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Towards ecosystem-based fisheries management in Norway – Practical tools for keeping track of relevant issues and prioritising management efforts

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ABSTRACT

The present paper presents the practical implementation of the Ecosystem Approach to Fisheries Management (EAFM) in Norway. This involves defining management objectives and developing simple and efficient tools to achieve an overview of management needs and prioritise among these, while integrating broader conservation issues and ensuring stakeholder involvement. A new Marine Resources Act entered into force in Norway in 2009. By integrating conservation and sustainable use as basic principles, the law represents a paradigm shift in the management of Norwegian fisheries. The law indicates which concerns should be addressed, but neither how nor how often evaluations should take place. That is for management to decide. A management principle in the Marine Resources Act confers on the Ministry an obligation to evaluate whether continued fishing at the present scale is justifiable, or whether improved management is required to ensure sustainability. A Stock table, and a table of "Catches of data-poor species" constitute a comprehensive system for monitoring the management principle. Along with a Fisheries table, these tables establish a framework for developing an ecosystem-based fisheries management by providing a basis and tools for prioritising the needs of new and/or revised management measures.

1. Introduction

The overall objective of the Ecosystem Approach to Fisheries Management (EAFM), adopted by many governments and international organisations and included in agreements since the 1990s, is to sustain healthy marine ecosystems and the fisheries they support [1,9–13,20,22,8]. According to Pikitch et al. [20] EAFM should, in particular, (i) avoid degradation of ecosystems; (ii) minimise the risk of irreversible change to natural assemblages of species and ecosystem processes; (iii) obtain and maintain long-term socioeconomic benefits without compromising the ecosystem; and (iv) generate knowledge of ecosystem processes sufficient to understand the likely consequences of human actions.

The Ecosystem Approach to Fisheries (EAF) has been adopted by the FAO Committee on Fisheries (COFI) as the appropriate and practical way to fully implement the Code of Conduct for Responsible Fisheries [10,13]. The foremost purpose of the EAF process is to develop and implement an integrated set of arrangements and tools for a fishery to generate more acceptable, sustainable, ecosystem concerned and beneficial community outcomes. Hence the word 'management' is not used in FAO's name of the approach. There are many different definitions of ecosystem-based approaches. All include the need to maintain the ecosystem resources for their sustainable use, and recognise that humans are an integral part of the process. It is hence a way of implementing management that involves a broad set of objectives and a participative and adaptive process. FAO [10,13] presents four main steps as one way forward in the process of planning and implementing EAF. These are: initiation and scope, identification of assets, issues and priorities, development of management system, and implementation, monitoring and performance review.

EAFM calls for a holistic management approach, and successful implementation of EAFM will ultimately depend on finding ways to manage scientific, administrative, and regulatory complexity, as well as effective communication, stakeholder engagement, and simplification [11,21]. Decisions on management objectives for the various species and stocks have turned out to be an important and integral part of the

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development of EAFM [11,22]. Different frameworks have been developed to meet these challenges, including the ERAEF (Ecological Risk Assessments for the Effects of Fishing) developed by Hobday et al. [15,16]. This framework, implemented for Australian fisheries management, includes an initial scoping phase to identify relevant fisheries and management objectives, followed by a comprehensive risk assessment of fisheries and the ecosystem components they affect (31 fisheries, > 1200 species, > 200 habitats). The risk is assessed in a systematic and hierarchical manner, ranging from qualitative assessments with minimal data requirements (level 1), to semi-quantitative assessments (level 2), and finally quantitative assessments with high data requirements (level 3).

In 2009, a new Marine Resources Act entered into force in Norway [3]. The previous act relating to fisheries focused mainly on the commercial exploitation of marine resources whereas the new act applies to all wild living marine resources and genetic material derived from them. Everything that lives in the marine environment – from virus to marine mammals and plants – is thus covered by the scope of application. The act states that its purpose is to ensure sustainable and economically profitable management of the resources, and several provisions describe conservation of biodiversity as an integral part of sustainable management. According to article 7 of the new act, it is mandatory for fisheries management to apply "an ecosystem approach, taking into account habitats and biodiversity" [3]. By integrating conservation and sustainable use as basic principles, the law represents a paradigm shift in the management of Norwegian fisheries.

