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Agriculture and Rural Development

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DATA-DEFICIENT FISHERIES IN EU WATERS

STUDY

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DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

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STUDY

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Abstract

The fundamental requirement for stock assessments is to provide a rational basis for the management of fishery resources. Data-deficient fisheries present a challenge as they only provide a limited basis for management decisions. The nature and extent of data-deficient fisheries in European waters is presented and the assessment and management procedures for data-deficient fisheries in European waters evaluated.

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LIST OF ABBREVIATIONS

ABC	Allowable Biological Catch
ACL	Annual Catch Limit
B	Spawning Stock Biomass
CPUE	Catch Per Unit Effort
DCF	Data Collection Framework
DLS	Data Limited Stocks
EEZ	Exclusive Economic Zone
F	Fishing Mortality
GFCM	General Fisheries Commission for the Mediterranean
GSA	Geographical Sub-Area
HSP	Harvest Strategy Policy
HSS	Harvest Strategy Statement
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IUU	Illegal, unregulated and unreported
MSE	Management Strategy Evaluation
MSY	Maximum Sustainable Yield
NAFO	Northwest Atlantic Fisheries Organisation
OFL	Overfishing Limit
RAC	Regional Advisory Council
SSB	Spawning Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries
VPA	Virtual Population Analysis

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EXECUTIVE SUMMARY

The underlying purpose of fish stock assessment is to enable informed rational resource management. In accordance with European fisheries policy objectives, stock assessments are required to provide information on the status of stocks in relation to objectives maximum sustainable yield (MSY). The most rigorous, robust and informative types of stock assessment are data intensive. Data-deficient fisheries therefore present a challenge to managers as there is more uncertainty associated with results and in many cases stock status and fishing mortality rates can not be directly evaluated in relation to policy objectives.

Data-deficient fisheries, hereby defined as fisheries on stocks that are not fully evaluated in relation to primary stock status and fishing mortality management reference points, are a significant feature of European fisheries. Approximately half of all landings from European Atlantic and Baltic waters under exclusive European management are taken from data-deficient stocks. In Mediterranean and Black Sea waters managed by the General Fishery Commission for the Mediterranean approximately 80% of landings come from data-deficient stocks.

Fisheries can be considered 'data-deficient' for a number of reasons. This can be due to limited data collection and reporting, but can also be due to limited biological information about the stock or limited resources to develop and apply appropriate assessment models. Although limited data collection and reporting is not the only reason that stocks are considered data-deficient it is a notable factor; no Member States are entirely compliant with the data reporting requirements of the European fisheries Data Collection Framework.

It is an over simplification to just consider stocks as either 'data-rich' or 'data-deficient'. In actuality there is a gradient of data availability from very data-rich stocks to truly 'data-poor' stocks. Acknowledging the gradient in information and data availability allows a range of different methods to be applied to make the maximum use of the data that is available for each stock.

A range of stock assessment methods and management procedures are available for application to data deficient fisheries. For stocks with minor data deficiencies, stocks can be assessed in relation to proxies for primary MSY related reference points. For data-poor stocks with significant data deficiencies it is not possible to assess stocks in relation to reference points related to MSY, although stocks can be assessed in relation to pragmatic reference points for maintaining sustainable yields.

Developing data-deficient assessment methods on a scientific basis proceeds hand-in-hand with management decisions on acceptable reference points and management procedures that can be applied in situations where stocks can not be formally evaluated in relation to the primary reference points associated with policy objectives.

Data-deficient stock assessments and management advisory procedures applied by ICES within European Atlantic and Baltic waters have recently undergone significant development with the introduction of the ICES data limited stock approach in 2012. Prior to the introduction of the data limited stocks approach data-deficient stocks were managed on a broadly ad hoc basis. The new data limited stocks approach provides a structured framework for assessing and advising on stock status across a range of data categories.

The new ICES data limited stock approach and associated data-deficient assessment methods, reference points and management procedures are broadly consistent with international best practice for assessing and managing data-deficient fisheries. However, not all of the methods have been fully evaluated, and the framework as a whole has not been evaluated to ensure a consistent approach to risk and precaution across the data categories.

Within the Mediterranean and Black Sea a more limited range of data-deficient stock assessment procedures are applied and no formal data-deficient management procedures have been defined.

When considering ways to address the challenge of managing data-deficient stocks trying to ensure that all stocks are data-rich may not be a rational use of resources or the optimum solution. An alternative approach would be to define a hierarchical set of assessment methods and management procedures requiring different amounts of data and then assign stocks to target data categories on the basis of a strategic risk and utility assessment.

Recommendations for actions are made. These are:

1. Ensure compliance with the Data Collection Framework.

2. Define target data categories for managed stocks on the basis of strategic prioritisation.

3. Evaluate management procedures through a rigorous management strategy evaluation to ensure procedures are robust to uncertainty.

4. Evaluate management procedures to ensure there are no perverse incentives to degrade data provision.

5. Define acceptable risk thresholds for management decisions.

6. Ensure political objectives are consistent with resources available for implementation.

1. BACKGROUND: DATA, STOCK ASSESSMENT AND FISHERIES MANAGEMENT

KEY FINDINGS

Fisheries management requires information on **stock abundance** and **fishing mortality rates** in relation to **management reference points** to allow management decisions to be made in relation to **policy commitments** for **maximum sustainable yield (MSY)**.

Stock status in relation to **fishing mortality** and **biomass MSY** reference points can be determined for **'data-rich'** stocks. Data-rich stock assessments require information on the **fishery**, **biological** information on the stock and a fitted **assessment model**. Stocks that are not assessed in relation to management reference points are considered **data-deficient**.

The **lack of quantitative advice** on stock status makes data-deficient stocks a **challenge for management** as data-deficient stocks can not be directly managed in accordance with **management objectives**.

Decisions on how to improve management of data-deficient stocks need to be **balanced with practical considerations**. The data and analysis requirements for a full age based assessment have a **significant associated cost** and it may not be considered appropriate to attempt to make all stocks 'data-rich'.

Pragmatically dealing with data-deficient stocks requires a balance of improving data collection and reporting, improving assessment methods that utilise limited data, and developing tested and robust **management control rules** for data-deficient stocks that are consistent with **the broad policy principles** even if the data-limited management control rules can not be directly applied with regards to MSY objectives.

1.1. Background to Fish Stock Assessment

The underling purpose of fisheries stock[1] assessments is to enable informed rational resource management. In simple terms stock assessments only provide two pieces of information. Firstly information on the current condition of a stock in relation to management objectives, and secondly information on acceptable catch levels consistent with maintaining, or rebuilding, the condition of the stock.

Assessments of the status of a stock are typically conducted in relation to a biomass reference point, a measure of the minimum biomass level that is considered acceptable for a stock. Assessments of catch levels are often conducted in relation to the fishing mortality rate reference point, a measure of the maximum rate of mortality that can be applied to a stock in order to maintain, or rebuild, the stock biomass to acceptable levels.

[1] A biological stock is a reproductively self-sustaining population. The stock is typical scale at which management is applied. The total distribution of a species may be made up of several separate stocks. Although a stock is considered to be an isolated self-sustaining unit, stocks can be connected through a limited exchange of individuals. A stock as a management unit can sometimes comprise several biological stock units of the same species or even different species.

Stock assessments are conducted to support management decisions. Depending on the management objectives and management tools available, wider information and assessments of fisheries may be required in addition to stock assessments. Under a quota based management system the only essential information is information on stock status and acceptable catch levels. In contrast under an effort based management system additional information is required on the relationship between fishing effort and the resulting catch, so that effort limits can be set consistent with ecologically defined catch limits. Similarly in a management system with explicit objectives for the wider ecological impacts of fishing, additional information will be required on the status of different ecosystem components and the impact of fishing operations on these ecosystem components.

This study addresses the nature and challenges of data-deficient fisheries in relation to the basic requirements for stock management and does not address the data-deficient fisheries in terms of potential wider information requirements for the wider assessment and management of fishing impacts on the marine environment.

Over the last 100 years a variety of different methods for assessing the status of stocks and providing catch advice have been developed. This variety in methods has developed due to:

- the different types and amount of information available for different fish[2] stocks,
- differing ways of conceptually representing the dynamics of fish stocks and analysing data,
- the different types of information required in different management settings.

This leads to the current situation where there is a spectrum of fish stock assessment methods ranging from complex data-intensive methods that provide complete assessments of the demographic status of a stock in relation to reference points for maximum sustainable yield, through to simple common sense methods that only require limited data but only provide guidance on ensuring the long-term sustainability of a stock without reference to possible maximum sustainable yields.

A range of different ‘data-rich’ and ‘data-deficient’ stock assessment methods are in use internationally. There is no single best solution and the differences in data-availability, biological situation and management setting between stocks can lead to different conclusions as to the best method to apply in any given situation. Furthermore, new methods and modifications to both data-rich and data-deficient assessment methods are regularly proposed.

The three factors mentioned above, data availability, the conceptual analysis approach and the management requirements are all inter-related and relevant to understanding how to manage or improve the status of data-deficient fisheries. However before these factors are discussed in more detail it is helpful to briefly consider what constitutes a ‘data-rich’ fishery in the context of management objectives for European fisheries, and the extent and nature of data-deficient fisheries in European waters.

[2] This report considered both fish and shellfish stock assessments. The underlying principles are the same for both fish and shellfish. For the sake of brevity, in this report the word ‘fish’ is used to refer to both fish and shellfish unless otherwise specified.

1.2. Data-Rich Fisheries and European Fisheries Management

The primary objectives of the Common Fisheries Policy (EC 2371/2002) are to enable a productive and competitive fisheries industry and ensure sustainable management of resources. The Community and Member States have also subscribed to the Johannesburg 2002 World Summit on Sustainable Development and 1995 United Nations Fish Stocks Agreement which respectively state the objectives to 'maintain or restore fish stocks to levels that can produce the maximum sustainable yield' and that 'the fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points'. Furthermore in 2006 the European Commission set out a plan for moving to maximum sustainable yield (COM (2006) 360 final).

These policy commitments clearly establish the objectives for management of biological resources within European fisheries management in the context of maximum sustainable yield (MSY), and establish objectives for MSY both in terms of the abundance of the stock and the fishing mortality rate applied to a stock. The management reference point associated with the abundance policy objective is B_{MSY}, this is the minimum spawning-stock biomass that will support the long-term harvesting of the maximum sustainable yield. The management reference point associated with the fishing mortality policy objective is F_{MSY}, the maximum mortality rate that can be applied to a stock that will generate the long-term maximum sustainable yield.

The technical definition of MSY is not specified in policy commitments, but at the European level MSY is interpreted as the maximum sustainable yield that can be generated on a stock by stock basis. Therefore under a strict interpretation of European fisheries management objectives B_{MSY} and F_{MSY} reference points should be defined for all stocks, and the status of stocks and catch advice assessed in relation to these reference points.

Bearing in mind the desire to assess stock status and fishing mortality in relation to MSY objectives, in this study stocks are considered 'data-rich' if they are assessed in relation to defined MSY based fishing mortality and biomass reference points and all other stocks are considered 'data deficient'. For the sake of accuracy it should be noted that for some 'data-deficient' stocks the data required to enable a full assessment may be available, but that the data has not been collated and an assessment model developed, or reference points defined. In this case it would be more correct to say that the stock is 'model-deficient' rather than 'data-deficient'. Therefore although this study considers 'data-deficient' stocks this should be read as 'data or model deficient' stocks.

There are two broad categories of assessment models that can be used to assess stocks in relation to MSY based reference points. These are briefly described below.

- **Age- and size-based models**

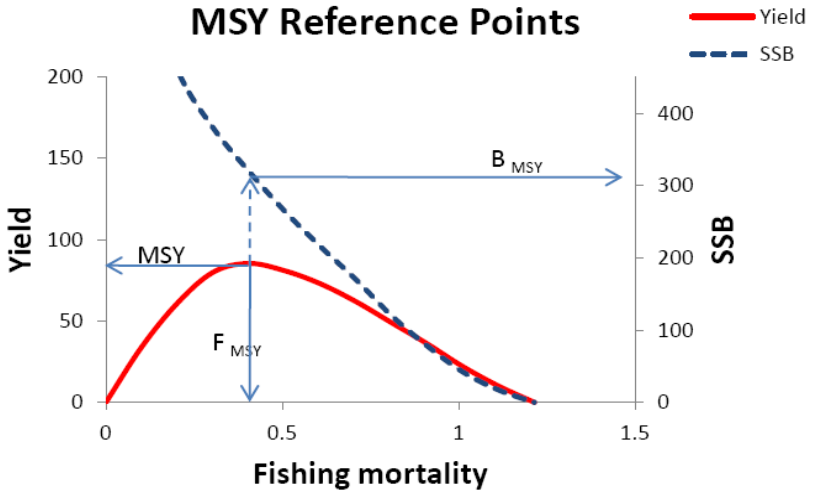
The most complete approach to the assessment of fish stocks is an age-based or size-based approach, where the status of a stock is considered in relation to the number of fish in each age or size class. In the case of age-based models the development of the stock over time is considered on an annual basis in relation to the number of 'recruits' joining the youngest age class and for the older age classes the number of fish growing from one age class to the next taking account the amount of natural and fishing related mortality that occurred during the year. If the relationship between the number of sexually mature adult fish (or the spawning-stock biomass) and the number of 'recruits' that join the population is known a dynamic population model can be developed where the size of the population and number of

individuals in each age class can be projected from year to year on the basis of the level of fishing mortality, growth and recruitment (Figure 1).

Once a population model has been established for a population the management reference points, F_{MSY} and B_{MSY}, are calculated by simulation on the basis of assumptions about the nature of the fisheries (Scott and Sampson, 2010) and environmental conditions. B_{MSY} is often not calculated as it depends strongly on feeding interactions between fish and environmental conditions. Recent stock estimates in heavily fished systems may not give a good indication of the nature of feeding interactions in a less fished system. Therefore it may not be considered possible accurately estimate B_{MSY}, and an alternative proxy such as $B_{trigger}$ may be calculated instead.

In order to establish an age-based assessment model for a stock with associated reference points the typical data requirements are time series information on landings of each age class, discard rate for each age class, size at age, a recruitment time series (number of young born each year), age of maturity and a time series of relative abundance (typically from a research survey).

Figure 1: General relationship between yield, spawning-stock biomass (SSB) and fishing mortality as calculated by an age-structured population model.



Source: ICES (2012a)

Collecting and assembling the data needed for an age based assessment requires a significant sampling and analysis process.

Information on total landings is collected nationally based on fisher's logbook returns. To calculate landings by age class from the total landings data two separate sources of information are needed: information on the length composition of landings (by fleet as length compositions of landings vary across fleets) and information on age-length relationships to convert length based information into age based information. The data on length composition of landings comes from national port-side monitoring of landings. Information on age-length relationship is calculated by 'reading' the age of a sample of fish and comparing with the length of the fish to create an 'age-length key' that can be used to convert lengths to age. Most fish species are aged by reading growth rings in the otoliths (ear bones) in a similar way to reading tree growth rings. Otoliths are collected by port-side samplers or during research vessel surveys. The otoliths then have to be individually

prepared, cut in half and polished before the growth rings can be counted. Information on discard rates are collected by at-sea monitors who travel on commercial vessels and monitor catches and discards at sea. A specified sample of fishing activities are monitored to allow the whole fleet discard levels to be calculated. Information on recruitment and relative abundance of the stock is collected from survey data, preferably from research surveys, although information from fishing activities can be used (with caveats). Age at maturity data is collected by visually inspecting maturity at size, either from individuals collected during research surveys or by port-side sampling.

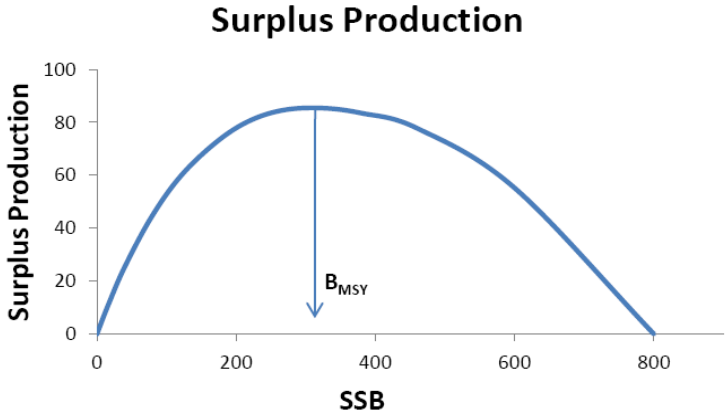
To enable the final analysis once the data has been collected the outputs from separate national monitoring programs need to be combined to the total international level. If data from just a single contributing nation is not provided, or considered non-representative of the activity being monitored, the accurate application of an assessment model may be compromised.

- **Surplus production models**

'Surplus production' models are an alternative, simpler, method for assessing stocks with simpler data requirements. However, as surplus production models are based on a simpler description of the dynamics of a stock than age-structured models, they can not be used to evaluate the implications of technical control measures (e.g. mesh size regulations) nor can they be used to evaluate the stock biomass at which reproduction may become impaired. Therefore they are not able to provide as comprehensive management advice as age-based models. Similarly surplus production models are based on a wider set of assumptions than age-based models, so the outputs may be considered less robust.

Surplus production models are based on considering a whole stock as a single object that can increase or decrease in size, and the total annual production by the stock as a whole is calculated. The amount of annual production by a stock is the total of the weight gained by growth of individuals in the stock and the weight of juveniles recruiting to the stock minus the loss from natural mortality. Although annual production can be variable it is related to stock size. At the maximum stock size there is no annual increase in stock size, and the amount of production gained by the stock is balanced by 'losses' through natural mortality.

Figure 2: General relationship between surplus production and SSB for a hypothetical stock.



Source: ICES (2012a)

Below the maximum stock size the annual production will be greater than the losses and the stock increases in size due to 'surplus production' (Figure 2). The surplus production is the amount the stock would increase by, or the amount of yield that can be taken from the stock

without changing the stock size. Stock production models can be developed to calculate the annual surplus production as a function of stock size (Figure 2). This can be used to calculate MSY along with the associated BMSY and FMSY reference points.

Surplus production models have simpler data requirements than age-based population models and only require time series information on total catches (including discards) and relative abundance from a survey index. However although the data requirements are simpler than for age-based model, in order for a Surplus production model to be accurately applied to a stock a fairly long time series of catch and abundance data is required, and the time series needs to cover periods of stock decline and stock abundance increases.

1.3. The Challenge of Data-Deficient Fisheries

The lack of quantitative assessment of status and advice for data-deficient stocks makes them a challenge for management as they can not be directly managed in accordance with the management objectives.

This challenge can be addressed in three ways, firstly by improving data collection to elevate data-deficient stocks to a 'data-rich' status, secondly to improve the assessment methods to provide quantified MSY based advice from limited data, or thirdly to apply agreed data-deficient management procedures developed for use with data-deficient stocks in a manner consistent with broad policy objectives, even if these methods can not provide the exact type of advice required by the policy objectives.

Decisions on how to improve management of data-deficient stocks need to be balanced with the practical considerations. The data and analysis requirements for a full age based assessment have a significant associated cost and it may not be considered appropriate to attempt to make all stocks 'data-rich'.

