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Management And Monitoring Of Deep-sea Fisheries And Stocks

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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 towards 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[1] Project so that it can fulfil its primary aim which is to develop strategic options for a short- and long-term management and monitoring ecosystem-based framework for the NE Atlantic. To provide a baseline, the current monitoring and management regime in the NE Atlantic is described, followed by a brief description of the regimes applying to deep-water fisheries in Australia and New Zealand, the Antarctic, the south-east Atlantic, Brazil, the north-west Atlantic and the Mediterranean. The strengths and weaknesses of these are then 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 NE Atlantic, and the requirements of EU regulations and developing policy that likely impact on deep-water fisheries in the NE Atlantic.

Keywords: deep-water, monitoring and management

Introduction

The monitoring and management of deep-water fisheries and ecosystems around the world is an important issue for a wide range of stakeholders including fishers, fisheries scientists, National Management Bodies, Non-Governmental Organisations (NGOs), Regional Fisheries Management Organisations (RFMOs) and the United Nations General Assembly (UNGA). Deep-water fisheries occur in all of the world's oceans and in the Mediterranean Sea and they are important to fishers because of their economic value and, in some areas, where they provide an alternative resource when fish 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 fisheries the availability of reliable information on stock status and fisheries

[1] EU FP 7 DEEPFISHMAN project (Grant agreement no. 227390)- Management and Monitoring of Deep-sea Fisheries and Stocks

production potential has lagged behind exploitation (Large *et al*, 2002). Furthermore, for some fisheries the availability of scientific advice has considerably preceded actions by management bodies. For example, the International Commission for the Exploration of Sea (ICES) first gave scientific advice on the status of deep-water stocks in the NE Atlantic in 1996, but it was not until 2003 that the European Union (EU) introduced management regulations. Regulations by the North-east Atlantic Fisheries Commission (NEAFC) following shortly thereafter. 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: (i) maturation at relatively old ages; (ii) slow growth; (iii) long life expectancies; (iv) low natural mortality rates; (v) intermittent recruitment of successful year classes; and (vi) spawning that may not occur every year (FAO, 2009). Deep-water fishery resources are, therefore, highly vulnerable to exploitation (Merrett and Haedrich, 1997; Koslow *et al*., 2000; Anon., 2001) and deep-water habitats are sensitive and in need of protection (OSPAR, 2000). Furthermore, 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 (Anon., 2001). An additional concern is that studies using fisheries-independent trawl survey data pre- and post-fisheries exploitation indicate that fishing can 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 of discards (which is considered to be very high 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 are therefore 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).

RFMOs and national management bodies around the world have responded to these concerns, and also requirements of UNGA Resolution 61/105 (2007) 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 (2009), which addresses management factors ranging from an appropriate regulatory framework to the components of a good data collection programme.

The aim of this paper is evaluate the strengths and weaknesses of the management and monitoring of deep-water fisheries in different areas of the world, with the objective of informing the EU FP7 DEEPFISHMAN[2] Project so that it can fulfil its primary aim which is to develop strategic options for a short- and long-term management and monitoring ecosystem-based framework for the NE Atlantic. In the context of this paper, monitoring excludes stock assessment and management mostly excludes consideration of biological reference points

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(BRPs) and harvest control rules (HCRs), as these are addressed in other parts of the project. 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 to deep-water fisheries and ecosystems in Australia and New Zealand, the Antarctic, the south-east Atlantic, Brazil, the north-west Atlantic and the Mediterranean. The strengths and weaknesses of these are then discussed taking into account outcomes from consultations with stakeholders in the deep-water fishing industry in the NE Atlantic, the requirements of EU regulations and developing policy that likely impact on deep-water fisheries and information on strengths and weaknesses identified in DEEPFISHMAN Case Study stocks/fisheries.

North-east Atlantic

The definition of "deep-water" species varies between organisations and countries and is addressed in the discussion. Here, deep-water species are broadly defined in line with those listed in annexes I and II of the EC Deep-water Licensing Regulation No 2347/2002. Deep-water fisheries in the NE Atlantic fall under the monitoring and management remit of NEAFC for international waters and sovereign states within their national exclusive economic zones (EEZs). The OSPAR Convention is the legal instrument guiding international cooperation on the protection of the marine environment of the NE Atlantic. It is not possible here to review all the relevant management and regimes as much of the national state policy is not readily available in English, so here we focus mainly on monitoring and management of EU vessels and those additional regulations applying in international waters in the NEAFC Regulatory Area (RA).

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 (Council Regulation (EC) No 2340/2002). The TAC and Quota Regulation was complemented by Council Regulation (EC) No 2347/2002 establishing specific access requirements and associated conditions applicable to fishing for deep-water stocks. This Regulation aimed to cap the expansion of fishing effort on deep-water species by requiring all vessels that capture more than 10 t of deep-sea species in year to have a deep-water fishing permit, otherwise their landings of deep-water species are limited to 100 kg per fishing trip. Moreover, the total capacity of vessels holding deep-sea fishing permits was restricted. Special reporting and control requirements were also introduced, including the development of biological sampling schemes and observer coverage and the requirement to land only to designated ports. To improve the sampling of deep-water species under the EU Data Collection Regulation (DCR) further sampling requirements were specified in Commission Regulation (EC) No 1581/2004. ICES advice for deep-water stocks is issued every two years and consequently the EU TAC regulations have been updated biennially and at times expanded to manage additional species and other pertinent deep-water issues. Council Regulation (EC) No 2270/2004 introduced TACs on a number of stocks for which catches were not previously restricted (deep-water sharks and forkbeards (*Phycis blennoides*)) and deleted some species (greater silver smelt (*Argentina silus*) and ling (*Molva molva*)) which were transferred to the EC Annual TAC and Quota Regulations. To take account of ICES advice that the stock of orange roughy (*Hoplostethus atlanticus*) in Sub-area VI was heavily depleted (ICES, 2003), closed areas in which fishing for this species is prohibited were introduced to the west of the British Isles. Council Regulations 27/2005 and 51/2006 required 10% and 20% reductions respectively in the number of kW-days deployed by vessels holding deep-water licences with respect to the levels deployed in 2003. Council

Regulation (EC) No 2015/2006 did not include TACs for tusk (*Brosme brosme*) and these were transferred to the EC Annual TAC and Quota Regulations. Greater argentines were excluded from the list of deep-water species for the purpose of effort calculations. Regulation 2015/2006 also introduced measures regarding the use gill, entangling and trammel nets in ICES areas VIa, b, VIIb, c, j, k and XII. Community vessels were prohibited from using these nets at any position in these areas east of 27^{0} where the depth is > 200 m, in ICES Zones VIa, b, VII b, c, j, k and XII east of 27^{o} W. Derogation is allowed for entangling nets with a mesh size ≥ 250 mm, provided that they are deployed in waters of < 600 m depth and must each be of ≤10 km in length. The total length of all nets deployed at any one time is ≤ 100 km per vessel. The maximum soak time allowed is 72 hours. All gear must be marked in accordance with EC Regulation No 356/2005 and all vessels deploying nets where the depth is > 200 m must have a fishing permit issued by the flag state and record in the logbook the amount and length of gear carried by a vessel before it leaves port and when it returns to port and account for any discrepancy between the two quantities. Council Regulation No 1359/2008 fixed TACs for deep-water stocks in 2009 and 2010, however blue ling (*Molva dypterygia*) in VI and VII was transferred to the EC Annual TAC and Quota Regulations to accommodate the introduction of new regulations to protect spawning aggregations of blue ling in Sub-Division VIa and to facilitate EU/Norway negotiations for this species. EC Council Regulation (EC) No 43/2009 introduced protection areas for spawning aggregations of blue ling on the edge of the Scottish continental shelf and the edge of Rosemary Bank for the period 1st March to 31st May. These measures include entry and exit protocols, prohibition of retaining in excess of 6 t of blue ling in either area per trip, and, once the vessel retains this quantity, prohibition of returning to these areas until the vessel has landed. In addition, vessels cannot discard blue ling in these areas and observers (deployed under EC Regulation (EC) No 2347/2002) should record the length and sexual maturity composition of catches of blue ling. Member States (MSs) must establish sampling protocols and collate data and information on the spatial and temporal distribution of observed fish length and maturity.

