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Deliverable D2.1

Guidelines for indicator use, importance criteria and weighing, to be used for policy makers, scientists and stakeholders in general

August, 2012

"Indicator is a variable, pointer, or index related to a criterion. Its fluctuations reveal the variations in those key elements of sustainability in the ecosystem, the fishery resource or the sector and social and economic well-being. The position and trend of an indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions (FAO 1999)"

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1. INTRODUCTION

Indicators are taking a prominent and legitimate role in monitoring, assessing, and understanding ecosystem status, impacts of human activities, and effectiveness of management measures in achieving objectives; and may have a growing role to play in rule based decision-making (Rice and Rochet, 2005; Rochet, and Rice, 2005). Various studies, projects and institutions with an interest in aquatic or marine systems have endorsed indicator-based approaches to management together with different frameworks for selecting suites of indicators for an EAF:

- Organization for Economic Co-operation and Development (OECD, 1993)
- Food and Agriculture Organization (FAO, 1999)
- US Environment Protection Agency (EPA, 2000)
- Link et al., 2001
- The World Bank (World Bank, 2002)
- The Institute for European Environmental Policy (Lutchman et al., 2004)
- Degnbol and Jarre (2004)
- International Council for the Exploration of the Seas (ICES, 2005)
- Rice and Rochet (2005)

In Europe, indicators are increasingly used to assess the efficacy of EU policies, including the extent to which environmental aspects are integrated into sectoral policies. However, most efforts have focused on quantitative ecosystem indicators for fisheries management to evaluate changes in the marine ecosystems for environmental, ecological and fisheries perspectives and has focused on the environmental, ecological aspects of fishing in particular with less attention paid to socio-economic indicators (Lutchman et al., 2004). For indicators to become a more effective management tool in European fisheries management, it is agreed that these indicators need to be robust and informative (ICES, 2005). Lately, substantial efforts have been made to develop suites of indicators that embrace all aspects of a specific fishery (ecological and human dimensions) (ICES, 2005).

Whether the indicators are intended to merely inform discussion or to support decision making directly, each different study states that the properties and selection criteria need to be clearly specified to develop a good suite of indicators. The important point is that indicators are a means to an end, *a priori* defined system characteristics that can provide feedback on progress towards management goals and objectives (Slocombe 1999). In the context of Ecosystem Approach to Fisheries (EAF) and Ecosystem Based Fisheries Management (EBFM) various authors (Rice and Rochet, 2005; Degnbol and Jarre, 2004; Link et al., 2001; ICES, 2001) have addressed approaches to evaluate ecosystem effects of fishing.

1.1. General framework

The aim of this guidance is to propose indicators to support the development and implementation of a responsive fisheries management system (RFMS) based on results management principles. According to EcoFishMan glossary:

RFMS is a term generated for use in the EcoFishMan project and it is used to refer to the new system that we are proposing to develop. The RFMS is an adaptive management system that is results –based and ecosystem based. The RFMS attempts to reduce micro-management by envolving stakeholders and has the capacity to include, or not, elements of rights-based management and co-management, as appropriate, (Source EcoFishMan,DoW).

The context of application of the RFMS is complex, mixed-fisheries and multi-stakeholder, fishery sectors with the intrinsic ecological, economic and social dimensions, as found in the EU-Common Fisheries Policy (CFP) area.

The basic aims of European Fisheries Policy (CFP) are as cited below:

- *The Common Fisheries Policy shall ensure exploitation of living aquatic resources that provides sustainable economic environmental and social conditions* (Council Regulation (EC) nr. 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy).
- *…no conflict between ecological, economic and social objectives in the long term… Ecological sustainability is therefore a basic premise for the economic and social future of European fisheries* (Green Paper, p.9)

To develop the proposed RFMS is necessary to make use of an adaptive management called Results Based Management (RBM). A system opposed to the top-down, micromanagement system currently in place. This new approach is specifically adapted to be implemented in the fisheries sector by region, under the new CFP framework. A results based management (RBM) allows:

To define an acceptable impact and leaving to resource users to identify the means to meet the requirements and to document the effectiveness of the means, and ultimately achieve the requirements (Source: EcoFisMan glossary DoW).

An implementation is mimicked during the EcoFishMan project, where the authority is responsible for designing a management system, together with the operators and other stakeholders such as governmental policy makers, fisheries directories, Regional Advisory Councils (RACs), associations of fishers and citizens from non-governmental organizations (NGOs). The management plan specifies the conditions under which the Operator can use the resource in question. According to EcoFishMan glossary (based on FAO 1999 and EcoFishMan DoW) a management plan is defined as:

A *formal arrangement between a management authority and interested parties that identifies the partners in the fishery and their respective roles, details of the agreed objectives for the fishery, specifies the management rules and regulations that apply to it and provides other details about the fishery that are relevant. In a RBM the development of the management plan is a delegated responsibility for an operator.*

The results obtained with the implementation of this management system are then evaluated by a scientific organization capable of assessing and reviewing the documentation that the Operator is responsible for delivering.

An operator is an organizational unit with delegated authority to develop management plans and oversee or conduct fishing operations within the standards decided by a management authority (Source EcoFishMan, WP4 Dow).

It is intended to use an adaptive fisheries management system, i.e., a trial-and-error method of bottom-up stakeholder participation and obligation to behave as a responsible actor, permanently assessed. The RBM first step is to establish a set of relevant outcome targets, representing management goals for the fishery, or acceptable impacts.

An ***outcome target*** *is a specific and measurable performance objective defined for a fishery on the basis of agreed and appropriately authorized general goals, standards and principles, as defined by the authorities based on policy objectives. In the case of an RBM, the outcome targets are found in policy documents. Since the exact formulation of the outcome targets depends on the infrastructure of RBM system, outcome targets are not found in conventional management settings.* (Source EcoFishMan Glossary)

When implementing the management plan, the operator is responsible for collecting information required for assessing whether or not the outcome targets are achieved, or the extent to which they are achieved.

1.2. Indicators properties and reference points

The instruments that can measure the degree of adherence to the outcome targets defined, as well as the level of quality achieved are defined as indicators. An Indicator is a variable, pointer, or index related to a criterion. Its fluctuations reveal the variations in those key elements of sustainability in the ecosystem, the fishery resource or the sector and social and economic well-being. The position and trend of an indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and actions (FAO, 1999).

The purpose of indicators is to enhance communication, transparency, effectiveness and accountability in natural resource management. Indicators assist in the process of assessing the performance of fisheries policies and management at global, regional, national and sub-national levels. They provide a readily understood tool for describing the state of fisheries resources and fisheries activity and for assessing trends regarding sustainable development objectives (FAO, 1999). Given all these roles, the suites of indicators intended to fulfill them must be chosen wisely.