Pragmatically dealing with data-deficient stocks is likely to involve a balance of improving data collection and reporting, improving assessment methods that utilise limited data, and developing tested and robust management control rules for data-deficient stocks that are consistent with the broad policy principles even if the data-limited management control rules can not be directly applied with regards to MSY objectives. This would imply a tiered approach to management where by different stocks are treated in different ways depending on the data available.

1.4. Study Scope and Structure

This study considers the management of data-deficient stocks in European waters. An overview of the proportion of landings coming from data-deficient stocks in European waters is presented to provide context on the scale of issue in European waters and the reasons for stocks being considered data-deficient are discussed. The current and recent approaches to assessing and managing data-deficient stock in European waters are reviewed followed by an overview of international approaches to assessing and managing data-deficient stocks.

On the basis of these reviews the European approaches to assessing and managing data-deficient stocks are evaluated in the context of alternative international approaches. Finally conclusion on possible solutions for managing data-deficient stocks will be presented.

The scope of the study is to examine data-deficient fisheries in European waters. In the North East Atlantic (including Baltic) Member States have declared 200 mile Exclusive

Economic Zones (EEZs). Fisheries in European Atlantic waters (including the Baltic) within Member States' EEZs are managed under the exclusive competence of the CFP. The International Council for the Exploration of the Seas (ICES) is the primary provider of scientific advice for fish stocks in the European Atlantic waters. Fisheries in European Atlantic waters are considered in this study in respect to advice provided by ICES.

Fisheries management in the Mediterranean and Black Sea beyond 12 nautical miles falls under the competence of the General Fisheries Commission for the Mediterranean (GFCM). The GFCM is an international Regional Fisheries Management Organization of which the European Union is a Contracting Party, along with the non-EU countries bordering the Mediterranean and Black Sea. The GFCM area covers waters belonging to both EU and non-EU countries and is not under exclusive European management. However, given the European interests in Mediterranean and Black Sea fisheries, and in accordance with the terms of reference for this study, fisheries in the GFCM area are considered within the scope of the study, although not with the same degree of detail as fisheries under exclusive European management in the 'ICES area'.

Stock assessments are a highly complex and technical process. To aid clarity of the study some generalisations and simplifications of stock assessment techniques and procedures have been deliberately used. Therefore some of the descriptions of both data-rich and data-deficient assessment methods provided in this study are not correct in every last detail. However every attempt has been made to ensure that the general understanding conveyed is accurate whilst keeping the study readable.

2. EXTENT AND NATURE OF DATA-DEFICIENT FISHERIES IN EUROPEAN WATERS

KEY FINDINGS

ICES is the primary body responsible for conducting stock assessments in **European Atlantic waters** (including the Baltic). The **GFCM** manages fisheries and conducts stock assessment in the **Mediterranean and Black Sea**. **STECF** conducts additional assessments in the GFCM area.

In total approximately **half** of landings in **European Atlantic waters** come from **data-deficient stocks**. In the **Mediterranean** and **Black Sea** approximately **80%** of landings come from **data-deficient** stocks.

There is **regional variation** in the extent that fisheries depend on data-deficient stocks. The **highest proportion** of landings from fully assessed stocks is in the **Baltic**, the **lowest proportion** of landings from fully assessed stocks is in the **Black Sea**. There is also **systematic variation** in the sectoral dependence on data-deficient stocks. **Small vessels** below 12m are more dependent on data-deficient stocks than **large vessels** over 12m. **Pelagic** stocks have the widest assessment coverage, followed by **demersal** stocks. Very few **invertebrate** stocks are assessed.

The new ICES **data limited stocks approach** is expected to provide quantitative catch advice for a further **10% of landings** from European Atlantic waters that is currently considered data-deficient stocks.

The **lack of full assessment** can be due to **limited data collection** and reporting, but also due to **limited biological information** and **resource limitations** in applying assessment models.

No Member States are considered **fully compliant** with the Data Collection Framework (DCF) **fisheries reporting** requirements. For nearly all data-deficient stocks **improved data** collection and reporting would lead to **improved management**. However simply improving fisheries data collection is not sufficient to enable all stocks to be covered by full analytical assessments.

2.1. The Extent of Data-Deficient Fisheries in European Waters

The Data Collection Framework (Council Regulation (EC) 199/2008) specifies 238 stocks in Northeast Atlantic European waters (including the Baltic) and 97 stocks in the Mediterranean and Black Seas that are covered by data collection requirements. ICES conducts annual stock assessments. In 2011 ICES conducted analytical assessments and provided catch advice in relation to MSY objectives of 31 stocks in the North East Atlantic. Stocks in the Mediterranean and Black Sea are not assessed annually. Between 2008-2010 the GFCM has conducted assessments in relation to MSY exploitation objectives for 39 stocks and STECF conducted assessments for 30 stocks.

The extent to which fisheries in European waters and the GFCM region depend on catches from data-deficient stocks is presented by displaying the proportion of the total landings by weight and value that came from stocks considered data-deficient. This is presented for all landings from Northeast Atlantic European waters and from the Mediterranean and Black Sea. The data was analysed by region, vessel size, fishing gear type, and stock category (pelagic, demersal, invertebrate) to identify particular regions and sectors of the industry that disproportionately utilise data-deficient stocks.

To examine the proportion of landings caught from data-deficient stocks, information on landings was cross referenced with information from ICES, STECF, GFCM and ICCAT stock assessments and landings categorised as coming from an assessed or unassessed stock. The STECF landings data used was data submitted by Member States to the 2012 DCF economic data call. This is the most comprehensive data set available allowing analysis at the desired scale. Data is available for 2008-2011. Spain and Greece have not submitted landings data for any of these years, and Cyprus, Ireland and Italy provided no data for 2011. Therefore the 2010 data, as the most recent and complete, is used for the main analysis of the proportion of landings that comes from data-deficient stocks. Incomplete reporting will affect the results of the analysis, particularly for 2011.

Stocks were classified as 'fully assessed' if they had an accepted fitted analytical assessment model that provided assessment of stock status and advice on catch options in relation to MSY based reference points, otherwise they were classified as not assessed and data poor. (A fuller description of the data analysis procedures is presented in Annex I.)

In the Northeast Atlantic European waters approximately half of landings by weight and value came from data-deficient unassessed stocks (Figure 3). For the Northeast Atlantic assessment coverage has remained reasonably stable over the last 3 years. In the Mediterranean and Black Seas approximately 80% of landings by weight, and 90% by value, came from unassessed stocks prior to 2011. There is an apparent variation in the proportion of landings coming from assessed stocks in 2011, however this variation may be an effect of less complete reporting of landings data for 2011.

There is better assessment coverage for stocks managed under TACs (Table 1), with approximately 60% of landings coming from assessed stocks, albeit it that this accounts for less than 30% of the number of stocks managed under TACs. Some stocks managed under TACs are considered 'partially assessed'; this is the case where more than one 'biological' stock makes up a 'management' stock unit. For example sole in the English Channel are managed with a single TAC, but separate assessments are conducted for the eastern and western Channel sole populations.

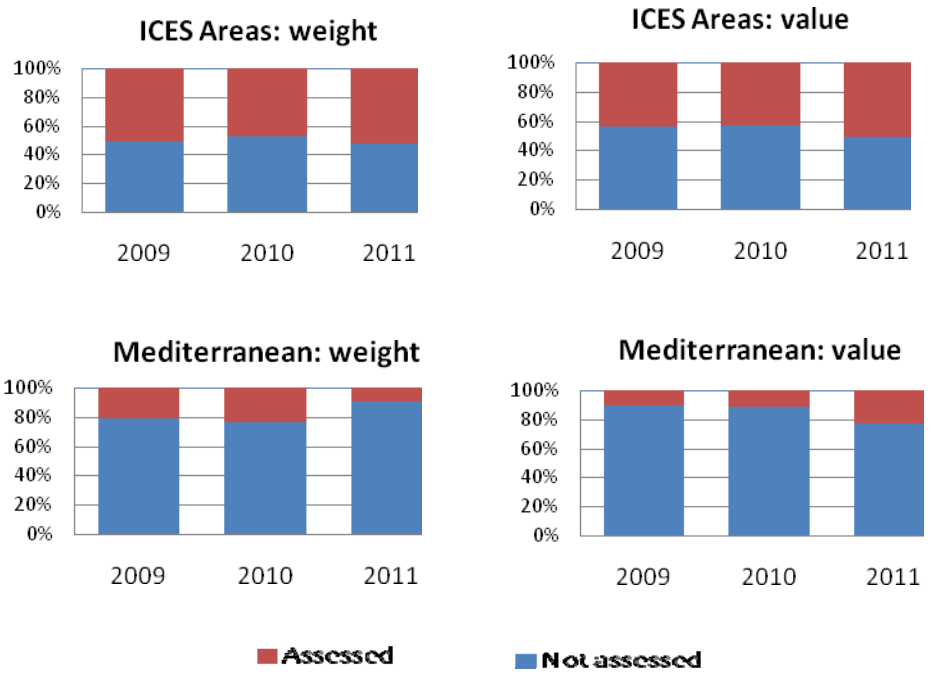
The longer term trend in coverage of stock assessments is shown for the North Sea where coverage of stock assessments has increased from 2 stocks in 1957 to 12 stocks by 2007 (Figure 4). In 1973, 6 North Sea stocks were assessed. Despite the number of assessed stocks doubling since 1973 the proportion of landings coming from assessed stocks has not particularly increased and has remained reasonably constant between 40-50% over this period.

Table 1: Number and proportion of TAC stocks covered by full assessments.

	Number of stocks			Weight of landings		Value of landings	
	Assessed	Not Assessed	Partially Assessed	Assessed	Not Assessed	Assessed	Not Assessed
2009	42	96	8	60%	40%	62%	38%
2010	39	98	9	57%	43%	59%	41%
2011	41	97	8	60%	40%	62%	38%

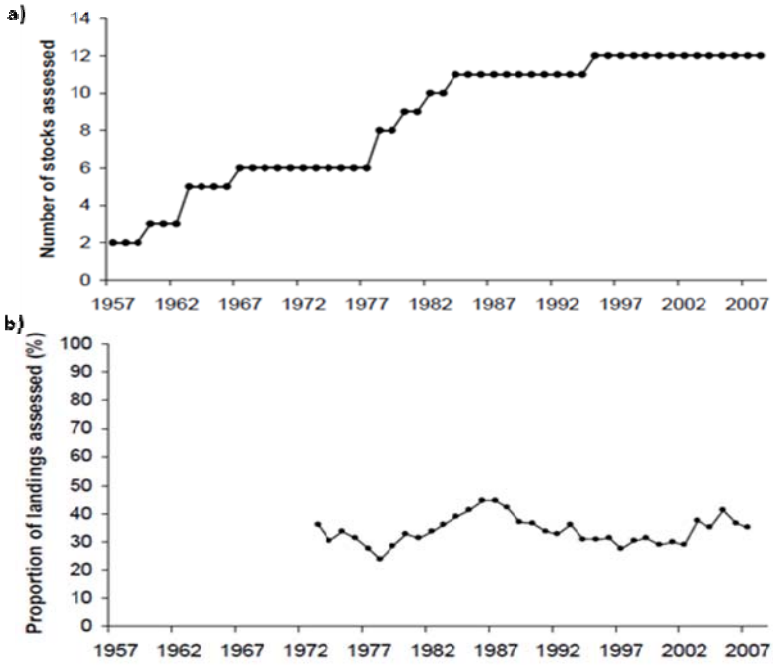
Source: Authors

Figure 3: The proportion of landings coming from assessed and data-deficient stocks from Northeast Atlantic European waters (ICES areas) and from the Mediterranean and Black Sea (GFCM areas) by weight and value. See text for comments on data coverage and aggregation.



Data Source: Authors

Figure 4: a) number of North Sea stocks covered by complete assessments, b) proportion of landings, by weight, coming from assessed North Sea stocks.

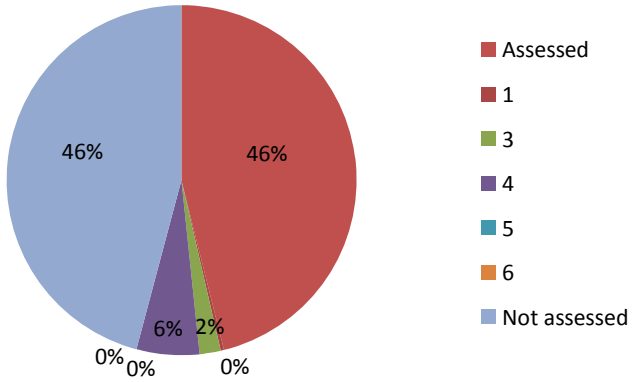


Source: Le Quesne *et al.* (2010)

The explanation for why the number of stocks assessed in the North Sea has doubled since 1973 yet the proportion of landings covered by assessments has remained reasonably constant has not been specifically analysed, however this probably reflects a decline in landings from the traditionally dominant stocks that would have been the focus for assessments. As landings from the main stocks have declined the proportion of landings from other stocks will have increased, and thus the proportion of landings that have come from assessed stocks does not mirror the increase in the number of stocks assessed.

In addition to data rich stocks that are assessed in relation to MSY reference points quantitative catch advice is now provided by ICES using the data limited stocks approach (DLS). This advice was first introduced in 2012, and the number of stocks covered by the DLS approach is expected to increase. In 2013 the DLS approach will increase the proportion of landings in the North East Atlantic and Baltic European waters coming from stocks with quantitative scientific catch advice by approximately 10%[3] (Figure 5).

Figure 5: Estimated proportion of landings in 2013 from the European Northeast Atlantic covered by full assessments or advice under the different ICES DLS data categories (1-6) by weight. See text for comments on data coverage and aggregation.

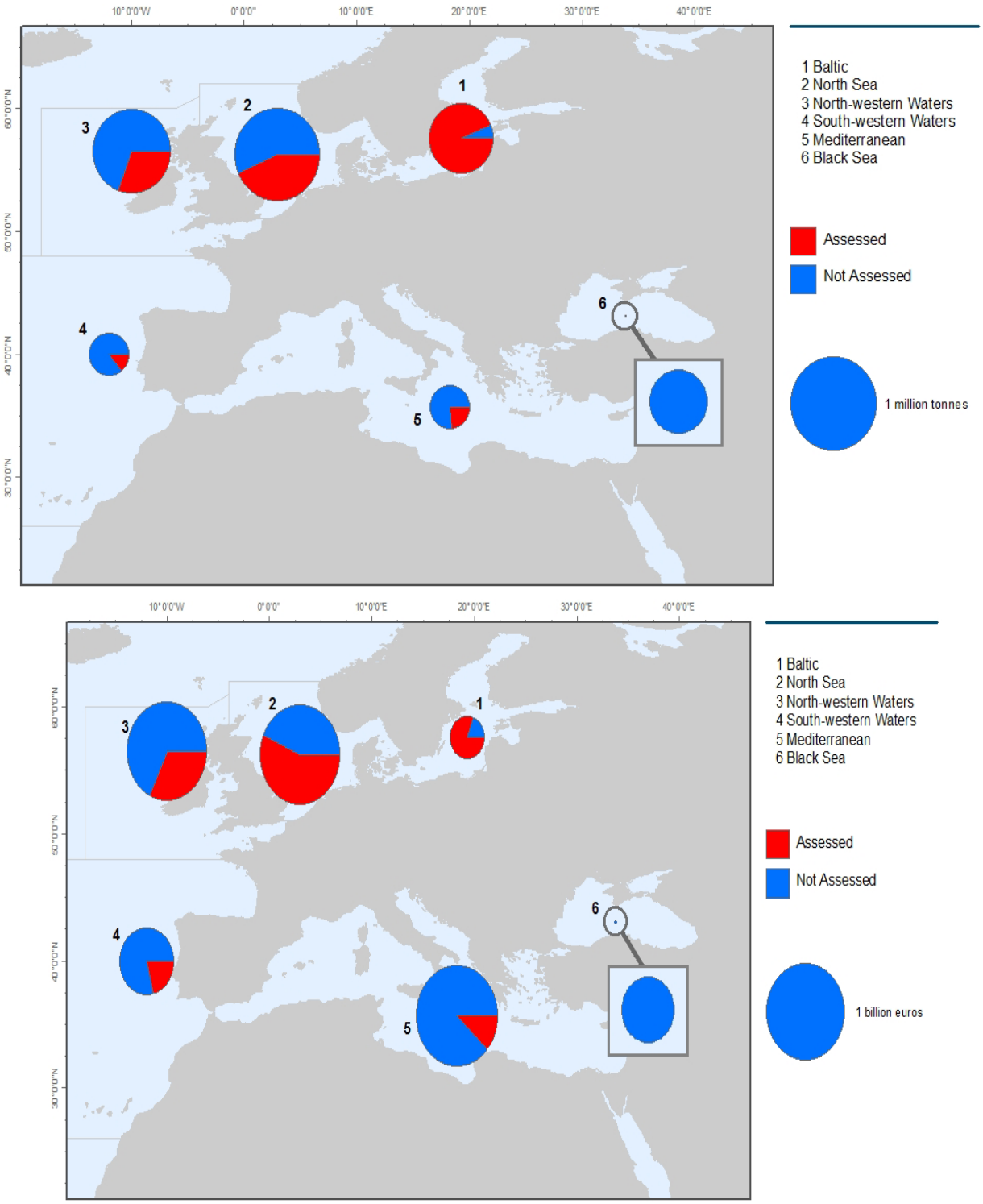


Source: Le Quesne *et al.* (2010)

There is clear regional variation in the extent of landings derived from unassessed stocks (Figure 6). In the Baltic over 80% of landings, by weight and value, come from fully assessed stocks with limited dependence on data-deficient stocks. The North Sea region is the area next best covered with assessments with over half the landings by value and over 1/3rd landings by weight coming from fully assessed stocks. In the Northwestern waters approximately 1/3rd of the landings come from assessed stocks. In the Southwestern waters and Mediterranean less than ¼ of landings come from assessed stocks, and in the Black Sea no stocks are fully assessed.

