FAO EAF–Nansen Project Report No. 7 EAF-N/PR/7 (En)

Report of the

EXPERT WORKSHOP ON THE DEVELOPMENT AND USE OF INDICATORS FOR AN ECOSYSTEM APPROACH TO FISHERIES

Rome, 20–24 April 2009

THE EAF-NANSEN PROJECT

FAO started the implementation of the project "Strengthening the Knowledge Base for and Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries (EAF-Nansen GCP/INT/003/NOR)" in December 2006 with funding from the Norwegian Agency for Development Cooperation (Norad). The EAF-Nansen project is a follow-up to earlier projects/programmes in a partnership involving FAO, Norad and the Institute of Marine Research (IMR), Bergen, Norway on assessment and management of marine fishery resources in developing countries. The project works in partnership with governments and also Global Environment Facility (GEF)-supported Large Marine Ecosystem (LME) projects and other projects that have the potential to contribute to some components of the EAF-Nansen project.

The EAF-Nansen project offers an opportunity to coastal countries in sub-Saharan Africa, working in partnership with the project, to receive technical support from FAO for the development of national and regional frameworks for the implementation of Ecosystem Approach to Fisheries management and to acquire additional knowledge on their marine ecosystems for their use in planning and monitoring. The project contributes to building the capacity of national fisheries management administrations in ecological risk assessment methods to identify critical management issues and in the preparation, operationalization and tracking the progress of implementation of fisheries management plans consistent with the ecosystem approach to fisheries.

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STRENGTHENING THE KNOWLEDGE BASE FOR AND
IMPLEMENTING AN ECOSYSTEM APPROACH TO
MARINE FISHERIES IN DEVELOPING COUNTRIES
(EAF-NANSEN GCP/INT/003/NOR)

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Rome, 20–24 April 2009

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2011

PREPARATION OF THIS DOCUMENT

The Expert Workshop on the development and use of indicators for an ecosystem approach to fisheries (EAF) took place in Rome from 20 to 24 April 2009, within the framework of the EAF-Nansen project (Strengthening the Knowledge Base for and Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries). This report captures the presentations made at the workshop and provides highlights of the discussions that followed. Many of the participants contributed to the preparation of this report both during and after the expert workshop.

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ABSTRACT

The Expert Workshop on the development and use of indicators for an ecosystem approach to fisheries (EAF) was held in Rome from 20 to 24 April 2009 under the EAF-Nansen project (Strengthening the Knowledge Base for and Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries). It was attended by 13 participants from Africa, Europe, Australia and Oceania, North America and FAO.

The main objectives of the expert workshop were to identify suitable indicators for fisheries management, discuss the properties of these indicators, and provide advice on methodologies for the derivation, integration/aggregation and visualization of the indicators. Emphasis was placed on applicability of the derived indicators in developing countries and/or data-poor situations. It was noted that in spite of the abundance of indicators for fisheries management in the scientific literature, there is limited practical guidance as regards their relevance and cost-effectiveness.

In preparation for the expert workshop, three expert reviews were commissioned by FAO to establish what relevant indicators are available for EAF, their properties, and whether/where they have been used. Each review was intended to provide a structured assessment of available indicators for fisheries management classified in accordance with the hierarchical tree framework for identifying major issues in fisheries. For each indicator, an assessment of its properties in relation to data availability, practicality, cost-effectiveness, comprehension, acceptability by stakeholders, and robustness was made. The adopted definition for an Indicator was taken as "*Something that is measured (not necessarily numerically) and used to track an operational objective*" and it was noted that any indicator that does not relate to an operational objective is not useful in this context. The participants concluded that the three background papers provided an excellent starting point for an FAO Technical Paper on the development and use of indicators in EAF.

A case study of the Tanzanian mixed coastal fishery was used to test whether the list of indicators was flexible enough to cover various situations (data rich/poor, high/low capacity, etc.) and how the trigger and reference points would differ depending on the objectives of each fishery. Using the indicators provided in the three reviews and the Tanzanian case study, the workshop defined a list of priority indicators.

The workshop was also informed on the IndiSeas (Indicators for the Seas) Programme, a EUR-OCEANS European Network of Excellence working group to gather and share indicator expertise across marine ecosystems and member institutions. Information was also received on a programme on incorporating the human dimension to the ecosystem approach to fisheries, and specifically on indicators for supply elasticity. It was noted that there are several areas where these projects could be linked with benefits to parties.

The participants agreed on a roadmap for further development and refinement of the derived indicators as inputs for the FAO Technical Paper and to organize a special workshop on indicators for ecosystem surveys using research vessels. It was also agreed to develop a template for reporting on the implementation of EAF for inclusion within the reporting on the FAO Code of Conduct for Responsible Fisheries (CCRF).

CONTENTS

INTRODUCTION

The Expert Workshop on the development and use of indicators for an ecosystem approach to fisheries (EAF) was held in Rome on 20–24 April 2009 under the EAF-Nansen project (Strengthening the Knowledge Base for and Implementing an Ecosystem Approach to Marine Fisheries in Developing Countries). The workshop was attended by 13 participants (Annex 1).

Kwame Koranteng, Coordinator of the EAF-Nansen project, welcomed the experts and thanked them for accepting to be part of the group. The experts introduced themselves, each giving a brief overview of their work in the area of indicators for natural resources management. Keith Sainsbury was elected chair of the workshop and the FAO staff members served as the rapporteurs.

The provisional agenda (Annex 2) was discussed. The experts felt the need to modify the agenda as the workshop progressed to allow for adaptation in line with the trend of the proceedings. The workshop took the form of presentations, discussions and group work using prepared case studies.

OBJECTIVES OF THE EXPERT WORKSHOP

Recapping on the objectives of the workshop, Gabriella Bianchi noted that the EAF is widely accepted as the most appropriate framework for achieving sustainability in fisheries, both in terms of ecological and human well-being. However, despite broad acceptance, experience in actually applying the EAF is very limited and tools and methodologies are not yet fully developed. She noted that FAO has produced technical guidelines for the implementation of EAF (FAO, 2003, 2005) that show how to translate high level policy goals into workable, operational objectives and how these should be supported by a framework of indicators, reference points, performance measures and decision rules for assessing and influencing the performance of the fishery. The application of EAF entails an expansion of fisheries management objectives as compared to more conventional practices, to include, for example, considerations on the impacts of fishing on the ecosystem or socio-economic aspects of the fishery system.

Ms Bianchi noted that despite the abundance of indicators for fisheries management in the scientific literature, there is limited practical guidance as regards their relevance and cost-effectiveness. She noted that the 1999 FAO Technical Guidelines for Responsible Fisheries, No. 8 on Indicators for Sustainable Development of Marine Capture Fisheries[1], for example, presents the Sustainable Development Reference System (SDRS) framework. These Guidelines see indicators as “providing an operational tool in fisheries management, as a bridge between objectives and management actions”. However, these guidelines do not provide a thorough review of available indicators or discuss practical issues, such as those related to data requirements. A 2004 Symposium on Quantitative Ecosystem Indicators for Fisheries Management[2] tried to address these deficiencies; however, the scope was mainly limited to the ecological/biophysical subset of indicators and did not look into use, viability and applicability of some of these indicators in developing countries.

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[1] See http://www.fao.org/DOCREP/004/X3307E/X3307E00.HTM
[2] See http://www.ecosystemindicators.org/

She recalled that the main objectives of the expert workshop were to:

i) identify suitable indicators for fisheries management, as required for the application of EAF;
ii) discuss the properties of these indicators, such as their relevance in relation to main subsets of management objectives, data availability, practicality and comprehension; and
iii) provide advice on methodologies for deriving indicators and for the integration/aggregation and visualization of indicators.

She noted the need to place special emphasis on applicability in developing countries and/or data-poor situations.

DISCUSSION ON THE DIRECTION OF THE WORKSHOP

A preliminary discussion dealt with the organization of the workshop and how to best achieve the set objectives. It was agreed that the first day would start with presentations on the three review papers complemented by the "peer reviewers" comments and followed by an open session of comments on the papers. Participants would share with the group their experiences in developing and using indicators in fisheries science and management to have an idea of what indicator frameworks are available and how these have been used in various contexts.

Days two and three were to be used for group work and real-life case studies to test the indicators presented in the three background papers. On day four, participants will provide advice on:

- the revision of the background papers and the best format in which to publish the papers;
- the future needs (e.g. guidebook and or guidelines on the use of indicators);
- what types of outputs are needed, for whom and what form and structure should they take? and
- the possible outline of the output.

In relation to group work, the experts felt the need to define criteria for indicator selection prior to initiating the group work and in relation to the definition of management objectives. It was decided that the group work be carried out both in plenary and in smaller groups. There was some discussion on the need to come up with a subset of indicators (minimum list) in relation to identified objectives.

There was some discussion on whether the workshop should adopt a systems approach to EAF indicators, which would allow for an understanding of how the various components interact in order to assist in developing a management strategy. The participants decided that, although a systems approach is in line with the EAF and is for EAF indicators, there was still a need to understand the contributions of each discipline separately. Therefore, it was agreed to use a hierarchical tree with "ecological well-being", "human well-being" and "ability to achieve" branches.

The importance of the relationship between management objectives and indicators was emphasized.

PRESENTATION OF THE THREE BACKGROUND REVIEW PAPERS

Introduction

Identification of key issues to be dealt with by fisheries management under an EAF framework consists of systematically analyzing the main issues of a fishery by working through three main categories, i.e. the issues related to ecological well-being, human well-being and the ability to achieve (governance and external drivers) (Figure 1).

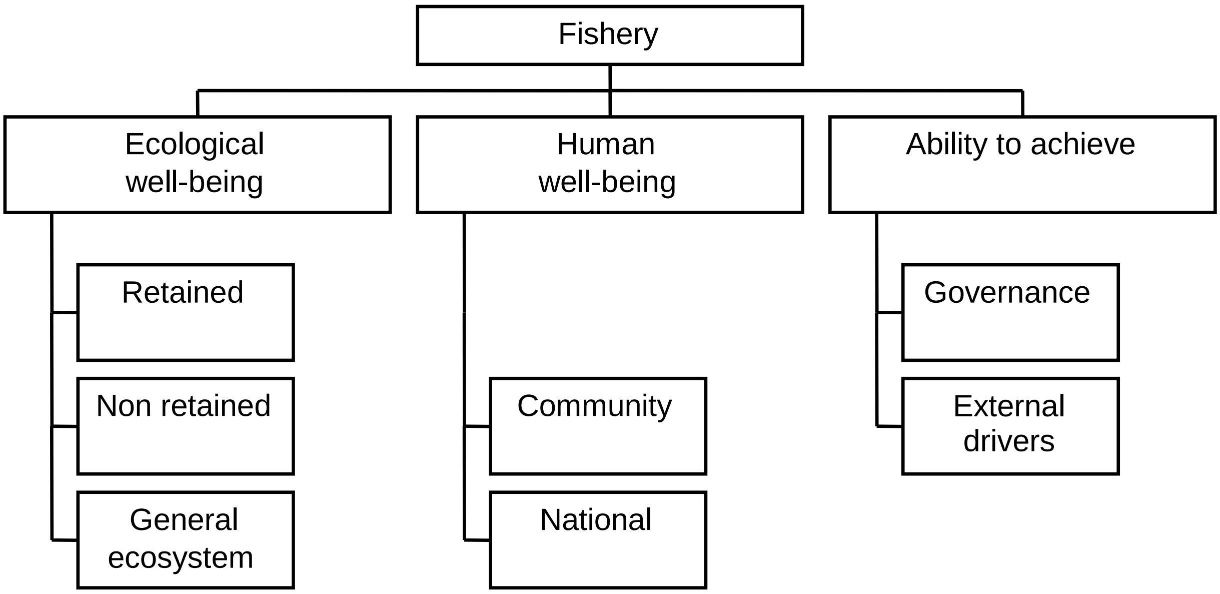

Figure 1: The Hierarchical Tree Framework for the Identification of EAF Issues

In preparation for the expert workshop, three expert reviews were commissioned by FAO to establish what relevant indicators are available for EAF, their properties, and whether/where they have been used. The reviews were provided by Keith Sainsbury of Australia, Martin De Wit of South Africa, and Robert Pomeroy of the United States for ecological well-being, human well-being and ability to achieve, respectively. Each review was to provide:

i) A structured assessment of available indicators for fisheries management, relevant to EAF issues and operational objectives, classified in accordance with the hierarchical tree framework for identifying major issues in fisheries (e.g. Figure 1).
ii) For each indicator, an assessment of its properties in relation to data availability, practicality, cost-effectiveness, comprehension [by experts and non-experts alike], acceptability by stakeholders, and robustness. Each indicator should be accompanied by examples of reference points (targets, limits and triggers) and decision rules, which describe actions to take once the reference points have been reached. Indicators derived from traditional knowledge should also be included in this review.
iii) Criteria for deriving indicators.
iv) Methodologies for integration/aggregation and visualization of indicators.

The reviews were to consider both indicators that are directly linked to specific management objectives and indicators for monitoring key features of socio-ecological systems. In particular, for the biophysical part of the ecosystem, indicators derived from data collected through scientific surveys were also to be dealt with. The reviews were also to put special emphasis on applicability in developing countries and/or data-poor situations. The reviews provided the background documents for the expert workshop. In addition, Keith Sainsbury was asked to provide some guidance on integration/aggregation of the indicators derived in the three reviews.

John Ward, Alida Bundy and Kjellrun Hiis Hauge were asked by the Secretariat to initiate the discussion on each background paper through an informal review and then the workshop participants provided additional comments and discussions to improve these reviews.

Review work on indicators relevant to "ecological well-being"
Keith Sainsbury presented the highlights of his review on indicators for ecological well-being (Annex 3). The report outline was as follows:

- Terminology
- Framework and major components of "ecological well-being"
    - Criteria for selection of indicators
- Indicators, reference points and decision rules for major components
    - There is broad agreement on the outcome norms for fisheries management through international agreements, many national policies and laws, and through the requirements of fisheries ecolabels.
    - Where possible, a quantitative specification of the outcome norms; this is for clarity and does not limit the means of achievement or the measurement of achievement.
- Application in data-poor fisheries.

The review was based on the hierarchical approach (FAO, 2003), which links fishery objectives to operational indicators. Based on this, Mr Sainsbury identified six components for which indicators were selected:

- Retained species (including target species and retained species that are not necessarily targeted);
- Discarded species;
- Threatened, Endangered or Protected (TEP) species;
- Food-webs and trophic interactions;
- Habitats; and
- Community structure.

