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Strengths and Weaknesses of the Management and Monitoring of Deep-Water Stocks, Fisheries, and Ecosystems in Various Areas of the World—A Roadmap Toward Sustainable Deep-Water Fisheries in the Northeast Atlantic?

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Abstract:

Scientific interest in deep-water marine resources has increased dramatically over the last 10–20 years as management bodies have sought advice on how to manage deep-water fisheries and protect deep-water ecosystems. The strengths and weaknesses of the management and monitoring of deep-water stocks, fisheries, and ecosystems in various areas of the world are described, with the objective of informing the EU FP7 DEEPFISHMAN project so that it can fulfill its primary aim, which is to develop strategic options for a short- and long-term management and monitoring ecosystem-based framework for the northeast Atlantic. To provide a baseline, the current monitoring and management regime in the northeast Atlantic is reviewed, followed by a brief description of the regimes applying to deep-water fisheries in the northwest Atlantic, the southeast Atlantic, off Brazil, in the Antarctic, off Australia and New Zealand, and in the Mediterranean. The strengths and weaknesses of these are discussed, taking into account additional information available from DEEPFISHMAN case study stocks, outcomes from consultations with stakeholders in the deep-water fishing industry in the northeast Atlantic, and the requirements of EU regulations and developing policy that will likely impact deep-water fisheries in the northeast Atlantic.

Keywords: deep-water ; Fisheries ; Ecosystem ; Monitoring ; management

1. Introduction

Deep-water fisheries occur in all of the world"s oceans and in the Mediterranean Sea, and 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/or 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. It is a considerable concern, however, that in most deep-water fisheries the availability of reliable information on stock status and fisheries production potential has lagged behind exploitation (Large et al., 2002).

Scientific interest in deep-water fish stocks and ecosystems stems largely from concerns that many deep-water marine living resources have biological features that are driven by the characteristics of the deep-water environment. These include: maturation at relatively old ages, slow growth, long life expectancies, low natural mortality rates, intermittent recruitment of successful year classes and spawning that may not occur every year (FAO, 2009). Deep-water fishery resources, therefore, are highly vulnerable to exploitation (Merrett and Haedrich, 1997; Koslow et al., 2000; ICES, 2001) and deep-water habitats are sensitive and in need of protection (OSPAR, 2000). Experience in the South Pacific and elsewhere has shown that deep-water fish stocks can be depleted quickly (Koslow et al., 2000) and that recovery can be very slow (ICES, 2001). An additional concern is that studies using fisheries-independent trawl survey data pre- and post-fisheries exploitation indicate that fishing, and trawling in particular, can also impact on non-target species. Analyses by Basson et al. (2001) indicated a decline in the biomass of unexploited deep-water species on the Hebridean continental slope to the west of Scotland (ICES Division VIa) to around half of the pre-exploitation biomass. They reported that this decline is consistent with available information on the mortality rate of discards, which is considered to be close to 100% for most species because of barotrauma and the low survival rate of escapees through trawl meshes (most deep-water fish lack a mucus covering and some are soft skinned, they are consequently vulnerable to abrasion (Connolly and Kelly, 1996; Koslow et al., 2000)). Bailey et al. (2009), using a similar general approach, observed that overall fish abundance in the Porcupine Seabight (ICES Division VIIj) had fallen significantly at all depths from 800 to 2500 m, considerably deeper than the maximum depth of commercial fishing in the area (approx. 1600 m).

Regional Fisheries Management Organisations (RFMOs) and national management bodies around the world have responded to these concerns 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 addresses management factors ranging from an appropriate regulatory framework to the components of a good data collection programme.

The aim of this article is to review the strengths and weaknesses of the management and monitoring of deep-water fisheries in different areas of the world, with the intention to inform the European Union (EU) Framework Programme 7 (FP7) DEEPFISHMAN Project so that it can fulfil its primary aim to develop strategic options for a short- and long-term management and monitoring ecosystem-based framework for deep-water stocks and fisheries in the North-east Atlantic. To provide a baseline, the current monitoring and management regime in the North-east Atlantic is described, followed by a brief description of the regimes applying in the North-west Atlantic, the south-east Atlantic, off Brazil, in the Antarctic Ocean, off Australia and New Zealand and in the Mediterranean Sea, noting that the definition of "deep-water" varies between regions, organisations and countries. The strengths and weaknesses of each management regime are discussed taking into account outcomes from consultations with stakeholders in the deep-water fishing industry in the North-east Atlantic, the requirements of EU regulations and developing policy and information on the strengths and weaknesses identified in the existing management and monitoring of DEEPFISHMAN Case Study stocks/fisheries. Assessment methodologies, biological reference points and harvest control rules are not addressed in detail here, as global reviews of these are in preparation and will be published separately.

2. Review of management and monitoring strategies by region

2.1. North-east Atlantic

Deep-water fisheries in the North-east 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). The Oslo Paris Convention (OSPAR) is the legal instrument guiding international cooperation on the protection of the marine environment of the North-east Atlantic. It is not possible here to review all the relevant national management and monitoring regimes, so we focus mainly on those applying to EU vessels and on the additional regulations applying to international waters in the NEAFC Regulatory Area (RA).

Explicit management measures for EU vessels carrying out deep-water 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, defined as those listed in Annexes I and II of Council Regulation (EC) No 2347/2002 (EC, 2002b). This Access Regime aimed to cap the expansion of fishing effort on deep-water species by requiring all vessels that capture more than 10 t of deep-water species in a year to have a deep-water fishing permit; otherwise their landings of deep-water species would be limited to 100 kg per fishing trip. 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, at times revised regarding species coverage and to address other pertinent deep-water issues. Examples of the latter include: the introduction of closed areas in which fishing for orange roughy (*Hoplostethus atlanticus*) to the west of the British Isles (ICES Subareas VI and VII) is prohibited (EC, 2004); sequential 10% and 20% reductions in the level of EU deep-water fishing effort (EC, 2005a; EC, 2006a); measures to address ghost fishing by abandoned, lost or otherwise discarded fishing gear (ALDFG) and specifically by gill, entangling and trammel nets in ICES areas VIa, VIb, VIIb, VIIc, VIIj, VIIk and XII (EC, 2005b and 2006b); and the introduction of protection areas for spawning aggregations of blue ling (*Molva dypterygia*) on the edge of the Scottish continental shelf and off Rosemary Bank (both in ICES Division VIa) (EC, 2009a).

The main EU Regulation applying to ecosystems in EU waters is the Marine Strategy Framework Directive (MSFD) (EC, 2008a), which addresses all human activities that impact on the marine environment. The Directive establishes a framework within which EU Member States (MSs) must take the necessary measures to achieve or maintain good environmental status (GES) in the marine environment by the year 2020 at the latest. Marine strategies must be developed and implemented in order to protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected. Marine strategies must apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of GES and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, whilst enabling the sustainable use of marine goods and services by present and future generations. The qualitative descriptors for determining GES of particular relevance to deep-water ecosystems are: biological diversity is maintained; populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock; all elements of the marine food webs occur at normal abundance and diversity and at levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity; sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems are not adversely affected; contaminants in fish and other seafood for human consumption do not exceed permitted levels; and properties and quantities of marine litter (including ALDFG) do not cause harm to the coastal and marine environment. MSs must by July 2012 complete an initial assessment of the waters concerned, a determination of GES and establish environmental targets and associated indicators. By 2014, MSs must establish and implement a monitoring programme for ongoing assessments and regular updating of targets, and develop by 2015 a programme of measures designed to achieve and maintain GES which are to be implemented by 2016. MSs have already made a start by introducing closed areas to protect cold-water corals (mainly *Lophelia pertusa*). For example, the UK has introduced a closed area to protect the Darwin Mounds to the north-west of Scotland. Similar measures have been or are in the process of being introduced by other MS.

NEAFC did not regulate deep-water fisheries in its RA (Figure 1) until 2003, when a freeze on deep-water effort was introduced. In response to ICES advice, this regulation has been strengthened and currently each Contracting Party (CP) must limit its deep-water fishing effort for 2010-2012 so that it does not exceed 65% of the highest level in previous years for the relevant species (NEAFC Recommendation 6/2010). NEAFC has also introduced measures to protect spawning aggregations of blue ling to the south-west of Iceland (ICES Division XIV) (Recommendation 10/2010), ban deep-water gill, entangling and trammel fisheries at depths >200 m (Recommendation 3/2006), ban vessels (using any type of fishing gear) discarding or releasing catches of any of the species listed in Annex IA of the Scheme of Control and Enforcement (Recommendation 16/2010), and introduce closed areas to protect vulnerable marine ecosystems (VMEs) (mainly cold-water corals) on Hatton Bank, Rockall Bank, on the Logachev Mounds, the West Rockall Mounds and the Mid-Atlantic Ridge (MAR) (Recommendations VMEs/2009 and 14/2011). Bottom trawling and fishing with static gear are prohibited within these areas.

Regarding regulations on bottom fishing, NEAFC has mapped “existing bottom fishing areas” (EBFAs) within its RA. All areas outside these are referred to as "new bottom fishing areas" (NBFAs). Scientific observer coverage is only required in NBFAs. There are no designated NEAFC observers. All vessels fishing in the RA are monitored using a vessel monitoring system (VMS).

All bottom fishing activities in NBFAs are treated as exploratory fisheries and must not commence until the following information has been provided to NEAFC: a harvesting plan outlining target species, dates and areas, a mitigation plan including measures to prevent significant adverse impacts (SAIs) to VMEs that may be encountered, a catch monitoring plan that includes recording/reporting of all species caught, and a data collection plan to facilitate the identification of VMEs/species in the area fished. On the basis of an assessment made by ICES, NEAFC will adopt conservation and management measures to prevent SAIs on VMEs if required. NEAFC has also introduced regulations applying to encounters with VME indicator species in both EBFAs and NBFAs. Vessels must cease bottom fishing activities in the RA where evidence of VMEs is encountered and report the encounter so that appropriate measures can be adopted in respect of the relevant site. An encounter is currently defined for all fishing gears as a catch per set of >60 kg of live coral and/or >800 kg of live sponge. In EBFAs, the vessel making the encounter must cease fishing and move away at least 2 nm from the encounter position. NEAFC compiles an annual report on single and multiple encounters and forwards this to ICES for evaluation. In NBFAs, observers identify corals and sponges to the lowest possible taxonomic level. If the quantity caught is greater than the thresholds described above, the same reporting protocols apply, with the addition that NEAFC immediately requests CPs to implement a temporary closure of 2 nm radius around the capture position. If, on the basis of an assessment by ICES, the area is declared a VME, NEAFC will request CPs to maintain the temporary closure until such time that NEAFC can introduce a permanent measure.

2.2. North-west Atlantic

The North-west Atlantic Fisheries Organisation (NAFO) monitors and manages a wide range of species in the NAFO RA (Figure 2), but the deep-water species of major commercial importance are roundnose grenadier (*Coryphaenoides rupestris*) in NAFO Sub-areas 0 and 1 and roughhead grenadier (*Macrourus berglax*) in Sub-areas 2 and 3.

