boat length classes.

Concerning deep-water fisheries, with the segmentation being carried out at the level of gear type, it is not possible to separate the economic variables for the deep-water fishery. As a consequence separate analyses that are specific to these fisheries cannot be carried out. Economic considerations might, however, be quite different in the deep-water sector compared to other fleets such as higher fuel costs, larger distances to fishing grounds, etc. More thoughts (e.g. comment from Svein: "*Although this may be true for some nations and areas, deep-water fisheries such as those in VIIIc, IXa and X are also prosecuted by small artisanal vessels close inshore"* (this is also the case for other widely distributed stocks covered by the DCF)"). There is no doubt that fisheries in the high seas are further away than fisheries in EEZ. In the North east Atlantic, fisheries on the Hatton Bank and the Mid-Atlantic Ridge are far away from land. This does not necessarily imply that these fisheries have higher fuel cost. The Spanish fishery for roundnose grenadier on the western and northern slope of the Hatton Bank is operated by freezer trawlers which stay at sea for 45 days. As a result, the total steaming time and fuel spent travelling by day-at-sea or day fishing may not be higher than for vessels operating on the shelf but returning to port more frequently. The French fishery along the slope of the Rockall through does not operate much further away from the coast than shelf fisheries for gadoids and Monkfish on the Scottish shelf. Further as these trawlers may prosecute a mixed activity. They may fish for gadoid on the offshore shelf, on the way to and back from deeper fishing tracks. Last but not least, significant amounts of demersal species are caught at upper slope depths. For example, to the west of Scotland, this is especially the case of hake and monkfish, the distance from coast to depth of 200-800m were these fisheries occur in hardly less than 800-1200 m fishing grounds for e.g. roundnose grenadier and black scabbardfish.

Biological variables. Biological variables that need to be collected under the DCF are split into metiers and stock related variables. The aim of the sampling programme relating to metiers is to provide data for quarterly length distribution of stocks specified in the DCF (listed in Annex VII of 2008/949/EC and 2009/10121(C) and summarised here in Table 10) in the catches and quarterly volumes of discards. The metier is defined by the gear type, the target group and the mesh size (or other selective devices). Specific deep-water metiers are defined for bottom trawls for most geographical regions; for the north Atlantic the deep-water metier is also specified for drifting and set longlines and set gill nets.

Metiers must be sampled if they contribute to the upper 90% of the national landings. To obtain length distribution data of the landings, the system of concurrent sampling has been introduced into the new DCF. The concurrent sampling regime is as follows.

Each stock is classified into one of three groups according to their management status. Group 1 (G1) species are subject to management and recovery plans and/or subject to EC no 2371/2002. Group2 (G2) species are internationally regulated and major internationally not regulated by-catch species. Group 3 (G3) are all other by-catch species. The sampling scheme in the concurrent sampling programme requires that there is either a comprehensive sampling of all the species during each sampling event or a combination of sampling of G1 and G2 species ashore, and sampling of G3 species at sea. Hence, it is necessary to obtain samples on all species caught and landed together. Sampling at sea requires collecting information on all by-catch species, not only the target species, as was the case in the old DCR. For discards it is required to estimate the quarterly rate of weights discarded for all three species groups, using the same metier selection as for landings except for metiers with high discarding rates (>10%), which always need to be included. In some cases, length and age measurements of discards have to be carried out.

In relation to deep-water species, the metier approach and the new concurrent sampling scheme is a large improvement over the old DCR. It will provide fisheries data directly relevant to deep-water metiers and it will allow assessing the proportion of by-catch species in the catch. This will greatly improve the data acquisition in relation to the ecosystem approach, as all species caught and landed are adequately documented.

The concurrent sampling approach does not impact on all deep-water metiers because the by-catch from some fisheries is minimal or is mainly comprised of sharks, for which sampling is essential (e.g., the fishery of the blackspot sea bream in the Strait of Gibraltar and the longline fisheries for black scabbardfish to the southwest of Portugal and around Madeira). In other fisheries, the concurrent sampling provides data that may allow the calculation of population and community indicators that are useful for assessments required under the MSFD. For example, in DEEPFISHMAN, community indicators such as the ratio of sharks to roundnose grenadier have been investigated using onboard observations. Such indicators may allow assessing the impact of fishing on the fish community and trophic webs, as required under MSFD descriptors D1 and D4. Nevertheless, the trade-off between sampling assessed stocks and other species/ecosystem components remains.

EU deep-water regulation 2008/949/EC should mean that the targeted fishery – on the larger vessels at least – has observers in place that should be able to ensure data collection on both the retained and discarded part of the catch. This should ensure higher coverage than would be expected if the fleet was only covered by the standard requirements of the DCF in terms of number of trips to be sampled. Article 3.2 of regulation 2347/2002 may need to be reviewed to ensure that the same information is obtained from the seasonal and artisanal fisheries.

Currently, both the DCF and regulation 2347/2002 require the sampling of deep-water fisheries. Regulation 2347/2002 does require sampling, including onboard observation, but does not define a level of sampling. DCF and regulation 2347/2002 need to be unified. Because deep-water fisheries are typically smaller that shelf fisheries, higher level of sampling may be required, in particular, the proportion of fishing trips and fishing operations to make onboard observations needs to be higher. Currently, the sampling intensity carriedd out under regulation 2347/2002 in higher at leat for some fleets than that under DCF, when the two are unified, this should be maintained. The level of sampling required could consider the following strata:

Fleet level: onboard sampling on vessels holding a deep-sea fishing permit should involve at least 10% of vessels per year and at least 10% of the catch and effort; the percentage of catch and effort can be changed, the percentage of vessels cannot be changed because some vessels hold permits and carry out deep-sea fishing occasionally, while a few of these are full time. For example, in the French fishery there are ca. 40 vessels with permits and less than 10 vessels land 90% of total deep-sea species landings.

- Catch level similar to that for other species, but with lower minimum, so that sufficient samples would be collected for some small fisheries (e.g. 400 t/y in the blackspot sea bream fishery of the strait of Gibraltar)
- Under the current DCF, the responsibility for sampling the catch is that of the country where the first sale takes place – this is not necessarily the country of landing. For example the catch from the French deep-water fishery to the West of Scotland is landed mostly in Scotland, the first sale takes place at French auction markets from where the vessels originate. The fish boxes are physically taken trough the auction market so that sampling can be done.