In the present paper, the practical implementation of EAFM in Norway is considered. While including several of the same steps, and similar consequence scores as in the ERAEF framework [15,16], the Norwegian framework is simpler but found to be efficient. It includes defining management objectives and some simple tools to achieve an overview of management needs and prioritise among these where development of new or revised management measures are most urgently needed, while integrating broader conservation issues and ensuring high stakeholder involvement on a regular basis. The practical implementation of EAFM is thus designed to meet the obligations of article 7 along with others included in the same section of the act, such as the precautionary approach.

2. Management of the economically most important marine resources in an ecosystem-based context

Over the last 20–30 years, there has been a dramatic change in the management of the economically most important marine fisheries resources, resources accounting for approximately 90% of total Norwegian first hand value [13,22]. Most of these stocks are transboundary, Norway sharing its management responsibilities with neighbouring coastal states. The International Council for the Exploration of the Sea (ICES) provides annual advice on Total Allowable Catch (TAC), based on extensive effort in fish stock monitoring and stock assessments. Based on long-term framework agreements, the relevant coastal states – bilaterally or multilaterally as appropriate – conduct annual negotiations where issues like next year's TACs, access to waters, sharing and exchange of quotas, technical regulations, reporting and control, and joint research programs are on the agenda.

The fisheries on the Norwegian share of these stocks are subject to comprehensive national regulations. At the annual Regulatory Meeting in November, discussions with stakeholders on details of next year's regulations take place, before the Director General of Fisheries presents her final proposals for the Minister's decision. The annual regulatory cycle (Fig. 1) with stakeholder participation has been in place since the 1970's, its scope now broadened by the provisions of the new act to include ecosystem and biodiversity related issues.

The setting of TACs based on precautionary management strategies and harvest control rules have since the turn of the century contributed to rebuilding depleted stocks and laid the foundation for improved profitability in fisheries [13,22]. Extensive efforts have also been directed towards improving exploitation patterns and reducing discards and other sources of unwanted mortality [12].

By closing the commons, terminating subsidies and introducing pervasive structural measures, Norway has succeeded in reducing the fishing fleet and halting the growth in fishing capacity [22]. The reduction in number of fishermen and vessels has helped increase productivity and profitability for those remaining in the industry. The industry's economic sustainability is thus considerably strengthened [13]. On the other hand, shrinking numbers of vessels and fishermen have reduced the industry's role in maintaining rural settlement and employment. However, departure from fishing has so far occurred in a period of generally low unemployment and good alternative job opportunities in Norway.

Further development to optimise management of the economically most important stocks in an ecosystem-based context will go along four parallel and inter-connected tracks:

- Increase economic output through further improvements in exploitation patterns and reduction of all forms of incidental and unwanted mortality.
- Optimise long-term economic yield through improvements and revisions of management strategies and harvest control rules.
- Incorporate additional ecosystem considerations as new scientific knowledge becomes available concerning multispecies interactions, effects of fishing on benthic habitats, effects of by-catch of fish, seabirds and marine mammals, etc.
- Keep fisheries profitable through structural policy measures that allow a continued gradual reduction in number of vessels as fishery efficiency increases.

These four bullet points summarise the practical approach to ecosystem-based management of the resources that are of greatest economic importance for the Norwegian fishing industry. The four tracks are inter-connected, and trade-offs have to be identified and agreed as part of the management process such as identification of and including ecosystem consequences of decisions related to the first two bullet points. The third bullet point includes assessment and management decisions regarding economically less important and unimportant species, or habitats. The management of these species follows a different track than the "TAC machine" for the data rich, commercially important species.

3. Management objectives of commercially less important species

In the last three decades, the Norwegian focus has been on rebuilding the economically most important fish stocks. Species of minor economic significance have not been subject to the same research and management efforts. Some of these resources are in a depleted state. As part of the development towards ecosystem-based fisheries management, more attention is now directed towards resources of low economic significance. This widening of focus has taken place since the turn of the millennium. However, the movement is not towards a management regime similar to that used for resources of greater national economic importance. The most important reason for this is that it will not pay as the costs of research, monitoring, management and control needed to optimise yield would exceed the surplus value obtained from an optimally managed stock. Furthermore, in contrast to the large oceanic fish stocks, exploited by a limited number of registered, commercial fishing vessels, the smaller stocks are often coastal resources, exploited in part by a large and unknown number of recreational fishers. Hence, the management and control tasks are significantly more challenging and costly. In accordance with the Precautionary Approach, limited information necessitates a more