Mr Sainsbury noted that the terminology used in the review follows FAO (2003). He stressed the definition of an Indicator as "*Something that is measured (not necessarily numerically) and used to track an operational objective*" and noted that any indicator that does not relate to an operational objective is not useful in this context. It was pointed out that "Ecological well-being is a condition in which the ecosystem maintains its diversity and quality – and thus its capacity to support people and the rest of life – and its potential to adapt to change and provide a viable range of choices and opportunities for the future" (Prescott-Allen, 2001; Garcia *et al.* 2003).

In the discussions that followed the presentation, it was recognised that Mr Sainsbury had provided an excellent, well-organized, clear and informative review of indicators for "ecological well-being" presenting the current state of knowledge and expertise. It was noted that there is a huge amount of literature on ecosystem indicators and that Mr Sainsbury had ably distilled this into a coherent report.

Other comments that followed Mr Sainsbury's presentation were related to:

- the challenge of communicating scientific information to stakeholders and of reconciling different views on the situation;
- the consideration that the middle class is increasing worldwide and recreational fishing is becoming a important new area for management for which indicators are required;
- being clear as to who is deciding the agenda, i.e. how are management objectives determined;
- the discussion of the categories "data poor/small scale" versus "data rich/industrial". It was noted that this dichotomy was overly simplistic in that, for example, often industrial fisheries are data poor. Also, under an EAF, well managed industrial fisheries may be data poor for a number of issues that were not considered under conventional fisheries management;
- the case of multispecies fisheries, where simple indicators that refer to a few, more vulnerable species can be used based on a preliminary Productivity-Susceptibility Analysis (PSA) indicating which species are most at risk. This is a conservative approach and has proved to be useful in multispecies and data poor fisheries;
- the discussion of desirability of fishery-independent versus fishery-dependent data.

Review work on indicators relevant to "human well-being"

Martin de Wit's presentation on indicators relevant to human well-being (Annex 4) started with a recognition of the paradigm for fisheries management which recognises that: *"The framework for a new fisheries management will have to be such that it can accommodate traditional knowledge, qualitative indicators, and proximate variables as means of evaluating the status of a fishery and determining future directions"* (Berkes *et al.* 2001). He also recalled the FAO definition of Ecosystem approach to fisheries "*... EAF strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries"* (FAO, 2003).

He looked at the current status of EAF and human well-being noting that human well-being is largely seen as "additional to" scientific assessments of fisheries. He also presented the conceptual framework for indicator development, indicator evaluation and frameworks for human well-being.

In the discussions that followed the presentation, it was pointed out that the EAF management makes the requirement of integrating human well-being in fisheries management more explicit, and so there is a need to identify meaningful indicators of human well-being. This requires understanding a complex, multifaceted problem that transcends traditional fisheries management. It was also noted that the management objectives create the criteria for deriving the indicators and that if the objective is the improvement of human well-being, then the indicators need to indicate whether human well-being is improving or declining for individuals, communities, nations, and regions. The participants noted the lack of sociologists in the meeting and, therefore, the need to enlist the assistance of a sociologist to develop a list of social indicators.

Review work on indicators relevant to "ability to achieve"

Cassandra De Young of FAO, in Robert Pomeroy's absence, presented the review of "ability to achieve" indicators. The "ability to achieve" indicators comprised governance issues as well as the ability of the fishery system to deal with factors outside its control, such as climate change and natural disasters. Fisheries governance is defined as the way in which users and their intentions are managed through a set of rights, rules, and shared social norms and strategies. The review also noted that a variety of factors exogenous to the fishery resource, fisher and community have an impact on the ability to achieve and that many of these factors are beyond the control of fishery management. The external drivers are surprises or shocks to the management system, brought about by macroeconomic, social, political or natural occurrences or interventions, which affect the survival of the management system.

As a basis for choosing indicators, the review used five high-level goals and 19 objectives for "governance" and two high-level goals and nine objectives for "impacts of environment" (see Annex 5). A total of 23 indicators were presented in the review, each analysed using the following framework:

- Name – name of the indicator.
- Goal and objective – to which goals and objectives this indicator corresponds.
- Difficulty rating – a rank of how difficult the indicator is to measure.
- What is "(indicator name)"? – Brief description of the indicator.
- Why measure it? – The purpose and rationale of the indicator.
- Requirements – Resources (people, equipment) needed to collect and analyze the information.
- How to collect the data – The method and approach used to collect information on the indicator.
- Strengths and limitations – How useful is the indicator overall and what problems may occur in using the indicator?
- Useful references and Internet links – Suggested sources of information on methods, and further explanation of the indicator.

The review reiterated that external drivers may also be social, economic, political and institutional in nature and provided a brief discussion of 17 potential indicators covering this subset of external drivers.

The workshop participants appreciated the clear link between management objectives and the choice of indicators as well as the overall structure of the review. The participants voiced some reservations as the objectives and indicators appeared to be relevant for marine protected areas (MPAs) and, therefore, were not necessarily appropriate for more general EAF. In addition, it was noted that the indicators were primarily "input" indicators (e.g. existence of a management plan) and that "output" indicators (i.e. trying to gauge effectiveness of the governance system) need to be investigated. The participants recommended a revision of the paper in line with the hierarchical tree structure mentioned above.

CASE STUDIES AND PRIORITY INDICATOR LISTS

Testing the background papers

Through case studies, this session aimed at testing whether the list of indicators was flexible enough to cover various situations (data rich/poor, high/low capacity, etc.) and how the trigger and reference points would differ depending on the objectives of each fishery. Three case studies were prepared for this exercise: Mesoamerican Spiny Lobster, Tanzanian Mixed Coastal fishery and Norway Barents Sea Cod.

For each case study, the group was to:

- define management objectives for each fishery;
- determine the indicators to measure attainment of objectives at the appropriate level (e.g. if the objective was food security of coastal communities, per capita consumption at community level could be the indicator to use);
- define relevant trigger and reference points;
- determine appropriate tools that would synoptically use the suite of indicators (visualization, integration) for providing management advice (traffic light, bioeconomic models, input/output models, fuzzy models, etc.); and
- identify what issues might arise in the collection, estimation, use and presentation of these indicators for management (e.g. combining qualitative and quantitative data, timing of data collection, combining scientific and traditional information, presenting to the appropriate users).

The group agreed on a template for the case studies to assist in testing the indicators (Annex 6).

Given the limited time available, the participants decided to separate into three sub-groups, one each for ecosystem well-being, human well-being and ability to achieve, and focused on only one of the three case studies: the Tanzanian mixed coastal fishery.

Priority indicators

Using the indicators provided in the three reviews and the Tanzanian case study, the subgroups defined a list of priority indicators as shown in Annex 7. The group hesitated to use the term "minimal list" of indicators so as not limit the use of available information (i.e. if more information exists, this information should be used). However, the participants agreed that a means to demonstrate how the relevant indicators can be calculated in data poor situations is required. Again, the need for more developed social indicators and revised governance indicators was noted.

INFORMATION ON ON-GOING ACTIVITIES

The IndiSeas Programme

Alida Bundy of the Indiseas Working Group made a presentation on the work of the group (Annex 9). She said that the IndiSeas working group was established in 2005 under the auspices of the EUR-OCEANS European Network of Excellence (www.eur-oceans.eu) to gather and share indicator expertise across marine ecosystems and member institutions, in order to:

- develop a set of synthetic ecological indicators;

- build a generic dashboard using a common set of interpretation and visualization methods;
- evaluate the exploitation status of marine ecosystems in a comparative framework.

IndiSeas has adopted a comparative approach because it adds significant power to the analysis of ecosystem change. In particular it:

- helps in selecting robust ecological indicators that would be meaningful and measurable over a set of diverse and contrasted situations, as well as in specifying their conditions of use;
- uses similar ecosystems as replicates, mimicking an experimental set-up where common, unique and fundamental features, as well as important responses to fishing, can be explored. At the same time, comparing ecosystems with contrasted exploitation and environmental conditions can help better determine the status of each ecosystem;
- provides a range of reference values (min, max) against which each ecosystem can be assessed, in a context where it is difficult to establish baseline levels and reference points for most ecosystem indicators;
- avoids repeating the same fisheries management mistakes as may have been the case in some "degraded" ecosystems in the set considered (i.e. provide early warning signals), and permits the ability to draw generalizations important to successful implementation of EAF;
- creates an incentive for politicians to consider management options with added responsibility with regard to the ecological quality of marine ecosystems worldwide.

The IndiSeas Web site www.indiseas.org has been developed as a platform to disseminate the results of the analyses beyond the scientific audience. It is to inform fisheries scientists, managers, policy-makers and the public at large of the state of the world's marine ecosystems as a result of fisheries exploitation.

Alida noted that the EAF-Nansen Project and IndiSeas have similar goals: that is to operationalize EAF and there are several areas where these projects could be linked, with benefits to both. The following are some of the common objectives:

- Both are selecting/proposing a subset of indicators from the vast numbers of indicators that exist in the literature to use for an EAF. FAO Nansen could use the results of the analysis conducted by IndiSeas to date and IndiSeas could incorporate indicators suggested by FAO Nansen into their second phase.
- Both recognize the need for indicators that can be applied across different ecosystems, which imply data constraints.
- Both are taking a global approach. To date, IndiSeas has data for 19 ecosystems. The intention is to expand this number. These ecosystems and data could also be used within the FAO Nansen project to test indicators and evaluate ecosystems.
- Range of Indicators: to date, IndiSeas has focused on ecological indicators, but plans to include socio-economic indicators in the next phase. FAO EAF Nansen has taken a broader approach covering ecological well-being, human well-being and ability to achieve. IndiSeas could incorporate and test some of the indicators suggested for human well-being and ability to achieve.
- IndiSeas has a working membership of over 30 scientists from Europe, Africa, North America, South America and Australia. This resource could be of great benefit to the FAO EAF Nansen project.

Incorporating the human dimension to the EAF Management – Indicators for Supply Elasticity

John Ward gave a brief introduction to research work in which he has been involved in the human dimension area of the EAF (Annex 10). He noted that the organizational and technical capabilities of humankind in conjunction with population growth, represent a significant part of the global ecosystem. Incorporating this human dimension into the EAF management cannot be neglected if meaningful and accurate information is to be provided to managers. FAO's own history has shown that without this information on human behaviour, seafood sustainability and safety are not guaranteed. To achieve this objective of providing accurate and meaningful information to managers, a simple to understand, but all-encompassing, metric such as own-price elasticity of supply is needed to capture the economic, biological, ecological, and socio-cultural changes that significantly affect the ecosystem.

The own-price elasticity of supply (ε_s) is an easy to estimate measure of the general health of an ecosystem consisting of single or multiple fisheries or participant groups. The thousands, if not millions, of factors that have a significant effect on either the ecosystem or the markets for fish are felt through the supply of fish delivered to the marketplace. Agricultural river runoff, for example, impacts marine habitat which can reduce abundance of valuable fish stocks and leads to a decline in market supply. Global warming can change sea water temperature affecting growth and reproduction of fish species which affects abundance and supply. While measuring the effect of different individual factors is time consuming and costly and also difficult to interpret given the scope of an ecosystem, own-price elasticity of supply captures all the significant influences in a single metric. Cross-price supply elasticities can be used to account for other anthropogenic effects on the ecosystem as well.

The supply elasticity is the percent change in kilos of fish supplied to the marketplace for each 1 percent change in price. While this percentage change can be estimated at the consumer or retail, wholesale, processor, or harvester level, the harvester level provides the easiest interpretation for the ecosystem approach to fisheries management. Copes (1970) extrapolated the supply curve that corresponded to the Gordon-Schaeffer sustainable yield curve for a fishery. This open access supply curve has a backward bend that reflected declines in stock abundance as effort levels increased resulting in declining harvest levels after maximum sustainable yield for the fish species was exceeded. As abundance declines, due to environmental, biological, or anthropogenic reasons, the own-price elasticity of supply, at first a positive value, will decrease in value and become negative once MSY is exceeded; i.e.:

$\varepsilon_s > 0$ then $B > B_{MSY}$
$\varepsilon_s = 0$ then $B = B_{MSY}$
$\varepsilon_s < 0$ then $B < B_{MSY}$

Supply elasticity can be calculated based on simultaneous equation estimation techniques using historic ex-vessel prices and landings data. Supply elasticity estimates can be made more accurate if data has been collected to estimate the population dynamics of a fish stock and associated species; e.g. eumetric supply elasticity. Similarly, if important fishing cost components such as fuel price or consumer descriptors such as disposal or per capita income are available, then supply elasticity estimates can be improved. However, even if this additional information does not exist, a trend in supply elasticity estimates over time will provide an indicator of stock abundance change and its related ecosystem health, which can be used by managers to improve the quality of life of participants in these fisheries and the industries dependent upon them.

1. NEXT STEPS

The group agreed on the need to improve and finalize the three background papers for publication as an FAO Technical Paper. The authors are to finalize their reviews in line with the discussion at the workshop. It was agreed that potentially some different people would be involved with finalising the governance review. It was also recognized that further work would be needed to bring the workshop discussions into the human wellbeing review.

Some members of the workshop expressed a desire for a hands-on approach to the Technical Paper, through a series of examples showing the applied use of the indicators. During the discussions, it became clear that Mozambique would provide an excellent example of the development and use of these indicators as much information is readily available. The group agreed that, for each indicator, a text box ("how to") would be developed following the outline presented in Annex 8. The boxes are to be populated with examples from the Mozambique case study. It was not determined exactly how that would be done, but there was discussion of focused activities to bring the data and examples together. This included the possibility of special workshops, or at least interactions between the authors and people who have access to the information, an understanding of the situation in Mozambique and the ability to calculate the specified indicators. One aspect of this was the need to demonstrate calculation of the indicators from the data collected from the fishery. This was seen as an important demonstration of the value of the monitoring and reporting.

The participants agreed on the following next steps:

- Revise and finalize the background papers including:
    - adding discussion on triggers and management responses;
    - developing social indicators;
    - revising objectives and indicators for governance;
    - including practical trials/demonstration examples ("how to" boxes).
- Publish the background papers as an FAO Technical Paper.
- Organize a special workshop on indicators for ecosystem surveys using research vessels.
- Develop a template for reporting on the implementation of EAF for inclusion within the CCRF reporting.
- Publish further guidance reports for:
    - technical audience;
    - policy/management audience.
- Develop stronger links among indicators and their uses (between the various branches of the components tree) to move toward a systems approach to indicators.