In relation to deep-water stocks, in the case of the UK this mainly relates to Anglo-Spanish vessels (UK flag vessels) that land into the UK, Ireland and Spain, and transport overland the fish for first sale in Spain – the responsibility for sampling becomes that of the Spanish even though the fish were caught by UK registered vessels. The sampling at sea of these type of vessels can remain an issue for the flag country – especially as many of them are undertaking too limited landings (some Anglo-Spanish vessels do not land to the UK at all) into the flag country to place an observer on board. Bilateral agreements can be made to cover these conditions between individual MS or as part of RCM agreements.

There are also major landings by French and other MS vessels into the UK which are then transported overland out of the UK for first sale – this becomes a sampling responsibility for the MS in which the sale takes place (in most cases this tends to be the vessel flag state). In the reporting requirement of the current DCF it is difficult to identify if these landings, for sale in another MS, are covered by the sampling plan submitted by the MS in which first sale takes place.

In addition to metier related variables, biological variables related to stocks are required. All stocks for which biological variables have to be collected are published in appendix VII of 2008/949/EC and 2009/10121(C). For the purpose of this review, the table has been condensed to only cover deep-water species. Stocks considered encompass however more species than those qualified deep-sea species in EU regulation 2347/2002. Selected species also include those that are subject to the EU deep-water regulation 2008/949/EC andassessed in WGDEEP and/or are case studies in DEEPFISHMAN. These deep-water stocks are listed in Table 10 with the variables that must be sampled in terms of age, length, weight, sex, maturity and fecundity, and specified sampling targets. There are exemption rules for this sampling programme, such as that the national quota is less than 10% of the total TAC (or EU landings for stocks which are not currently subject to a TAC) or less than 200 t on average in the last three years.

In the Mediterranean Sea, no species included in in the EU regulation 2347/2002 are sampled under the DCF. The species occuring at greater depth included in the DCF for the Mediterranean Sea are deep-water red shrimps (*Aristeomorpha foliacea*, *Aristeus antennatus*) and are not addressed here.

Table 10. Sampling levels for biological variables for deep-water stocks; Category 1: Deep-water species listed under in EC council regulation 2347/2002 Annex I (landings of these species require that the vessel holds a "deep-sea fishing permit"), category 2: species listed under in EC council regulation 2347/2002 Annex II (catch of the fleets holding a deep-sea fishing permit and associated fishing effort should be reported similarly as for species category 1) category 3: deep-water stock assessed by WGDEEP, category 4: deep-water stocks assessed by WGEF, category 5:deep-water stock subject to case study under DEEPFISHMAN project. See main text for definitions of species groups G1, G2 and G3. Frequency codes Y- yearly, T- every three years.

Species	Latin name	Area/Stock	Deep-water category	Species group	Age no/1000 t	Weight	Sex	Maturity	Fecundity
Tusk	*Brosme brosme*	I, II	3	G2	250	T	T	T	
Deep Sea redfish	*Sebastes mentella*	I, II	5	G1	125	Y	Y	Y	
Roundnose grenadier	*Coryphaenoides rupestris*	IIIa	1,3	G2	100	T	T	T	
Argentine	*Argentina* spp.	IV	1,3	G2	50				
Tusk	*Brosme brosme*	IV, IIIa	3	G2	250	T	T	T	
Bluemouth rockfish	*Helicolenus dactylopterus*	IV	2,3	G2	250	T	T	T	
Roughhead grenadier	*Macrourus berglax*	IV,IIIa	2,3	G2	250	T	T	T	
Blue ling	*Molva dypterygia*	IV,IIIa	1,3	G1	125	T	T	T	
Ling	*Molva molva*	IV,IIIa	3	G2	125	T	T	T	
Greater forkbeard	*Phycis blennoides*	IV	1, 3	G2	50	T	T	T	
Deep-water shark	*Shark-like Selachii*	IV	1,4,5	G1		T	T	T	
Smoothhead	*Alepocephalus bairdii*	VI,XII	2,3	G2		T	T	T	
Scabbardfish	*Aphanopus* spp.	all areas	1,3, 5	G1	50	Y	Y	Y	
Argentine	*Argentina* spp.	all areas	1,3	G2	50	T	T	T	
Alfonsinos	*Beryx* spp.	all areas excluding X and IXa	1,3	G1	50	Y	Y	Y	
Alfonsinos	*Beryx* spp.	IXa and X	1,3	G1	125	T	T	T	
Gulper shark	*Centrophorus granulosus*	all areas	1,4,5	G1		T	T	T	
Leafscale gulper shark	*Centrophorus squamosus*	all areas	1,4,5	G1		T	T	T	
Portuguese dogfish	*Centroscymnus coelolepis*	all areas	1,4,5	G1		T	T	T	
Roundnose grenadier	*Coryphaenoides rupestris*	all areas	1,3,5	G1	100	Y	Y	Y	
Bluemouth rockfish	*Helicolenus dactylopterus*	all areas	2,3	G2	100				
Birdbeak dogfish	*Deania calcea*	All areas	1,4,5	G1		Y	Y	Y	
Orange roughy	*Hoplostethus atlanticus*	all areas	1,3,5	G1	50	Y	Y	Y	
Silver scarbbardfish	*Lepidopus caudatus*	IXa	2,3	G2		T	T	T	
Blue ling	*Molva dypterygia*	all areas excluding X	1,3,5	G1	125	T	T	T	
Blue ling	*Molva dypterygia*	X	1,3	G1	125	T	T	T	
Ling	*Molva molva*	all areas	3	G2	125	T	T	T	
Greater forkbeard	*Phycis blennoides*	all areas	1,3	G2	50	T	T	T	
Sea bream	*Sparidae*	all areas (*P. bogaraveo* in VIII & IXa)	2,3,5	G2	50				
Sea Bream	*Pagellus bogaraveo*	IXa, X	2,3	G1	250	T	T	T	
Wreckfish	*Polyprion americanus*	X	2,3	G2	125				
Deep-sea redfish	*Sebastes mentella*	ICES sub-areas V,VI,XII,XIV &NAFO SA 2 +(Div.1F+3K).	5	G2	250	Y	Y	Y	

Species	Latin name	Area/Stock	Deep-water category	Species group	Age no/1000 t	Weight	Sex	Maturity	Fecundity
Grenadier	*Macrouridae*	SA 2+3	1	G2	250		T	T	
Greenland halibut	*Reinhardtius hippoglossoides*	3KLMNO	5	G1	200	Y	Y	Y	
Black scabbardfish	*Aphanopus carbo*	Madeira	1,3	G1		T	T	T	
Silver scabbardfish	*Lepidopus caudatus*	Mauritania	2,3	G2					

For some stocks the landings by individual MS may all be less than 200 t per annum and also less than 10% of the TAC or total EU landings, meaning there is no requirement to sample even G1 stocks under the current guidelines. This could lead to >1000 t of landings not being sampled which could be the entire TAC. In these instances WGDEEP needs to inform the relevant RCM to ensure a sampling plan can be put in place for these stocks (some sole stocks are a good example of this where the total TAC may only be 400-500 t with 3-4 MS taking 100-150 t each).