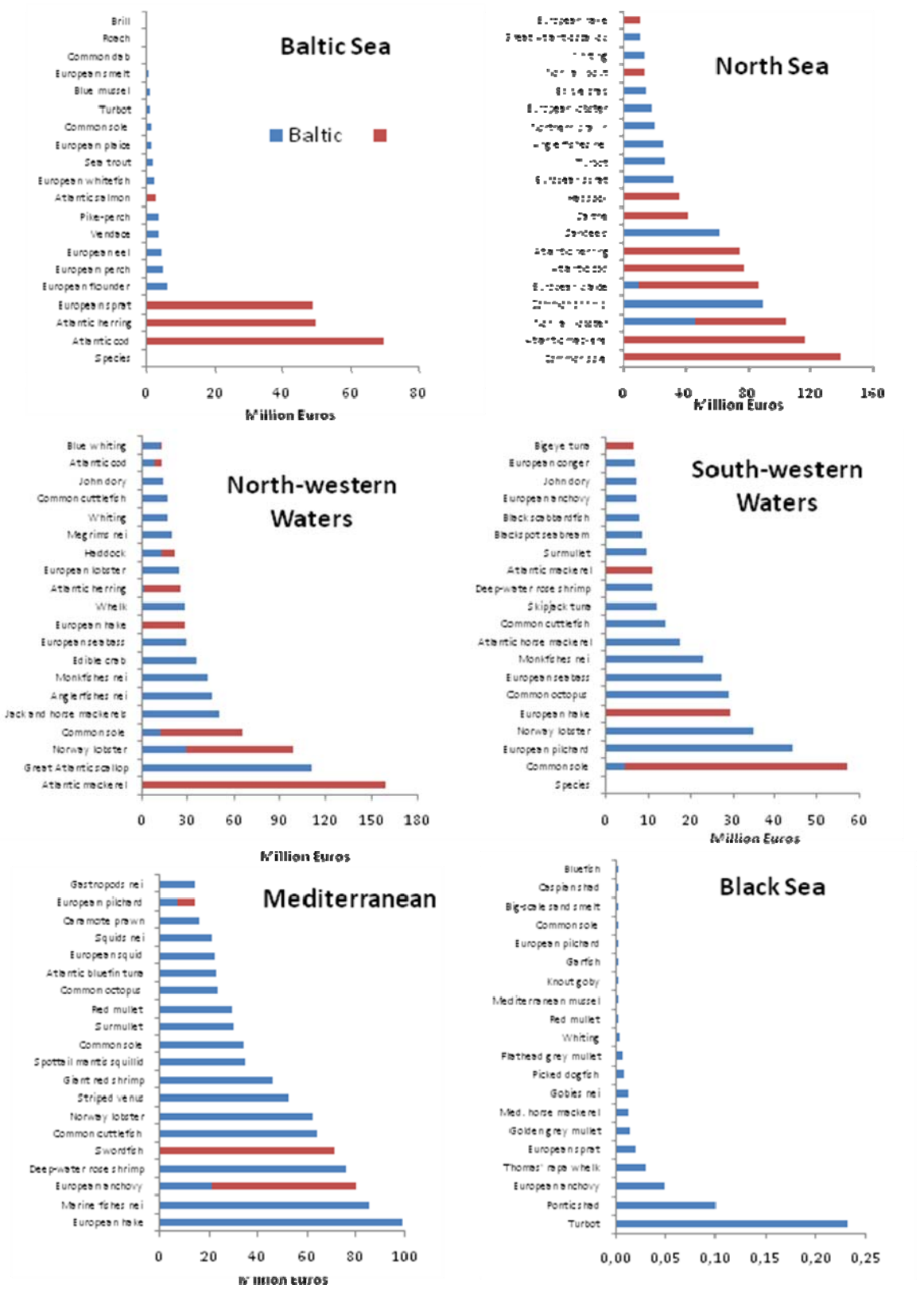
[3] The proportion of landings in 2013 coming from stocks with catch advice based on the ICES DLS approach was calculated with the 2010 landings figures as these were the most up-to-date and complete landings figures available at the time of writing.

Figure 6: The proportion of landings from assessed and unassessed stocks by a) weight and b) value of landings. See text for comments on data coverage and aggregation.



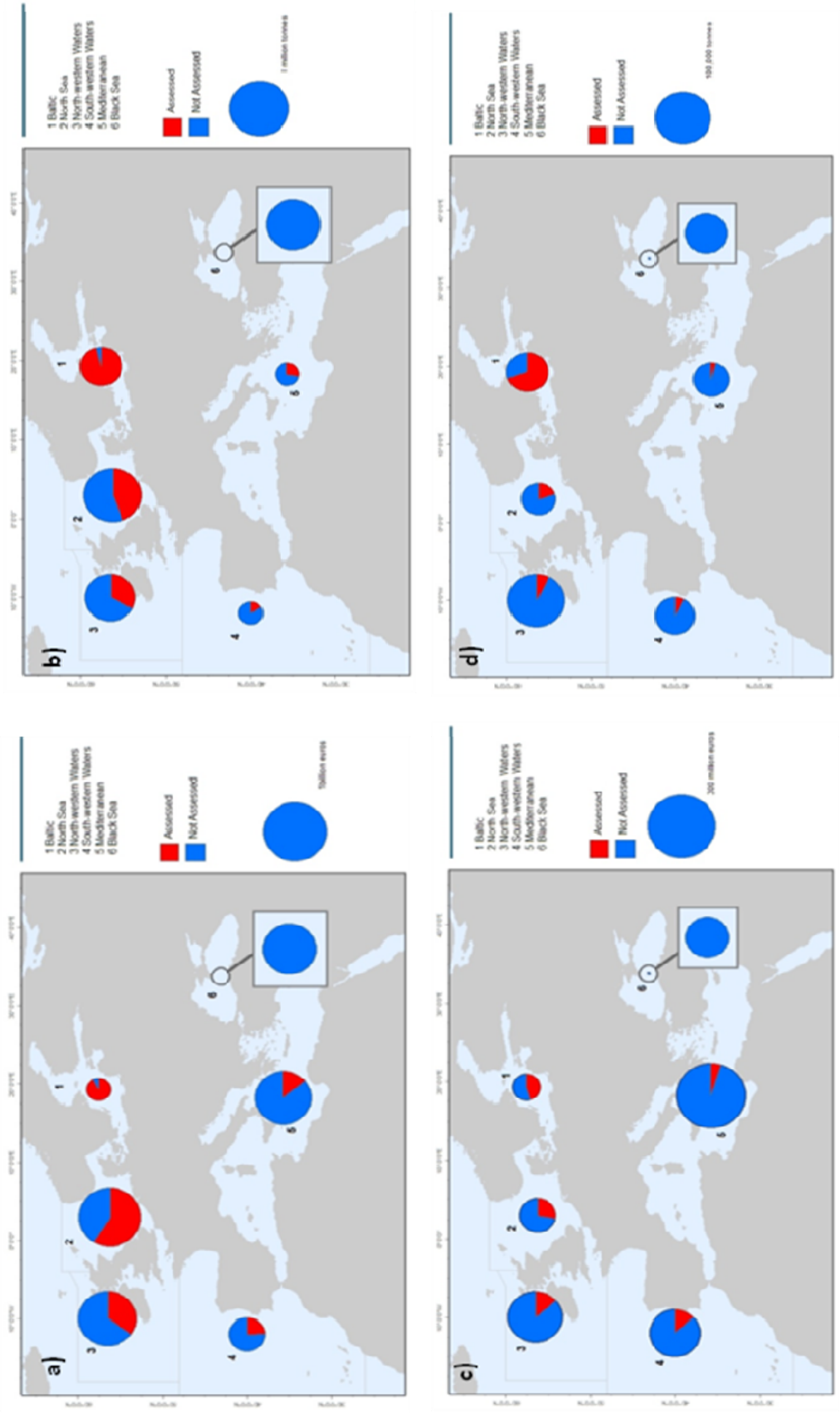
Source: Authors

Figure 7: Assessment coverage of the top 20 species by value by region. Species can be partially assessed where several separate stocks occur with in the region. 'nei' means not elsewhere identified for landings that can have not been attributed to a specific stock category. See text for comments on data coverage and aggregation.



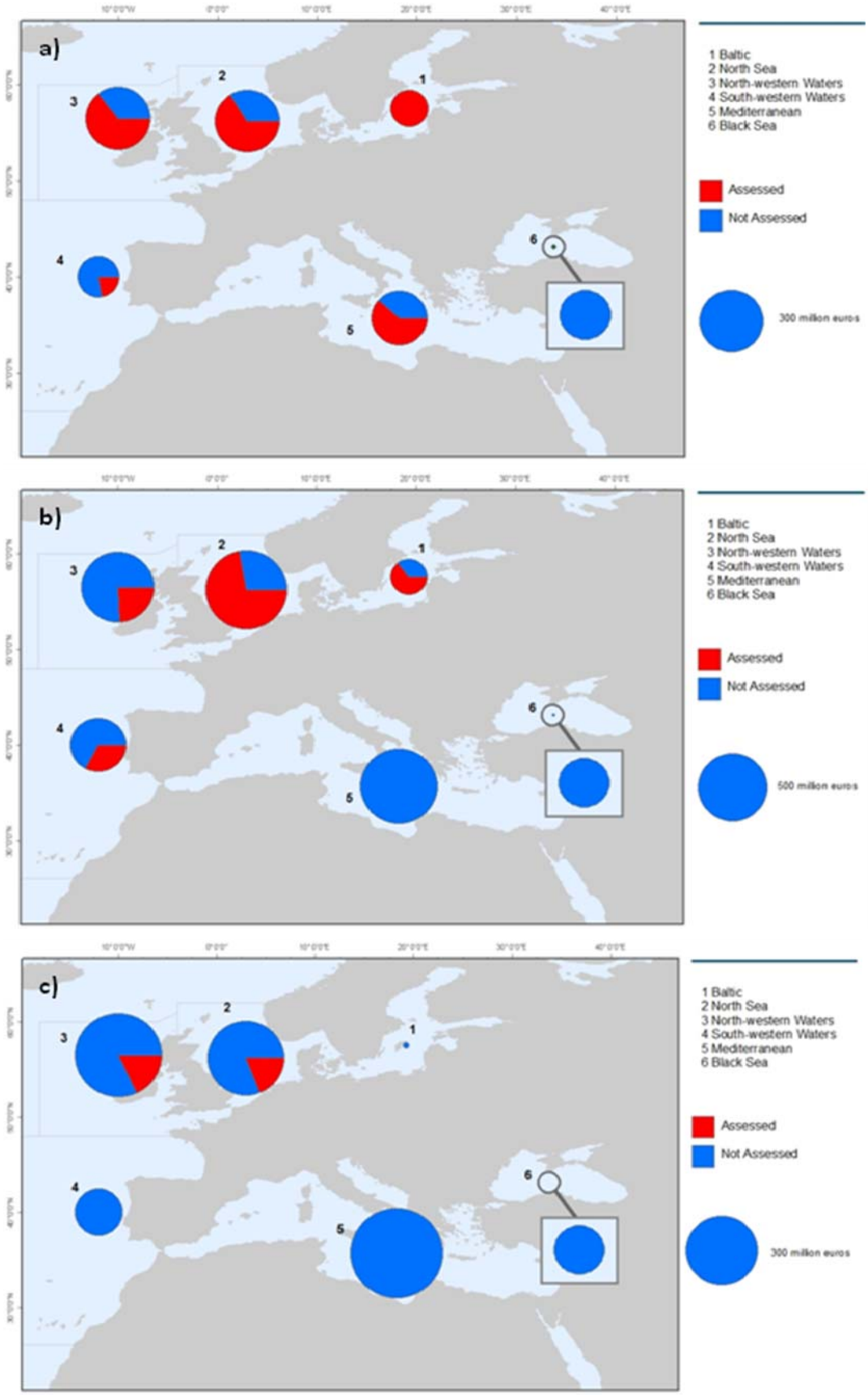
Source: Authors

Figure 8: Proportion of landings by value (a, c) and weight (b, d) taken from assessed and data-deficient stocks by vessels over 12m (a, b) and vessels under 12m (c, d) based on STECF 2010 landings data.



Source: Authors

Figure 9: Proportion of landings by value from a) pelagic, b) demersal, c) invertebrate stocks covered by assessments based on 2010 STECF landings data.



Source: Authors

Box 1: Deep water fisheries

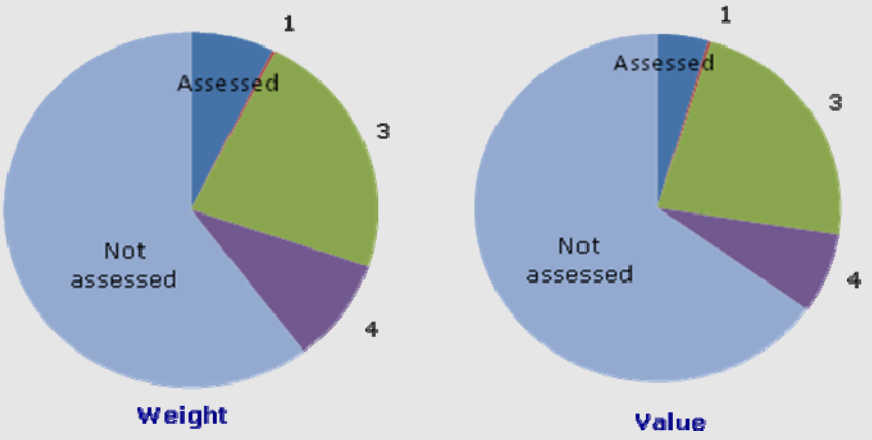
DEEP WATER FISHERIES

Deep water species are of particular concern to fisheries managers as many deep water fish are slow growing, late maturing and have low reproductive output. Slow growing, late maturing species are particularly sensitive to fishing mortality and have very long recovery times. Orange roughy (*Hoplostethus atlanticus*) is an extreme example of long lived, slow growing deep water species. Orange roughy can live for well over 100 years and typically mature around the age of 30 years. However other deep water species such as blue ling (*Molva dypterigia*) are faster growing with a life-history similar to a typical shallow water cod-like species.

Forty six species of fish are listed under Annexes I and II of the Council Regulations for deep water fisheries (EC 2347/2002). In 2012 only one stock, roundnose grenadier (*Coryphaenoides rupestris*) in ICES divisions Vb, XIIb and subareas VI and VII, could be considered fully assessed in relation to defined MSY based fishing mortality and biomass reference points. This accounts for approximately 7% of the landings from deep water stocks. However quantitative advice is being provided for an increasing number of stocks under the ICES DLS framework. In 2013 it is expected that approximately 30% of landings of deepwater species will be derived from stocks with quantitative advice assuming the catch patterns in 2010 are maintained. The application of the DLS framework for deepwater stocks is based on standard methods defined within the framework and also methods developed within the DEEPFISHMAN project.

Assessment of deep water stocks is compromised by the lack of fishery independent stock surveys. Relying only on catch data recorded in EC logbooks is significantly limiting to the ability of assessments and can lead to the identification of spurious trends (Trenkel *et al*. 2010). The quality of assessments for deep water species would be notably enhanced with access to survey data. An internationally coordinated fishery independent trawl survey was proposed by the ICES deep water working group in 2009 and subsequently formally proposed by the ICES Planning Group on the North-east Atlantic Continental Slope Survey (PGNEACS); no survey has been brought into existence.

Box Figure: The estimated proportion of landings of deep water fish in 2013 in the Northeast Atlantic covered by full assessments or advice under different ICES DLS data categories. See table 2 for definition of ICES DLS data categories.



Source: Authors

The considerable regional variation in stock coverage by assessments between regions is due to regional variation in biodiversity as well as any regional variation in data collection and assessment activity. For example to compare the Baltic and the North Sea, by weight over 90% of landings in the Baltic come from assessed stocks where as in the North Sea less than half the landings come from assessed stocks, however in the Baltic only 4 of the top 20 species by value are covered by assessments, yet in the North Sea more than twice as many of the top 20 species are covered by assessments (Figure 7). The lower coverage of landings by assessments in the North Sea even though more stocks are assessed is because the North Sea is more diverse than the Baltic and landings in the North Sea are made up of a broad range of species where as over 90% of landings in the Baltic come from just 3 species which are assessed. The Black Sea is similar to the Baltic in having reduced salinity and reduced diversity; however the Black Sea does not share the Baltic's high coverage of landings by assessments.

Variation in dependence on data-deficient stocks occurs across sectors as well as across regions. In all regions, apart from the Black Sea, large vessels over 12m take a significantly higher portion of the landings from assessed stocks than small vessels under 12m (Figure 8). Therefore the small vessel, predominantly inshore, fleet is more dependent on data-deficient stocks than the large offshore fleets. This is partially because the small vessel fleets target a higher proportion of invertebrates, and invertebrates are less well covered by stock assessments than fish. Furthermore smaller inshore vessels typically target a more diverse range of species than offshore vessels.

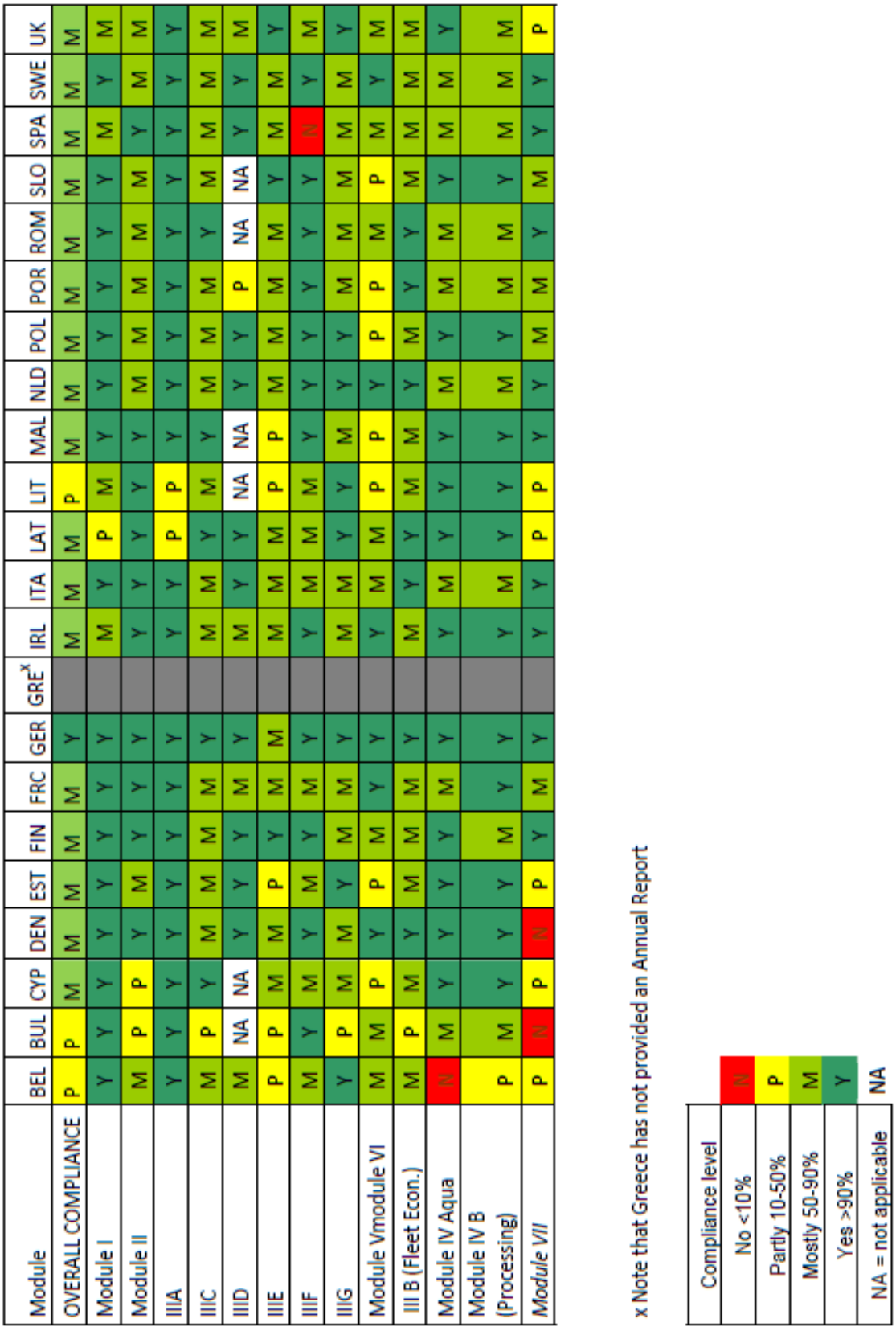
There is also variation in assessment coverage between fisheries (Figure 9). Pelagic stocks have the fullest assessment coverage, followed by demersal stocks, and then invertebrates (Species categories are listed in Annex II). Although pelagic stocks have the highest proportion of assessment coverage across all regions, in the North Sea and Southwestern waters regions there is greater assessment coverage (by value of landings) of demersal stocks. No invertebrate stocks are covered by assessments in the Baltic, Southwestern Waters, Mediterranean and Black Sea regions.