The main EU Regulation applying to ecosystems in EU waters is the Marine Strategy Framework Directive (MSFD) *(*EC DIRECTIVE 2008/56/EC, 2008*)* which addresses all human activities that impact on the marine environment. The achievement of the objectives of this Directive should ensure the integration of conservation objectives, management measures and monitoring and assessment activities set up for spatial protection measures such as special areas of conservation (SACs), special protection areas (SPAs) or marine protected areas (MPAs). Account should also be taken of biodiversity and the potential for marine research associated with deep-water environments. The Directive establishes a framework within which MSs shall 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 shall 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, while enabling the sustainable use of marine goods and services by present and future generations. MSs must make an initial assessment of their marine waters by July 2012, taking account of existing data where available. The qualitative descriptors for determining GES of particular relevance to deep-water ecosystems are that (i) biological diversity is maintained, (ii) 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, (iii) all elements of the marine food webs occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity, (iv) 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, (v) contaminants in fish and other seafood for human consumption do not exceed levels established by EC legislation or other relevant standards, and (vi) properties and quantities of marine litter (including lost and abandoned fishing gear) 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. MSs must establish and implement by July 2014 a monitoring programme for ongoing assessments and regular updating of the targets and develop by 2015 a programme of measures designed to achieve of maintain GES and to put in operation the programme of measures by 2016 at the latest. MSs have already made considerable progress introducing closed areas to protect cold-water corals (mainly *Lophelia pertusa*). For example, the UK has introduced a closed area to the protect the Darwin Mounds to the north-west of and Scotland and Ireland is proposing introducing SACs to protect localized concentrations of cold-water corals on the margins of the Porcupine Band and Porcupine Bight. Similar measures have been or are in the process of being introduced by other MSs.

NEAFC did not regulate deep-water fisheries in the RA until 2003 when a temporary freeze on deep-water effort was introduced. Taking account ICES advice on deep-water stocks, in subsequent years this regulation has been strengthened and currently each Contracting Party (CP) must limit the effort for 2010-2012 so that it does not exceed 65% of the highest level put in previous years for the relevant species (NEAFC Recommendation VI/2010). Effort is calculated as aggregate power, aggregate tonnage, fishing days at sea or number of vessels. NEAFC has also introduced regulations to control fisheries for orange roughy and blue ling. (Recommendations IX and X, 2010, respectively). Directed fisheries for orange roughy in ICES Sub-areas V, VI and VII are currently prohibited. In other areas of the RA directed fisheries may only be undertaken if certain conditions are met which include a restriction of the annual catch of any CP to 150 t and a requirement for CPs to develop research and sampling plans to provide information relevant to the development of procedures for monitoring the Ecosystem effects of fisheries. Following repeated ICES advice to introduce closed areas to protect spawning aggregations of blue ling, NEAFC has banned all fishing with bottom contact gear in an area south-west of Iceland (ICES Division XIV) during the spawning period. Other relevant NEAFC Regulations include a ban on deep-water gill, entangling and trammel fisheries at depths >200 m (Recommendation III, 2006), a ban on 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 XVI, 2010)[3] and the introduction of closed areas to protect VMEs (mainly cold-water corals) on Hatton Bank, Rockall Bank, on the Logachev Mounds and the West Rockall Mounds. Bottom trawling and fishing with static gear is prohibited within these areas.

[3] This has not been agreed by the EU which has lodged an objection. This measure does not apply to deep-water species.

Regarding general regulations on bottom fishing, NEAFC has mapped "existing bottom fishing areas" (EBFAs) within its RA. All areas outside the EBFA are referred to as "new bottom fishing areas" (NBFAs). All bottom fishing activities in NFBAs are treated as exploratory fisheries and must not commence until the following information has been provided to NEAFC: (i) a harvesting plan outlining target species, dates and areas, (ii) a mitigation plan including measures to prevent significant adverse impacts (SAIs) to VMEs that may be encountered, (iii) a catch monitoring plan that includes recording/reporting of all species caught, and (iv) 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 then 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 the EBFA and NFBAs. Vessels without delay must cease bottom fishing activities at any site in the RA where evidence of VMEs is encountered and report the encounter (including the location, and the type of ecosystem) 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 the EBFA, the vessel making the encounter must cease fishing and move away at least 2 nm from the position that is closest to the exact encounter location. NEAFC compiles an annual report on single and multiple encounters and forwards this to ICES for evaluation. NEAFC then considers the ICES advice and will then adopt conservation and management measures to prevent SAIs on VMEs if required. In NBFAs, observers identify corals and sponges and other VME organisms to the lowest possible taxonomical level. If the quantity of VME element or indicator species caught in a fishing operation is greater than the thresholds described above the same reporting protocols as for the EBFA apply with the addition that the NEAFC immediately requests CPs to implement a temporary closure of 2 nm radius around the reporting position. If, on the basis of assessment by ICES, the area is a VME, NEAFC will request CPs to maintain the temporary closure until such time that NEAFC can introduce a permanent measure.

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. Other Australian deep-water fisheries comprise the Northern Trawl Fishery (landing deep-water prawns and orange roughy) and the South Tasman Rise fishery (targeting orange roughy aggregations). 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). Only the CTS, GABTS and ECDTS sectors support substantial dedicated deep-water fishing activity. Management plans are required for fisheries unless AFMA has determined that a management plan for a particular fishery is not warranted. Each management plan sets out the objectives, measures by which the objectives are to be attained and performance criteria against which the measures taken can be assessed. Each plan is prepared in consultation with participants in the fishery and is made available in draft for public comment. The management objectives, strategies and tools relevant to the deep-water fisheries in the CT, ECDWT and GABT Sectors fall in the SESSF fishery plan (SESSF, 2007).

A key feature of Australian fisheries management is the formalised stakeholder liaison and consultation that occurs continuously through sectoral Management Advisory Committees (MACs). MACs are a major source of advice to the AFMA, reflecting the experience and expertise of the range of stakeholders. MACs draw upon and consider advice provided by Resource Assessment Groups (RAGs) which have been established for each major fishery group or for individual species. RAGs comprise fishery scientists, industry members, fishery economists, management and other interest groups. The wide membership ensures that, in addition to scientific information on each fish stock, industry knowledge and developments in management strategies, market prices and the costs of harvesting are also taken into account. RAG meetings are partially funded by AFMA from the AFMA Research Fund and partially industry funded through a cost recovery regime (levies). RAGs are not a body of the MACs and operate independently from them, although the two groups work closely together. The main role of RAGs is to provide advice on the status of fish stocks, and on the impact of fishing on the marine environment. RAGs also evaluate alternative harvest options proposed by MACs, including impact over time of different harvest strategies, stock depletion or recovery rates, confidence levels for fishery assessments, and risks to the attainment of approved fishery objectives. The RAGs also evaluate and report on economic and compliance factors affecting the fishery. RAGs report their recommendations through the individual fishery MACs to the AFMA on issues such as the setting of TACs, stock rebuilding targets, BRPs etc. RAGs are not mandated to update stock assessments on an annual (or biennial) basis. SESSFRAG is the RAG dedicated to the SESSF stock assessments. SESSFRAG consists of five assessment groups. One of these groups, the Deepwater Resource Assessment Group (DEEPRAG), is responsible for assessing SESSF deep-water stocks deeper than 600 m.

General management objectives and principles for Australian fisheries may be found 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 management objective 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, B_{MEY}, the average stock biomass level corresponding to MEY, is the legal management target, and is estimated to 48-50% of the virgin biomass. Management targets have not been established for the other Australian deep-water stocks.

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 more particularly relevant to the management of Australian deep-water fisheries. The HSP represents an operational framework that explicitly enables the implementation of the requirements of the Fisheries Management and Administration Acts 1991, but also of the holistic Environment Protection and Biodiversity Conservation Act 1999. Therefore, the HSP is not a single-species, but rather an ecosystem-based fisheries management (EBFM) policy (Smith *et al.*, 2007). Minimum standards have been established for the HSP reference points. Thus, target biomass (B_{TARG}) and limit biomass (B_{LIM}) should respectively be above B_{MEY} (or 1.2 B_{MSY}[4] if B_{MEY} is unknown,) and ½B_{MSY}, limit fishing mortality F_{LIM} should be lower than F_{MSY}, while F_{TARG} should be the F level required to maintain the stock biomass at about B_{TARG}. Rebuilding strategies are developed for those stocks harvested below B_{LIM}, and these involve setting targeted catches to zero. If those stocks biomass drops substantially below B_{LIM}, they may also be included in the list of threatened species established by the Environment Protection and Biodiversity Conservation Act (EPBC, 1999). Such stocks would then be subject to a formal recovery plan. In December 2006, orange roughy was listed as conservation dependent under the EPBC Act. The conservation program prevents targeting of orange roughy in all fishing zones except the Cascade Plateau.