The situation with data in stock assessed is reviewed stock-by-stock in Table 11. Stock assessments have been produced in recent years with considerable input from DEEPFISHMAN. Data from DCF surveys carried out on the shelf are used for some species considered deep-water species, such as greater forkbeard and blackbelly rosefish. Amongst deep-water stocks covered by DCF, a few produce low landings and are either not actually sampled or data are not reported to e.g. ICES. For stock giving rise to landings of several thousand tonnes, the problem that some MS are not required to sample their small catches of deep-water species may not be of major importance, as in most cases there are 1 or 2 MS or other countries catching the bulk of the landings.

Table 11. Review of the situation of fisheries and data for DCFspecies/area from table 10

Species	Latin Name	Area/Stock	Comments
Tusk	*Brosme brosme*	I, II	No quantitative assessment. Only trends in unstrandardised LPUEs and mean length are available
Deep-sea redfish	*Sebastes mentella*	I, II	The stock is mainly distributed out of EU waters. A stock assessment was carried out in 2012 based on a statistical catch-at-age model. The historical recruitment was estimated as part of DEEPFISHMAN and monitoring requirements were described (Planque et al; 2011, 2012)
Roundnose grenadier	*Coryphaenoides rupestris*	IIIa	There is no current fishery, so no DCF sampling. After high catches in 2000-2006 the fishery, which was unsustainable but was not left going long enough to collapse the stock, was halted by regulation. The Norwegian shrimp survey may allow monitoring the rebuilding of the biomass
Argentine (Greater silver smelt)	*Argentina* spp.	IV	International landings in ICES Subarea IV below 1000 t, ca. 2% of total Argentine landings in the NE Atlantic
Tusk	*Brosme brosme*	IV, IIIa	
Bluemouth rockfish	*Helicolenus dactylopterus*	IV	By-catch species, no data collected (ICES 2012a)
Roughhead grenadier	*Macrourus berglax*	IV,IIIa	Insignificant landings (<100 t acumulated since year 2000) , no data collected (ICES 2012a)
Blue ling	*Molva dypterygia*	IV,IIIa	Minor by-catch in these areas, no data collected (ICES 2012)
Ling	*Molva molva*	IV,IIIa	Data from Norway and UK (Scotland) observer trips are available for ling in these areas, these countries make up more than 80% of the landings
Greater forkbeard	*Phycis blennoides*	IV	Minor fishery (<200 t/y including IIIa), by-catch fishery, no data collected (ICES 2012a)
Deep-water shark	*Shark-like Selachii*	IV	No assessment
Smoothhead	*Alepocephalus bairdii*	VI,XII	The species forms the bulk of the discarded biomass, sampling is carried onboard French and Spanish trawlers
Scabbardfish	*Aphanopus* spp.	All areas	Two main fisheries (i) trawling fishery in Vb, VI and VII, and (ii) longline fishery in IXa. A state-space of the stock component in IXa has been developed in DEEPFISHMAN. This model uses DCF data from both IXa and Vb, VI and VII as the two components are assumed part of one single stock connected by migrations. DCF data include catch and effort and size distribution in both areas. Standardised LPUEs are calculated using GLM models in both areas
Argentine	*Argentina* spp.	All areas	Major fisheries are monitored. There are stock identity issues. An assessment is carried for ICES Division Vb but is not considered reliable

Species	Latin Name	Area/Stock	Comments
Alfonsinos	*Beryx* spp.	All areas excluding X and IXa	Insignificant and occasional fishery, mostly a Spanish fishery of ca 100 t/y in ICES VIIIc, Cantabrian Sea, no regular data collection (ICES 2012a)
Alfonsinos	*Beryx* spp.	IXa and X	Small fishery varying from 200-600 t/y since the late 1980s in ICES Division Xa (Azores). Longline fishery operating on seamount, landings and fishery-dependent data may be affected by several factors
Gulper shark	*Centrophorus granulosus*	All areas	Fishery dependent data restricted to on(board observations as a consequence of ban of landings
Leafscale gulper shark	*Centrophorus squamosus*	All areas	Fishery dependent data restricted to on(board observations as a consequence of ban of landings
Portuguese dogfish	*Centroscymnus coelolepis*	All areas	Fishery dependent data restricted to on(board observations as a consequence of ban of landings
Roundnose grenadier	*Coryphaenoides rupestris*	All areas	In ICES Division IVb, VI and VII, data collected under DCF include length distribution of landings (ports and onboard data) and discards (port). Age estimation has been interrupted. Catch and effort are used to estimate LPUEs from both logbook and fisher's own tallybook (haul-by-haul data). Following stock assessment trials as part of DEEPFISHMAN and ICES benchmarking (ICES 2010), a Bayesian surplus production model is fitted to all data, the stock and returns reliable estimated of exploitation rate and biomass (ICES, 2012a). Problems are met with data in ICES Division XIIb, Western Hatton Bank (ICES, 2012a). Insignificant fishery in other areas
Bluemouth rockfish	*Helicolenus dactylopterus*	All areas	Commercial landings of the species come mainly from ICES Division Xa (Azores) where 200-400 t/y are landed. In other areas fisheries have increased in the 1990s and until 2008 and then decreased. DCF survey data provided populations indicators. Because of its moderate size, the species is probably subject to discards in most areas and fisheries
Birdbeak dogfish	*Deania calcea*	All areas	
Orange roughy	*Hoplostethus atlanticus*	All areas	EU fisheries for this species are closed. Only onboard observations provide data, that are being used to carry out a Productivity susceptibility analysis as part of DEEPFISHMAN
Silver scarbbardfish	*Lepidopus caudatus*	IXa	
Blue ling	*Molva dypterygia*	All areas excluding X	The main EU fisheries occur in ICES Division Vb and Subareas VI and VII. EU landings are mainly from France. Onboard observations and port sampling provide length and age distribution quarterly. Additional data are collected during onboard observations, such as maturity at spawning time. Catch and effort are used to estimate LPUEs from both logbook and fisher's own tallybook (haul-by-haul data). Two assessment approaches have been developed in DEEPFISHMAN, as stock reduction analysis (SRA) and a multi-year catch curve (MYCC) model. These allow for reliable assessment of the stock
Blue ling	*Molva dypterygia*	X	Blue ling is not caught in this area; the landings should be ascribed to the closely related *Molva macrophtalma*. Landings are minor and no data are collected (ICES 2012)
Ling	*Molva molva*	All areas	Survey indictors from DCF surveys are used assessments and advice purposes in ICES areas VI and VIII
Greater forkbeard	*Phycis blennoides*	All areas	Survey indictors from DCF surveys are used assessments and advice purposes in ICES areas VI and VIII

