IMAGE

Indicators for fisheries **MA**na**G**ement in **E**urope

Proposal/Contract no.: **FP6 – 044227**

Final Activity Report

SPECIFIC TARGETED RESEARCH PROJECT
Thematic Priority 8.1 Modernisation and sustainability of fisheries, including aquaculture-based production systems

Period covered: from 1-11-2006 to 31-10-2009 Date of preparation: 11-03-2010

Start date of project: 1-11-2006
Duration: 3 years

Project coordinator name: Gerjan Piet
Project coordinator organisation name: IMARES

Table of Contents

1 The IMAGE project

1.1 Objectives

The principal objectives of IMAGE were:

1. To develop an operational framework of candidate indicators (ecological, economic, social) that can support ecosystem-based fisheries management at the regional and pan-European scale
2. To elaborate these indicators in comprehensive dashboards (e.g. current values, trends, reference levels)
3. To develop methodology to integrate this information into tools supporting the decision-making process
4. To develop a framework that can evaluate management strategies based on indicators
5. To advise on how indicators can be used to support EBFM in selected regional case studies based on the new RAC areas

In meeting these objectives we will also

1. Help to further stakeholder awareness and understanding of EBFM through directly engaging with the RACs
2. Develop a scientific framework for support of the integration of environmental protection requirements into the CFP
3. Support the revision of the Data Collection Regulation (DCR) by identifying the requirements for data to support EBFM
4. Share experiences and insight developed in the project among Institutes, among RACs and with the EC
5. Disseminate project information and results to the science community and stakeholders
6. Increase the international profile of the EU in developing science to support an EBFM,
7. Produce software that will be globally available as part of the FLR package
8. Enhance scientific co-operation in EU
9. Support the EC in saving monitoring costs through advising on the integration of ‘fisheries’ and ‘environmental’ data collection
10. Identify mechanisms for harmonizing EU fisheries and environment policy at the operational level.

In this report we will describe how the work we conducted to address these objectives contributed to develop an indicator-based operational framework for supporting an ecosystem-based approach to the management of European fisheries.

1.2 Consortium

The composition of the IMAGE Consortium is reflected in table 1.

Table 1. The IMAGE consortium

Partic. Role	Partic. No.	Participant name	Partic. Sh. name	Country
CO	1	Wageningen IMARES, Institute for MArine Resources and Ecosystem Studies	IMARES	The Netherlands
CR	2	The Secretary of State for Environment, Food & Rural Affairs acting through the Centre for Environment, Fisheries & Aquaculture Science	Cefas	United Kingdom
CR	3	Institut Francais de Recherche pour l'Exploitation de la mer	IFREmer	France
CR	4	Technical University of Denmark, National Institute of Aquatic Resources	DTU-AQUA	Denmark
CR	5	Institute for Fisheries Management & Coastal Community Development	IFM	Denmark
CR	6	COISPA Tecnologia & Ricerca	COISPA	Italy
CR	7	University of Tartu, Estonian Marine Institute	EMI	Estonia

1.3 Outline of results

In the following paragraphs we distinguished different parts of the work. These parts are to some extent, but not directly, linked to the different objectives. The paragraph 2 “Operational framework” addresses the 1st IMAGE objective, paragraphs 3 and 4 address the 2nd objective, paragraph 5 is linked to the 3rd and 4th objectives while paragraphs 6, 7 and notably 8 are linked to the 5th objective.

2 Operational framework

2.1 Operationalizing the high-level CFP objective

We developed framework that allows the translation from high-level objectives to operational objectives including indicators. For IMAGE this was done for the CFP but the relevance for other marine policy frameworks follows from the fact that and a comparable process has now been initiated for the Marine Strategy Framework Directive (MSFD) where 11 so-called descriptors are distinguished that together should allow assessment of the main objective of the MSFD: the achievement of Good Environmental Status (GES) by 2020. For each of these descriptors one or more indicators need to be identified covering different components or attributes of these descriptors.

In IMAGE we developed an operational framework to support the integration of environmental protection requirements into the CFP. To identify the issues to be addressed by indicator-based management, we needed to translate the strategic highest level (i.e. level 1) objectives as stated in Article 2 of the Council Regulation Nr 2371/2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy

"Precautionary approach shall be applied in taking measures designed to protect and conserve living aquatic resources, to provide for their sustainable exploitation and to minimise the impact of fishing activities on marine eco-systems. It shall aim at a progressive implementation of an eco-system based approach to fisheries management. It shall aim to contribute to efficient fishing activities within an economically viable and competitive fisheries and aquaculture industry, providing a fair standard of living for those who depend on fishing activities and taking into account the interests of consumers"

into the following increasingly operational management objectives (level 2 = 1,2,3; level 3 = a,b,c,…..):

1. *"To maintain fishing mortality at or below levels that are necessary to achieve maximum sustainable yield for all targeted stocks",*
    a. *"To maintain fishing mortality at or below levels that are necessary to achieve maximum sustainable yield for stock A",*
    b. *"To maintain fishing mortality at or below levels that are necessary to achieve maximum sustainable yield for stock B",*
    c. *"To maintain fishing mortality at or below levels that are necessary to achieve maximum sustainable yield for stock C",*

2. *"To maintain or reduce fishing impact on the ecosystem at or below sustainable levels"*
    a. *"To maintain or reduce fishing impact on ecosystem component/attribute A at or below sustainable levels"*
    b. *"To maintain or reduce fishing impact on ecosystem component/attribute B at or below sustainable levels"*
    c. *"To maintain or reduce fishing impact on ecosystem component/attribute C at or below sustainable levels"*

3. *"To develop a viable, economically efficient and globally competitive European fisheries and aquaculture industry".*
    a. *To develop an optimally diversified fishing fleet in the ……RAC area where the individual vessels are viable and economically efficient.*
    b. *To develop an optimally diversified regional fish processing industry where the individual enterprises are viable and economically efficient.*
    c. *To develop an optimally diversified regional aquaculture industry where the individual enterprises are viable and economically efficient.*

These operational objectives then required one or more indicators to assess the state of European marine ecosystems, at the RAC scale and in relation to the stated objectives of the CFP.

2.2 Ecological objectives

In all RAC areas examined (Baltic, South-western waters RAC, North Sea RAC, Mediterranean RAC) there were fishing impacts that compromised the 'ecological' objectives (1 and/ or 2) and throughout the European area there were parts of the industry that did not meet the economic objective (3). All the impacts that compromise objectives were identified as priority impacts, for which indicators would need to be developed, in order to assess the progress of management. We recommend a process for identifying and selecting indicators and the associated indicators and reference points, based on linking indicators to operational objectives that relate to the impacts that compromise the higher level objectives. The indicators identified were further investigated and developed in subsequent IMAGE workpackages.

components		Attributes			
		structure	**abundance**	**production**	**Other functions (specify)**
fish	populations	N,B,W,M	N,B,W,M	N,B,W,M	
fish	communities	N,W,M	N,W,M	N,W,M	
cephalopod	populations				
cephalopod	communities				
phytoplankton	populations				
phytoplankton	communities				
zooplankton	populations				
zooplankton	communities				
benthic invertebrate	populations	N,W,M	N,W,M	N,W,M	
benthic invertebrate	communities	N,W	N,W	N,W	
macrophyte	habitat				
seabird	populations		N	N	
mammal	populations				
reptile	populations				
benthic	habitat				

Table 2. Ecosystem components and attributes for which there is consistent scientific evidence that fishing impact compromises one or more of the CFP objectives in each of four RAC areas: N=North Sea, B=Baltic Sea, W=Western waters, M=Mediterranean.

One of the main lessons of this analysis was that ensuring the sustainability of fishing effects on target stocks remains an overriding management challenge in the RAC areas. Any progress made towards controlling fishing rates on overfished target stocks is likely to have concomitant benefits for other components of the ecosystem by helping to meet the objectives that have been set for them.

2.3 Socio-economic objective

Fishery management systems need to support the achievement of objectives that relate to all three pillars of sustainability, i.e. ecological, social and economic. The properties of the ecological system, however, place ultimate constraints on the social and economic systems. This is reflected in the revised CFP as well as the Marine Strategy framework Directive (MSFD) giving the ecological pillar ultimate precedence – since the eventual loss of an ecological resource base will mean that no social and economic benefits can be derived from the sea. Thus, while much of the indicator development focused on delivering the ecological sustainability it is essential that science to support management advice should focus on understanding how ecological constraints affect progress towards social and economic objectives so that it becomes clear how meeting targets for ecological indicators will affect the capacity to meet social and economic objectives. Therefore within IMAGE we not only attempted to develop indicators reflecting the progress towards social and economic objectives but also to which extent these are compromised by ecological constraints.

The progress towards social and economic objectives was assessed through two indicators of the short-term (based on the gross cash flow) and medium-term (based on revenue) economic performance of the EU fishing fleets, which were developed by STECF economists in the annual reports "Economic Performance of Selected European Fishing Fleets":

- Short-term = Gross cash flow this year/Average gross cash flow previous years.
- Medium-term = Average revenue/Break-even revenue

These indicators showed that for the EU fleet in 2004 only 34 of totally 89 fleet segments, representing 56% of the landing value showed strong economic performance in the medium term while of these fleet segments a majority of 60% showed a deterioration in their short-term performance. This was found to be representative for each of the RAC areas thereby showing that the CFP objective "*To develop an optimally diversified fishing fleet in the ……RAC area where the individual vessels are viable and economically efficient*" (see chapter 2.1) was not met either at the EU level or in any of the RAC areas separately. While this analysis was only performed with the data available in 2005 this assessment can be conducted on an annual basis with the data as they are currently collected as part of the DCF (Data collection framework)..

A major shortcoming of this analysis comes from the fact that the socio-economic data collected within the DCR and now the DCF are primarily of economic character and that suitable data necessary to calculate other (e.g. social) indicators are still lacking, thereby preventing an assessment of the social and cultural dimensions of viability as mentioned in the CFP objective. Therefore a list of seven headline socio-economic indicators for fisheries communities and sectors has been devised: 1) profitability; 2) fisheries related activity; 3) economic value; 4) population; 5) social well-being; 6) social policy; and 7) fisheries governance. These span industry, community and institutional aspects and require both quantitative (such as that traditionally collected under the DCF) and qualitative socio-economic data. These headline indicators and their associated specific indicators and datasets would not only allow an improved assessment of the progress towards economic and social CFP objectives but also provide time-series of socio-economic information that determines the fishers behaviour impacting the ecosystem and thus can support both policy-making and other socio-economic impact assessments.

2.4 Linking ecological and socio-economic objectives

In order to determine how ecological constraints hamper the progress towards social and economic objectives IMAGE started off by providing an overall understanding of the "fisheries system" from a social science point of view through a framework identifying the social, economic and institutional drivers behind the human behaviours impacting the ecosystem. Understanding all the interrelationships between these drivers and linking this in a quantitative manner to fishers behaviour which would in turn determine the fishing pressure on the ecosystem is of course the ultimate, and very ambitious, goal but not feasible with the information currently available or the resources available in IMAGE. Therefore as a start, two studies were conducted attempting to analyse fishers behaviour, structured in two levels of time response scale: Long and short-term behaviour response.

- Long-term behaviour (strategies) is year to year changes in the dynamics of the capacity of the fleet (fleet efficiency or number of vessels entering or leaving the fishery due to decommission, investment or attrition) and was studied in the Bay of Biscay showing there is plasticity in the fleet composition and functioning as fleets were adapting to change through migration of some of their units between gears, species, and fishing areas.
- Short-term behaviour (tactics) is mainly made on the basis of a trip and is generated by the decisions that fishermen make about when and where to fish (in terms of choice of fishing location, target species or type of gear/rigging) and which fish to land or discard. This was studied for the Danish North Sea gillnet fleet through a questionnaire revealing the relative importance of factors such as season, weather, the present situation, regulations, information from other fishermen, distance or fuel cost.

These studies confirm that the behaviour of the fisher changes both in the long- and short-term and even though the factors driving this are not always fully understood there is potential for management of the fishing pressure through the fishers behaviour.

One other major deficiency in the data as they are currently collected through the DCF is that despite the regional approach of the DCF, the data cannot be disaggregated to a community level. Without such local-scale data, the analysis of socio-economic impacts of policy on fishing communities is not possible.

For the IMAGE project the departure was that easily accessible, policy-facing and relevant socioeconomic information is critical to the development of sound management advice in support of sustainable fisheries. However, while recently economic data is being collected as part of the DCR, social data relating to European fisheries and fishing communities tends to be piecemeal, suffers from incompatibility within and across member states, and is inaccessible to decision-makers and other interests. The social information available also lacks the detailed and rigorous analysis reserved for biological data relating to stock assessments and TACsetting. More importantly, there is no established, all-encompassing structure for incorporating social and economic information into evaluations of fisheries management policies and regulations. The dataframe approach that was applied in the IMAGE project is considered a first step towards the development of indicators applicable at RAC level on industry, community, well-being, and social and institutional arrangements.

3 Indicator development and selection

Fishery papers on ecosystem indicators, or ecological indicators, have flourished over the last ten years, and many were justified by referring to the ecosystem approach to fisheries management (EAFM). Because of this abundance of indicators we did not put much emphasis on the development of new indicators, except in cases where we believed suitable indicators were missing. Much of our focus was on the development of an operational framework of indicators and elaborating them in comprehensive dashboards. In order to achieve this we used several methods to come up with a final suite of “best” indicators for application in what was going to be our operational framework that can support ecosystem-based fisheries management at the regional and pan-European scale. While our work did not manage to provide this final suite of indicators, it did provide several candidate indicators and much information that can be used in the process that could lead to the establishment of such a suite of indicators. The different methods that were applied for the selection of indicators as well as the further elaboration in terms of reference levels and trends are presented in the following sections of this paragraph.

A number of frameworks have been proposed as sustainable development reference systems. The Sustainable Livelihood (SL) framework has been used widely for agricultural development and forestry systems, and the Pressure State Response (PSR) framework is popular for fisheries applications. The Institutional Analysis and Development (IAD) framework adopted for the socio-economic analyses encompasses both the structurally-oriented SL framework and the process-oriented PSR framework and has a number of features that make it suited for complex marine fisheries. The IAD framework highlights that in order to understand the actual behaviour you have to include also the influence of human capital, and social capital, which is expressed in institutions or “rules-in-use”. The IAD has a strong empirical orientation, necessary for experimental ecosystem-based fisheries management, and offers several potential advantages compared to the PSR and SL frameworks as a platform for monitoring the sustainability of complex fishery systems.

3.1 Development of new indicators

As already stated in the state-of-the-art section of the IMAGE proposal: many indicators have already been developed and presented in scientific literature, outputs of SCOR-IOC working group 119, several EU funded projects and many other fora. However, an evaluation of the suitability of these indicators for assessments relating to ecological, social or economic sustainability showed that these are mostly indicators of ecological sustainability with a few economic indicators and only one indicator of social sustainability. Application of these ecological indicators in the context of the Pressure-State-Response framework showed that most indicators are state indicators with a few pressure indicators and a complete lack of response indicators. Further, even if pressure and response could be measured the links between pressure and response and state were often not well known or proved difficult to model.

Having established all the components and attributes that need to be distinguished to describe the state of the ecosystem it also emerged that most of the proposed state indicators describe one component of the ecosystem, i.e. fish, with few indicators of the other components. Thus, while many indicators exist their applicability is heavily skewed towards ecological indicators describing the state of the fish in the ecosystem. While having state indicators for fish is necessary given the almost ubiquitous failure to meet management objectives for fish populations and communities, the pressure-state-response links have only been well established for target stocks.

Within IMAGE we addressed the bias towards ecological indicators by proposing a suite of seven socio-economic indicators that span industry, community and institutional aspects and require both quantitative (such as that traditionally collected under the Data CollectionFramework) as well as qualitative socio-economic data (Table 3). These seven socio-economic indicators are underpinned by more specific indicators or datasets on related variables and should provide a critical link between fleet segments and other aspects of the fishing industry and communities. For example, profitability is an indicator, with associated specific indicators on costs and earnings. Population is another indicator, with specific indicators on number, gender, age, employment, education, health and ethnic diversity.