2. CONCLUSIONS AND RECOMMENDATIONS

The participants concluded that the three background papers provided an excellent starting point for the development and use of indicators in EAF. The refinement of these papers based on comments received and the addition of "how to" boxes will improve the uptake of the use of indicators. The recommended Technical Paper will provided EAF implementers with the necessary guidance.

Other conclusions stemming from the workshop include:

- Prioritized management objectives form the criteria for deriving the indicators and their reference points.
- Further experience in the actual development and application of these indicators in various contexts is necessary and will need to be documented for further knowledge sharing.
- Further development on the integration and visualization of the indicators for their use in management is necessary.

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APPENDIX 1

LIST OF PARTICIPANTS

Tarub BAHRI
Fishery Resources Officer
Marine and Inland Fisheries Service (FIRF)
Fisheries and Aquaculture Department
FAO
Viale delle Terme di Caracalla
00153 Rome
Italy
Tel.: +39 0657055233
E-mail: Tarub.Bahri@fao.org

Gabriella BIANCHI
Senior Fishery Resources Officer
Marine and Inland Fisheries Service (FIRF)
Fisheries and Aquaculture Department
FAO
Viale delle Terme di Caracalla
00153 Rome
Italy
Tel.: +39 0657053094
E-mail: Gabriella.Bianchi@fao.org

Alida BUNDY
Research Scientist,
Marine Fish Division,
Bedford Institute of Oceanography
PO Box 1006,
Dartmouth, N.S.,
B2Y 4A2
Canada
Tel.: + 1 902 426-8353
Fax: + 1 902 426-1506
E-mail: BundyA@mar.dfo-mpo.gc.ca

Cassandra DE YOUNG
Fishery Planning Analyst
Economics and Policy Division (FIE)
Fisheries and Aquaculture Department
FAO
Viale delle Terme di Caracalla
00153 Rome
Italy
Tel.: +39 0657054335
E-mail: Cassandra.DeYoung@fao.org

Martin DE WIT
De Wit Sustainable Options (Pty) Ltd
PO Box 546
Brackenfell 7561
South Africa
Tel.: +27(0) 21 9827862
Fax: +27(0) 86 6123642
Mob: +27(0) 84 5563366
E-mail: martin@sustainableoptions.co.za

Paul FERNANDES
Sea Fisheries Group Leader
Marine Laboratory Aberdeen
Marine Scotland-Science
PO Box 101, Victoria Rd.,
Aberdeen AB11 9DB,
Scotland, United Kingdom.
Tel.: +44 1224 295403
E-mail: fernandespg@marlab.ac.uk
P.Fernandes@MARLAB.AC.UK

Domingos GOVE
Mozambique National Fisheries Research Director (IIP)
Caixa Postal 4603, Maputo
Mozambique
Tel.: +258 82-3075280 / 21-490406
Fax: +258 21-492112
E-mail: domingosgove@moziip.org

Kjellrun HIIS HAUGE
Institute of Marine Research
Post-box 1870 Nordnes
5817 Bergen
Norway
Tel.: +47 55238590
E-mail: kjellrun.hiis.hauge@imr.no

Kwame KORANTENG
EAF-Nansen Coordinator
Marine and Inland Fisheries Service (FIRF)
Fisheries and Aquaculture Department
FAO
Viale delle Terme di Caracalla
00153 Rome
Italy
Tel.: +39 0657056007
E-mail: Kwame.Koranteng@fao.org

Keith SAINSBURY
Sain Solutions Pty Ltd.
41 Powell Rd
Blackmans Bay, Tasmania
Australia 7052
Tel.: +61 3 62291767
Cell: +61 417 308 480
E-mail: ksainsbury@netspace.net.au

Souad KIFANI
Institut National de Recherche Halieutique (INRH)
2, Rue Tiznit
Casablanca
Morocco
Tel.: +212 522220245
E-mail: kifani@inrh.org.ma

Tore STROMME
Fisheries Management and Conservation Service (FIMF)
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00153 Rome
Italy
Tel.: +39 0657054735
E-mail: Tore.Stromme@fao.org
tore.stroemme@imr.no

John WARD
Teamleader/Economist
NMFS, NOAA, F/FS-8
1315 East West Highway, Room 9555
Silver Spring, MD 20910
United Status of America
Tel.: +1 301 7139504
E-mail: John.M.Ward@noaa.gov

APPENDIX 2

PROVISIONAL AGENDA

DAY 1 (Monday 20 April 2009):	
09.00	Opening
	○ Opening remarks by Dr Kevern Cochrane, FIMF Service Chief ○ Introduction ○ Election of Chairs/Moderators and Rapporteurs ○ Adoption of the Agenda ○ Objectives of the Expert Meeting (Gabriella Bianchi)
10.30	*Morning Tea / Coffee*
10.50	Presentation of the three background review papers ○ Review work on indicators relevant to “ecological well-being” ○ Discussions
12.30	*Lunch*
13.30	○ Review work on indicators relevant to “human well-being” ○ Discussions
15.00	*Afternoon Tea / Coffee*
15.20	○ Review work on indicators relevant to “ability to achieve” ○ Discussions
16.50	General discussions and additional information by participants
17.30	Close of Day 1 sessions
DAY 2 (Tuesday 21 April 2009)	
09.00	○ Participants to share with the group their experiences in developing and using indicators, especially in fisheries science and management.
10.30	*Morning Tea / Coffee*
10.50	○ Testing the indicators identified in the background papers ⇒ Ability to Achieve
13.00	*Lunch*
14.00	○ Testing the indicators identified in the background papers ⇒ Human well-being
15.30	*Afternoon Tea / Coffee*
15.50	○ Testing the indicators identified in the background papers ⇒ Ecological well-being
17.30	Close of Day 2

DAY 3 (Wednesday 22 April 2009)	
09.00	○ Testing the indicators => real life case studies. ⇒ (Presentation of case studies by Cassandra de Young) ⇒ determine appropriate tools that would use the suite of indicators ⇒ identify what issues might arise in the use and presentation of these indicators for management
10.30	*Morning Tea / Coffee*
10.50	○ Testing the indicators cont.
12.30	*Lunch*
14.00	○ Testing the indicators cont.
15.30	*Afternoon Tea / Coffee*
16.00	○ Testing the indicators
17.30	Close of Day 3
DAY 4 (Thursday 23 April 2009)	
09.00	○ Categorization of indicators according to their relevance in selected context
10.30	*Morning Tea / Coffee*
11.00	○ Categorization of indicators cont.
12.30	*Lunch*
13.30	○ Categorization of indicators cont.
15.30	*Afternoon Tea / Coffee*
16.00	Providing advice • Revision of the background papers and the best format in which to publish these papers • What types of outputs are needed for whom and what form and structure should they take?
17.00	Close of Day 4
DAY 5 (Friday 24 April 2009)	
09.00	Providing advice (cont.)
10.30	*Morning Tea / Coffee*
11.00	Providing advice cont. • workshop recommendations
13.00	*Lunch*
	Closing of workshop

APPENDIX 3

SUMMARY OF THE REVIEW OF INDICATORS FOR ECOLOGICAL WELL-BEING

Outline

- Terminology
- Framework and major components of "ecological well-being"
  - Criteria for selection of indicators
- Indicators, reference points and decision rules for major components
  - There is broad agreement on the outcome norms for fisheries management through international agreements, many national policies and laws , and through the requirements of fisheries ecolabels
  - Where possible a quantitative specification of the outcome norms; this is for clarity and does not limit the means of achievement or the measurement of achievement
- Application in data-poor fisheries

Terminology

From the FAO (2003) technical guidelines for EAF and the hierarchical tree structure link high level principles and operational interpretations:

Principle – A high-level statement of "how things should be".
Conceptual objective – A high-level statement of what is to be attained.
Component – A major issue of relevance within a conceptual objective.
Operational objective – An objective that has practical interpretation, usually for a component.
Indicator – Something that is measured (not necessarily numerically) and used to track an operational objective. An indicator that does not relate to an operational objective is not useful in this context.
Reference point – A "benchmark" value of an indicator, usually in relation to the operational objective, e.g. target reference point, limit reference point and trigger reference point. A target reference point could serve as an operational objective.
Performance measure – A relationship between the indicator and reference point that measures how well intended outcomes are being achieved.

Components of ecological well-being

Two important developments in the last decades:

1. An expanded range of issues and responsibilities for fisheries management; no longer limited to the target species but now also includes impacts on the ecosystem and maintaining natural ecological structure, productivity and processes.

2. Improved experience and understanding of what is required for ecological (and hence socioeconomic) sustainability in fisheries, including in context of other human uses and environmental drivers.

Components of ecological well-being recognised and used in this review:

- Retained species (including target species and retained species that are not necessarily targeted);
- Discarded species;

- Threatened, Endangered or Protected (TEP) species;
- Food-webs and trophic interactions;
- Habitats;
- Community structure.

Criteria for selection of indicators
Used criteria of Rice and Rochet (2005) – see Appendix 4 of the written review.
Each criterion scored as High, Medium or Low.

1. Concreteness
2. Theoretical basis
3. Reference points
4. Public awareness
5. Cost and use in data-poor fisheries
6. Measurement
7. Comparative data
8. Sensitivity
9. Responsiveness
10. Specificity

In scoring indicators using these criteria the full range of developing nation fisheries (i.e. from highly industrialised to subsistence) was considered, and consequently the score sometimes has a wide range. Scoring of the same indicators for a particular fishery and circumstance would give a narrower range.

Indicators, reference points and decision rules for <u>retained species</u> (see Tables 1 and 7 of the written review)
H,M,L ranking here only for the selection criterion "cost and ease of use in data-poor fisheries"

Indicator	**Cost and use in data-poor fisheries**
Population biomass – empirical estimation	M
Population biomass – model-based estimation	L
Population biomass depletion – empirical estimation	M–L
Population biomass depletion – model-based estimation	L
Fishing mortality	M–L
Total mortality	H
Exploitation rate	H
Percentage spawners per recruit (obtain target and limit for F)	M–H
Catch	M–L
Catch per unit effort or catch rate	H
Mean length in catch (or other descriptor of the length composition)	H
Maximum length in catch	H
Area occupied by species	H
Area overlap of species and fishery	H
Susceptibility to fishing	H

Using different <u>retained species</u> indicators for the same purpose

The same sustainable stock goals may be achieved in different ways depending on the information available, but with increasingly uncertain information and stock status measures there is a need for more caution

- Gives rise to tiered rules for linking the indicator value to the management response for different amounts and kinds of information.

Design of the appropriate trigger point and management response to achieve the sustainability goals with the available information and indicators is critical.

Example of tiered decision rules to determine the target catch of retained species with different information availability.

Information available	**Target catch**
B and B_{MSY} and reliable probability distribution of F_{MSY}	Target catch from B and F_{MSY}
B, B_{MSY}, F_{MSY}, $F_{35\%}$, and $F_{40\%}$	Target catch from B and F_{MSY} scaled back by $F_{40\%}/F_{35\%}$
B, and $F_{40\%}$	Target catch from B and $F_{40\%}$
B and natural mortality rate M	Target catch from B and 0.75M
Exploitation rate (e.g. F/M)	Target catch from current catch scaled by current exploitation rate in relation to target exploitation rate
Reliable catch and effort history	Target catch from current catch scaled by whether recent catch rates increasing, decreasing or stable
Reliable catch history	Target catch from 0.75 average past catch

Retained species in multi species fisheries

The limit reference points are the same as for single species interpretations and must have a low chance of violation.

Target reference points can be varied to give best overall outcome.

Potential use of:

Aggregate species groups for assessment and management

- Care to avoid sequential depletion of species within aggregate species groups
- Targeted monitoring of most vulnerable

Indicator species for assessment and to set management arrangements

- Care to ensure these are chosen so as to avoid limit reference points for all species
- Usually the least productive must be included

Indicators, reference points and decision rules for <u>discarded species</u> (see Tables 2 and 8 of the written review)

H, M, L ranking here only for the selection criterion “cost and ease of use in data-poor fisheries”

Indicator	**Cost and use in data-poor fisheries**
Same species specific indicators as for retained species but the methods and reference points are generally different for discarded species	M–L
Discarded catch (total or by species groups)	M

General comments on <u>discarded species</u>

The same indicators and limit reference points as for retained species are relevant

- Target reference point not relevant; no intended catch but usually a general aim to minimise
- Limit reference point must be sufficient to prevent reaching the criteria for listing as threatened or endangered

Usually greater use of approaches requiring limited data

Usually greater use of aggregate groupings and indicator species

Catch limits can be determined from simple models (e.g. CCAMLR and PBR methods)

Indicators, reference points and decision rules for <u>threatened, endangered or protected (TEP) species</u> (see Tables 3 and 9 of the written review)

H, M, L ranking here only for the selection criterion "cost and ease of use in data-poor fisheries"

Indicator	Cost and use in data-poor fisheries
Same species specific indicators as for retained species, but the methods and reference points are different for TEP species	M–L

General comments on <u>TEP species</u>

Usually legislatively determined objectives, targets and limits

- Focus on recovery and/or on protection irrespective of population status

Indicators generally the same as for retained species

Some well developed assessment methods available, including for data-poor situations (lessons from these for use of information on area, population size and precautionary catch limits that could be applied to retained or discarded species).

Indicators, reference points and decision rules for <u>food-webs and trophic interactions</u> (see Tables 4 and 10 of the written review)

H, M, L ranking here only for the selection criterion "cost and ease of use in data-poor fisheries"

Indicator	Cost and use in data-poor fisheries
Population depletion for keystone prey and keystone predator species	M
Mean trophic level of catch (Marine trophic Index, MTI)	M–L
Ratios of trophic indicator groups	H–M
Primary Production Required (PPR) to support catches	M–L
Fishery in Balance (FiB)	M–L

General comments on <u>food-webs and trophic interactions</u>

This is an emerging area in both science and fishery management

There is a clear need to protect keystone prey species

- Keystone prey are those on which the ecosystem is highly dependent, such as the species at the centre of "wasp-waist" food webs, and not prey species or preyed upon life history stages in general

Useful and feasible indicators are mean trophic level in catch and ratios of indicator groups

- Empirical indicators perform well
- Reference points empirical so need contrasting situations

Model based measures are rapidly improving

Indicators, reference points and decision rules for Habitats (see Tables 1 and 7 of the written review)
H, M, L ranking here only for the selection criterion "cost and ease of use in data-poor fisheries"

Indicator	Cost and use in data-poor fisheries
Area (seabed) or volume (pelagic) of relevant habitats	H–M
Quality of habitat by type	M–L

General comments on Habitats
Habitat identification and protection has rapidly developed as a fishery management issue in the past ten years.