Species	Latin Name	Area/Stock	Comments
Sea bream	*Sparidae*	All areas	This category implies that any sea bream species supporting a significant fishery in an area should be sampled. The blackspot seabream (*Pagellus bogaraveo*), used to support large catches in ICES subareas VI and VII. These collapsed in years 1975-1985. Current minor catches are not sampled and are so low that sampling would not be possible. Based on archive data and analyses carried out in DEEPFISHMAN, it is postulated that the current EVHOE (=western IBTS survey) provides the appropriate sampling to detect a population rebuilding, which the current management makes possible (Lorance, 2011).
Sea Bream	*Pagellus bogaraveo*	IXa, X	In IXa, the fishery is mainly Spanish; the species is not part of the Spanish DCF sampling plan because of landings smaller than 1000 t/y. However, length composition data are sampled. For this high value species there is however option to integrate it in DCF programme and carry out age estimation. There is currently no reliable stock assessment. In ICES Subarea X, length and age composition are available from both commercial catch and survey. The fishery operated around Azores islands and on seamounts, several factors might affect LPUE and length and age composition of the catch so that no reliable assessment is achieved
Wreckfish	*Polyprion americanus*	X	This is a significant fishery in the Azores, in particular when the commercial price of the species is considered. Average landings have been 500 t/y since 1990. Only landings and survey data are collected. It is probably difficult to assess such a stock because of the habitat in the area where artisanal fisheries operate at discrete locations (e.g. seamounts) and several factors may affect fishery dependent data such as LPUE and size and age composition of fish caught
Deepsea redfish	*Sebastes mentella*	ICES sub-areas V, VI, XII, XIV & NAFO SA 2 +(Div.1F+3K)	
Grenadier	*Macrouridae*	SA 2+3	
Greenland halibut	*Reinhardtius hippoglossoides*	3KLMNO	Analytical assessment remains unreliable probably because of lack of knowledge of migration and/or stock structure. Data of other type than those collected under DCF may be required
Black scabbardfish	*Aphanopus carbo*	Madeira	No assessment carried out at the moment. Further expansion of the modelling carried out in DEEPFISHMAN for the West Portugal Mainland stock may be considered in the future
Silver scabbardfish	*Lepidopus caudatus*	Mauritania	

For a number of stocks, data collected under DCF are used for assessments. The status of stock s of G1 is summarised in Table 12. Reliable stock assessment have been produce for several deep-water stocks, DEEPFISHMAN case studies have significantly contributed to this progress.

Table 12. Overview of the assessment carried for deep-water G1 stocks, corresponding DEEPFISHMAN case studies and stock assessment/population dynamics developments. DCF data mentioned only include those reported to ICES WGDEEP or known to DEEPFISHMAN.

Species	Latin name	Stock	DCF data	Assessment	DEEPFISHMAN case study	DEEPFISHMAN methodological developments

Species	Latin name	Stock	DCF data	Assessment	DEEPFISHMAN case study	DEEPFISHMAN methodological developments
Deep Sea redfish ()	*Sebastes mentella*	I and II		Statistical catch-at-age	CS4	Rebuilding of time-series of recruitment Options for monitoring Gadget
Blue ling ()	*Molva dypterygia*	IIIa, IV	None	None		
Deep-water shark ()	*Shark-like Selachii*				CS2	Survey indicators Spatial indicators
Scabbardfish (	*Aphanopus* spp.	Vb, VI and VII		Trend-based	CS2	Standardisation of LPUEs, Assessment method simulations
Scabbardfish	*Aphanopus* spp.	IXa		Trend-based	CS3c	State-space model
Alfonsinos	*Beryx* spp.	Mostly VIIIc	None	No		
Alfonsinos	*Beryx* spp.	X	Survey indices	No		
Gulper shark	*Centrophorus granulosus*		On-board		CS2	Survey indicators
Leafscale gulper shark	*Centrophorus squamosus*		On-board		CS2	Survey indicators
Portuguese dogfish	*Centroscymnus coelolepis*		On-board		CS2	Survey indicators
Roundnose grenadier	*Coryphaenoides rupestris*	Vb and XIIb, VI and VII	On-board Landings, discards length composition	Bayesian surplus production	CS2	Standardisation of LPUEs, SVPA, Bayesian surplus production, Assessment method simulations
Birdbeak dogfish	*Deania calcea*				CS2	Spatial indicators (lumped as deep-water sharks)
Orange roughy	*Hoplostethus atlanticus*	VI	Onboard, discards		CS1b	None
		VII	On-board, discards		CS1b	PSA
Blue ling	*Molva dypterygia*	Vb, VI and VII	landings, discards, onboard, length, age		CS1c	Standardisation of LPUEs, MYCC, SRA, continuous state space model, Assessment method simulations
Blue ling	*Molva dypterygia*	X	None			
Sea bream	*Pagellus bogaraveo*	IXa	Landings, sales, length, age	XSA (not reliable)	CS3a	Assessment method simulations
Sea bream	*Pagellus bogaraveo*	VI, VII, VIII	None		CS3a	Modelling of archive data
Greenland halibut	*Reinhardtius hippoglossoides*	NAFO 2 and 3KLMNO	Landings discards on-board, length and age	XSA (not reliable)	CS5	None
Black scabbardfish	*Aphanopus carbo*	Madeira	Landings	?		

Transversal variables. The list of transversal variables includes the capacity which includes the number of vessels, GT, kw and vessel ages, the effort category which contains variables used for effort evaluation such as number of vessels, days at sea, fishing days, number of trips, fishing operations and other effort variables such as number of hooks. The third category is the landings category which includes the value of landings, price of species and live weight of landings and per species. The aggregation level depends on variables and range between fleet segment, metier and metier fleet segment with a periodicity ranging between annual and monthly. The detailed table is given in Appendix VIII of 2008/949/EC and 2009/10121(C).

Concerning deep-water, the segmentation for the DCF transversal variables occurs at a higher disaggregation level than the economic variables. The level of aggregation should correspond to the most disaggregated level required. With this level of disaggregation, effort evaluation as well as landings value and weight can be specifically assessed for deep-water metiers.