According to ICES (2005) effective indicators should have the following properties:

- *Measurable*. Indicators should be measurable in practice and in theory. They should be measurable using existing instruments, monitoring programmes, and analytical tools available in the regions, and on the time-scales needed to support
- *Management.* They should have minimum or known bias, and the signal should be distinguishable from noise
- *Cost-effective*. Indicators should be cost-effective because monitoring resources are limited. Monitoring should be allocated in ways that provide the greatest benefits to society and the fastest progress towards sustainable development
- *Concrete*. Indicators which are directly observable and measurable rather than reflecting abstract properties which can only be estimated indirectly are desirable. This is because concrete indicators are more readily interpretable by the diverse stakeholder groups that contribute to management decision-making

- *Interpretable*. Indicators should reflect properties of concern to stakeholders, and their meaning should be understood by as wide a range of stakeholders as possible. Public understanding of the indicator should be consistent with its technical meaning
- *Grounded in theory*. Indicators should reflect features of ecosystems and human impacts that (according to well-accepted peer-reviewed scientific theory) are relevant to the achievement of operational objectives. They should not be based on theoretical links that are poorly defined or validated
- *Sensitive*. Trends in the indicator should be sensitive to changes in the ecosystem properties or impacts, which the indicator is intended to measure.
- *Responsive*. Indicators should be responsive to effective management action and provide rapid and reliable feedback on the consequences of management actions
- *Specific*. Indicators should respond to the properties they are intended to measure rather than to other factors, and/ or it should be possible to disentangle the effects of other factors from the observed response

The role of indicators is central because they permit assessment of the status of a system and because they form the basis, both empirical and theoretical, for the development of reference values (Link et al., 2005). For indicators to support decision-making, managers need to know the values associated with specific ecosystem states. These values are known as reference points. Reference points that might support ecosystem-based management include those for the unexploited ecosystem target reference points associated with the favored state of the ecosystem (as a trade-off among environmental, ecological, biological social, and economic benefits), and limit reference points which, if exceeded, indicate that the ecosystem will be subject to serious or irreversible harm or that society has driven the ecosystem to a state where it does not want to go (Fig. 1). As estimates of indicators contain measurement error, precautionary reference points may be used to guarantee a high (preferably specified) probability that the limit reference point is not exceeded. Indicators must be assessed regularly in relation to reference points, to identify changes in the status of the system (ICES, 2005).

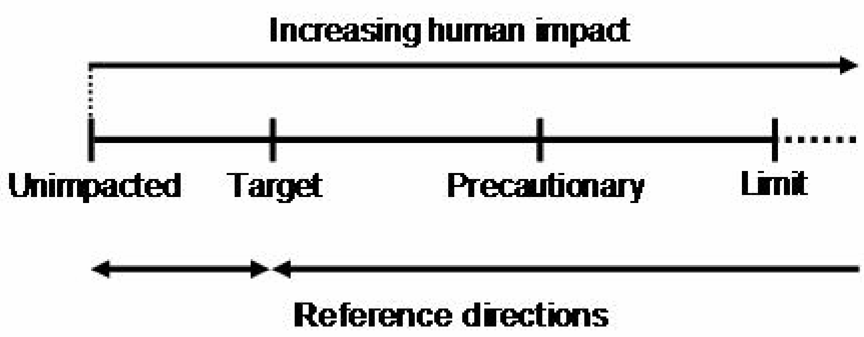

Figure 1. The relationship between target, limit, precautionary and unexploited reference points (adapted from ICES, 2005).

In classical fisheries models, reference points to define overfishing limits are generally based on spawning stock biomass and fishing mortality. If the reference points are exceeded, control rules are triggered to reduce fishing. The challenge is to establish ecosystem control rules that prescribe particular management actions if the indicator based thresholds are exceeded. In general, reference values are mathematically linked to a particular ecosystem process, their choice is ultimately arbitrary. That is, other than having these values map nicely to a particular point of change in the functional relationship between two parameters, one might have chosen a different level for equally good reasons.

Moreover, most reference points rely heavily upon empiricism (experimental or observational) that links a rate or state variable to a function of something that nominally can be managed. Ultimately, the definition of appropriate decision criteria (reference points, directions or surfaces, thresholds, limits, targets, action triggers, etc.) should reflect the necessary tradeoff between the human and ecological dimensions of a specific fishery and evaluate what steps need to be taken to achieve the goals (ICES, 2005; Link et al., 2002; Link et al., 2005).

In the EcoFishMan context **a reference point** is:

A classification device, defined in relation to the measure of an indicator, for distinguishing different management relevant-relevant states of the system under management. ***A Biological Reference*** *point is a metric of stock status.* ***A Target Reference Point*** *indicates a state of a system which is considered to be desirable and at which management action should aim.* ***A Limit Reference point*** *indicates a state of a system which is considered to be undesirable and which management action should avoid, (EcoFishMan glossary DoW).*

2 FRAMEWORK FOR INDICATOR SELECTION

2.1 General criteria for indicator selection

A framework can be devised in a way that reflects the *pressures* of human activities, the *state* of human and natural systems and the *responses* of society to changes in those systems.

In order to clarify the inter-relationships between human beings and the environment, the OECD, the FAO, the European Environment Agency (EEA) Eurostat and many other institutions have adopted conceptual frameworks for the derivation of indicators.

Commonly used terms for this type of framework are Pressure-State-Response (PSR), Driving force-State-Response (DSR) or Driving force-Pressures-State-Impact-Response (DPSIR) (Garcia *et al*, 2000; Smeets and Wetering, 1999; EEA, 2000; FAO, 1999). EEA, Eurostat and European institutions tend to use the DPSIR framework, while OECD uses PSR and the UN Commission on Sustainable Development favors DSR. There are critics of these frameworks. DPSIR and its variations, as direct cause-effect models, have limitations because they over-simplify reality and ignore many of the linkages between issues and feedbacks within the socio-ecological system. The relations between the elements of the framework such as driving forces and pressures may not always be simple; responses to one pressure can become a pressure on another part of the system. The demarcation between components is not always clear and debate on the usefulness of these models is ongoing (Garcia and Staples, 2000). The conceptual frameworks are essentially variations on a similar theme and provide a convenient way to organize indicators in relation to system components and ensure they correspond to different purposes within the system.

The purpose of indicators is to enhance communication, transparency, effectiveness and accountability in natural resource management. Indicators assist in the process of assessing the performance of fisheries policies and management at global, regional, national and sub-national levels. They provide a readily understood tool for describing the state of fisheries resources and fisheries activity and for assessing trends regarding sustainable development objectives (FAO, 1999). Given all these roles, the suites of indicators intended to fulfill them must be chosen wisely.

In general for management goals and objectives the criteria for selecting key performance indicators should be SMART, (Doran, 1981) which means:

1. Specific
2. Measurable
3. Achievable
4. Realistic
5. Time bound

On the purpose and scope of sustainable development of fisheries (FAO,1999; UNCSD, 2001), five sequential steps need to be addressed in order to develop a meaningful set of indicators out of thousands of actual and potential indicators.