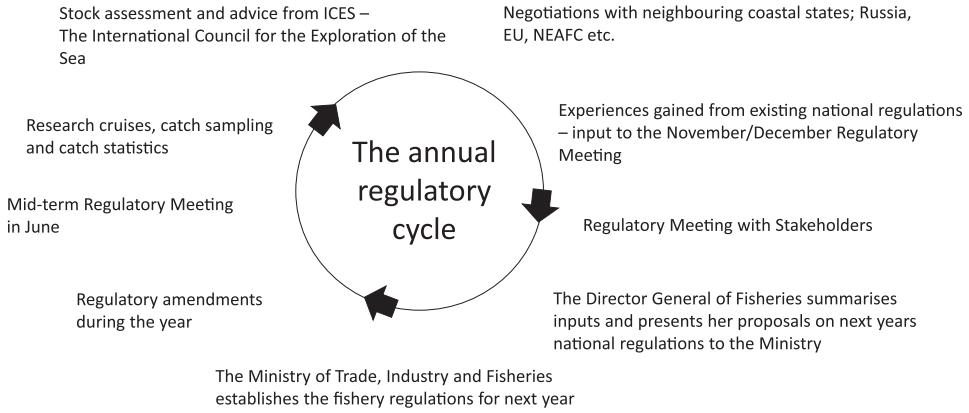

Fig. 1. The annual adaptive regulatory cycle for quota-regulated stocks – the "TAC-machine".

cautious management, implying medium to low fishing pressure until information improves. This is an issue in an ongoing debate with the stakeholders, a debate that on the positive side has led to an increased awareness by stakeholders that funds for management and research are limited, and that priorities have to be made. These priorities then govern any trade-offs that have to be made between profitability and conservation.

The stocks and species that contribute 90% of total Norwegian first hand value from fisheries are managed with the objective of optimising long-term economic yield (Table 1). How and to what extent this objective in future will evolve into revised harvest control rules in each individual case (maximum sustainable yield (MSY), maximum economic yield (MEY), multispecies MEY etc.) remains to be seen. Stocks with some economic importance, but about which information is scarce, are managed with the objective of securing a high, and if possible, stable long-term yield (Table 1). Catches may occasionally be higher, or lower, than would have been regarded as optimal if more information had been available. Such stocks may account for another 5–7% of the total first hand value.

For the many species that constitute the last 3–5% of the total first hand value, no such ambitious objectives are set. Similarly, such objectives do not apply to non-commercial species, including incidental by-catches of seabirds and marine mammals, for which there is no intended catch. However, in compliance with the new Marine Resources Act, the minimum objective, regardless of species, is to protect biological diversity and ecosystem function (Table 1). Deciding on management objectives for the various stocks was an important and integral part of the development towards an ecosystem-based fisheries management. The process, which started in Norway in 2009 by the introduction of the new act, revealed unclear management objectives for many species and stocks. Now that these deficiencies have been rectified, with input from stakeholders obtained in separate and dedicated meetings as well as in the ordinary Regulatory meetings, future revisions of objectives are anticipated only on a case-by-case basis.

Table 1
The management objectives for the various types of Norwegian marine stocks.

Category	Type of stock	Management objectives
1	Economically most important marine fish stocks	Economically optimal long-term sustainable yield
2	Stocks of some economic importance, but about which information is scarce	High and, if possible, stable long-term sustainable yield
3	Stocks of low economic importance and non-commercial species	Ensure biodiversity and ecosystem function
4	Alien species	Reduce stock
0		Unsettled

To operationalise and achieve these objectives, the official Norwegian Red List for Species [14] (see below) has become an important tool or yardstick for management of economically less important species. Species affected by fisheries are managed with the aim of minimizing the risk of future listing, and if already listed management measures are tailored for that particular species to be delisted. Such management measures may include ban on directed fishing, bycatch rules, protected areas, gear restrictions etc.