The main management tool for fisheries in the NAFO RA is TACs and quotas. Regarding by-catch regulations, vessels of a CP must limit their retained by-catch to ≤2500 kg or 10%, whichever is the greater, for each species listed for which no quota has been allocated in that NAFO Division to that CP. In cases where a ban on fishing is in force or an “others” quota has been fully utilised, the by-catch of the species concerned must be ≤1250 kg or 5%, whichever is the greater. If the percentage of by-catch in any one haul exceeds the relevant limit, the vessel must immediately move a minimum of 10 nm away from any position of the previous set and throughout the next set keep a minimum distance of 10 nm from any position of the previous set. If after moving, the next haul exceeds the by-catch limit, the vessel must leave the Division and not return for at least 60 hours. Following an absence from a Division of at least 60 hours, skippers must undertake a trial tow, the duration of which must not exceed 3 hours. Regarding regulations applying to directed fisheries, skippers must not conduct directed fisheries at species for which by-catch limits apply. A directed fishery is defined as when that species comprises the largest percentage by weight of the total catch in any one haul.

NAFO has been a front-runner in introducing measures to regulate and monitor bottom fisheries. Some other RFMOs such as NEAFC and the South-east Atlantic Fisheries Organisation (SEAFO) have adopted the VME encounter protocols and thresholds introduced by NAFO. Regulations relating to exploratory fishing (defined as bottom fishing activities in NFBAs or with bottom gear not previously used in the area concerned), a very similar to those of NEAFC, in that proposals must be submitted in advance of fisheries commencing. In addition, a range of closed areas to bottom fishing has been introduced in recent years. These comprise six closures applying to seamounts, introduced in accordance with the PA to protect likely locations of VMEs and associated fish species, and 12 areas mostly around the Flemish Cap to protect corals and sponges.

The management and monitoring regime is supported by NAFO observers who only collect fishing and compliance information (100% coverage) and CP scientific observers who collect fisheries and biological information and carry out biological sampling (coverage varies between countries – for Spain and Portugal, for example, circa 15% of fishing days are covered and funded under the EU Data Collection Framework (DCF) (EC, 2008b)). For roughhead grenadier, abundance and biomass indices are available from Canadian bottom trawl spring and autumn surveys, an EU (Spain and Portugal) Flemish Cap survey, and an EU (Spain) Div. 3NO survey, noting that these surveys are directed primarily at non-deep-water species. All vessels catching fish/shrimp species under NAFO‟s jurisdiction must have VMS.

2.3. South-east Atlantic

In international waters, the South-east Atlantic Fisheries Organisation (SEAFO) is responsible for the management of fisheries for species under its jurisdiction. Fisheries in the SEAFO Convention Area (CA) (Figure 3) currently comprise a longline fishery in Sub-Division D1 for Patagonian toothfish, a trap fishery in Sub-Division B1 for deep-water red crab (*Chaceon* spp.), and a mid-water trawl fishery just outside the Angolan and Namibian EEZs for alfonsino (SEAFO, 2010). Although there is evidence of sporadic fishing activity in recent decades, compared with most other RFMO areas in the Atlantic Ocean, fishing pressure in the SEAFO CA is currently relatively low. There are, however, considerable challenges in developing management measures for fisheries. Even though there has been some improvement in the quantity and quality of fisheries monitoring data available for stock assessments in recent years, all the fisheries and stocks in the SEAFO CA can be defined as „data-poor‟. SEAFO has therefore invoked the PA and introduced precautionary TACs to restrict fisheries to low levels until data are collected and assessments carried out to confirm that higher catch levels are sustainable. As part of the International Plan of Action to protect sharks (FAO, 1999), SEAFO has banned fisheries directed for deep-water sharks until information becomes available to identify sustainable harvesting levels. Management measures to reduce the incidental by-catch of seabirds have also been introduced. The use of gillnets is banned to reduce the impact of ALDFG on habitats and biodiversity (by ghost fishing).

Closed areas, bottom fishing regulations and encounter protocols are the main management tools affording protection to VMEs. VME encounter protocols apply to both EBFAs and NBFAs and are very similar to those currently applied by NEAFC and NAFO (including the VME thresholds). To address UNGA Resolution 61/105 on Sustainable Fisheries, SEAFO has implemented an interim measure applying to the existing and new bottom fishing areas outside the SEAFO closed areas. CPs with vessels involved in bottom fishing activities are required to map EBFAs within the SEAFO CA. SEAFO is currently developing a comprehensive overall map of EBFAs, the so-called „fishing footprint‟. Fisheries conducted in the NBFAs are treated as exploratory fisheries and before they can take place a detailed proposal (with almost identical requirements to those required by NEAFC must be submitted to SEAFO for scrutiny. Exploratory fishing cannot proceed until permission is given by SEAFO.

To account for the possible existence of chemosynthetic communities at depths >1000 m and considering that the maximum potential depth of deep-water fishing is around 2000 m, SEAFO has closed 11 areas to protect geographically discrete aggregations of seamounts penetrating into the upper 2000 m of the water column, which, on the basis of historical fishing patterns, are considered to be unexploited or only slightly exploited. All fishing activities for fisheries resources covered by the SEAFO Convention are prohibited in these areas.

Fisheries are currently monitored using landings and effort data reported by CPs, VMS data and observer reports. CP scientific observers are mandatory on SEAFO licensed vessels (100% coverage), but there are no designated SEAFO observers. Historically there was no distinction between reported landings and catches, but discard information (discarding is allowed in the SEAFO CA) is now available for all vessels. There is a paucity of abundance data from commercial vessels and, critically, a total absence of regular structured surveys aimed at collecting biological and abundance data for use in assessments and for ecosystem monitoring.

2.4. Brazil

At the end of the 1990s, the government stimulated deep-water fishing development through a programme that allowed national companies to operate in Brazilian waters using technologically efficient foreign vessels specialized in oceanic and deep-water fisheries (Wahrlich et al., 2004). The development of deep-water fisheries was mainly in the south-eastern and southern sectors of the Brazilian coast (Figure 4), where longliners, gillnetters, potters, and trawlers started fishing on the upper continental slope (250-500 m) mostly targeting monkfish (*Lophius gastrophysus*), Argentine hake (*Merluccius hubbsi*), Brazilian codling (*Urophycis mystacea*), wreckfish (*Polyprion americanus*), Argentine short-fin squid (*Illex argentinus*), and deep-water red crabs. Between 2004 and 2007, chartered trawlers established a valuable fishery for deep-water shrimps (family Aristeidae), heavily exploiting the lower slope (500-1000 m) (Perez et al., 2009).

Until 1998, fisheries management was the responsibility of the Ministry of the Environment. In 1999, due to political pressure from the fishing industry interested in a more "development than an environmentally-oriented philosophy", a second management authority was created under the Ministry of Agriculture and Livestock, with a mandate to develop and manage the economic exploitation of stocks defined as "sub-exploited, unexploited, and highly migratory"(Perez et al., 2009). Concerns about the sustainability of the target species as well as environmental, social, economic, and political impacts of such an uncontrolled scenario led to the creation in 2002 of the Consultant Committee for the Management of Deep-water Resources. However, Perez et al.(2009), citing monkfish as an example, reported that a management plan was not approved and implemented until 2005, by which time the stock was overexploited. The management of other deep-water resources such as crabs, shrimps, and other fish species has faced similar difficulties. Current management measures vary between fisheries and stocks and include TACs, vessel limitations, effort restrictions, mesh size limitations and by-catch limits.

The deep-water fishery developed off Brazil was one of the most intensely monitored fisheries in Brazilian waters. In addition to the use of official data collection logbooks, observers and VMS programmes (both requiring 100% vessel coverage) were implemented. Observers collected biological samples of catches and recorded biological data for the main target species. Information on by-catch species including incidental by-catch of cetaceans and seabirds, was also collected. Complementary data were obtained during the same period for landings by the national fleet. Fisheries and biological data were also obtained from surveys, mostly conducted by research vessels in 2001 and 2002 as part of the REVIZEE Programme (Anon., 2006; Costa et al., 2005; Rossi-Wongtschowski et al., 2006). Most of the data collected and results arising from these surveys were only available for the main, largely upper slope demersal species, monkfish and hake for example.

2.5. Antarctic

Antarctic fisheries are limited to four species, two of which live in deep water: Patagonian toothfish and Antarctic toothfish (*Dissostichus eleginoides* and *D. mawsoni*, respectively). Toothfish are found throughout the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) CA (Figure 5) on continental shelves, sub-Antarctic Islands and seamounts. CCAMLR strives to implement an ecosystem approach to the management of marine living resources. The CA is not limited by spatial scope of the Antarctic Treaty (60°S), but extends northwards to approximate the oceanographic feature of the Antarctic Polar Front. This is regarded as the biogeographical boundary of many Antarctic marine species" assemblages. Management (which for toothfish includes TACs, closed areas/seasons, vessel/gear licensing and moratoriums) also strives to follow the PA. Harvesting is conducted in accordance with the following principles: (i) prevention of a decrease in the size of harvested populations to levels below those which ensure their stable recruitment; (ii) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in (i); and (iii) prevention of change(s) or minimisation of the risk of change(s), in the marine ecosystem which are not potentially reversible over two or three decades. CCAMLR"s management approach seeks to determine a long-term annual catch limit that is highly likely to be sustainable despite uncertainties in stock dynamics and key population parameters. The long-term annual catch limit is set at the highest catch that results in both a median expectation that the stock is greater than or equal to the target level at the end of 20 years or one generation period for the stock (whichever is greater), and there being only a 10% chance or less that the stock will become depleted (below the limit reference point over that time) (Mooney-Seus and Rosenberg, 2007).

CCAMLR recognises that fisheries need to be managed from the time they start. In CCAMLR terms, a „new" fishery is one for a species and/or on a ground that has not previously been fished, or an established fishery where there is an intention to use a new fishing technique. A new fishery lasts for one year and in the second year becomes an „exploratory fishery". For the exploratory toothfish fishery in the Ross Sea, all vessels and CPs intending to fish are required to notify CCAMLR in advance. These intentions are then confirmed in CCAMLR Conservation Measures, which specify fishing opportunities by CP and the number of vessels each is permitted to deploy. This carries a financial cost, a levy that is non-refundable and helps to finance the cost of administering the scheme. Fishing effort is restricted to those CPs and vessels that have declared an intention to fish. CCAMLR has a requirement that exploratory toothfish fisheries follow clearly defined experimental fishing plans. This approach strives to maximise the data collection potential of fishing vessels while ensuring that unacceptable damage is not inflicted on stocks for which key stock status information is missing. Fishing vessels are required to undertake research on stock distribution and abundance as part of the development of either new or exploratory fisheries.

Discarding is allowed but CCAMLR requires that the effects of fishing non-target species be accounted for in its management practices. In some cases, TACs for target species are linked to allowable by-catch. A fishery may be closed when it reaches the TAC for the by-catch of particular species even if the TAC of the target species has not been taken. Also, move-on rules triggered by by-catch thresholds have been applied in some exploratory fisheries to encourage vessels to improve gear selectivity and fishing methods. CCAMLR has also implemented measures to protect endangered, threatened or trophically important species along with their habitats. These include a mitigation programme that encourages innovation to reduce mortality of seabirds in longline fisheries and a ban on deep-sea gillnetting.

