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An overall indicator for the good environmental status of marine waters based on commercially exploited species

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ABSTRACT

An indicator is presented to assess and monitor the good environmental status of national marine waters based on the status of commercially exploited marine fishes and invertebrates, including fully-assessed as well as data-limited stocks. The overall-indicator consists of one number per year. It summarizes the following sub-indicators: the stock size relative to the size that can produce the maximum sustainable fishing yield; the mortality caused by fishing relative to the natural rate of mortality; the mean length in the catch relative to the length where 90% of the females reach sexual maturity; and the abundance in national waters relative to mean abundance in the time series. For the example of German marine waters, the overall-indicator shows that only 3 of 19 stocks (Baltic Sea dab, North Sea plaice and North Sea sprat) were above the limit reference point for the overall indicator in 2011. North Sea herring was close to reaching the threshold, but most other stocks were still far below. Apparently fishing mortality was too high to allow recovery of more stocks to levels capable of producing the maximum sustainable yield. The chosen indicators and reference points may prove useful to other scientists tasked with assessing the environmental status of their national waters.

1. Introduction

Conservation of biological diversity has been recognized as a key responsibility of states to preserve or rebuild healthy ecosystems for the wellbeing of current and future generations [5]. A central theme in this context is the application of the precautionary principle in the exploitation of living marine resources and the preservation of the marine environment [35]. Towards this goal, states have developed indicators to assess and monitor the status of biological diversity within their jurisdiction. The overarching legal framework for suitable indicators and reference points for commercially exploited marine stocks is provided by the United Nations Convention on the Law of the Sea [34] and the Agreement for the implementation of the provisions of the United Nations Convention on the Law of the Sea [35]. From a European perspective there are in addition the Marine Strategy Framework Directive of the European Union [25,8] and the 2013 reform of the European Common Fisheries Policy [6].

There have been several attempts to provide indicators for the assessment of the environmental status of European Seas based on the status of commercially exploited species [20,30], albeit with reference points that had no base in fisheries science or in the legal instruments cited above, and which led to unrealistic positive results. Thus, the purpose of this study is to present indicators and reference points for the status of commercial stocks in national marine waters based on the concept of maximum sustainable yield and on the existing legal framework [34,35,25,6]. These indicators are combined into one annual overall indicator and are applied to exploited marine fishes and invertebrates in the territorial waters and the exclusive economic zone (EEZ). Germany was chosen as a test case for the suitability and for the potential results of the proposed indicators.

2. Materials and methods

A detailed presentation of the data, the methods, and the application of the methods to the different stocks was beyond the amount of text, tables and figures acceptable for publication in scientific journals. Such detailed presentation is instead made available as online material ([14], 95 p.).

2.1. Selection of stocks

Over 200 stocks of commercially exploited marine fishes and invertebrates occur in the Northeast Atlantic and about 100 of

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these may occur in German marine waters. However, no stock is endemic to German marine waters and many species occur there only as strays (rare visitors) and are not commercially exploited there. For example, Saithe (*Pollachius virens*) is fished by German fishers in the central and northern North Sea, but it is only infrequently found in the southern North Sea. Similarly, the cod (*Gadus morhua*) stock of the eastern Baltic is important to German fisheries but does not occur in German marine waters. For the purpose of this study only species and stocks that occur regularly in German marine waters and for which suitable data were available were used. The 19 stocks that fulfilled these requirements are listed in Table 1.

2.2. Available data

Annual stock assessments of exploited species in the Northeast Atlantic are done by the respective working groups of the International Council for the Exploration of the Seas (ICES). However, full assessments with indication of stock size, fishing mortality and recruitment are done for only a subset of stocks, including seven of the 19 selected stocks. For the remaining 12 stocks only data on reported landings and data from research surveys were available [14]. For these stocks, approximate parameters (proxies) were used [6], e.g. for stock size, fishing mortality, and respective reference points. For some commercial species that are heavily fished in German waters, such as Brown shrimp (*Crangon crangon*) or Blue mussel (*Mytilus edulis*), no suitable data were found and thus these species could not be included. The only invertebrate species with some suitable data was the Norway lobster (*Nephrops norvegicus*).