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 F are available from catch curve analyses (with some knowledge of natural mortality (M)); Tier 4 stocks are those for which only CPUE trends are available. Each Tier has its own HCR that is applied to calculate RBCs (Recommended Biological Catches), which are then used to advise on TACs. SESSFRAG advises on the tier to which the different SESSF stocks should be allocated. SESSF fisheries are managed using a mixture of input and output (TAC) 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 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.

For Australian fisheries the AFMA has a responsibility to monitor the impact of fishing under its arrangements and must collect and verify data for this purpose. AFMA uses data from a range of sources, including data supplied by the fishing industry as well as data from independent sources. These data are mainly used as inputs to the stock assessments carried out by the RAGs, but also for compliance purposes. The data comprise catch and effort logbooks, independent observer data (including biological and discard data), catch disposal records, vessel monitoring system (VMS) data and prior reporting. The fishing industry is the main funding body of the data collection program (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). Acoustic and egg production surveys, which provide absolute biomass estimates, have been conducted by both CSIRO (Australia's Commonwealth Scientific and Industrial Research Organisation)

[4] Where B_{MSY} is the level of biomass required to achieve the maximum sustainable yield (MSY) in the long term

and the fishing industry, to evaluate orange roughy stocks and to contribute to analytical stock assessments.

In New Zealand, deep-water species are defined very broadly as species found: (i) deeper than 600 m (orange roughy, oreos, black cardinalfish *(Epigonus telescopus)*, alfonsino), (ii) other species generally distributed between 200 and 600 m (including ling), and deep-water crabs which can be found at varying depths down to 1500 m. Here we focus on the deep-water species found that depths >600 m. Unlike in Australia, the orange roughy fishery is still active, although closures have been enforced in relation to three stocks (Puysegur Bank, Challenger Plateau and West Coast South Island).

Catch limits in the form of TACs have traditionally been the main regulatory tools for all the New Zealand fisheries. Whereas input-based measures (limited entry, gear and mesh size restrictions) are implemented in Australia, such measures have only rarely been enforced in New Zealand, where the Ministry of Fisheries has almost exclusively opted for results-based management. After setting a TAC, an allocation decision is made specifying allowances for, (1) the customary (Maori), (2) recreational fishers and, (3) a virtual allocation including other sources of F (e.g. illegal fishing). The TAC allocation is not based on any clear scientific or policy basis. 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). It corresponds conceptually to the Australian (and EU) TAC. TACCs are distributed to quota holders as ITQ shares. Each ITQ (expressed as a percentage of the TACC) generates for each quota holder and each stock, a catching right (in kg) 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 in New Zealand for almost all species managed under the quota management system (QMS) and therefore not an option to balance catches with TACCs. Fishers and/or quota-holders have two options. 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. There has not been to date any clear policy or rationale as to how the deemed value should be calculated. However, 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. The Ministry of Fisheries has recognised the need to strengthen the background around deemed value setting and 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). Similar to the Australian Fisheries Management Act 1991, the overarching objectives include biological sustainability, socio-economic, environmental and ecosystem requirements (Marchal *et al*. 2009). One outstanding feature is the explicit reference to B_{MSY} 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 B_{MSY} (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. However, there are many stocks for which B_{MSY} cannot be estimated reliably. Such difficulties have, on some occasions, limited the applicability of the Act in the context of fisheries management, and amendments to the Fisheries Act 1996 have recently been recorded. Unlike the Australian SESSF fishery, fishery plans have not to date been developed to manage comprehensively New Zealand deep-water fisheries. However, Harvest Strategy Standards (HSS), along with operational guidelines, have since 2008 been introduced for all stocks under the Quota Management System (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 objective is to achieve a high probability of achieving targets, a very low probability of breaching limits, and acceptable probabilities of rebuilding depleted stocks. 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 soft limit is ½B_{MSY} or 20% of virgin biomass (B_0), whichever is higher; and (iii) a hard limit below which fisheries should be considered for closure. The default hard limit is ¼B_{MSY} or 10% B_0, whichever is higher.

Consultative processes are well established with good access by and inclusion of interested parties. The many Fish stock Assessment Working Groups (FAWGs) allow contracted work to be undertaken and for work in response to FAWG feedback. The FAWG culminate in an Assessment Plenary meeting which serves a limited review function and provides final input to report preparation. The Ministry of Fisheries is responsible for producing annual Plenary Reports, which include sections on all stocks, whether or not they have been considered that year. Most of the commercially important stocks are considered every 2-3 years. Research providers such as NIWA (The National Institute of Water and Atmospheric Science), government scientists and managers, industry representatives and occasionally NGOs participate in FAWG and Plenary processes. In the case of deep-water FAWG, the main industry contributors are the Seafood Industry Council (SeaFIC) and the Deep-water Group Ltd. There is no "closed shop" approach to any science groups and there is no restricted final science advisory committee.

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 vessel monitoring systems (VMS) data, and the fishing industry is the main funding body of the data collection program. Biological data collection and research surveys (acoustic, trawl and egg surveys in the case of deep-water stocks) are conducted by both NIWA and the fishing industry, under the auspices of the Ministry of Fisheries. Unlike in 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. ACE holdings and trading prices are recorded in ACE and Quota Share registers for each stock and quota holder. Information on fish prices is derived from a survey conducted annually by the Ministry of Fisheries, which collects prices paid by licensed fish receivers to fishers. The outcomes of the survey are used to calculate the levy charged to quota holders for the costs of fisheries management and stock assessment, which may incentivise fishers to report low prices.

The New Zealand Government recently released Fisheries 2030, which provides strategic direction for the New Zealand 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 bycatch 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 may be possible to use data from wide-area trawl surveys; Tier 3 species are incidental bycatch 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.

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) Area on continental shelves, sub-Antarctic Islands and seamounts. The two principal methods of catching Patagonian toothfish are trawling and longlining. Trawlers are confined to fishing at relatively shallow depths and on fairly smooth grounds and currently only operate around Heard Island catching primarily juvenile fish. Longliners operate in deeper water (550-2000 m) targeting adults.

The CCAMLR Convention has its origins in the Antarctic Treaty System (ATS). CCAMLR strives to implement a holistic, or 'ecosystem' approach to the management of marine living resources. Consistent with an ecosystem approach, the Convention Area 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 (Antarctic Convergence). This is regarded as the biogeographical boundary of many Antarctic marine species' assemblages. Management also strives to follow the PA. Harvesting and associated activities are conducted in accordance with following principles: (i) prevention of a decrease in the size of harvested populations to levels below those which ensure their stable recruitment. For this purpose its size should not be allowed to fall below a level, (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) above, and (iii) prevention of change(s) or minimization of the risk of change(s) in the marine ecosystem which are not potentially reversible over two or three decades. Management measures applied to toothfish stocks include TACs, closed areas/seasons, vessel/gear licensing and moratoriums. 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 the legally binding CCAMLR Conservation Measures (e.g. CM 41-09 (2005) (see CCAMLR, 2005), 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. All vessels report their catch to CCAMLR and the fishery is closed when the TAC is taken. Fishing effort is restricted to those CPs and vessels that have declared an intention to fish. 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 bycatch. A fishery may be closed when it reaches the TAC for the bycatch of particular species even if the TAC of the target species has not been reached. In addition, move-on rules have been applied in some exploratory fisheries to encourage vessels to improve gear selectivity and fishing methods. The rule requires vessels to monitor the bycatch of *Macrourus* spp. relative to that of *Dissostichus* spp. at ten-day intervals. If the catch of *Macrourus* spp. taken by a single vessel in any two ten-day periods in a single small-scale research spatial unit (SSR) exceeds 16% by weight of the vessel's catch of *Dissostichus* spp. then the vessel is required to cease fishing in that SSRU for the remainder of the season. Other bycatch reduction measures include a requirement for CPs to report annually on both the incidence of marine debris encountered in the CA and the resultant impact (including entanglements with marine mammals and seabirds) and mesh size limits for pelagic and bottom trawls (120 mm for *Dissostichus eleginoides)*. 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 (Conservation Measure 22-04). Regarding seabird mitigation methods, longlines are set at night, offal is not thrown overboard during setting, and streamer lines (tori lines) are deployed to minimize potentially damaging interactions with foraging seabirds (Kock, 2001). Also, the opening the toothfish season has been moved to a time when fewer birds are likely to be in the CA or proximal to fishing vessels.