- Now several states and international agreements give legal and operational basis for management
- Information sources from science and from fishers are highly complementary
  - it is usual for the fishers to have good knowledge of the habitats being fished, what constitutes good habitat quality and what risks these habitats are exposed to

Reference points are emerging

- target is usually no net change
- limit to loss of about 50–60 percent

Indicators, reference points and decision rules for Community structure (see Tables 6 and 12 of the written review)
H, M, L ranking here only for the selection criterion "cost and ease of use in data-poor fisheries"

Indicator	Cost and use in data-poor fisheries
Mean length or weight of individuals in community	M–H
Proportion of fish in indicator length ranges	H–M
Slope and intercept of the abundance–length spectrum	M–L
Diversity indices	M–L
K-dominance curves and Abundance Biomass curves (ABC)	M–L
Species composition	M–L
Abundance of indicator species or groups of species	H–M

General comments on community structure
A newly emerging area in fishery management

- There is a mixed science background (e.g. strong in diversity related indicators but weak in prediction of community properties)
- There is very limited experience of how to connect indicators to a specific management response
  - cause and effect often not clear and so the appropriate management response not clear, or at least contestable
  - the behaviour of indicators and the interpretation of indicator trends is often understood to be context specific (e.g. the kind of ecosystem, the state of the ecosystem and history of exploitation when the indicator was measured), but is not well enough understood to provide clear guidance for specific fisheries management action

  - other human activities and uses of the ecosystem can influence the indicators but there is often limited ability to attribute indicator change to particular causes and hence to identify best management responses

Direct and empirical indicators generally perform well

- e.g. community indicator groups and species-abundance curves (K-dominance or ABC)

Reference points are mostly empirical where they exist

- This means great importance on the ability to identify reference points empirically by one or more of the following:
  - historical data and contrast (e.g. information from the history of fishery development on a reef that can be used to identify an acceptable or desired state of the fishery);
  - spatial contrast within the fishery at any point in time (e.g. different reefs with different current fishing pressure that can be surveyed and used to identify an acceptable or desired fishing pressure);
  - comparison across similar fisheries.

Application in data-poor fisheries

Data poor fisheries are well represented in developed and developing country situations.

- They often occur in small scale fisheries (i.e. the fisheries generate insufficient benefits to support or warrant detailed data collection and analysis).
- They also occur in large scale fisheries (i.e. there is no mechanism to support detailed data collection and analysis).

Data poor situations are usually likely to involve higher uncertainty about fishery status at the point of management decision making, and so require higher precaution.

- Achieving ecological outcomes with limited data will reduce economic outcomes, either in a planned way (e.g. intentionally precautionary management) or in an unplanned way (e.g. through loss of biological productivity and ecosystem amenity when overharvesting eventually happens in a fishery managed with insufficient data to detect and correct undesired trends as they start to happen).

Data poor fisheries can use different methods to achieve the same ecological outcomes as data rich fisheries but in different ways. Especially:

  - risk-based methods
  - empirical indicators and decision rules
  - tiered decision rules
  - importance of simulation testing – ability to identify indicators, trigger points and triggered management responses that are likely to work in the context of the information and management for the fishery.

There are some well developed methods available to assess data poor fisheries and to identify indicators/management responses that are likely to be successful.

- Risk-based methods of assessment:
  - There have been several recent advances in ecological risk assessment and they provide a methodology for recognizing ecological risks in both data rich and data poor situations.
- Empirical indicators and decision rules:

  These are approaches that do not use formal stock assessment (e.g. estimate population biomass or fishing mortality) but that directly link the management triggers and management control rules to the directly measured indicator (e.g. mean length). These are increasingly recognised and used, and are particularly appropriate for developing country management. Some example applications are:

- Swordfish and coastal tuna: decision tree to vary allowable catch and effort based on catch rate and size composition of catch in the fishery.
- Scallops: surveys by fishers, minimum areas of viable beds before allowing fishing; 40 percent beds fully protected when fishing allowed.
- Squid and some shrimps: in season depletion measures from commercial data and surveys by fishers.
- Coral reef fishery for aquarium trade: Ecological Risk Assessments.
- Tropical lobsters and trochus: surveys by fishers, spatial closures, “move on” spatial rules based on catch rate.
- Tropical trap, line and trawl: effort levels set for vulnerable (less productive) species.

Fisher surveys:

- Quality Assured/Quality Controlled surveys by fishers provides a powerful means of measuring indicators, of supporting participatory assessment and management processes, and of providing a cost-effective management system.

EAF Indicators and data sources

EAF requires at least one indicator per component.

A set of indicators and data sources that should be feasible in most circumstances are:

Essential Indicators	**Information source**
Catch[1,2,4,5,6,8]	Verified fisher Catch[1,2,4,5,6,8]
Catch per unit effort [1,2,4,5,6,8]	Verified fisher Catch and verified fisher Effort[1,2,4,5,6,8]
Mean length (or other descriptor of length composition) in catch[1,2]	Verified fisher length composition of Catch[1,2]
Discards [1,2,4,5,6,8]	Verified fisher Catch[1,2,4,5,6,8]
Habitat area/volume[7]	Verified fisher observations of habitat[7]

Desirable indicators	**Information source**
Percentage spawners per recruit (for target and limit for F)[1,2]	Life history information[1,2]
Total mortality (or fishing mortality or exploitation rate)[1,2]	Verified fisher length composition of catch or structured fisher survey or scientific survey[1,2]
Population biomass (or depletion) – empirical estimation[1,2,3,4,5,6,8]	Fisher or scientific surveys[1,2,3,4,5,6,8]
Mean length (or other descriptor of length composition) in population [1,2,4,8]	Structured fisher or scientific surveys[1,2,4,8]
Catch[3]	Verified fisher Catch[3]
Catch per unit effort[3]	Verified fisher Catch and verified fisher Effort[3]
Habitat area/volume[7]	Structured fisher or scientific surveys[7]
Habitat quality[7]	Structured fisher or scientific surveys[7]

Footnotes

1. retained species
2. may be collected for only selected indicator or key species in highly multispecies fisheries
3. selected species that may be of key ecosystem significance (e.g. keystone prey) or at risk of becoming TEP
4. TEP species
5. keystone predators
6. trophic indicator groups
7. habitats
8. community structure indicator groups

APPENDIX 4

SUMMARY OF THE REVIEW OF INDICATORS FOR HUMAN WELL-BEING

A shift in thinking on the management of natural resources has been taking place:

- interactions between land, water and living resources have become more acknowledged – the driving force for integrated natural resource management;
- explicit acknowledgement of the delicate balance between conservation, sustainable use and equity.

New approaches to fisheries management have emerged, as reflected in the following quotes:

"The framework for a new fisheries management will have to be such that it can accommodate traditional knowledge, qualitative indicators, and proximate variables as means of evaluating the status of a fishery and determining future directions" (Berkes *et al*. 2001).

Ecosystems approach to fisheries *an ecosystem approach to fisheries (EAF) strives to balance diverse societal objectives, by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries* (FAO, 2008).

As regards the current status of EAF and human well-being, the following points are key:

- EAF is broadly accepted;
- limited experience in implementing;
- human well-being generic on high level, can be specific at a site-level;
- human well-being largely seen as "additional to" scientific assessments of fisheries;
- little application in integrated frameworks.

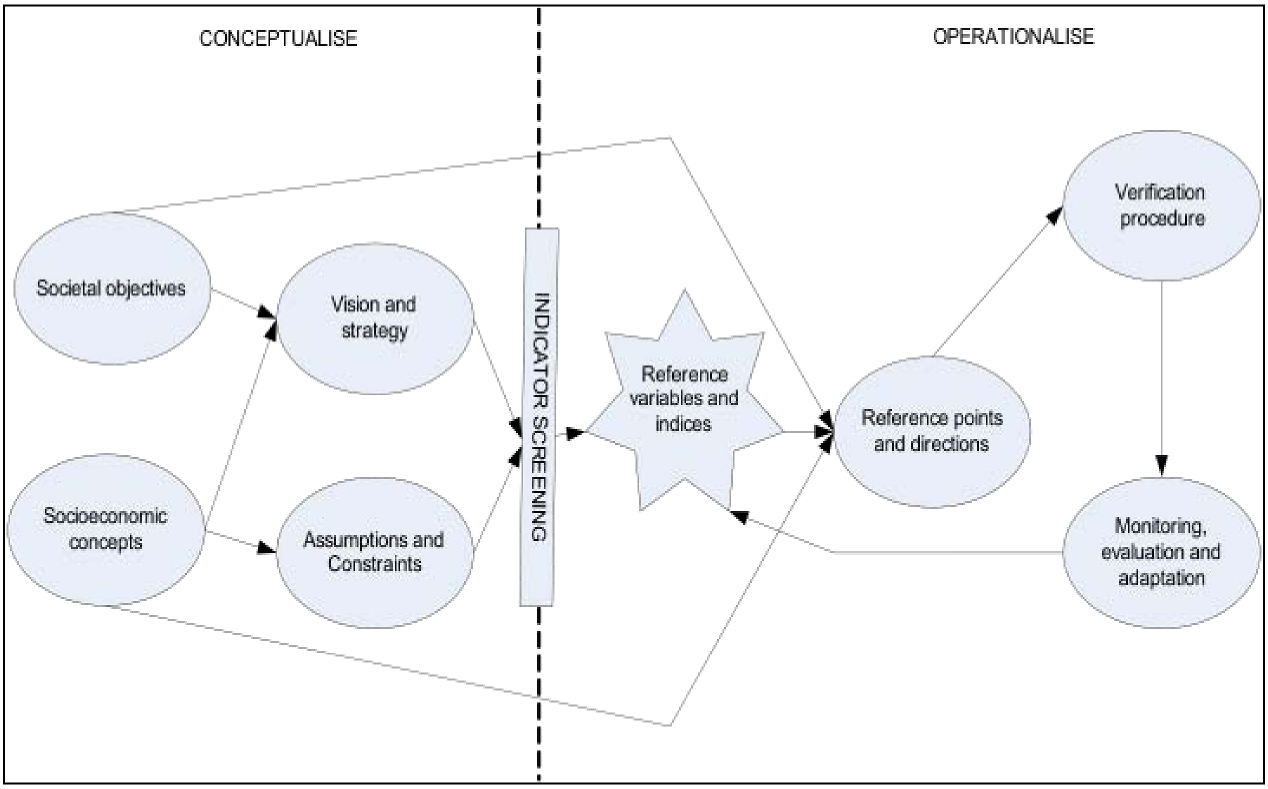
Indicators in the developing world:

- site, group, sector specific incomes – inequality;
- management priorities towards poverty/development;
- conflicts among users – allocation rights;
- information from non-scientific sources;
- data focused on biological indicators or may not exist at all;
- data may not be used effectively to inform management;
- fisheries not officially measured.

Included in the review:

- the criteria for deriving indicators;
- a structured assessment of available indicators for fisheries management, relevant to EAF issues and operational objectives (hierarchical tree framework);
- for each indicator, an assessment of its properties in relation to the criteria, as well as other factors such as data availability, practicality, cost-effectiveness, comprehension (also by non-experts), and robustness, etc. ;
- examples of decision triggering rules for each indicator (e.g. reference points, trends); indicators derived from traditional knowledge are also included in this review;
- a review of methodologies for integration/aggregation and visualization of indicators.

The conceptual framework for indicator development is shown in the diagram below:



Indicators and management approaches:

- participatory
- importance of traditional knowledge
- subsistence, artisanal
- identify drivers of human well-being
- rights-based
- decision-rule
- effort control

Traditional knowledge:

- valuable, but does not exclude scientific information
- social cohesion, local authority
- examples are limited
- limitations
- TK protected as a source of power (e.g. fishing grounds)

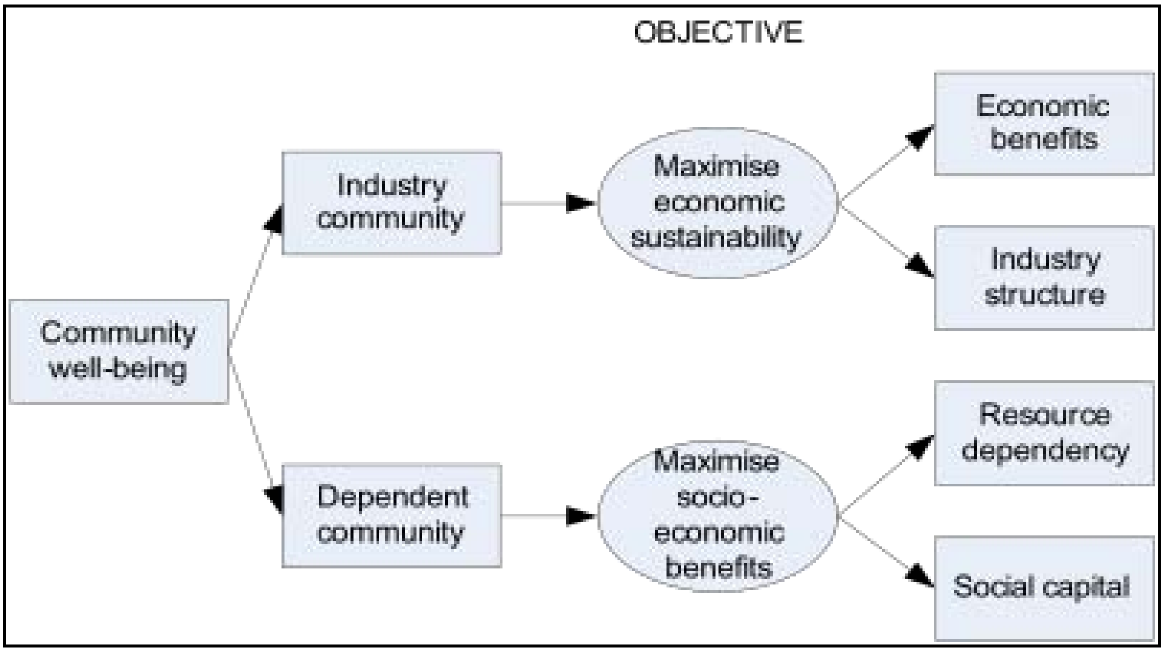
Criteria for indicators (technical initiatives):