Management measures are in place to limit damage to benthic ecosystems. Bottom trawling is prohibited in the high seas of the CA, as is all bottom fishing in waters shallower than 550 m around the entire Antarctic continent. Protected areas also exist. CCAMLR has also introduced measure to minimise SAIs on VMEs by longliners. Vessels must mark fishing lines into line segments (a 1000-hook section of line or a 1200 m section of line, whichever is the shorter) and monitor all line segments for the number of VME indicator units. If 10 or more VME indicator units are recovered in one line segment, vessels must complete hauling any lines intersecting with the "risk area" and not set any further lines intersecting with the risk area. The vessel must communicate immediately to CCAMLR the location of the midpoint of the line segment from which those VME indicator units were recovered along with the number of VME indicator units. CCAMLR then notifies all fishing vessels in the relevant fishery that the risk area is closed. The area remains closed for any fishery until reviewed and management actions are determined by CCAMLR.

Monitoring methods include: demersal trawl surveys and scientific observers (100% observer coverage in all fisheries except krill, which for longline toothfish fisheries can comprise two observers per vessel, facilitating 24 h observer coverage) and mark-recapture information for toothfish from tagging.

2.6. Australia and New Zealand

The Australian Fisheries Management Authority (AFMA) manages fisheries on a segmented management unit basis. The main deep-water fisheries are operated within the Southern and Eastern Scalefish and Shark fishery (SESSF) management unit, targeting orange roughy, alfonsino (*Beryx splendens*), oreos (*Allocyttus niger*, *Neocyttus rhomboidalis* and *Pseudocyttus maculatus*), ribaldo (*Mora moro*) and deep-water sharks. The SESSF is structured in four sectors: the Commonwealth Trawl sector (CTS), Great Australian Bight Trawl sector (GABTS), East Coast Deep-water Trawl sector (ECDTS), gillnet, hook and trap sectors (GHTS) (Figure 6).

Management objectives and principles are addressed in the Fisheries Management Act 1991 (Anon., 2009). The Act highlights the principles of ecological and environmental sustainability, the PA, and also the objective of optimising resource utilisation. The Act stipulates that the balance between conservation and utilisation should be achieved by "Maximising the net economic returns to the Australian community from the management of Australian fisheries". For many Australian fish stocks, this has been translated into a management target, the maximum economic yield (MEY) and its related reference points. MEY is the largest economic return that can be achieved over a prolonged period of time while maintaining the stocks" productive capacity. For all SESSF deep-water stocks, BMEY, the average stock biomass level corresponding to MEY, is the legal management target, and is estimated to 48-50% of the virgin biomass.

SESSF fisheries are managed using a mixture of input and output controls. TACs are the main management instrument but there is also a limit on the number of vessels that operate in each sector as well as limits on mesh size and the amount of fishing gear that can be used. Individual Transferable Quotas (ITQs) were first introduced into the SESSF in 1992 but were only broadly introduced for deep-water species in 2005 and 2006. Despite the flexibility brought about by quota transferability, catch-quota balancing has proved to be an issue in SESSF. Discarding, which is allowed in Australia, has been used as an instrument to achieve catch-quota balancing (Sanchirico et al., 2006). There is increasing pressure from the Australian Government towards the use of input rather than output controls.

Management plans are required for fisheries and these set out the objectives, measures by which the objectives are to be attained, and performance criteria against which the measures taken can be assessed. Management strategies have since 2007 been made explicit within the management plans that have been established for several Commonwealth fisheries, and these are referred to as HSPs (Harvest Strategy Policies) (DAFF, 2007). Here we briefly summarise the main features of the Commonwealth HSP and highlight those aspects that are particularly relevant to the management of deep-water fisheries. The HSP is not a single-species, but rather an ecosystem-based fisheries management (EBFM) policy (Smith et al., 2007). An important development of the HSP has been the inclusion for all SESSF stocks of an even more comprehensive decision-making support framework referred to as the "tiered approach" (Smith et al., 2007). This provides an extra layer of precaution which reflects the levels of uncertainty in stock status. Typically target exploitation rates would decrease as the uncertainty increases. A 4-Tier approach has been implemented: Tier 1 stocks are subject to a robust and quantitative stock assessment; Tier 2 stocks are subject to a quantitative but preliminary stock assessment; Tier 3 stocks are not assessed quantitatively but estimates of fishing mortality (F) are available from catch curve analyses (with some knowledge of natural mortality (M)); Tier 4 stocks are those for which only catch per unit effort (CPUE) trends are available. Each Tier has its own harvest control rule (HCR) that is applied to calculate RBCs (Recommended Biological Catches), which are then used to advise on TACs.

The AFMA has a responsibility for monitoring the impact of fishing using data from a range of sources, including the fishing industry as well as from independent sources. The fishing industry is the main funding body for the data collection programme (100% of logbook costs, 80% of observer costs). The economic status of the main Australian fisheries is monitored through collection of economic data and the derivation of appropriate performance indicators (Hohnen et al., 2008).

In the New Zealand EEZ (Figure 7), deep-water species are defined very broadly as species found: (i) >600 m (orange roughy, oreos, black cardinalfish (*Epigonus telescopus*), alfonsino (*Beryx splendens* and *Beryx decadactylus*), (ii) other species generally distributed between 200 and 600 m, including ling (*Genypterus blacodes*), and deep-water crabs which can be found at varying depths down to 1500 m. Here we focus on the deep-water species found at depths >600 m.

Catch limits in the form of TACs have traditionally been the main regulatory tool for all fisheries. After setting a TAC, an allocation decision is made specifying allowances for, (i) the customary (Maori), (ii) recreational fishers and (iii) a virtual allocation including other sources of F (e.g. illegal fishing). After these allowances are made, the remaining share is allocated to the commercial fishing sector, and is referred to as the TACC (Total Allowable Commercial Catch). TACCs are distributed to quota holders as ITQ shares. Each ITQ generates for each quota holder and each stock, a catching right referred to as the annual catch entitlement (ACE). ACEs, like ITQs, are freely tradable on the open market, and accessible to any New Zealand citizen. Despite that flexibility, and even where fishers are allowed to acquire catch rights after landing fish, aggregate commercial catches may not always match up with TACCs.

With the exception of certain circumstances when government observers are present, discarding is prohibited for almost all species managed under the quota management system (QMS). Discarding is therefore not an option to balance catches with TACCs. If the mismatch between catch and quota is limited, quota-holders are allowed to carry forward up to 10% of their quota. If the mismatch is greater, fishers are allowed to land species in excess of their ACE, even when the overall TACC for these species has been exceeded. In this case, fishers are charged at the end of the fishing year a landing tax or deemed value for each unit of catch they land above their ACE. The deemed value is set annually by the Government. The level at which the deemed value is set may have dramatic consequences for the fisheries sustainability (Marchal et al., 2009). While a high deemed value (i.e. well above the ACE price) may encourage fishers to shift target species once their ACE is exceeded, a deemed value set at a low level (i.e. close to, and *a fortiori* below, the ACE price) may incentivise fishers to pay the charge requested and continue targeting the same stock, even when they have no ACE. To mitigate this, the Ministry of Fisheries is in the process of approving and implementing a Deemed Value Standard.

Management objectives and principles have been established under the legal framework of the Fisheries Act 1996 (Anon., 2005). The overarching objectives include biological sustainability, socio-economic, environmental and ecosystem requirements (Marchal et al., 2009). One outstanding feature is the explicit reference to BMSY as a management target. If a stock is below the target, the Minister is legally obliged to take corrective action to rebuild biomass to or above BMSY (or a related target level). In New Zealand, the MSY concept in the context of management objectives is overall well accepted by managers and stakeholders.

Harvest Strategy Standards (HSS), along with operational guidelines, have since 2008 been introduced for all stocks under the QMS, including deep-water stocks (NZMFISH, 2008a and 2008b). The purpose of the HSS is to provide a consistent and transparent framework for setting fishery and stock targets and limits and associated timely management actions. The HSS consists of three core components: (i) a specified target based on MSY reference points that should be achieved with at least a 50% probability; (ii) a soft limit that triggers a requirement for a formal, time-constrained rebuilding plan (the default is ½BMSY or 20% of virgin biomass (B0), whichever is higher); and (iii) a hard limit below which fisheries should be considered for closure.

Fisheries and stock monitoring in New Zealand is similar to that in Australia. The main instruments include catch and effort logbooks, independent Ministry observer data, and VMS data, and the fishing industry is the main funding body of the data collection programme. Biological data collection and research surveys (acoustic, trawl and egg surveys in the case of deep-water stocks) are conducted by both the National Institute of Water and Atmospheric Science (NIWA) and the fishing industry, under the auspices of the Ministry of Fisheries. Unlike Australia, economic data are not routinely collected, which hampers the monitoring of the economic status of fisheries. The only source of economic data regularly recorded is on individual ACE and fish prices.

The New Zealand Government recently released Fisheries 2030, which provides strategic direction for the fisheries sector. This 10-year programme will represent a significant increase in deep-water research and monitoring and is structured using a tier approach. Tier 1 species are high volume and/or high value fisheries and are traditionally targeted; Tier 2 species are typically by-catch fisheries or occasionally target fisheries at certain times of the year – the size/value of the fishery means that research needs will be met primarily through observer sampling but it may be possible to use data from wide-area trawl surveys; Tier 3 species are incidental by-catch species that are not currently managed under the QMS but are caught during deep-water fishing activity. Monitoring will be through observer sampling and monitoring trends in CPUE.

2.7. Mediterranean Sea

The Mediterranean Sea is a semi-enclosed sea characterized by a continental shelf frequently reduced to a narrow coastal fringe covering <30% of the total sea area, bathyal grounds accounting for about 60% of the whole basin, and the remainder mostly comprising an abyssal plain (Sardá et al., 2004; Cartes et al., 2004) (Figure 8). Trawl fisheries down to 200 m target mainly decapod resources and hake. On the upper slope (down to 500 m) there are important fisheries in specific areas for Norway lobster (*Nephrops norvegicus*) and rose shrimp (*Parapenaeus longirostris*). Deeper water fisheries down to 800 m target almost exclusively aristeid shrimps. Other deep fisheries also exist in the Mediterranean, but on a smaller scale (Cartes et al., 2004a) and these include longliners targeting hake, red (blackspot) seabream (*Pagellus bogaraveo*), wreckfish, and the deep-water six-gilled shark (*Hexanchus griseus*), and gillnetters targeting hake and red (blackspot) seabream. Some of these fisheries are locally collapsed (Mytilineou and Machias, 2007).

Unlike other regions of the world, the Mediterranean coastal states have generally renounced their right to extend national jurisdiction to 200-mile wide EEZs. The semi-enclosed nature of the Mediterranean and the large number of coastal states explain this cautious approach which is aimed at avoiding territorial conflicts. International waters account for around 80% of the Mediterranean Sea and the RFMO for these waters is the General Fisheries Commission for the Mediterranean (GFCM). In 2009, the Commission implemented mesh size restrictions for trawls and a reduction of fishing effort, which is the main management control tool in the area. The Commission has expressed concern regarding the adequacy of current monitoring of fisheries and exploited resources which results in an underestimation of effort and catches. Effort control is acknowledged by the GFCM Scientific Advisory Committee (SAC) as a sufficient management measure to regulate fisheries, when accompanied by measures such as landing sizes, gear configuration and no-take zones (GFCM/SAC, 2010). Failure to quantify the real effort exerted places managers in a dilemma as to whether this is actually the best tool to proceed with in the future. Minimum landing sizes are in place for red (blackspot) seabream, wreckfish, Norway lobster, rose shrimp and hake (*Merluccius merluccius*).