The extent to which different fleet segments (vessels operating with different fishing gears) take landings from data-deficient stocks varies between regions (data not shown). However there are no clear trends in utilisation of data-deficient stocks by different fleet segments across the regions, with the extent that different fleet segments utilise data-deficient stocks in different regions simply reflecting the nature of the fishing operations and the species that are covered by assessments. The only consistent pattern across regions is that dredge fisheries (DRB) that are used in shellfish fisheries take very few landings from stocks coverage by assessments. This reflects the low coverage of shellfish by stock assessments.

2.2. Why Are There Data Deficient Stocks?

Given the widespread significance of unassessed stocks to landings and the extent of data collection requirements what stops assessments being conducted, and to what extent are data-deficiencies the cause of the lack of assessments? Member States are obliged to provide data on fisheries, landings, economic and biological data in accordance with the requirements of the Data Collection Framework (COM(2009)10121 final) to support stock assessments. Member States' annual reports for the DCF are evaluated by the STECF. The

Figure 10: Evaluation of overall compliance of 2011 Member State annual DCF reports.



Source: STECF-OWP-12-05

STECF evaluation of the 2011 DCF reports (Figure 9) concluded that no Member States were in full compliance with the DCF data reporting requirements, Greece did not provide an annual report and three further Member States were considered to have poor compliance. Module III of the DCF report contains the key information required for stock assessments; no Member States were in full compliance with the DCF module III data reporting, and Spain provided no information for section III F 'transversal variable' including information on landings.

The reasons for the lack of assessments and advice on data-limited stocks are various: missing and unreliable information on catches, incomplete surveys and poor sampling; together with underlying uncertainties about the biology of the stock, as well as lack of human resources in the scientific advisory process.

Unreported discarding and illegal, unregulated and unreported fishing (IUU) are sources of unreported mortality that are taken into account by stock assessment, and compromise the quality of an assessment. These factors can be of particular concern in situations with poor fisheries control or excess fishing effort in relation to the catch opportunities available.

In general unaccounted mortality leads to assessments under estimating true stock size. Where the unaccounted mortality is consistent overtime this will lead to a consistent offset in the assessment and appropriate advice can still be generated. If the unaccounted mortality varies over time the quality of advice will be significantly impacted. There are no clear objective methods for categorically identifying unreported mortality in an assessment; the impact of unreported mortality on the quality of an assessment is often based on the subjective opinion of a stock assessment group and their wider knowledge of the fishery. If large and variable unaccounted mortality is considered to be occurring a stock assessment group may decide that it is inappropriate to conduct an assessment.

Changes to fisheries management and control in European fisheries over recent years are expected to have lead to a significant reduction in discarding and IUU, and therefore have improved data quality for assessments.

There were also developments towards improved compliance which in turn has led to improved quality of scientific data and stock assessments, together with a reduction in discarding and IUU fishing. A satellite vessel monitoring system was introduced in 1998 (EC 2003) and the establishment of a European Fisheries Control Agency in 2005 (EC 2005) has co-ordinated fishery control and inspections and standards. Several states have introduced sales audits in the fish supply chain which have addressed illegal (so-called black) landings. Enforceability has also been improved by more inclusive engagement with fishers and other stakeholders in decision making: this was also addressed in the 2002 reform with the establishment of the Regional Advisory Councils (RACs). In addition, many countries such as the Netherlands, Denmark and the UK introduced tradable fishing rights, a system already operating in Iceland which gives fishers greater incentives to conserve the resource.

In relation to regulating effort and reducing discarding some countries began to implement substantial fleet reduction schemes and fishing gear technical measures around 2000 to lessen dependence on TACs in order to reduce fishing pressure. Further major policy changes were introduced under CFP reform in 2002 (COM 2009) which included detailed stock recovery plans including effort control (restrictions on days at sea). This was introduced as part of the implementation of management and recovery plans which determine the annual exploitation rate consistent with longer term objectives as well as laying down other measures such as effort regulations.

Data deficiencies are not the only reason why stocks may not be assessed. Additional reasons for not assessing stocks include a lack of biological information about the stock (e.g. growth rate, distribution and migration) or limited resources to conduct assessments, as mentioned previously. Therefore whilst there are undoubtedly data-deficiencies in terms of reporting data in relation to DCF obligations, to what extent is this the cause of 'data-deficient' stocks not being assessed?

It is beyond the scope of this study to examine every unassessed stock on a case by case basis to establish why it is not assessed, however to provide a selected analysis of the reasons why assessments are not carried out the species not covered by assessments in the list of the 20 most valuable species caught from the Northwestern Waters region are examined.

Of the 13 species (or species groups) that are not covered by assessments in the 20 most valuable species landed in the Northwestern waters region 6 species are invertebrates. Invertebrates are consistently challenging for stock assessments as they can be difficult to age and there is uncertainty over aspects of their biology and life-history that make data interpretation and defining the appropriate form of assessment model difficult irrespective of the quantity and quality of the data. None the less stock assessments are conducted for some invertebrate stocks.

- European lobster (*Homarus gammarus*), edible crab (*Cancer pagurus*) and cuttlefish (*Sepia officianalis*) are covered by the DCF data collection requirements, however no assessments are conducted. The lack of assessments is due to a lack of information and also the differences in the biology of these invertebrates means that stock assessment models developed for fish can not be directly applied. These stocks particularly lack fishery independent abundance data as they are poorly sampled in the large scale fish surveys and no specific surveys have been established. Furthermore they are not amenable to the same techniques for aging and estimating natural mortality as applied to fish and therefore regular reliable biological data is limited. The lack of assessments for these invertebrates also partly reflects the focus that has typically been placed on fish stock assessment and the comparative lack of focus on invertebrates. Finally in relation to scallop (*Pecten maximus*) and whelks (*Buccinum undatum*) these stocks are not listed under the DCF as being covered by data collection requirements and no regional assessment is conducted.

- Anglerfish (*Lophius piscatorius* and *Lophius budegassa*) are assessed separately but managed under a single TAC. Assessments for these species in the Northwestern waters region do not occur for two reasons; biological uncertainty over aging data and lack of reporting of data. The standard method of ageing fish is to count the rings in the fishes otoliths (ear bones). However with angler and monk fish there is uncertainty on the number of growth rings laid down each year so no age information is available and age based assessments can not be conducted. In addition not all the data on landings and discards required under the DCF is provided by all Members States to the ICES working group compromising the ability of robust assessment.

- European Seabass (*Dicentrarchus labrax*) are not assessed due to uncertainty over biological data and limited fisheries data. There are specific uncertainties over the stock structure of bass and whether fish in a region can be considered and managed as a single population, or if the fish in a region consist of a number of smaller populations that should be individually assessed. This is of particular importance to bass due to homing behaviour and territorial juvenile usage of estuaries and coastal areas and appropriate stock units have not been defined; this biological uncertainty

limits the application of a full stock assessment. In addition there is limited data on recreational fisheries for bass which are though to be an important component of total landings, and also limited time series information on juvenile abundance in inshore areas.

- Four whiting (*Merlangius merlangus*) stocks and three megrim (*Lepidorhombus whiffiagonis*) stocks are assessed separately in the Northwestern waters region and they show similar patterns in patchy assessments. For both the West of Scotland whiting, and Celtic Sea megrim stocks full age based assessment models have been fitted but due to uncertainty over data quality and lack of full reporting of discard data the models are only treated as trends assessments and no reference points defined. Data quality for West of Scotland whiting is improving and new surveys have been recently initiated. Celtic Sea whiting received a full assessment for the first time in 2012 (figure 7 is based on 2010 data) and are no longer considered data deficient. For the other whiting and megrim stocks varying types of non-age based assessments are applied and although the West of Scotland megrim assessment is hampered by aging issues all these other assessments are hampered by incomplete data reporting.

- Horse mackerel (*Trachurus trachurus*) has an age based assessment but no biomass reference points have been defined. There is considerable uncertainty associated with the assessment estimate of biomass due to limitations in the fishery independent surveying. Partial reporting of discard estimates and biological sampling undermine the precision of the assessment.

- The remaining fish stock considered data-deficient of the 20 most valuable species landed in the Northwestern waters region is John Dory (*Zeus faber*). John Dory is covered under the DCF data reporting requirements however no assessments have been attempted for John Dory.

This analysis of the most valuable data-deficient species in the Northwestern water region may not be representative of European waters as a whole but it highlights a number of key factors relating to data deficient stocks that broadly apply across European waters. Firstly the lack of an assessment is not simply a matter of data-deficiency in terms of fisheries data, but is also due in cases to information deficiency and model deficiency.

Assessment coverage of stocks in European waters would be improved by improved fisheries data reporting, but this would not be enough by itself to enable full assessments of all stocks. Additional biological information such as reliable aging information and information on invertebrate life-histories would be required to enable full assessments to be extended across all stocks. Secondly simply treating stocks as fully assessed and ‘data-rich’ or unassessed and ‘data-deficient’ masks a spectrum of data availability; just because a stock does not have a full assessment this does not mean there is no data available for the stock. The range of data available for ‘data-deficient’ stocks ranges from almost having a complete assessment to only very limited landings data. Thirdly in many cases not all of the data specified under the DCF was made available to the formal stock assessment working groups, or data that was provided was considered unrepresentative or unreliable. As noted above complete data reporting would not immediately allow full assessment coverage, but full data reporting would allow some assessments to be upgraded to a full assessment and in other cases would allow the nature and quality of advice on stock status to be improved.

3. EUROPEAN APPROACHES TO ASSESSMENT AND MANAGEMENT ADVICE FOR DATA-DEFICIENT FISHERIES

KEY FINDINGS

Before 2012 ICES only provided **qualitative advice** for data-deficient stocks that could not be assessed in relation to **MSY** based management **reference points**. **Data-limited assessment methods** were applied on an **ad hoc basis** as there was **no guidance** to support application of data-limited methods.

Since 2006 the **European Commission** has been developing an increasingly **formalised framework** for making management decisions for data-deficient stocks on the basis of **qualitative assessments and catch advice**.

Following a request from the European Commission, ICES established a programme of work to **develop** data-deficient **assessment methods** and data-limited **management control rules**. This lead to the development of the ICES **data limited stocks approach** (DLS) that was applied for the first time in **2012**.

The DLS approach identified that simply classifying stocks as data-rich or data-limited was an **over simplification** and that lots of useful data and information was **not being fully utilised**. Under the DLS approach stocks are assigned to one of 6 **data categories** ranging from fully assessed data-rich stocks to by-catch species with almost no information. The DLS approach acknowledges that for data-deficient stocks managing on the basis of **limited data** is preferable to taking no action due to the lack of perfect data.

The DLS **stock categories** are defined on the basis of **data availability**. Different stock **assessment procedures** and **management control rules** are proposed for each data category. Uncertainty increases moving down through the data categories. The basis of the management control rules also varies across data categories ranging from decision in respect of **MSY proxies** through to **common sense** rules with no specific biological foundation.

Management strategy evaluation (MSE) is a powerful simulation method for testing the robustness of paired data-deficient assessment methods and management control rules to uncertainty. Limited MSE evaluations have been applied to date to the ICES DLS approach.

Within the **GFCM region** management decision for data-deficient stocks are taken on an **ad hoc** basis. A variety of data-deficient methods are applied in the GFCM region; stock assessments are almost exclusively confined to assessments of **fishing mortality rate** and assessment of stock biomass is not conducted.

The challenge of managing data-deficient stocks can be addressed either by improving the assessment of data-deficient stocks or by altering the nature of management advice required to utilise existing data-deficient assessment methods within the management process. These two components can be considered separately in relation to ‘data-deficient assessment methods’ and ‘data-deficient management advisory procedures’. In this section the data-deficient assessment and data-deficient management advisory procedures that have been applied in the EU are presented; the two aspects are considered separately.

3.1. Data-Deficient Assessment Methods in European Waters

ICES provides scientific fish stock assessments and management advice for European fisheries in the Baltic and north east Atlantic to the European Commission. In this role ICES is the primary body conducting scientific assessments and evaluating management options for fish stocks under European management. STECF also provides scientific assessments of stocks and management options. STECF provides an annual report on the status of fishery resources relevant to the European Community, however for stocks covered by ICES, the STECF reflects the ICES assessments and advice unless specifically requested by the Commission to re-evaluate stocks that have been addressed by ICES.

The General Fisheries Commission for the Mediterranean (GFCM) is the competent authority for managing fishery resources in the Mediterranean and Black Sea and the primary body responsible for scientific assessments of stocks. Due to the limited extent of stock assessments conducted by the GFCM, the STECF has established an Expert Working Group on Assessment of Mediterranean Stocks to provide technical support and resources to improve assessment coverage in the Mediterranean and Black Sea Regions.

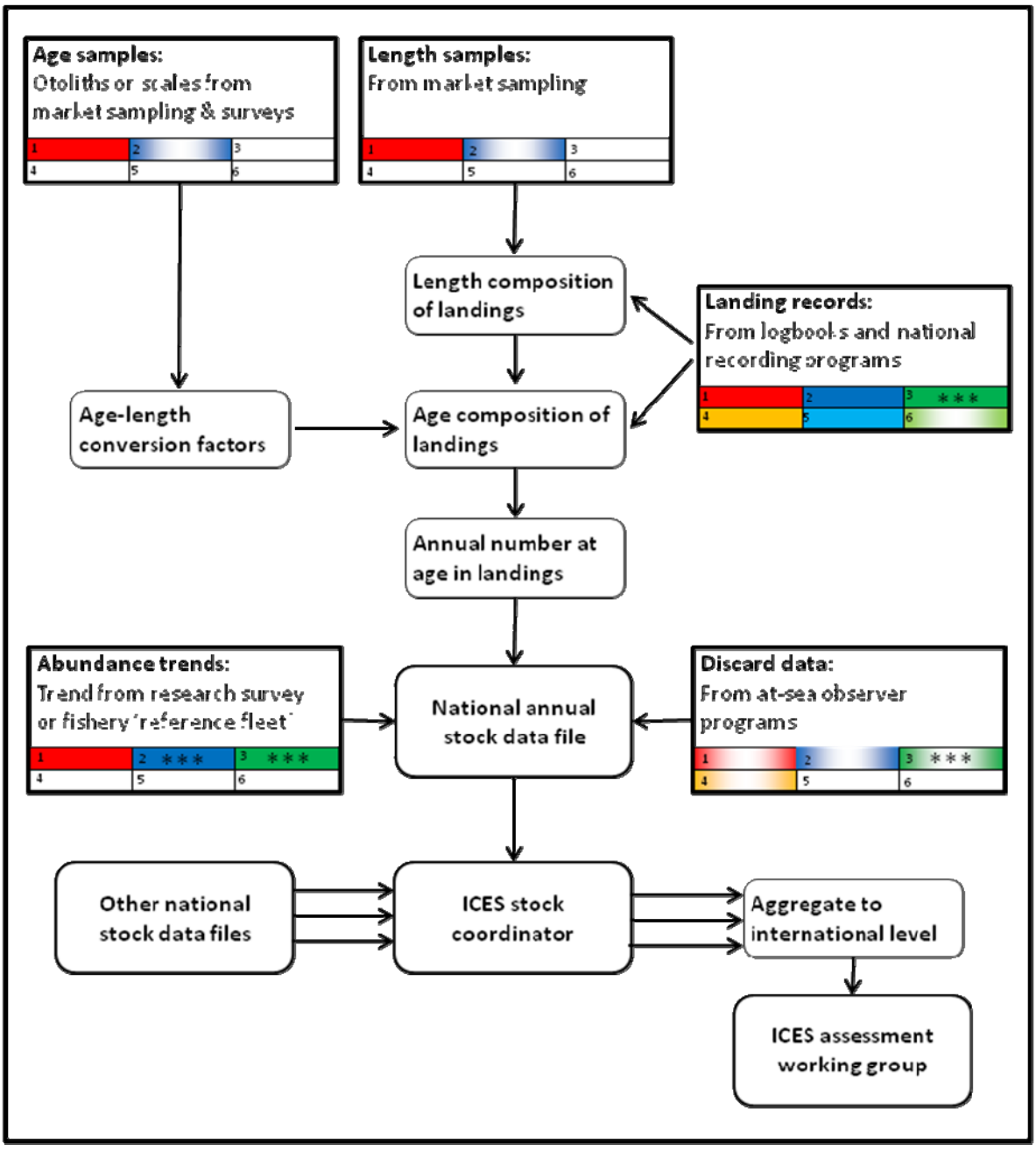
Prior to 2012 ICES only provided quantitative management advice for stocks that were fully assessed, and of the approximately 200 stocks that ICES provides advice for 122 were without quantitative forecast and advice. However in 2012 ICES started providing quantitative catch advice for data limited stocks on the basis of its new Data Limited Stocks (DLS) approach. The introduction of quantitative advice based on the DLS approach has marked a significant change in the advice provided by ICES for data limited stocks, and the approaches used before and after the introduction of the new advice will be considered separately.

Stock assessments in ICES are conducted by working groups on the basis of data supplied to the working group by Member States' national data co-ordinators for stocks specified by the Data Collection Framework (DCF). In order to provide advice in relation to MSY reference points, stock assessment groups will attempt to apply 'data-rich' age- or length- based assessment models to the stocks under consideration on the basis of available data and to some extent the time and expertise available. For each stock an assessment model is applied and the ability of the model to 'fit' the data evaluated to decide whether to accept or reject the model. If an assessment model is accepted the model will be used to provide quantitative 'data-rich' advisory outputs. In the case that the model fit is not accepted, or an assessment model is not applied because of data limitations, an alternative assessment model with different data requirements may be applied.

The most common form of assessment model applied by ICES, a virtual population analysis (VPA), requires unbroken time series data on catch by age class, and data on size at age and an abundance trend. If it is not possible to 'fit' a VPA assessment model due to data gaps or data inconsistencies there are other forms of age- or length-based assessment methods that can provide quantitative assessments in relation to MSY objectives and that use the available data in more flexible formats (Table 2). Applying other assessment methods of this form may enable stocks that would otherwise be considered data-deficient to be fully assessed and considered to be 'data-rich'. Although these other styles of age or length-based assessments can use data more flexibly they are still data intensive methods and only provide limited additional coverage for data-deficient stocks.