Management measures are in place to limit damage to benthic ecosystems (CCAMLR, 2009). Bottom trawling is prohibited in the high seas of the CCAMLR convention area (and currently only takes place around Heard Island), as is all bottom fishing in waters shallower than 550 m around the entire Antarctic continent. Protected areas also exist. For example, fishing for all finfish is prohibited around the Antarctic Peninsula and the South Orkney Islands to protect finfish stocks that were depleted prior to the establishment of CCAMLR. CCAMLR has also introduced measure to minimise SAIs on VMEs by longliners (Conservation Measure 22-06). Vessels must mark fishing lines into line segments (a 1,000-hook section of line or a 1,200 m section of line, whichever is the shorter) and monitor all line segments for the number of VME indicator units[5]. If ≥10 VME indicator units are recovered in one line segment vessels must

[5] VME indicator unit' is 1 litre of designated VME indicator organisms that can be placed in a 10-litre container or 1kg of those organisms that do not fit into a 10-litre container

complete hauling any lines intersecting with the "risk area[6]"without delay and not set any further lines intersecting with the risk area. The vessel immediately communicates 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 and that all vessels must immediately cease setting any further lines intersecting with the risk area. The area remains closed for any fishery until reviewed and management actions are determined by CCAMLR.

A fairly standard suite of monitoring methods: demersal trawl surveys, commercial CPUE, scientific observer data are augmented with mark-recapture data from tagging. Only recently have tagging data become available and prior to this the assessment of toothfish, as for any deep-water species, was difficult. CCAMLR has a requirement that exploratory toothfish fisheries follow clearly defined experimental fishing plans. This approach strives to maximize 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. There is 100% observer coverage in all CCAMLR fisheries except krill, and this can comprise two observers per vessel facilitating 24hr observer coverage and allowing, for example, the comprehensive, although potentially time consuming VME monitoring protocol described above to be accomplished.

South-east Atlantic

The South-east Atlantic Fisheries Organisation (SEAFO) is the RFMO responsible for fisheries management in international waters. Fisheries in the SEAFO Convention Area 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 historically 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. Notwithstanding, there are considerable challenges in developing management measures for fisheries. Even though there has been some improvement in the quantity and quality of fisheries monitoring data and 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 higher catch levels are sustainable. Current landings restrictions comprise precautionary low TACs on deep-water red crab, Patagonian toothfish, orange roughy and alfonsino (SEAFO, 2010). The TAC is set to zero for the seriously depleted orange roughy stock in Sub-division B1 and to only 50 t for the remainder of the SEAFO CA to prevent a rapid increase in activity but to permit exploratory fishing. Other management measures in place include those applying to sharks, seabird bycatch mitigation, gillnetting and VMEs. As part of International Plan of Action to protect sharks (FAO, 1999), SEAFO has banned fisheries directed at deep-water sharks until information becomes available to identify sustainable harvesting levels (SEAFO, 2008b). Management measures to reduce the incidental

[6] An area where ≥10 VME indicator units are recovered within a single line segment. A Risk Area has a radius of 1 nm from the midpoint of the line segment from which the VME indicator units are recovered.

by-catch of seabirds in the SEAFO CA stipulate that all longline vessels fishing south of the parallel of latitude 30° south must carry and use bird-scaring lines (tori poles). Longlines must be set at night and the dumping of offal is prohibited while gear is being shot or set. Similar regulations (except allowing fishing during day-time) are also in place for trawlers. The use of gillnets is banned in the SEAFO CA to reduce the impact of abandoned, lost or otherwise discarded fishing gear (ALDFG) on habitats and biodiversity (ghost fishing). The only other fisheries that currently pose potential ALDFG problems are longline fisheries for Patagonian toothfish and trap fisheries for deep-water red crab. Management measures relating to the retrieval and reporting of ALDFG are in place.

Closed areas, bottom fishing regulations and encounter protocols are the main management tools affording protection to VMEs in the SEAFO CA. To account to some extent for the possible existence of chemosynthetic communities at depths >1000m and that the maximum potential depth of deep-water fishing is around 2000m, SEAFO has closed 11 areas to protect geographically discrete aggregations of seamounts penetrating into the upper 2000m 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. To address the UNGA Resolution on Sustainable Fisheries (A/RES/61/105), SEAFO has implemented an interim measure applying to the EBFA and NBFAs 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 (see above)) must be submitted to SEAFO for scrutiny. The SEAFO Scientific Committee then provides a recommendation to the SEAFO Commission which will then allow, prohibit or restrict bottom fishing activities, require specific mitigation measures or request changes in gear design and/or deployment and any other relevant requirements or restrictions to prevent SAIs to VMEs. Critically, exploratory fishing cannot proceed until permission is given by SEAFO (SEAFO, 2008b). VME encounter protocols apply to both EBFAs and NBFAs and these (including the VME thresholds) are very similar to those currently applied by NEAFC (see above) and the Northwest Atlantic Fisheries Organization (NAFO) (see below).

Fisheries are currently monitored using landings and effort data reported by CPs, VMS data and observer reports. Scientific observers are mandatory on SEAFO licensed vessels (100% coverage) fishing in the SEAFO CA. Historically there was no distinction between reported landings and catches, however discard information (discarding is allowed in the SEAFO CA) is now available for all vessels. Furthermore, fishing effort and biological (length, weight and sex ratio) data are now routinely recorded by observers. Maturity information is available from vessels fishing for toothfish. Data recorded by observers also includes bycatch information as well as incidental catches such as seabirds, turtles, marine mammals and VME indicator species (corals and sponges). Observers also report information on ALDFG. There is paucity of abundance data from commercial vessels and a total absence of regular structured surveys aimed at collecting biological and abundance data for use in assessments and for ecosystem monitoring. Abundance indices based on commercial catch-rate data are only available orange roughy and Patagonian toothfish.

Brazil

At the end of the 1990s, a government led scientific program was established to assess fishing potential in the Brazilian EEZ (REVIZEE Program; Anon., 2006). This program 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 (19°-34° S), where longliners, gillnetters, potters, and trawlers started fishing on the upper continental slope (250-500 m) mostly targeting monkfish (*Lophyus gastrophysus*), Argentine hake (*Merluccius hubbsi*), Brazilian codling (*Urophycis mystacea*), wreckfish (*Polyprion americanus*), Argentine short-fin squid (*Illex argentinus*), and deep-water crabs (*Chaceon* spp.). 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, 2009b).

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 in "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, 2009b). 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 are described in Table 1.

Table 1. Management elements of the deep-water fisheries in south-eastern and southern Brazil. Logbooks and VMS: 100% coverage. Observers: 100% cover-age. Exceptions are indicated in specific cases (from Perez et al, 2009b)

	Bottom longline	Double-rig trawl (shelf break)	Bottom trawl (upper slope)	Bottom trawl (lower slope)	Gillnet	Trap	Trap	Trap
Management plan	No	2008	2008	Now implementing	2008	2008	2005	Now implementing
Target and accessory species	*Polyprion americanus* (*); *Lopholatilus villarii*; *Pseudopercis numida*; *Epinephelus niveatus*; *Urophycis mystacea*; *Galeorhinus galeus*; *Genypterus brasiliensis*; *Helicolenus lahillei*	Multispecies (**)	*Urophycis mystacea*; *Merluccius hubbsi*; *Zenopsis conchifera*; *Illex argentinus*	*Aristaeopsis edwardsiana*; *Aristaeomorpha foliacea*; *Aristeus antillensis*	*Lophius gastrophysus*	*Chaceon notialis*	*Chaceon ramosae*	*Chaceon fenneri*
Fleet size	Unlimited	Unlimited among coastal pink-shrimp trawlers	17 (< 600 HP)	2	9	2	2	1
Area	Brazilian EEZ	18°20' S to the Southern limit of the Brazilian EEZ; 100-250 m depth	18°20' S to the Southern limit of the Brazilian EEZ; 250-500 m depth	18°20' S to 28°30'; 500-1000 m depth	21°' S to the Southern limit of the Brazilian EEZ; > 250 m depth	32° S to the Southern limit of the Brazilian EEZ; > 200 m depth	19° S to 30° S; > 500 m depth	NE coast > 200 m depth
Fishing season	Jan-Dec	March - May	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec
TAC	No	No	No	60 $ton.year^{-1}$. Individual (not-transferable) quotas of 7.5 $ton.trimester^{-1}$	1.500 $ton.year^{-1}$	735 $ton.\ year^{-1}$	420 $ton.year^{-1}$	No
Effort limits	No	No	No	No	Up to 1000 $nets.vessel^{-1}$ (maximum net length: 50 m)	No	Up to 900 $traps.vessel^{-1}$	
Minimum legal sizes	Yes, species-specific	No	No	No	No	No	No	No
Gear restrictions	No	Double-rig trawl	Stern trawl; minimum cod-end mesh size 90 mm stretched	Stern trawl; minimum cod-end mesh size 60 mm stretched	Minimum mesh size 280 mm stretched; nets tagged with vessel register	Mesh size 120 mm stretched; escape panels; traps tagged with vessel register	Mesh size 120 mm stretched; escape panels; traps tagged with vessel register	Mesh size 120 mm stretched; escape panels; traps tagged with vessel register
By-catch limits	No	*Lophius gastrophysus* (5%); other coastal species*** (15% of the total catch)	*Chaceon* spp. (5%); *Lophius gastrophysus* (5%); Aristeidae shrimps (1% of the total catch)	*Chaceon* spp. (15%); *Lophius gastrophysus* (5% of the total catch).	*Lopholatilus villari* (5%); *Chaceon* spp. (5% of the total catch)	No	No	No

The deep-water fishery developed off the 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 programs were implemented for the first time in order to enforce the legal obligations of the chartered fleet when the REVIZEE scientific exploration program was commissioned. Observer and VMS coverage applied to all vessels (100% coverage). Observers collected biological samples of catches and recorded biological data for the main target species. Information on bycatch species including incidental bycatches of cetaceans and seabirds was also recorded. Complementary data was 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 program (Cergole *et al.*, 2005; Costa *et al.*, 2005; Rossi-Wongtschowski *et al.*, 2006). However, much of the data collected and results arising (exploitable biomass estimates using swept area raising methods), were only available for the main largely upper slope demersal species, monkfish and hake for example.