Module of evaluation of the effects of the fishing sector on the marine ecosystem

For the new DCF, a set of indicators was chosen to evaluate the effect of fishing onto the ecosystem. These can be found in Appendix XIII of 2008/949/EC and 2009/10121(C) and are summarized here according to the data sources they require.

There are four survey based indicators, which include (i) the conservation status of fish species, (ii) the proportion of large fish, (iii) the mean maximum length of fishes, and (iv) the size at maturation of exploited fish. These survey indicators aim to assess and report trends in biodiversity, the size structure and life history composition of the fish community, as well as potential genetic effects on fish populations. They are based on species data, and length and abundance measurements from independent fisheries surveys. For the maturity indicator, sex and maturity measurements are also required. For surveys to be able to provide these data, they need to sample the community effectively, cover the main proportion of the marine region to be assessed, and have an existing time series. Species that have catchability issues cannot be included in the analysis. The indicators have been developed for shelf seas (particularly the North Sea) and groundfish communities sampled by bottom trawl on ground fish surveys (IBTS in particular).

There are three indicators based on the position and vessel registration information of VMS data, including (i) the distribution of fishing activities, (ii) the aggregation of fishing activities, and (iii) areas not impacted by mobile bottom gear (in the preceding year). The first two indicators are reported together and require that the VMS positions are linked with the metier level. The third indicator measures the response to changes in the fishing behaviour by mobile bottom gear in relation to establishments of MPAs, for example, or effort or catch controls and technical measures. The last group of ecosystem indicators is based on discard rates and fuel efficiency of fish capture, which measures the relationship between fuel consumption and the value of landed catch.

Most deep-water ground fish communities are currently not adequately covered by independent fisheries surveys under the DCF or nationally funded programmes. Thus the effect of fishing on the deep-water ecosystem cannot be assessed in most regions. As many of the deep-water fish communities have been subjected to intense fishing pressure in the last decades, this is of concern, as there is no fisheries independent monitoring programmes which assess the current effect and the potential recovery of past fishing pressures.

In relation to the survey indicators chosen, these have been developed for shelf species in the North Sea and some optimisation or adaptation might be required to apply these indicators to deep-water species (e.g. size threshold of 40 cm, size). In addition, some catchability issues could arise with some of the very vulnerable deep-water species, such as deep-water sharks and orange roughy.

In relation to VMS data, the fact that in the new DCF, VMS must be linked to logbook data for fishing activities will contribute greatly to the evaluation of a deep-water fishing footprint where areas impacted on by fishing can be determined. There might, however, be an issue with the timeframe of

1 year fishing. It has been shown in ICES 2009 that the fishing footprint of deep-water fisheries in the NEA has retracted in the last 10 years. Given the slow recovery time of some deep-water ecosystems, such as cold water corals, to the impact of bottom fishing, the period of 1 year for the evaluation of areas not affected by fishing is likely to be too short. This time period of 1 year is inappropriate for VMEs, it may be appropriate for sedimentary bottoms. As a consequence, a way forward in the management of deep-water fisheries may be to constraint them to sedimentary bottoms (i.e. freeze and restrict the footprint to these areas/habitats) and then apply the DCF method to assess the proportion of sedimentary seabed not affected by fishing.

Research surveys under the new DCF

There is a list of surveys published in the Appendix IX of 2008/949/EC and 2009/10121(C) that are funded under the new DCF. Table 13 summarises the deep-water stocks reviewed in this document in relation to the DCF, what surveys are currently undertaken, which surveys are discontinued and which surveys partially cover the stock. It is apparent that for most deep-water stocks, in particular in the areas V to VIII, there is no adequate survey coverage under the DCF or national funding programmes. As a consequence for most stocks, fisheries independent data for the evaluation of stock trends are not available and cannot contribute to stock assessment. As highlighted in the previous section on ecosystem indicators, this is of concern as many of the stocks have been exposed to heavy fishing pressure in the past and are now depleted. There is currently no independent monitoring programme that follows stock trends and assesses potential recovery of these stocks. However, in 2012 some stocks have been shown to have started recovering from assessment trend-based assessment using LPUEs and mean length and quantitative assessment. The production of these assessments without survey may question the view that surveys are necessary. The list of surveys eligible for funding under EUMAP 2014-2020 is due to be reviewed in 2012/13.

Comprehensive reviews on historic and current deep-water surveys are given in ICES 2007 (WGDEEP) and ICES 2009 (PGNEACS).

Table 13. Fisheries surveys funded under DCF or national programmes that cover deep-water stocks (list from table 10).. Colour code: green = survey exists; yellow = survey exists but might give inadequate coverage in space, depth or in time, or uses non optimal gear, orange = discontinued time series and/or subject to funding; red = no survey to provide information. Letter code: DCF = funded by Data collection framework; NF = nationally funded.

Species	Latin Name	Area/Stock	Survey	Survey details
Tusk	*Brosme brosme*	I, II	NF	Norwegian Greenland halibut, but no longline
Deep Sea redfish	*Sebastes mentella.*	I, II	DCF/NF	International/Norwegian red fish survey
Argentine	*Argentina* spp	all areas	NF	Norwegian silver smelt survey
Roundnose grenadier	*Coryphaenoides rupestris*	IIIa	DCF, NF	IBTS. Norwegian shrimp/silver smelt survey,
Tusk	*Brosme brosme*	IV, IIIa	DCF, NF	IBTS, Norwegian silver smelt survey, but no longline survey
Bluemouth rockfish	*Helicolenus dactylopterus*	IV	DCF, NF	NS-IBTS, too shallow
Roughhead grenadier	*Macrourus berglax*	IV, IIIa	DCF, NF	IBTS, Norwegian silver smelt survey
Blue ling	*Molva dypterygia*	IV, IIIa	DCF, NF	IBTS, Norwegian silver smelt survey, trawl, no longline survey
Ling	*Molva molva*	IV,IIIa	DCF, NF	NS-IBTS, Norwegian silver smelt survey, trawl no long line survey, IBTS
Greater forkbeard	*Phycis blennoides*	IV	DCF, NF	NS-IBTS, Norwegian silvers smelt survey
Deep-water shark	*Shark-like Selachii*	IV	DCF, NF	IBTS Norwegian silver smelt survey, but no longlining
Smoothhead	*Alepocephalus bairdii*	VI, XII	DCF	Part of PGNEACS proposal