Figure 11: Schematic diagram of the data pathways to enable data-rich stock assessment by ICES

The numbered coloured boxes refer to the data required for different ICES data-limited methods. Data required for 'full' assessment are red (box 1). The number in the boxes refers to the different ICES DLS stock data categories (Table 2). If a box is filled with a solid colour the data is required for inclusion in the stock data category, if a box is partially filled the data is an optional requirement, if the box contains stars only relative trend information is needed.



Source: Authors

For stocks that do not have age or length based data, surplus production models and related delay-difference models, are the only alternative approaches that can be applied to provide MSY based advice (Table 2). Surplus production models only require time series catch and relative abundance data and may be more widely applicable than age-based methods for data deficient stocks. However, although surplus production models only require limited data inputs they require a long time series of data showing periods of both stock increase and decrease to be accurately applied, and appropriate time-series are absent for many stocks.

ICES only makes limited use of surplus production models. In 2012 a surplus production model was only used to assess white and black bellied angler fish (*Lophius piscatorius* and *Lophius budegassa* respectively) in the Bay of Biscay and Iberian waters, two stocks that are managed with a single combined TAC.

Table 2: Summary overview of the main categories of data-limited and data-rich assessment methods available. Non-age structured models have more limited data requirements than the age-structured models.

Model Type	Minimum data requirements	Management advice
Non-age structured models		
Catch only		
No population dynamics, trend analysis	Catch data	Very limited advice regarding state of catch trends
Time series analysis		
No population dynamics, trends analysis of catch and abundance data	Catch and relative abundance time series data	Qualitative advice on population trend and possible advice on catch limits in relation to abundance targets under some additional assumptions
Surplus production model		
Dynamic model of aggregate population biomass, no age structure	Catch and relative abundance time series data	Advice on stock abundance and harvest rates in relation to MSY objectives, but no information on population age-structure
Delay-difference model		
Dynamic model of aggregate population biomass except population structure into two age-classes	Catch and relative abundance time series data, life-history information on growth and natural mortality	Advice on stock abundance and harvest rates in relation to MSY objectives with limited information on age-structure
Age- or length-structured models		
Age-structured production model		
Full age structure	Catch and relative abundance time series data. Natural mortality, weight/fecundity at age, fishing selection pattern	Advice on stock abundance and harvest rates in relation to MSY objectives and information on age-structure
VPA-based model		
Full age structure	Complete catch-at-age and weight-at-age time series data. Abundance time series data.	Complete advice in relation to MSY objectives and forecast evaluations of catch options.
Statistical catch-at-age model		
Full age structure	Catch-at-age and weight-at-age time series data. Abundance time series data. Some missing data allowed	Complete advice in relation to MSY objectives and forecast evaluations of catch options.
Integrated analysis model		
Full age structure (length structured mode can be applied)	Catch-at-age(length) and weight-at-age(length) time series data. Abundance time series data. Some missing data allowed.	Complete advice in relation to MSY objectives and forecast evaluations of catch options.

Source: Adapted from ICES 2012b

For stocks where there is not enough reliable data to allow an age-based or surplus production model to be fitted it is not possible to provide advice in relation to MSY objectives and advice. Prior to the introduction of the ICES data limited stocks approach in 2012, ICES only provided qualitative advice for stocks with no analytical assessments. The data-deficient advice did not provide any information on stock status in relation to MSY objectives and was purely based on a consideration of whether stocks appear to be increasing, declining or stable under current catch rates. For these data-deficient stocks ICES provided qualitative advice on the basis of expert evaluation of the available time series, such as catch trends, or catch and abundance trends in association with any additional information available such as the relative vulnerability of the stock.

The use of catch or landings only data to assess stock status and provide management advice is limited as changes in catches may not reflect similar changes in stock status. For example a decline in catches may reflect a decline in stock abundance, or may just reflect a decline in fishing effort. Similarly if there is a large increase in fishing effort, or a change in fishing behaviour, it is possible for catches to increase whilst the stock abundance is declining. Therefore catch only data can only be used to derive very limited conclusions in support of management.

Combined analysis of catch data and an abundance trend allow a more informed assessment of the impact of fishing on a stock as the condition of the stock is monitored independently of the catches. The catch:abundance ratio provides a relative measure of the level of fishing mortality and catch advice to decrease or increase fishing mortality can be given on the basis of the catch:abudance ratio and trends in stock abundance.

Combined analysis of catch and abundance data requires a reliable relative abundance trend time series. Relative abundance data can come from either fisheries independent surveys or from ‘reference’ fishing fleets. Fisheries independent research surveys are the best source of information for abundance trends as surveys follow a fixed sampling design and the estimated abundance should be a consistent estimate of actual population abundance. Catch-per-unit-effort (CPUE) data from commercial fishing vessels has been used as a source of relative abundance data for fisheries with no independent survey coverage, where it is assumed that the CPUE data provides a measure of abundance (higher catch rates when abundance is high, lower catch rates when abundance is low), however fishery-dependant abundance data is susceptible to producing biased estimates of true abundance. For example, abundance measures from commercial vessels can mask declines if the fishery consistently moves to areas of high resource abundance following depletion of previously fished areas (such as with deep water fisheries), or if the distribution of the stock contracts around a central core area where high catch rates can be maintained. For example the abundance of Canadian and Grand banks cod was incorrectly overestimated prior to the stock collapse as fishing activities used to calculate relative abundance estimates became increasingly concentrated in core areas where catch rates were maintained whilst the area of stock distribution contracted around these core areas.

Trends data on landings, catches, relative abundance or catch:abundance ratio were all applied by ICES in developing qualitative advice on stock status prior to the introduction of the DLS approach. However the advice provided by ICES could not be provided in relation to specified MSY reference points and there was no structured framework for developing advice on the basis of trends analysis so the advice provided was ad hoc and qualitative.

The Commission did not consider the qualitative advice for data-deficient stocks provided by ICES as compatible with the management framework and the desire for quantitative advice. However as data-deficient stocks could not be directly assessed in relation to management

objectives (MSY reference points) ICES did not provide quantitative advice as there was no scientific basis for justifying quantitative advice. Where the Commission required quantitative advice on catch opportunities for data-deficient stocks, the Commission requested STECF to provide quantified catch advice. STECF provided quantified catch options by applying specified harvest control rules to the qualitative trends based advice, rather than applying different data-deficient approaches (see section 3.2).

From this it can be seen that prior to the development of the ICES DLS approach management uncertainty regarding data-deficient stocks was addressed in two ways. Firstly alternative 'data-rich' methods with different data requirements were applied in some instances to cover more stocks with 'data-rich' assessments and secondly in the case of STECF evaluating specified harvest control rules the information requirements of the management system were adapted to the information that was available (i.e. quantified management advice was given without reference to MSY objectives), albeit that this was conducted in a reasonably ad hoc manner.

Following a request from the Commission, ICES established a programme of work to develop data-deficient assessment methods and processes for developing quantified advice. This programme of work considered all three parts of the equation for dealing with data-deficient stocks, i) data availability, ii) assessment approach applied and iii) the development of alternative methods for specifying quantified advice based on data-deficient methods (ICES 2012c, 2013). This led to the introduction of the ICES data limited stocks approach (ICES 2012d). The ICES data-deficient programme of work is ongoing and refinement and revision of the methods is expected. However the work undertaken during the WKLIFE workshops to-date has identified several key points:

- Simply categorising stocks as data-rich or data deficient is too simplistic, more data is available for many 'data-deficient' stocks than is currently used.

- Several different data categories were defined ranging from data-rich through to extremely data-poor (Table 3) to support a structured approach to dealing with data-deficient stocks, different assessment approaches and procedures for developing management advice were specified for each data-category and stocks assigned to data categories to make best use of available information.

- Knowledge of life-history relationships from well known species can be used to infer life-history parameters for less well known species enabling the definition of life-history based MSY proxy reference points for data-deficient stocks.

- Formal analysis approaches can be applied to stocks with catch and abundance trend data to provide objective methods for establishing catch advice.

- Proposed data-deficient harvest control rules for providing catch advice can be simulation tested through management strategy evaluations to explore the precaution and robustness of proposed harvest control rules.

Although new technical methods for developing reference points or applying time-series analysis for data-deficient stocks were proposed by the ICES work, the main emphasis of the work was to develop a more structured approach to providing catch advice for data-deficient stocks. The categorisation of stocks under the ICES DLS approach (Table 3) reflects a hierarchy of methods that can be applied as data availability decreases. Therefore conclusions on the state of stocks and level of fishing pressure become less certain as one goes down the categories. Similarly the ability to provide specific management advice

declines as one goes down the table from mechanistic assessments in relation to MSY objectives for data-rich stocks, through to advice on sustainable yields for stocks with survey-based assessments and 'down' to simple common sense based rules for data-poor and by-catch stocks. Different methods for analysis and subsequent rules for providing management advice were specified for each stock category.

Table 3: Information requirements of the different DLS categories, parenthesis indicate optional data requirement.

Data category primary data-requirements are shown in figure 10. 1 Either available, or can be assumed zero. 2 If landings or catches are unreliable, directional qualitative data can be used.

ICES stock category	Information required					
	Population estimate	Survey data	Fishing mortality	Biomass	Discards	Landings
1: Data rich – Full analytical assessment and forecast used for advice	√	√	√	√	√[1]	√
2: Qualitative assessment and forecasts – quantitative assessment and forecast available but they are only considered indicative of trends only.	**Trend**	**(√)**	**Trend**	**Trend**	**(√)**	√
3: Survey-based trends assessment – surveys are reliable indicators of trends, but no quantitative assessment is available		**Trend**	**trend**	**Trend**	√[1,2]	√[2]
4: Catch data available over a short time series					√[1]	√
5: Data poor – only landings data available					**(√)**	√
6: By-catch or negligible landings – stocks with landings that are negligible in comparison to discards or part of stock complexes and caught primarily as by-catch in target fisheries						**(√)**

Source: Modified from ICES (2013)

Three main technical modifications were proposed by WKLIFE (ICES 2012c, 2013) to ICES data deficient stock assessments. These were:

- life-history based yield-per-recruit and spawner-per-recruit reference points can be applied as direct proxies for MSY reference points in the absence of knowledge of the stock-recruit relationship of a stock.

- time series analysis methods (e.g. Depleted-Correct Average Catch, MacCall (2009)) can be used within objective formulaic advice setting procedures.

- catch-curve analysis methods can be used to estimate fishing mortality in the absence of alternative data. (Catch-curve analyses assume that the length distribution of individuals in the catch reflects the length distribution of individuals in the population and can be used to infer mortality rates.)

All of these approaches had been previously developed and proposed for use in fisheries management but not previously been formally incorporated into the ICES advisory processes. Limitations with all these methods are well recorded, but their adoption indicates

a change in mindset to developing data-deficient assessments and advice from only using the best knowledge to using all available information in the best way. Although limitations with data-deficient methods are well recorded what is important to understand is how these limitations affect management advice and ultimately the performance of the fishery, and this will be influenced both by the limitations of the assessment method and by the harvests control rules that are applied on the basis of the data-deficient advice. The robustness of harvest control rules to different types of assessment and advice can be analysed by management strategy evaluation (MSE) analysis (see section 3.2).

Despite the incorporation of new technical assessment methods the main development of the ICES DLS approach can be seen as a development in formalising the management process by linking harvest control rules to data-deficient analyses, rather than a technical development in data-deficient approaches per se. The manner in which management advice is applied to data-deficient assessment methods is discussed in section 3.2 below.

The assessment approaches applied in the GFCM area are more limited due to data and resource constraints; data time series are typically shorter than available in the ICES area and there is limited age-reading to allow calculation of age-based data on the basis of direct age sampling. Where age or length based assessments are applied this is on the basis of converting length data to age data via the application of growth formulae. Assessments in the GFCM area are almost exclusively conducted solely in relation to exploitation (F) with almost no stocks assessed in relation to biomass. 29 stocks have been assessed by the GFCM since 2010 and 30 stocks assessed by STECF. Given the range of stocks to be assessed, state of current assessment in the GFCM area and available resources, stocks are not assessed on an annual basis.

Due to the lack of full age-based assessments and calculation of stock-recruit relationships almost no stocks in the GFCM area are assessed in relation to direct MSY reference points and are instead based on a yield-per-recruit life-history based proxy for MSY. As no stock-recruit relationships have been satisfactorily defined biomass reference points can not be calculated as the population size leading to impaired recruitment can not be defined.

The assessment methods applied by the GFCM and STECF in the GFCM area could be almost entirely defined as ‘data-deficient’ approaches. Due to the lack of direct age information nearly all the assessments use a form of cohort slicing to estimate catch numbers-at-age from catch numbers-at-length. The estimated catch at age information is then used to estimate fishing mortality rates directly on the basis of a catch curve analysis or by applying the catch-at-age information in a VPA style analysis. Additionally for some stocks with sufficient survey coverage a survey based assessment approach is applied (Beare *et al*. 2005). There is very limited application of production models in the GCFM area, the GFCM assesses pink shrimp (*Parapenaeus longirostris*) in GSAs 01, 03 & 04 with a production model. The STECF applied a production model to common octopus (*Octopus vulgaris*) in GSA 5. Unlike the length-based methods applied in the GFCM area, production models can be used to define both exploitation and biomass reference points directly in relation to MSY; the GFCM has defined both biomass and exploitation reference points for pink shrimp on the basis of the production model, whereas the STECF only defined an exploitation reference point for common octopus.

Management in the GFCM area is based on effort controls, as opposed to TAC limits in the ICES area. Currently assessments of stock status provided by the GFCM and STECF are only used to provide qualitative statements regarding fishing opportunities. The GFCM currently does not have a formalised approach to determining fishing opportunities on the basis of assessment advice.

3.2. Data-Deficient Management Advice in EU Waters

Since 2006 the Commission has published annual policy statements defining the principles and approach that will be applied for setting fishing opportunities for the following year (e.g. Com(2006) 499 final). In these policy statements the Commission sets out the approach that will be applied for both fully assessed stocks and data-deficient stocks. The approach that the Commission has laid out for setting fishing opportunities for data-deficient stocks has developed over the course of the seven years that annual policy statements have been published. Starting from the 2006 policy statement that laid out general provisions for setting fishing opportunities for data-deficient stocks, subsequent policy statements have proposed an increasingly formalised framework for setting fishing opportunities for data-deficient stocks and increasingly stringent restrictions on fishing opportunities for stocks without quantitative scientific advice. At the same time there has been greater acknowledgement and more formalised allowance for quantitative scientific advice to be based on a range of methods drawing on differing quantities and quality of data, although as uncertainty increases more caution is used in setting fishing opportunities in accordance with the precautionary principle.

In relation to data-deficient stocks the 2006 policy statement (Com(2006) 499 final) simply stated that for stocks without assessments, but where evidence strongly suggests the stocks are outside safe biological limits TACs will be set at levels that do not allow an increase in fishing mortality rates, and for stocks where the status is unknown but not considered at high risk there should be no expansion of fisheries. The approach for setting TAC advice for stocks without quantitative assessments was developed in the 2007 policy statement (Com(2007) 295 final) to translate qualitative advice on status to specific catch options. In summary this approach stated that for stocks that were qualitative considered to be increasing the TAC should increase by 15%. For stocks considered to be declining the TAC should decrease by 15%. Where a specific catch level was advised the TAC should move towards this level in steps of up to 15% per year, and where the advice is that stocks are depleted and lowest possible catches to be taken the largest reduction in TAC compatible with mixed fishery considerations will be proposed.

The specification of approaches for setting fishing opportunities for data-deficient stocks become more formalised in subsequent policy statements with the introduction of specified stock categories with associated TAC definition rules in the 2008 policy statement (COM(2008) 331 final). The reasoning behind the introduction of specified management controls for data-limited stocks was that qualitative advice should be taken as seriously as quantitative advice and that valuable non-quantified statements about the state of a stock have to be translated into practical measures.

Two points should be noted in relation to this approach to defining management advice for data-deficient stocks. Firstly all stocks were treated as either data-rich (assessed) or data-deficient and there was no discrimination between different levels of ‘data deficiency’ and the same approach was applied in all cases despite the varying levels of knowledge associated with the different data-deficient stocks. Secondly the measures proposed (e.g. 15% TAC reduction) were established on the basis of a common sense pragmatic approach rather than through specific scientific analysis. There is no specific scientific reason to cut TACs for declining species by 15%, and for non-assessed stock there is no way of knowing what the response of the stock will be, however a 15% TAC reduction is considered sufficiently large that it could have a notable effect and the response of the population can be evaluated in future assessments. In other words for data-deficient stocks management decisions are made regarding the sustainability of fishing without specific reference to MSY objectives. Whilst this does not meet with the strict formal requirements for managing

stocks in relation to MSY it is a pragmatic example of applying management to meet the broad policy objectives within the context of the precautionary approach.

To support improvement in the provision of data and scientific advice for data-deficient stocks in 2011 the Commission proposed an automatic 25% reduction in fishing opportunities for stocks without scientific advice and put pressure on Member States to fulfil their data collection and reporting obligations under the Data Collection Framework (Com (2011) 298 final). The Commission also tasked scientific agencies to develop assessment methods and associated robust harvest control rules for data-deficient stocks to ensure sustainable management in data-deficient situations.

In response to the Commission's request, ICES established a programme of work to develop data-deficient assessment methods (see section 3.1) and associated advisory procedures to provide quantitative catch advice for each of the stock data categories (Table 2). In 2012 ICES provided quantitative catch for data-deficient stocks for the first time. Prior to the development of these methods ICES had only provided qualitative advice for data-deficient stocks. Different approaches for developing catch advice are implemented for each of the different stock data categories (the full procedures are presented in ICES 2012d), some of the methods have been tested by simulation, others require further simulation work, and some are based on common sense.

The basic principle behind the definition of the catch advice procedures for the different stock categories is to provide quantitative advice that is consistent with the MSY approach, but based on assessments that do not support direct analysis of stock status in relation to MSY objectives. For some of the data categories it is possible to define MSY proxies (e.g. yield-per-recruit based F_{MSY} proxies for some category 2 and 3 stocks) and harvest control rules can be developed that operate within the MSY framework, albeit that greater uncertainty is associated with these approaches than with a full assessment. Where MSY proxies can not be defined, advice is developed to ensure stock sustainability and sustainable yields rather than maximum sustainable yield. To reflect the lack of direct MSY based assessment and increased uncertainty associated with data-deficient methods, the harvest control rules are specified within a precautionary framework to ensure that advised exploitation rates are more conservative than F_{MSY}. As such the definition of the data-deficient harvest control rules are not a development of technical data-deficient assessment methods, rather data-deficient methods for providing quantified catch advice codify the management advice rules that are applied to stock without full assessments. Codifying the provision of data-deficient catch advice, or data-deficient harvest control rules, is beneficial as it:

- allows even treatment of data-deficient stocks across the management area,
- provides transparency in the decision making process,
- provides more certainty in quota allocation
- allows the assessment procedure and associated harvest control rule to be simulation tested.

Although different procedures for developing advice are applied to each stock data category within the ICES DLS approach there are two over-arching principles that apply across all the procedures, these are related to uncertainty and precaution:

- Uncertainty cap: as data-deficient methods are expected to be more susceptible to noise than full assessments a change limit of ±20% compared to the previous year's advice is applied.