Table 3. Seven headline socio-economic indicators and their specific indicators spanning industry, community and institutional aspects

Industry Indicators (community-scale information to be gathered annually via existing data collection routines)	
Profitability	• costs/earnings per sector • general local economic performance
Fisheries-related activity	• number of businesses • full-time/part-time employment by gender, age, nationality per sector • % total local employment
Economic value	• economic value per local sector • % economic value relative to total sector • % local GDP from fisheries
Community Indicators (qualitative data to be gathered annually via community fora)	
Population (fisheries/general)	• community size • community diversity • community skills • employment/training opportunities
Social well-being (fisheries/general)	• job satisfaction • cost of living (qualitative) • perception of choice community-identity fit
Institutional Arrangement Indicators (qualitative data to be gathered annually via community fora)	
Social Policy	• accessibility of advice, support and funds • degree of advice, support and funds
Fisheries Governance	• understanding of fisheries management • perception of fleet restrictions • legitimacy of fisheries management • participative opportunities in fisheries management

As stated previously with regard to the PSR framework: much indicator development has thus far focused on state and considerably less so on pressure or the relationship between the two while almost completely neglecting the potential of response indicators. This focus on pressure and state indicators suggests a belief that within an EAFM only this part of the PSR framework needs to be developed to achieve the management objectives. This is now challenged by one outcome of the IMAGE project using results from traditional fisheries management, showing that unless response indicators become an integral part of the EAFM it will not perform much better than traditional fisheries management has so far. The two response indicators that were developed within IMAGE were:

- the extent to which scientific advice is incorporated in decision-making,
- the compliance of industry and the relevant authorities to these decisions.

Because in our operational framework we identified that one of the ecosystem components for which the objectives are most likely to be compromised by fishing is fish we did not develop any indicators for other ecosystem components. We did, however, develop one more indicator for fish (but one that can easily be applied to other ecosystem components such as benthic invertebrates) because this indicator captures an attribute not covered by any of the known indicators but that may strongly determine the response to natural or anthropogenic influences. The Occupancy-Abundance (O-A) relationship is an indicator of spatial structure reflecting the degree to which this species concentrates in increasingly smaller patches as abundance declines. This makes it more susceptible to fisheries targeting these aggregations (perhaps even the last aggregation) which was one of the most compelling explanations for the notable decline of once massive northern Atlantic cod stock which presently exists at about 1% of its peak biomass. The decline of this indicator in the quality of the fits and slope over species was significantly related to fishing effort and total groundfish landings while combined with a life history derived measure of population “resiliency” it allows categorization of a species potential for increased catchability with changing abundance.

3.2 Selection of indicators

In order to reduce the number of indicators that need to be considered in a management context we applied two different but complementary methods to derive a suite of “best” indicators: (1) based on the assumption that this selection should be based on the preferences of stakeholders and involved application of the tool of Analytical Hierarchy Process (AHP), (2) based on an evaluation of indicators against criteria.

AHP was one of the decision-support tools identified in the IMAGE review and applied in the Mediterranean case study (see Spedicato et al WP4 Appendix 5) to show the preferences of different stakeholders on different types of indicators (table 4).

Table 4. Scores of the combination between objectives and alternatives (indicators) from stakeholder groups (FA=fishermen associations; EN=environmental organizations, RS=researchers; IS=Institutional bodies). The five higher score preferences for each stakeholder group are highlighted.

	Symbol	**FA**	**EN**	**RS**	**IS**
Ecological state					
Maintain safe level of reproductive potential	1				
Size at maturation	A	0.0526	0.0166	0.1994	0.0166
Spawning stock biomass	B	0.0408	0.0439	0.0470	0.1316
Conserve abundance and biodiversity	2				
Biomass of all species	C	0.0401	0.0741	0.0629	0.1762
Diversity index	D	0.0519	0.0602	0.0255	0.0249
Proportion of selachians	E	0.0109	0.0999	0.0179	0.0149
Preserve population and community structure	3				
Proportion of large fish	F	0.0456	0.1045	0.0439	0.0223
Mean maximum length of fish	G	0.0977	0.0739	0.0981	0.0050
Pressure/impact					
Maintain or reduce mortality	4				
Fcurr/Fmsy	H	0.0285	0.0295	0.0433	0.0499
Zcurr/Zmbp	I	0.0348	0.0442	0.0685	0.0100
Maintain or reduce fishing intensity	5				
N.vessels by fish. tech./surface	L	0.0132	0.0167	0.0229	0.0322
Aggregation of fishing activities	M	0.0309	0.0286	0.0478	0.0604
Area not impacted	N	0.0063	0.0462	0.0182	0.0133
Reduce discards	6				
Discard rate of comm. exp. species	O	0.1672	0.1170	0.0598	0.0286
Economic state					
Maximise income	7				
Revenue	P	0.0156	0.0049	0.0038	0.0153
GP/effort	Q	0.0246	0.0105	0.0092	0.0531
Improve cost efficiency	8				
Total landing value/fuel cost	R	0.0680	0.0301	0.0320	0.3340

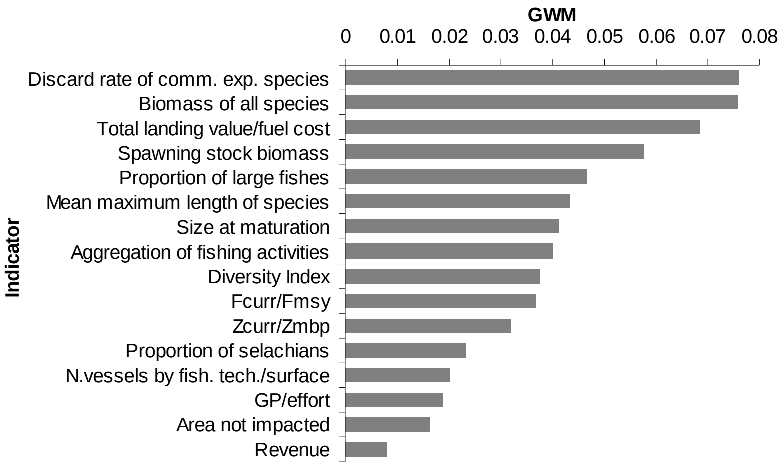

Fig.1. Aggregated preferences vector (geometric weighed mean=GWM) of indicators from stakeholders.

The study did produce aggregate preferences showing that the Discard rate of commercial species and the biomass of all species were overall preferred but also revealed distinct differences between the different stakeholder groups suggesting that the composition of group may affect the outcome of this analysis.

Piet et al. (2008) applied the criteria developed by (Rice & Rochet 2005) to identify the preferred indicators but found that the ranked scores of indicators are affected by the level of detail, both in terms of criteria and indicators, provided in the questionnaires.

Table 5. Mean specific indicator scoring (with rank order in brackets) for specific indicators based on three different questionnaire (SN, SS, SF). Scores range from 1 (worst) to 5 (best).

Headline indicator	Specific indicator	SN	SS	SF
Physical environment	Temperature (Temperature)	2.9 (41)	3.7 (2)	2.2 (23)
	NAO (NAO)	2.6 (46)	3.0 (25)	1.7 (45)
Chemical environment	Salinity (Salinity)	2.7 (44)	3.5 (4)	2.2 (25)
	Oxygen concentration (Oxygen)	2.8 (43)	3.5 (5)	2.1 (28)
	N and P levels (Eutrophication)	2.9 (40)	3.2 (18)	1.8 (40)
Phytoplankton	Primary production (Prim Prod)	3.1 (37)	2.9 (31)	1.8 (37)
	Water transparency (Wat transparency)	2.1 (51)	3.3 (14)	1.8 (40)
	Chl. *a* (Chlorophyll a)	2.6 (47)	3.1 (21)	1.8 (37)
Zooplankton	CPR-derived plankton indicators (CPR)	2.6 (45)	2.5 (43)	1.4 (51)
	Zooplankton biomass (zooplankton)	3.2 (36)	2.7 (39)	1.8 (40)
Abundance commercial stocks	Proportion within safe biological limits (Safe Biol Limit)	4.5 (3)	3.4 (8)	2.5 (10)
Abundance other populations	Numerical abundance selected species (Abundance)	4.2 (5)	3.3 (10)	2.3 (17)
	Biomass selected species (Biomass)	3.9 (16)	3.3 (14)	2.4 (16)
	Measure of decline (Meas Decline)	4.1 (8)	3.0 (26)	2.2 (23)
Size/age structure species	Average length selected species (Average length)	4.2 (6)	3.5 (6)	2.6 (5)
	Average weight selected species (Average weight)	3.9 (14)	3.4 (7)	2.6 (5)
	Average age selected species (Average age)	3.7 (21)	3.3 (9)	2.5 (10)
Genetic composition species	Maturation norm (Maturation norm)	2.8 (42)	2.6 (40)	1.7 (45)
Size structure community	Mean weight (Mean weight)	3.4 (29)	3.3 (13)	2.6 (2)
	Mean length (Mean length)	3.4 (29)	3.3 (12)	2.6 (2)
	Proportion of large fish (% large fish)	3.5 (25)	3.3 (10)	2.6 (5)
Species composition community	Mean maximum length (Mean max len)	3.3 (32)	3.2 (20)	2.6 (5)
	Biodiversity - Hill's N0 (Biodiversity N0)	2.4 (50)	2.4 (45)	1.8 (37)
	Biodiversity - Hill's N1 (Biodiversity N1)	2.4 (48)	2.4 (46)	1.9 (34)
	Biodiversity - Hill's N2 (Biodiversity N2)	2.4 (48)	2.4 (46)	1.9 (34)
	Proportion of target species (% target spcs)	3.3 (32)	3.1 (23)	2.5 (10)
Abundance community	Total numbers (Total numbers)	3.5 (24)	2.9 (31)	2.5 (10)
	Total biomass (Total biomass)	3.5 (27)	2.9 (29)	2.5 (10)
Status marine mammals	Abundance selected marine mammal species (Mammals)	3.9 (16)	2.8 (33)	1.8 (40)
Status seabirds	Abundance selected seabirds species (Seabirds)	3.6 (22)	2.8 (37)	1.7 (48)
Status marine reptiles	Abundance selected marine reptile species (Reptiles)	3.1 (37)	2.8 (35)	1.5 (49)
Status benthos	Abundance sensitive benthic species (Sens. Benthic)	3.9 (16)	2.8 (33)	2.3 (20)
	Epibenthos community (Epibenthos)	3.3 (31)	2.6 (41)	2.1 (31)
	Infauna community (Infauna)	3.0 (39)	2.4 (44)	1.9 (34)
Status sensitive habitat	Area coverage sensitive habitats (Habitats)	3.5 (25)	3.1 (22)	2.2 (25)
Ecosystem functioning	Ecosystem functioning (Ecosystem funct)	3.8 (20)	2.1 (50)	2.1 (28)
	Primary Production Required (PPR)	3.6 (23)	2.6 (42)	2.0 (32)
	Catch ratios (Catch ratios)	3.9 (19)	3.1 (24)	2.3 (17)
	Mean transfer efficiency (Transfer eff)	3.2 (34)	2.2 (49)	1.8 (40)
	Trophic level (Trophic level)	3.9 (14)	2.7 (38)	2.3 (20)
	Fishing in Balance index (FIB)	3.2 (34)	2.3 (48)	1.7 (45)
	Finn Cycling Index (Finn Cycling)	3.4 (28)	2.0 (51)	1.4 (50)
Fleet capacity	Fleet capacity (Number vessels)	4.2 (6)	3.9 (1)	2.8 (1)
Fishing effort	Fishing effort (Hours fishing)	4.5 (2)	3.7 (2)	2.6 (2)
Fishing impact	Mortality commercial species (Mort Commercial)	4.6 (1)	3.2 (19)	2.6 (5)
	Mortality other fish species (Mort Other fish)	4.1 (8)	3.0 (28)	2.3 (20)
	Mortality benthic species (Mort Benthic)	4.1 (11)	2.8 (35)	2.1 (28)
	Mortality marine mammals (Mort Mammals)	4.1 (11)	3.0 (27)	1.9 (33)
	Mortality vulnerable species (Mort vulnerable)	4.5 (3)	2.9 (30)	2.2 (25)
	Proportion catch discarded (Catch discarded)	4.1 (11)	3.2 (16)	2.4 (15)
	Proportion area affected (Area affected)	4.1 (8)	3.2 (16)	2.3 (17)

Clearly, the process of indicator selection for an EAFM in the EU should involve enough respondents from different stakeholder groups and nationalities with sufficient expertise to ascertain commitment to the evolving suite of indicators. While scoring is a convenient aid in summarizing the evaluations by different people, there may be no need to score indicators against criteria in the actual selection process. An indicator might just pass or fail against each criterion, or might be evaluated more qualitatively with 'pros' and 'cons', while the final selection could be the result of a negotiation rather than of some numerical scoring. As all scientific activity needs to be balanced against the resources available, our experience has been that asking a large group of respondents to go through extensive questionnaires may not be the best way to use these resources.

Since too many indicators will aggravate the evaluation process, we would advise to start with a limited suite of indicators. Concrete indicators have been developed for some ecosystem features, while none exist for others. We addressed this problem by distinguishing two hierarchical levels of indicators: headline indicators and specific indicators. While this distinction was intended to resolve discrepancies between types of indicators available, the feedback of (notably the non-scientific) respondents showed that for an evaluation by different stakeholders it may be more appropriate to have them evaluate headline indicators as specific indicators are often meaningless to them and could obfuscate the evaluation. The evaluation and selection of each of the specific indicators belonging to a particular headline indicator could then be done by scientists who are sufficiently familiar with their merits.

Several considerations determine the choice of the number of selected indicators. The first is determined by the number of ecosystem components and attributes that we consider necessary to describe the ecosystem sufficiently comprehensive while acknowledging that it is not possible to fully describe this ecosystem in all its complexity. The second consideration is that we need indicators for state, pressure and response (Jennings 2005).

A minimum requirement for the ecosystem state indicators would be that for each ecosystem component and attribute for which operational objectives are formulated at least one headline indicator with a specific indicator is selected. Whether or not to include more indicators should be determined by how much additional information every next specific indicator provides.

The same applies for the pressure indicators where each type of pressure (i.e. human activity) would need at least one headline indicator with a specific indicator but as with the state indicators this may be several if these provide sufficient additional information. Both examples include several specific pressure indicators each representing different aspects of how fishing may affect the ecosystem.

Response indicators are by far the least developed. Probably the same applies for these types of indicators as for the pressure and state indicators but within the IMAGE project we only explored two potential types of response. Probably many more relevant types of societal response exist for which headline and one or more specific indicators need to be developed but this was not further pursued within IMAGE, partially because data availability hampered progress.

An important issue that applies whenever several specific indicators need to be combined into one headline indicator (i.e. both for pressure-state-response as well as ecological-socio-economic indicators) is that there is no single preferred way in which these specific indicators are aggregated into the one headline indicator. How to aggregate and whether this should be done through some formal algorithm or expert judgement therefore needs to be considered (and thus this is the underlying problem with these headline indicators).

Another reason which prevented the IMAGE project producing one final list of indicators was identified by the work of Rochet & Trenkel (2009) who distinguished different ways indicators might be used to give management advice in the context of an EAF because this is often overloaded with too many roles and interpretations. For example, if an indicator species is used for a given habitat or community, managing the indicator species instead of (and potentially at the detriment of) the habitat or community of interest might be rewarding in terms of management performance but not in terms of the actual objective i.e. conservation of the habitat or community. Therefore they propose three separate tools fulfilling different functions (in **bold**), each linked to a definition of what they consider the most appropriate term (in *italics*).

- **Trigger/Control**: As a trigger for management measures we propose to use *metrics* which are variables that summarize a process or pattern of interest in an exploited ecosystem. A structured suite of metrics will reveal important changes or differences to decision makers. Metrics are control tools used for giving science-based advice to management bodies and should provide a comprehensive overview of the ecosystem with all its components and attributes.
- **Evaluation/Audit**: In order to measure the performance of management we propose to use *indicators* which are variables that quantify how well a fishery (or any other manageable human activity) is managed. These indicators should therefore be tightly linked to the objectives and their relevance is determined by their usefulness in a management context.
- **Communication**: For this function we propose to use *indices* which are tools supposed to summarize complex phenomena in order to reveal important changes or differences to stakeholders. Their relevance is determined by their usefulness to a wide audience consisting of various stakeholder groups.