Species	Latin Name	Area/Stock	Survey	Survey details
Scabbardfish	*Aphanopus* spp.	all areas	DCF	Part of PGNEACS proposal
Argentine	*Argentina* spp.	all areas	NF	Norwegian silver smelt survey covers II, IV, IV, III
Alfonsinos	*Beryx* spp.	all areas excluding X and IXa		
Alfonsinos	*Beryx* spp.	IXa and X	NF	Azores long line survey
Gulper shark	*Centrophorus granulosus*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Leafscale gulper shark	*Centrophorus squamosus*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Portuguese dogfish	*Centroscymnus coelolepis*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Roundnose grenadier	*Coryphaenoides rupestris*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Birdbeak dogfish	*Deania calcea*	All areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Bluemouth rockfish	*Helicolenus dactylopterus*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Orange roughy	*Hoplostethus atlanticus*	all areas	DCF	Part of PGNEACS proposal not currently on DCF survey list
Silver scarbbardfish	*Lepidopus caudatus*	IXa	DCF	Part of PGNEACS proposal not currently on DCF survey list
Blue ling	*Molva dypterygia*	all areas excluding X	DCF	Part of PGNEACS proposal, not currently on DCF survey list
Blue ling	*Molva dypterygia*	X	?	Specie does not occur in the area. M macrophthalma instead
Ling	*Molva molva*	all areas	DCF	IBTS, only shallow part of distribution. However, western IBTS sampled down to 600 m is appropriate, the problem is the low number caught that suggest a very high sampling effort would be necessary
Greater forkbeard	*Phycis blennoides*	all areas	DCF	IBTS, only shallow part of distribution, but cover the recruitment of the species
Sea Bream	*Pagellus bogaraveo*	IXa, X		Azorean longline survey in X
Wreckfish	*Polyprion americanus*	X		Azorean longline survey in X(?)
Deepsea redfish	*Sebastes mentella.*	ICES sub-areas V, VI, XII, XIV & NAFO SA 2 +(Div.1F+3K)		More details needed from Klara
Grenadier	*Macrouridae*	SA 2+3	DCF/NF	
Greenland halibut	*Reinhardtius hippoglossoides*	3KLMNO	DCF/NF	Does not cover entire stock
Black scabbardfish	*Aphanopus carbo*	Madeira	G1	Madeira long line survey
Silver scabbardfish	*Lepidopus caudatus*	Mauritania	?	?

References

(EC) No 2347/2002: COUNCIL REGULATION of 16 December 2002 establishing specific access requirements and associated conditions applicable to fishing for deepsea stocks.

(EC) No 199/2008 COUNCIL REGULATION of 25 February 2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy.

(EC) No 949/2008 COMMISSION DECISION of 6 November 2008 adopting a multiannual Community programme pursuant to Council Regulation (EC) No 199/2008 establishing a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy.

(EC) No 665/2008 COMMISSION REGULATION of 14 July 2008 laying down detailed rules for the application of Council Regulation (EC) No 199/2008 concerning the establishment of a Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy.

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Topic 9. Deep-sea fishery independent surveys and monitoring regimes

Introduction

For most deep-water stocks, in areas V to VIII in particular there is no adequate survey coverage. As a consequence, fisheries independent data for the evaluation of stock trends are not available and cannot contribute to stock assessments. In addition, there is currently no independent monitoring programme that follows stock trends and assesses potential recovery of stocks that have been exposed to heavy fishing pressure and are likely to be depleted (Review of the National Data Collection Framework in relation to deepwater species).

Coordination of deepwater surveys: PGNEACS

PGNEACS was formed and met for the first time in 2008 with the overall TOR to review existing NEA deep-water and slope surveys, in terms of sampling strategy, protocols and intercomparability and, based on this review, suggest a plan for internationally coordinating annual or regular deepwater surveys in the north-east Atlantic.

Proposals for coordinated surveys under PGNEACS

Between 2008 and 2009 the group drafted a proposal for three coordinated deep-water surveys in the Northeast Atlantic (ICES 2008 and ICES 2009).

The first survey proposal covers Nordic deep-water trawl surveys. There are several Nordic deepwater trawl surveys currently undertaken by Norway, Iceland, Faroe and Greenland, which provide abundance indices for deep-water species in particular Greenland halibut to ICES AFWG and NWWG. These national surveys are established time-series, but they are similar in their scientific objectives and design, and under PGNEACS they will undertake to enhance their coordination in terms of spatial and temporal coverage, data collection, management and analysis.

The second survey proposal by PGNEACS consists of a coordinated deep-water trawl survey along the Central European slope and associated banks and seamounts, stretching from the Faroese Plateau (Vb) to the Goban Spur (VIII). There are a number existing survey programs operating in the area (mainly Scotland and Ireland), however their spatial extent does not cover sufficiently the stock distribution and main fisheries of the deep-water species in the area.

The third PGNEACS proposal covers surveys in the southern area (IX and X). It covers an existing longline survey and it is proposed under PGNEACS to extend this survey to greater depths (down to 1200 m deep) including covering new sea mounts. The proposed new survey extensions in the south would require additional funding to be implemented.

Current situation in relation to funding

The Nordic deep-water surveys are currently financed under national funding programmes and it is envisaged that these programmes will continue, hence WGNEACS' role will be one of improved coordination and collaboration. For the central European deep-water survey, it is hoped that the survey programme will be included in the new European data collection framework (EC199/2008). This is of particular importance as there is currently not sufficient national funding to carry out a survey in the area west of the British Isles that covers the stock area of the main deepwater species. The newly proposed extensions in the southern area are also dependent on DCF funding.

National surveys

National surveys that cover deep-water stocks are briefly described below by nation (ICES WG Report 2011).

Faroe Islands

The Faroese groundfish survey for cod, haddock and saithe is a fixed station trawl survey conducted annually on the Faroe Plateau. The spring survey (conducted in February-March) began in 1994 and covers 100 stations, while the autumn survey (conducted in August) began in 1996 covering 200 stations. The surveys also yield useful information on many other species. It must be kept in mind that the spring surveys are restricted to depths shallower than 500 m, so it only covers a part of the distribution area of deep-water species. The autumn survey was expanded in 2000 to cover depths to 1200 m.

Greenland

Greenland has conducted stratified random bottom-trawl surveys in ICES XIVb since 1998 (except 2001) covering depths between 400 and 1500 m. The survey is aimed at Greenland halibut but estimates of biomass and abundance and length frequencies on roundnose and roughhead grenadier are also available. Information on sex, length and weight on the very few tusk, ling, smoothheads, argentines and different species of elasmobranchs have also been recorded. The utility of this survey for assessment purposes cannot yet be evaluated.