2.3. Selection of sub-indicators and reasonable proxies for data-limited stocks

The Marine Strategy Framework Directive [25] of the European Union "establishes a framework within which Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest." A qualitative descriptor for determining good environmental status of exploited stocks is given in Annex I of the MSFD as Descriptor 3: "Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock." The European Commission [8] further specified three indicators for Descriptor 3:

1. The level of pressure of the fishing activity, measured either as fishing mortality F relative to the one associated with the maximum sustainable yield (F_{msy}) or, if F is unknown, the ratio between catch and biomass, with a reference point that is compatible with F_{msy}.
2. The spawning stock biomass (SSB) relative to the one that can produce the maximum sustainable yield (SSB_{msy}) or other suitable biomass indices.
3. The age and size distribution within the population, with the sub-indicators
   i. Proportion of fish larger than the mean size of first sexual maturation;
   ii. Mean maximum length across all species found in research vessel surveys;
   iii. 5% percentile of the fish length distribution observed in research vessel surveys;
   iv. Size at first sexual maturation [relative to historic sizes], which may reflect the extent of undesirable genetic effects of exploitation.

Indicators 1 and 2 of Descriptor 3 were accepted for the purpose of this study and respective estimates or suitable proxies were obtained as described below. Looking at indicator 3 and its four sub-indicators for age and size distribution within a population, sub-indicator ii refers to different species and is thus not suitable for assessing the status of a given population. Sub-indicator iv refers to the reduction in mean size at maturity that is known to occur in many stocks. However, the genetic component of such change acts on a time scales of generations and thus requires sufficiently long time series of maturity data to be detectable. This sub-indicator was therefore not suitable for the short time series that were available for several stocks used in this study. Sub-indicator iii refers to the 95th percentile of fish length distributions in research surveys. This indicator will decline in years with strong recruitment, thus giving a misleading negative signal in response to a positive event [30]. Given these shortcomings of sub-indicators ii–iv, sub-indicator i, referring to the proportion of mature fishes, was chosen as sub-indicator for size and age and implemented as described below.

Table 1
English and scientific names of species, stock delineation and ICES identification code of stocks evaluated in this report. Stocks with full assessments (time series data on *SSB* and *F*) are marked with an asterisk (*) in the last column.

English name	Scientific name	Stock	ICES ID
Cod	*Gadus morhua*	North Sea, Subarea IV, Divison VIId & Division IIIa (Skagerrak)	cod-347d*
		Baltic Sea, Subdivisions 22–24	cod-2224*
Dab	*Limanda limanda*	North Sea, Subarea IV and Division IIIa	dab-nsea
		Baltic Sea, Subdivisions 22–32	dab-2232
Dogfish/Spurdog	*Squalus acanthias*	Northeast Atlantic	spurdog
European eel	*Anguilla anguilla*	Northeast Atlantic	eel-eur
Flounder	*Platichthys flesus*	North Sea, Division IIIa and Subarea IV	fle-nsea
		Baltic Sea, Subdivisions 22–32	fle-2232
Herring	*Clupea harengus*	North Sea, Subarea IV, Divisions VIId & IIIa (autumn-spawners)	her-47d3*
		Baltic Sea, Subdivisions 22–24 and Division IIIa (spring-spawners)	her-3a22*
Norway lobster	*Nephrops norvegicus*	North Sea, Subarea IV	nep-IV
Plaice	*Pleuronectes platessa*	North Sea, Subarea IV	ple-nsea*
		Baltic, Kattegat, Belt and Sounds, subdivisions 21–23	ple-2123
		Baltic, subdivisions 24–32	ple-2432
Sole	*Solea solea*	North Sea, Subarea IV	sol-nsea*
Sprat	*Sprattus sprattus*	North Sea, Subarea IV	spr-nsea
		Baltic Sea, Subdivisions 22–32	spr-2232*
Turbot	*Scophthalmus maximus*	North Sea, Subarea IV and Division IIIa	tur-nsea
		Baltic Sea, Subdivisions 22–32	tur-2232