They also suggest different criteria should be applied to select the best indicators[1] depending on the function they are supposed to have in the management process. This, together with the previous studies shows that different stakeholders display different preferences for indicators (Spedicato et al) possibly because they give different weightings to the criteria (Piet et al) suggesting that the selection process of indicators in terms of the function they need to fulfil not only requires different weightings of the criteria but also different representation in terms of stakeholder groups. For example: the selection process of metrics for the Trigger/Control function can be done primarily by scientists with the help of managers, the selection process of indicators for the Evaluation/Audit function would require mostly managers and scientists while the indices for Communication would need a balanced selection of all stakeholder groups.

Table 12.2 Criteria (From Rice and Rochet 2005) relevant to evaluate metrics, indices, and indicators as defined in the text. i is for criteria to be considered for each individual variable, s for criteria relevant for a suite of variables

Criterion	Metrics	Indices	Indicators
Concreteness		i	
Theoretical basis	i + s	i	
Public awareness		i	
Cost	s	s	s
Accurate measurement	i		
Availability of historic data	i		
Sensitivity to fishing impacts			i
Responsiveness to management actions			i
Specificity to fishing impacts			i

[1] While the different terms (metrics/indicators/indices) may be helpful we will use the term indicators throughout this report to refer to them.

Thus, the IMAGE project has distinguished several classifications of the quantitative information available to guide this management process:

Specific – Headline
Metric (Trigger/Control) – Indicator (Evaluation/Audit) – Index (Communication)
Pressure – State – Response

To some extent these classifications are inter-related. For example:
For the Trigger/Control function many specific metrics (with an emphasis on state) are required to provide a comprehensive overview of the ecosystem with all its components and attributes but these could well be combined into a smaller number of headline indicators that would facilitate the transfer of the (mostly scientific) advice to the appropriate bodies.
For the Evaluation/Audit function the emphasis will be on pressure and response type of indicators but similar to the previous function it may be beneficial to the process if many specific indicators can be combined into relatively few headline indicators.
For the communication function relatively few headline type of indices should be used. These may consist of state, pressure or response type of indices as long as these are well understood and considered informative by a wide audience consisting of all relevant stakeholder groups.

With all these different classifications, their inter-relatedness and the many different criteria that could get different weightings depending on the function the suite of indicators needs to perform, it appears as if the selection of indicators should be a very complicated process involving many different stakeholders and long questionnaires. Practice, however, has shown that this does not have to be the case. For several fora suites of indicators have been created involving relatively small numbers of experts/stakeholders and in a reasonably short period (e.g. Environmental indicators for the CFP as identified in 2008/949/EC or Indicators for Good Environmental Status according to the MSFD). However, these indicators, excluding those for fished stocks that were already well established, have yet to be progressed to the stage that they would be accompanied by reference points, which is a much more controversial part of the process because the choice of reference points will determine the extent to which fishing activities are likely to be curtailed. The choice of reference points, although likely guided by scientists, will to a large extent depend on what matters to society and stakeholders, and if any prior decisions about reference points were made by scientists without including these groups then they are likely to be challenged.

4 Application of indicators

4.1 Reference levels

In conventional fisheries management involving single stocks, two main indicators have been widely used, fishing mortality and spawning stock biomass, and related to (precautionary or limit) reference values in order to achieve more or less explicit objectives of keeping fishing pressure at a sustained level and maintaining stock reproductive capacity.
For ecosystem-based fisheries management the initial approach was therefore to apply something similar but involving more indicators including their reference levels in order to achieve the wider range of objectives. Also, international commitments made by European nations at the World Summit on Sustainable Development and elsewhere will mean that the upcoming revision of the CFP should consider new reference levels such as based on the concept of Maximum Sustainable Yield (MSY). In this section we present the work aimed at determining reference levels for potential new indicators as well as MSY-based and other reference levels for existing indicators applied in conventional fisheries management.

Two population dynamics models were developed to identify the reference levels for existing fisheries management indicators. One model (ALADYM) was developed and applied for the Mediterranean,

the other for the North Sea. They use the same toolbox of population dynamics equations, but differ slightly in terms of their requirements for input data, components, and general configuration. An exercise was conducted to calibrate against each other. Together these models should be able to simulate biological processes, fishing pressure scenarios and to calculate reference levels for any of the stocks occurring in European waters for which data are available
.
While these models can calculate the required reference values the application of them on a number of stocks (European hake, red mullet and deep-water rose shrimp in the Mediterranean and cod, plaice and herring in the North Sea) has shown that the identification of these reference values, even with the existing models, is not straightforward as it still requires assumptions on the stock recruitment function as well as the natural mortality. Moreover, the existing variation in biological processes such as growth or maturation causes considerable uncertainty around these values necessitating precautionary ranges similar to what is currently done around the existing limit reference values.

In a first attempt to identify reference levels for an ecosystem component other than the commercial fish stocks, another simulation model was developed for the North Sea fish community. This simulation model calculated some of the most common fish community indicators and determined the MSY-based reference value for what is considered the most promising fish community indicator, the “proportion of large fish” also used in OSPAR’s EcoQO framework. It was shown that the community-based reference value for FMSY (fishing mortality to achieve MSY) was well below the FMSY values of some of the main commercial species. The consequence for management are discussed in paragraph 5.

Another important outcome of this exercise is that it showed that the identification of reference values for other ecosystem components or attributes is certainly not a trivial exercise and may often require the development of extensive simulation models that come with huge demands on scientific knowledge and data. Further, reference values have been very hard to develop by all involved in this process because there has never been a conclusive open debate about ‘what matters’ in relation to fishing impacts on many components and attributes of the ecosystem. Therefore we did not pursue the identification of reference values for any other ecosystem components or attributes.

4.2 Trends

When sufficient knowledge is lacking to establish reference levels for individual indicators, trends and reference directions may offer an effective and logical alternative or complement to reference levels, at least when the objective of management is to move the state of a component or attribute away from an unwanted state but when the long-term target for state has yet to be defined. Within IMAGE we conducted several studies that either use trends, develop the methodologies to establish them or show how trends in indicators can be used to establish which external drivers have caused the observed changes in the ecosystem and thus need to be managed in order to achieve the stated objectives.

In one study (Blanchard et al submitted) time series of ecological and exploitation indicators collected from 19 ecosystems around the world were analysed using various linear and non-linear techniques in order to identify trends of six indicators. While the expected direction of change for a deteriorating ecosystem is a decline in all indicators we observed a mixture of negative and positive directions of change. While this outcome may be partially caused by the fact that not all time series were complete or contiguous it may also reflect the different historical exploitation patterns, management and environmental regimes these systems have experienced. Finally it also shows that when considering several ecosystems each indicator may bring complementary information and thus removal of indicators probably results in the loss of information. In contrast another study (Trenkel & Rochet, submitted) on one ecosystem (Eastern English channel) did show redundancy among a suite of size-based indicators. Thus, there is no definitive answer on how many indicators are needed to comprehensively describe the European waters but the methodology to assess redundancy among indicators is available. There are also further questions to address about whether a comprehensive description based on indicators is needed to support management, or a better focus on those components or attributes that are clearly impacted by fishing.

Several other studies explored how combined time trends in indicators help identify, among the known changing pressures, which are the most likely to be having an impact on various functional groups, and thus, which kind of action should be taken to mitigate these changes. One method in particular, i.e. combining likelihood values for joint time trends in multiple metrics, proved powerful in detecting changes and identifying their likely causes. However, application of this method in various North-Mediterranean and Eastern Atlantic ecosystems showed that often several impacts were found equally likely, generating ambiguous results that might be difficult to use for ecosystem assessment and decision making. Because this is partly inherent to using noisy data and indirect evidence, something unavoidable in such complex assessments involving multiple pressures and interactions, it should be considered a way to acknowledge uncertainty. It could be used either to trigger further investigation or for precautionary management by taking action as soon as a human activity is identified as a potential factor of changes, even if it is not the only likely factor.

Thus, the studies conducted as part of IMAGE have shown the potential of trends to be used complementary to reference levels as part of indicator-based management. Trends have the advantage of requiring less quantitative information but the outcome of the assessment may often be ambiguous and dependent on strong assumptions such as the model of the system functioning. This approach is novel and more work is required to further develop and test it.

4.3 Linking indicators

4.3.1 Qualitative

In the qualitative approach the direction of change in different indicators is used to determine the main driver(s) acting on the ecosystem. Changes in temperature and hydrodynamic conditions will result in changes in primary production timing, amount, and quality, hence modifying food availability. The latter in turn will positively or negatively affect recruitment and/or individual growth, depending on the biology of each species. Similarly, eutrophication will locally enhance primary production and possibly indirectly fish growth. We used ecological knowledge and modelling to predict the impact of changes in pressures, fishing or ecosystem productivity, on two classes of metrics, a first class expressing abundance and a second related to size structure. Starting from an equilibrium state, sustained changes in the inputs to the system (fleet fishing effort or ecosystem productivity) were predicted by qualitative analysis to result in a shift in the equilibrium state, that is, changes in equilibrium abundance and life expectancy (or size) of various functional groups. These predicted directions of change take account both of the direct effect of environmental pressures and their indirect effects propagated through the food web. Having predicted the expected changes in abundance and size following changes in pressure, we reverse the reasoning and use a given combination of time trends in these metrics as indication for a given process change, based on likelihood principle. First, three monotonic (increasing, decreasing and stable) trends were fitted to each standardised metric and the log-likelihood for each trend was calculated. Second, the joint log-likelihood of metric trend combination indicating specific process changes was calculated by summing across metrics. Third, log-likelihood differences with the process change having the maximum log-likelihood were calculated. Process changes with differences smaller than a given cut-off value were interpreted as being likely. Applied to 14 exploited shelf groundfish communities from the Mediterranean and Eastern Atlantic, the method proved powerful in detecting changes and identifying their likely causes.

4.3.2 Quantitative

Several simulation models were developed within IMAGE and used for different purposes. In paragraph 2 we identified that the ecosystem components for which the ecological objectives are most likely to be compromised by fishing are: fish populations, fish communities, benthic invertebrate populations and benthic invertebrate communities. As resources for simulation model development were limited we focused on two of these components, fish populations and fish communities, and developed for each one or more simulation models. These models were then applied to deliver information on reference levels, the relationship between pressure (usually Fishing mortality F) and state (in case of population usually SSB, for community it can be several indicators) or as the operating model in an MSE framework.

The two population-level models are both intended to be generic but as they were initially developed for different European waters, i.e. the North Sea and the Mediterranean, they differ in terms of their data requirements.

The North sea model was set-up such that the biological data collected as part of the Data Collection Regulation (DCF) can be used directly for parameterization. The advantage of this, other than just user-friendliness, is that this allows the estimation of uncertainty around these reference levels and relationships and hence the explicit incorporation of this in the MSE. These results are presented and discussed in more detail in respectively paragraphs 3 and 5.

In contrast, the Mediterranean model (ALADYM, Lembo et al. 2009) operates using life-history parameters with associated variation and mimicking the population at sea by the generation of numbers at age. To represent the uncertainty inherent in the stock dynamics, the model uses different stock-recruitment relationships and natural mortality options, while the implementation of a Monte Carlo approach allows it to account for uncertainty in knowledge about recruitment, growth and maturity parameter values. The stochastic effects thus incorporated into some of the key life-history traits simulate the uncertainty in the input data and parameter relationships, accounting for measurement, process and estimation errors. A harvest control rule based upon actions directed to the control of fishing pressure through mortality reduction, change in mesh size, and closed season makes this model particularly useful to explore changes resulting from management measures as those generally adopted for the Mediterranean.

The two population-level models developed as part of IMAGE were calibrated against each other, exploring the viability of different mortality levels in long-term scenarios. The effects of fishing pressure changes on key population indicators, such as the abundance or the structure of the spawning stock biomass were identified through the relationships between fishing mortality and population metrics. Significant negative pairwise correlations between pressure factors and population metrics were highlighted from ALADYM model results, confirming also for the North Sea plaice case study that indicators of life history traits (mean length of SSB and catches) and of sustainability (SPR) were more sensitive compared to production indicators (catches and biological production) and total biomass, while responsiveness was equivalent (same time lag, year) for all the analysed metrics. Details on model parameterization and results are reported in D2.

From the comparison of the two population models, several differences became apparent. I.e. ALADYM uses a monthly time step which is favourably when modelling species with relatively fast dynamics as growth. This in contrary to the yearly time step used in the North Sea model. As well, ALADYM uses sex differentiation where the North Sea model does not. In general the biological dynamics are modelled in almost an identical way, where the models occasionally differ in the number of options available e.g. the natural mortality scenario’s. Both models assume that the population at the start of the simulation is in an equilibrium situation. The parameter input used for both methods depend on extensive data sampling, and functional relation fitting based on the underlying data. ALADYM uses mean parameter estimations accompanied with SD’s, while the North Sea model uses Non-Linear model fitting based on least-squares minimisation from which the variance-co-variance matrix can be used to generate new sets of parameters.

From the perspective of maintaining or reducing fishing impacts on the ecosystem at or below sustainable levels, as stated in one of the CFP objectives, there are two relevant and complementary attributes of the fish community: species composition and size-structure. Notably the latter attribute was thought to be affected by fishing and thus one indicator that reflects this was chosen to reflect the Ecological Quality (EcoQ) of the fish community in the OSPAR EcoQO framework. Therefore a size-structured model of the fish community was developed such that it could best represent this attribute. The model was then parameterized to reflect the North Sea fish community and validated against some single-species metrics. This showed yields are within ±50% of observed catches and modeled growth rates were also consistent with observed mean weight-at-age for each species, thereby confirming that, at least at the population-level, the model is capable of producing realistic values.

As most, if not all, indicators put forward to assess the state of the ecosystem and its components and attributes are based on monitoring programmes it was necessary to be able to translate the output of the size-structured model (i.e. the actual fish community as it exists below the surface) into the reality as we observe it (i.e. based on monitoring programmes). The main monitoring programme for the North Sea fish community is the International Bottom Trawl Survey (IBTS). Therefore we developed an observation-error model that with its current parameterization mimics the IBTS so that the outcome of this modelling exercise is not only comparable to what is found in the scientific literature but also to reference values as identified in the EcoQO context.

Application of these models (i.e. size-structured fish community model and the observation error model) delivered the following major outcomes:
all community-level indicators ("Slope of the size spectrum", "Mean weight", "Mean maximum weight" and "Proportion of large fish") showed trends in the expected direction (i.e. decline) as the consequence of exploitation. With the models we established Pressure-State relationships linking the value of the indicators to the level of fishing mortality. This allowed us for example to determine what level of F is required to achieve a specific fish community-related objective. For results see paragraph 5.2.2.

5 Indicator-based management

Within IMAGE we explored several approaches towards indicator-based management. The main distinction is probably between the "hard-wired" quantitative and the much "softer" qualitative approaches. At the onset of IMAGE the focus was much more on the "hard-wired" quantitative side of the continuum which necessitates a final suite of indicators including their reference levels and HCRs based on a thorough understanding of the P-S relationship that allow us to achieve our objectives within a certain time-frame. However, during the project we learned that it is not possible to decide on one final suite of indicators, that reference levels do not exist for most indicators and that it requires considerable scientific effort to determine them. Finally it became obvious that only in very few cases we understand the P-S relationship sufficiently to develop appropriate HCRs that at least have a chance to achieve our objectives. Because of this we also explored approaches that would be closer to the "softer" qualitative part of the continuum and only require a sense of the direction the indicator should go to and how this can be achieved with specific measures. This could then be implemented as part of an adaptive management framework where in case of active adaptive management short-term management policies are developed in an experimental design and the outcomes are analyzed for further development and implementation of management policy (Walters 1986). In contrast there are increasing proponents of passive adaptive management, aiming at learning from the past even in the absence of a true experimental design (Degnbol 2002) which is probably more realistic in the European situation. Here, the role of science is to monitor and provide interpretation of management results and propose changes in management measures. However, it still remains a big question about how this should be done.
While further developing the science required to inform the managers of the appropriate action to take in order to achieve the objectives it became obvious that scientific advice is not necessarily

implemented or complied with and that the management process would benefit from application of indicators that reflect these and possibly other relevant societal responses.

