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VOLUME 5

METHODOLOGY FOR THE ASSESSMENT OF LARGE MARINE ECOSYSTEMS

METHODOLOGY FOR THE GEF TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

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METHODOLOGY FOR THE GEF TRANSBOUNDARY WATERS ASSESSMENT

VOLUME 5

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PREFACE

The GEF Medium Size Project (MSP) *Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme,* approved in January 2009, was envisioned as a partnership among existing programmes, which was considered to be more cost effective than the conduct of an independent data and information gathering exercise. The Project Objective was to develop the methodologies for conducting a global assessment of transboundary waters for GEF purposes and to catalyse a partnership and arrangements for conducting such a global assessment.

This Project has been implemented by UNEP as Implementing Agency, UNEP Division of Early Warning and Assessment (DEWA) as Executing Agency, and the following lead agencies for each of the water systems: the International Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) for transboundary aquifers including aquifers in small island developing states (SIDS); the International Lake Environment Committee (ILEC) for lake basins; UNEP-DHI Centre for Water and Environment (UNEP-DHI) for river basins; and Intergovernmental Oceanographic Commission (IOC) of UNESCO for LMEs and the open ocean.

This Project resulted in developed methodologies for the following five transboundary water systems: (i) groundwater aquifers; (ii) lake/reservoir basins; (iii) river basins; (iv) large marine ecosystems; and (v) open oceans.

The results of this Project are presented in the TWAP MSP Publication, *Methodology for the GEF Transboundary Waters Assessment Programme*, which consists of the following six volumes:

- *Volume 1 – Methodology for the Assessment of Transboundary Aquifers, Lake Basins, River Basins, Large Marine Ecosystems, and the Open Ocean;*
- *Volume 2 – Methodology for the Assessment of Transboundary Aquifers;*
- *Volume 3 – Methodology for the Assessment of Transboundary Lake Basins;*
- *Volume 4 – Methodology for the Assessment of Transboundary River Basins;*
- *Volume 5 – Methodology for the Assessment of Large Marine Ecosystems; and*
- *Volume 6 – Methodology for the Assessment of the Open Ocean.*

The volume 1 is a summary of the detailed methodologies described in volumes 2 – 6. At the back cover of the volume 1 is attached a DVD that contains electronic version of all six volumes.

CONTENTS

LIST OF ACRONYMS

AC	Assessment Consortium
AMAP	Arctic Monitoring and Assessment Programme
AoA	Assessment of Assessments
AIS	Automatic Identification Systems
AP	Assessment Partners
CAP	Coordinating Assessment Partner
CBD	Convention on Biological Diversity
CCA	Causal Chain Analysis
CERMES	Centre for Resource Management and Environmental Studies
COP	Community of Practice
CWG	Correspondence Working Group
CZCS	Coastal Zone Colour Scanner
DDT	Dichlordiphenyltrichloroethane
DEWA	Division of Early Warning and Assessment (UNEP)
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
DPSIR	Driver-Pressure-State-Impact-Response
ECC	Ecosystem Carrying Capacity
FAO	Food and Agriculture Organization of the United Nations
FiB	Fishing in Balance Index
FSP	Full Size Project
GEF	Global Environment Facility
GEO	Global Environmental Outlook
GESAMP	Group of Experts on Scientific Aspects of Marine Environmental Protection
GIWA	Global International Waters Assessment
GPA	Global Programme of Action for Protection of the Marine Environment from Land-based Sources of Pollution
HAB	Harmful Algal Bloom
HDI	Human Development Index
ICM	Integrated Coastal Management
IGBP	International Geosphere Biosphere Programme
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IWC	International Whaling Commission
LME	Large Marine Ecosystem
LOICZ	Land-Ocean Interaction in the Coastal Zone Programme
LRIT	Long-Range Identification and Tracking
MAI	Marine Activity Index
MDG	Millennium Development Goal
MA	Millennium Ecosystem Assessment
MEV	Marginal Economic Value
MPA	Marine Protected Area
MSP	Medium Size Project
MSY	Maximum Sustainable Yield
MTI	Marine Trophic Index
NEWS	Nutrient Export from Watersheds
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration (US)
OHI	Ocean Health Index
PBT	Persistent Bioaccumulating and Toxic (chemicals)
PCB	Polychlorinated Biphenyls
POPs	Persistent Organic Pollutants
PPR	Primary Production Required
RSCAPs	Regional Seas Conventions and Action Plans
RSP	Regional Seas Programme
SAHFOS	Sir Alistair Hardy Foundation for Ocean Science
SAP	Strategic Action Programme
SCOR	Scientific Committee on Ocean Research
SeaWIFS	Sea-Viewing Wide Field-of-View Sensor
SIDS	Small Island Developing States
SST	Sea Surface Temperature
TDA	Transboundary Diagnostic Analysis
TEV	Total Economic Value
TL	Trophic Levels
TWAP	Transboundary Waters Assessment Programme
UBC	University of British Columbia
UNEP	United Nations Environment Programme
UNEP-WCMC	UNEP-World Conservation Monitoring Centre
URI	University of Rhode Island
VOS	Voluntary Observing Ship Program
WCPA	World Commission on Protected Areas
WDPA	World Database on Protected Areas
WG	Working Group
WHOI	Woods Hole Oceanographic Institute
WIO-LaB	Addressing Land-Based Activities in the Western Indian Ocean
WRI	World Resources Institute
WSSD	World Summit on Sustainable Development