Iceland

The Icelandic groundfish survey, which has been conducted annually since 1985, yields information on the variation in time of the fishable biomass of many exploited stocks in Division Va, and also useful information on many other species. More than 500 stations are fished annually, but the survey depth is restricted to the shelf and slope shallower than 500 m. Therefore the survey area only covers part of the distribution area of ling and blue ling as their distribution extends into greater depths. Another annual deep-water groundfish survey has been carried out all around Iceland since 1996. Although the main target species in this survey are Greenland halibut (*Reinhardtius hippoglossoides*) and deep-water redfish (*Sebastes mentella*), data for all species are collected. Further, this survey corvers depth down to 1500 m and it is therefore much more relevant to deep-water species that the spring survey. Data include length distributions and number of all species caught as well as weight, sex and maturity stages of selected ones.

Ireland

The Marine Institute ran 10 deep-water surveys along the northeastern shelf edge between 1992 and 1999, five each by trawl and longline. This survey programme was an important source of information on the distribution and abundance of deep-water fish during the early development of the commercial fishery, and provided samples of deep-water fish for biological analysis. The surveys have also produced catch per unit of effort (CPUE) and discarding information.

In 2006 the Marine Institute recommenced its deep-water survey programme with a slope survey covering the continental slope in Area VIa and the northern Porcupine Bank in Area VIIc. Overall, 27 hauls were carried out at four depths, 500 m, 750 m, 1000 m and 1500 m. The survey attempted to standardize gear, sampling strategy and protocols with the Scottish survey as much as possible. As part of this standardisation and intercomparison, RV Celtic Explorer carried out eight comparative tows with the Scottish research vessel, RV Scotia. The objective of the survey was to collect abundance data and biological information on the main deep-water fish species, including weight, length and maturity, and also to collect benthic invertebrates and bottom sediment samples. CTD transects, grab sampling, and cetacean studies were also carried out. It is envisaged that this survey will provide a time-series for CPUE for the main deep-water species in the survey area in future.

Portugal (Azores)

Since 1995, a longline survey has been conducted annually by the Department of Oceanography and Fisheries at the University of the Azores (DOP), during spring, covering the main areas of distribution of demersal species (the coast of the islands, and the main fishing banks and seamounts), with the primary objective of estimating fish abundance for stock assessment (Pinho, 2003). The survey has supplied information needed to estimate the relative abundance of commercially important deep-water species, from ICES Area X. Bottom longline was adopted as a sampling survey technology in the Azores because the seabed is very rough, which does not permit use of other gears (e.g. trawl), and also due to a combination of behavioural and physiological factors of the demersal species (e.g. deep-water species are difficult to detect acoustically, particularly those living near the seabed, and mark recapture studies are ineffective for some of the species because they die when brought to surface).

Spain

From 2001 a new bottom-trawl survey started in the Porcupine Bank to estimate abundance indices of commercial species and the distribution patterns of the demersal and benthic species in the area. The area covered in Porcupine 2005 survey is the Porcupine Bank extending from longitude 12°W to 15°W and from latitude 51°N to 54°N, covering depths between 150 and 800 m. The cruise was carried out between September and October.

UK (Scotland)

A deep-water trawl survey of the continental slope to the west of Scotland has been carried out biennially in September by FRS, The Marine Laboratory since 1998. In 2005, it was combined with the Rockall haddock survey, upgrading both to annual status. A TV sled survey for deep-water Nephrops burrows is carried out at night at selected sites on Rockall and the slope, and TV drop frame deployments are also carried out as part of collaboration with JNCC (Joint Nature Conservation Committee) to map habitat in these areas. The survey contains stations extending from the Wyville–Thomson Ridge in the north to south of the Hebridean Terrace, although coverage has varied from year to year. Fishing is stratified by depth and currently ranges from 400 to 1900 m.

Deep-water stocks in relation to current and discontinued surveys

Table 13 (above) summarises the deepwater stocks in relation to the DCF, what surveys are currently undertaken, which surveys are discontinued and which surveys partially cover the stock. It is apparent that for most deep-water stocks, in particular in the areas V to VIII, there is no adequate survey coverage under the DCF or national funding programmes.

Monitoring of deep-water fisheries in the NE Atlantic (DEEPFISHMAN deliverable 2.3)

Deep-water fisheries in the NE Atlantic fall under the monitoring and management remit of the North-east Atlantic Fisheries Commission (NEAFC) for international waters and the EU and sovereign states for waters within their exclusive economic zones (EEZs). Explicit management measures for EU vessels fishing did not come into force until January 2003, when Total Allowable Catches (TACs) were introduced for selected deep-water species (EC, 2002a). This was complemented by the introduction of an EU Access Regime establishing specific access requirements and associated conditions applicable to fishing for deep-water species. This aimed to cap the expansion of fishing effort. The total capacity of vessels holding deep-water permits was also restricted. Special reporting and control requirements were also introduced, including the development of biological sampling and/or scientific observer schemes.

ICES advice for deep-water stocks is issued every two years and the EU TAC Regulation has been updated biennially and at times revised regarding species coverage and to address other pertinent deep-water issues. Examples of the latter include (i),the introduction of closed areas, (ii) reductions in the level of EU deep-water fishing effort (EC, 2005a; EC, 2006a), (iii) measures to address ghost fishing by abandoned, lost or otherwise discarded fishing gear, and (iv) the introduction of protection areas for spawning aggregations for some stocks.

Summary and conclusions of the DEEPFISHMAN review of Topic 9

- *For most deep-water stocks there is no adequate survey coverage*
- *There is currently no independent monitoring programme that follows stock trends and assesses potential recovery of depleted stocks*
- *Nationally funded surveys are carried out by Norway, Faroes, Iceland, Ireland, Scotland, Portugal and Spain*
- *Target species are Greenland halibut and deep-water redfishin the Faroe Islands, Norway and Iceland, although data for other species are also collected. The main commercial targets of the Scottish and Irish surveys are roundnose grenadier and black scabbardfis, these survey also provide indicators for deep-water sharks and all species caught are smapled.*
- *Only few surveys funded by DCF may give adequate coverage in space, depth or in time*
- *PGNEACS followed by WGNEACS was created to review existing NEA deep-water and slope surveys and to suggest a plan for internationally coordinating annual or regular deepwater surveys in the north-east Atlantic*
- *Implementation of WGNEACS proposals is depending on DCF funding*

Topic 10. Management of mixed-fisheries: species/fishery level

Introduction

A particular problem in fisheries management is where one species may be more vulnerable or depleted than another, yet exploited within the same fishing activity. Such 'technical interactions' in mixed fisheries can result in the over-exploitation of one of the species in order to maximise yield of the other, which under a system of Total Allowable Catches (TACs) can also be a cause of discarding of the species for which the TAC is exhausted.