5.1 Qualitative

The following process provides an example of how a combination of trend-based and reference points approaches might be used. We use the large fish indicator as an example of the audit indicator.

1. The proportion of large fish (LFI, large fish index) is used as an audit indicator; it is associated with a (more or less) arbitrary reference point, set either on scientific grounds or by negotiation (or both).

2. At regular time-intervals (maybe not every year), the LFI is compared to its reference point and this determine the desirable direction. e.g. if LFI<LFI target, then it is necessary to increase the proportion of large fish in the ecosystem.

3. The conceptual model (possibly elaborated by negotiation with stakeholders, or users) is used to determine which management actions may make it possible to reach this objective. Qualitative analysis reveals which pressure changes could yield the desired changes in large fish (e.g. size of fish in various trophic groups / abundance of predators vs preys): this provides reference directions at a more detailed level than would the simple pressure-state relationship between the LFI and a single pressure indicator.

4. Combined trends are used to examine whether the system is going in the desired direction, and if not, which measures could be taken to change directions

5. If the system is already in a satisfying state (LFI>=LFItarget), still the trends are checked to identify ongoing changes and warn that the system might not stay in the desired state in the following years.

5.2 Quantitative

For two of the ecosystem components for which we found consistent scientific evidence that fishing impact compromises one or more of the CFP objectives (see section 2.2) we were able to develop and apply what we believe could be the full quantitative approach. This consists of the selection of the most appropriate indicators, including reference levels, understanding the Pressure-State relationship, the development of HCRs and the evaluation of these indicators and HCRs through MSE.

5.2.1 Choice of indicators and reference levels

The choice of indicators both for the fish population as well as for the fish community was largely determined by their use in existing management/policy frameworks.

For the fish populations many existing management/policy frameworks apply indicators that reflect the level of exploitation and the reproductive capacity of the populations. In the ICES area (that covers three of the RAC areas covered within IMAGE) these indicators are Spawning Stock Biomass (SSB) and Fishing mortality (F). While initially limit (lim) and precautionary (pa) reference levels were used we now differentiate from the current practice in that we follow the commitment expressed at the World summit of sustainable development (United-Nations 2002) to “Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015.”, and suggest MSY (Maximum Sustainable Yield) to be used as the reference level. In addition to the SSB and F indicators yield was used as this is one of the main indicators for the fishing industry and allows an economic evaluation of the management measures. In the Mediterranean where the management/policy framework is less structured than in ICES area and management is essentially based on fishing effort regulations, F, Fmax as proxy of Fmsy, Fmsy, SPR and Zmbp (total mortality at the maximum biological production) are the reference levels mostly used. The latter is a target level for productivity that Die and Caddy (1997) showed to be safer than MSY and that Caddy and Csirke (1983) pointed out as especially significant for fisheries where many species contribute to the catch. In such cases, large changes in abundance caused by fishing beyond MBP may alter the ecology of the fish community and affect stable fishery production of other species.

For the fish community several indicators reflecting both the size-structure (e.g. slope of the biomass-size spectrum, mean weight, proportion of large fish) and the species composition (e.g. mean maximum weight) were put forward in the scientific literature.

Of these indicators the "mean maximum length" and "large fish indicator" (LFI) were introduced by OSPAR as part of the development of Ecological Quality Objectives (EcoQOs) and more specifically the element of ecological quality for the North Sea fish community that was established in 2002 as "Changes in the proportion of large fish and hence the average weight and average maximum length of the fish community" (Heslenfeld 2008). Work by ICES further developed the LFI and determined a reference level. The LFI is now defined as the proportion by weight of fish greater than 40 cm in length in trawl samples collected by the ICES International Bottom Trawl Survey (IBTS) carried out in the first quarter of each year (Q1). The target reference level should be 0.3, thus the EcoQO for the North Sea demersal fish assemblage is "the proportion (by weight) of fish greater 40 cm in length should be greater than 0.3 (Heslenfeld, 2008).

For further work developing indicator-based management towards fish community objectives we used the above indicators with a specific focus on the LFI as this is furthest developed and most widely accepted.

5.2.2 P-S relationships

Population-level and community-level models were developed to establish the P-S relationships for respectively the fish populations and fish communities considered as part of the IMAGE project. The P-S relationships of several of these populations are shown in the appendices of D2, those of the fish community are shown in D5 and figure 2.

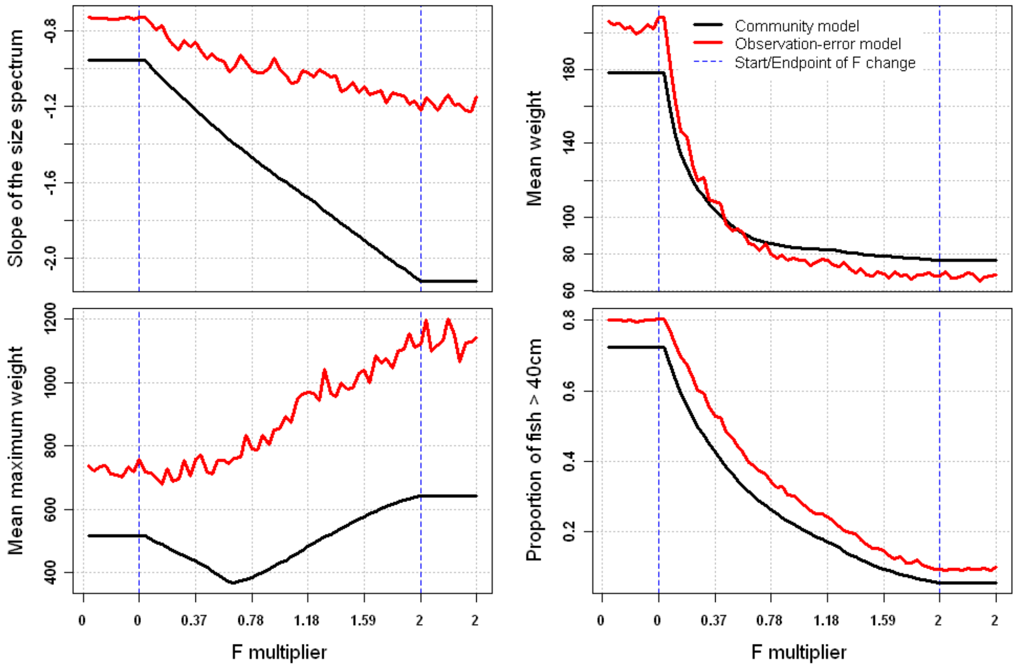

Figure 2. Values of four community-level indicators one reflecting the actual fish community (black), the other as it is perceived through the monitoring program (red). Three periods are shown: one where F is maintained at 0 and values of 10 consecutive years are shown, the second where F is gradually increased as multiplications of the F values of the major species in the base year 1991 up to F=2 and the model is allowed to reach equilibrium and finally a period where F is maintained at 2 and again 10 consecutive years are shown.

5.2.3 HCRs and Management Strategy Evaluation

As the management of the fish populations is further advanced than that of the fish community much more sophisticated harvest control rules (HCRs) were applied to the former involving reductions in direct effort and fishing mortality (F) together with set TACs for a multi-fleet fishery while for the fish community only an F-multiplier is varied that represents a specific size- and species-specific fishing pattern. For the fish populations the input for the HCRs consists of F and effort levels in the previous year while for the fish communities the values of the community indicators are used with or without a specific decision-support tool (CUSUM method).

MSE was used to evaluate the performance of indicator-based management aimed at achieving single-species, population-level (BS) and community-level objectives (NS).

Management Strategy Evaluation (MSE) is applied in the Baltic Sea to evaluate the EU 2008 multi-annual plan for Baltic cod stock recovery. This plan combines harvest control rules setting a TAC with direct effort and fishing mortality (F) reduction. Performance and robustness of the plan are tested with MSE for the Eastern and Western Baltic cod stock showing that the plan in its current design is likely to reach precautionary targets and that this outcome is more sensitive to implementation errors (e.g. catch mis-reporting) than to observation errors (e.g. data collection).

In the North Sea MSE was applied to show (1) that it is possible to apply “hard-wired” quantitative indicator-based management to ecosystem components other than the commercial fish stocks and (2) evaluate how the different indicators and configurations of the HCRs perform in terms of regulating the fishery and keeping the fish community within “acceptable” ranges.

5.3 Scientific advice

Piet et al. (2010) make a plea for increasing the transparency of the management process by specifically reflecting societal response such as the extent to which scientific advice is incorporated or the compliance of the industry. They observe that much of the effort in indicator development is focused on the “Pressure” and “State”-type of indicators and suggest that more effort should be dedicated to the development of “Response”-type of indicators. Without transparent decision-making that takes scientific advice into account, or the compliance of industry as reflected by the type of response indicators explored, the effectiveness of new developments in fisheries management, such as application of an ecosystem approach, will be compromised, as has been the case with conventional fisheries management measures.

To illustrate this two response indicators were developed within IMAGE:

the extent to which scientific advice is incorporated in decision-making,

the compliance of industry and the relevant authorities to these decisions.

Based on the most comprehensive set of data on the management process of 125 stocks for which ICES provided advice over the period 1987–2006, they explored these response indicators and found that for just 8% of the stocks, the official total allowable catch (TAC) equalled to the scientific advice, and that in recent years the official TAC overshot scientific advice by >50%. Compliance levels appear to be reflected in the percentage of stocks for which landings exceed the official TAC, decreasing from ~8% to 2%. The first indicator therefore clearly shows that scientific advice is often not or insufficiently considered while the second indicator suggests compliance of the industry is less of a problem. However, pertaining to this indicator several issues were identified:

reported landings do not necessarily correspond to the actual catches taken from the sea, so the indicator may only indicate the reporting compliance of industry and the relevant authorities.

results suggest the chosen indicator may not be appropriate because the TAC is often no longer limiting, possibly because of burgeoning other measures, such as effort limitation, closed areas, and gear restrictions.

6 Application across case studies

Several of the topics, tools or methodologies discussed in previous chapters were applied in one or more geographic (RAC) areas (see table 6)

Topics/tools/methodologies		B	W	M	N
Objectives	Ecological	X	X	X	X
	Economic	X	X	X	X
Indicators	Ecological	X	X	X	X
	Economic	X	X	X	X
Linking indicators	Qualitative		X		
	P-S	X	X	X	X
Reference levels		X	X	X	X
Decision-Support tools		X	X	X	X
Management	Qualitative		X		
	Quantitative (MSE)	X			X
Scientific advice		X	X		X

Table 6. Matrix of topics/tools/methodologies developed in methodological WPs and applied in one or more of four RAC areas: B=Baltic Sea, W=Western waters, M=Mediterranean, N=North Sea.

Socio-economic indicators was ticked for a particular case study even if these were only marginally considered in that case study. For example in the Baltic Sea evaluation of the cod stock recovery plan, Yield was the indicator that was used to incorporate the socio-economic considerations.

The results on scientific advice are based on the ICES area which covers three of the case studies but not the Mediterranean.

7 Stakeholder involvement

The IMAGE project required interaction with the RAC and we thought it instructive to report on types of interaction we had and their successes and failings. This is because there are increasing demands on 'stakeholders' to provide input to the development of scientific projects and because we recognize the very busy schedules of short-term work that RAC are already expected to accomplish. Our general view of the process is that the receipt of feedback from relatively strategic scientific projects is not a high priority because the outcome does not have an immediate effect on their day-to-day business. Presenting the work briefly and concisely at existing RAC meetings (e.g. NSRAC executive committee) is sufficient only when little feedback is expected from the RAC; organising separate meetings with RAC invitees provides a complementary strategy. Alternatively a follow-up strategy after the meeting to approach the stakeholders with a short communication and/or questionnaire allows their response to be used in a formal manner. Some of the methods developed in WP4 could support this.

Baltic RAC

Results from the Baltic case study were presented at the Baltic Sea RAC Science workshop in May, 2009. The Baltic case study provides an easily communicated framework (by applying multi-criteria decision analysis, incl. Fuzzy logic) for integrating different biological/ecological and fisheries information related to the long-term development of the three main commercial fish species in the central Baltic Sea – cod, herring and sprat. This approach provided a straightforward way to assess the success or failure of fisheries management in terms of the development of the stocks towards the agreed management objectives.

Participants of the meeting welcomed the presentation and stressed that it helped to describe the past and current status of the major commercial fish stocks in relation to management targets, and whether we are moving in a right direction with respect to these targets. The analysis presented was thought to usefully represent interactions between science and policy decisions. However, it was stressed that the use of indicators in fisheries management is a complicated issue and concern was expressed about the extent to which the results were representative.

Mediterranean

During the IMAGE Project the Mediterranean RAC was in the process of being established and this course was completed between April and June 2009, but this was close to the end of the IMAGE project. Despite of this, contacts were established with the RAC representatives who participated to the Workshop on the Green Paper held in Italy on 25 June 2009, where the contribution of the IMAGE project to the EAFM was presented and leaflets distributed to the participants.

Relationships with Fishermen Associations and Environmental Organisations at national level (Italy) allowed us to involve stakeholders in evaluation processes based on DA (decision analysis) exercises. Two main initiatives were undertaken.

Perception of Indicators evaluation framework from stakeholders. This study provided knowledge on how stakeholders perceive the European scientific evaluation framework, and in particular on how they recognize the importance of indicators to monitor the stocks, the ecosystem and the fishery sector.
Perception of Management plans from stakeholders. This survey gathered knowledge on how stakeholders perceive the potential effects of reducing fishing pressure, adopting alternative management measures, to address a more sustainable development of the demersal coastal fishery in

the long-term.

These pilot studies provided insights into the potential participatory role of stakeholders to the fishery monitoring framework and to the management process, and were considered useful exercises to be expanded at RAC level also adding new objectives. Thus there was a plan to continue with these interactions in the next future.

South-western Waters

The Southern WW RAC was created in April 2007 and we met some of its representatives in June 2007 to present the IMAGE project and case study. A steering committee for the Bay of Biscay IMAGE case study was formed, composed of French fishermen representatives who were members of the working group on demersal fisheries in the Bay of Biscay. The steering committee met in October to prioritize the issues to be dealt with in the indicators dash board. Conceptual models were developed for two of the three issues identified, with input from the steering committee, using a cognitive map approach (March 2008 meeting). A prototype dashboard of indicators for one of the three issues was presented to the steering committee, and other RAC members, in May 2009, and their feedback was used to improve the presentation and content of the dash board.

General features of the IFREMER – RAC interactions included:

Owing to limited time during RAC meetings, it was not possible to interact directly with the RAC itself and to discuss the project in plenary sessions of RAC meetings. Rather only a small French sub-group was involved in the project. This problem of non-representativity, primarily due to only French participants, was consistently pointed out by the steering committee members throughout the project, but could not really be solved owing to the limited resources of the RAC and the project. Involving Spanish or Portuguese RAC members would have entailed large logistic and translation costs
There was generally a good will to collaborate, but again limited time to devote to steering committee meetings.
There was an obvious interest of the steering committee members for the project topic, especially for the ecosystem approach to fisheries and for the economic indicators. The steering committee members are looking forward to the outputs of the project, including the dashboard of indicators.