North-west Atlantic

NAFO monitors and manages a wide range of species in the NAFO RA but here, as for NEAFC above, we focus on those currently defined in EC Regulations as deep-water-species which are roundnose grenadier (*Coryphaenoides rupestris*) in 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 area is TACs and quotas. An unknown proportion of the reported commercial catches of roundnose grenadier from Sub-areas 0 and 1 (Davis Strait) is roughhead grenadier. Analytical assessments are not carried out and consequently the current level of exploitation is not known. The biomass of roundnose grenadier is indicated by available abundance data is considered to be at a very low level. Scientific advice since 1996 has been that there should be no directed fishing and that catches should be restricted to bycatches in fisheries targeting other species. There are no reference points available for this stock. Roughhead grenadier is taken as by catch in the Greenland halibut trawl fishery, mainly in NAFO Divisions 3LMN. Advice on stock status is currently based on qualitative assessment of trends in abundance indices from fisheries-independent surveys. These surveys indicate that the total biomass of roughhead grenadier exhibits a continuing increasing trend and remains at the high level observed in recent years. Biological reference points are not currently used. The majority of catches comprise immature fish. The only management regulation applying to this species is a general groundfish regulation requiring the use of a minimum 130 mm mesh size.

Regarding bycatch regulations in the NAFO RA, vessels of a CP must limit their retained bycatch 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 utilized, the bycatch of the species concerned must be ≤1250 kg or 5%, whichever is the greater. If the percentage of bycatch in any one haul exceeds the relevant limit the vessel must immediately move a minimum of 10 nm 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 bycatch 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 for 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.

Measures are place to regulate the finning of sharks. CPs report data for all catches of sharks (all species including deep-water sharks), including available historical data. Fishing vessels must fully utilize their entire catches of sharks. Full utilization is defined as retention by the fishing vessel of all parts of the shark except head, guts and skins, to the point of first landing. Vessels must not have onboard shark fins that total more than 5% of the weight of sharks onboard, up to the first point of landing. In fisheries that are not directed at sharks, CPs shall encourage the release of live sharks, especially juveniles, to the extent possible, that are caught as bycatches and are not used for food and/or subsistence.

NAFO has been a front-runner in introducing measures to regulate and monitor bottom fisheries in response to UNGA Resolution 61/105 on deep-water high seas fisheries (2007) and the FAO International Guidelines for the Management of Deep-water Fisheries in the High Seas (2009). A bottom fishing "footprint" has been developed for the NAFO RA using very similar criteria to those subsequently applied by NEAFC and SEAFO. General regulations on bottom fishing, including VME encounter protocols and thresholds, are currently almost identical to those now used by NEAFC and SEAFO. Regulations relating to exploratory fishing (defined as bottom fishing activities in NFBAs or with bottom gear not previously used in the area concerned), are almost 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 6 closures applying to seamounts, introduced in accordance with the PA to protect likely locations of VMEs and associated (but mostly unknown) fish species, and 12 areas mostly around the Flemish Cap to protect corals and sponges, the locations of which are based on available scientific information.

In NAFO there are two types of observers: NAFO observers who only collect fishing and compliance information and are regulated by the NAFO Observer Program (100% coverage) and national scientific observers that collect fisheries and biological information and carry out biological sampling. The coverage of the national observers is not the same for all countries and years and for the EU countries is funded under the DCF (Spain and Portugal circa 15% of trips are covered). 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. The availability of these data and time-series catch at age data back to 1992 has facilitated the exploration of a range of assessment methods, however only the qualitative assessment based on abundance indices from the Canadian autumn survey and the EU (Spain) survey in Div. 3NO are used to evaluate stock status. Although these surveys do not cover the entire distribution of the stock they are considered to be the best survey information to monitor trends in resource status because their depth coverage is down to 1500 m. All vessels catching fish/shrimp species under NAFO's jurisdiction must have VMS. Fisheries for crabs and tuna, are not required to be monitored under the NAFO scheme. Position reports are transmitted every hour, and various other data on catch. VMS data are available for scientific analysis but only in summary form. The NAFO Secretariat carries out post processing/GIS work of VMS data to plot vessel fishing activity and fishing effort. Owing to the difficulty in identifying gear and associating catch composition from VMS reports, this information is of limited scientific use at present. Efforts are being made to collect more comprehensive information that will make the data more useful for stock monitoring.

Mediterranean Sea

The Mediterranean Sea is a semi-enclosed sea characterized by a continental shelf frequently reduced to a narrow coastal fringe and covering less than 30% of the total sea area, bathyal grounds accounting for about 60% of the whole basin, and the remainder mostly comprises an abyssal plain (Sardà et al., 2004; Cartes et al., 2004a). 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 waters 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 black-spot seabream (*Pagellus bogaraveo*), wreckfish and the deep-water six-gilled shark *Hexanchus griseus* and gillnetters targeting hake and red black-spot seabream. Some of these fisheries are locally collapsed (Mytilineou and Machias, 2007). Some bottom trawl fisheries extend to a depth of almost 1000 m. Deep-water fishing is carried out due to the narrowness of the shelf that brings the deep depths within a few miles of the coast and due to the high demand for marine products which are traditional in the Mediterranean diet. Unlike in 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 of 40 mm square or 50 mm diamond mesh trawl cod ends and a general 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 Advisory Committee as a sufficient management measure to regulate the Mediterranean fisheries, when accompanied by additional measures such as landing sizes, gear configuration, no-take zones (GFCM/SAC, 2010). However, failure to quantify the real effort exerted places managers in a dilemma if this is actually the best tool to proceed in the future. Minimum landing sizes are in place for red (blackspot) seabream, wreckfish, Norway lobster and rose shrimp.

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 1967/2006). Furthermore, since January 2006, three ecologically important deep-water areas have been protected off the waters of Italy (cold-water coral (mainly *Lophelia pertusa)* off Capo Santa Maria di Leuca, Cyprus (the Eratosthenes seamount which hosts rare coral species) and Egypt (a chemosynthetic-based ecosystem offshore in the Nile Delta. Bottom trawling is prohibited in these areas. Since 2002, all Mediterranean EU MSs are mandated under the DCF to collect and report data on a list of species including deep-water species such as the red shrimps *Aristaeomorpha foliacea* and *Aristeus antennatus,* Norway lobster and red (blackspot) seabream. These data are extracted either from the vessel logbooks or collected by on board observers. In addition, fisheries-independent surveys are deployed to monitor the status of marine resources. MEDITS (MEDIterranean Trawl Survey) is a multi-annual bottom trawl survey initiated in 1994 involving all Mediterranean EU MSs. Survey coverage is stratified by depth: 0-50m, 50-100m, 100-200m, 200-500m, 500-800 m (Bertrand *et al.*, 2002). From 2000, MEDITS was included in the DCF. Furthermore, a number of short-term surveys, dedicated to the investigation of marine life in the marine domains have been carried out. These surveys significantly contribute to the monitoring of fisheries and environment together with other fisheries monitoring and research projects. Only a few species are subject to quantitative assessments in the Mediterranean Sea. Under the DCF scheme for 2011-2013 assessment will be mandatory for some species including hake, Norway Lobster, rose shrimp and red shrimp.