4. The management principle and its application on data-poor species

Previous fisheries law permitted fishing without any quantitative restrictions (e.g., TAC, gear or effort restrictions) as long as fishing for the species and stocks in question was not explicitly restricted through a specific regulation. During preparation of the new Marine Resources Act, discussions arose whether this legal situation should continue, or if all fishing should be subject to prior scientific assessment and specific regulations. In practical terms, the latter position would imply a significant obstacle to some smaller, directed fisheries, as well as a general problem with by-catches from data-deficient stocks. There would be a need to prioritise scientific resources to such stocks as well as increase the amount of management resources to develop and implement specific regulations. However, since both scientific and management resources are limited the resources available for these species would most likely be too small to secure an effective implementation comparable to the more economically important fisheries. The solution to this dilemma was a compromise called "The Management Principle", embodied in Section 7 of the Marine Resources Act [3] and which reads: *The Ministry shall evaluate which types of management measures are necessary to ensure sustainable management of wild living marine resources*. This principle confers on the Ministry an obligation to evaluate whether continued fishing at the present scale is justifiable, or whether improved management is required to ensure sustainability. The law indicates which concerns should be addressed, but neither how nor how often evaluations should take place. That is for management to decide.

5. Tools to obtain an overview and to prioritise

5.1. The stock table and the fisheries table

A practical approach to developing ecosystem-based fisheries management requires consideration of an increasing number of issues, species, contexts and concerns. Issues could originate out of distinct conservation concerns, or out of concerns related to fishing industry

STOCK	Status of knowledge 1-3	Key role 1-2	State of stock 0-6	Fishing mortality 0-5	Red/Black-listed 0-6	Pollution 0-2	Catch value 1-5	Recreational value 1-3	Recreational share 1-4	Shared stock 1-4	Management objective 0-4	Measures implemented 1-3	Priority new measures 1-3	Comment box
Sprat high seas	2	2	1	2	1	1	4	3	4	2	3	1	1	
Sprat coastal	2	2	0	0	2		3	3	4	3	3	1	3	
Blue whiting	1		1	2	1		2	3	4	1	1	1	2	Unsolved multilateral question
Capelin I, II	1	1	1	2	1	1	2	3	4	1	1	1	1	
Capelin IIa, Va, XIV	2	1	0	0	1		3	3	4	1	1	1	1	
Mackerel	2		1	2	1		1	1	4	1	1	1	2	Unsolved multilateral question
Herring IIIa, IVa,b	1	2	1	2	1	1	3	2	4	1	1	1	1	
Herring I, II, IVa	1	1	2	2	1		1	2	4	1	1	1	2	Unsolved multilateral question
Silvery pout	3		3	3	1		4	3	4	2	3	3	1	
Horse mackerel	2		0	4	1		3	3	4	2	3	2	1	
Sandeel	2	1	5	2	1		3	3	4	2	2	1	1	
Greater argentines	2		3	3	1	0	3	3	4	2	2	1	1	
Norway pout	2	2	1	2	1		3	3	4	2	3	1	1	
Blue ling	3		5	0	4	0	4	3	4	2	3	1	1	
Tusk	2		3	4	1	0	3	2	4	2	2	1	1	
Whiting	2		3	3	1	1	4	2	4	1	1	1	1	
Haddock IV	1		1	2	1	1	3	2	4	1	1	1	1	
Haddock I, II	1		1	2	1	0	1	2	4	1	1	1	1	
Ling	2		3	3	1	0	2	2	4	2	2	1	1	
Pollack	3		5	0	1	0	3	1	2	3	3	3	2	Minimum size
European hake	2		3	3	1	0	3	2	3	3	3	3	2	
Saithe IIIa, IV	1		4	2	1	0	2	1	3	1	1	1	1	
Saithe I, II	1		3	4	1	0	1	1	3	3	1	1	1	
Greater forkbeard	3		3	3	1		4	3	4	2	3	3	1	
Coastal cod I, II	2		5	5	1	2	2	1	2	1	2	1	1	
Coastal cod IIIa, IV	2		6	5	1	2	4	1	1	1	3	1	3	
Cod IIIa, IV	1		2	2	1		3	2	4	1	1	1	3	Revision of the management plan
Cod I, II	1		1	2	1	1	1	2	4	1	1	1	1	