- Precautionary buffer: in accordance with the precautionary principle a precautionary margin of -20% in TAC is applied for all stocks where stock status or exploitation rate is not known in relation to quantitative reference points. Exceptions to this rule can be made in cases where expert judgement determines that a stock is not reproductively impaired, or where there is evidence that stock size is significantly increasing or exploitation is significantly declining. When the precautionary buffer is applied catch advice is held constant for a number of years (unless new information is available) to allow a clear signal in the stock response to develop.

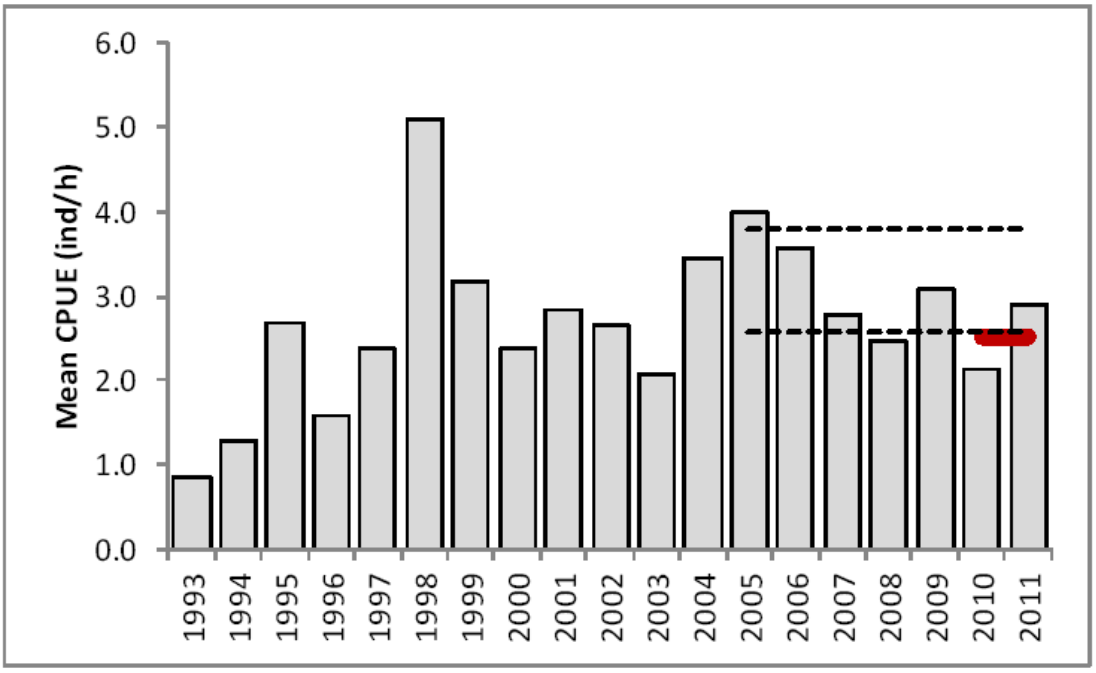
In cases where both the uncertainty cap and precautionary buffer are applied the precautionary buffer is applied after the uncertainty cap has been applied.

An example of the application of the ICES data-deficient framework is presented for small-eyed ray (*Raja microocellata*) in the Celtic Sea (ICES divisions VIIf,g) (ICES 2012e, Advice book 5, Section 5.4.43.7). Advice for fishing opportunities for small-eyed ray was developed on the basis of a survey based abundance trend. No reference points are available for this stock. Under the ICES data-deficient framework this stock is categorised as a Category 3 stock and catch advice is calculated using method 3.2.0 (ICES 2012d). For stocks with survey abundance data only catch advice is calculated by multiplying the catch from the previous year by the ratio of the average survey abundance for the last 2 years compared with the average survey abundance of the previous 5 years and then the uncertainty cap and the precautionary buffer applied. In the case of small-eyed ray in ICES division VIIf,g the average survey abundance for the last 2 years was 21% below the average of the previous five years (Figure 11). As the survey abundance had declined by more than 20% the uncertainty cap was applied and the reduction in catch opportunity 'capped' at 20%, then the precautionary buffer of an additional 20% reduction was applied. The final catch advice is therefore calculated as a 36% reduction in catch (100 x 0.8 x 0.8) compared to the previous year's estimated catch.

Management strategy evaluations (MSE) provide a framework for testing data-deficient assessment methods and associated harvest control rules (e.g. Butterworth *et al*. 2010). The concept of an MSE is that a core 'operating model' that models the dynamics of a stock in relation to fishing impacts is set up within the MSE model on the basis of 'perfect' information. A separate management sub-model is then established that emulates the data collection, assessment and management procedure (complete with error and uncertainty) and this is used to control fishing in the operating model. The 'true' response of the stock can be monitored in response to the emulated assessment and management procedure. The 'pseudo' sampling data that is used in the management sub-model reflects the actual 'poor' information that is provided to assessors and managers. Therefore MSE provides a powerful framework for testing the potential response of a real stock to data limited assessments and management advice, and comparative simulations can be run using different harvest control rules, different assumptions about the underlying stock dynamics, or by allowing the management sub-model to operate on the basis of different levels of knowledge.

Figure 12: Catch per unit effort (CPUE) survey abundance for small-eyed ray from the UK (E&W) VIIa,f BTS survey.

Dashed line indicates the mean annual CPUE for 2005-2009 +/- 1 standard deviation. The red line shows the mean annual CPUE for 2010-2011.



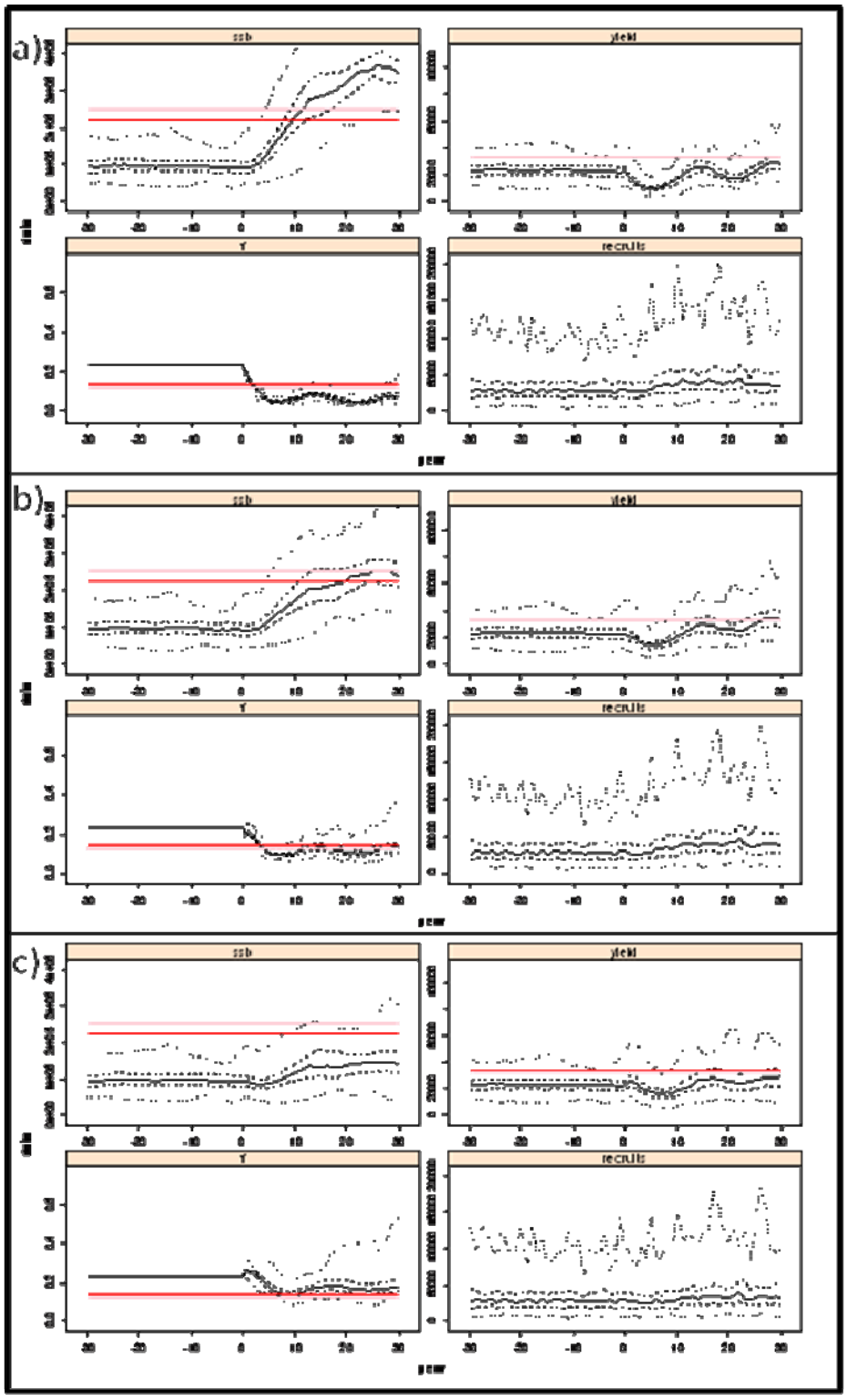
Source: ICES (2012e)

Outputs of an MSE assessment of proposed category 3 advisory procedure (Figure 12) demonstrates the performance on the advisory procedure for managing a previously over-exploited stock, and the implications of bias in the assessment on the performance of the management procedure. When the advisory procedure was emulated without a bias in the assessment (Figure 12 b) the advisory procedure leads to fishing at F_{MSY}, and allows the stock to rebuild above B_{MSY} and yields increase to MSY. However when bias in the assessment is incorporated into the MSE, either a bias to under estimate individuals in the stock (Figure 12 a) or to over estimate individuals in the stock (Figure 12 c) the advisory procedure fails to achieve MSY. Although the assessment and advisory procedure is susceptible to bias, in both of the scenarios incorporating bias the application of the advisory procedure and harvest control rule leads to increases in stock abundance and yields compared with the status quo conditions, albeit not to the MSY level. Therefore although not perfect the assessment and advice procedure may be considered sufficiently robust to potential bias to provide a sufficient 'better' option.

An alternative example of an MSE assessment of a proposed advisory procedure examined the application of a catch curve analysis to define the reference points for a category 3 stock (Figure 13). In this instance the advisory procedure continually identifies the stock as overfished and reduces the TAC to zero. Therefore it may be concluded that the assessment method and advisory procedure are not appropriate and need to be revised and re-evaluated before application.

Figure 13: Simulation MSE evaluations of the proposed data category 3 advice procedure for different levels of assumed bias in the assessment.

In each set of plots the figures show the response of stock abundance (top left), fishing mortality (bottom left), yield (top right) and recruitment (bottom right) to the introduction of the harvest control rule imposed at year 0 (mid-point on x-axis) for a stock that was previously overexploited. In panel a) it is assumed there is a bias leading to the assessment under counting individuals, in panel b) it is assumed there is no bias in the assessment, and in panel c) it is assumed there is a bias leading to the assessment over counting individuals in the stock.

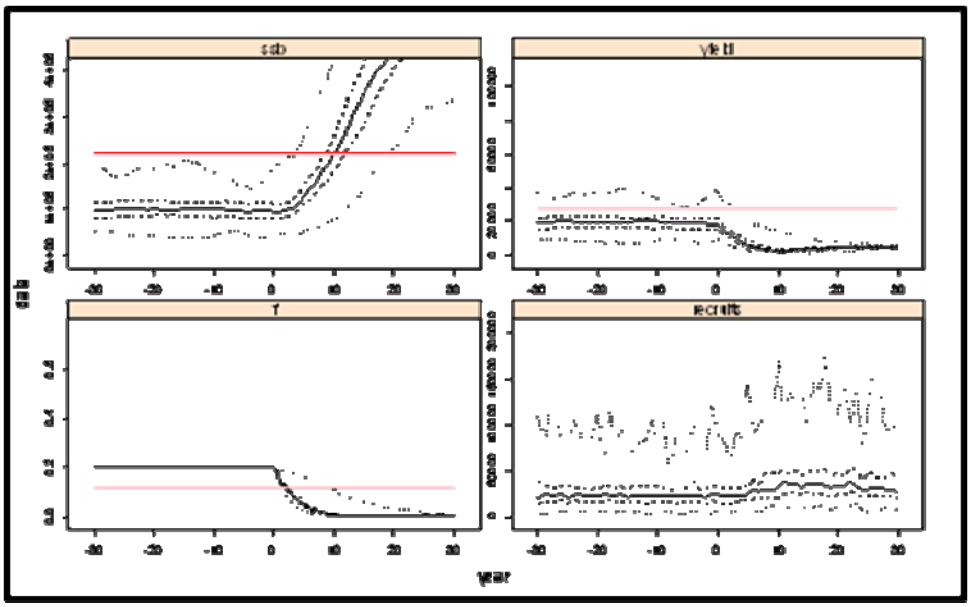


Source: De Oliveira *et al*. (2012)

To-date simulation testing has only been conducted for some of the linked assessment and advisory procedures incorporated in the ICES DLS approach and only for limited scenarios; further simulation testing is planned on a prioritised basis. Rigorous MSE simulation testing of the ICES DLS advisory procedures should be conducted to assess the robustness of the advisory procedures to potential errors and bias in the data, assessment and harvest control rules as MSE provides a method for rigorously assessing the robustness of what are otherwise at times arbitrarily defined rules.

Figure 14: Simulation MSE evaluation of a proposed category 3 advisory procedure based on a catch curve analysis.

The panels show the response of stock abundance (top left), fishing mortality (bottom left), yield (top right) and recruitment (bottom right) to the introduction of the harvest control rule imposed at year 0 (mid-point on x-axis) for a stock that was previously overexploited.



Source: De Oliveira *et al*. (2012)

4. INTERNATIONAL APPROACHES TO DATA-DEFICIENT FISHERIES.

KEY FINDINGS

Data-deficient fisheries are **a challenge in all regions**. There are **fundamental similarities** in the approaches to data-deficient fisheries assessment and management in all regions.

Australia and the USA categorise stocks into a **hierarchy of data categories** and apply different assessment and management procedures for the different data categories.

Increasing levels of **precaution** are applied as **uncertainty** increases to try and establish an **even level of risk** across all data categories or assessment types.

In all regions different **reference points** are evaluated depending on the data available for assessment.

Evaluation of assessment methods and harvest control rules by **management strategy evaluation** is widely applied to asses the robustness of management strategies to uncertainty.

Australia explicitly attempts to seek a balance between the **costs** of data collection and assessment with the **benefits** of improved assessment to ensure **cost effective fisheries management**.

Data-deficient fisheries are a challenge in all fisheries management regions. A range of different assessment methods and management procedures are in operation internationally. However despite these differences there are many fundamental similarities to the different data-deficient stock assessment approaches applied. The similarities arise as data-deficient fisheries present essentially the same issue in different regions although it may be in a slightly different context, and because through international collaboration and comparison no area or region has developed data-deficient stocks assessment and management in isolation. The main drivers leading to different approaches to data-deficient fisheries internationally is the nature of different data-collection regimes leading to different data being available in different regions, variation in management requirements between regions, and variation in resources available for data collection analysis and assessment.

A few different international approaches to data-deficient stock assessment and management are highlighted below.

4.1. United States of America

Beyond 3 nautical miles fisheries management is conducted at the federal level, fisheries management is implemented by eight Regional Fishery Management Councils. The reauthorisation of the Magnuson-Stevens Fishery Conservation and Management Act in 2006 specified that annual catch limits (ACLs) are set for all stocks covered by fishery management plans in relation to MSY criteria for over fishing. For each stock an over fishing limit (OFL) is defined, this is the maximum yield that can be removed by fishing at F_{MSY}. The acceptable biological catch (ABC), which is lower than the OFL, is defined taking account of scientific uncertainty to provide a 'buffer' between the OFL and ABC. Finally ACLs are set on the basis of the ABC and additional considerations such as stock rebuilding plans and socio-economic considerations. In essence defining OFLs and ABCs is a technical scientific

challenge, whereas defining the ACLs (i.e. TACs) takes account of management considerations.

The requirement of the reauthorized Magnuson-Stevens Act for ACLs to be established for all stocks on the basis of scientific recommendations has initiated the development and formalisation of data-deficient methods in the USA. For example, as of 2010 less than 30% of stocks considered by the Pacific Fisheries Management Council had been assessed (Ralston *et al*. 2011). The National Marine Fisheries Service has conducted separate reviews of data-poor and data-moderate stock assessment methods to establish a set of endorsed data-deficient assessment methods. Details of the stock assessment methods considered and review panel comments are contained in the review reports (NMFS 2012).

Stocks are defined in relation to three tiers of data availability, data-rich (tier 1), data-moderate (tier 2) and data-poor (tier 3). Data-poor stocks are categorised as stocks for which only catch (or landings) data are available, and data-moderate stocks have both catch (or landings) data and a time series of abundance data (e.g. from a scientific survey series). For tier 2 stocks it is possible to conduct assessments that allow OFLs to be defined in relation to the policy objectives, however in the case of tier 3 stocks it is not possible to provide advice directly in relation to policy objectives, although advice in relation to possible sustainable yields can be provided. The national guidelines for implementation of the Magnuson-Stevens Act (NMFS 1998) specifies proxies that should be used for data-moderate and data-poor stocks and the default reference points values that should be used unless alternative proxies or reference point values are justified. Some management strategy evaluation simulation testing has been conducted for linked data-deficient assessment methods and associated control rules, but more extensive simulation testing is called for (NMFS 2011).

4.2. Australia

The management of commercial species taken in Australia's Commonwealth fisheries is conducted within the framework established by the Commonwealth Fisheries Harvest Strategy Policy and Guidelines. The Harvest Strategy Policy (HSP) establishes the objective to ensure the sustainability of key commercial stocks; the main biological objective is to maintain fish stocks, on average, at a biomass level equal to the stock size required to produce maximum economic yield. (Maximum economic yield is a higher biomass level than the stock sizes that produces maximum sustainable yield.) Harvest strategies must specify both a process for monitoring and assessment of stock status, and control rules that regulate the intensity of fishing according to stock status defined by the assessment.

Information is limited and high levels of uncertainty are associated with many Australian stocks. The HSP acknowledges that in many cases it may not be possible to directly evaluate stocks in relation to reference points specified by the HSP. Scientifically defensible proxies for reference points and corresponding control rules are required to be specified for data-deficient stocks.

The HSP Guidelines specify that full quantitative assessment of all stocks is not expected and instead a risk based approach should be applied to ensure that fisheries are managed at an acceptable level of risk. The HSP Guidelines also specify that legislative requirement for cost effective and efficient fisheries management and that during the development of harvest strategies the costs associated with data collection and assessment should be evaluated. It is therefore accepted that for low value fisheries management may have to remain precautionary and low levels of research initiated to match the management costs with the business environment of the fishery.

To address data-deficient stocks with variable levels of associated information a tiered approach to data collection, assessment and control rules is encouraged. The tiered approach should provide increasingly levels of precaution in association with increasing levels of uncertainty about stock status to ensure the level of risk is approximately constant across all tiers.