Discussion

The aim of this paper is evaluate the strengths and weaknesses of the management and monitoring of deep-water fisheries, stocks and ecosystems in various areas of the world, with the objective of informing the EU FW7 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 the NE Atlantic. In discussing the strengths and weaknesses of the management and monitoring regimes described it is useful to be aware of the outcomes from consultations with stakeholders in the deep-water fishing industry in the NE Atlantic and the requirements of EU regulations and developing policy that likely impact on deep-water fisheries in the NE Atlantic. So these are briefly discussed before developing a broader discussion of which also takes into account strengths and weaknesses identified in DEEPFISHMAN Case Study stocks/fisheries (which for brevity cannot be fully described in this paper).

Deep-water fisheries in the NE Atlantic are mostly data-poor, often with only landings, commercial LPUE, biological data and information of life history, length and maturity compositions but rarely fisheries-independent survey data available. Furthermore time-series data are often short. Many deep-water species are also difficult to age or age estimates are not validated. As a consequence assessments of deep-water stocks have been mostly exploratory (Large *et al.*, 2003; ICES, 2008). However, fishers possess knowledge and often data which can contribute to assessments of stock status (Neis *et al.*, 1999). The challenge is to access and formulate this knowledge and data in a reliable and scientifically useful way. Large *et al.* (2010) used fishers and biologists knowledge obtained with a questionnaire survey in addition to other information to map spawning areas for blue ling. Fishers also have quantitative information on fish abundance as many keep tallybooks with haul-by-haul landings information. If good collaboration between fishers and scientists can be established these data can be very useful (Dobby *et al.*, 2008; Lorance *et al.*, 2010; Lorance *et al* submitted). In the DEEPFISHMAN project, two stakeholder workshops have been conducted thus far. A group of a priori identified stakeholders was invited to the first in Brussels in June 2009 but due to problems regarding stakeholder availability only French fishers attended. Two major outcomes were the identification of the stakeholder community (Burkardt and Ponds, 2009) and a SWOT (Strengths, Weaknesses, Opportunities and Threats) (Horn et al, 1994) analysis of the management regimes and fisheries assessments methods currently applied in some deep-water fisheries around the world (Table 2).

Table 2. SWOT (Strengths, Weaknesses, Opportunities and Threats) of current management measures applied to deep-water fisheries (from Pascal *et al*, sub.)

Management measures	Strengths	Weaknesses	Opportunities	Threats
TAC	Simple and easy to allocate; simple to monitor and control; allow to establish track record; effective for small fleet of large fishing vessels	Implementation stock by stock; relationship between F and catches; efficiency linked to effort management; account of discards and bycatch; discarding; monitoring and control cost	Can be improved by taking discards into account; can be improved with better fishery data	Total allowable landings, not TAC; unrealistic if based on unrealistic assessment; does not allow for changes in fish size distribution
Effort limitation (days at sea, days fishing)	Adapted for mono-specific fisheries and on a single-gear basis; easy to monitor and control; potentially good as the relationship between fishing mortality (F) and effort is believe to be mostly linear	Allocation by fishery and métier; effort is a vector several inputs; monitoring for passive gears; effort track records; control; difference between logbook effort units and regulation; technical creep	Managed at international (fishery) rather than national level could lead to simplification (unification); Could be controlled; Controls fleet capacity and therefore profitability.	Technical creep
Control Measures (a) Licensing (b) Port State Control, designated ports, VMS (c) Enforcement observers	Easy monitoring and control; (a) caps the fishery (b) transparent (c) collection of fisheries and biological data; validates catch data accuracy	(a) Relies on a reference level; dependent on initial allocations (b) Cost (c) Cost; Conflicts between scientific and enforcement duties	(b) Improvement of fishery data; industry-led improves governance; RAC-based management; EU-led enforcement	(b) Non-compliance; IUU
4. Technical measures (gear, MLS(1), mesh size, escapement devices	Easy to monitor and control	Not adapted to shape and size of deep species; high escapees mortality	Regionalisation, not central control; Shark excluding device	Lack of implementation; Easy to mitigate effects (2)
5.Area closures (a) Spatial aspect (b) Temporal aspect	Protection of habitat, spawning aggregation, nurseries; Easy monitoring and control; more adaptive for fishers than technical measures	Impact on other fisheries; redistribution of effort; lost knowledge of dynamics in area; definition of area and gear allowed	Effective in real-time (adaptive); (a) opportunities for sentinel fisheries. (b) closure time can be well defined	Appropriateness may change over time; Non-compliance; (a) definition of closure and re-opening conditions

(1) Minimum landing size
(2) Through e.g. a change in mesh size may be counter-balanced by a change in trawl rigging

To supplement the outcomes from the workshop, a questionnaire was distributed to obtain opinions and management preferences from staheholders. Forty-four questionnaires were returned from stakeholders in the NAFO Greenland halibut fishery, the mixed trawl fishery to the west of the British Isles and three artisanal fisheries (longline fishery for black scabbardfish off Portugal and red seabream fisheries in Greek Ionian waters and in the Strait of Gibraltar). Respondents seemed overall dissatisfied with current fisheries management, none responding that management tools should not be changed. Around 50% of responses suggested that TACs, effort control, licenses, closures and gears bans should be changed to varying degrees ranging from radical to minor adjustments. Changes in licensing, spatial/seasonal closures, gear ban and control of recreational fishing were favoured in the two red seabream fisheries together with changes in TAC in the strait of Gibraltar fishery. The majority of respondents considered licensing, effort restrictions, spatial/seasonal closures and gear bans suitable to protect the ecosystem. Control of recreational fisheries also highlighted for the red seabream fisheries where juveniles are seasonally coastal. Technical measures thought to be most suitable for trawl and mixed fisheries were reduction of bycatch/discards to an agreed level and bycatch reduction devices. Respondents from artisanal fisheries suggested mostly banning of certain fishing practices, spatial and/or temporal closures, by-catch restriction measures and reduction devices.

A second stakeholder workshop, held in Lisbon in December 2009, was attended by 21 stakeholders including Spanish and Portuguese fishers and catching sector representatives, Portuguese national and regional administration and government representatives, international and regional NGO representatives and external scientists. Cognitive maps (Özesmi and Özesmi, 2003; Prigent *et al*., 2008) were used to solicite stakeholder views on driving factors and regional management issues for the four deep-water fisheries they were involved in: black scabbardfish fisheries around Madeira and off mainland Portugal, NAFO Greenland halibut and red seabream around the Azores. Considering the direct or indirect impact of each variable on the fishery or the exploited stock, a number of measures that might positively influence the fishery were collated (Table 3). The management measures differ somewhat between stocks, though spatial closures and gear selectivity were recurrent themes.

Table 3. Potential management levers derived from cognitive maps drawn for stocks by stakeholder groups. BSF: black scabbardfish; GHL: Greenland halibut; RSB: red seabream (from Pascal *et al*, submitted).

Stock	Likely management levers for improving fishery conditions
BSF Madeira	knowledge of life cycle (increase), temporal closure (during spawning season), sequential fishing (modify juveniles fished elsewhere), prefer nearby fishing grounds, contaminants (reduce), allow for regional management measures
BSF Portugal	bycatch in all fisheries (reduce), subsidies (reduce), spatial closure, fleet size
GHL NAFO	crew availability (increase), imports (reduce)
RSB Azores	spatial closure (juveniles), gear selectivity (hook size)

The EU management of deep-sea fish stocks in the NE Atlantic was reviewed by the EC in 2007 in a discussion document circulated to MSs and stakeholders (EC Com, 2007). It was noted that most deep-water fisheries catch a mixture of species, and that only one or two of them are deliberately targeted. Some deep-water species with ranges that extend to the slopes of the continental shelf, such as ling and tusk, may also be taken as by-catches in shallow-water demersal fisheries. It was argued that for TACs to be effective in mixed fisheries they should be fixed relative to one another at levels that minimise discards and bycatches. Moreover, of the 48 species listed in Annexes I and II of Regulation 2347/2002, TACs are set for only 9 of them. However it was stated that most of the other species are taken too sporadically or in quantities too small to make it feasible to set TACs. The Commission was of the view that the restricted number of species managed by TACs had encouraged misreporting. Another problem of trying to manage deep-water stocks using TACs is that little is known about the geographical stock structure of species and TACs are therefore often set over large management areas. Notwithstanding, the Commission was of the view that TACs have probably had some effect in curbing F on some of the main targeted species. However, they observed that for long-term management they must be complemented with other measures, particularly the restriction of fishing effort. It was argued that capacity ceilings (EC Regulation 2347/2002) probably have had little effect on limiting the expansion of fisheries because of two reasons: (i) they included vessels that are not targeting deep-water species but are only taking them as a bycatch in other fisheries and (ii) the ceilings were set unrealistically high because the qualifying criteria were set too loosely. The Commission argued that these shortcomings had undermined subsequent imposed effort reductions (EC Regulations 27/2005 and 51/2006). It was noted that it was unclear as to whether effort reductions were sufficient to comply with the NEAFC requirement for a 30% reduction in deep-water effort in the NEAFC RA. Regarding the submission of Sampling Plans for scientific sampling and observer programmes (a requirement of EC Regulation 2347/2002), the Commission reported that initial compliance had been poor and had only improved following further requests. It was identified that a major shortcoming is that there is no clearly defined sampling strategy insofar as even if the requirement to implement a Sampling Plan is fulfilled the quality of the data may be poor or difficult to combine with those from other MSs. Other conclusions included the need for more rigorous monitoring and control procedures and the need for greater emphasis on the collection of data to assess the ecosystem impacts of deep-sea fisheries, both from commercial vessels and from co-ordinated research vessel surveys.