Mixed fisheries approaches

A number of approaches to address mixed fisheries management problems have been developed, including optimisation approaches which generally seek to maximise yield from a complex of species without overexploiting any one species whilst calculating foregone yields (Da Rocha et al., 2012; Gröger et al., 2007), which may also include extend to the consideration of multi-species (predator-prey) interactions (Mackinson et al., 2009), and the exploration of technical conservation measures which may align objectives more closely in mixed fisheries, such as changes to mesh size (Froese et al., 2008), as well as spatially and seasonally explicit management (Mahévas and Pelletier, 2004; Murawski and Finn, 1988).

Efforts to reconcile single species objectives have focussed on demersal fisheries, mainly through the development of MTAC (Multi-Species Total Allowable Catches; Vinther et al., 2004), which assigned partial fishing mortalities to fleets based on catch and effort data and used resultant catchabilities combined with single-species forecast methods to forecast catches by fleet in subsequent years. This approach was further refined by the introduction of metiers (similar gear types, in similar seasons targeting similar species assemblages) within the FCube – fleet and fisheries forecast - approach (Ulrich et al., 2011). FCube now forms the basis of advice provided on the consequences of technical interactions on the mixed fisheries for cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*), saithe (*Pollachius virens*), plaice (*Pleuronectes platessa*), sole (*Solea solea*) and Nephrops (*Nephrops norvegicus*) in the North Sea (ICES, 2012). Outputs from the model are based on a number of scenarios, such as fishing to the last quota, or stopping when the first stocks exploitation limit is reached which, rather than being provided as advice, are presented as outlining the potential consequences of technical interactions in the fisheries under current exploitation patterns. This approach is being developed further within ICES to explore the application of the approach to the West of Scotland demersal fisheries, as well as consideration of its extension to other fisheries in the future (Iriondo et al.; Maravelias et al., 2012).

In principle an FCube type methodology could be applied to explore technical interactions in deep-sea fisheries. However, it should be noted that (i) the current implementation of FCube operates within the FLR framework (Kell et al., 2007) which restricts its application to stocks that are currently assessed through methods implemented in FLR, (ii) FCube is reliant on calculating catchability coefficients for fisheries which requires an analytical assessment in order to provide the population – and catch – at age (or length), this means that it is generally restricted to the 'main' commercial species with assessments, and (iii) a specific and detailed data call has been put together for the WGMIXFISH meeting which is based on, but not limited to, the data required under the STECF effort working group. Data requirements are generally the catch (landings and discards) by species and effort for a number of vessels segments as well as the single species assessment data. Specific data requirements would need to be considered for deep sea fisheries. Should the lack of analytical assessments present a problem for deep sea mixed fisheries modelling, a simpler CPUE approach may be able to outline some of the short term management issues on the assumption that CPUE is likely to be broadly stable in the short term.

A number of mixed-fisheries approaches have been developped in DEEPFISHMAN. Marchal and Vermard (in prep.) used a spatially-explicit bioeconomic modelling framework to evaluate management strategies, considering both data-hungry and data-limited harvest control rules, for a mix of deepwater fleets and species (blue ling, saithe, roundnose grenadier, black scabbardfish and deepwater sharks). The modelling reproduced successfully some of the key issues that may compromise the efficiency of single-species management plans in a mixed fisheries context, and provided harvest control rules able to better account for technical interactions.

Trenkel et al. (2012) also used spatially explicit simulations to evaluate the effects of different effort regimes corresponding to MSY harvesting of black scabbardfish, blue ling or roundnose grenadier on deep-sea sharks and the non-target species. The results demonstrated that managing blackscabbardfish for MSY will overexploit the other three species groups. Further, deep-sea shark bycatches depended on the target species which determined the spatial allocation of a given level of effort.

Blachard et al., (2011) used a size-based model of the deep-water fish community where the depth-distribution overlap of species is used to weigh their predator-prey interactions. This model allowed to simulate the likely side effects of exploiting the target species at a given level for the other species, including deep-sea sharks and the numerous smaller species in the fish community. Further work is underway on this approach; the final model and results will be published.

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Annex 1. Proposed list of species to be used for licensing purposes in a revised EU Deep-sea Access Regime

Scientific name	Common name
Aphanopus carbo	Black scabbardfish
Apristurus spp.	Iceland catshark
Argentina silus	Greater silver smelt
Beryx spp.	Alfonsinos
Centrophorus granulosus	Gulper shark
Centrophorus squamosus	Leafscale gulper shark
Centroscyllium fabricii	Black dogfish
Centroscymnus coelolepis	Portuguese dogfish
Coryphaenoides rupestris	Roundnose grenadier
Dalatias licha	Kitefin shark
Deania calcea	Birdbeak dogfish
Etmopterus princeps	Great lanternshark
Etmopterus spinax	Velvet belly
Galeus melastomus	Blackmouth dogfish
Galeus murinus	Mouse catshark
Hoplostethus atlanticus	Orange roughy
Molva dypterygia	Blue ling
Phycis blennoides	Forkbeards
Centroselachus crepidater	Longnose velvet dogfish
Scymnodon ringens	Knifetooth dogfish
Hexanchus griseus	Six-gilled shark
Chlamydoselachus anguineus	Frilled shark
Oxynotus paradoxus	Sailfin roughshark (Sharpback shark)
Somniosus microcephalus	Greenland shark
Pagellus bogaraveo	Blackspot seabream
Chimaera monstrosa	Rabbit fish
Macrourus.berglax	Roughhead grenadier
Mora moro	Common mora
Antimora rostrata	Blue antimora (Blue hake)
Epigonus telescopus	Black (deep-water) cardinal fish
Helicolenus dactylopterus	Bluemouth (Blue mouth redfish)
Alepocephalus bairdii	Baird’s smoothhead
Lycodes esmarkii	Eelpout
Raja hyperborea	Arctic skate
Hoplostethus mediterraneus	Silver roughy (Pink)
Trachyscorpia cristulata	Spiny (Deep-sea) scorpionfish
Raja nidarosiensis	Norwegian skate
Chaceon (Geryon) affinis	Deep-water red crab
Raja fyllae	Round skate
Hydrolagus mirabilis	Large-eyed rabbit fish (Ratfish)
Rhinochimaera atlantica	Straightnose rabbitfish
Alepocephalus rostratus	Risso’s smoothhead
Polyprion americanus	Wreckfish
Brosme brosme	Tusk
Sebastes mentella	Beaked redfish
Reinhardtius hippoglossoides	Greenland halibut