Fig. 2. An excerpt from the 2016 stock table. Red colour coding indicates substantial impacts/importance, yellow indicates medium, and green indicates that there are no or only small impacts/importance. For further explanation of figure legends and colour coding, see Anon [6].

profitability. Conservation and profitability have previously often been treated separately: in different forums, at different time scales, by different people and sometimes even by different agencies and ministries. Ecosystem-based fisheries management will require that the two policy streams converge, both types of concerns considered within a single framework. This generates the need for a simple, yet systematic and updated overview of potentially relevant issues with regard to all stocks and fisheries, seen from the perspective of both policy streams simultaneously. With limited resources for research and management, there is a strong need for a tool that can help prioritise these various issues according to the need and urgency of new or improved management measures.

As a tool to obtain such an overview, the Norwegian Directorate of Fisheries has developed two Excel spreadsheets – the Stock Table and the Fisheries Table – that provide an overview of issues related to stocks and fisheries relevant for Norwegian fisheries management (Figs. 2 and 3; Appendix Tables 1 and 2). The tables allow for the inclusion of new stocks or fisheries by increasing the number of lines, and of new and emerging issues by adding new columns. So far, 74 species/stocks and 57 fisheries have been included. The Stock Table includes information on the status of stocks, exploitation level, management objective, priority for action, etc. Stakeholders were introduced to this table in spring 2009, and priorities for the next year's development of improved management measures have subsequently been based on an annually updated version of this table. Similarly, the Fisheries Table was introduced in spring 2011 and priorities discussed with stakeholders. The Fisheries Table includes information for each fishery on species and size selectivity, discard problems, incidental mortality, effect on bottom habitats, etc.

The elements of the two tables are graded according to impact or importance and presented with traffic light colours (high (red), medium (yellow) or low (green)) to facilitate the overview. The grading is in many cases based on qualitative expert judgment, and both researchers and stakeholders contributed to this process. Considerable effort was put into harmonising the grading across species/stocks and fisheries to ensure consistency and objectivity throughout the tables. Different persons will obviously grade differently, depending on background and point of view. To avoid positioning and lengthy "negotiations" about grading, it was therefore made clear right from the start that the grading was there only to get an overview of challenges and concerns, and did not constitute a prioritisation itself.

Updated each spring, both the content of the tables and priorities for next year are up for discussion with stakeholders at the June Regulatory Meeting ([6], Fig. 1). In the discussion, different positions with regards to urgent challenges and risks are voiced. Although differences of opinion among stakeholders exist, it is not a general experience that the differences are insurmountable or increasing over time. On the contrary, the now well-established and recognizable annual cycle facilitates an approach between different positions. The outcome of the discussions are summarized by the Director General of Fisheries, and her final priorities for next year feeds into the Ministry of Trade, Industry and Fisheries' preparation of next year's budget proposal to the Parliament. These priorities will eventually materialise in the Ministry's annual Letter of Expectations in December to the Directorate of Fisheries and/or the Institute of Marine Research. As an example of the nature of priorities, here is the outcome of the discussions with stakeholders in June 2016:

2017 priority list – stock-related issues

- Monkfish (revision of management measures).
- Joint EU-Norway stocks in the North Sea (revision of management plans).
- Atlantic halibut (revision of management measures).
- Coastal sprat (revision of management measures).
- Coastal cod south of 62°N (improve management measures).
- Wrasse (revision of management measures).
- Spurdog (picked dogfish) (revision of management measures).
- North Sea/Skagerrak shrimp (establish management plan).
- Plaice north of 62°N (assessment according to the management principle).
- Norway lobster (a strategy for future management).
- Skates and rays (assessment according to the management princi-