These are:

1. Specifying the scope and purpose of the Sustainable Development Reference System, which human activities to cover, the issues to be addressed and the boundaries of the system under consideration, i.e. fishery, area, region, ecosystem;
2. Developing a framework to agree on components within the system;
3. Specifying the criteria, objectives, potential indicators and reference values (targets, thresholds or standards);
4. Choosing a set of indicators and reference values; and
5. Specifying the method of aggregation and visualization.

More recently, in the specific context of fisheries management, Rice and Rochet (2005) presented a framework designed to be a guide for practice, consisting of a series of steps and specific tasks to be performed at each step. Hence allowing that governance processes ensure that indicators are selected in dynamic and interactive exercises in a flexible application.

2.2 Steps evaluation for selecting indicators

To select the indicators in the EcoFishMan context we propose the adoption of a sequence of 8 steps taking into the consideration the above approaches and following Rice and Rochet (2005) framework. This methodology intends to provide guidance on pitfalls to be avoided at each step and these steps are proposed to be done interactively with the users of the indicators in order to provide guidance and a continuous feedback on the process.

The eight number of steps helps to address the issues in the selection process in a systematic manner, enhancing efficiency and transparency. The important function of this framework lies in its potential to structure the dialogue. If all steps are included in the dialogue leading to the selection of the final suite of indicators, the most important stumbling blocks should have been addressed. Table 1 presents the 8 steps adopted for the EcoFishMan project, following Rice and Rochet (2005).

Table 1 – Eight step evaluation framework for selecting indicators for ecosystem-based fisheries management (adapted from Rice and Rochet, 2005).

Step 1 Determine user needs -identifies user groups and their needs, featuring the setting of operational objectives

Step 2 Develop a list of candidate indicators -identifies a corresponding list of candidate indicators.

Step 3 Determine screening criteria -assigns weights to nine screening criteria for the candidate indicators: concreteness, theoretical basis, public awareness, cost, measurement, historic data, sensitivity, responsiveness, and specificity.

Step 4 Score indicators against criteria - scores the indicators against the criteria

Step 5 Summarize the scoring results. Steps 3-5 offer technical aspects on which guidance is provided, including scoring standards for criteria and a generalized method for applying the standards when scoring individual indicators.

Steps 6 Decide how many indicators are needed. This step requires strong interaction with the ultimate users.

Step 7 Make final selection -are concerned with deciding how many indicators are needed, and making the final selection of complementary suites of indicators.

The final Step 8 Report on the suite of indicators -is the clear presentation to all users of the information contained.

2.3 Determine screening criteria

In Step 3 potential candidate indicators from fisheries management (biological, social, governance and economic), are evaluated against nine (9) criteria as proposed by Rice and Rochet (2005). For each criterion a score of High=4; Fair=3; Moderate=2; Low=1 was given according to the associated constituent considerations (table 2). In this first screening of the candidate indicators, two matrices are to be considered: one with the weights assigned by each different group of scorers to the nine criteria and the other with the scores of all nine criteria on each candidate indicator. This procedure provided unique scores for each proposed indicator. The criteria are described in Table 2. According to Rice and Rochet (2005). All nine criteria should always be considered, but they are not equally important in every case. Different participants in the process are likely to value the importance of criteria diferently. However to keep the screening process the relative importance of the nine criteria should be established before the screening is done.

Table 2 – Screening criteria and corresponding constituent considerations (sub-criteria) for indicator scoring (H, high; F, fair; M, moderate; L, low). (adapted from Rice and Rochet, 2005)

CRITERIA	Constituent Considerations
1.Concreteness	• Concrete property of physical/biological world (H), or abstract concept (L)? • Units measurable in the real world (H), or arbitrary scaling factor (L)? • Direct observations (H), or interpretation through model (L)?
2.Theoretical basis	• (i) Not contested among professionals (H); (ii) basis credible, but debated e can account for patterns in many data sets (H-F, depending on how other models fit the same data); (iii) credible, but competing theories have adherents and empirical support is mixed (M); (iv) adherents, but key components untested or not generally accepted (M-L) • If IND derived from empirical observations: (i) concepts readily reconciled with established theory (H); (ii) concepts not inconsistent with, but not accounted for by, ecological theory (M); (iii) concepts difficult to reconcile with ecological theory (L) • Theory allows calculation of reference point associated with serious harm (M)
3.Public awareness	• Is it a property with a high (H) or low (L) public awareness outside the use as an IND? • Does public understanding correspond well (H) or poorly (L) with technical meaning of IND? • If awareness high, is public likely to demand action that is: (i) proportional to IND value as determined by experts (H); (ii) disproportionately severe (M); (iii) largely indifferent (L) • Does the nature of what constitutes "serious harm" (used to define a reference point) depend on values that are widely shared (H) or vary widely across interest groups (L)? • Internationally binding agreements, national or regional legislation require that a specific IND be reported at regular intervals (H), to agreements/legislation require environmental status reporting, but IND not specified (M) to no such requirements (L)
4.Cost	Uses measurement tools that are widely available and inexpensive to use (H), to needs new, costly, dedicated, and complex instrumentation (L)
5. Measurement	• Can variance and bias of IND be estimated? Yes (H); No (L) • If variance can be estimated, is variance low (H) to high (L) • If bias can be estimated, is bias low (H) to high (L)? • If IND biased, is direction usually towards overestimating risk (H), or towards underestimating risk (L) • If both can be estimated, have variance and bias been consistent over time (H), or have they varied substantially (L) • Probability that IND value exceeds reference point can be estimated with accuracy and precision (H), to coarsely or not at all (L) • IND measured using tools with known accuracy and precision (H), to unknown or

	poor/ inconsistent (L) • Value obtained for indicator unaffected by sampling gear (H), to sampling methods can be calibrated (M), to calibration difficult or not done (L) • Seasonal variation unlikely or highly systematic (H) to irregular (L) • Geographic variation irrelevant or stable and well quantified (H), through random (M) to systematic on scales inconsistent with feasible sampling (L) • Taxonomic representivity: IND reflects status of all taxa sampled/modeled (High), through ecologically predictable subset of species (M), to only specific species with no identifiable pattern of representivity (L)
6.Historical data	Necessary data are available for: periods of several decades (H) to only relatively recent period (M), to opportunistic or none available (L) • Necessary data are: from the full area of interest (H), to restricted but consistent sampling sites (Moderate), to opportunistic and inconsistent sources, or none (L) • Necessary data have high contrast, including periods of harm and recovery (H), to high contrast but without known periods of harm and recovery (M), to uninformative about range of variation expected (Low) • The quality of the data and archiving is known and good (H), to data scattered with reliability but not systematically certified, and archives not maintained (L) MP (e.g. environmental IND); • Data sets are freely available to research community (H), to private or commercial holdings (L)
7.Sensitivity	• IND responds to fishing in ways that are: (i) smooth, monotonic, and with high slope (H)**; (ii) smooth, monotonic, and with low slope (M); (iii) smooth, monotonic over a restricted range of effort characteristics (M-F); (iv) unreliable (M-F, depending on when it fails to inform about fishing effects); (v) insensitive or irregular. Magnitude of response does not depend on magnitude of signal in effort (L)
8.Responsiveness	• IND changes within 1-3 years of implementation of measures (H), to IND only reflects system responses to management on decadal scales or longer (L)
9.Specificity	• Is impact of environmental forcing on IND known, and small (H) or strong (L)? • If environmental forcing affects IND, effect systematic and known (H), to irregular or poorly understood (L) • Relative to other factors, IND: (i) known to be unresponsive (H); (ii) responds to specific factors in known ways (M); (iii) thought to be unresponsive (F); (iv) responds to many factors in only partly understood ways (L)

3. INDICATOR SCORING AND WEIGHING

In Step 4 indicators are scored and weighed. An application of this framework was performed.