- Bellagio principles (1997)
- Baltic 21 initiative (2000)
- FAO criteria for SDRS (1999)
- Balaton Group (1999)
- Rice and Rochet (2005)
- Policy-maker's preferences (e.g. Pintér *et al.* 2005)

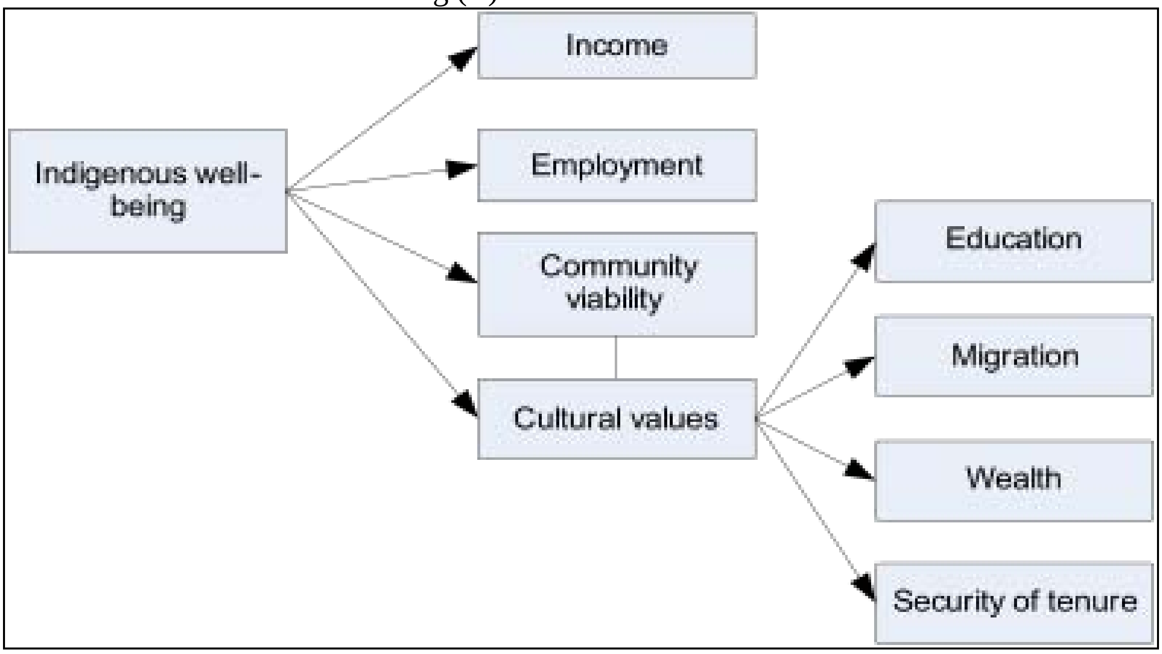
Indicator frameworks:

- pressure-state-response
- sustainable development (thematic) classification (e.g. Adriatic)
- capital accounting
- hierarchical structure
- systems outcomes

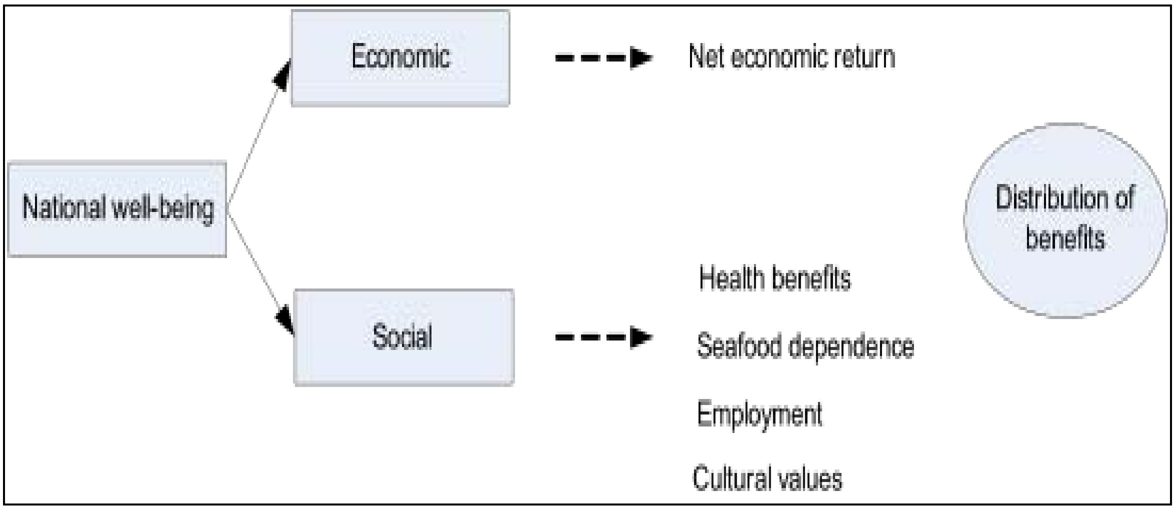
Frameworks for human well-being (I)



Frameworks for human well-being (II)



Frameworks for human well-being (III)



Hierarchical classification:

- Global well-being
- National well-being
- Composite indicators: assess national achievement towards sustainable development
- Economic
- Social
- Indigenous well-being
- Community well-being
- Industry
- Dependent community

Systems classification:

- Highlights interconnectedness
- Cross cutting indicators for human well-being-, natural- and economic support systems.

Indicators in a systems approach

Basic orientor	Viability of affecting system	Contribution to affected system
Existence	Is the system compatible with and can it exist in its particular environment?	Does the system contribute its part to the existence of the affected system?
Effectiveness	Is it effective and efficient?	Does it contribute to the efficient and effective operation of the total system?
Freedom of action	Does it have the necessary freedom to respond and react as needed?	Does it contribute to the freedom of action of the total system?
Security	Is it secure, safe and stable?	Does it contribute to the security, safety and stability of the total system?
Adaptability	Can it adapt to new challenges?	Does it contribute to the flexibility and adaptability of the total system?
Coexistence	Is it compatible with interacting subsystems?	Does it contribute to the compatibility of the total system with its partner systems?
Psychological needs	Is it compatible with psychological needs and culture?	Does it contribute to the psychological well-being of people?

Indicator evaluation

Criteria	Definition
Data availability	The highest score (3) is given to data published in United Nations and related publications, while the lowest score (1) is given where primary data needs to be collected.
Practicality	We use the dictionary definition which is concerned with actual use rather than theoretical possibilities.
Cost-effectiveness	In most cases similar to data availability, except for certain industrial or communal fisheries the data may be available but difficult to get hold of.
Comprehension	An indicator scores highest if it is well-known (such as GDP), or self evident (e.g. protein consumption), and scores lowest if it is a composite indicator (such as living standards measure).
Acceptability by stakeholders	A score of 3 was awarded to those indicators with widespread acceptance, 2 to indicators accepted within their discipline and 1 for more controversial indicators.
Robustness	The definition we have adopted is whether or not an indicator is able to withstand intellectual challenge.

Decision triggering rules:

- Trend analysis move towards desired outcomes
- Attribute analysis measure against norms, standards

Methods of integration and aggregation:

- Standardization, weighting, combining
- Different methods, pros and cons
- Choice per situation
- Visualising
- Graphics
- Indices

Evaluation of management performance:

- Indicator-based
- Selected indicators tested against trends, norms
- Non-indicator based
- Interviews to assess effectiveness of management and institutions
- Using “softer” incentives for better management (e.g. labelling)
- Adaptability and flexibility in the management process to deal with uncertainty and surprise

APPENDIX 5

SUMMARY OF THE REVIEW OF INDICATORS FOR ABILITY TO ACHIEVE

Introduction

The purpose of this paper is to review work on indicators relevant to “Ability to Achieve”:

1. governance issues, and
2. the ability of the fishery system to deal with factors outside its control, such as climate change, natural disasters etc.

The review will consider both indicators that are directly linked to specific management objectives, and indicators for monitoring key features of socio-ecological systems.

Governance

- Fisheries governance is the way in which users and their intentions are managed through a set of rights, rules, and shared social norms and strategies.
- Among the issues to be addressed for effective implementation of EAF are the appropriate governance arrangements and scale for management.
- EAF must be implemented at the multiple spatial and temporal scales that reflect the natural hierarchical organization of ecosystems.
- Issues of scale also include “scaling-up” from other management arrangements.

Ability of the fishery system to deal with factors outside its control, specifically environmental impact on the fishery

- A variety of factors exogenous to the fishery resource, fisher and community have an impact on the ability to achieve.
- These are factors which are beyond the control of fishery management, and at times also higher level entities.
- These are surprises or shocks to the management system, brought about by macroeconomic, social, political or natural occurrences or interventions which affect the survival of the management system.
- For this review, the focus was primarily on environmental issues which can impact on the fishery.
- Critical issues may include climate change, natural disasters, eutrophication, sediment loads, destruction of fish habitat, introduction of exotic species, and contamination of fish products through chemical pollution from agriculture and industry.
- Additional external factors that may impact upon the ability to achieve may be social, economic, political and institutional.

Goals and objectives

For this review, five generic GOVERNANCE goals and 19 generic governance objectives for EAF, developed from a review of fisheries management and marine protected area plans, were used:

Goal 1. Effective management structures and strategies maintained
Goal 2. Effective legal structures and strategies for management maintained
Goal 3. Effective stakeholder participation and representation ensured
Goal 4. Management plan compliance by resource users enhanced
Goal 5. Resource use conflicts managed and reduced

For this review, two generic IMPACTS OF ENVIRONMENT goals and nine generic impacts of environment objectives for EAF, developed from a review of fisheries management and marine protected area plans, were used:

Goal 1. Habitat protected
Goal 2. Degraded areas restored

Indicator description

Each of the governance and impacts of environment indicators identified that are relevant to EAF issues and goals and objectives were described using the following headings:

- **Name** - name of the indicator.
- **Goal and objective** – to which goals and objectives this indicator corresponds.
- **Difficulty rating** – a rank of how difficult the indicator is to measure.
- **What is "(indicator name)"?** – Brief description of the indicator.
- **Why measure it?** – The purpose and rationale of the indicator.
- **Requirements** – Resources (people, equipment) needed to collect and analyze the information.
- **How to collect the data** – The method and approach used to collect information on the indicator.
- **Strengths and limitations** – How useful is the indicator overall and what problems may occur in using the indicator?
- **Useful references and internet links** – Suggested sources of information on methods, and further explanation of the indicator.

Governance indicators for EAF

1. Level of resource conflict
2. Existence of decision-making and management body
3. Existence and adoption of a management plan
4. Local understanding of rules and regulations
5. Existence and adequacy of enabling legislation
6. Availability and allocation of administrative resources
7. Existence and activity level of community organization
8. Degree of interaction between managers and stakeholders
9. Proportion of stakeholders trained in sustainable use
10. Level of training provided to stakeholders in participation
11. Level of stakeholder participation and satisfaction in management processes and activities
12. Level of stakeholder involvement in surveillance, monitoring and enforcement
13. Clearly defined enforcement procedures
14. Enforcement coverage
15. Degree of information dissemination to encourage stakeholder compliance
16. Existence and application of scientific research and input
17. Institutional integration
18. Appropriate scale
19. Accountability of decision-making bodies

Indicators of ability of the fishery system to deal with factors outside its control, specifically impacts of environment indicators for EAF

1. Habitat distribution and complexity
2. Composition and structure of the community
3. Water quality
4. Area showing signs of recovery

Indicators of other external factors
Other external factors that may impact upon the ability to achieve may be social, economic, political and institutional.

Potential social indicators include (what types of people are affected by management and impacts; importance of marine use; how to tailor management strategies):

- Society, history and tradition impacts on decision-making
- Ethnicity, caste and religious background
- Population and migration trends within the country
- Food security and nutrition
- Poverty levels
- Household livelihood strategies
- Income and wealth levels and distribution
- Influence of social and economic "elites"

Potential economic indicators include (value of resources in economic, or monetary, terms and indicate actual and potential pressures on resources):

- Macroeconomic policies and changes
- Markets and trade
- Consumer demand changes

Potential political indicators include (political will, political continuity in policies; and ability to safely work and manage the area):

- Elections
- Political conflict
- Level of peace and order
- Regional and national social and economic development policies

Potential institutional indicators include (government's ability to provide resources to management; and government's support for EAF):

- Government downsizing
- Regional and national fisheries policies

Conclusions

- Given the complex nature of fisheries and marine ecosystems and their governance, EAF is confronted with the challenge of establishing measurement systems able to adequately track the progress of efforts.
- Greater emphasis on performance can help make EAF more oriented toward output- and outcome-based results rather than on input-based accounting.
- In order to measure performance, EAF initiatives should be characterized by clear goals accompanied by quantifiable objectives so that a meaningful analysis and assessment can be carried out.
- This review and assessment of indicators relevant to governance issues of EAF identified that very little has been published on the governance dimensions of EAF as compared to the ecological and socioeconomic dimensions.
- This review and assessment of indicators also identified that very little has been specifically published on the ability of the fishery system to deal with factors outside its control.

- Possibly relevant environmental, social, economic, political and institutional indicators were presented.
- These indicators will need to be further assessed and tested to ensure that they are useful at different scales of EAF management.
- As management is scaled up, indicators developed for site level assessments will need to be evaluated to determine if they are useful at the network or system level.
- The indicators presented in this paper are meant to be used at the EAF management area level.
- Most fisheries agencies in developing countries are finding it difficult to manage fisheries effectively using conventional fisheries management measures.
- There is a lack of understanding of EAF in most fisheries agencies and capacity building will need to be undertaken to develop this knowledge of and constituency for EAF.
- This will be extremely important at the local government level to which responsibility and authority for fisheries management has been devolved.
- There is a general lack of incentive to adopt EAF and to start with new management models and tools.