In the Mediterranean basin the protection of deep-water biodiversity from impacting fishing practices is addressed by a ban on bottom trawling at depths >1000 m introduced by GFCM in 2005 (EC, 2006c). In 2006, areas closed to bottom trawling were introduced to protect cold-water coral (mainly *Lophelia pertusa*) off Capo Santa Maria di Leuca in Italy, rare coral species on the Eratosthenes seamount off Cyprus, and a chemosynthetic-based ecosystem offshore of the Nile Delta. Since 2002, all Mediterranean EU MSs are funded under the DCF to collect and report data for deep-water species such as the red shrimps (*Aristaeomorpha foliacea* and *Aristeus antennatus*) and Norway lobster. These data are extracted either from the vessel logbooks or collected by on board observers or by sampling at ports. In addition, fisheries-independent surveys are deployed to monitor the status of marine resources. The internationally coordinated MEDITS (Mediterranean Trawl Survey) is a multi-annual bottom trawl survey in parts of the Mediterranean involving all Mediterranean EU MSs. The survey has provided time-series data of population indicators (abundance, biomass, mean size, etc.) since 1994 or 1998, depending on area. A number of short-term surveys have also contributed to the monitoring of fisheries and the environment. Only a few species are currently subject to quantitative stock assessments in the Mediterranean Sea, although under the DCF for 2011-2013, assessments will become mandatory for some species including hake, Norway lobster, rose shrimp and red shrimp.

3. Review of strengths and weaknesses

In discussing the strengths and weaknesses of the management and monitoring regimes described above, it is useful to be aware of the outcomes from DEEPFISHMAN consultations with stakeholders in the deep-water fishing industry in the North-east Atlantic, and the requirements of EU regulations and developing policy that likely impact on deep-water fisheries in the North-east Atlantic. These are presented below. Strengths and weaknesses identified in the management and monitoring of individual DEEPFISHMAN Case Study stocks/fisheries (which for brevity cannot be fully described in this article) are summarised in boxes under the heading for each area reviewed.

3.1. Findings of DEEPFISHMAN consultation

Using SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis (Horn et al., 1994), a questionnaire survey and cognitive maps (Özesmi and Özesmi, 2003; Prigent et al., 2008), Lorance et al. (2011) explored the views of stakeholders on the monitoring and management regimes currently applied in a number of deep-water fisheries in the North Atlantic. Stakeholders were dissatisfied overall with current fisheries management. Around 50% of questionnaire responses suggested that TACs, effort control, licenses, closures and gear bans should be changed to varying degrees ranging from radical to minor adjustments. The majority of respondents considered licensing, effort restrictions, spatial/seasonal closures and gear bans suitable to protect the ecosystem. Control of recreational fisheries was highlighted where juveniles are seasonally coastal, for red (blackspot) seabream for example. Technical measures thought to be most suitable were reduction of by-catch/discards to an agreed level, by-catch reduction devices. Cognitive maps suggested that the management measures that might have a positive influence differed somewhat between fisheries, although spatial closures and gear selectivity were recurrent themes.

The EU management of deep-water fish stocks in the North-east Atlantic was reviewed by the EC in 2007 (EC, 2007a). Most fisheries catch a mixture of species. Some species with ranges that extend to the slopes of the continental shelf, such as ling (*Molva molva*) and tusk (*Brosme brosme*), may also be taken as by-catch in shallow-water demersal fisheries. The Commission argued that for TACs to be effective in mixed fisheries they should be fixed relative to one another at levels that minimise discards and by-catch. Moreover, of the 48 species listed in Annexes I and II of Regulation 2347/2002 (EC, 2002b), TACs are set for only 9 of them. However, it was recognised that most of the other species are taken too sporadically or in quantities too small to make it feasible to set TACs. Notwithstanding, the view was expressed that the restricted number of species managed by TACs had encouraged misreporting. Another problem of using TACs is that little is known about the geographical stock structure of species, and TACs are therefore often set over large management areas. It was considered that TACs have probably had some effect in curbing F on some of the main targeted species. However, for long-term management they must be complemented with other measures, particularly the restriction of fishing effort. It was argued that capacity ceilings (EC, 2002b) probably have had little effect on limiting the expansion of fisheries because they included vessels not targeting deep-water species but only taking them as a by-catch in other fisheries, and because the ceilings were set unrealistically high. The Commission argued that these shortcomings had undermined subsequent imposed effort reductions (EC, 2005a and EC, 2006a) and noted that it was unclear as to whether effort reductions were sufficient to comply with the NEAFC requirements. Regarding the submission of Sampling Plans for scientific sampling and observer programmes (EC, 2002b), the Commission reported that initial compliance had been poor and had only improved following further requests. A major shortcoming is that there is no clearly defined sampling strategy and protocols. Other conclusions included the need for more rigorous monitoring and control procedures and for greater emphasis on the collection of data to assess the ecosystem impacts of fisheries.

The EU is currently undertaking a review of the deep-sea access regime (EC, 2009b). Three options are proposed: (i) minimal changes only to comply with the new EU framework regulation on control; (ii) reducing the regulatory content of the regime to the minimum required to fulfil NEAFC agreements; and (iii) improve all parts of the regime based on an analysis of their current functioning and relevance, and to include outstanding conservation concerns which were identified as discard practices, by-catch, ghost fishing, definition of fleets and control and monitoring. Interestingly, concerns regarding discards are limited to the collection and availability of data and the need to integrate these into stock assessments. Regarding by-catch, a number of initiatives were put forward for discussion including the inclusion of certain species into Annex 1 of the regime, setting of by-catch limits and associated move-on rules and the establishment of trawler-free zones and temporary closure areas. It was identified that ghost-fishing, particularly by the deep-water gillnet fishery, remains an issue, and it is suggested that reporting obligations and net retrieval programmes could be established. A review of the definition of the fleets allowed to land deep-water species is suggested, including a re-assessment of landings thresholds and a revision of qualifying species. It is proposed that a review of control and monitoring should be mostly concerned with aligning the access regime with the new EU control regulation.

The main policy drivers impacting on deep-water fisheries in the North-east Atlantic over and above, and in some cases operating synergistically with those identified earlier (UNGA, 2007; FAO, 2009 and the EU MSFD), include: (i) the requirement of the 2002 World Summit on Sustainable Development (WSSD) to maintain or restore stocks to levels that can produce MSY, with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015 (and the subsequent EC Communication and identifying that MSY is characterised by a level of F that will, on average, result in a stock size that produces the MSY (EC, 2006d)); (ii) developing EU policy to reduce unwanted by-catch and eliminate discards in European fisheries (EC, 2007b); (iii) the role of the Common Fisheries Policy (CFP) in implementing an ecosystem approach to marine management (EC, 2008c); (iv) the Green Paper on Reform of the CFP (EC, 2009c) which, amongst other things, argues that the fishing industry can be given more responsibility through self-management which would be results-based. This would have to be linked to a reversal of the burden of proof, in that it would be up to the industry to demonstrate that it operates responsibly in return for access to fishing; and finally (v) the OSPAR Commission's Biological Diversity and Ecosystems Strategy applying to the entire North-east Atlantic.

3.2. Strategy assessment by region

3.2.1. North-east Atlantic

In the North-east Atlantic, although the EU has made considerable progress in the management and monitoring of deep-water stocks and fisheries (see Box 1), there remain a number of concerns that have not been addressed. These concerns are: (i) there is a need to evaluate the appropriateness of the orange roughy protection boxes now that the TAC for this species is zero; (ii) regarding the protection areas introduced for spawning aggregations of blue ling, there is a need to know how effective they have been in reducing effort and catch in these areas, whether biological sampling information (principally length, sex and maturity) has been recorded by observers, and if these data are available (so that the boundaries of these areas can be reviewed); (iii) there is currently no requirement for deep-water fishers in EU waters to report and mitigate encounters with VMEs that are currently not protected by closed areas; (iv) there is an overlap between the EU Access Regime and the new DCF regarding sampling and observer requirements; and (v) there is a paucity of dedicated fisheries-independent deep-water surveys that can be used as a basis for ecosystem monitoring and as a source of abundance indices/scientific information for use in stock assessments. Regarding the DCF, the segmentation applied is at the level of gear type, and consequently it is not possible to quantify the economic variables for the deep-water fleets and to carry out analyses that are specific to these fisheries.

As noted in the Commission review of the EC Access Regime, NEAFC has so far not established a comprehensive management policy towards deep-water species. A number of issues are a concern: (i) there is no consensus between CPs on an agreed reference period against which effort reductions can be measured. CPs are permitted to set their own reference period which, for some with very high levels of effort historically, may mean that reported reductions in effort may have little relevance to the level of fishing effort in recent years. NEAFC calculates deep-water effort as aggregate power, aggregate tonnage, fishing days at sea or number of vessels. This is a very loose definition, particularly the inclusion of „number of vessels", as the power, tonnage and fishing effort of these vessels can change with time. (ii) NEAFC has not introduced closed/protection areas for spawning aggregations of blue ling known to exist in ICES sub-Division VIb and Division Vb. (iii) Although NEAFC has implemented a ban on discards, this does not apply to deep-water species, and NEAFC has no regulations in place to mitigate these. (iv) As in EU waters, there is a marked absence of fisheries-independent deep-water surveys that can be used as a basis for ecosystem monitoring and as a source of abundance indices/scientific information for use in stock assessments. (v) As in the NAFO area, there is no mandatory impact assessment required before exploratory fisheries can commence. Furthermore with the exception of vessels carrying out exploratory fishing in NBFAs, vessels in the remainder of the RA are under no obligation to carry observers. This is likely to reduce compliance to management regulations and impact on the fisheries and scientific information available for monitoring. (vi) The VME threshold values used in encounter protocols currently were estimated for trawlers but are applied to all fisheries using different types of fishing gears. Also, the retention efficiency of each gear type is not considered and if this is low, fishing activity with apparently low by-catch of VME indicator species may still have considerable SAIs on VMEs (Auster et al., 2011). These concerns also apply to the thresholds adopted by other RFMOs.

Box 1. Assessment of DEEPFISHMAN case studies falling within NEAFC regulatory area.

DEEPFISHMAN Case Study
Stock/fishery Orange roughy (*H. atlanticus*) in ICES Sub-areas VI and VII Blue ling (*M. dypterygia*) in Vb, VI, VII and XIIb French mixed demersal trawl fishery in Vb, VI and VII Red (blackspot) seabream (*P. bogaraveo*) in the Strait of Gibraltar and Bay of Biscay Portuguese fishery for black scabbardfish (*A. carbo*) in Sub-area IX **Management** Weaknesses include lack of (i) explicit recovery plans for blue ling, orange roughy and red seabream, noting that strong management actions have already been taken (e.g. reductions in TACs and the protection of spawning aggregations of blue ling; a zero TAC for orange roughy; and a ban on targeted fishing and the introduction of minimum landing size for red (blackspot) seabream); (ii) short-term management plans to ensure that F ≤ FMSY by 2015, including suitable reference points and HCRs (subjected to management strategy evaluation (MSE) where possible), and (iii) long-term management plans with clearly defined objectives. **Monitoring** Weaknesses in most stocks/fisheries include a paucity of (i) dedicated deep-water fisheries-independent surveys resulting in reliance on abundance indices based on commercial CPUE, and an almost total lack of monitoring of ecosystem health and functioning; (ii) information on stock structure; and (iii) length and age data for black scabbardfish over its likely range of spatial distribution.