During the EcoFishMan project a list of over 200 candidate indicators where suggested by scientists of governance, economic, biological and ecological backgrounds. To reduce the number of candidate indicators they were first evaluated against the nine criteria as described in Rice and Rochet (2005). A screening exercise was performed with the scientists from WP2 EcoFishMan partners (the same experts who proposed candidate indicators in first place) using two groups of expertise: fisheries scientists and social scientists, namely from IPIMAR, MATIS, University of Aberdeen, University of Iceland, CNR-ISMAR and CETMAR. Therefore expert judgment was used to assign each indicator a score in the nine criteria. According to the associated constituent considerations a unique score was given to each indicator.

No significant differences were found between the two groups of social and fisheries expertise. Hence it was possible to compute a final score for each indicator defined as the sum of the matrix products of (equivalent) weights by scores. As this simple approach tends to give similar scores to indicators with similar properties a follow up analysis is advised to be made to eliminate redundant indicators and foster complementary indicators that were previously underscored. After preliminary analysis, indicators with comparable properties were considered redundant and excluded from the analysis. Nevertheless, for example indicators designated as *number of vessels* and *fishing effort* were both retained as they may be both necessary to characterize the indicator *fishing pressure,* depending of historic data availability in a given fishery. In Figure 2 we have an example of similar fishing exploitation indicators at different levels of available information, the boxes on the left describe the growing resolution of the information required to achieve a high-level fishing pressure indicator (right panel).

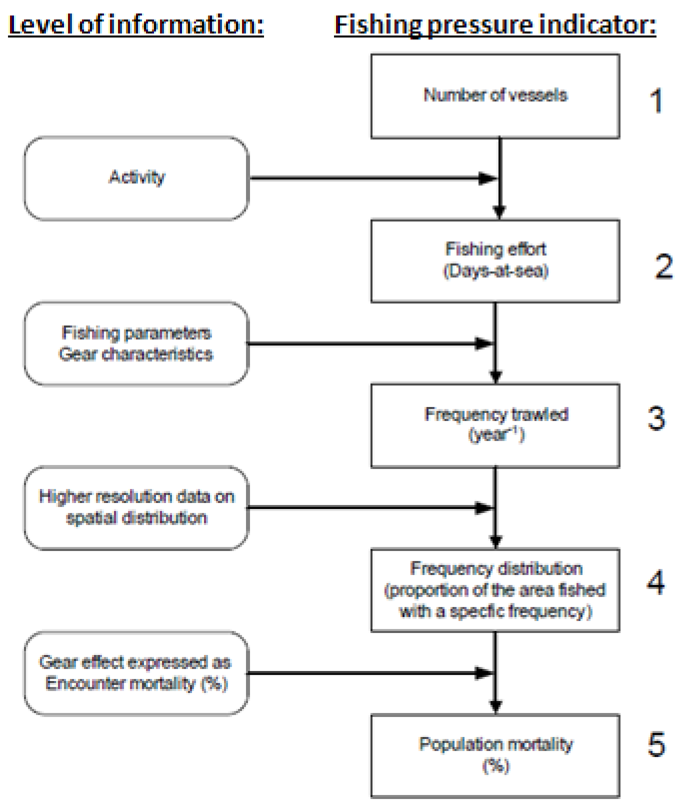

Figure 2. An example framework of fishing pressure indicators at different levels of information content (adapted from Andrulewicz, 2005).

3.1. Summarize scoring results

As the number of criteria is to a certain extent large and the property that a criterion is trying to capture often can be viewed from different perspectives (constituent considerations, table 2), the information on these different aspects might be conflicting. Therefore, interpretation may not always be straightforward and visualizing the coefficient of variation (CV) of each criteria and associated number of constituent considerations within each criterion helps to determine the criteria that have consistent sub-criteria and which ones do not. From the analysis of the variability within each criterion in all indicators no relationship was found between the number of associated sub-criteria and variability in each criterion. As an example, the *sensitivity* criteria (with only 1 sub-criteria) and h*istorical data* (5 sub-criteria) had the highest scoring variability. The criteria *measurement* with the highest number of sub-criteria reached a comparatively low CV (Table 3).

Table 3 – All indicators scoring variability within each criteria.

Criteria	Number of sub-criteria	CV
Measurement	11	0.171
Public awareness	5	0.192
Historical data	5	0.256
Concreteness	3	0.150
Theoretical.Basis	3	0.111
Specificity	3	0.144
Sensitivity	1	0.231
Responsiveness	1	0.147
Cost	1	0.147

From the analysis of the indicators scores grouped by subject (Ecological, Economic, Governance and Social) we observe that the higher mean scores were obtained in the economic indicators and with less variability. Governance and social indicators achieved slightly lower mean scores, but were inside the range of variation of ecological and economic subject of indicators (Table 4).

Table 4 – Indicator mean score by subject with associated standard deviation and coefficient of variation (CV).

Subject	Number of indicators	Mean score	Std deviation	CV
Ecological	36	25.555	3.13	0.122
Economic	35	27.596	2.73	0.099
Governance	42	24.774	2.67	0.108
Social	28	23.642	2.96	0.125

Table 5 shows the mean score for each criteria by indicator subject, scoring variability amongst all criteria was lower in economic indicators and ecological and social indicators reached higher variance across all criteria. In general, *concreteness* and *theoretical basis* were the criteria with higher scores across all subjects.

Table 5 - Mean score for each criterion across indicator subjects and associated coefficient of variation [CV] between brackets.

Criteria / Subject	Economic	Ecological	Governance	Social
Concreteness	3.62 [0.10]	3.28 [0.14]	3.25 [0.15]	3.06 [0.18]
Theoretical Basis	3.54 [0.09]	3.28 [0.11]	3.14 [0.10]	3.18 [0.09]
Public awareness	3.05 [0.13]	2.30 [0.22]	2.79 [0.14]	2.65 [0.19]
Cost	3.11 [0.13]	2.53 [0.18]	2.80 [0.14]	2.78 [0.15]
Measurement	3.26 [0.13]	2.92 [0.16]	2.82 [0.20]	2.85 [0.15]
Historical data	2.99 [0.18]	2.76 [0.23]	2.47 [0.23]	2.22 [0.35]
Sensitivity	2.76 [0.15]	2.99 [0.16]	2.17 [0.19]	2.10 [0.22]
Responsiveness	2.79 [0.10]	2.89 [0.18]	2.93 [0.12]	2.48 [0.14]
Specificity	2.47 [0.12]	2.60 [0.17]	2.40 [0.15]	2.34 [0.11]

The boxplot is a convenient way of graphically depicting the scoring results by indicator subject across all criteria. Figure 3 shows the frequency distributions of the scores across all indicators by subject with the computed median (solid line), the upper and lower quartiles (box ends), the extreme values (whiskers) and outliers plotted individually. From simple visual inspection becomes clear that the higher scores were obtained in the economic indicators across all criteria (except for the sensitivity, responsiveness and specificity) with less variability.