North Sea

In order to present the IMAGE results from the North Sea to the relevant stakeholders and use their feedback we followed two approaches:

We organized a stakeholder meeting in a central and easily accessible location (Schiphol Airport in the Netherlands). In order to offer the stakeholders a comprehensive and interesting program that involved several aspects of ecosystem-based management and avoid stakeholder fatigue we put together a program with two other FP6 projects (INEXFISH, RECLAIM) that also cover this topic. We managed to get representatives from policy (Dutch ministry and EU), industry (Scottish Fishermen's Federation, Pelagic Freezer-trawler association, Danish Fishermen's Association, Fishing Shipowners Association, Dutch Fish Product Board) as well as NGOs (Greenpeace international, Joint Nature Conservation Committee, Northsea Foundation, Seas at Risk) but the attendance was low considering the number of stakeholders that were invited. For me the main message is that there is general interest and many stakeholders react enthusiastically when approached if they want to attend such a meeting but shortly before the meeting there is often this other more important meeting that forces them to cancel
As Regional Advisory Councils were put forward as the platform for stakeholder involvement we approached the NSRAC Executive Secretary to ask for a slot of time to present the IMAGE results at a NSRAC executive committee meeting. This could be easily arranged and the presentation was received with much attention. Unfortunately there was very little time for discussion or input other than a few questions. A recommendation would be to use such a meeting to set up the possibility to approach the members after the meeting with specific questions or a questionnaire.
We also met with the NSRAC SEFG in Edinburgh in April 2008 to discuss the DATAFRAME

approach developed by the group in collaboration with the North Sea Women's Network and pilot tested in three UK sites (Peterhead, Amble, and Shetland). It was agreed in a collaborative mode to further test this framework in a number of fishing communities around the North Sea, provided that funds external to IMAGE could be mobilised. As we failed on this, we could only within the WP3 apply the methodology in one site (Thorsminde in Denmark) and make some comparison with the pilot study findings. The collaborative effort was reported to the NSRAC EC by the SEFG chair (Nicky Holmyard). A second meeting with the SEFG was held in October 2009, on which we reported on the IMAGE WP3 and an up-coming EC initiative of particular interest to the NSRAC. (EC-commissioned study on "Regional social and economic impacts of change in fisheries-dependent communities" to be led by MRAG). The Pelagic RAC has made a formal request to the DG MARE to get involved in the selection of study sites and we understand that the NSRAC has done the same.

8 Applying IMAGE results

The CFP requires the progressive implementation of an ecosystem approach to fisheries management (EAFM). This will include the integration of environmental protection requirements into the CFP, including measures to 'limit the environmental impact of the CFP'. The EAFM requires that managers take account of a wide range of fisheries impacts when setting objectives, and attempts to meet these objectives will need to be supported by reliable scientific advice and effective management decision making. Indicators can support the decision making process by (1) describing the pressures affecting the ecosystem, the state of the ecosystem and the response of managers, (2) tracking progress towards meeting management objectives and (3) communicating trends in complex impacts and management processes to a non-specialist audience.

IMAGE sought to develop an operational framework of candidate indicators to support ecosystem-based fisheries management, to elaborate these indicators into comprehensive dashboards, to support management decision making and to test their applicability in regional case studies, taking into account the diversity of the fishery systems in Europe. In IMAGE the development of social, economic and ecological indicators was considered.

The IMAGE project proposed an operational framework to support the integration of environmental protection requirements into the Common Fisheries Policy (CFP) and considered and tested means by which support for environmental integration might be achieved. The development of indicators requires significant scientific resources and it was clear at the outset that any proposed framework would require that the issues to be addressed should be clearly prioritised. This was achieved by reviewing the state of European marine ecosystems and the social and economic performance of fisheries, at the Regional Advisory Council (RAC) scale, in relation to the stated objectives of the CFP. The CFP objectives were drawn from the text of the 2002 CFP and clarified with the EC. They were (1) "To maintain fishing mortality at or below levels that are necessary to achieve maximum sustainable yield for all targeted stocks", (2) "To maintain or reduce fishing impact on the eco-system at or below sustainable levels" and (3) "To develop a viable, economically efficient and globally competitive European fisheries and aquaculture industry".
In all RAC areas examined (Baltic, South-western waters RAC, North Sea RAC, Mediterranean RAC) there were fishing impacts that compromised the 'ecological' objectives (1 and/or 2) and throughout the European area there were parts of the industry that did not meet the social and economic objective (3). All the impacts that compromise objectives were identified as priority impacts, for which indicators would need to be developed. A range of relevant indicators were developed and tested in the project and a range of methods by which they might be used in management were proposed. The project, however, did not deliver THE definitive suite of indicators because we found that depending on how the criteria for good indicators were applied, different prioritisations emerged. Even though these criteria are useful to make a first selection of indicators, we now believe that from this suite the final selection of one or two indicators per ecosystem component/attribute (or in case of the MSFD, GES descriptor/attribute) should be determined by the performance of those indicators in the methods that are applied to achieve the objectives either by tracking changes in state, managing pressure or describing response. Examples of this are documented in the relevant work packages.

The project set out to establish indicator systems to support decision rules, limiting the number of indicators through a prioritisation process. However, progress with identifying indicators was most substantial and universal when these were related to the management of target stocks. Some progress was made with economic indicators and indicators for fish communities in some RAC areas and with indicators for fish communities in others. The reasons why it was only possible to develop a small range of indicators were that the relevant data were not collected at a relevant scale, that methods for linking state and pressure were not developed or could not be developed and that there was no policy or societal/ managerial view on 'what matters' for many issues (e.g. to allow the setting of reference points). The latter issue could be rapidly resolved once GES has been defined and if the 2012 CFP specifies operational objectives for an EAFM. More progress with developing indicators will have to be made given the political incentive to move beyond single-species management to an EAFM, the need to make best use of relevant data supported by the DCF and the requirement of the CFP to support the achievement of GES.

A prototype for an indicator dash board based on the analysis of trends was elaborated for the Bay of Biscay case study. One of the three issues identified in WP1 as compromising the CFP objectives, namely, the impact of fishing on groundfish communities, was selected as an example. A conceptual model of major interactions in the demersal fisheries was elicited from a South-Western RAC working group. Economic and ecological indicators were presented and their trends combined to report on the influence of stock status on fleet performance, and the influence of fleet status on fish stock dynamics. The results showed that fishing capacity as measured by number of vessels, number of seamen and total horsepower decreased in the Bay of Biscay from 2000 to 2007. Vessel profitability decreased while the salaries of seamen increased. Over the 1992-2006 period, many stocks showed increased abundances and/or decreased length. Owing to high variability in the system and noisy data, it was not possible to unambiguously ascribe these trends to the decreased fishing pressure. Favourable environmental conditions, or mixed causes, might explain these changes as well. Symmetrically the favourable changes in resources had no impact on fleet dynamics; only the collapse of the anchovy stock in 2005 was shown to have (unfavourable) consequences for pelagic fleets.

The Baltic case study focused on the central Baltic Sea and on the three major commercial fish stocks: eastern Baltic cod, herring and sprat, which all together constitute ca 95% of fish biomass in the system. The available knowledge (including that from the completed INDECO project) enabled an ecosystem approach for elaboration of a prototype for an indicator dash board within IMAGE. This considered the impact of fishing on fish population structure, abundance and production.

In the Baltic case study we i) investigated links between pressure, state and response indicators; ii) studied the effect of exploitation levels on the structure, abundance and production of fish stocks under different environmental regimes; iii) evaluated the response of fish stocks to the recommended exploitation reference levels; iv) assessed the choice of reference points for the cod stock; v) evaluated bio-economic consequences of different management regimes and scenarios of the cod stock under different environmental situations; and vi) evaluated the effect of spatio-temporal fishing closures for fish stocks depending on climate-driven hydrographic regime. This was achieved by development and application of food-web, ecosystem and fisheries modeling approaches. In addition, we developed a framework to combine ecological/biological, environmental and fisheries indicators related the three principal fish species, based on the multi-criteria decision support tools methodology. This allowed us to synthesize and visualize long-term changes in parameters determining dynamics of the three major commercial fish species; (ii) evaluate the relative impact of fishing on these stocks; and (iii) track the performance of fisheries management in terms of its influence on stock trends.

The main results highlight that high variability of fish stock dynamics are to be attributed to both natural causes and fishing impact. Concerning the eastern Baltic cod, the EC target exploitation level was found to be sustainable for promoting recovery of the cod stock, also under unfavorable hydrographic/climate conditions.

8.1 Use of indicators

In practice, IMAGE showed that indicators had two main uses, both of which support existing reporting and management systems. The first is to support the reporting of state or pressure (social, economic, ecological) and the second is to support decision rules that are directly used to modify pressure and hence state. The results show that (1) the response rates of indicators to changes in management are variable, (2) the strength of (and the capacity to describe) the relationship between pressure and state is variable and (3) when trends in indicators need to be interpreted then stakeholders can contribute to the interpretation in a transparent process.

The IMAGE prioritisation process showed that there were sufficient data to determine whether or not fishing compromised progress towards some of the social, economic and ecological objectives but, with the exception of impacts on target stocks, data were insufficient to develop indicators to track progress in relation to all objectives in all RAC areas.

When prioritisation of impacts that might compromise high level objectives for ecosystem components and attributes is feasible, indicators can usually be defined, but the development of reference points can rarely be progressed in the absence of clear operational objectives that reflect a societal view about 'what matters'. A process to formulate and express such a view is needed to progress the development of reference points. The only reference points that have been consistently used in most RAC areas are those that are used for the management of target stocks. The process of defining GES for the MSFD may provide additional insight into how stakeholder views can be incorporated when establishing reference points, although the process to date has only involved scientists. The project also showed that in many instances, setting reference points is not feasible given the present state of knowledge and/or policy development, and that this situation may not change in a foreseeable future. However, in many cases reference directions can be defined and tools were developed to use indicators and reference directions. Given the current state of European marine ecosystems, the accurate setting of reference points is quite a secondary issue and reference directions may be useful and probably sufficient for several decades.

Management advice that is based on a clear understanding of the links between pressure and state is thought to be desirable, but the adoption of 'hard wired' frameworks (where 'hard wired' frameworks are defined as those that can link management actions to changes in the state of the environment, as defined by the value of an indicator in relation to a reference point) for management decision making is a challenge owing primarily to the difficulty of defining reference points and predicting pressure-state relationships. Regional (RAC areas) clearly differ in their capacity to develop 'hard wired' frameworks. 'Hard wired' frameworks with decision rules require that the pressure-state links are well established, that it is possible to measure pressure and state, that it is possible to implement management and that reference levels can be defined. 'Hard wired' frameworks have only been employed for the management of target stocks subject to quantitative assessment. The study in the Baltic RAC, where a few target species dominate total biomass, shows their potential value in supporting an EAFM.

Within the project, however, there has been one attempt to develop a hard-wired framework that goes beyond the target fish stocks. In the North sea RAC …..

The reasons for the differences among RAC in their capacity to develop 'hard wired' frameworks are differences in ecology (e.g. few species or many species dominate total biomass as is the case in the Baltic and Mediterranean respectively) and differences in fisheries (whether few or many species are targeted, whether fishing pressure is attributed mostly to small or large vessels and whether it can be measured). In practice, indicator systems tend to be developed based on 'what matters' and 'what is available'- genuinely new science is costly in time and funding. This was reflected in the different ways that the development of indicators was approached in the WP case studies, from a single species focus in the Baltic to a focus on communities in the south-western waters and North Sea RAC.

8.2 The changing policy environment

In the course of IMAGE, there were ongoing policy changes that influenced the type of indicator systems that may need to be developed to support implementation of an EAFM.

The Marine Strategy Framework Directive of 2008 identified a clear role for the CFP in contributing to the marine environmental management that is needed to achieve Good Environmental Status. Thus the CFP is identified as the primary instrument to manage the environmental impacts of fishing to the extent necessary to achieve GES. The efficient development of indicators and reference points to support management, that would necessarily avoid replication or the delivery of inconsistent information among policies, would be achieved by ensuring that the indicators used to support fisheries management would also be used to assess progress towards GES when fisheries were the main human impact that could influence GES.

Article 1 of the MSFD stated that ‘marine strategies [in each ecoregion] shall apply an ecosystem-based approach to the management of human activities, ensuring that the collective pressure of such activities is kept within levels compatible with the achievement of good environmental status and that the capacity of marine ecosystems to respond to human-induced changes is not compromised, while enabling the sustainable use of marine goods and services by present and future generations’. The reference to ‘collective pressure’ clearly places management of fisheries in an integrated framework with management of all other human activities. Further, the MSFD aims to achieve Good Environmental Status (GES) for ecosystem components and attributes (e.g. Commercial fish stocks, food webs, seabed habitats, biodiversity) that are impacted by human activities. The role of the CFP in contributing to the marine environmental management that is needed to achieve GES was explicit in the text of the MSFD. First, fisheries regulatory measures needed to achieve GES were to use the CFP to the fullest extent possible, and second, the CFP and future revisions of the CFP should take into account the environmental impacts of fishing and the objectives of the MSFD. The MSFD provides a clear context for the 2012 revision of the CFP and for starting to operationalise parts of an EAFM, since the revised CFP needs to support the management of the environmental impacts of fishing to the extent necessary to achieve GES.

The MFSD identified the need for regional management, recommending that management was conducted in ‘ecoregions’ and smaller ‘subregions’ as necessary. These ecoregions were based on biogeographic and oceanographic features, taking account of existing political, social, economic and management divisions. The ecoregions broadly coincide with RAC areas, again providing opportunities for improving compatibility of approaches.

8.3 Additional data to support an EAFM

While the commitment to adopting an EAFM provides a strong incentive to move beyond single species management, the completion of the revision of the Data Collection Framework (DCF) ensured that data to track the wider impacts of fishing on ecological and social systems will be collected and available in all RAC areas. These are in addition to the data already collected on a less (internationally) formalised basis as part of research activities and national monitoring activity.

Data collected with the support of the DCF can be used to calculate pressure indicators of the spatial and temporal distribution of fishing activity and state indicators of population and community attributes. These indicators could be used to (1) provide information on how trends in pressure and state respond to target species management and to make additional modifications to such management if it is not meeting objectives, (2) to assess state in relation to the reference point and use this with a decision rule to provide explicit ‘hard wired’ management advice on how pressure should be changed or (3) provide information on trends that could be examined to make recommendations for management based on a synthesis of the observed trends. For approach (2) any debate about ‘what matters’ will be ultimately resolved when ‘what matters’ could be expressed in terms of a reference point. However, we also note from a practical perspective that it is necessary to start adopting and using indicators as soon as possible given the political needs and this, coupled with different capacity to introduce hard wired systems in different RAC areas may necessitate a combined approach. The main questions about any approach are how the practical arrangements for making decisions would be established, how would the composition of decision making bodies be determined and how would the legitimacy of the process be maximised.

8.4 Setting reference points and directions

If reference points are not easily defined then there is still the option to work with reference directions in the initial phase of implementation. Thus if the state of the environment, society or the economy, as described by an indicator, is clearly not consistent with the state that meets the objective then management action might legitimately be required to achieve a trend in the state indicator indicative of progress towards meeting the objective. However, such approaches based on trends do not accurately address the challenging issue of what state should be (the target). Since forthcoming policy objectives will focus on meeting targets (and already do in the case of MSY in the revised CFP and GES within the MSFD) the targets will need to be defined at some stage even if reference directions can support management for at least the first few years.

Ultimately, the setting of reference points and directions reflect views of society about how the environmental, social or economic system should perform and will require that the related objectives are interpreted (because the wording of objectives is rarely sufficiently explicit to make the definition of RP unambiguous). In practice, we suggest some degree of risk may need to be taken when establishing reference points by putting forward a proposition, since this will encourage them to be contested and refined.

If objectives are not being met but a reference point has not been defined then a trend can be used as the starting point for management- but we conclude that there will always need to be a debate, and resolution, about the value of a target in the longer term.

8.5 The future

Given the time pressures to apply indicators in management (that are now strongly dictated by the commitment to adopting EAFM, the MSFD and the forthcoming 2012 revision of the CFP) it is clear that we will largely have to work with the current tool box (in terms of models of pressure-state links and data inputs). Notwithstanding the consistency encouraged by the DCF we believe that it will be hard to achieve standardisation of approaches among RAC areas and that this may not be strictly necessary given ecological and societal differences. However, we also note that policy requires that high level objectives (e.g. GES, any operational objectives identified in a reformed CFP) should be met by all European countries. For this reason, a management system that is based on common high level objectives but allows some regional flexibility in the choice of operational objectives and indicators is likely to be most satisfactory. The process of identifying indicators in the project also demonstrated that we did not find it straightforward to identify indicators with all the properties that we considered theoretically desirable. A high level of compromise will be needed when developing management systems, although it is hoped that challenge to the initial systems will lead to modifications and improvement through time.

The timing of the 2012 CFP reform and the introduction of the MSFD are quite compatible in terms of allowing for the further development of indicators to support both processes. Thus the initial assessment of the current environmental status of a Member State's marine waters and a determination of what GES means for these waters is to be completed by 2012 and targets and indicators that will be used to show whether a Member State is achieving GES are also to be established by 2012. The establishment of programmes of measures designed to achieve or maintain GES should be developed by 2015 and implemented by 2016 with the aim of achieving GES by 2020.