DEEPFISHMAN Case Study
Stock/fishery Oceanic redfish (*S. mentella*) This species is not classified as a deep-water species in the EU Access Regime, it is found and fished extensively in the deep water (highest densities occurring at about 400-600 m). Consequently, the strengths and weaknesses of the management and monitoring of this species are relevant here. **Management** There is good application of PA principles – current exploitation is restricted in an attempt to secure future recruitment and the stock is managed using a wide range of management tools including MPAs, gear restriction, sorting grids, by-catch regulations and TACs in international waters. However, annual catches are often much larger than recommended TACs and there is currently no agreement on the TAC in international waters within the NEAFC RA. **Monitoring** Major weaknesses include a lack of regular surveys covering the full geographical and demographic extent of the stock, and problems with species differentiation (*S. mentella* versus *S. marinus*) in fisheries data.

3.2.2. North-west Atlantic

In the North-west Atlantic, although NAFO has an extensive management and monitoring regime in place, there is a heavy reliance on TACs and quotas (which are often exceeded for some stocks, greenland halibut (*Reinhardtius hippoglossoides*) for example; see Box 2) and little use of other forms of management, such as fishing effort controls and rights-based management. There is good availability of fisheries-independent surveys but most are directed at non deep-water species. Compulsory observer coverage on all vessels is likely to result in improved compliance with regulations and result in greater availability of fisheries information, however scientific observer coverage is considerably <100% and it is uncertain whether this impacts on the range and quality of biological information available. In contrast to EU and NEAFC regulations, there are robust by-catch regulations in place and an agreed definition of directed fishing at the set level. A weakness though, is that some CPs do not report separate information on discards but report „catch" information (i.e. retained and discarded combined). As for NEAFC, there is no mandatory impact assessment required before exploratory fisheries can commence. There is no recovery plan in place for roundnose grenadier, which is seriously depleted.

Box 2. Assessment of DEEPFISHMAN case studies falling within NAFO regulatory area.

DEEPFISHMAN Case Study
Stock/fishery Greenland halibut (*R. hippoglossoides*) in NAFO Subarea 2 and Divisions 3KLMNO While this species is not classified as deep-water in the EU Access Regime, it is found and fished extensively in deep water (highest densities occurring at about 700-1200 m). Despite extensive scientific research of this species in the North Atlantic, the stock structure of this species remains uncertain. **Management** The species is managed as separate spatial components, however the biological interaction between management units is uncertain and this may impact on the accuracy of stock assessments. Spawning and recruitment processes and dynamics are poorly understood and there are also some ageing problems. **Monitoring** Latest studies show that ages are under-estimated particularly for older fish (ages 5+) (ICES, 2011). It is not known how these ageing problems impact on stock assessments. A single survey series covering the entire distribution of this species in the NAFO RA is not available.

3.2.3. South-east Atlantic

In the South-east Atlantic, fisheries in the SEAFO area are extremely data-poor. There is a paucity of time-series abundance and fisheries-independent data. Given this, SEAFO has applied precautionary TACs set at low levels until information is available to demonstrate that higher levels of exploitation are sustainable (reversal of the burden of proof). Although SEAFO has similar bottom fishing regulations in place to those applied by NAFO and NEAFC, a fishing footprint has not been finalised and this impacts on the current application of these regulations. This is an important weakness, as fishing pressure shows evidence of increasing. However, when the footprint is finalised, there are mechanisms in place to prevent new fisheries developing until an impact assessment has been evaluated and approved. The recent revision of seamount closed areas takes account of three factors not previously addressed by SEAFO (or other RFMOs): (i) seamounts penetrating into depths <2000 m and therefore those that potentially afford protection to any chemosynthetic communities that may exist; (ii) fishing for all SEAFO resources is prohibited, including semi-pelagic trawling for species such as alfonsino which may impact on benthic communities; and (iii) information of biogeographical provinces defined by Longhurst (1995; 1998; 2006). Regarding the impact of ALDFG on habitat and biodiversity through ghost fishing, the use of gillnets is banned in the SEAFO CA but, as in the CCAMLR area, historically there have not been any fisheries using this gear.

Box 3. Assessment of DEEPFISHMAN case studies falling within SEAFO regulatory area.

DEEPFISHMAN Case Study
Stock/fishery Orange roughy (*H. atlanticus*) inside the Namibian EEZ Fishery commenced in 1994, but since 1997 catches and CPUE steadily declined. The fishery has been closed since 2008. **Management** The stock was managed by TAC. **Monitoring** Extensive monitoring information from trawl and acoustic surveys and observers underpinned scientific advice. However, this is another example of a „boom and bust" orange roughy fishery, which, given the level of monitoring applied, demonstrates how difficult it is to monitor and manage fisheries for this species and the need to take full account of the PA when setting exploitation levels.

3.2.4. Brazil

The development of the deep-water fisheries off Brazil is a useful example from which much can be learned regarding the application of monitoring and management frameworks. When the chartering programme commenced, the goal of a new sustainable, well-monitored and managed deep-water fishery appeared to be achievable. The fishery was relatively small-scale in terms of the number of vessels participating; all vessels were monitored by VMS and there was 100% observer coverage. Moreover, there was a comprehensive scientific monitoring regime in place comprising comprehensive biological sampling and regular stock assessments. However, Perez et al. (2009) noted that "Despite intensive data collection, the availability of timely stock assessments, and a formal participatory process for the discussion of management plans, deep-water stocks are already considered to be overexploited due to limitations of governance". An important weakness in the management regime was that HCRs were not in place and this can adversely impact on management when there is conflict of interest between conservation, socio-economic and stakeholder interests. An additional weakness is that assessments likely over-estimated MSY levels. There would appear to have been a strong case on commencement of fisheries for applying precautionary TACs/effort limits set at very low levels. These levels would have remained low until it was reliably demonstrated that higher levels of exploitation were sustainable. However, this approach would have been in conflict with the socio-economic (and possibly political) objectives of the chartering programme which was to accelerate the development of deep-water fisheries. Such objectives are very laudable, either to develop new fisheries or to preserve existing small-scale artisanal fisheries, however there may be an argument for deep-water fisheries (where there is often high uncertainty regarding estimates of virgin biomass, MSY, current biomass, current level of exploitation, a paucity of information on stock identity and migration, and limited fisheries-independent monitoring) for socio-economic considerations to have a lower weighting in the management and governance process.

3.2.5. Antarctic

In the Antarctic, perhaps the strongest attribute of CCAMLR"s management of deep-water fisheries is the recognition that they need to be managed from the time they start, and to have a management and monitoring framework in place as they develop from new to exploratory to established. The corollary of this, management lagging behind exploitation, has been a major weakness of much of management of deep-water fisheries around the world, but particularly in EU and NEAFC waters, where management regulations were not introduced until 2003 despite fisheries commencing in the 1980s and 1970s respectively. A further positive feature is CCAMLR‟s early acceptance of the need for a holistic approach to fisheries management fully incorporating the EA and the PA. The management measures applied by CCAMLR are fairly standard for high seas fisheries (TACs, closed areas/seasons, vessel/gear licensing and moratoriums), however TACs are not managed individually and fisheries may be closed even if the TAC of a by-catch species has been reached. This presumably reduces discarding. CCAMLR also applies move-on rules if by-catch thresholds are exceeded. CCAMLR‟s deployment of seabird mitigation methods has been applauded and copied by other RFMOs where the incidental mortality of rare and endangered seabirds due to fishing is potentially high, in SEAFO waters for example. CCAMLR‟s almost total ban on bottom trawling should be seen in the context that longline fisheries for toothfish are economically viable, unlike longline fisheries for many other deep-water species around the world. A notable feature of the CCAMLR monitoring scheme is 100% observer coverage across all toothfish vessels to the extent that, where possible, two scientific observers are carried per vessel allowing 24 h coverage of fishing activities and facilitating the comprehensive VME monitoring in place. The success of CCAMLR‟s management and monitoring approach can perhaps be measured by the number of fisheries that have been assessed and certified as sustainable by the Marine Stewardship Council. Certified deep-water fisheries include those for South Georgia Toothfish and Ross Sea Toothfish.

3.2.6. Australia and New Zealand

A comparison between strengths and weaknesses of the Australian and New Zealand fishery management and monitoring regimes is instructive. Most orange roughy fisheries are still active in New Zealand, whereas almost all orange roughy fisheries in Australia are closed. This divergence may be due to the contrasted size and productivity of the orange roughy stocks in both countries, but it could also be linked to slightly different management attitudes. The accepted management targets in New Zealand and Australia have been respectively BMSY and BMEY for decades. BMEY is a more conservative target than BMSY for any fish stock and is particularly true for orange roughy stocks, where BMSY is estimated to 30% B0 in New Zealand and BMEY is estimated to be 48-50% B0 in Australia. Further, both countries have recently implemented management strategies. The Australian HSP, and more particularly the tier approach incepted to manage the SESSF deep-water stocks, comprises a number of elements that are more conservative than the New Zealand HSS. Firstly, the levels of biomass that trigger management action and fishery closure are greater in the case of the SESSF stocks (respectively 40% B0 and 20% B0) than for the New Zealand stocks (20% B0 and 10% B0). Secondly, while both management strategies account for uncertainty in different ways, the Australian tier system provides incentive (via TAC increases) to reduce that uncertainty in the future. However it should be noted that New Zealand is now applying a tier system, although the degree that this extends beyond stock assessment and monitoring into management is unclear. In both countries the primary management tool is TACs, which for most deep-water stocks in Australia (all of them in New Zealand) are allotted to stakeholders in the form ITQs. This move towards rights-based management is generally regarded as positive (FAO, 2007). However, although ITQs create individual incentives to avoid catching of non-ITQ species, it is almost inevitable that the species composition of catches will not exactly match the portfolio of available catch rights (Marchal et al., 2009). There are a number of alternative means to deal with this problem which have been applied with mixed success in ITQ fisheries around the world (Sanchirico at al., 2006). Discarding fish is one of the options than can be employed in Australia, although this is probably one of the least satisfactory ways of achieving catch-quota balancing. In New Zealand, where discarding is prohibited, a deemed value applies to fish landed over quota. However, this may increase the risk that some species will be exploited to the point where their sustainable value is diminished and possibly their viability threatened, especially when the deemed value is set too low. The monitoring of Australian and New Zealand deep-water fisheries is based on collaboration between management authorities, the industry and scientists. This participative and cost-effective process is a strength, and probably an appropriate example to consider in the EU context. The reliability of discard estimates is questionable though, especially in New Zealand where discarding practices are banned except on the small fraction of trips carrying an observer mandated by the management authority. Discarding practices are likely influenced, although to an unknown extent, by whether observers are onboard or not. Possible ways to resolve this could be to implement 100% observer coverage and/or to video-monitor fishing activities. In an ITQ system such as that in place in New Zealand and to some extent in Australia, discards would then be discounted against the fishers" catch entitlement as in some Canadian fisheries (Branch et al., 2006). A difference between the countries" monitoring systems is in how economics are incorporated in the advisory and management processes. In New Zealand, there is no formal requirement for monitoring and incorporating the fleets" economic performance, whereas in Australia economics data and information are monitored and incorporated in the scientific process. Deep-water surveys and assessments are not carried out on a regular basis in both countries to reduce advisory costs which are mainly recovered from the industry. This is clearly a different situation to that in the EU, where from an advisory and management standpoint deep-water stocks are considered by ICES and the EU every two years, and costs are not mitigated. While cost-effectiveness is a recognised merit, a risk of not monitoring and managing stocks on a regular basis may result in a failure to notice substantial regime shifts in the dynamics of populations and/or exploitation. However, if stocks are seriously depleted and recovery is expected to be slow, then more infrequent monitoring and management may be appropriate, particularly in the North-east Atlantic where the costs of monitoring surveys (if introduced) are likely to be high due to the large areas involved.