The EU is currently undertaking a review of the deep-sea access regime (EC Regulation No. 2347/2002) and a consultation and reflection document was circulated to stakeholders in December 2009 (DG MARE/C2.2009). 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 access 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, bycatches, ghost fishing, definition of fleets and control and monitoring. Interestingly, concerns regarding discards were limited to the collection and availability of data and the need to integrate these into stock assessments. Regarding bycatches, a number of initiatives were put forward for discussion including the inclusion of certain species into Annex 1 of the access Regime, setting of bycatch 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.

Before discussing the strengths and weakness of the management and monitoring regimes applied in the areas studied in this paper, there is a need to be aware of the main policy drivers impacting on deep-water fisheries in the NE Atlantic over and above, and in some cases operating synergistically, with those already identified earlier (UNGA Resolution 61/10 (2007), the FAO International Guidelines for the Management of DWFs in the High Sea (2009) and the EU MSFD). These include (i) the requirement of the World Summit on Sustainable Development (WSSD, 2002) 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 confirming adherence to this and identifying that MSY is characterized by a level of F that will, on average, result in a stock size that produces the MSY (EC COM, 2006); (ii) developing EU policy to reduce unwanted by-catches and eliminate discards in European fisheries COM (March 2007; (iii) the role of the Common Fisheries Policy (CFP) in implementing an ecosystem approach to marine management (EC COM, 2008), defined by the Commission as one that "strives to balance diverse social objectives, by taking into account knowledge and uncertainty about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries". The MSFD forms the basis for implementing an EA to the marine environment; (iv) the Green Paper on Reform of the CFP (EC, April 2009) which amongst other things argues that the fishing industry can be given more responsibility through self-management which would be results-based. Public authorities would set the limits within which the industry must operate, such as a maximum catch or maximum by-catch of young fish, and then give industry the authority to develop the best solutions economically and technically, subject to central auditing of outcomes. This would have to be linked to a reversal of the burden of proof, 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 NE Atlantic.

Below follows a discussion of the strengths and weakness of the management and monitoring regimes applied in the areas/fisheries studied in this paper, which also takes into account additional information on strengths and weakness available from DEEPFISHMAN Case Study stocks/fisheries.

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 all orange roughy fisheries in Australia, except the Cascade Plateau fishery, 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 B_{MSY} and B_{MEY} for decades. B_{MEY} is a more conservative target than B_{MSY} for any fish stock and is particularly true for orange roughy stocks where B_{MSY} is estimated to 30% B_0 in New Zealand and B_{MEY} is estimated to be 48-50% B_0 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% B_0 and 20% B_0) than for the New Zealand stocks (20% B_0 and 10% B_0). 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, 2007b). 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 every kg of 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 trips carrying an observer mandated by the management authority. Discarding practices are likely influenced, although to an unknown extent, by whether observers are on board 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 is monitored and incorporated in the scientific process delivered by the RAGs. This could be considered a strength compared to the New Zealand approach. 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. While cost-effectiveness is a recognised merit, a risk of not monitoring and managing stocks on a regular basis may be to fail 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 NE Atlantic where the costs of monitoring surveys (if introduced) are likely to be high due to the large areas involved.

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In the *Antarctic*, perhaps the strongest attribute of CCAMLR's management of deep-water stocks and 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 bycatch species has been reached. This presumably reduces discarding which is allowed. CCAMLR is also advanced in applying move-on rules if bycatch thresholds are exceeded. CCAMLR's deployment of seabird mitigation methods has been applauded and copied by other RFMO 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 although much praised 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 24hr coverage of fishing activities and facilitating the comprehensive VME monitoring scheme in place. Unlike almost all deep-water fish species, toothfish can be tagged using conventional tagging methods allowing mark-recapture data to be used in assessments. In addition, and feeding into stock assessments, abundance indices from surveys and commercial and catch-at-length and age data are available for most areas. 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 South Georgia Toothfish (certified 2004, re-certified with no conditions 2009) and Ross Sea Toothfish (under recommendation for certification, as of February 2010).

In the *south-east Atlantic,* deep-water fishing in international waters was unregulated until the SEAFO convention came into force in 2003. Fisheries in the SEAFO area are extremely data-poor as there is a sparsity of time series abundance data and a total lack of fisheries independent data. Given this, SEAFO has made good use of the PA and 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 at NAFO and NEAFC, a fishing footprint has not been finalized 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 finalized, there are mechanisms in place to prevent new fisheries developing until an impact assessment has been evaluated and approved by SEAFO. The recent revision of closed areas takes account of three additional factors not previously addressed by SEAFO (or other RFMOs): (i) the areas take into account seamounts penetrating into depths

<2000m and therefore potentially afford protection to any chemosynthetic communities that may exist; (ii) all fishing for SEAFO resources is prohibited including semi-pelagic trawling for species such as alfonsino which may impact on benthic communities; and (iii) the spatial distribution of closed areas takes into account information of biogeographical provinces defined by Longhurst (Reference). 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. A trawl fishery for orange roughy inside the Namibian EEZ (a DEEPFISHMAN Case Study) commenced in 1994 but since 1997 catches and CPUE steadily declined. The fishery has remained closed since 2008. The stock is managed by TAC and scientific advice, when the fishery was open, was based on extensive monitoring information from trawl and acoustic surveys and observers. 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.

The development of the deep-water fishery off *Brazil* is a useful example from which much can be learned regarding the application of monitoring and management frameworks. When the chartering program 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*., (2009b) 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. Given the above, there would appear to have been a strong case on commencement of the fisheries for invoking the PA and the application of 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 program 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 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.

In the *North-west Atlantic,* NAFO has an extensive management and monitoring regime in place**.** However, there is a heavy reliance on TACs and quotas and little use of other forms of management e.g. fishing effort controls and rights-based management. There is also no recovery plan in place for roundnose grenadier which is seriously depleted. There is generally 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. Coverage by scientific observers is considerably lower and it is uncertain as whether this impacts on the range and quality of biological information available. In contrast to EU and NEAFC regulations, there are robust bycatch regulations in place and an agreed definition of directed fishing at the haul 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. Critically, there is no mandatory impact assessment required before exploratory fisheries can commence. Greenland halibut in NAFO Subarea 2 and Divisions 3KLMNO is a DEEPFISHMAN Case Study and while this species is not classified a deep-water species in the EU Access Regime, it is found and fished extensively in the deep water (highest densities occurring at about 500-1200 m) and consequently the strengths and weaknesses of the management and monitoring of this stock are relevant to the discussion here. Despite extensive scientific research of this species in the North Atlantic and, particularly in the NAFO Area, the stock structure of this species remains uncertain. Notwithstanding, this species is monitored and managed as separate spatial components, however the biological interaction between these different management units is uncertain and this may impact on stock assessments. Spawning and recruitment processes and dynamics are poorly understood and there are also some aging problems for this species. The latest studies show that ages are under-estimated, particularly for the older ages. It is not known how these ageing problems impact on stock assessments. Regarding fisheries-independent data, a single survey series which covers the entire stock in the NAFO area is not available.

The management of deep-water fisheries in the *Mediterranean Sea* differs fundamentally to 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. Red (blackspot) seabream in the eastern Mediterranean is a designated DEEEPFISHMAN Case Study and in common with many other deep-water species is regarded as data-poor in that there is paucity of data of effort, landings, discards and revenues. Also biological information regarding spawning period, size at maturity, feeding habits, preferred habitat and migration is sparse. 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. To date, no attempts have been made to assess stock status. 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 largely confined technical measures such as minimum landing size and mesh size.