The HSP Guidelines specify some proxies that can be applied in data-deficient situations. It is acknowledged in some circumstances it will not be possible to apply the proxies, in these cases alternative approaches should be formulated. The alternative approaches need to be consistent with the principles of the HSP and tested using a management strategy evaluation.

To support a cost effective risk based evaluation of the effects of fishing on commercial stocks and other ecosystem components CSIRO in Australia has developed and applied a hierarchical ecological risk assessment framework to assess the effects of fishing that has been applied to over 30 fisheries (Hobday *et al*. 2011). Australian marine biological resources have only limited coverage by scientific surveys. This provides a specific challenge for data-deficient assessments of fishing impacts and stock status. CSIRO has developed a quantitative method for assessing the sustainability of fishing impacts on diverse data-deficient stocks using a susceptibility and overlap approach to assessing fishing impacts on stocks (Zhou *et al*. 2009, Zhou *et al*. 2011).

The HSP and associated Guidelines encourages the application of management strategy evaluation in the development of harvest strategies, particularly when information is incomplete or imprecise. It is acknowledged that management strategy evaluations are technically demanding and time intensive process so that in instances harvest strategies will have to be implemented before full evaluations have been completed; in these instances the harvest strategy should undergo subsequent evaluation following implementation of the strategy.

4.3. New Zealand

The Harvest Strategy Standards (HSS) for New Zealand Fisheries and associated Operational Guidelines provides a statement of standards for setting fishery and stock targets and limits for fish stocks managed under New Zealand's quota management system. Harvest strategies should specify target and limit reference points and management actions associated with meeting targets and avoiding limits. The HSS and associated guidelines provide guidance on how fisheries policy should be implemented in practice in a consistent and transparent manner. The HSS aims to formalise and standardise alternative approaches based on differing data availability whilst maintaining sufficient flexibility to address the unique aspects of each fishery. The HSS specifies that stock targets and limits should be set more conservatively for stocks with lower levels of information or higher levels of uncertainty.

The biological objectives for New Zealand fisheries policy are to maintain stocks on average at levels consistent with achieving MSY, 'soft' and 'hard' limits are set in relation to lower biomass levels. The HSS specifies that where possible stocks biomass and fishing mortality rates should be set in relation to MSY-consistent reference points. Where specific MSY based reference points can not be defined 'analytical' proxies or 'conceptual' proxies for MSY reference points should be defined. Analytical proxies for MSY reference points are quantitative surrogates that are based on theoretical modelling studies or meta-analyses of data-rich stocks. Conceptual reference points are qualitative proxies that are not directly linked to theoretical understanding of population dynamics but embrace the spirit and intention of policy objectives. Analytical proxies are generally applicable in 'data-moderate'

situations, and conceptual proxies are generally applicable in 'data-poor situations. Initial default values for the analytical and conceptual reference points are specified.

The HSS makes reference to the application of management strategy evaluations, but their application is not mandatory. However it is noted that management strategy evaluations can be applied to evaluate the probability of meeting targets or avoiding limits associated with different management strategies.

Although the HSS and associated Operational Guidelines set out a framework for a formalised and consistent approach to defining management reference points and assessment approaches for data-deficient stocks, many inshore fish stocks are assessed on the basis of ad hoc evaluations of trends in available data such as catch-per-unit-effort indices from commercial fishery operations or abundance indices from scientific surveys.

4.4. NAFO

NAFO (Northwest Atlantic Fisheries Organisation) is a regional fisheries management organisation that is the competent authority for the management of fishing and fishery resources in the NAFO Regulatory Area which covers international waters in the northwest Atlantic. NAFO manages 11 species in relation to MSY objectives within the Precautionary Approach.

Data-rich stocks are assessed with variations of an age-based virtual population analysis approach. Stock production models are applied to stocks with sufficient catch and abundance data. Data-poor stocks are assessed on the basis of ad hoc assessments of trends in catch, abundance, CPUE or catch:abundance ratio. For most data-deficient stocks no specific reference points are defined.

5. EVALUATION OF EUROPEAN APPROACHES TO DATA-DEFICIENT FISHERIES

KEY FINDINGS

Assessment and management advice for data-deficient stocks in European **Atlantic and Baltic** waters has recently undergone a **significant development** with the introduction of the ICES **data limited stocks approach**.

The data limited stocks approach provides a **clear framework** for assessing and advising on data-deficient stocks and thus provides more **certainty, stability and clarity** to setting catch opportunities for data-deficient stocks.

The data limited stocks approach is a **state-of-the-art framework** for assessing and advising on data-deficient stocks. The data-deficient assessment methods applied are broadly consistent with state-of-the-art approaches however **not all methods have been fully evaluated**.

The overall data limited stocks approach has **not been evaluated** to ensure a consistent approach to **risk and precaution** across the data categories.

Rough comparison suggests that the condition of many data-deficient stocks in European waters is **broadly similar** to that of assessed stocks.

Lack of resources has been one of the main challenges affecting the application of stock assessments within the GFCM area and only a limited range of data-deficient assessment methods have be evaluated.

No formal data-deficient management procedures have been defined in the GFCM area.

The evaluation of European approaches to the assessment and management of data-deficient fisheries will focus on fisheries in European Atlantic and Baltic waters under direct European management, and less focus given to evaluating the approaches applied by the GFCM in the Mediterranean and Black Sea as this lies outside the area of exclusive European management.

The evaluation of the European approach to data-deficient fisheries will be considered separately in relation to the data-deficient assessment methods applied and the data-deficient management procedures applied. The evaluation of the European approach to data-deficient fisheries is challenging due to the recent changes that have taken place, and are ongoing, in relation to the introduction of the ICES DLS approach. 2012 was the first year that the ICES DLS approach was applied and it is expected to be further developed and refined in 2013 and following years.

In summary the ICES DLS approach marks a significant step forward in managing data-deficient fisheries in European waters. The DLS framework has only been applied for 1 year and requires significant further development, evaluation and refinement before it is fully established. However the DLS approach marks a significant step forward as it provides a framework for integrating data-limited assessment method and data-limited management advice procedures. These two factors are closely related and some of the previous perceived failings associated with management of data-deficient stocks in European waters have resulted from a lack of connection between the development of assessment methods and advisory procedures. Similarly the introduction of the ICES DLS approach signifies a change

in mindset from *only* conducting quantified assessments when the required data is available, to conducting quantified assessments with the data *that is* available with a variety of different methods applicable to different data circumstances.

The DLS approach provides a clear framework for assessing and advising on data-deficient stocks and thus provides more certainty and stability to catch opportunities, and increases transparency in the management process. Coupling data-deficient assessment methods with management procedures allows formal management strategy evaluation procedures to be conducted to evaluate the robustness of different procedures to uncertainty.

The DLS framework provides a clear and structured approach to the management of data-deficient stocks and can be seen as a state-of-the-art framework to the management of data-deficient stocks. The assessment methods currently applied under the DLS approach are broadly consistent with state-of-the-art methods applied internationally, although these methods are constantly developing. However the whole DLS approach has not be rigorously tested to ensure a consistent approach to risk and precaution and further evaluation is required.

A rigorous assessment of the success of the management of data-deficient stocks is by definition challenging and a detailed analysis beyond the scope of this study. However, of the 23 stocks assessed under the ICES DLS approach in 2012 in relation to MSY proxies or biomass trends (data categories 2 & 3) 44% were considered to be stable or increasing. Similarly a recent assessment of the status of fully assessed data-rich stocks in European Atlantic and Baltic waters found that in 2010 44% of stocks were fished at levels consistent with objectives for fishing mortality (Cardinale *et al*. 2013). Whilst not a complete analysis, this indicates that the state of data-deficient stocks may be broadly comparable with the state of fully assessed stocks, and that the main challenges associated with successful fisheries management in Europe in recent years have not been dominated by the quality and nature of stock assessments. However as increasing steps are taken to set fishing opportunities in line with scientific advice the quality of data and nature of stock assessments may become a more dominant factor.

5.1. Evaluation of assessment methods

Prior to the introduction of the ICES DLS approach qualitative advice was only provided for stocks with full analytical assessments. Qualitative advice was provided on the basis of the ad hoc application of a limited number of data-deficient methods. One of the main reasons that ICES only provided qualitative advice for data-deficient stocks was the lack of guidance on how to provide quantitative advice with regards to management objectives. In other words there was a disconnection between development of data-deficient assessments and the development of management procedures.

The development of the DLS approach provides a structured approach for developing quantitative management advice on the basis of different forms data-deficient stock assessments. The DLS approach now provides a structured framework that can incorporate a greater range of data-deficient methods in support of developing quantitative advice. The incorporation of reference points based on life-history characteristics and catch-curve analysis are examples of new assessment methods that have been incorporated within the DLS approach. Not all data-deficient methods that are applied internationally are used within the ICES DLS approach or have been fully evaluated for their suitability.

The introduction of the DLS approach has enabled the assessment and advisory system to make better use of the data that is available, however not all data that is collected is currently used. This is due to not all data that is collected being reported and due to resource limitation amongst assessment working groups. The introduction of the DCF has formalised data-reporting requirements. No member states are entirely compliant with requirements of the DCF. Improved data reporting would in many cases improve the quality of assessments and in cases would allow stocks to be elevated to higher data categories and assessed using more robust methods.

5.2. Evaluation of management procedures

Prior to the introduction of the ICES DLS approach management advice for data-deficient stocks was based on semi-arbitrary control rules that advised specified decreases or increases in catch opportunities depending on the perceived status of data-deficient stocks. These management procedures had been developed based on pragmatic management criteria with little direct linkage to theoretical understanding of stock dynamics.

The development of the DLS approach provides a structured method for developing management advice based on the different assessment methods associated with different data availability. Where possible the management procedures are linked to theoretical understanding of population dynamics, albeit that the links to theoretical understanding of population dynamics declines through the data categories.

Do the management procedures apply the precautionary approach? There are two ways in which the precautionary approach is applied within the ICES DLS approach; the application of the 'precautionary buffer' and testing proposed management procedures through management strategy evaluation.

The 'precautionary buffer' is a blanket reduction in the advised catch limit of 20% that is applied to all stocks for which quantitative catch advice is provided without reference to known reference points. The value of a 20% reduction was selected on arbitrary grounds; whilst this provides a pragmatic starting point more explicit methods for quantifying and allowing for uncertainty could be assessed (e.g. Ralston *et al*. 2011).

Management strategy evaluations allow the robustness of proposed management procedures to be evaluated in the light of uncertainty. Testing management procedures therefore can form a key part of the precautionary approach. To date a limited set of management strategy evaluations have been conducted for certain combinations of assessment methods and management procedures within the DLS framework. However, not all methods incorporated within the DLS framework have been evaluated, nor has the framework as a whole been evaluated to ensure a consistent approach to risk and precaution across the whole DLS framework.

5.3. Data-deficient assessment and management in the GFCM

Lack of resource has been one of the main challenges affecting the application of stock assessments within the GFCM area, and much of the available data has not been incorporated into stock assessments conducted by the GFCM. This is borne out by the additional assessments of stocks within the GFCM area that have been conducted by the STECF. Virtually all of the stock assessments within the GFCM can be considered data-deficient as they are not assessed in relation to both fishing mortality and biomass reference

points. The coverage of stocks has increased over recent years, however only a limited range of data-deficient methods have been applied or evaluated in the GFCM area.

Fisheries within the GFCM area are based on effort control rather than TAC limits. The management advice for most stocks is qualitative in nature and no specific management control rules are in place. The data-deficient procedures in the GFCM area have not been evaluated by management strategy evaluation.

5.4. Beyond data-deficient stocks

This study has considered the nature of data-deficient fisheries in terms of single species stock assessments. While stock assessments are key component of the information required by fishery manager they are not the total of required information. The full extent of the information required varies depending on the management levers applied and the range of objectives that are incorporated into management decisions.

As environmental impacts of fishing and socio-economic considerations incorporated into fishery management objectives, due to requirements under the Marine Strategy Framework Directive and the Habitats Directive, additional streams of information are required to inform evidence based management decisions.

Effort based management regimes and effort based management plans require information on the relationship between fishing activity (by area and season) and the resulting catches, in addition to information on stock status and acceptable levels of catches. Similarly determining the relative catch rates of different stocks could become a key feature of the evaluation of management plans consistent with the discard ban.

Policy developments in relation to the discard ban, incorporation of environmental objectives and implementation of an ecosystem approach will increase the data and information requirements needed to support informed fisheries management. Ensuring that fisheries assessments can live up to these additional expectations will require rigorous prioritisation of effort and resources within a risk based framework to focus the available resources on the key areas of concern. Furthermore it should be ensured that the resources available to fisheries data collection and assessment are sufficient to meet political expectations and objectives.

6. RECOMMENDATIONS FOR ACTIONS IN RELATION TO DATA-DEFICIENT FISHERIES

KEY RECOMMENDATIONS

1. **Ensure compliance with the Data Collection Framework.**
2. **Define target data categories for managed stocks on the basis of strategic prioritisation.**
3. **Evaluate management procedures through a rigorous management strategy evaluation to ensure procedures are robust to uncertainty.**
4. **Evaluate management procedures to ensure there are no perverse incentives to degrade data provision.**
5. **Define acceptable risk thresholds for management decisions.**
6. **Ensure political objectives are consistent with resources available for implementation.**

1) Ensure compliance with data collection regulations:
No member states are entirely compliant with the European fisheries Data Collection Framework. For nearly all data-deficient stocks improved data reporting would improve the basis upon which management advice is provided and would allow many data-deficient stocks to be assessed under a higher data category.

2) Conduct a strategic ranking of target data categories for managed stocks:
It may not be feasible, or desirable, for all stocks to be elevated to a data-rich status. Similarly it may not be necessary for all stocks to be data-rich in order to meet political objectives for fisheries management. A strategic stock ranking could be conducted to specify target data categories for different stocks to ensure proportionate and cost effective data collection and assessment. Definition of stock target data-categories could be based on a combined utility and risk assessment to ensure. The strategic evaluation should also consider the required frequency of assessments.

The utility assessment would evaluate the balance between the costs associated with data collection and assessment, and the additional fishing opportunities that may be achieved as the result of a more data intensive and sophisticated stock assessment. The risk assessment would evaluate the relative vulnerability of stocks to fishing evaluated on the basis of a productivity and susceptibility analysis. The risk assessment would support fulfilling the requirements of the precautionary approach as stocks considered more vulnerable to over fishing could be identified for particular attention. It should be noted that for some of less abundant and vulnerable stocks it may never be practically possible to elevate these stocks beyond the data-poor data category due to the limited numbers of individuals encountered either by commercial fishing operations or by research surveys.

3) Evaluate management procedures through a rigorous management strategy evaluation to ensure management processes are robust to uncertainty:
Management strategy evaluations provide a powerful tool for assessing the robustness of combined data-deficient assessment methods and management procedures to uncertainty. Management strategy evaluations can form a key element of ensuring that the management procedures are consistent with the precautionary approach. Management procedures for data-deficient stocks in management plans should be rigorously evaluated using

management strategy evaluations including national management plans developed under Article 19 of regulations for fisheries management in the Mediterranean (EC 1967/2006).

4) Evaluate management procedures to ensure there are no perverse incentives to degrade data provision:

The range of assessment and management procedures applied to different data-categories of stocks should be evaluated to ensure that degrading data provision does not lead to increased fishing opportunities. If fishing opportunities were greater for stocks assessed through data-deficient procedures than if they were subject to 'data-rich assessments there could be an incentive for data provision to be compromised to increase fishing opportunities. The full range of assessment and management procedures applied to different data categories of stocks should be evaluated to ensure a consistent approach to uncertainty and precaution.

5) Define acceptable risk thresholds for management decisions:

Addressing data-deficient fisheries requires both scientific evaluations and management decisions. Defining acceptable risk thresholds for management is a decision for managers rather than a scientific task, although scientific analyses can inform the choice of acceptable risk thresholds. Managers need to define acceptable risk thresholds in order to allow stock assessments and analyses of catch options and control rules to be developed and evaluated against the defined risk threshold. The definition of appropriate risk thresholds is necessary to ensure that the management procedures are consistent with the precautionary approach.

6) Ensure political objectives are consistent with the resources available for implementation:

Data collection, collation and stock assessment demand time and resource. Access to resources already hampers i) full use of collected data, ii) application of the appropriate data-deficient assessment methods to all stocks, and iii) the further development and evaluation of data-deficient assessment methods and management procedures. The resource requirements associated with data collection and assessment should be considered in establishing the target data categories and assessment frequency of managed stocks to ensure that political objectives are consistent with the resource available for implementation.

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ANNEX I. DATA ANALYSIS PROCEDURE

The analysis of the proportion of landings, by weight and value, covered by full assessments used the STECF data on landings by weight and value provided by Member States for the 2012 DCF fishing fleet economic data call. The STECF data set is the only collated data set that provides landings data by weight and value at a sufficient level of disaggregation to enable the analysis. Species for which the total value of landings across the EU was less than 1000 Euros per year were excluded from the analysis.

The data set provides data on landings by weight and value, by species, by area, by vessel length class and gear type. To enable analysis of assessment coverage by species category each stock was defined i) according to the species category (pelagic, demersal, deep water, invertebrate) according to the stock categories listed in Annex II, and ii) defined as a 'TAC stock' or 'non-TAC stock' according to the list of stocks managed under TACs listed in Annex III. To enable additional analysis of assessment coverage by region each landing record was categorised according to the Regional Advisory Council region it came from.

To analyse the proportion of landings coming from fully assessed or data-deficient stocks, each stock in the STECF landings data was classified as assessed or not-assessed by cross referencing the landings data with information from ICES, STECF, GFCM and ICCAT stock assessments. Stocks were classified as 'fully assessed' if they are assessed in relation to defined MSY based fishing mortality and biomass reference points, otherwise they were classified as not assessed and data poor.

For the annual ICES advice the catch advice provided, and published, in one year relates to the advised catch options for catches that will be taken the following year. For example, the assessments and advice conducted, and published, in 2010 relate to the catch options that can be taken in 2011. In the analysis the data are presented in relation to the year that landings occurred, rather than the year in which the advice was published.

In the GFCM region stocks are assessed in relation to 30 separate geographical sub-areas (GSAs), however the STECF landings data is only available for the Black Sea as a whole or by three different sub-basins in the Mediterranean. To resolve this scale incompatibility, all the landings from a sub-basin were classified as assessed if one of the GSA stocks in a sub-basin was assessed. This will lead to a biased overestimate of the proportion of landings from the Mediterranean that comes from assessed stocks.

ANNEX II. SPECIES CATEGORY LIST

Stock categorisation used for stock assessment coverage analysis. Deep water species defined as per Annexes I and II of the deep-sea access regulations (EC 2347/2002). The pelagic and industrial stocks category covers the main pelagic and industrial stocks, including small and large pelagics. The demersal category all fish species not considered in the previous categories. 'nei' means 'not elsewhere identified'.