3.2.7. Mediterranean Sea

The management of deep-water fisheries in the Mediterranean Sea differs fundamentally from that described for other fisheries/areas as it is effort-based. The advantages (ease of monitoring particularly as regards licensing) and disadvantages (technological creep and relating effort to F) are well known, however this method is attractive when managing large numbers of geographically widely distributed artisanal vessels where it is difficult to collate and monitor catches. Effort-based management can also be effective in other types of fishery where fisheries-based rather than stock-based management may be more appropriate, in mixed fisheries for example. Box 4 summarises the findings of the DEEPFISHMAN case study of Red (blackspot) seabream in the eastern Mediterranean.

Box 4. Assessment of DEEPFISHMAN case studies falling within GFCM regulatory area.

DEEPFISHMAN Case Study
Stock/fishery Red (blackspot) seabream (*P. bogaraveo*) in the eastern Mediterranean This species is regarded as data-poor, as there is a paucity of biological information regarding spawning period, size at maturity, feeding habits, preferred habitat and migration. **Management** Data on fishing effort, landings, discards and revenues are sparse. To date, no attempt has been made to assess stock status, largely because the absence of TACs as a management measure in the Mediterranean has established the belief that stock assessment is of no use if quotas are not set. Scientific advice has been mostly confined to technical measures such as minimum landing size and mesh size. **Monitoring** Numerous scientific surveys conducted in the past 20 years hold significant amounts of data on *P. bogaraveo*, but these surveys are inconsistent seasonally and spatially, since their goal was not to study designated species but marine species assemblages in general. This highlights the need to balance ecosystem and stock monitoring needs.

4. Overview

The deep-water fisheries management and monitoring strategies reviewed in this article (summarised in Table 1)have each evolved to accommodate the different requirements of a diverse combination of species (both target and by-catch), stock dynamics, habitats, historical fishing practices and practitioners, national and international interests and responsibilities (political, economic and environmental), management authorities and their priorities. It is clear that no single management and monitoring strategy is suitable for all fisheries, as the strengths of one strategy for one fishery may not be suitable for the prevailing or historical conditions of another, even if targeting the same species. This situation, however, has not prevented the cross-fertilisation of good environmental and managerial practices across management authorities. Older management authorities that oversee long-established fisheries have demonstrated what strategies have been more or less successful in terms of achieving a sustainable fishery (e.g., NAFO"s VME encounter protocols now used by NEAFC and SEAFO). This experience is of benefit to younger management authorities or those tasked with managing newer fisheries. In turn, more recently established management authorities that oversee relatively newer deep-water fisheries may not be constrained by polarised cultural or political baggage, and therefore are able to implement fresh and effective strategies from which older fisheries may eventually benefit should they prove successful (e.g., seabird mitigation methods introduced by CCAMLR and now copied by other RFMOs, or mandatory impact assessments before exploratory fisheries can commence).

Most of the monitoring and management regimes described here, including those in the North-east Atlantic, would benefit from addressing four major weaknesses: (i) there is lack of an agreed definition of deep-water species and deep-water fishing activity; (ii) only rarely are regulations in place to collect socio-economic data; (iii) most have no mechanisms in place to monitor parasites , pollutants, contaminants , viral, bacteriological, fungal and protistan pathogens in deep-water fish, shellfish and other marine organisms; and (iv) there is little monitoring of ecosystem composition, health and productivity. In the North-east Atlantic, this mostly stems from the paucity of extensive internationally coordinated fisheries-independent surveys which can be used as a platform for ecosystem monitoring.
There are no explicit recommendations made here, as the information presented will now be evaluated in the final work package of the DEEPFISHMAN Project, so that it can fulfil its aim to develop strategic options for a short- and long-term management and monitoring ecosystem-based framework for deep-water stocks and fisheries in the North-east Atlantic. The present review, however, has already been of use to the European Commission during its negotiations with stakeholders, and the final decision for fishing opportunities in the deep-sea were based on the Project"s outcomes.

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Tables

Table 1. Summary of strengths and weaknesses of deep-water fisheries management and monitoring strategies in selected regions.

	North-east Atlantic	North-west Atlantic	South-east Atlantic	Brazil	Antarctic	Australia and New Zealand	Mediterranean Sea
RFMO	NEAFC	NAFO	SEAFO	-	-	-	GFCM
Other management authorities	EU & MSs governments within own EEZs, ICES	Canada & EU (Spain & Portugal) governments		Ministry of Agriculture and Livestock		AFMA	Coastal states
Subscribed to	OSPAR, MSFD				CCAMLR	Fisheries Management Act 1991 (Aus) Fisheries Act 1996 (NZ) Fisheries 2030 (NZ)	OSPAR, MSFD
Management introduced	2003	1979	2005-2007	1999-2005	1985	1991	2005-2009
Management measures	• TACs for selected spp. • EU Access Regime & restricted deep-water fishing permits • Introduction of permanent and temporary closed areas and protection areas for spawning aggregations • Sequential reduction in fishing effort • Addressing ALDFG • VME encounter protocols (threshold based)	• TACs, quotas, by-catch regulations and move-on rules when quotas exceeded • Fishing bans • VME encounter protocols (threshold based) • Introduction of closed areas around VMEs	• Precautionary TACs • Ban on deep-water shark fisheries • Ban on use of gillnets (to reduce impact of ALDFG) • Reduce incidental by-catch of seabirds • VME encounter protocols (threshold based) • Introduction of closed areas around VMEs & chemosynthetic communities shallower than 2000 m • CPs required to map all EBFAs	• TACs • Vessel limitations • Effort restrictions • Mesh size limitations • By-catch limits	• TACs and moratoriums • Closed areas and seasons • Vessel and gear licensing • Mandatory research on stock distribution and abundance for new or exploratory fisheries • Move-on rules triggered by by-catch thresholds • Measures to protect endangered, threatened or trophically important species, VMEs, seabirds and to reduce ALDFG	• RBCs (Aus) and ACEs (NZ) to inform TACs and TACCs (NZ) • Vessel limitations • Effort limitations • Mesh size limitations • Use of ITQs and discards (Aus), and HSS under QMS (NZ) for catch-quota balancing • EBFM policies, such as HSPs • BMSY as a management target (NZ)	• Effort control • Mesh size restrictions for trawls • Effort reductions • Restrictions of landing sizes and gear configuration • No-take zones • Trawling ban at depths >1000 m • Introduction of closed areas around VMEs & chemosynthetic communities
Monitoring schemes	• Biological sampling • Scientific observers • VMS • Reporting VME encouters	• Biological sampling • Scientific observers • VMS	• Landings, effort and discard data available • VMS • Mandatory scientific observers	• Official data collection logbooks • Biological sampling • Scientific observers • VMS	• Non-target species (by-catch and discards) accounted • Demersal trawl surveys • Scientific observers • Toothfish mark-recapture tagging	• Biological surveys and sampling • Scientific observers • Assessment of economic data and performance indicators (Aus) • Catch and effort logbooks • VMS	• Scientific observers • Catch logbooks and landings • Fisheries-independent surveys of resources (MEDITS)

	North-east Atlantic	North-west Atlantic	South-east Atlantic	Brazil	Antarctic	Australia and New Zealand	Mediterranean Sea
Main target species	Orange roughy Blue ling	Roundnose grenadier Roughhead grenadier	Patagonian toothfish Deep-water red crab Alfonsino	Monkfish Argentine hake Brazilian codling Wreckfish Argentine short-fin squid Deep-water red crab and shrimp	Patagonian toothfish Antarctic toothfish	Orange roughy Alfonsino Oreos Ribaldo Deep-water sharks Black cardinalfish Ling Deep-water crabs	Crabs Hake Norway lobster Rose and aristeid shrimp Red black-spot seabream Wreckfish Deep-water six-gilled shark
Strengths	• Good examples of the application of PA principles, including restricted exploitation and deployment of wide range of management tools	• Good availability of fisheries-independent surveys (but mostly from shallow seas) • Robust by-catch regulations	• Mechanisms in place to prevent new fisheries developing until an impact assessment has been evaluated and approved • Use of gillnets is banned	• All vessels monitored by VMS and 100% observer coverage • Comprehensive biological sampling and regular stock assessments	• Management and monitoring framework in place before deep-water fishery starts • Holistic approach to fisheries management • 100% observer coverage across all toothfish vessels	• Rights-based management • Monitoring based on collaboration between management authorities, the industry and scientists, therefore, participative and cost-effective	• Effort-based approach suitable for fishery-wide management • Ease of monitoring, particularly as regards licensing
Weaknesses	• Management lagging behind exploitation • Restricted number of species managed by TACs had encouraged misreporting • Geographical stock structure of species means that TACs set over large areas • Capacity ceilings set unrealistically high • No mandatory impact assessment required before exploratory fisheries can commence	• Heavy reliance on TACs and quotas • Little use of fishing effort controls and rights-based management practices • Some CPs do not report separate information on discards • No mandatory impact assessment required before exploratory fisheries can commence	• Extremely data-poor • Fishing footprint not finalised	• Deep-water stocks overexploited before management measures implemented due to limitations of governance • HCRs not in place • Assessments likely over-estimated MSY		• Reliability of discard estimates is questionable	• Generally data poor, as difficult to collate and monitor catches • Technological creep and relating effort to F
Relevant literature	EC (2002a & b) EC (2004) EC (2005a & b) EC (2006a & b) EC (2008a) EC (2009a)	EC (2008b)	SEAFO, 2010 FAO, 1999	Wahrlich et al. (2004) Perez et al. (2009) Anon. (2006) Costa et al. (2005) Rossi-Wongtschowski et al. (2006)	Mooney-Seus & Rosenberg (2007)	Anon. (2005) Anon. (2009) Sanchirico et al. (2006) DAFF (2007) Hohnen et al. (2008) Marchal et al. (2009) NZMFISH (2008a & b)	Cartes et al. (2004a) GFCM/SAC (2010) EC (2006c)

Figures

Figure 1. NEAFC Regulatory Area (in orange) (source: NEAFC).