	FISHERY				SPECIES SELECTIVITY								
Num.	Gear	Target specie(s)	Catch area	Nationality	Endangered marine species	Other marine specie	Sea mammal	Seabird	Size selectivity	Discarding	Incidental mortality	Effect on seabed	Comment box
1	Demersal trawl	Cod, haddock, saithe etc.	I and II	Both	1	1	1	1	1	3	1	3	
2	trawl	Saithe	IIIa and IV	Norwegian	1	1	1	1	1	1	1	2	
3	trawl	Mixed fisheries	IIIa and IV	Norwegian	3	2	1	1	3	2	1	2	
4	trawl	Mixed fisheries	IIIa and IV	Foreign	3	3	1	1	3	3	1	2	
5	trawl	Norway pout	IIa, IV	Both	1	2	1	1	3	1	1	2	
6	trawl	Blue whiting	IIa, IV	Both	1	2	1	1	3	1	1	2	
7	trawl	Sandeel	IVa,b	Both	1	1	1	1	2	1	1	1	
8	trawl	Flatfishes	IIIa and IV	Foreign	0	0	1	1	0	3	1	2	
9	trawl	Greater argentines	IIa	Norwegian	1	0	1	1	0	0	1	3	
10	trawl	Northern shrimp	I and II	Both	1	2	1	1	2	2	1	3	
11	trawl	Northern shrimp	IIIa and IV	Both	2	3	1	1	3	3	1	3	
12	Midwater trawl	Mackerel	IIa and IVa,b, VIa and IIIa	Both	1	2	1	1	1	1	1	1	
13	Midwater trawl	Horse mackerel	II a, IVa and VIa	Both	1	2	1	1	1	1	1	1	
14	Midwater trawl	Herring	I, IIa, IVa	Both	1	2	1	1	1	1	1	1	
15	Midwater trawl	Herring	IVa and IVb	Both	1	2	1	1	1	1	1	1	
16	Midwater trawl	Capelin	I and II	Both	1	2	1	1	1	1	1	1	
17	Midwater trawl	Beaked Redfish	I and II	Both	1	1	1	1	1	1	1	1	
18	Midwater trawl	Blue whiting	IIa, IVa, Vb, VI, VIIb,c	Both	1	1	1	1	1	1	1	1	
19	Midwater trawl	Greater argentines	IIa	Norwegian	1	3	1	1	1	1	1	1	
20	Midwater trawl	Antarctic krill	CCMLAR	Norwegian	1	1	1	1	1	1	1	1	
21	Kelp trawl	North European kelp	IIa, IV	Norwegian	1	1	1	1	1	1	1	2	
22	Purse seine	Mackerel	IIa and IVa,b, VIa and IIIa	Both	1	1	1	1	1	1	2	1	
23	Purse seine	Horse mackerel	IIa, IVa	Both	1	2	1	1	1	1	2	1	
24	Purse seine	Herring	I, IIa, IVa	Both	1	1	1	1	1	1	2	1	
25	Purse seine	Herring	IVa and IVb	Both	1	1	1	1	1	1	2	1	
26	Purse seine	Capelin	I and II	Both	1	2	1	1	1	1	2	1	
27	Purse seine	Capelin	IIa, Va, XIV	Both	1	1	1	1	1	1	1	1	

Fig. 3. An excerpt from the 2016 fisheries table. Red colour coding indicates substantial impacts/importance, yellow indicates medium, and green indicates that there are no or only small impacts/importance. For further explanation of figure legends and colour coding, see Anon [6].

ple).
- Snow crab (a strategy for future management).
- Pacific oyster (a strategy for future management).
- Unresolved issues regarding the sharing of joint stocks.

2017 priority list – fishery-related issues

Selectivity and discards:

- Further develop the Real-Time Closure program for the North Sea and Skagerrak.
- Mapping of species and size distribution in the Norway pout fishery.
- Measure to improve selectivity and reduce discarding in the North Sea/Skagerrak shrimp fishery.
- Revision of criteria for the intermixture of juveniles, and testing of new concepts to reduce such by-catches in the shrimp fisheries north of 62°N.
- Measures to reduce by-catches in the trawl fishery for Argentines.

Incidental mortality:

- Retrieval of lost gill nets to minimise ghost fishing, and testing of technology to facilitate recovery of lost nets.
- Introduction of fish release technology to avoid unwanted mortality from too large catches in Danish seine and cod trawl.
- Assessment of the extent and consequences of lost shellfish pots – possible measures to reduce ghost fishing.

Effects from fisheries on bottom habitats:

- Revision of management measures with regards to trawling in pristine areas.

The prioritised issues will enter next year's work plan of the Directorate of Fisheries and/or the Institute of Marine Research and remain on the work plan until appropriate measures have been developed and implemented. Depending on the issue, an appropriate measure can be anything from revision of management plans to improved technical regulations, new technology, catch limitations, or area closures.