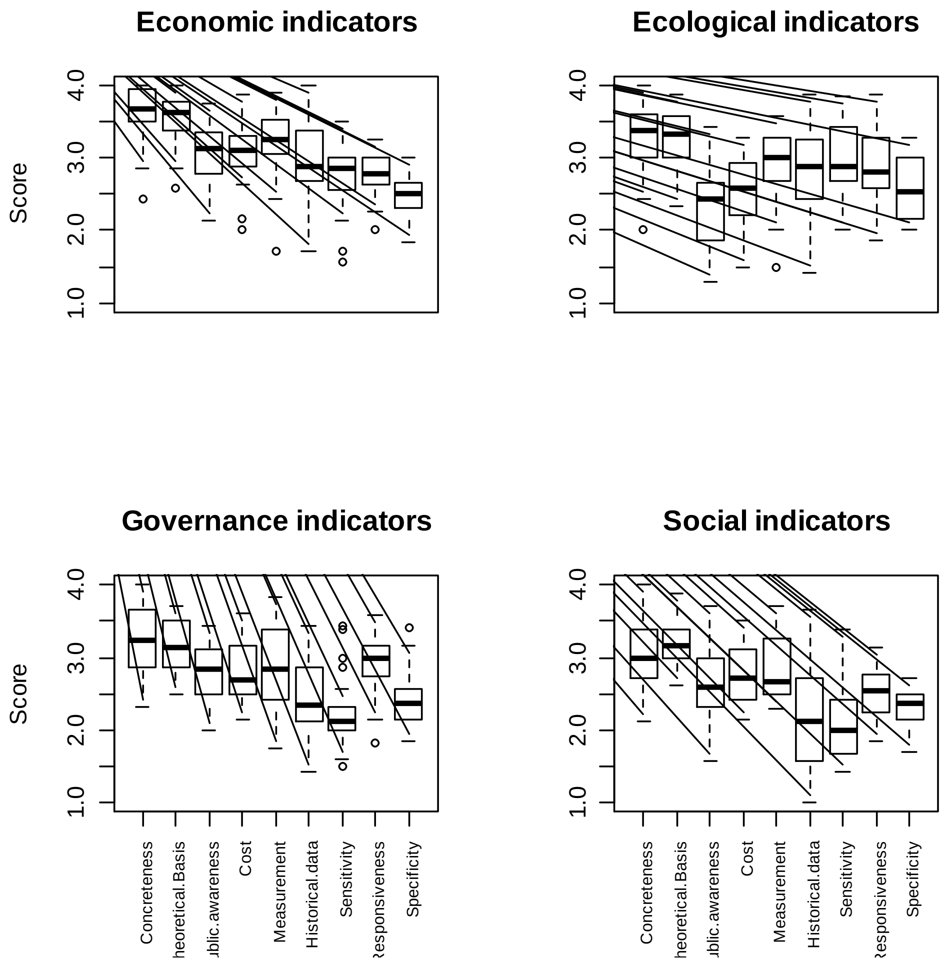

Figure 3. Frequency distributions of the scores across all indicators by subject (ecological, economic, social and governance). Solid line: median, box ends: upper and lower quartiles, whiskers: extreme values excluding outliers, plotted individually

The biplot (Fig. 4) depicts all analyzed indicators displayed as points (numbers) and the indicator scoring criteria´s are displayed as vectors. The length of the vectors correspond to the associated scoring variability and vectors that point in the same direction correspond to criteria that have similar response profiles. Simple visual inspection reveals association between *three distinct criteria groups*:

- Sensitivity/ Responsiveness/ Specificity
- Concreteness/ Cost/ Measurement
- Theoretical basis/Public awareness/ Historical data

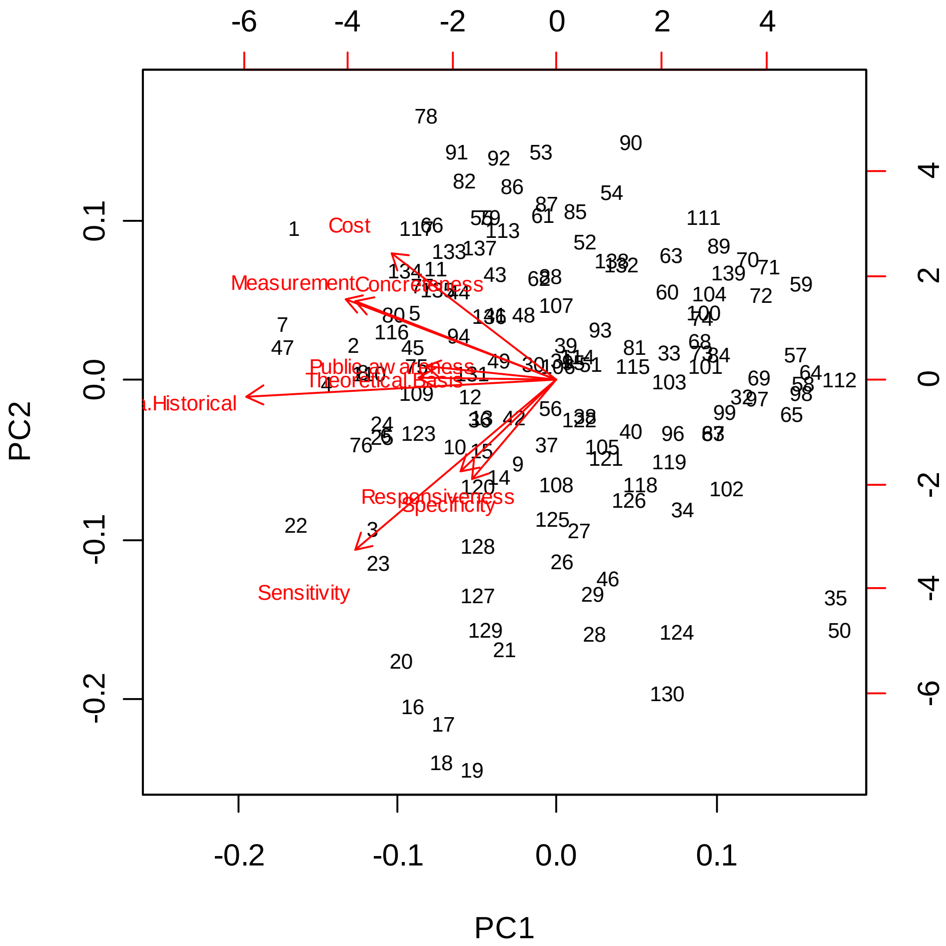

Figure 4. Biplot of all indicator scores across the nine criteria. Indicators displayed as points (numbers) and criteria displayed as vectors (see text for details)

3.2. Indicators scoring results

Table 6 – Indicator scoring by EcoFishMan WP2 research team. Average scores for each indicator across all nine criterion.