Deepwater Species			
Alfonsino	Blue ling	Greenland shark	Portuguese dogfish
Alfonsinos nei	Bluntnose sixgill shark	Gulper shark	Rabbit fish
Arctic skate	Common mora	Japanese catshark	Roughhead grenadier
Atlantic thornyhead	Conger eels nei	Kitefin shark	Round ray
Baird's slickhead	Deep-sea red crab	Knifetooth dogfish	Roundnose grenadier
Birdbeak dogfish	Deep-water catsharks	Leafscale gulper shark	Silver scabbardfish
Black cardinal fish	European conger	Lings nei	Splendid alfonsino
Black dogfish	Forkbeard	Longnose velvet dogfish	Straightnose rabbitfish
Black scabbardfish	Forkbeards nei	Mediterranean slimehead	Tusk(=Cusk)
Blackbelly rosefish	Frilled shark	Mouse catshark	Velvet belly
Blackmouth catshark	Great lanternshark	Norwegian skate	Wreckfish
Blackspot(=red) seabream	Greater argentine	Orange roughy	
Demersal Species			
African striped grunt	Dogfishes nei	Monkfishes nei	Sichel
Allis and twaite shads	Dusky grouper	Moras nei	Sillago-whitings
Allis shad	Eelpout	Morays	Silver hake
Amer. plaice(=Long rough dab)	Escolar	Mottled grouper	Silversides(=Sand smelts) nei
American angler	European barracuda	Mugil spp	Silvery John dory
Angelshark	European eel	Mullets nei	Sind danio
Angler(=Monk)	European flounder	Murex	Small-eyed ray
Anglerfishes nei	European hake	Mytilus spp	Small-spotted catshark
Angolan dentex	European perch	Northern pike	Smooth-hound
Angular roughshark	European plaice	Norway pout	Smooth-hounds nei
Annular seabream	European seabass	Nursehound	Sockeye(=Red)salmon
Asp	European smelt	Ocean sunfish	Solea spp
Atlantic bumper	European whitefish	Oceanic puffer	Soles nei
Atlantic cod	False scad	Offshore rockfish	Sompat grunt
Atlantic gobies nei	Finfishes nei	Oilfish	Southern rays bream
Atlantic halibut	Flatfishes nei	Orfe(=Ide)	Spectrunculus grandis
Atlantic pomfret	Flathead grey mullet	Painted comber	Spinefeet(=Rabbitfishes) nei
Atlantic redfishes nei	Four-spot megrim	Pargo breams nei	Spiny butterfly ray
Atlantic salmon	Freshwater bream	Parrotfish	Splitfins nei
Atlantic searobins	Freshwater breams nei	Percoids nei	Spotted flounder
Atlantic wolffish	Freshwater fishes nei	Picarel	Spotted ray
Axillary seabream	Gadiformes nei	Picarels nei	Spotted seabass
Ballan wrasse	Garfish	Picked dogfish	Squeteague(=Gray weakfish)
Barracudas nei	Gilthead seabream	Pike-perch	Stargazer
Basketwork eel	Gobies nei	Pilotfish	Stargazers

Basking shark	Golden grey mullet	Piper gurnard	Starry ray
Bastard grunt	Golden redfish	Plain bonito	Starry smooth-hound
Big-scale sand smelt	Goldfish	Pollack	Sticklebacks
Black goby	Great barracuda	Pomadasys spp	Stingrays nei
Black scorpionfish	Greater amberjack	Pompanos nei	Streaked gurnard
Black seabream	Greater forkbeard	Pontic shad	Surmullet
Blackbellied angler	Greater weever	Poor cod	Surmullets(=Red mullets) nei
Blackspotted smooth-hound	Green jobfish	Porbeagle	Swallowtail seaperch
Blonde ray	Greenland halibut	Porgies, seabreams nei	Tench
Blotched picarel	Grey gurnard	Pouting(=Bib)	Thickback sole
Blue butterfish	Grey triggerfish	Pricklebreast poacher	Thickback soles
Blue runner	Groundfishes nei	Rainbow trout	Thicklip grey mullet
Blue shark	Groupers nei	Raja rays nei	Thinlip grey mullet
Blue skate	Groupers, seabasses nei	Ratfishes nei	Thornback ray
Bluespotted seabream	Grunts, sweetlips nei	Rays and skates nei	Thresher
Boe drum	Gulf menhaden	Rays, stingrays, mantas nei	Thresher sharks nei
Bogue	Gurnards nei	Red bandfish	Tiger shark
Boxlip mullet	Gurnards, searobins nei	Red gurnard	Tocantinsia depressa
Brazilian groupers nei	Haddock	Red mullet	Tope shark
Brill	Hairtails, scabbardfishes nei	Red pandora	Torpedo rays
Brown meagre	Hakes nei	Red porgy	Transparent goby
Brown ray	Hammerhead sharks nei	Red scorpionfish	Triggerfishes, durgons nei
Brown wrasse	Hapuku wreckfish	Redbanded seabream	Trouts nei
Burbot	Jacks, crevalles nei	Requiem sharks nei	Tub gurnard
Canary drum (=Baardman)	John dory	River eels nei	Turbot
Canary tonguesole	Knout goby	Roach	Turbots nei
Carangids nei	Large-eye dentex	Rock cook	Two-spotted goby
Caspian shad	Largehead hairtail	Rocklings nei	Undulate ray
Catsharks, etc. nei	Large-scaled gurnard	Roughsnout grenadier	Various sharks nei
Catsharks, nursehounds nei	Leaping mullet	Rubberlip grunt	Vendace
Centroscymnus spp	Leerfish	Ruffe	Vimba bream
Chub mackerel	Lefteye flounders nei	Saddled seabream	Wedge sole
Comber	Lemon sole	Saithe(=Pollock)	Weeverfishes nei
Combers nei	Ling	Salema	Weevers nei
Common carp	Longbill spearfish	Sand gaper	Wels(=Som)catfish
Common dab	Longfin gurnard	Sand smelt	West African goatfish
Common dentex	Longnose spurdog	Sand sole	White bream
Common eagle ray	Longnosed skate	Sand steenbras	White grouper
Common pandora	Lowfin gulper shark	Sandy ray	White hake
Common sole	Lumpfish(=Lumpsucker)	Sargo breams nei	White seabream
Common stingray	Lusitanian toadfish	Scorpionfishes nei	White skate
Common two-banded seabream	Madeiran sardinella	Scorpionfishes, rockfishes nei	Whitefishes nei
Crest-tail catsharks nei	Marbled electric ray	Scyliorhinidae,Dogfishes and hounds nei	Whiting
Croakers, drums nei	Marine fishes nei	Sea lamprey	Witch flounder

Crucian carp	Marlins, sailfishes,etc. nei	Sea trout	Wolffishes(=Catfishes) nei
Cuckoo ray	Meagre	Seabasses nei	Wrasses, hogfishes, etc. nei
Damselfish	Mediterranean moray	Senegalese hake	Zebra seabream
Deep-sea smelt	Mediterranean rainbow wrasse	Senegalese sole	
Deep-water rose shrimp	Mediterranean sand smelt	Shagreen ray	
Demersal percomorphs nei	Mediterranean spearfish	Sharks, rays, skates, etc. nei	
Dentex nei	Mediterranean starry ray	Sharpnose sevengill shark	
Dogfish sharks nei	Megrim	Sharpsnout seabream	
Dogfish sharks, etc. nei	Megrims nei	Shi drum	
Pelagic Species			
A. rochei, Frigate and bullet tunas	Blue jack mackerel	Herrings, sardines nei	Shortfin mako
Albacore	Blue marlin	Jack and horse mackerels nei	Skipjack tuna
Argentine	Blue whiting(=Poutassou)	Little tunny(=Atl.black skipj)	Swordfish
Argentines	Bluefish	Mediterranean horse mackerel	True tunas nei
Atlantic bluefin tuna	Boarfish	Pelagic fishes nei	Tunas nei
Atlantic bonito	Boarfishes nei	Pelagic percomorphs nei	Twaite shad
Atlantic herring	Bullet tuna	Round sardinella	Wahoo
Atlantic horse mackerel	Chilean jack mackerel	Sandeels(=Sandlances) nei	White trevally
Atlantic mackerel	European anchovy	Sardinellas nei	Yellowfin tuna
Atlantic sailfish	European pilchard(=Sardine)	Scomber mackerels nei	Yellowtail amberjack
Bigeye tuna	European sprat	Seerfishes nei	
Black marlin	Frigate tuna	Shads nei	
Invertebrate Species			
Alloteuthis spp	Donax clams	Mediterranean slipper lobster	Scarlet shrimp
American yellow cockle	Edible crab	Midsize squid	Sea mussels nei
Antarctic scallop	European common squid	Musky octopus	Sea snails
Atlantic surf clam	European flat oyster	Natantian decapods nei	Sepiolidae, Cuttlefish, bobtail squids nei
Banded carpet shell	European flying squid	Neon flying squid	Sevenstar flying squid
Barnacle	European lobster	Noah's ark	Shortfin squids nei
Bean solen	European razor clam	Northern prawn	Slipper lobsters nei
Blue and red shrimp	European squid	Northern quahog(=Hard clam)	Smooth callista
Blue mussel	Flat oysters nei	Northern shortfin squid	Solenocerid shrimps nei
Blue-leg swimcrab	Gastropods nei	Norway lobster	Solid surf clam
Broadtail shortfin squid	Giant red shrimp	Octopuses nei	Southern pink shrimp
Caramote prawn	Golden shrimp	Octopuses, etc. nei	Spinous spider crab
Caribbean spiny lobster	Great Atlantic scallop	Oval surf clam	Spiny lobsters nei

Carpet shells nei	Great Mediterranean scallop	Pacific calico scallop	Spottail mantis squillid
Cephalopods nei	Green crab	Pacific cupped oyster	Squids nei
Chilean nylon shrimp	Grooved carpet shell	Palaemonid shrimps nei	Squillids nei
Chinese mitten crab	Grooved sea squirt	Palinurid spiny lobsters nei	Stony sea urchin
Clams, etc. nei	Horned and musky octopuses	Pandalid shrimps nei	Striped venus
Cockles nei	Horned octopus	Pandalus shrimps nei	Surf clams nei
Common cuttlefish	Hunter shrimp	Pearly razorfish	Sword razor shell
Common edible cockle	Inshore squids nei	Penaeus shrimps nei	Tellins nei
Common European bittersweet	Japanese carpet shell	Periwinkles nei	Thomas' rapa whelk
Common octopus	King crabs, stone crabs nei	Pink cuttlefish	Tuberculate abalone
Common periwinkle	Knobbed triton	Pink spiny lobster	Undulate venus
Common prawn	Kuruma prawn	Pod razor shell	Variegated scallop
Common shrimp	Lesser slipper lobster	Portunus swimcrabs nei	Various squids nei
Common spiny lobster	Lobsters nei	Pullet carpet shell	Veined squid
Common squids nei	Manila clam	Purple dye murex	Velvet swimcrab
Crangon shrimps nei	Marine crabs nei	Queen scallop	Venus clams nei
Craylets, squat lobsters	Marine crustaceans nei	Razor clams nei	Warty crab
Cupped oysters nei	Marine molluscs nei	Razor clams, knife clams nei	Warty venus
Cuttlefishes nei	Mature dosinia	Red crab	Whelk
Delta prawn	Mediterranean mussel	Scallops nei	

ANNEX III. TAC STOCKS LIST

List of TAC stocks used for the analysis of the coverage of TAC stocks by assessments.

Common name	TAC Unit	Common name	TAC Unit
Anchovy	IX,X,CECAF 34.1.1.	Norway lobster	VIIIc
Anglerfish	VII	Norway lobster	VIIIabde
Anglerfish	IIa (EC), North Sea (EC)	Norway lobster	IX and X; EC waters of CECAF 34.1.1
Anglerfish	VIIIabde	Norway lobster	VI; EU and international waters of Vb
Anglerfish	VIIIc,IX,X,CECAF 34.1.1	Norway lobster	VII
Anglerfish	Vb (EC), VI, XII, XIV	Norway lobster	VII - Porcupine Bank special condition
Boarfish	VI, VII, VIII EC	Norway pout and associated by-catches	IIIa; EU waters of IIa and IV
Cod	VIIb,c,e-k, VIII,IX,X,CECAF 34.1.1 (EC)	Other species	EU waters of IIa, IV, VIa north of 56°30'
Cod	Skagerrak	Plaice	Sub-divisions 22-32
Cod	Kattegat (IIIa(S))	Plaice	VIIbc
Cod	IV; Union waters of IIa; that part of IIIa not covered by the Skagerrak and Kattegat	Plaice	VIIde
Cod	VIId	Plaice	VIIfg
Cod	VIa	Plaice	VIIhjk
Cod	VIb (Rockall subunit) …	Plaice	IV; EU waters of Iia; that part of IIIa not covered by the Skagerrak and Kattegat
Cod	VIIa	Plaice	Kattegat
Combined quota	Vb, VI, VII (EC) [Norway quota]	Plaice	Skagerrak
Dab and flounder	IIa (EC), North Sea (EC)	Plaice	VIII,IX,X,CECAF 34.1.1
Grenadier (roundnose)	I, II, IV	Plaice	VIIa
Grenadier (roundnose)	EU and international waters of III	Plaice	Vb (EC waters), VI, XII, XIV
Grenadier (roundnose)	EU and international waters of Vb, VI, VII	Pollack	VII
Grenadier (roundnose)	EU and international waters of VIII, IX, X, XII, XIV	Pollack	VIIIabde
Haddock	VIIb-k, VIII, IX, X, CECAF 34.1.1 (EC)	Pollack	VIIIc
Haddock	IIa (EC), IV (EC)	Pollack	IX,X,CECAF 34.1.1 (EC)
Haddock	IIIa, EU waters of subdivisions 22-32	Pollack	Vb(EC), VI, XII, XIV
Haddock	EU and international waters of Vb,VIa	Porbeagle	all areas

Common name	TAC Unit	Common name	TAC Unit
Haddock	EU and international waters of VIb, XII, XIV	Redfish (deep pelagic)	EU and international waters of V; international waters of XII and XIV
Haddock	VIIa	Redfish (shallow pelagic)	EU and international waters of V; international waters of XII and XIV
Hake	VIIIc, IX, X, CECAF 34.1.1 (EC)	Saithe	IIIa and IV; EU waters of IIa, IIIb, IIIc and subdivisions 22-32
Hake	IIa, IIIa, IV / Vb, VI, VII, XII and XIV / VIIIabde	Saithe	VII, VIII, IX, X, CECAF 34.1.1 (EC)
Hake	EU waters of IIa and IV	Saithe	VI; EU and international waters of Vb, XII and XIV
Hake	IIIa, EU waters of subdivisions 22-32	Salmon (Atlantic salmon)	Sub-divisions 22-31
Hake	VI and VII; EU and international waters of vb; international waters of XII and XIV	Salmon (Atlantic salmon)	Sub-division 32
Hake	VIIIabde	Sandeel	EU waters of IIa, IIIa and IV
Halibut (Greenland halibut)	EU waters of IIa and IV; EU and international waters of Vb and VI	Skates and rays	IIa (EC), IV - North Sea (EC)
Herring	VIa Clyde	Skates and rays	IIIa
Herring	Subdivisions 22-24	Skates and rays	VIId
Herring	Sub-divisions 25-27, 28.2, 29, 32	Skates and rays	EC Waters of VI, VIIa-c, VIIe-k
Herring	Sub-division 28.1	Skates and rays	EC waters of VIII, IX
Herring	Sub-division 30-31	Smelt (greater silver)	III,IV EC + int. waters
Herring	VIIef	Smelt (greater silver)	V,VI,VII EC + int. w.
Herring	VIIghjk	Sole (common sole)	VIIbc
Herring	By-catches in IV, VIId and in EU waters of IIa	Sole (common sole)	VIId
Herring	IIIa	Sole (common sole)	VIIe
Herring	IIIa (by-catches)	Sole (common sole)	VIIfg
Herring	IVc, VIId	Sole (common sole)	VIIhjk
Herring	Eu and Norwegian waters of IV N of 53°30	Sole (common sole)	EU waters of IIa and IV
Herring	EU and international waters of Vb, Vib and VIa (N)	Sole (common sole)	IIIa, IIIbcd (EC)
Herring	VIa (S), VIIbc	Sole (common sole)	VIIIab
Herring	VIIa	Sole (common sole)	VIIIcde,IX,X, CECAF 34.1.1 (EC)
Horse mackerel	X; EU waters of CECAF (Azores)	Sole (common sole)	Vb(EC), VI, XII, XIV
Horse mackerel	EU waters of IVb, IVc, VIId	Sole (common sole)	VIIa
Horse mackerel	VIIIc	Sole (lemon sole and witch)	EU waters of IIa and IV
Horse mackerel	IX	Sprat	VIId and VIIe

Common name	TAC Unit	Common name	TAC Unit
Horse mackerel (and associated by-catches)	EU waters of IIa, IVa; VI, VIIa-c, VIIe-k, VIIIabde; EU and international waters of Vb; international waters of XII and XIV	Sprat	Sub-divisions 22-32
Horse mackerel (and associated by-catches)	IIa, IVa, VI, VII, VIIIabde; EU waters of Vb, XII, XIV	Sprat (and associated by-catches)	EU waters of IIa and IV
Ling	IIIa, EC waters of IIIb, IIIc, IIId	Sprat (and associated by-catches)	IIIa
Ling	EU waters of IV	Spurdog	EU and international waters of I, V, VI, VII, VIII, XII, XIV
Ling	EC and international waters of V	Spurdog	EU waters of IIa and IV
Ling	EC and international waters of VI, VII, VIII, IX, X, XII, XIV	Spurdog	IIIa
Ling (blue ling)	EC and international waters of II and IV	Tuna (yellowfin tuna)	Atlantic east of 45° N and Med.
Ling (blue ling)	EC and international waters of III	Turbot and Brill	EU waters of IIa and IV
Ling (blue ling)	EC and international waters of Vb, VI, VII	Tusk	IIIa and EU waters of 22-32
Mackerel	IIIA and IV; EU waters of IIA, IIIbcd	Tusk	EU waters of IV
Mackerel	VI, VII, VIIIabde; EU and international waters of Vb; international waters of IIa, XII, XIV	Tusk	EU and international waters of V,VI,VII
Mackerel	VIIIc, IX, X; Eu waters of CECAF 34.1.1	Whiting	IX and X; EU waters of CECAF 34.1.1
Megrims	VII	Whiting	VIIb-k
Megrims	IIa (EC), IV (EC)	Whiting	IV; EU waters of IIa
Megrims	VIIIabde	Whiting	IIIa
Megrims	VIIIc,IX, X, CECAF34.1.1(EC)	Whiting	VIII
Megrims	Vb(EC), VI, XII, XIV	Whiting	Vb(EC waters), VI, XII, XIV
Northern prawn	EU waters of IIa and IV	Whiting	VIIa
Northern prawn	IIIa	Whiting (blue whiting)	EU and international waters of I to VII; VIIIabde, XII, XIV
Norway lobster	EU waters of IIa and IV	Whiting (blue whiting)	VIIIc, IX, X, EU waters of CECAF 34.1.1
Norway lobster	IIIa; EU waters of subdivisions 22-32		

NOTES

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