In the *North-east Atlantic*, although NEAFC and the EU has in recent years made considerable progress in the management and monitoring of deep-water stocks and fisheries, there remains a number of concerns that have not been addressed in recent EC reviews: (i) there is a need to evaluate the appropriateness of the orange roughy protection boxes now that the EU TAC is zero; (ii) the number of species managed by TACs is quite small and there may be a need to include other deep-water species to deter mis-reporting and also to prevent the rapid, development of new fisheries or increased landings; (iii) EU Regulations concerning gillnet soak-time and net length are not based on fisheries data or on ICES advice and there may be a need to evaluate if they are fit for purpose; (iv) regarding the protection areas introduced for blue ling, there is a need to know how effective they have been in reducing effort and catches 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); (v) the present deep-sea access regime places no obligation on deep-water fishers in EU waters to mitigate encounters with VMEs that are currently not protected by closed areas. Furthermore, there are no reporting protocols in place; (vi) there is an overlap between the access regime and the new DCF regarding sampling and observer requirements and this needs to be reviewed; and (vii) perhaps most importantly of all, there is a paucity of dedicated fisheries-independent 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 of deep-water species of significant interest to EU MSs. Regarding the DCF in more detail, the segmentation applied is at the level of gear type, consequently it is not possible to quantify the economic variables for the deep-water fleets. Separate analyses that are specific to these fisheries cannot be carried out. This is important as economic considerations might be quite different in the deep-water sector compared to other fleets because of factors such as higher fuel costs, larger distances to fishing grounds etc. In contrast, the metier approach to biological sampling and the new concurrent sampling scheme is a considerable improvement over the old DCR as it will facilitate the provision of fisheries and biological data directly relevant to deep-water metiers. Also, under the new DCF, VMS data has to be linked to logbook data and this will contribute greatly to the development of a deep-water fishing footprint. DEEPFISHMAN Case Study Stocks/fisheries occurring in EU waters comprise orange roughy in ICES Sub-areas VI and VII, blue ling in Vb, VI, VII and XIIb, the French mixed demersal trawl fishery in Vb, VI and VII, red (blackspot) seabream in the Strait of Gibraltar and Bay of Biscay; and the Portuguese fishery for black scabbardfish in Sub-area IX. Management weaknesses include a lack of (i) explicit recovery plans for blue ling, orange roughy and red 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.Weaknesses in the monitoring of most of these 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; (iii) length and age data for black scabbardfish over its likely range of spatial distribution.

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. 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. The current NEAFC regulations for orange roughy (annual catches of any CP shall not exceed 150 t) are not in accordance with ICES advice which is for no directed fishing. MSY for one of the largest stocks thus far identified in the NE Atlantic (ICES Sub-area VI) is probably <100 t (Large, Working Paper submitted to ICES WGDEEP, 2002), so potential current cumulative catches across CPs are very likely unsustainable. A further concern is that NEAFC, unlike the EC in EU waters, has not introduced closed/protection areas for spawning aggregations of blue ling known to exist in the NEAFC RA in ICES sub-Division VIb and Division Vb. 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 (noting that the EU has anyway objected to the ban and opted out). In the NEAFC RA, 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. Critically, 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. Regarding VME encounter protocols, the VME threshold values (80 kg live corals and 800 kg sponge) currently used were estimated for trawlers but are applied to all fisheries and are not optimised for different gears. A further concern is that the retention efficiency of each gear type is not considered and if this is low, fishing activity with apparently low bycatches of VME indicator species may still have considerable SAIs on VMEs (Auster *et al.*, in review). This concern also applies to the thresholds adopted by other RFMOs. Oeanic redfish (*Sebastes mentella*) in the north-east Atlantic is a DEEPFISHMAN Case Study, and while this species is not classified 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) and consequently the strengths and weaknesses of the management and monitoring of this stock are relevant to the discussion here. 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 TACs at the international level within NEAFC. From a monitoring standpoint, 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.

Most of the monitoring and management regimes described in this paper, including the north-east Atlantic, have in addition four major weaknesses: (i) the there is lack of an agreed definition of deep-water species and deep-water fishing; (ii) only rarely are regulations in place to collect socio-economic data; (iii) most have no mechanisms in place to monitor pollutants and contaminants in deep-water fish, shellfish and other marine organisms; and (iv) there is little monitoring of ecosystem composition, health and productivity. In practice, two depths are used regularly as the limit for deep water, >200 m by the FAO and >400 m by ICES. Justification for a depth limit may be sought through understanding the bathymetry. The major difference between deep and shallow environments is found at the offshore edge of the shallow continental shelf, where the seafloor transitions to the continental slope at the continental shelf break and is characterized by a markedly increased slope toward the deep ocean bottom. In oceanographic terms it is the informal common practice to consider the difference between shallow and deep oceans to be at the shelf break and to think of this as at 200 m. However, none of the environmental arguments provides a strong rationale for either 200 or 400 m as a set depth for the upper boundary. 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 and the FAO use of the limit between shallow and deep water. The definition of deep-water fish and crustacean species is a complex issue and is not driven solely by the salient characteristics or definition of the deep-water environment. Many deep-water marine living resources have biological features that are driven by the characteristics of the deep-water environment. These include slow growth and long life expectancies. However, not all deep-water resources exhibit these features. For example, black scabbardfish and alfonsino, both considered to be deep-water species in that they are found mainly at depths 400 to 600 m and 200 m to 1700m respectively, are relatively fast growing and are not lived (maximum age 12-14 and 15-20 years). Consequently deep-water marine living resources cannot be defined solely on the basis of their life history characteristics. The use of depth distribution data in a definition is also problematic because many fish species found on the continental shelf are also found in deep water (whether defined as depths below 200 or 400 m). In the north-east Atlantic these include ling, tusk, anglerfish (*Lophius* spp.), deep-water redfish (*Sebastes* spp.) and Greenland halibut (Gordon *et al*., 2003). To further complicate the issue, the species addressed by the ICES Working Group on the biology and Assessment of Deep-sea Fisheries Resources (ICES WGDEEP) are somewhat eclectic and include long-lived, slow-growing species found at depths greater than 600 m, orange roughy for example, but also ling and tusk. A suitable definition may be those species where most of the biomass is at depths below 200 m and this may provide a working definition for revising the species listed in the Access Regime. Given the problems defining deep-water marine living resources it is not surprising that scientists and fisheries managers have encountered problems developing criteria to differentiate deep-water fisheries from other types of fisheries. The definition of deep-sea fisheries is crucial both to DEEPFISHMAN aims and to proposed revisions of EU Deep-Sea Access Regime. One approach that may help address this issue is to carry out a principal components analysis on haul by haul catch composition data for a DEEPFISHMAN case study fleet that participates in a range of fisheries. From these outputs it may possible to develop simple metrics that could enable managers to differentiate between different types of fisheries. A suitable DEEPFISHMAN Case Study would be the French mixed demersal trawl fleet fishing to the west of the British Isles, as this fleet prosecutes a directed deep-water fishery for blue ling, a mixed demersal fishery for deep-water species and a directed fishery on the continental slope for saithe (*Pollachius virens*). Another approach would be to define directed deep-water fishing as those sets where the catch of deep-water species exceeds 50% of the total catch (assuming that catch reporting is set-by-set).

Regarding socio-economic data, in almost all of the management regimes described above socio-economic factors are accounted for at the political level within management bodies. Consequently, there is rarely any routine collection of socio-economic data, development of socio-economic fleet profiles or scientific evaluation of the socio-economic impacts of management decisions. However, this is the case for most fisheries around the world, not just deep-water fisheries.

There is a paucity of monitoring of the health status of deep-water fish species. A clear gap in knowledge is of the presence and effect of viral, bacteriological, fungal and protistan pathogens in deep-water fish. This is a significant area that requires study since these pathogens are normally associated with acute infections and frequently lead to physiological impairment, debilitation and death. Without collecting baseline information it is impossible to estimate their effect on individuals and populations. It has been demonstrated that parasites can be of significant use as stock indicators in exploited stocks in shallow seas. There is excellent potential for developing this ability based on parasite fauna, provided material can be obtained. This will probably not require extensive annual monitoring since available evidence from previous investigations in shallow water stocks suggests that patterns are relatively stable over several years extending to decades and possibly further. There remains a general lack of information on contaminant burdens over much of the globe with some areas more extensively studied. Although contaminant burdens are generally not high enough for human health concern, it has been established that the deep sea fauna has higher burdens of organochlorine compounds than in 'surface' living species (Froeschecis *et al*., 2000). Also heavy metal burdens can be above EU limits and vary considerably between species. There are currently no data on toxicopathic effects of these substances in deep-water fish.

Finally, there is little monitoring of ecosystem composition, health and productivity in most deep-water regions including the north-east Atlantic, and this mostly stems from the paucity of extensive internationally coordinated fisheries-independent surveys which can be used as a platform for such studies.

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