Indicator	Concreteness	Theoretical Basis	Public awareness	Cost	Measure-ment	Historical data	Sensitivity	Responsive-ness	Specificity	SCORE	Subject
Catch	4.000	3.714	3.429	3.286	3.429	3.857	3.429	3.571	3.286	32.000	Ecol.Econ
Number of vessels	4.000	4.000	2.875	3.875	3.750	4.000	3.250	3.125	2.875	31.750	Econ
Number of vessels (divided into type)	4.000	3.889	3.111	3.778	3.889	4.000	3.222	2.778	3.000	31.667	Econ
Landing Prices	4.000	4.000	3.667	3.778	3.889	3.889	2.889	2.778	2.556	31.444	Econ
Employment in fisheries	4.000	3.889	3.667	3.444	3.333	3.667	3.375	2.778	2.667	30.819	Econ.S
Rate of Utilization of quotas	4.000	3.500	3.375	3.375	3.375	3.250	3.375	3.429	2.750	30.429	G
Effort	3.667	3.778	3.556	3.111	3.222	3.250	3.500	3.222	3.000	30.306	Ecol.Econ
Net profit margin	3.875	3.750	3.750	3.000	3.750	3.250	3.000	3.250	2.500	30.125	Econ
Ratio of value of fisheries to GDP	3.778	3.667	3.556	3.333	3.556	3.444	3.222	2.778	2.667	30.000	Econ.G
Catch per unit effort or catch rate	3.714	3.714	2.571	3.143	3.286	3.429	3.429	3.429	3.286	30.000	Ecol
Ratio of value of fish exports to value of total exports	3.778	3.667	3.333	3.444	3.556	3.667	3.222	2.778	2.444	29.889	Econ

Exploitation rate	3.625	3.625	3.000	2.625	3.375	3.000	3.625	3.875	3.125	29.875	Ecol.Econ
Existence and adoption of management plans	3.833	3.667	3.167	3.167	3.833	3.333	2.167	3.500	3.167	29.833	G
(Financial) profit	3.556	3.889	3.444	3.111	3.556	3.222	3.222	3.111	2.667	29.778	Econ.S
Mean length in catch	3.857	3.571	2.571	3.286	3.571	3.429	3.286	3.000	2.857	29.429	Ecol
Maximum length in catch	3.857	3.429	2.571	3.286	3.571	3.429	3.286	3.000	3.000	29.429	Ecol
Seafood prices index	3.750	3.625	3.250	3.250	3.625	3.375	2.875	3.125	2.375	29.250	Econ.S.G
Revenue	4.000	3.875	3.375	3.500	3.375	3.000	2.857	2.625	2.571	29.179	Econ
Population biomass – empirical estimation	3.429	3.857	3.000	2.143	3.000	3.571	3.571	3.429	3.000	29.000	Ecol
Economic performance	3.625	3.750	3.375	3.000	3.500	3.125	2.875	3.250	2.500	29.000	Econ
Overshoot	3.571	3.714	3.286	3.000	3.286	3.286	2.857	3.286	2.714	29.000	G
Average wage	4.000	3.667	3.556	3.111	3.333	3.125	3.000	2.556	2.333	28.681	Econ.G
Existence of decision-making and management body	3.800	3.600	3.000	3.600	3.800	3.400	1.600	3.400	2.400	28.600	G
Number of accidents on the fisheries sector (land or sea)	3.429	3.286	3.714	3.429	3.714	3.429	2.429	2.857	2.286	28.571	S
EBITDA	4.000	3.857	3.143	3.286	3.429	2.714	2.833	2.571	2.667	28.500	Econ
Trawling intensity Index	4.000	3.500	2.875	3.125	3.500	3.375	2.500	3.125	2.375	28.375	Econ
Invested Capital	3.667	3.778	3.000	3.444	3.444	3.111	2.556	2.667	2.667	28.333	Econ

Fishing mortality	3.000	3.286	2.714	2.286	3.143	3.429	3.833	3.857	2.714	28.262	Ecol.Econ
Activity rate / unemployments	3.875	3.500	2.875	3.000	3.375	3.625	2.875	2.500	2.625	28.250	S.G
Economic profit	3.556	3.667	3.444	2.889	3.111	2.889	3.000	3.000	2.667	28.222	Econ.S.G.Ecol
Protection of Small-Scale Fisheries Index	3.714	3.000	3.429	3.333	3.286	2.857	2.571	3.571	2.429	28.190	G
Population biomass – model-based estimation	3.000	3.571	2.714	2.286	3.000	3.571	3.571	3.429	3.000	28.143	Ecol
Collapse Index	3.714	3.286	3.286	3.429	3.000	3.429	3.429	2.143	2.429	28.143	G.Ecol
Operating cost	4.000	3.875	3.250	3.250	3.250	2.875	2.571	2.750	2.286	28.107	Econ
Marine protection Index	4.000	3.571	3.286	3.286	3.571	3.000	1.857	2.833	2.571	27.976	G
Rate of return on investment (ROI)	3.667	3.667	3.222	2.889	3.333	2.667	2.889	2.889	2.667	27.889	Econ.Ecol.S
Fisheries Policy Resources Index	3.875	3.500	3.000	3.500	3.375	3.000	2.125	3.143	2.125	27.643	G
Ratio of profit to sales (RPS)	3.444	3.556	3.222	2.889	3.222	2.778	2.889	2.889	2.625	27.514	Econ
Average number of fishermen per vessel	3.875	3.125	2.125	3.500	3.750	3.500	2.625	2.625	2.375	27.500	Econ
Conservation Status of Fish Species(CSF)	3.500	3.833	2.667	2.500	2.800	3.000	3.400	2.800	3.000	27.500	Ecol
Value added	3.333	3.556	3.111	3.000	3.000	2.889	3.000	3.000	2.556	27.444	Econ
Total mortality	2.857	3.286	2.571	2.143	3.000	3.429	3.714	3.714	2.714	27.429	Ecol