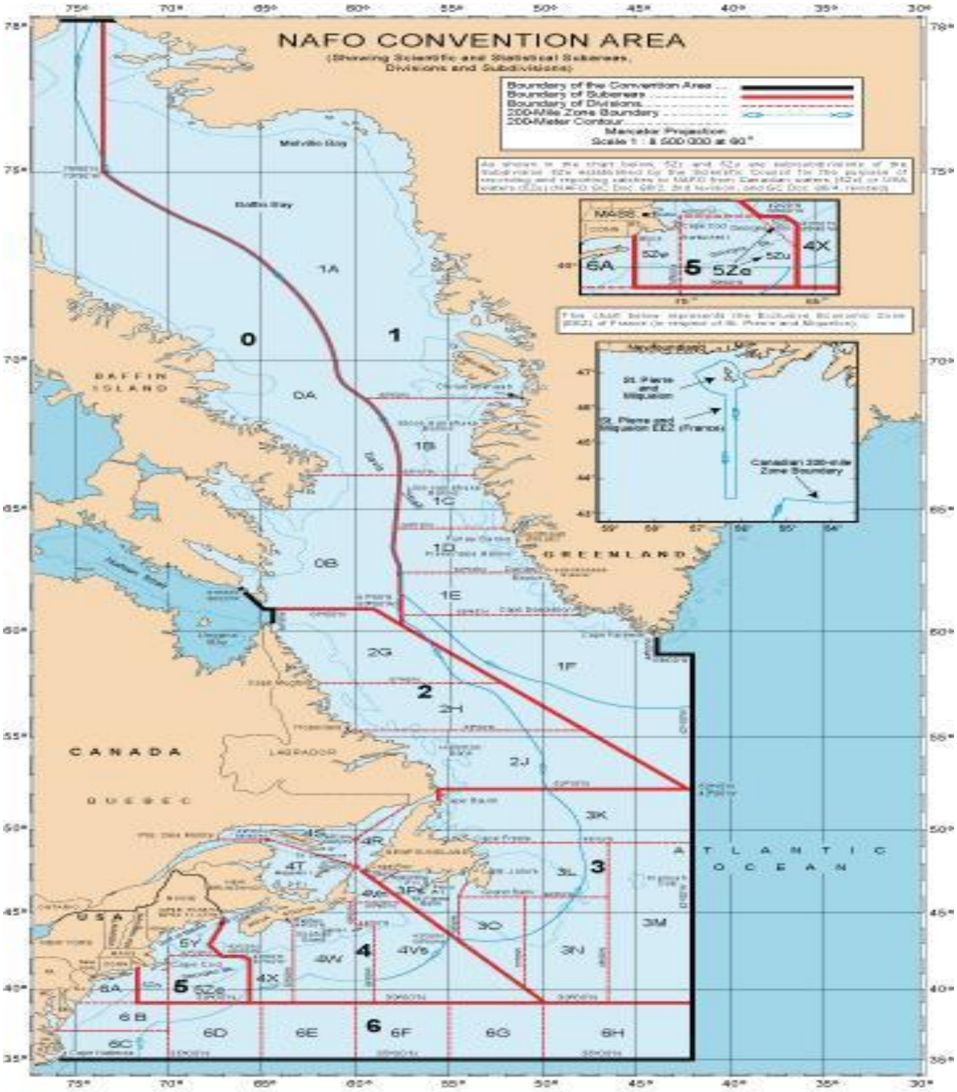

Figure 2. NAFO Convention Area (note that the NAFO RA is the part of the CA outside national EEZs) (source: NAFO).

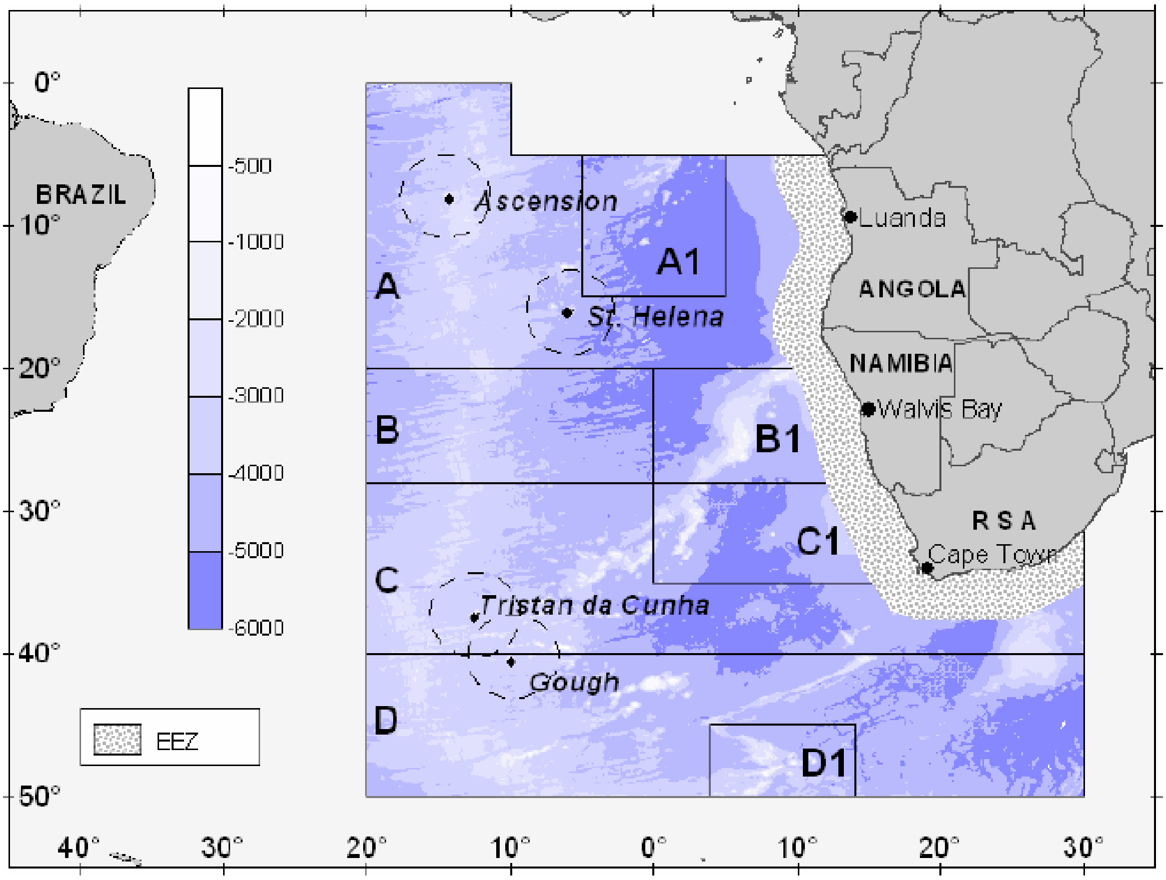

Figure 3. Bottom topography of the SEAFO Convention Area also showing SEAFO Divisions and Sub-divisions (depth scale is in metres) (source: SEAFO, 2006).

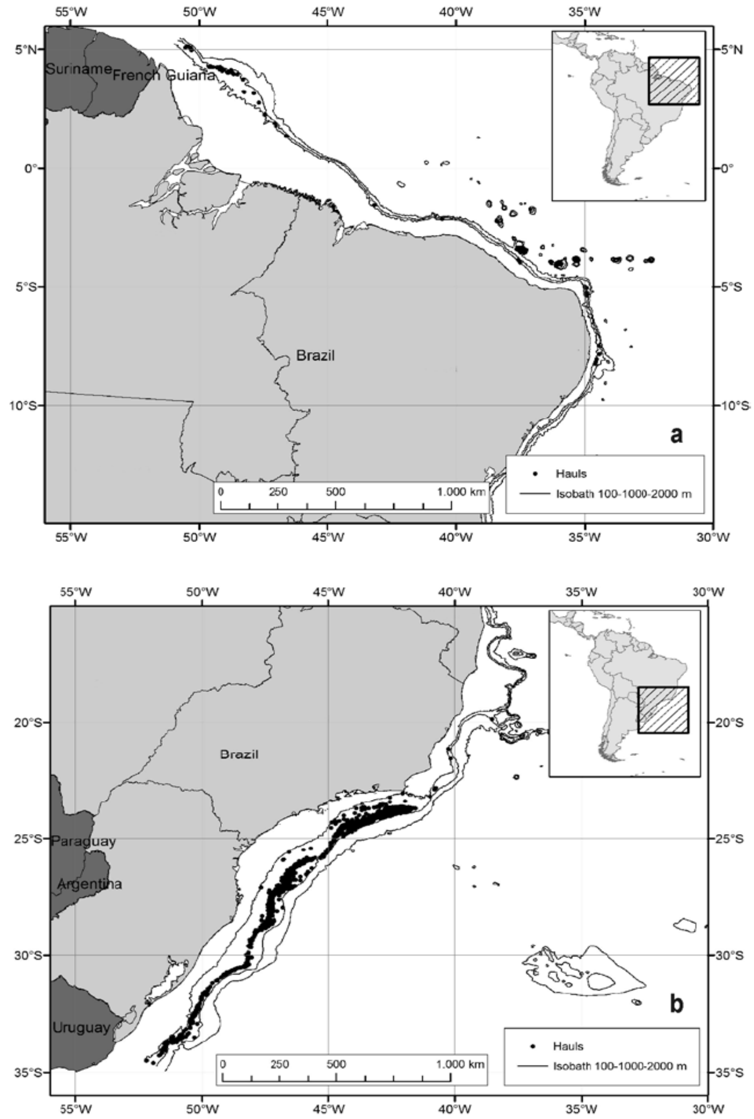

Figure 4. Continental margin off Brazil, SW Atlantic. (a) Northern and north-eastern sectors, (b) central, south-eastern, and southern sectors. Dots represent fishing hauls conducted by the chartered trawlers. Chartered gillnetters, potters, and longliners operate in the same areas as those occupied by trawlers but are not represented for clarity (source: Perez et al., 2009).

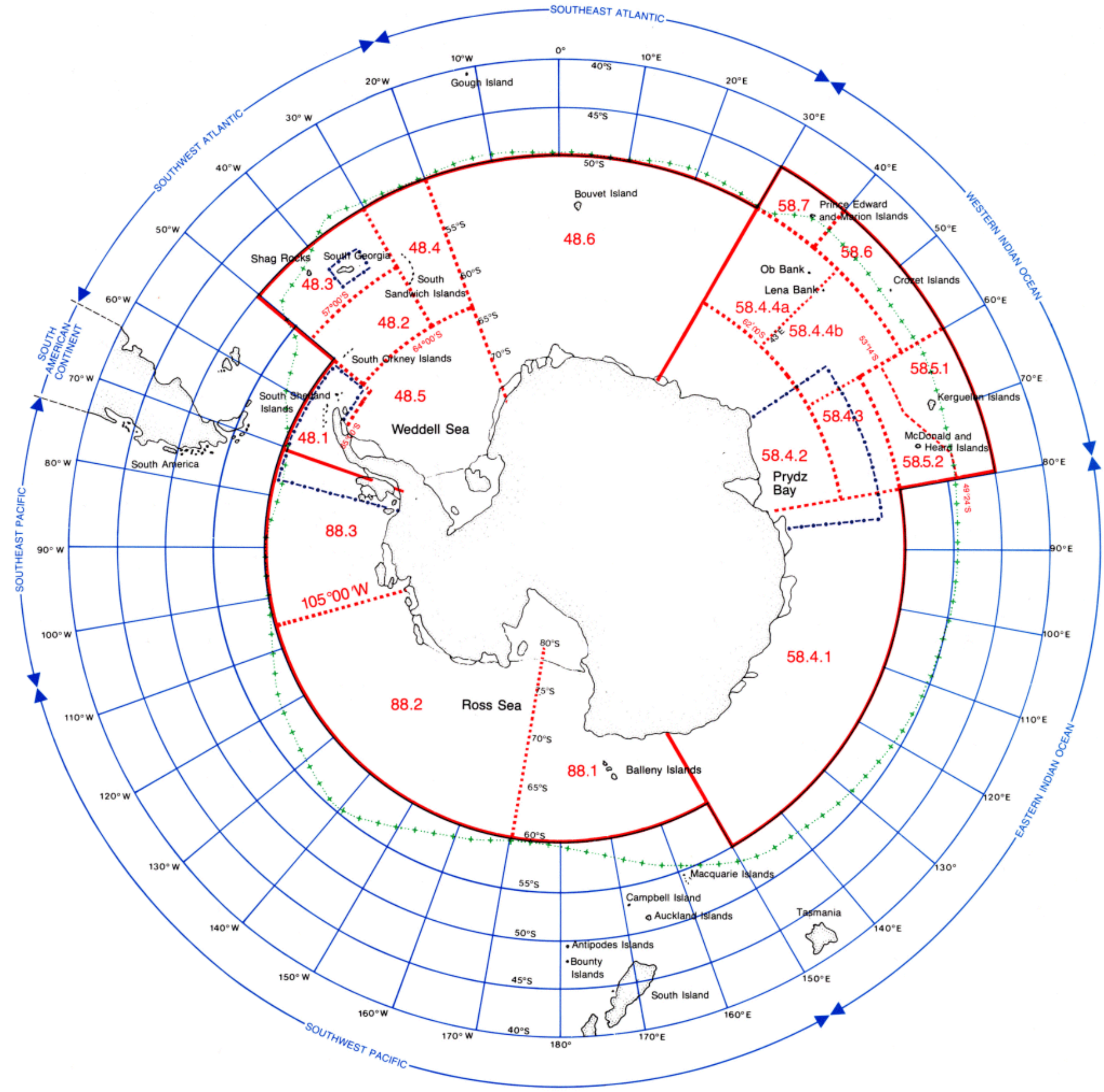

Figure 5. Map of CCAMLR Convention Area, with Subareas delineated in red (source: CCAMLR).