APPENDIX 6

TEMPLATE FOR EVALUATING INDICATORS

Fishery

Management objectives:

1. ecological
2. social (national/fishing community)
3. economic (national/fishery)

Indicators:

Ecological

Indicators	Questions			
	Feasibility (e.g. data)	Trigger points and management response defined/ definable	Visualization/ communication	Issues with implementation
Essential				
Retained species Catch[2]				
Retained species Catch per unit effort[2]				
Retained species Mean length (or other descriptor of length composition) in catch[2]				
Retained species Discards[2]				
TEP species catch				
TEP species catch per unit effort				
Keystone predator catch				
Ratios of trophic indicator groups in catch				
Habitat area/volume from fishery observations				
Habitat quality form fishery observations				
Community indicator groups catch per unit effort				
Species composition of the catch (intermittent)				
Mean length or weight of species in catch (intermittent)				

Desirable				
Retained species biomass[2] in community				
Retained species length composition[2] in community				
Retained species biological parameters[2]				
Discards of selected species (key prey or species at risk of TEP)				
TEP species population size in community				
Ratios of trophic indicator groups in community				
Habitat area/volume in community				
Habitat quality in community				
Species composition in community				
Mean length or weight of species in community				
Any additional indicators needed?				

Footnotes
[2] may be collected for only selected indicator or key species in highly multispecies fisheries

Human well-being

Indicators	Questions			
	Feasibility (e.g. data)	Trigger points and management response defined/ definable	Visualization/ communication	Issues with implementation
Essential				
A. Economic				
Net benefits (benefits-costs)				
Elasticity of supply (harvests/prices)				
Employment (input/output multiplier)				
Employment (census information)				
Distribution (% wages of total costs)				
Distribution (salary compared with minimum salary)				
Distribution (value-added)				

B. Dependent community				
Resource dependency (% fisheries income of household income)				
Resource dependency (% households in communities depending on fisheries)				
Resource dependency (% fisheries to household protein)				
Social capital (organizational structures)				
Social capital (level trust in community)				
C. Social capital (resilience)				
Social capital (cultural attachments)				
Any additional indicators needed?				

Ability to achieve

Indicators	Questions			
	Feasibility (e.g. data)	Trigger points and management response defined/ definable	Visualization/ communication	Issues with implementation
Essential				
Governance				
Clear and long-term prioritized objectives				
Compatibility between international national state and local rights and obligation				
Effective, transparent, accountable and credible decision-making process and management body				
Participatory processes proscribed and implemented				
Stakeholder understanding of rules and regulations				
Legislation adequate and coherent				
Availability and allocation of adequate human and financial resources				
Adequate and used information system				

Stakeholders identified and represented in management processes				
Adequate training provided to stakeholders				
Level of stakeholder satisfaction				
Clear enforcement procedures				
Enforcement effective				
Incentive mechanisms for sustainability				
Integration of institutional processes and functions				
Operational on appropriate scale				
Accountability of decision making bodies				
Level of resource conflict				
Frequency/severity of legal infringements				
Management effectiveness performance evaluation (frequency and adequacy)				
Capacity/presence of institutional learning				
Any additional indicators needed?				

APPENDIX 7

PRIORITY INDICATORS

Priority indicators of ecological well-being

Retained species
Essential (**)

- Catch, catch rate, size composition, mean length from catch or landings (these indicators may be collected for only selected indicator or key species in highly multispecies fisheries).
  Note: Size composition used to measure mean length, an indicator in its own right but it also enables exploitation rate or total mortality to be measured, and if augmented by percentage SPR can provide F or exploitation rate reference point. CPUE in absence of surveys gives a proxy for biomass.

Desirable (*)

- Empirical biomass from surveys (structured fisher surveys or scientific surveys); also to calibrate CPUE and/or provide direct estimates of abundance, distribution, size composition, and biological parameters.

Population biomass – Empirical estimation[2]	*
Total mortality (or fishing mortality or exploitation rate)[2]	*
% spawners per recruit (obtain target and limit for F or related parameter) [2]	*
Catch[2]	**
Catch per unit effort or catch rate [2]	**
Mean length or other descriptor of length composition in catch[2]	**

Discarded species
Essential (**)

- Measure of discards of important or indicator retained species

Desirable (*)

- Measure of catch of species that may be of key ecosystem significance (e.g. keystone prey) or at risk of becoming TEP

Discards of Retained species[2]	**
Discards of selected species (key prey or species at risk of TEP)	*

TEP species
Essential (**)

- Monitor catch and catch rate – usually as mandated by relevant legislation

Desirable (*)

- Population size (e.g. survey; catch rates probably not representative because of mitigation measures)

Catch	**
Catch per unit effort	**
Population size in community	*

Food webs
Essential (**)

- Catch and catch rate of keystone prey (precautionary catch of keystone prey spp.)

- Ratios of trophic indicator groups in catch

Desirable (*)

- Ratios of trophic indicator groups in surveys (quality assured fisher surveys or scientific surveys)

Catch of keystone prey	**
Catch per unit effort of keystone prey	**
Ratios of trophic indicator groups in catch	**
Ratios of trophic indicator groups in community	*

<u>Habitats</u>

Essential (**)

- Habitat space (seabed area and/or pelagic volume as appropriate) from verified fishers observations

Desirable (*)

- Habitat space from surveys (quality assured fisher surveys or scientific surveys)
- Habitat quality (e.g. density/health of most important habitat forming species for seabed habitats, water quality for seabed and/or pelagic habitats)

Habitat area/volume from verified fisher observations/catches	**
Habitat area/volume in community	*
Habitat quality	*

<u>Community structure</u>

Essential (**)

- Catch rate of indicator species or species groups
- Species composition of the catch (can be used to calculate K-dominance curves, ABC or diversity indices) [essential on intermittent basis]
- Mean length or weight of individuals in the catch [essential on intermittent basis]

Desirable (*)

- Species composition in surveys (quality assured fisher surveys or scientific surveys)
- Mean length or weight of individuals in surveys (quality assured fisher surveys or scientific surveys)

Mean length or weight of individuals in community	*
Species composition	**
Indicator species or groups of species	**

Notes:

a. In selecting or interpreting indicators there must be consideration of the spatial and temporal scale of the fishery in relation to the species/ecosystem boundary.
b. The descriptions of the indicators, and options for variations of these indicators, are as in Tables 1-6 of the “ecological well-being” review

Priority indicators composite summary

Essential indicators	Information source
Catch[1,2,4,5,6,8]	Verified fisher Catch[1,2,4,5,6,8]
Catch per unit effort [1,2,4,5,6,8]	Verified fisher Catch and verified fisher Effort[1,2,4,5,6,8]
Mean length (or other descriptor of length composition) in catch[1,2]	Verified fisher length composition of Catch[1,2]
Discards [1,2,4,5,6,8]	Verified fisher Catch[1,2,4,5,6,8]
Habitat area/volume[7]	Verified fisher observations of habitat[7]

Desirable indicators	Information source
% spawners per recruit (for target and limit for F) [1,2]	Life history information[1,2]
Total mortality (or fishing mortality or exploitation rate) [1,2]	Verified fisher length composition of catch[1,2]
Population biomass (or depletion) – empirical estimation[1,2,3,4,5,6,8]	Fisher or scientific surveys[1,2,3,4,5,6,8]
Mean length (or other descriptor of length composition) in population [1,2,4,8]	Structured fisher or scientific surveys[1,2,4,8]
Catch[3]	Verified fisher Catch[3]
Catch per unit effort[3]	Verified fisher Catch and verified fisher Effort[3]
Habitat area/volume[7]	Structured fisher or scientific surveys[7]
Habitat quality[7]	Structured fisher or scientific surveys[7]

Footnotes

1. retained species
2. may be collected for only selected indicator or key species in highly multispecies fisheries
3. selected species that may be of key ecosystem significance (e.g. keystone prey) or at risk of becoming TEP
4. TEP species
5. keystone predators
6. trophic indicator groups
7. habitats
8. community structure indicator groups

Priority indicators individually

Indicator	Observation type						
	Verified fisher Catch	Verified fisher Effort	Verified fisher length composition of Catch	Verified fisher observations of habitat	Life history information	Structured fisher or scientific surveys	Remote sensing and other public data
Essential							
Retained species Catch[1]	x						
Retained species Catch per unit effort[1]	x	x					
Retained species Mean length (or	x		x				

other descriptor of length composition) in catch[1]							
Retained species Discards[1]	x						
TEP species catch	x						
TEP species catch per unit effort	x	x					
Keystone predator catch	x						
Ratios of trophic indicator groups in catch	x						
Habitat area/volume from fishery observations				x			
Habitat quality form fishery observations				x			
Community indicator groups catch per unit effort	x	x					
Species composition of the catch (intermittent)	x						
Mean length or weight of species in catch (intermittent)	x		x				
Desirable							
Retained species biomass[1] in community						x	
Retained species length composition[1] in community						x	

Retained species biological parameters[1]	x				x	x	
Discards of selected species (key prey or species at risk of TEP)	x						
TEP species population size in community						x	
Ratios of trophic indicator groups in community						x	
Habitat area/volume in community				x		x	x
Habitat quality in community				x		x	x
Species composition in community						x	
Mean length or weight of species in community						x	

Footnotes
1. May be collected for only selected indicator or key species in highly multispecies fisheries

Priority indicators of human well-being

Objective: Maximize human well-being

Function of:
A. Economic
B. Social
C. Community

A. Economic

Industrial/artisanal/recreational (last more difficult to measure)
- Maximize landings and value
- Supply (landings) and demand (consumer surplus) functions
    - Key indicators:
        - Net benefits
            - Inputs: Benefits - Costs:
                - direct fisheries industry information (issue how to deal with subsidies),
                - intangible benefits for recreation e.g. Travel Cost
        - Elasticity of supply (percentage change in price per change in harvest) – if negative, message to manager to be more careful with resource)
            - Inputs: Harvest, Prices (incl. prices substitutes, complements).
        - Employment
            - based on input-output multiplier (Net benefit * multiplier)
            - or based on census information
        - Distribution
            - percentage wages to total cost
            - difference between average salary per employed and minimum salary
            - value added based on census

B. Dependent community (industrial, artisanal, subsistence (including recreational subsistence)
- Definition of community: fisheries dependent communities
- Resource dependency
    - percentage of fisheries income to household income
    - percentage of fisheries labour dependent households
    - percentage of fisheries contribution to household protein
    - social capital
- Evidence of working organizational structures
- Levels of trust in community
- Measures of resilience
- Measures of cultural attachment to the resource and lifestyle
    - value people place on activity of fisheries

Priority governance indicators

1. Existence of clear long term and prioritized policies and objectives (**Priority**; Goals: 2A).
2. The level of compatibility between international, national, state and local rights and obligations (**Priority**).
3. Existence of effective, transparent, accountable and credible decision-making processes and management body (**Priority**).
4. Existence and adoption of a coherent and integrated management plan (**Priority**)
5. Participatory processes proscribed and implemented (**Priority**).
6. Stakeholder understanding of rules and regulations and their purpose (Goals: 2F).
7. Existence, adequacy and coherence of enabling legislation (**Priority**).
8. Availability and allocation of human and financial resources for management structures (**Priority**; Goals: 1d, 4c).
9. Well designed and used information system (**Priority**).
10. Stakeholder groups identified and represented in management processes.
11. Level of training provided to stakeholders in participation.
12. Level of stakeholder satisfaction in management processes and activities (**Priority**).
13. Clearly defined enforcement procedures (**Priority**).
14. Enforcement coverage (**Priority**).
15. Incentive mechanisms developed (all goals).
16. Institutional integration (**Priority**).
17. Appropriate scale (**Priority**).
18. Accountability of decision-making bodies.
19. Level of resource conflict (**Priority**).
20. Number of infractions to the law.
21. Performance evaluation regularly undertaken (**Priority**).
22. Capacity for institutional learning (**Priority**)[1].

Indicators for possible external drivers

Critical environmental issues may include:

- Effects of climate change on distribution of stocks and sea level rise on nursery habitats;
- Natural disasters caused by typhoons, earthquake, flooding, etc.;
- Eutrophication of coastal waters resulting from excess nutrients from agriculture and sewage;
- Sediment loads from agriculture, forestry and construction of infrastructure in catchment that degrade coastal ecosystems;
- Destruction of fish habitat through foreshore development;
- Introduction of exotic species through ballast water and on the hulls of ships;
- Contamination of fish products through chemical pollution from agriculture and industry.

In addition to the impact on environment indicators, external factors that may impact upon the ability to achieve may be social, economic, political and institutional. These will be briefly discussed.

1. **Social** indicators can be relevant to the ability to achieve by understanding:

- what types of people are affected by management and how to maximize positive and minimize negative impacts on them e.g. if a manager knows the ethnic diversity of the stakeholders, it is possible to determine if one group will be more affected by management programs than another and revise plans to ensure better distribution of impacts.
- how important marine use is to the stakeholders and to the whole community; how much they will be affected by management strategies e.g. if most mangrove cutters are poor and dependent on mangrove cutting for much of their livelihood, they will be heavily affected by restrictions on mangrove cutting;
- how to tailor management strategies to stakeholder needs and backgrounds e.g. if the fishermen have a secondary level education then the education programs should be developed to that level.

Potential social indicators include:

- Society, history and tradition impacts on decision-making;
- Ethnicity, caste and religious background;
- Population and migration trends within the country;
- Food security and nutrition;
- Poverty levels;
- Household livelihood strategies;
- Income and wealth levels and distribution;
- Influence of social and economic “elites”.

2. **Economic** indicators can be relevant to the ability to achieve by understanding:

- the value of resources in economic, or monetary, terms, which are used to evaluate the costs and benefits of alternative management actions; and
- indicate actual and potential pressures on resources e.g. high demand for fish.

Potential economic indicators include:
- Macroeconomic policies and changes;
- Markets and trade;
- Consumer demand changes .

3. **Political** indicators can be relevant to the ability to achieve by understanding:
- political will to support management actions;
- political continuity in policies; and
- ability to safely work and manage the area.

Potential political indicators include:
- Elections;
- Political conflict;
- Level of peace and order;
- Regional and national social and economic development policies.

4. **Institutional** indicators can be relevant to the ability to achieve by understanding:
- governments ability to provide resources to management; and
- governments support for EAF.

Potential institutional indictors include:
- Government downsizing;
- Regional and national fisheries policies.