Proportion of large fish (LFI)	3.667	3.667	1.833	2.833	3.167	2.833	3.400	2.800	3.200	27.400	Ecol
Index of catch stability	3.286	3.429	2.429	3.429	2.857	3.571	2.429	3.000	2.833	27.262	Econ.G
Salary per crew	4.000	3.375	2.625	3.000	3.250	3.375	2.500	2.625	2.500	27.250	Econ
% stocks within Safe Biological Limits SBL	3.333	3.500	2.667	2.667	2.667	3.000	3.600	2.800	3.000	27.233	Ecol.S
Invested Capital	3.750	3.750	3.125	3.250	3.250	2.750	2.571	2.500	2.286	27.232	Econ
Existence and adequacy of enabling legislation	3.667	3.500	2.833	3.167	3.500	3.000	1.833	3.000	2.667	27.167	G
Economic profit	3.500	3.500	3.250	3.250	3.250	2.625	2.857	2.500	2.429	27.161	Econ
International law and declarations are included in the management scheme	3.333	3.500	2.667	3.500	3.333	3.333	2.000	2.833	2.500	27.000	S
Fishing sanctions index	3.667	2.833	2.833	2.667	3.000	3.333	3.000	2.833	2.833	27.000	G
Catching efficiency	3.556	3.444	2.667	3.000	2.778	2.778	3.333	2.667	2.556	26.778	Econ
% Spawners per recruit (obtain target & limit for F)	3.000	3.286	2.000	2.571	3.143	3.000	3.429	3.429	2.857	26.714	Ecol
Mean length or weight of individuals in community	3.857	3.429	2.000	2.714	3.286	3.143	3.000	2.857	2.429	26.714	Ecol
Subsidies per value catches Index	3.750	3.500	3.125	3.125	3.125	2.875	2.250	2.875	2.000	26.625	Econ

Maximum economic yield (MEY)	3.000	3.000	2.625	3.125	3.250	2.750	3.000	3.000	2.750	26.500	Econ
Species composition	3.857	3.429	2.429	3.000	3.143	3.000	2.714	2.714	2.143	26.429	Ecol
Level of quotas exchange	3.875	3.250	2.625	3.250	3.625	2.875	2.125	2.429	2.375	26.429	G
Concentration of Right-based fisheries management index	3.750	3.375	2.500	3.286	3.500	2.750	2.000	3.000	2.250	26.411	G
Clearly defined enforcement procedures	3.200	3.000	3.200	2.600	2.600	2.800	2.200	3.400	3.400	26.400	G
Wage distribution in fishing communities	3.875	3.500	2.750	2.750	3.250	3.125	2.375	2.375	2.375	26.375	Econ.S
Abundance of indicator species or groups of species	3.500	3.500	2.125	3.000	3.000	2.875	2.875	2.875	2.500	26.250	Ecol
Area occupied by species	3.429	3.571	2.571	2.286	2.857	2.286	2.857	3.143	3.000	26.000	Ecol
fuel efficiency	3.750	3.375	2.375	2.875	3.375	2.625	2.625	2.500	2.500	26.000	Econ.Ecol
Social Sustainability Attractiveness of the fisheries sector	3.286	3.143	3.429	2.571	2.714	2.429	2.714	3.143	2.571	26.000	S.G
Durability of right-bfm index	3.625	3.500	2.500	3.250	3.375	2.375	2.000	3.000	2.250	25.875	G
Number fisheries with Certification	3.500	3.125	2.625	3.125	3.500	2.375	2.625	2.625	2.250	25.750	S

Stakeholder participation index	3.500	3.000	3.167	2.833	2.833	2.333	2.167	3.333	2.500	25.667	G
Length distributions in relation to minimum landing size	3.833	3.167	1.833	2.500	3.500	3.333	2.833	2.333	2.333	25.667	Ecol
Transferability of Right-bfm index	3.250	3.250	2.250	3.250	3.375	2.625	2.125	3.000	2.500	25.625	G
Management Cost Index	3.500	3.250	3.125	2.875	2.875	2.625	2.125	2.875	2.375	25.625	G.Econ
Average profit rate in the sector	3.500	3.375	2.714	2.625	3.000	2.500	2.750	2.875	2.250	25.589	Econ
Number of accidents in the fishing industry	3.375	3.250	3.000	3.250	3.125	2.750	2.250	2.250	2.250	25.500	S
Area overlap of species and fishery	3.429	3.571	2.286	2.286	2.857	2.286	2.714	3.000	3.000	25.429	Ecol
Right-Based Fisheries Management Index	3.625	3.250	2.500	3.143	3.375	2.125	2.000	3.000	2.250	25.268	G
Mean trophic level of catch (Marine trophic Index, MTI)	3.286	3.000	2.000	3.000	3.286	3.000	2.833	2.667	2.167	25.238	Ecol
Proportion of fish in indicator length ranges	3.429	3.143	1.714	2.571	3.286	2.857	2.857	2.857	2.429	25.143	Ecol
Legitimacy of fisheries management	3.571	3.143	2.714	2.714	2.429	3.143	2.143	3.000	2.286	25.143	G
Illegal, Unreported and Unregulated (IUU) catches Index	2.857	3.571	3.429	2.714	2.429	2.714	2.429	2.714	2.286	25.143	G

Number of coast guard personals per fisherman	3.875	3.000	2.500	3.250	3.500	2.500	2.500	2.125	1.875	25.125	S
Subsidies per employment	3.375	3.375	3.125	2.750	2.750	2.375	2.500	2.750	2.125	25.125	Econ.S
Population depletion for keystone prey and keystone predator species	2.875	3.250	2.625	2.250	2.750	2.429	3.143	3.000	2.429	24.750	Ecol
Diversity indices	3.571	3.571	1.857	2.714	3.000	2.714	2.571	2.714	2.000	24.714	Ecol
Susceptibility to fishing	2.857	3.429	1.857	2.429	2.714	2.429	3.286	2.714	3.000	24.714	Ecol
Time to reach a decision	3.571	2.857	2.571	2.714	3.000	2.286	2.000	3.286	2.429	24.714	G
Existence and application of scientific research and input	2.500	3.500	3.000	2.500	2.833	2.667	2.167	3.167	2.333	24.667	G
Rent from fisheries	2.857	3.286	2.857	2.857	3.000	2.429	2.571	2.429	2.286	24.571	Econ.S
Transparency Initiatives Index	2.333	2.667	3.333	2.500	2.833	2.500	2.000	3.167	3.167	24.500	G
Discard rate	3.500	3.375	2.875	1.875	2.375	2.250	3.000	2.750	2.500	24.500	Ecol.Econ
Ratios of trophic indicator groups	3.286	3.000	1.714	3.000	3.000	3.000	2.833	2.500	2.000	24.333	Ecol
% of habitat type area not impacted by mobile bottom gears	2.833	2.833	3.000	2.167	2.167	1.667	2.667	3.800	3.200	24.333	Ecol
Enforcement coverage	2.857	3.000	2.857	2.571	2.571	2.714	2.429	2.857	2.429	24.286	G