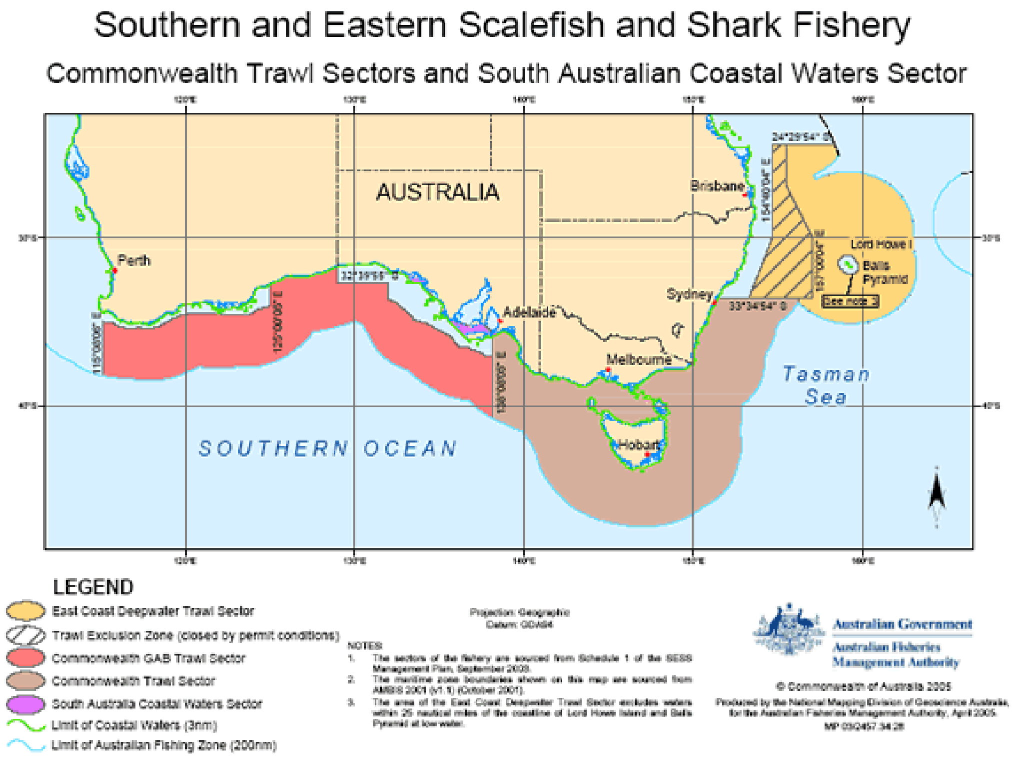

Figure 6. Map of the different sectors of activity of the SESS fishery, © Commonwealth of 2005 (source: http://www.afma.gov.au/information/maps/sess_cts.htm)

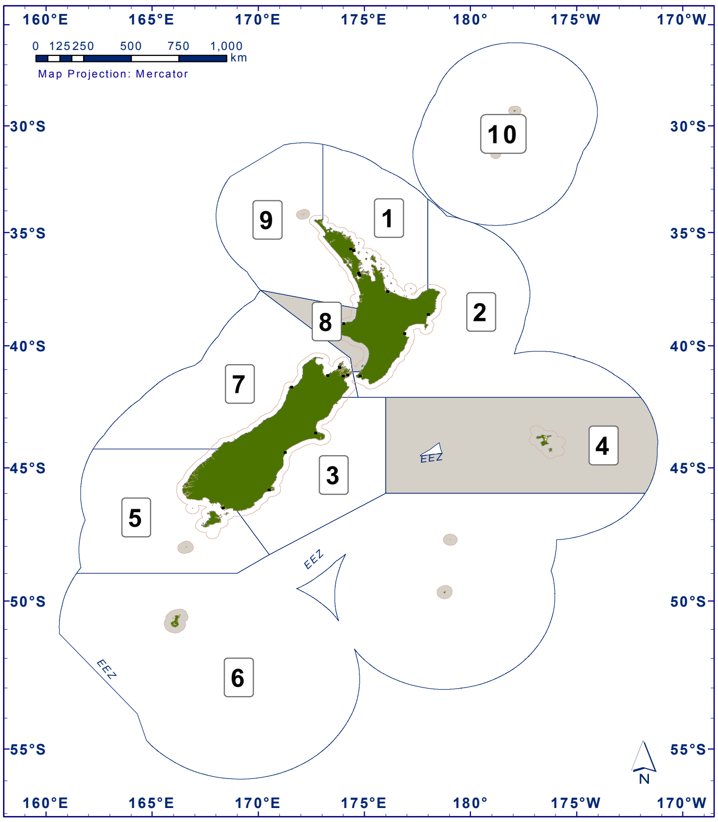

Figure 7. Map of the New Zealand Exclusive Economic Zone including Fisheries Management: (1) Auckland (East); (2) Central (East); (3) South-East Coast; (4) South (Chatham Rise); (5) Southland; (6) Sub-Antarctic; (7) Challenger/Central (Plateau); (8) Central (Egmont); (9) Auckland (West); (10) Kermadec (source: http://www.fish.govt.nz).

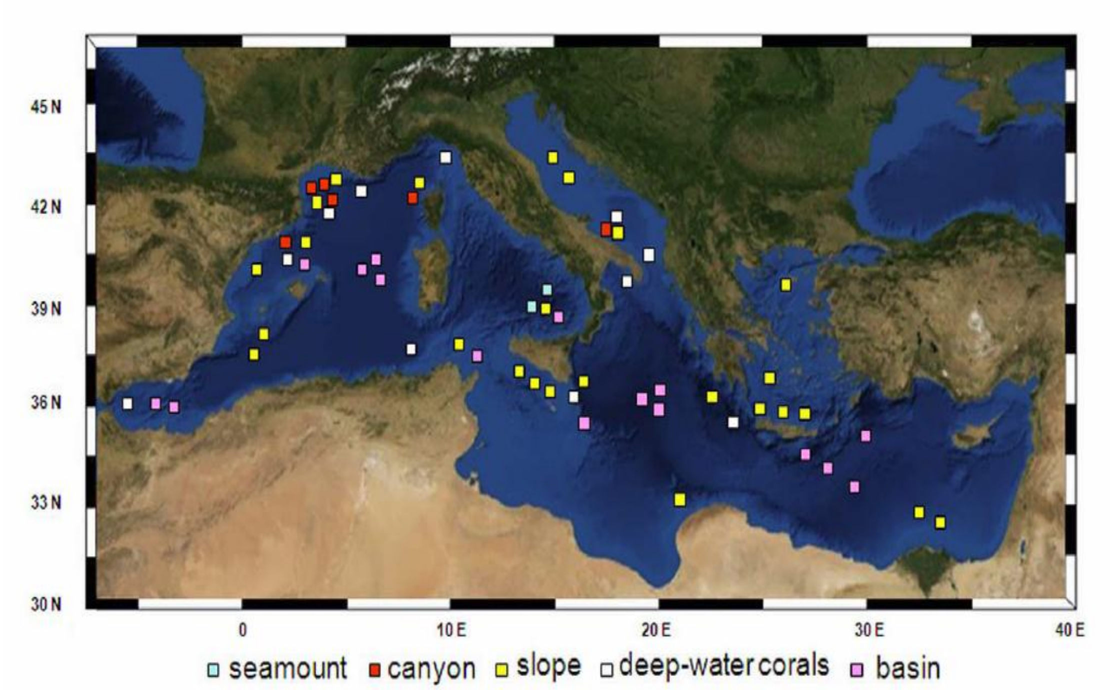

Figure 8. Deep-water areas of interest in the Mediterranean Sea (source: Danovaro et al., 2010)

Glossary of acronyms

ACE	Annual catch entitlement
AFMA	Australian Fisheries Management Authority
ALDFG	Abandoned, lost or otherwise discarded fishing gear
BMEY	Average stock biomass level corresponding to MEY
BMSY	Average stock biomass level corresponding to MSY
CA	Convention area
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CFP	Common Fisheries Policy
CP	Contracting party
CPUE	Catch per unit effort
CTS	Commonwealth trawl sector
DCF	Data Collection Framework
DWF	Deep-water fisheries
EA	Ecosystem approach
EBFA	Existing bottom fishing area
EBFM	Ecosystem-based fisheries management
ECDTS	East Coast deep-water trawl sector
EEZ	Exclusive economic zone
EU	European Union
F	Fishing mortality
FAO	Food and Agriculture Organisation
FMSY	Fishing mortality that produces the MSY
GABTS	Great Australian Bight trawl sector
GES	Good environmental status
GFCM	General Fisheries Commission for the Mediterranean
GHTS	Gillnet, hook and trap sectors
HCR	Harvest control rule
HSP	Harvest strategy policy
HSS	Harvest strategy standards
ICES	International Council for the Exploration of the Sea

ITQ	Individual transferable quotas
M	Natural mortality
MAR	Mid-Atlantic ridge
MEDITS	Mediterranean trawl survey
MEY	Maximum economic yield
MS	Member state
MSE	Management strategy evaluation
MSFD	Marine Strategy Framework Directive
MSY	Maximum sustainable yield
NAFO	North-west Atlantic Fisheries Organisation
NBFA	New bottom fishing area
NEAFC	North-east Atlantic Fisheries Commission
OSPAR	Oslo Paris Convention
PA	Precautionary approach
QMS	Quota management system
RA	Regulatory Area
RBC	Recommended biological catch
RFMO	Regional Fisheries Management Organisation
SAI	Significant adverse impact
SAC	Scientific advisory committee
SEAFO	South-east Atlantic Fisheries Organisation
SESSF	Southern and Eastern Scalefish and Shark fishery
SWOT	Strengths, weaknesses, opportunities and threats
TAC	Total allowable catch
TACC	Total allowable commercial catch
UNGA	United Nations General Assembly
VME	Vulnerable marine ecosystem
VMS	Vessel monitoring system
WSSD	World Summit on Sustainable Development