Generic governance goals

Goal 1. Effective and adaptive management structures and strategies maintained

1A Management planning implemented and process effective and adaptive
1B Rules for resource use and access clearly defined and socially acceptable
1C Decision-making, decision-making process and management bodies present, effective, and accountable
1D Human and financial resources sufficient and used efficiently and effectively
1E Local and/or informal governance system recognized and strategically incorporated into management planning
1F Periodic monitoring, evaluation, and effective adaptation of management plan ensured
1G Appropriate scale of management linking ecosystem and jurisdictional boundaries
1H Sectoral integration for cooperation, coordination, consultation and joint decision-making
1I Decision-making under uncertainty enhanced

Goal 2. Effective legal structures and strategies for management maintained

2A Existence of policies and adequate legislation ensured
2B Compatibility between formal and informal arrangements maximized and ensured
2C National and/or local legislation effectively incorporates rights and obligations set out in international legal instruments
2D Compatibility between international, national, state and local rights and obligations maximized or ensured
2E Enforceability of arrangements ensured
2F Rules and responsibilities of stakeholders well defined

Goal 3. Effective stakeholder participation and representation ensured

- 3A Representativeness, equity, and efficacy of participatory management systems ensured
- 3B Stakeholder capacity effectively built to participate in management
- 3C Community organizing and participation strengthened and enhanced

Goal 4. Management plan compliance by resource users enhanced

- 4A Surveillance and monitoring of coastal areas improved
- 4B Improved willingness and acceptance of people to behave in ways that allow for sustainable management
- 4C Stakeholder ability and capacity built to implement management plan effectively
- 4D User participation in surveillance, monitoring, and enforcement increased
- 4E Application of law and regulations adequately maintained or improved

Goal 5. Resource use conflicts managed and reduced

- 5A User conflicts managed and/or reduced: 1) who controls the fishery (access issues)?; 2) how the fisheries is controlled (enforcement issues); 3) relations between the fishery users; 4) relations between fishers and other resource users; and 5) relations between fishers and non-fishery issues.

APPENDIX 8

OUTLINE FOR INDICATOR TEXT BOXES (FOR THE TECHNICAL REPORT)

Example from the field: indicator name
What is this indicator? Text description of what it is, the estimator and estimate in Mozambique
Why is it estimated?

- what objectives is it helping us monitor?
- what is it telling us about these objectives?
- what would we be missing if we couldn't/don't estimate the indicator?

What data and/or information is needed?

- how is the information collected?
  - fisheries data, fisheries (in)dependent surveys, community surveys, national census, etc.
- what is the temporal scale?
  - time series or one-off estimation?
  - daily, monthly, annually,...
- what is the spatial scale?
  - international, national, regional, local.

How is it calculated?

- what, if any, calculations are required (for example, what is the equation)?
- what are the units of the indicator (if applicable)?
- what models and methods are used for/with indicator?
- what visualization methods are particularly useful for this indicator?

How is the indicator analysed, interpreted and used for decision-making?

- what types of trigger and reference points are associated with this indicator?
- how were these trigger and reference points determined?
- what decision rules are associated with this indicator?

Strengths and weaknesses of the indicator

- what didn't this indicator tell us? (how not to use this indicator)
- what issues arose in the estimation and use of this indicator?

How can this indicator be used in combination with other indicators?

- what indicators provide complimentary information?

What happens when we don't have sufficient data to estimate the indicator? (last resort)

- downward direction: possible substitutes (quick and dirty)

Where could we go from here?

- upward direction: moving to better indicators

APPENDIX 9

COMPARING ECOLOGICAL INDICATORS ACROSS THE WORLD'S MARINE ECOSYSTEMS: THE IndiSeas EXPERIENCE
(Yunne Shin, Lynne Shannon and Alida Bundy)

Over the last two decades, the foundations of the EAF have been elaborated and prioritized in both scientific and management spheres. Key frameworks, plans and commitments have paved the way towards the implementation of EAF around the world, e.g. the 1995 FAO Code of Conduct for Responsible Fisheries, the 2001 Reykjavik Declaration and the 2002 World Summit on Sustainable Development. To make progress towards implementing the EAF, carefully selected and appropriate indicators are required to translate ecosystem impacts and changes into management and policy measures that can be assessed for their effectiveness. The scientific community is challenged to provide a generic set of synthetic indicators to accurately reflect the effects of fisheries on marine ecosystems, to facilitate effective communication of these effects and to promote sound management practices.

The IndiSeas working group (Indicators for the Seas) was established in 2005 under the auspices of the EUR-OCEANS European Network of Excellence (www.eur-oceans.eu) to gather and share indicator expertise across marine ecosystems and member institutions, in order to:

- develop a set of synthetic ecological indicators;
- build a generic dashboard using a common set of interpretation and visualization methods;
- evaluate the exploitation status of marine ecosystems in a comparative framework.

IndiSeas has adopted a comparative approach because it adds significant power to the analysis of ecosystem change. In particular it:

- helps in selecting robust ecological indicators that would be meaningful and measurable over a set of diverse and contrasted situations, as well as in specifying their conditions of use;
- uses similar ecosystems as replicates, mimicking an experimental set-up where common, unique and fundamental features, as well as important responses to fishing, can be explored. At the same time, comparing ecosystems with contrasted exploitation and environmental conditions can help better determine the status of each ecosystem;
- provides a range of reference values (min, max) against which each ecosystem can be assessed, in a context where it is difficult to establish baseline levels and reference points for most ecosystem indicators;
- avoids repeating the same fisheries management mistakes as may have been the case in some "degraded" ecosystems in the set considered (i.e. provide early warning signals), and permits the ability to draw generalizations important to successful implementation of EAF;
- creates an incentive for politicians to consider management options with added responsibility with regard to the ecological quality of marine ecosystems worldwide.

The IndiSeas WG agreed on a suite of eight ecological indicators to measure fishing-induced impacts on marine ecosystems, assess the recent state of fished marine ecosystems, and compare changes in ecosystems over the past few decades (Table 1). The combination of selected indicators is intended to suitably reflect different ecosystem dynamics, track processes that cover different management goals and display differential responses to fishing, and together is meant to provide a complementary means of assessing marine ecosystem changes and states. The eight indicators were selected after careful consideration of several criteria, such as whether they encapsulated ecological processes adequately, the availability and cost of generating the data required, their sensitivity to fishing pressure and their ability to be understood and adequately interpreted by stakeholders and the general public. A particular constraint was that estimation of these indicators needed to be feasible across a wide spectrum of ecosystems, including data-poor areas.

A suite of papers to be published in ICES Journal of Marine Science in 2010 presents the initial results of comparative analyses of the 19 fished marine ecosystems (Shin and Shannon, 2010; Shin *et al.*, 2010a). The suite includes interpretations of combined sets of indicators representing ecosystem states (Shin *et al.*, 2010b), interpreting trends in indicators (Blanchard *et al.*, 2010), and developing various methods (ranking, decision tree, models-based indicators) for assessing the status of exploited marine ecosystems (Coll *et al.*, 2010; Bundy *et al.*, 2010; Shannon *et al.*, 2010). Practical concerns underlying the estimation of IndiSeas indicators from trawler-based data are addressed by Jouffre *et al.* (2010). Capturing signals from environmental variability and how they combine with fishing effects is also addressed through empirical approaches (Link *et al.*, 2010).

Having completed these initial phases, several next steps have been identified for IndiSeas, including building bridges with other scientific fields. Additional indicators from other scientific fields need to be considered to strengthen the ecosystem diagnosis and to provide a more integrative evaluation of ecosystems states in support of ecosystem-based fisheries management. Five future tasks have been identified:

1. *Studies of the joint effects of climate and fishing changes on the selected indicators*
   Ecosystems need to be managed in the context of environmental variability, decadal-scale change and longer-term environmental climate change. Time series analyses of fishing effort and regional climate indices are needed. Ecosystem and end-to-end models can also be used to assess the specificity of ecosystem indicators to fishing effects versus climate effects.

2. *Integration of conservation and biodiversity issues in the diagnosis of ecosystem states*
   Indicators that quantify the biodiversity and conservation risks in ecosystems will be considered in the future.

3. *Integration of socio-economic issues*
   Recent worldwide evaluation of ecosystem status has been undertaken using socio-economic indicators with emphasis on the vulnerability of ecosystems to the impact of climate change on fisheries (Allison *et al.*, 2009), on the performance of nations in managing their fisheries (Alder and Pauly, 2008) or on their compliance with the FAO Code of Conduct for responsible fisheries (Pitcher *et al.*, 2009).The IndiSeas WG plans to build bridges with these socioeconomic networks.

4. *Testing the performance of ecosystem indicators in fisheries management*
   How do we know how well an indicator indicates and guides management decisions? Performance testing is a formal procedure to assess whether an indicator and accompanying decision rule actually guide decision-makers to make the "right" decision, in hindsight. The suite of indicators collected under the IndiSeas initiative provides a unique opportunity to test their performance across a range of ecosystems.

5. *Developing reference levels for indicators*
   Establishing reference levels for ecosystem indicators has proven to be a major challenge to implementing EAF, due to the complexity of ecosystems and their response to fishing in a changing environment. Ecosystem models will be used for identifying reference points.

The IndiSeas website www.indiseas.org has been developed as a platform to disseminate the results of the analyses beyond the scientific audience. The aim of the IndiSeas website is to inform fisheries scientists, managers, policy makers and the public at large of the state of the world's marine ecosystems as a result of fisheries exploitation.

The goal of the FAO Nansen Project and IndiSeas is similar: to operationalize EAF. There are several areas where these projects could be linked, with benefits to both:

- Both are selecting/proposing a subset of indicators from the vast numbers of indicators that exist in the literature to use for an EAF. FAO Nansen could use the results of the analysis conducted by IndiSeas to date and IndiSeas could incorporate indicators suggested by FAO Nansen into their second phase.
- Both recognize the need for indicators that can be applied across different ecosystems, which imply data constraints.
- Both are taking a global approach. To date, IndiSeas has data for 19 ecosystems (Figure 1). It is intended to expand this number. These ecosystems and data could also be used within the FAO Nansen project to test indicators and evaluate ecosystems.
- Range of Indicators: to date, IndiSeas has focused on ecological indicators, but plans to include socio-economic indicators in the next phase. FAO Nansen has taken a broader approach covering ecological well-being, human wellbeing and ability to achieve. IndiSeas could incorporate and test some of the indicators suggested for human wellbeing and ability to achieve.
- IndiSeas has a working membership of over thirty scientists from Europe, Africa, North America, South America and Australia. This resource could be of great benefit to the FAO Nansen project.

Currently, we (Alida Bundy, Lynne Shannon and Yunne Shin) have applied for an ICES SCOR Working Group to facilitate plans for the second phase of IndiSeas over the next few years.

Table 1: Minimal list of indicators for establishing the dashboard (L: length (cm), i: individual, s: species, N: abundance, B: biomass, Y: catch, TL: trophic level).

Indicators	Calculation, units	Comments to guide calculation of indicators
Mean length	$\overline{L} = \frac{\sum_i L_i}{N}$ (cm)	*Data:* all surveyed species[1] *Question: In places where there is no data for length, what about weight?* Weights are converted to lengths using w-l relationships. Reason for choosing length – more meaningful to public; length is less directly affected by environmental change.
TL landings	$\overline{TL}_{land} = \frac{\sum_s TL_s\ Y_s}{Y}$	*Data:* Fixed non-integer TL per species. All retained species[2]. Can be calculated from Ecopath model or diet data. *Question: If there is no Ecopath model implemented nor diet data available, can this indicator be calculated?* As a stopgap, the estimates of TL in Fishbase (www.fishbase.org) are used.
Proportion of under and moderately exploited stocks	Number (under+moderately exploited stocks)/total nb of stocks considered	*Method*: 3 methods were tested: 1) using only local expertise on a list of assessed stocks, 2) using only FAO database (stock status and number of assessed stocks), 3) using FAO stocks list but also local expertise to refine FAO assessments when possible. The first method was biased because in some cases the number of assessed stocks was too low compared to the number of stocks that are actually exploited. The second method was not always satisfying because FAO regions are too large compared to the ecosystems considered in the WG: list of stocks were not always adapted and stock status not necessarily the same over the whole FAO region (e.g. stocks off Namibia and South Africa). The third method was adopted according to the following step-by-step procedure: - listing the stocks that are referenced by FAO in the area of concern (http://www.fao.org/docrep/009/y5852e/Y5852E10.htm#tbl); - cutting this FAO list according to what is effectively retained in the ecosystem (= tot nb of stocks considered); - adding local expert knowledge to refine the FAO classification of stock status and fill the gaps, providing sources (WG reports, published literature, pers. comm.). The advantage of the above method is adoption of the same reference list of major world stocks that was already established by FAO.
Proportion of predatory fish	Prop predatory fish = B predatory fish/B surveyed B surveyed = B (demersal fish+pelagic fish+commercially imp. invertebrates)	*Question: Are invertebrate species to be included in the predators pool?* No, see definition of "predatory fish species"[3]. As such, this indicator can reflect a potential decrease in demersal stocks, and a parallel increase in forage or invertebrate species.

Mean life span	$\dfrac{\sum_S (age_{\max} B_S)}{\sum_S B_S}$ (year)	*Meaning*: Proxy for turnover rate. Conveys the idea that fishing favours the emergence of species with a short life span. Fishing may affect the longevity of a given species (phenotypic plasticity and genotype selection), but the purpose here is not to track those effects at the species level, but to track changes in species composition. *Data*: Calculated for surveyed species[1]. Fixed longevity for each species. Life span may vary under fishing pressure, so we conventionally adopt the max longevity observed for each species.
1/Coefficient of variation of total biomass	Mean (total *B* for the last 10 years) /sd (total *B* for the last 10 years)	*Data*: biomass of all surveyed species[1]
Total biomass of surveyed species	*B* (tons)	*Data:* all surveyed species[1]. Specific surveys conducted for sampling eggs, larval and juvenile stages should not be considered. This B index is used only for trends so absolute biomass estimates are not needed. *Question: Do different surveys have to be combined (demersal trawl, pelagic acoustic …)?* In some cases, considering only the demersal trawl surveys provides an adequate estimate of biomass of demersal/pelagic fish and commercially important invertebrates. However, in some systems (such as upwelling ones), small pelagic fish are not adequately sampled in the demersal trawl surveys and thus dedicated small pelagic surveys are carried out. In those cases, local experts are to decide on appropriate methods of combining different surveys to provide a single total biomass index for the ecosystem.
1/(landings /biomass)	B/Y retained species[2]	*Meaning*: Indicates a global fishing pressure at the community level. *Data*: Use total landings and biomass of retained species[2]. Used for trends: so biomass indices can be used (but must be consistent across species and over the time series).