Right-bfm participation index	3.750	3.500	2.500	3.000	3.125	1.750	1.625	2.714	2.125	24.089	G
Public costs	3.625	3.125	2.875	2.750	2.750	2.250	2.143	2.250	2.286	24.054	Econ
Slope and intercept of the abundance-length spectrum	3.286	3.143	1.286	2.714	3.143	2.714	2.857	2.714	2.143	24.000	Ecol
Appropriate scale	3.125	3.250	2.625	2.625	2.750	2.250	2.000	2.857	2.375	23.857	G
Corporate Social Responsibility Index	2.857	2.714	3.000	2.571	2.429	2.286	2.429	3.000	2.571	23.857	G
Amount of tonnage caught in each fishing trip according to vessel size	3.429	2.429	1.714	3.000	3.571	2.714	2.429	2.429	2.000	23.714	Ecol
Percentage of protein intake from fish products	3.000	3.167	2.167	3.333	2.600	2.600	2.000	2.400	2.400	23.667	Econ.S.G
Level of stakeholder participation and satisfaction in management processes and activities	3.000	3.000	3.000	2.571	2.429	1.714	2.286	3.000	2.429	23.429	G
Level of stakeholder involvement in surveillance, monitoring and enforcement	3.125	3.125	2.750	2.500	2.375	2.125	1.750	3.000	2.625	23.375	G
Global Seafood Market Performance Index	3.167	3.167	2.667	2.167	3.000	2.333	2.333	2.667	1.833	23.333	Econ.S.G

Number of people living under poverty rate	2.714	3.000	3.000	3.000	3.167	2.714	2.143	1.857	1.714	23.310	S
Roving Bandits Index	2.333	2.833	2.833	2.167	2.167	2.333	2.500	3.167	2.833	23.167	G
Enforcement perception index	2.571	2.714	2.857	2.571	2.571	2.143	2.286	2.857	2.571	23.143	G
K-dominance curves and Abundance Biomass curves (ABC)	3.143	3.000	1.571	2.571	2.857	2.429	2.857	2.571	2.000	23.000	Ecol
Area (seabed) or volume (pelagic) of relevant habitats	3.286	3.286	2.429	1.857	2.429	1.857	2.500	2.571	2.571	22.786	Ecol
Funding for research, observers, monitoring control and surveillance for the fishery is obtained by cost recovery from the industry	3.143	2.667	2.000	2.857	3.143	2.000	2.000	2.571	2.143	22.524	S
Post-harvest fisheries sector acknowledged to have a important social and economic role in a community	2.500	3.333	2.333	2.667	2.667	2.000	1.667	2.667	2.667	22.500	S
Number of unemployed people which formerly worked in the fishing industry	3.000	2.875	2.875	2.625	2.625	2.250	2.125	2.125	2.000	22.500	S

Long term and clear management objectives are stated and translated into management actions	2.571	3.571	2.429	2.857	2.286	2.000	1.857	2.286	2.571	22.429	S
Consumers access to wholesome and unadulterated fish and fish products	2.833	3.167	3.000	2.500	2.500	1.833	2.000	2.000	2.333	22.167	S
Bad and Ugly subsidies Index	3.143	2.857	2.857	2.857	2.429	1.857	1.571	2.714	1.857	22.143	Econ
The fishery is managed to minimizes conflicts and disputes are resolved in a timely, peaceful and cooperative manner	2.857	3.143	2.571	2.143	2.286	2.000	1.857	2.857	2.429	22.143	S
Fishery in Balance (FiB)	3.143	2.857	1.857	2.571	2.571	2.429	2.333	2.333	2.000	22.095	Ecol
Level of training provided to stakeholders in participation	3.000	2.875	2.250	2.750	2.429	2.000	1.857	3.000	1.857	22.018	G
Perception of Fleet restrictions	3.000	3.000	2.714	2.500	1.857	1.857	2.333	2.571	2.143	21.976	G
Code of Responsible Fisheries Index	3.125	3.250	2.250	2.625	2.375	1.429	2.333	2.333	2.143	21.863	G
Degree of interaction between manager and stakeholders	3.000	2.857	2.571	2.286	2.286	1.714	2.000	3.000	2.143	21.857	G

Security of Right-BFM index	2.875	3.375	2.375	2.429	2.875	1.750	1.500	2.571	2.000	21.750	G
Level of Institutional integration	2.714	3.000	2.000	2.429	2.571	2.286	1.857	2.857	2.000	21.714	G
Existence and activity level of administrative of community organizations	3.250	2.500	2.250	2.375	2.500	2.250	1.625	2.875	1.875	21.500	G
Indigenous peoples rights and needs are being met	3.000	3.200	2.600	2.600	2.600	1.200	1.800	2.000	2.400	21.400	S
Level of Resource Conflict	2.750	2.714	2.250	2.143	2.125	2.125	2.375	2.571	2.143	21.196	G
Administrative burden index	3.000	2.833	2.833	2.667	2.167	1.833	2.000	1.833	2.000	21.167	G
Accountability of decision-making bodies	2.875	2.750	2.875	2.500	1.750	1.625	2.000	2.750	2.000	21.125	G
Social impacts of a change in a management plan is evaluated	2.143	3.000	2.571	2.429	2.571	1.714	1.667	2.286	2.714	21.095	S
Fisheries are integrated into coastal management where appropriate	3.000	3.000	2.143	2.429	2.429	1.571	1.429	2.571	2.429	21.000	S

Social, economic and institutional factors related to sustainability are evaluated with data in the management process	2.167	3.500	2.500	2.167	2.667	1.000	1.667	2.833	2.500	21.000	S
The needs of local fishing communities are being met	3.167	3.000	2.500	2.400	2.333	1.333	1.667	2.000	2.333	20.733	S
Primary Production Required (PPR) to support catches	2.429	2.857	1.857	2.143	2.429	2.429	2.000	2.167	2.000	20.310	Ecol
Cost-effectiveness	2.125	2.625	2.250	2.375	2.500	1.500	1.625	2.625	2.375	20.000	S
Available data and reports on decision making processes	2.750	2.750	2.000	2.500	2.500	1.250	1.625	2.375	2.125	19.875	S
Stakeholders involvement available and in active use	2.571	3.000	1.571	2.286	2.571	1.143	1.714	2.857	2.143	19.857	S
Stakeholders understanding of rules and regulations	2.500	2.875	2.125	2.286	1.875	1.750	1.714	2.571	2.000	19.696	G
CO2 emissions per tonnage landed	2.625	2.750	2.500	2.125	2.250	1.500	2.000	1.875	2.000	19.625	Ecol
Bottom effects of fishing gear	2.429	2.333	2.571	1.500	1.500	1.429	2.500	2.167	2.500	18.929	Ecol
Quality of habitat by type	2.000	2.833	1.833	1.667	2.000	1.500	2.400	2.333	2.333	18.900	Ecol
Cost of climate change Index	2.429	2.571	2.429	2.000	1.714	1.714	1.714	2.000	1.857	18.429	Econ

4. DECIDE HOW MANY INDICATORS ARE NEEDED AND MAKE FINAL SELECTION

Steps 6,7 and 8, decide how many indicator are needed , make final selection and report on the suit of indicators are dependant of strong interaction among the ultimate users. It is simultaneously desirable to have the fewest possible number of indicators, while having all key system components featuring the in the objectives covered by trustworthy indicators.
In the context of EcoFisMan the Outcome targets are decided for a fishery management plan by case studies identified in the project in the WP5 and with interaction with the final users (WP7).

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