This effectively means that the quantification of pressure-state links is not necessary to support the MSFD in 2012 (although it is clearly a necessary ambition and would support the CFP), but will need to have been achieved by 2015 to develop the programmes of measures that are relevant to those descriptors of GES that might be impacted by fishing. The descriptors that are most likely to be routinely impacted by fishing and thus responsive to fisheries management measures are 1, 3, 4 and 6 where (1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions; (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; (4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity and (6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. Clearly the definitions of the descriptors include many terms such as 'normal' and 'not adversely affected' that have yet to be defined, a task assigned to the ICES-JRC task groups supporting this work.

8.6 Conclusion

The main conclusions of IMAGE are that a common framework for indicator-based management can be developed for European waters but it may perform better conceptually than practically. Regional (among RAC area) differences in the environment, society, economies and science capacity mean that different indicators and methods for using indicators in management may be more desirable and more cost-effective than pan European standardisation, so long as these indicators support management that meets the high level objectives of the CFP (as expressed in the 2012 revision) and GES (as required by the MSFD). Data from the new DCF provide a concrete opportunity to pilot indicators and to establish initial reference points or directions that may evolve once they are used, evaluated and contested by stakeholders.

State can only be managed if the relationships with fishing (pressure) are known. Significant work is still required to understand the links between fishing pressure and the value of indicators and to establish reference points. Predicting such relationships is fundamental to developing an EAFM but the relationships can be very challenging to detect or to model in practice. A number of approaches are proposed that range from assessing empirical trends in multiple state indicators and relating these to fishing pressure to models that link the structure of the fish community and indicators of this structure to fishing mortality. None of these approaches are sufficiently developed to allow full implementation at this time.

References (other than those in the dissemination section)

Caddy, J.F. and J. Csirke (1983). Approximations to sustainable yield for exploited and unexploited stocks. Oceanogr. Trop. 18(1): p 3-15

Die, D. and J.F. Caddy (1997). Sustainable yield indicators from biomass: are there appropriate reference points to use in tropical fisheries? Fish. Res. 32: 69-79.

Heslenfeld P, Enserink, E. L. (2008) OSPAR Ecological Quality Objectives: the utility of health indicators for the North Sea. ICES Journal of Marine Science, 65: 1392-1397

Jennings S (2005) Indicators to support an ecosystem approach to fisheries. Fish and Fisheries 6:212-232

Rice JC, Rochet M-J (2005) A framework for selecting a suite of indicators for fisheries management. ICES Journal of Marine Science 62:516

United-Nations (2002) Report of the World Summit on Sustainable Development, Johannesburg. A/CONF199/20*:167

9 Dissemination

The IMAGE exploitable knowledge (see table 7) consisted mostly of scientific findings and computer code written in R so that it could be used as part of the Fisheries Library in R (FLR). For the IMAGE dissemination activities of this knowledge we distinguish between various oral dissemination activities (see table 8) such as through conferences, workshops, stakeholder meetings etc. and written dissemination activities (section 9.2) such as through publication in peer-reviewed scientific journals, reports, newspaper articles, flyers and our website.

Table 7. IMAGE exploitable knowledge

Exploitable Knowledge	**Exploitable product(s) or**	**Sector(s) of application**	**Timetable for**	**Patents**	**Owner & Other Partner(s)**
Framework	Report and publications	EAFM	2010, use in further studies	None	All partners
Quantitative models to calculate reference levels	Data, report and publications	EAFM	2010, use in further studies (i.e. MEFEPO, MEECE)	None	All partners
Quantitative models to calculate P-S relationships	Data, report and publications	EAFM	2010, use in further studies (i.e. MEFEPO, MEECE)	None	All partners
New indicators: Ecological, socio-economic, societal response	Data, report and publications	EAFM	2010, use in further studies (i.e. MEFEPO, MEECE)	None	All partners
Framework for socio-economic data collection and analysis	Report	Socio-economics	2010, applied in an ongoing study of 18 european cases of fisheries dependent communities. contract Fish 2006/2009: "Assessment of the status, development and diversification of fisheries dependent communities	None	5
Qualitative models for data-poor circumstances	Data, report and publications	EAFM	2010, use in further studies	None	All partners
Generic framework for MSE	Report	EAFM	2010, use in further studies (i.e. MEFEPO, MEECE)	None	All partners
Code for indicator-based management	Available as part of Fisheries Library in R (FLR)	EAFM	2010, use in further studies (i.e. MEFEPO, MEECE)	None	All partners

9.1 Oral dissemination

Table 8. IMAGE oral dissemination activities

Date	Event	Dissemination	Countries	Audience	Forum	Partner
Feb-07	AIFRB 50th Anniversary Symposium "The Future of Fishery Science in North America", Seattle, USA	Presentation: Why and how could indicators be used in an ecosystem approach to fisheries management?.	Global	Mostly science, few stakeholders	Conference	3
Jun-07	8e Forum Halieumétrique, La Rochelle, France	Presentation: Une approche non-paramétrique pour caractériser les changements récents dans les séries temporelles d'indices de population (présentation orale)	France	Mostly science, few stakeholders	Conference	3
Jun-07	Southern Western Waters RAC	Presentation of IMAGE project and Bay of Biscay case study.	Western waters	Stakeholders	RAC	3
Sep-07	ICES Annual Science Conference, Helsinki, Finland	Presentation: How could indicators be used in an ecosystem approach to fisheries management?	Global	Mostly science, few stakeholders	Conference	3
Sep-07	ICES Annual Science Conference, Helsinki, Finland	Presentation: Do population and community metrics tell the same story about recent changes in Northern Mediterranean fish communities?	Global	Mostly science, few stakeholders	Conference	3
Oct-07	Southern Western Waters RAC	First steering committee meeting for the Bay of Biscay IMAGE case study to prioritize the issues to be dealt with with the indicators	Western waters	Stakeholders	RAC	3
Nov-07	Environmental indicators: utility in meeting regulatory needs (ICES Symposium), London, UK	Keynote speaker “Indicator systems to support marine environmental management”.	Global	Mostly science, few stakeholders	Conference	2
Nov-07	ICES Symposium “Environmental indicators: utility in meeting regulatory needs”, London, UK	Presentation: Exploring the relationship between ecological state and fishing pressure as the basis for a framework for indicator-based management	Global	Mostly science, few stakeholders	Conference	1

Nov-07	ICES Symposium "Environmental indicators: utility in meeting regulatory needs", London, UK	Member Scientific Committee	Global	Mostly science, few stakeholders	Conference	1
Nov-07	MCS Sustainable Seafood Conference, Portsmouth	Keynote: "Fishery-environment interactions"	Global	Stakeholders	Conference	2
Mar-08	Southern Western Waters RAC	Development of conceptual models for existing issues	Western waters	Stakeholders	RAC	3
Apr-08	Body-size and ecosystem dynamics (Sizemic Meeting), University of Cambridge	Keynote: "Size and species-based analyses of food webs".	Global	Science	Conference	2
Apr-08	EU Fisheries Stakeholder Workshop held at Amsterdam Schiphol Airport, Netherlands	Presentation: Indicator-based fisheries management	EU	Stakeholders	Workshop	1
Apr-08	EU Fisheries Stakeholder Workshop, Amsterdam	Invited talk. "Indicators for fisheries management in Europe"	EU	Stakeholders	Workshop	2
Apr-08	XI International Symposium on Oceanography of the Bay of Biscay, San Sebastian, Spain	Presentation: An integrated assessment of the ecological and economical status of French fisheries in the Bay of Biscay	Global	Mostly science, few stakeholders	Conference	3
Apr-08	XI International Symposium on Oceanography of the Bay of Biscay, San Sebastian,Spain	Poster: Fish diversity in the Bay of Biscay is higher on the continental slope than on the shelf,	Global	Mostly science, few stakeholders	Conference	3
Apr-08	NSRAC Socio Economic Focus Group, Edinburgh, UK	Presentation IMAGE results and dialogue	North Sea	Stakeholders	Conference	5
May-08	Danish Technical University, Copenhagen	Invited talk. "Indicator systems to support marine environmental management"	Denmark	Mostly science, few stakeholders	Conference	2

May-08	Workshop on the participatory management and management plan	Discussion	Italy	Stakeholders	Workshop	6
Jun-08	Colloque «Approche Systémique des Pêches», Boulogne-sur-Mer, France	Assessing the reference state in the Bay of Biscay	Western waters	Mostly science, few stakeholders	Conference	3
Jun-08	Colloque «Approche Systémique des Pêches», Boulogne-sur-Mer, France	Presentation: Viabilité économique des flottilles de pêche et état de l'écosystème: vers une évaluation conjointe. Une application au golfe de Gascogne.	Western waters	Mostly science, few stakeholders	Conference	3
Jun-08	Eurocean symposium, Rome, Italy	Presentation: Using metric trends to evaluate the changes in exploited marine communities: identifying pressures.	EU	Mostly science, few stakeholders	Conference	3
Jun-08	IIFET 2008, Vietnam	Presentation: An integrated assessment of the ecological and economical status of French fisheries in the Bay of Biscay	Global	Mostly science, few stakeholders	Conference	3
Sep-08	ICES Annual Science Conference, Halifax, Canada	Presentation: Trophic cascades in size-spectra" (sept. 2008; Halifax, Canada).	Global	Mostly science, few stakeholders	Conference	4
Oct-08	Robert Marsham Anniversary, Linnean Society, London	Guest lecture "Monitoring marine resources"	UK	Mostly science, few stakeholders	Conference	2
Nov-08	Annual Conference of CoNISMa	Discussion	Italy	Science	Conference	6
Nov-08	National scientific Conference of CoNISMa. Lecce, Italy	Presentation: Le risorse demersali del Tirreno Meridionale: sostenibilità dei prelievi ed impatti della pesca. Quali mari italiani?	Italy	Mostly science, few stakeholders	Conference	6
Feb-09	Dutch ministry, The Hague, Netherlands	Presentation: Operationalizing the Ecosystem approach	Netherlands/North Sea	Policy	Ministry	1

Mar-09	ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB), Rostock, Germany	Presentation: Environmental assessment of the Baltic Proper: preliminary results	Baltic	Stakeholders	Workshop	4
Mar-09	Workshop within the Italian Marine Biologists Association-SIBM	Discussion	Italy	Science	Workshop	6
Apr-09	Bevan Series on Sustainable Fisheries, University of Washington	Invited speaker "Progress towards an ecosystem approach to fisheries in Europe"	UK	Mostly science, few stakeholders	Conference	2
Apr-09	MariFish Workshop on The use of Indicators to support an Ecosystem Approach to Fisheries Management, Dublin Ireland	Key note speaker: The use of indicators to operationalize the Ecosystem Approach	EU	Mostly science, few stakeholders	Conference	1
Apr-09	Scientific-Medits Coordination Meeting	Discussion	Mediterra nean	Science	Conference	6
May-09	8th Indo Pacific Fish conference, Fremantle, Australia	Key note speaker: Using metrics' trends to evaluate the changes in exploited marine communities: Identifying pressures.	Global	Mostly science, few stakeholders	Conference	3
May-09	Baltic RAC, Gdynia, Poland	Presentation: Indicators for fisheries management: EU FP6 project IMAGE case study for the Baltic Proper	Baltic	Stakeholders	RAC	4
May-09	BSRAC science workshop, Gdynia, Poland	Presentation: Indicators for fisheries management: EU FP6 project IMAGE case study for the Baltic Proper.	Baltic	Stakeholders	RAC	4
May-09	Oceans Past II Conference on Multidisciplinary Perspectives on the History and Future of Marine Animal Populations , Vancouver, Canada	Presentation: Application of historical data for evaluation of management success: case study for the open Baltic	Baltic	Mostly science, few stakeholders	Conference	7

May-09	Southern Western Waters RAC	Presentation of indicator dashboard.	Western waters	Mostly science, few stakeholders	RAC	3
Jun-09	9ième forum halieumétrique, Brest	Presentation: Vers un tableau de bord d'indicateurs sur la pêche et l'écosystème: où cours-je, mais pas dans quel état j'erre.	France	Mostly science, few stakeholders	Conference	3
Jun-09	9ième forum halieumétrique, Brest	Presentation: Une approche par maximum de vraisemblance de combinaison des tendances de plusieurs métriques pour identifier les causes probables des changements observés.	France	Mostly science, few stakeholders	Conference	3
Jun-09	Biolfish Workshop	Discussion	Mediterra nean	Stakeholders	Workshop	6
Jun-09	Estonian Ministry of Environment, Tallinn, Estonia	Presentation: Assessment of the management success of the main commercial fish of the Baltic Sea during the past three decades.	Baltic	Stakeholders	Ministry	4
Jun-09	ICES Review Group for Evaluation of the North-Eastern Cod Management Plans.	Application: MSE framework developed by Bastardie et al. (2010) used for evaluation management plan	Baltic	Stakeholders	Workshop	4
Jun-09	National Oceanography Centre, Southampton	Invited lecture "Size-based processes in marine ecosystems"	UK	Mostly science, few stakeholders	Conference	2
Jun-09	NSRAC Executive Committee meeting, Gothenburg, Sweden	Presentation of IMAGE results	North Sea	Stakeholders	RAC	1
Jun-09	Sizemic workshop, Sweden	Presentation: Trophic cascades in marine ecosystems.	Global	Science	Workshop	4
Jun-09	Workshop Il Green Paper e la riforma della politica comune della pesca., Monopoli, Italy	Presentation: Nuovi paradigmi della ricerca sulla pesca.	Italy	Policy	Workshop	6
Jul-09	Reform of the Common Fisheries Policy, London	Invited talk "The knowledge base for the policy"	EU	Policy	Ministry	2

Sep-09	ICES Annual Science Conference, Berlin, Germany	Presentation: Ecological Network Analysis, indicators of food-web changes in the Baltic Sea.	Global	Mostly science, few stakeholders	Conference	4
Sep-09	ICES Annual Science Conference, Berlin, Germany	Presentation: Ecological Forecasting under Climate Change – the case of Baltic cod	Global	Mostly science, few stakeholders	Conference	4
Sep-09	ICES Annual Science Conference, Berlin, Germany	Presentation: The joint dynamics of fish stocks and fishing fleets: testing hypotheses in the Bay of Biscay.	Global	Mostly science, few stakeholders	Conference	3
Sep-09	ICES Annual Science Conference, Berlin, Germany	Presentation: Qualitative food-web modelling for predicting the joined directions of change of population and community indicators: identifying dominant process changes as a step towards an EAF.	Global	Mostly science, few stakeholders	Conference	3
Sep-09	Opening of the Centre for Marine Policy, Leeuwarden	Invited talk "Human-environment interactions on the Dogger Bank"	Netherlands/North Sea	Stakeholders	Conference	2
Oct-09	Workshop on the participatory management	Discussion	Italy	Stakeholders	Workshop	6
Oct-09	NSRAC Socio Economic Focus Group, IJmuiden, Netherlands	Presentation IMAGE results and dialogue	North Sea	Stakeholders	Conference	5
Nov-09	ICES/PICES/UNCOVER Symposium on Rebuilding Depleted Fish Stocks– Biology, Ecology, Social Science and Management Strategies, Warnemünde, Germany	Presentation: An ecosystem-based framework for tracking performance of fish stocks and related forcings using fuzzy-logic approach.	Global	Mostly science, few stakeholders	Conference	7
Nov-09	Symposium on Rebuilding Depleted Fish Stocks-Biology, Ecology, Social Science and Management Strategies, Warnemünde, Germany	Presentation: Evaluation of the multiannual plan for the cod stocks in the Baltic Sea.	Baltic	Mostly science, few stakeholders	Conference	4

Nov-09	Symposium on Rebuilding Depleted Fish Stocks-Biology, Ecology, Social Science and Management Strategies, Warnemünde, Germany	Presentation: An indicator-based framework for tracking performance of fish stocks and related forcings in the Baltic Sea.	Baltic	Mostly science, few stakeholders	Conference	4
Nov-09	Workshop on the participatory management	Discussion	Italy	Stakeholders	Workshop	6
Feb-10	Workshop on Ecosystem Based Approach to Management of Baltic herring, funded by Nordic Council, Charlottenlund, Denmark	Presentation: An indicator-based framework to advance EAF in the Baltic Sea: recognizing potentials and limitations of fisheries management.	Baltic	Mostly science, few stakeholders	Workshop	4
Apr-10	ICES Baltic Fisheries Assessment Working Group (WGBFAS)/Baltic Integrated Assessment Working Group (WGIAB) meeting	Presentation: An indicator-based framework to advance EAF in the Baltic Sea: recognizing potentials and limitations of fisheries management.	Baltic	Mostly science, few stakeholders	Workshop	4
Sep-10	IMR, Bergen, Norway	Presentation IMAGE final results	Norway	Science	Meeting	1
To be planned	EU, Brussels	Presentation IMAGE final results	EU	Policy	Meeting	1

9.2 Written dissemination

9.2.1 Peer-reviewed journals

Andersen and, K.H.; and M. Pedersen. 2010. Damped trophic cascades driven by fishing in marine ecosystems. Proc. Roy. Soc. London B 277, 795–802 (2010). doi: 10.1098/rspb.2009.1512.