[1] Surveyed species

These are species sampled by researchers during routine surveys (as opposed to species sampled in catches by fishing vessels), and should include species of demersal and pelagic fish (bony and cartilaginous, small and large), as well as commercially important invertebrates (squids, crabs, shrimps…). Intertidal and subtidal crustaceans and molluscs such as abalones and mussels, mammalian and avian top predators, and turtles, should be excluded. Surveyed species are those that are considered by default in the calculation of all survey-based indicators.

[2] Retained species (landed)

These are species caught in fishing operations, although not necessarily targeted by a fishery (i.e. include bycatch species), and which are retained because they are of commercial interest, i.e. not discarded once caught, although this does not imply that sometimes certain size classes of that species may be discarded. A non-retained species is considered to be one that would never be retained for consumptive purposes. Intertidal and subtidal crustaceans and molluscs such as abalones and mussels are to be excluded. Retained species are those that are considered by default in the calculation of all catch-based indicators.

[3] Predatory fish species

Predatory fish are considered to be all surveyed fish species that are not largely planktivorous (i.e. phytoplankton and zooplankton feeders should be excluded). A fish species is classified as predatory if it is piscivorous, or if it feeds on invertebrates that are larger than the macrozooplankton category (>2cm). Detritivores should not be classified as predatory fish.

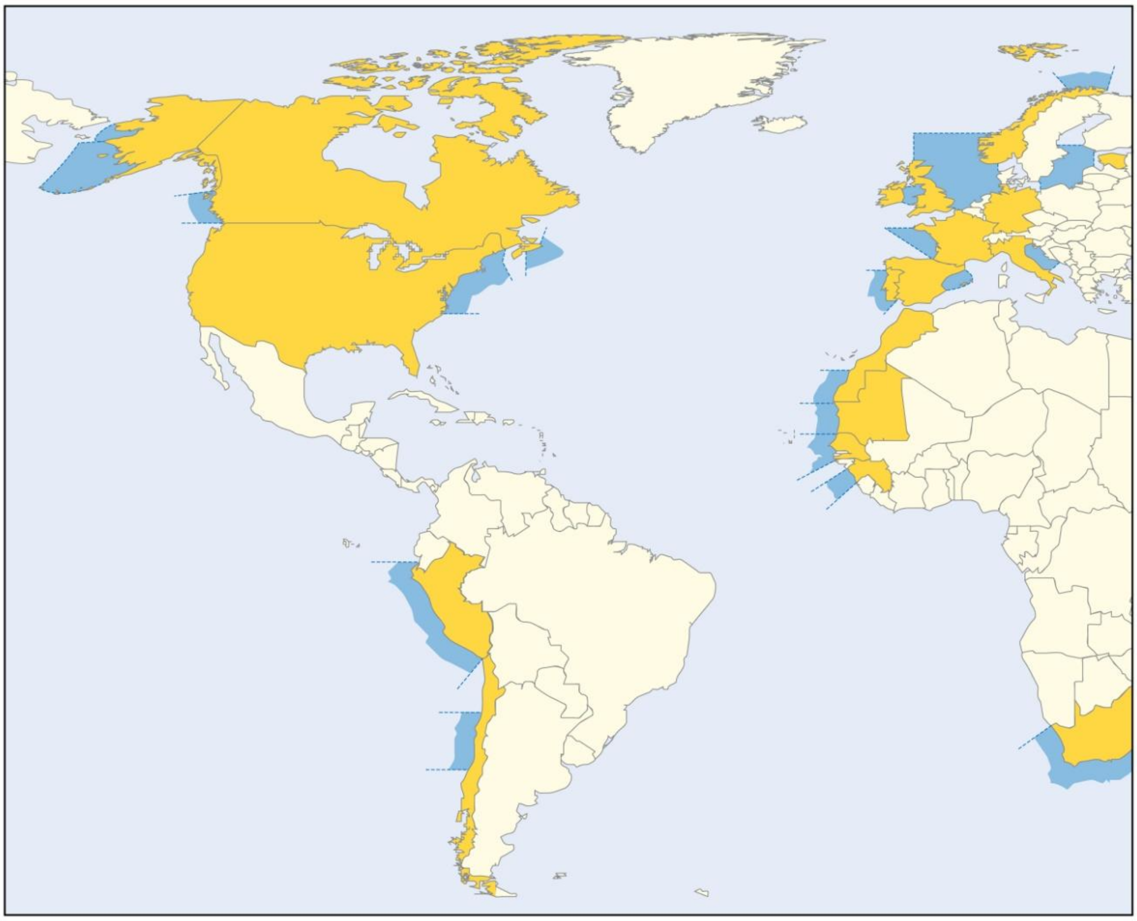


Figure 1: Marine ecosystems considered in the IndiSeas Working Group. In blue, the marine ecosystem, in yellow, the countries participating in the analyses.

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APPENDIX 10

INCORPORATING THE HUMAN DIMENSION TO THE ECOSYSTEM APPROACH TO FISHERIES – SUPPLY ELASTICITY EXAMPLE (John Ward)

In a marketplace, price and quantity equilibriums occur at many different levels; final consumer, retail, wholesale, processor, and in the case of fisheries the initial harvester of the living marine resource. General equilibrium theory allows the estimation of economic value in the form of net benefits at any of these market levels. The preference of the analyst is really determined by the availability of the necessary data. For the EAF management the harvest level data is available and will provide a direct assessment of ecosystem status of the fishery. A case study of a Mozambique fishery was to be used to demonstrate this approach, but data availability and travel restrictions prevented its use within the time frame necessary to complete this appendix, so an alternative data set available on the internet was substituted.

The first step is to collect landings and value data at its greatest level of disaggregation. In this case study, landings and value data are available by year, species, and gear type. This information is used to estimate a price per unit of weight, pounds in this case, which is then deflated using an appropriate index (Producer Price Index for fish products). Next, a simultaneous equation system of supply and demand is estimated using seemingly unrelated regression techniques, based on a synthetic demand formulation and a stock constant supply function. This econometric model results in a demand equation with a statistically significant negative slope and a supply function with a statistically significant positive slope (Table 1). From these estimated equations it is possible to estimate the economic value of the fishery in terms of benefits net of costs using integration techniques from the calculus for any combination of price and quantities produced (Table 2). The revenues estimated by this approach can also be used to determine how economic impacts have changed over time if the appropriate input-output multipliers are available.

Developing an index of ecosystem health requires that the supply equation be decomposed into annual supply equations that are not stock constant; this open-access, supply function is also referred to as a Copes (1970) model. This open access supply curve has a backward bend that reflects declines in stock abundance as effort levels increase resulting in declining harvest levels after maximum sustainable yield for the fish species is exceeded. As abundance declines, due to environmental, biological, or anthropogenic reasons, the own-price elasticity of supply (ε_s), at first a positive value, will decrease in value and become negative once MSY is exceeded; i.e.:

$\varepsilon_s > 0$ then $B > B_{MSY}$
$\varepsilon_s = 0$ then $B = B_{MSY}$
$\varepsilon_s < 0$ then $B < B_{MSY}$

If a natural logarithmic transformation of the data is used, then the estimated coefficient of price in the supply equation is equal to the own-price and the cross-price elasticity of supply. The own-price supply elasticity estimates are a direct, empirical index of fish stock biomass abundance, while the cross-price supply elasticities indicate the degree of dependence of different stocks in the combined marine and marketplace ecosystems.

Using the annualized, open-access, supply function, annual estimates of own-price elasticity of supply can be plotted to demonstrate how stock abundance has changed over time as market, biological, and ecosystem changes have occurred. In Figure 1 both the annual (A) and a ten year moving average(*) of own-price elasticity estimates are presented. While individual year supply elasticities indicate that MSY has been exceeded, the overall trend indicated by the moving average shows a decline in biomass that has not yet exceeded the MSY biomass levels ($\varepsilon_s > 0$ then $B > B_{MSY}$).

While this may appear complex to the uninitiated in natural resource economics, this approach provides a rapid assessment technique to fishery managers in need of an overall metric of ecosystem health including both the biological and human dimensions. The availability of additional information such as that found in a standard stock assessment or more in-depth economic surveys of fisheries and fishery dependent communities will improve the depth and breadth of the estimates of supply elasticity, increasing the information available to fishery managers.

Table 1

Atlantic cod	**Coefficient**	**Standard Error**	**t-value**	**Probability**
Demand price	-0.04002	0.001125	35.56	<.0001
Supply price	0.610975	0.004498	135.84	<.0001

Table 2

Net benefits	**Coefficient**	**Standard Error**	**t-value**	**Probability**
Cod consumer surplus		3.03279		
Cod producer surplus		.001850613		
Total net benefits		3.03464		
Sea scallops consumer surplus		6.4093E102		
Sea scallops producer surplus		0.61086		
Total net benefits		6.4093E102		
MonkFish consumer surplus		7.1238E260		
MonkFish producer surplus		-4023.13		
Total benefits		7.1238E260		
Surf clam consumer surplus		2.8228E17		
Surf clam producer surplus		-4416919.08		
Total benefits		2.8228E17		
Ocean quohog consumer surplus		3.8776E79		
Ocean quohog producer surplus		1.6384E227		
Total net benefits		1.6384E227		

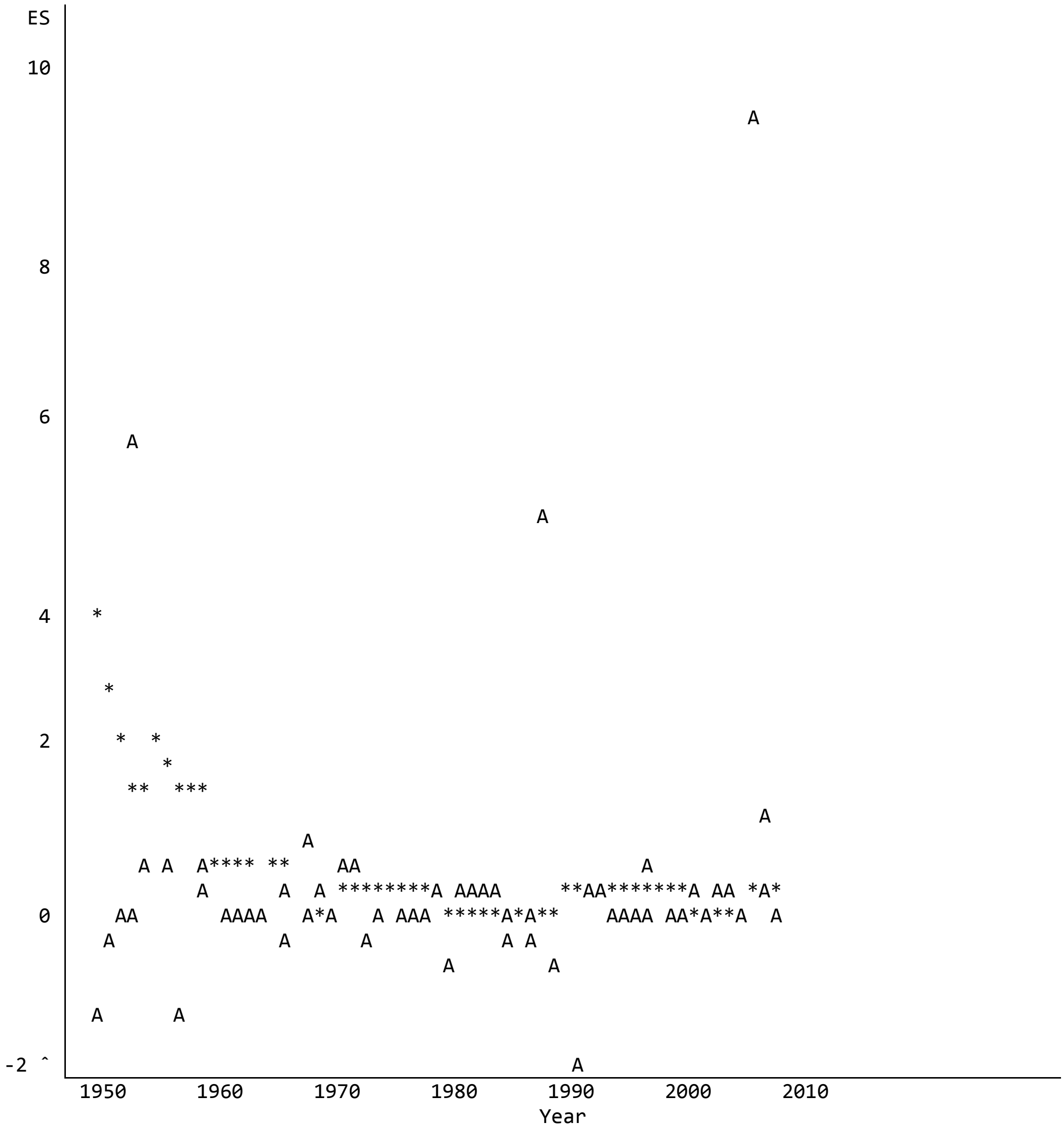

Figure 1 Striped Bass
Key: Own-Price (A) and Moving Average (*) Elasticity of Supply over time

APPENDIX 11

ROADMAP

	By (months in 2009)	Responsibility
1. Meeting report finalization – Concise workshop report including: • summary of presentations	 Mid-May (draft) End-May (final draft) End of April	 Kwame to coordinate Authors background papers
2. Further development – Revise input papers (as input to 3), based on workshop recommendations and including identification of practical trials/ demonstration examples – Ecological (two days) – Human well-being (one week) – Ability to achieve (three weeks) **2.1 Determine box content/structure:** – Box content – Preliminary indicator, trigger and management response tests on datasets from Mozambique: 1. identify indicator (one per component) 2. define data needs 3. supply test data (about 1 month) 4. test (about 1 month) – Test through field work (Mozambique, one week) – Consolidated conclusions (three weeks)	 Mid- June (draft) End July (final draft) ASAP End of July End of August End of September October End of October	 Cassandra, Gabriella Cassandra, Gabriella, experts
3. Integrated reports (includes ecological, human and ability to achieve in each) – FAO Technical Paper based on revised background documents and including practical examples, with emphasis on data-poor situations (1 month) – Manual – Guidelines for policy/management audience	 End of November (first draft) Revisit after Tech. Paper Revisit after Tech. Paper	 Cassandra, Gabriella, experts