5.2. *The table of "landings of data-poor species"*

To meet the obligation for species for which little information is available (see Section 3), a third table was created, entitled "Landings of data-poor species", to keep track of the harvesting of minor, data-poor, or non-quota-regulated species (Appendix Tables 3 and 4). The table, which presents annual landed catches (in tonnes) of such species since 2000, was presented to stakeholders for the first time at the June 2014 Regulatory Meeting [6]. Species with very small catches are grouped together (for example under "other flatfishes"), but readers can access the catch figures for each species within a group by clicking on that particular line. At present, to limit the scope and workload, only species with an annual catch of more than 100 t, and species that are on the official Norwegian Red List for Species [14] or are otherwise known to be in a precarious state, will be subject to evaluation according to Section 7 of the law.

The state of all species, including the data-poor ones in the table of "Landings of data-poor species", is assessed according to the IUCN Red List Categories and Criteria at least once every five years by Artsdatabanken (The Norwegian Biodiversity Centre) as part of their work with the Norwegian Red List for Species [19]. Some data-poor species may also be assessed more frequently by the Institute of Marine Research based on bycatch data in scientific surveys. The institute also presents an overview of the status of all commercial Norwegian species

in their annual report "Havforskningsrapporten" (Report on Ocean Research) [7]. Based on this scientific input, the Directorate of Fisheries will then evaluate present harvesting levels and consider the need for regulatory interventions. In all, the state of eighteen species was assessed in the years 2014–2016. Present harvesting was rated as satisfactory for fourteen of these species, while four species were considered in need of some sort of follow-up.

Changes in landings statistics over time could be caused by changes either in fishing effort or in the abundance of fish. The assumption is that the official landings statistics, collected and maintained by the Directorate of Fisheries, will be a first indicator of any significant changes in abundance that need further investigation. Such indications will trigger further actions and link management to science. Measures of fishing effort and/or scientific surveys independent of fisheries are necessary to reveal the reasons for changes in the landings statistics. This kind of information is collected, analysed and made available by the Institute of Marine Research.

Comprehensive scientific surveys have been conducted for decades in Norway. The longest time series used in quantitative fish stock assessments extend back to about 1980. In the first years, species of low commercial value were grouped together, but in later years all fish and shellfish have been identified to species. Several of these surveys also provide data on oceanographic and hydrographic conditions and benthic fauna. Time series from standardised surveys are of great value and substantially improve our ability to evaluate reasons for changes in multispecies ecosystems.

6. Integration of the management principle in scientific assessment and advice

Integration of the ecosystem-based Management Principle has revealed a need for a metadata listing for each fish stock summarising the currently available data and methods used in stock monitoring and assessments. The Institute of Marine Research is therefore currently developing a Stock Assessment Metadatabase, which includes all stocks being monitored by the institute. The database is web-based (http://webprod1.nodc.no:8080/sambagui/html/main.html), making the information available to the public. At the present stage, the Stock Assessment Metadatabase consists of a table presenting information per stock on quota advice, responsible Regional Fishery Bodies and assessment working groups, and Red List assessments by Artsdatabanken (The Norwegian Biodiversity Centre). The table also has columns containing ICES stock categories [17,18], the management objectives from the Stock Table of the Fisheries Directorate, and name(s) of contact persons (scientist(s)) for each stock at the Institute of Marine Research.

Follow up work will connect the Stock Assessment Metadatabase to the existing data framework at the Institute of Marine Research. The goal is that anyone should be able to retrieve stock-specific information on assessment input data (fisheries dependent and independent), survey design, assessment model, and uncertainty estimates. The Stock Assessment Metadatabase will make it possible to standardise data collection and assessment procedures across stocks, and will provide the Institute of Marine Research with a holistic overview, facilitating decisions about which monitoring and research tasks to prioritise. Last, but not least, the Stock Assessment Metadatabase will provide an overview of available knowledge and status for stocks on the priority list of the Directorate of Fisheries.

7. Discussion and conclusions

As fishing mortality rates are reduced to precautious levels, and the likely most important impact factor is hence brought under control, the relative impact of the intrinsic bioecological processes on stock dynamics increases. This makes EAFM even more crucial in efforts to improve fisheries management and obtain higher sustainable and stable yields. Further development of the EAFM should hence involve (i) multispecies harvest strategies, taking species interactions into account, and (ii) ecosystem/trophic level considerations of harvest strategies.