Andersen, K,H., K. Farnsworth, M. Pedersen and H. Gislason. 2009. How community ecology links natural mortality, growth and production of fish populations. ICES J. mar. sci. 66(9) 1978-1984 doi:10.1093/icesjms/fsp161 (2009).

Bastardie, F., Baudron, A., Bilocca, R., Boje, J., Bult, T. P., Garcia, D., Nielsen, J.R., Petursdottir, G., Poos, J.J., Sanchez, S., Ulrich, C. 2009. Evaluating Biological Robustness of Innovative Management Alternatives. In: Hauge, K.H. and D.C. Wilson (Eds) 2009. Comparative Evaluations of Innovative Fisheries Management: Global Experiences and European Prospects Dordrecht The Netherlands: Springer Publishing.

Bastardie, F., Nielsen, J.R.., and Kraus, G. 2010a. The eastern Baltic cod fishery: a fleet based management strategy evaluation framework to assess the cod recovery plan of 2008. ICES J. Mar. Sci. 67: 71-86.

Bastardie, F., Vinther, M., Nielsen, J.R., Ulrich, C. and Storr-Paulsen, M. 2010b. Stock-based vs. fleet-based evaluation of the multi-annual management plan for the cod stocks in the Baltic Sea. Fish. Res. 101 (2010): 188-202. doi:10.1016/j.fishres.2009.10.009

Blanchard, J. L., Coll, M., Trenkel, V. M., Vergnon, R., Yemane, D., Jouffre, D., Link, J., Shin, Y.-J. (2010) Trend analysis of indicators: a comparison of recent changes in the status of marine ecosystems around the world. ICES Journal of Marine Science, 67, 732-744.

Blanchard, J.L., Jennings, S., Law, R., Castle, M.D., McCloghrie, P., Rochet, M.-J., & Benoit, E. (2009) How does abundance scale with body size in coupled size-structured food webs. Journal of Animal Ecology, 78, 270-280.

Blanchard, J.L., Maxwell, D.L. & Jennings, S. (2008) Power of monitoring surveys to detect abundance trends in depleted fish populations: the effects of density dependent habitat use, patchiness and climate change. *ICES Journal of Marine Science*, **65**, 111-20.

Cotter, J., Petitgas, P., Abella, A., Apostolaki, P., Mesnil, B., Politou, C.-Y., Rivoirard, J., Rochet, M. J., Spedicato, M. T., Trenkel, V. M., and Woillez, M. 2009. Towards an ecosystem approach to fisheries management (EAFM) when trawl surveys provide the main source of information. Aquatic living resources, 22: 243-254.

Dambacher, J. M., Gaughan, D. J., Rochet, M. J., Rossignol, P. A., and Trenkel, V. M. 2009. Qualitative Modelling and Indicators of Exploited Ecosystems. Fish and Fisheries, 10: 305–322.

Daurès, F., Rochet, M. J., Van Iseghem, S., and Trenkel, V. M. 2009. Fishing fleet typology, economic dependence, and species landing profiles of the French fleets in the Bay of Biscay, 2000-2006. Aquatic living resources, 22: 535–547.

De Lara, M., Doyen, L., Guilbaud, T., and Rochet, M.-J. 2007. Is a management framework based on spawning stock biomass indicator sustainable? A viability approach. ICES Journal of Marine Science, 64: 761-767.

Dulvy, N.K., Jennings, S., Rogers, S.I., & Maxwell, D.L. (2006) Threat and decline in fishes: an indicator of marine biodiversity. *Canadian Journal of Fisheries and Aquatic Science*, **63**, 1267-1275.

Eero, M., Jarre, A., Ojaveer, H., Köster, F.W., Lindegren, M., Tomczak, M.T. An indicator-based framework to advance ecosystem approach to fisheries in the Baltic Sea: recognizing potentials and limitations of fisheries management (Submitted).

Eero, M., MacKenzie, B.R., Köster, F.W., Gislason, H. Multi-decadal responses of a cod (*Gadus morhua*) population to human-induced trophic changes, exploitation and climate variability. Ecological Applications (in press).

Frisk, M. G., Duplisea, D. E., Trenkel, V. M. In press. Exploring the abundance-occupancy relationships for the Georges Bank finfish and shellfish community from 1963-2006. Ecological Applications.

Ojaveer, H. and Eero, M. An indicator-based framework for evaluation of the status of the Baltic Sea ecosystem. Manuscript.
Jennings, S & Rice, J.C. (in press) Towards an ecosystem approach to fisheries in Europe: a perspective on the current state and future directions. Fish and Fisheries.
Jennings, S. (2007) Reporting and advising on the effects of fishing. *Fish and Fisheries*, **8**, 269-276.
Lee, J., South, A & Jennings, S. (in press). Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. ICES Journal of Marine Science.
Lembo G., Abella A., Fiorentino F., Martino S. and Spedicato M.-T. 2009. ALADYM: an age and length-based single species simulator for exploring alternative management strategies Aquat. Living Resour., 22: 233–241.
Lindegren, M., Möllmann, C., Nielsen, A. & Stenseth, N. C. 2009 Preventing the collapse of the Baltic cod stock through an ecosystem-based management approach. Proc. Natl Acad. Sci. USA. 106, 14 722–14 727.
Lorance, P., Bertrand, J. A., Brind'Amour, A., Rochet, M. J., and Trenkel, V. M. 2009. Assessment of impacts from human activities on ecosystem components in the Bay of Biscay in the early 1990s. Aquatic living resources, 22: 409-431.
Margit Eero, Astrid Jarre, Henn Ojaveer, Friedrich W. Köster, Martin Lindegren, Maciej Tomasz Tomczak. An indicator-based framework to advance ecosystem approach to fisheries in the Baltic Sea: recognizing potentials and limitations of fisheries management. Submitted to Canadian Journal for Fisheries and Aquatic Sciences.
Mills, C.C., Townsend, S.E., Jennings, S., Eastwood, P.D., & Houghton, C.A. (2007) Estimating high resolution trawl fishing effort from satellite-based vessel monitoring system data. *ICES Journal of Marine Science*, **64**, 248-255.
Nielsen, J.R. and Limborg, M. 2009. Managing fleets and fisheries rather than single stocks – conceptual change in European fisheries management advice. World Fishing 58 (1): 8-9.
Persohn, C., Lorance, P., and Trenkel, V. M. 2009. Habitat preferences of selected demersal fish species in the Bay of Biscay and Celtic Sea, North-East Atlantic. Fisheries Oceanography, 18: 268-285.Piet, G. J., Jansen, H. M., and Rochet, M.-J. 2008. Evaluating potential indicators for an ecosystem approach to fishery management in European waters. ICES Journal of Marine Science, 65: 1449-1455.
Piet GJ, Jansen HM, Rochet MJ (2008) Evaluating potential indicators for an ecosystem approach to fishery management in European waters. Ices Journal of Marine Science 65:1449-1455
Piet GJ, van Overzee HMJ, Pastoors MA (2010) The necessity for response indicators in fisheries management. ICES Journal of Marine Science 67:559-566
Piet, GJ, Hintzen, NT, Bogaards, JA, van Hal, R and Brunel, T. The sensitivity of fish population dynamics to biological variation: consequences for fisheries management. Submitted to ICES Journal of Marine Science.
Prigent, M., Fontenelle, G., Rochet, M.-J., and Trenkel, V. M. 2008. Using cognitive maps to investigate fishers' ecosystem objectives and knowledge. Ocean & Coastal Management, 51: 450-462.
Rochet, M. J., and Trenkel, V. M. 2009. Why and how could indicators be used in an ecosystem approach to fisheries management? In Future of Fishery Science in North America, pp 209-226. Ed. by R. J. Beamish and B. Rothschild. Fish & Fisheries Series, 31, Springer,
Rochet, M. J., Prigent, M., Bertrand, J. A., Carpentier, A., Coppin, F., Delpech, J.-P., Fontenelle, G., Foucher, E., Mahé, K., Rostiaux, E., and Trenkel, V. M. 2008. Ecosystem trends: evidence for agreement between fishers' perceptions and scientific information. ICES Journal of Marine Science, 65: 1057-1068.
Rochet, M. J., Trenkel, V. M., Carpentier, A., Coppin, F., Gil de Sola, L., Léauté, J.-P., Mahé, J.-C., Maiorano, P., Mannini, A., Murenu, M., Piet, G. J., Politou, C.-Y., Reale, B., Spedicato, M. T., Tserpes, G., and Bertrand, J. A. Submitted. Do changes in environmental pressures impact marine communities? An empirical assessment.
Spedicato M.T., J-C. Poulard, C.-Y. Politou, K. Radtke, G. Lembo and P. Petitgas 2010. Using the ALADYM simulation model for exploring the effects of management scenarios on fish population metrics. Aquat. Living Resour., DOI: 10.1051/alr/2010.
Tomczak M.T. ,Heymans J.J., Blenckner T. , Niiranen S. Ecological Network Analysis, indicators of food-web changes in the Baltic Sea. ICES ASC Berlin 2009. ICES CM 2009/P:04

Trenkel, V. M., and Rochet, M. J. 2009. Intersection-union tests for characterising recent changes in smoothed indicator time series. Ecological Indicators, 9: 732 – 739.
Trenkel, V. M., and Rochet, M.-J. In press. Combining time trends in multiple metrics for identifying persistent changes in population processes or environmental stressors. Journal of applied ecology,
Trenkel, V. M., Rochet, M.-J., and Mesnil, B. 2007. From model-based prescriptive advice to indicator-based interactive advice. ICES Journal of Marine Science, 64: 768-774.

9.2.2 IMAGE reports

Jennings, S. Piet, G.J. Rochet, M-J, Sverdrup-Jensen, S. Eliasen, S., Jarre, A. Lembo, P., Ojaveer, H. Spedicato, M-T, 2008. Design operational framework. IMAGE D1
Rochet, M-J, Andersen, K., Blanchard, J., Eero, M., Lembo, P. Lindegren, M. Lorance, P. Ojaveer, H. Piet, G.J., Spedicato, M-T, Tomczak, M.T., and Trenkel, V.M. 2009. Indicators for ecological operational objectives. IMAGE D2
Sverdrup-Jensen, S. Eliasen, S. 2009. Socio-economic indicators and their application. IMAGE D3
Jarre, A., Rochet, M-J, Spedicato, M-T. 2009. Decision-support tools. IMAGE D4
Piet, G.J., Andersen, K., Bastardie, F. Blanchard, J., Eero, M., Hintzen, N., Jennings, S., Nielsen, J.R., Paulsen, M.S. Ulrich, C., Vinther M. 2010. Management Strategy Evaluation. IMAGE D5
Piet, G.J. Jennings, S. Rochet, M-J, Eero, M., Sverdrup-Jensen, S., Eliasen, S., Jarre, A. Lembo, P., Ojaveer, H. Spedicato, M-T, 2008. An indicator-based framework for an ecosystem approach in the management of European Fisheries. IMAGE D7
Jennings, S. Piet, G.J. Rochet, M-J, Eero, M., Sverdrup-Jensen, S., Eliasen, S., Jarre, A. Lembo, P., Ojaveer, H. Spedicato, M-T, 2008. Policy implementation plan. IMAGE D8

9.2.3 Other reports

Bertrand, J. A., Brind'Amour, A., Cochard, M.-L., Coppin, F., Léauté, J.-P., Lorance, P., Mahé, J.-C., Morin, J., Rochet, M. J., Salaun, M., Schlaich, I., Souplet, A., Trenkel, V. M., and Vérin, Y. 2009. Atlas des grands invertébrés et poissons observés par les campagnes scientifiques. Bilan 2008. EMH : 09-003, 90 pp.
Daurès, F., Planchot, M., Demanèche, S., Van Iseghem, S., Berthou, P., Leblond, E., and Jezequel, M. 2007. Contribution et Dépendance des Flottilles de Pêche aux espèces commerciales majeures du Golfe de Gascogne (2005). Rapport interne Département d'Economie Maritime, 66 pp.
Daurès, F., Van Iseghem, S., Demanèche, S., Leblond, E., Brigaudeau, C., Guyader, O., and Berthou, P. 2008. Re-assessing the French small-scale coastal fisheries: from fleet activity to economic performance. ICES CM 2008 / K:10,
Lorance, P. 2008. Fish diversity in the Bay of Biscay is higher on the continental slope than on the shelf (poster). In XI International Symposium on Oceanography of the Bay of Biscay, 2-4 April 2008, San Sebastian (Spain), pp 275. Ed. by A. Borja. Revista de Investigacion Marina, 3, AZTI-Technalia,
Lorance, P., Rochet, M.-J., Brind'Amour, A., Trenkel, V.M. (2009) Marine strategy directive and ecosystem-based approach to fisheries: assessment of a reference state of the Bay of Biscay ecosystem. 9ième forum halieumétrique, Brest 31 juin -2 juillet 2009. Prigent, M., Rochet, M. J., Bertrand, J. A., Carpentier, A., Coppin, F., Delpech, J.-P., Fontenelle, G., Foucher, E., Mahé, K., Rostiaux, E., and Trenkel, V. M. 2007. Comparing fishers perceptions and scientific descriptions of recent trends in the Eastern Channel ecosystem and fisheries. ICES CM 2007 / O:05, 18 pp.
Rochet M.-J., Trenkel, V., Carpentier, A., Coppin, F., Gil de Sola, L., Léauté, J.-P., Mahé, J.-C., Maiorano, P., Mannini, Al., Murenu, M., Piet, G., Politou, C.-Y., Reale, B., Spedicato, M.-T., Tserpes, G., Bertrand, J. Do changes in environmental and fishing pressures impact marine communities? An empirical assessment. Journal of Applied Ecology, submitted.
Rochet, M. J., Daurès, F., Trenkel, V. M., and van Iseghem, S. 2009. La pêche et les communautés démersales dans le Golfe de Gascogne – Prototype d'un tableau de bord. 7 pp.
Rochet, M. J., Trenkel, V. M., Forest, A., Lorance, P., and Mesnil, B. 2007. How could indicators be used in an ecosystem approach to fisheries management? ICES CM 2007/ R: 05, 15 pp.

Rochet, M. J., Trenkel, V. M., Gil de Sola, L., Politou, C.-Y., Tserpes, G., and Bertrand, J. A. 2007. Do population and community metrics tell the same story about recent changes in Northern Mediterranean fish communities? ICES CM 2007 / D:16, 16 pp.
Rochet, M.-J., Daurès, F., Van Iseghem, S., and Trenkel, V. M. 2009. The joint dynamics of fish stocks and fishing fleets: testing hypotheses in the Bay of Biscay. ICES CM 2009/O: 08, 17.
Spedicato M.-T., I. Bitetto, G. Lembo. How stakeholders perceive the potential effects of reducing fishing pressure driven from alternative management measures: a case study from the Mediterranean. 2010b. MS for submission.
Spedicato M.-T., I. Bitetto, G. Lembo. Stakeholder perception of the evaluation European framework for a sustainable fishery management: a case study from the Mediterranean. 2010a. MS for submission.
Trenkel, V. M., and Rochet, M.-J. 2009. Qualitative food-web modelling for predicting the joined directions of change of population and community indicators: identifying dominant process changes as a step towards an EAF. ICES CM 2009/P:02, 9.

9.2.4 Standard reporting

All deliverables are listed in table 9. In general more person months were spent on the deliverables than planned. Notably for D2 as much of the (additional) work conducted in the case studies could be used in this deliverable. The large amount of work on the methodological WPs and thus mainly deliverables 1-5 resulted in a reduction of the time available for the final WP10 and thus D7. From the onset of the project and notably the work in WP1 it became clear that much additional work is needed before indicator-based management can be operationalized. The shift in workload reflects this.
Pertaining to D6: New code for the “Fisheries Library in R” (FLR) to support the evaluation of management systems based on indicators in the RAC areas. The multispecies size-spectrum model developed for the North sea case study was coded in R to facilitate future uptake into the FLR package and was made available to other partners in the project. Now, the first steps have been taken to enable wider applications in the future by developing more generic software and the advantages of implementing directly into the FLR framework over a stand-alone package with output transferred to FLR are being evaluated. The actual implementation in FLR was thus not achieved as this proved les straightforward than anticipated.

Table 9: Deliverables List
List all deliverables, giving date of submission and any proposed revision to plans.

Del. no.	Deliverable name	WP no.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
1	Design operational framework	1	5	7	9	10	2
2	Indicators for ecological operational objectives	2	19	34	41	75	3
3	Indicators for socio-economic operational objectives	3	19	34	11	13	5
4	Tools for decision support	4	27	34	25	35	4
5	Management Strategy Evaluation framework	5	31	36	22	24	1
6	New software routines for "Fisheries Library in R" (FLR, http://flr-project.org)	5	31	?	2	1	1
7	An indicator-based operational framework for an ecosystem approach in the management of European fisheries	10	36	36	17	10	2
8	Policy Implementation Plan (PIP) regarding the policy consequences of an indicator-based operational framework for supporting an ecosystem-based approach to the management of European fisheries	10	36	36	3	3	2
9	IMAGE webpage	11	1		2	2	1
10	Final report	11	36	40	1	1	1
11	Interim activity report	11	12	13	1	1	1
12	All reports specified in article II.7.2 of Annex II of the contract	11	18	18			1
13	All reports specified in article II.7.2, II.7.3 and II.7.4 of Annex II of the contract	11	36	40			1
14	Consortium Agreement	11	1	1			1
15	A 2-4 page glossy flyer containing: general information about the work programme, participants, objectives and planning of IMAGE.	11	3	3			1

All milestones were achieved (see table 10). For all milestones that involve completion of the deliverables D2, D3 and D4: The main deviation from the work programme involving these milestones is that the deliverable coming from the work-packages 2,3 and 4 could only be finished after completion of the case study work-packages (6-9) as results from these case studies needed to be included in these deliverables. Consequence is that these milestones were only achieved at the end of the project

Milestone 2: Even in month 6 we had not succeeded in engaging with all the RACs because not all RACs already existed (Mediterranean), difficulty in finding a suitable date or when RAC meetings were planned, to be allowed the time to actually engage with them. The feedback we did get from the RACs as well as the commission allowed us to commence with WPs 2 and 3 with only minor delay. Certainly in the beginning of the project communication with the RACs proved difficult and has caused considerable delay.

Pertaining to the budget (Table 11) and person-months (Table 12) markedly more time was spend on the project than was budgeted for, i.e. 36% (182.5 person-months instead of 134 person-months). This was done to a more or lesser extent by all partners. The main deviation to the work in terms of allocation of person-months to WPs was caused by one partner (2, CEFAS) who spend considerably more time on WP1 and to a lesser extent WP2 in relation to what was planned than on WPs 5, 9 and 10. The following explanation was given: In relation to WP 1 and 2 Cefas had to put in more effort than expected, especially when developing an operational framework (WP1) and in the process of selecting indicators (WP2), where they supported the quantitative work that was a precursor of the main model development. This was a necessary part of identifying realistic indicators for selection, given that previous work on the pressure-state links proved to be quite limited.

In the latter stages (WP 5, 9, 10) Cefas were able to meet the deliverables with less effort because, in the absence of other support, Julia Blanchard and then Simon Jennings undertook most of the work and given their previous experience in these areas meant could do the work that we were able to do quite rapidly. Investment in the North Sea model wasn't as great as predicted, since this was reliant on Julia Blanchard's input and she had other essential commitments at this time. Since Cefas are not actually claiming costs for all of this time, it is, in effect providing added value for the EC.

Table 10: Milestones List

Mile-stone no.	Milestone name	Work-package no.	Date due	Actual/ Forecast delivery date	Lead contractor
1	Draft operational objectives and identification of fishing impacts and management actions that might compromise the achievement of operational objectives.	1	1	2	2
2	Completion of consultations with RACs, (allows WP2 and WP3 to begin work)	1	3	6	2
3	Delivery of report describing operational framework (D1)	1	5	7	2
4	Evaluation, modification (if necessary) and adoption of the list of indicators of the INDECO project	2	5	6	3
5	Workshop and section of the report on reference points / states / directions	2	13	15	3
6	Workshop and section of the report on linking pressure and state indicators and completion of deliverable D2	2	19	34	3
7	Development of the system framework including indicators and data requirements will commence.	3	6	6	5

8	Pilot test of the framework in collaboration with selected stakeholders (eg. Through focus group interviews, including assessment of data availability and revision of framework will be completed.	3	12	13	5
9	Completion of the application of the revised framework in collaboration with stakeholders in the area covered by the North Sea RAC and Finalization of D3	3	19	34	5
10	Review completed	4	15	20	4
11	Workshop on toolbox and decision support tool development	4	20	24	4
12	Implementation to case studies completed	4	26	32	4
13	Workshop on conclusions from case studies	4	27	32	4
14	Completion of the report D4	4	31	34	4
15	Complete the development of the simulation model that can evaluate the performance of the operational framework in a management context	5	24	32	1
16	Complete evaluation of the effects of choosing different reference points and directions for candidate indicators and the data collection and monitoring processes to support them	5	28	32	1
17	Complete evaluation of the performance of specific indicators and/or configurations of expert systems and delivery of FLR code (D5) and the report D6.	5	31	36	1
18	Identification of operational objectives for the region (linked to WP 1)	6	5	4	4/7
19	Selection of indicators and defining the relationship between pressure and state indicators (links to WP 2 and WP 3)	6	10	21	4/7
20	Completion of deliverables D2 and D3	6	19	34	4/7
21	Completion of the application decision-support tools (link to WP 4), of the Management strategy evaluation (link to WP 5) and production of D4 and D5.	6	31	34	4/7
22	Identification of operational objectives for the region (linked to WP 1)	7	5	4	3
23	Selection of indicators and defining the relationship between pressure and state indicators (links to WP 2 and WP 3)	7	10	21	3
24	Completion of deliverables D2 and D3	7	19	34	3
25	Completion of the application decision-support tools (link to WP 4) and production of D4 and in case MSE will be applied to the western waters D5.	7	31	34	3
26	Identification of operational objectives for the region (linked to WP 1)	8	5	4	6
27	Selection of indicators and defining the relationship between pressure and state indicators (links to WP 2 and WP 3)	8	10	21	6
28	Completion of deliverables D2 and D3	8	19	34	6
29	Application decision-support tools (link to WP 4), completion of deliverable D4	8	31	34	6

30	Identification of operational objectives for the North Sea region (linked to WP 1)	9	5	4	1
31	Selection of indicators and definition of the relationship between pressure and state indicators (links to WP 2 and WP 3)	9	10	21	1
32	Completion of deliverables D2 and D3	9	19	34	1
33	Completion of the application decision-support tools (link to WP 4), of the Management strategy evaluation including an example of assessment and management advice for some identified management objectives in the North Sea (link to WP 5) and production of D4 and D5.	9	31	34	1
34	Complete assessment of and reporting on the strengths and weaknesses of the indicator frameworks as applied for each RAC	10	28	35	2
35	Complete review of priorities for data collection and report on same.	10	28	35	2
36	Complete guidance on development of methods for the provision of ecosystem-based fishery management advice.	10	32	36	2
37	Complete review of strengths and weaknesses of the implemented indicator frameworks in supporting the emerging EMS and report on the way in which RAC outputs should be used to report integration of environmental protection requirements into CFP at pan European scale	10	32	36	2
38	The first IMAGE meeting will be used to determine the outline of the project and more specifically start the work on WP 1, 2 and 3. A detailed time table and workplans for WP1 and how it is linked to the case studies (WPs 6-9) will be agreed.	11	1	2	1
39	In this project meeting we will discuss the outcomes of WP1. At this stage the WPs 2 and 3 have just begun allowing the partners in these WPs to prepare for this meeting so that we can agree on the time table and work plan for these WPs and their implementation in the case studies (WPs 6-9).	11	6	6	1
40	At this stage WPs 2 and 3 should have developed to the extent that methodologies can be communicated to the case study partners and implementation in WPs 6-9 can commence. It also marks the start of WP4 and the partners will agree on the workplan for this WP.	11	13	16	1
41	This marks the end of the development WPs 2 and 3 and the implementation of their results in WPs 6-9. At this meeting the deliverables 2 and 3 will be finalized. Also progress and provisional results of WPs 4 and 5 will be presented and discussed.	11	19	23	1
42	At this stage WPs 4 and 5 should have developed to the extent that methodologies can be communicated to the case study partners and implementation in WPs 6-9 can commence.	11	25	30	1

43	This marks the end of the development WPs 4 and 5 and the implementation of their results in WPs 6-9. At this meeting the deliverables 4 and 5 will be finalized. The results from the different regions will be presented and the work plan for the Pan-European synthesis will be agreed upon.	11	31	32	1
44	Before the end of the project results of WP10 will be presented and discussed and the outline of deliverable 7 will be prepared.	11	36	34	1

Table 11: Budget vs. Actual Costs

Cost Budget Follow-up Table

Contract N°: 044227		Acronym: IMAGE			Date: 27.05.2010		
PARTICIPANTS	TYPE of EXPENDITURE (as defined by participants)	BUDGET	ACTUAL COSTS (EUR)			Pct. spent	Remaining Budget (EUR)
			Period 1	Period 2	Total	Total	
		e	1/11/06 to 30/4/08	1/5/2008 to 31/10/2009	e1	a1+b1+c1+d1/e	e-e1
Part. 1: IMARES	Total Person-month	32	14.9	23.9	38.8	121%	-6.8
	Personnel costs	340278	107698	180368	288066	85%	52212
	Consumables		500	2223	2723	na	-2723
	Travel	10500	4495	8374	12869	123%	-2369
	Other costs ('the rest')	69000	29452	34075	63527	92%	5473
	Total Costs	419778	142145	225040	367185	87%	52592.79
Part. 2: CEFAS	Total Person-month	27.00	23.16	7.22	30.38	1.13	-3.38
	Personnel costs	198445	116841	30026	146867	0.74	51578
	Consumables	3000	485	35	520	0.17	2480
	Travel	10500	3778	3007	6785	0.65	3715
	Other costs ('the rest') OHD + Audit	131745	86322	23620	109942	0.83	21803
	Total Costs	343690	207427	56688	264115	0.77	79575
Part. 3: IFREMER	Total Person-month	30	17.45	14.77	32.22	107%	-2.22
	Personnel costs	328067	139278	113752	253031	77%	75036
	Consumables	6000	0	139	139	2%	5861
	Travel	10500	10297	7899	18196	173%	-7696
	Other costs ('the rest')	115395	91994	71664	163658	142%	-48263
	Total Costs	459962	241570	193455	435024	95%	24938
Part. 4: DTU Aqua	Total Person-month	20	4.3	22.62	26.92	135%	-6.92
	Personnel costs	132278	27743	149276	177020	134%	-44742
	Consumables		0	731	731	na	-731
	Travel	10500	984	12065	13049	124%	-2549
	Other costs ('the rest')	144183	17815	110873	128688	89%	15495
	Total Costs	286961	46542	272946	319487	111%	-32526
Part. 5: IFM	Total Person-month	14	7.5	7.6	15.1	108%	-1.1
	Personnel costs	114417	71682	66099	137781	120%	-23364
	Consumables	2000	739		739	37%	1261
	Travel	9000	4658	2581	7239	80%	1761
	Other costs ('the rest')	25083	15268	1881	17149	68%	7934
	Total Costs	150500	92347	70561	162908	108%	-12408
Part. 6: COISPA	Total Person-month	30	17.4	12.6	30	100%	0
	Personnel costs	100000	51890	48517	100407	100%	-407
	Subcontractor	8000	4000	4000	8000	100%	0
	Travel				0	0%	0
	Other costs ('the rest')	57804	29992	27500	57492	99%	312
	Total Costs	165804	85882	80017	165899	100%	-95
Part. 7: EMI	Total Person-month	9	1	8.1	9.1	101%	-0.1
	Personnel costs	21600	1738	24602	26340	122%	-4740
	Consumables	2000	1618	0	1618	81%	382
	Travel	10500	3336	4020	7356	70%	3144
	Other costs ('the rest')			767	767	na	-767
	Total Costs	34100	6692	29389	36081	106%	-1981
TOTAL	Total Person-month	132	68.31	84.21	152.52	116%	-20.52

Table 12: Person-Months Status Table[2]

CONTRACT N°:		44227	Partner - Person-month per Workpackage								
ACRONYM:		IMAGE									
PERIOD:		01/11/2006 to 31/10/2009									
Workpackage		WP total	Budget	Part. 1: IMARES	Part. 2: CEFAS	Part. 3: IFREMER	Part. 4: DTU Aqua	Part. 5: IFM	Part. 6: COISPA	Part. 7: EMI	**TOTALS**
1	Operational framework	Actual	22.0	2.3	14.0	2.0	1.2	1.0	1.0	0.5	**22.0**
		Planned	9.0	1.0	3.0	1.0	1.0	1.0	1.0	1.0	**9.0**
2	Selection Ecological indicators	Actual	32.2	6.4	6.2	9.0	2.6		8.0		**32.2**
		Planned	22.0	3.0	3.0	6.0	2.0		8.0		**22.0**
3	Selection Socio-economic indicators	Actual	10.1					10.1			**10.1**
		Planned	8.0					8.0			**8.0**
4	Tools for decision support	Actual	23.0			6.0	11.0		6.0		**23.0**
		Planned	20.0			6.0	8.0		6.0		**20.0**
5	Management Strategy Evaluation framework	Actual	14.9	12.4	2.6						**14.9**
		Planned	21.0	13.0	8.0						**21.0**
6	Case study: Baltic Sea	Actual	16.7				9.9			6.8	**16.7**
		Planned	13.0				7.0		6.0		**13.0**

[2] For AC contractors, a tabular overview of all resources employed on the project and a global estimate of all costs

7	Case study: Western waters	Actual	14.0			14.0					**14.0**
		Planned	13.0			13.0					**13.0**
8	Case study: Mediterranean Sea	Actual	14.7			0.2			14.5		**14.7**
		Planned	15.0			2.0			13.0		**15.0**
9	Case study: North Sea	Actual	14.5	8.3	3.7			2.5			**14.5**
		Planned	16.0	8.0	5.0			3.0			**16.0**
10	Pan European evaluation and synthesis	Actual	13.3	2.4	3.9	1.0	2.2	1.5	0.5	1.8	**13.3**
		Planned	20.0	2.0	8.0	2.0	2.0	2.0	2.0	2.0	**20.0**
11	Project co-ordination	Actual	7.1	7.1							**7.1**
		Planned	5.0	5.0							**5.0**
Total Project Person-month		Actual total:	182.5	38.8	30.4	32.2	26.9	15.1	30.0	9.1	**182.5**
		Planned total:	134.0	32	27	15	20	14	23	3	**134**

Table 13: Workpackages - Plan and Status Barchart. All WPs have now been completed.

WP	Name	Month																																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	Operational framework	■	■	■	■	■																															
2	Selection Ecological indicators				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
3	Selection Socio-economic indicators				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																	
4	Tools for decision support													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
5	Management Strategy Evaluation framework															■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					
6	Case study: Baltic Sea				■	■							■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■					
7	Case study: Western waters				■	■							■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■					
8	Case study: Mediterranean Sea				■	■							■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■					
9	Case study: North Sea				■	■							■	■	■	■	■	■	■	■					■	■	■	■	■	■	■	■					
10	Pan European evaluation and synthesis																									■	■	■	■	■	■	■	■	■	■	■	■
11	Project co-ordination	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Meetings consortium	■					■							■						■						■						■					■