The application of the Ecosystem Approach to Fisheries Management (EAFM) is now mandatory in Norway through the Marine Resources Act. Based on international law one could claim that the application of EAFM should be regarded as mandatory even without being included specifically in national legislation. The tools described in the present paper may therefore be of use in management regimes other than the one employed in Norway.

The overall objective of EAFM is to sustain healthy marine ecosystems and the fisheries they support. The objective is clear, but how to achieve it is not, at least if we are looking for a generic approach that will work across different management regimes. The process of developing the tools described in the present paper has shown us that the implementation of EAFM must be based on the existing governance system, and thereafter gradually developed further, as knowledge becomes available. The sequence of the steps should be based on a process that identifies shortcomings and negative impacts to the ecosystem caused by fishing, and hence make it possible to prioritise which actions to take. The process has also highlighted the value and necessity of a close working relationship between science, management and stakeholders.

Together, the tables presented should cover the most important issues relevant to ecosystem-based fisheries management. However, the tables are not intended to cover development needs related to fleet capacity adaptation. This is done by the fleet structural program, which allows for licence aggregation, facilitating the gradual reduction in number of fishing vessels as efficiency increases. Nor do the tables cover resource allocation between national user groups, fisheries control issues, or the annual operational adjustments of already established regulatory measures and quota schemes (the annual "TAC-machine", Fig. 1), all of which are vital and basic elements in ecosystem-based fisheries management. The two tables do not constitute any model describing ecosystem relationships. However, findings from such models could motivate prioritising development of management measures to address a specific issue highlighted by one of the tables. Furthermore, the tables are not designed to cover cross-sectorial issues related to multiple stressors, competing use, or impact on fishing from other industries such as oil, shipping, offshore wind energy, mining, or aquaculture. These issues are dealt with in the three Integrated Ocean Management Plans for the Lofoten–Barents Sea [4], the Norwegian Sea [2], and the North Sea/Skagerrak [5] respectively. The utility of the two tables is thus restricted to the further development of ecosystem-based fisheries management.

In principle, conservation and prudent long-term fisheries management go hand in hand. There are, however, issues where conservation and fisheries come in conflict: fisheries do, after all, leave an environmental footprint. In the end, it is a political issue to decide what an acceptable footprint is and what is not. The tables do not solve that problem, but they contribute by clarifying the issues, and by giving stakeholders and government an annual opportunity to voice their opinions on which issues should be prioritised. In this regard, the tables help bridge the gap between the two policy streams of conservation and fisheries by including both in the same prioritisation process [22].

There are many stakeholders in the management of ocean resources, often with conflicting interests, for instance fisheries, the oil and gas industry, and environmental NGOs. Conflicts of interest of various degrees can also exist between different government bodies. The tools described here help ensure stakeholder input both before and during the Regulatory meetings, and all the documents and the tools are accessible to the public. This transparency creates the basis for a constructive dialogue between all stakeholders, and increases their level of acceptance of the decisions made. Ultimately, acceptance by stakeholders is necessary to achieve the overall objective of EAFM.

Due to the simplicity of the approach taken by Norway, and the flexibility of gradual development with increasing knowledge, the approach may also be relevant for other coastal states, including developing countries. Of course, policy objectives may certainly differ, lack of data and scientific input may be a serious obstacle, and the management infrastructure may be insufficient and fragile. Still, there are commonalities. One of them is the need to get an overview of important challenges; another is the need to prioritise use of scarce scientific and management resources; a third and very relevant commonality is the problem of how to approach the issue of managing data-poor stocks. In this context, the three tables may be practical and useful tools for any coastal state. Given the tables' flexibility in terms of the number of columns and lines, one can start from a limited number of the most important stocks and fisheries, and gradually extend the scope to new stocks and fisheries, and new concerns, as fisheries management develops. The current approach may hence be a systematic, structured and useful contribution – or an alternative – to the more extensive processes that are needed to compile ecosystem approach fishery plans according to the FAO concept, or establishing comprehensive ERAEF frameworks [16].

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2016.11.032.

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