SUMMARY FOR DECISION MAKERS

BACKGROUND AND OBJECTIVES

The methodology for assessment of Large Marine Ecosystems (LMEs) was developed under the Global Environment Facility (GEF) medium size project (MSP) '*Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme* (TWAP)'. Large Marine Ecosystems, 64 of which have been defined globally, are natural regions of coastal ocean space encompassing waters from river basins and estuaries to the seaward boundaries of continental shelves and seaward margins of coastal currents and water masses. They are relatively large regions of 200 000 km^2 or more, the natural boundaries of which are based on four ecological criteria: bathymetry, hydrography, productivity, and trophically related populations.

The TWAP project arose out of the need for a systematic and scientifically robust methodology and institutional arrangements for assessing the changing conditions of transboundary water systems (groundwater aquifers, lakes/reservoirs, river basins, LMEs, and open ocean areas) resulting from human and natural causes. The goal of TWAP is to establish, in a follow up phase, a programme for continuous assessment of major transboundary aquatic systems. Such an assessment would allow the GEF, policy makers, and the international community to set science-based priorities for financial resource allocation and to evaluate and monitor the impacts of their interventions in international waters (IW). It is expected that the sustainability of the programme's benefits and financing would be partially addressed by its links with existing and planned regional and international research, monitoring, and assessment initiatives and programmes around the globe. Among these are GEF LME projects and the UN regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects.

The MSP was executed by the United Nations Environment Programme, Division of Early Warning and Assessment (UNEP DEWA) in Nairobi, Kenya. The Intergovernmental Oceanographic Commission (IOC) of UNESCO coordinated the LME component between September 2009 and November 2010, and established a Working Group (WG) of experts and institutional partners to develop the LME assessment methodology. Two WG meetings were held in February and June 2010. In addition, the draft methodology was presented at three external forums for feedback from participants (Twelfth Annual LME Consultative Committee Meeting, July 2010, Paris; Twelfth Global Meeting of the Regional Seas Conventions and Action Plans (RSCAPs), September 2010, Norway; and the Conference 'A Unified Approach for Sustainability in a Changing World: From Ocean Policy to Observations', October 2010, Lisbon).

The LME assessment methodology is described in this Volume 5. Further information on the TWAP project is given in the Volume 1.

SCOPE OF THE ASSESSMENT

The TWAP assessment will consist of two levels and include priority and emerging issues and hotspots, interlinkages between water systems, and cross-cutting issues (nutrients and mercury). Level 1 will be a global comparative assessment of the current state, including their role in supporting biodiversity and ecosystem services, of all LMEs (including their transboundary estuaries/deltas where these occur) and the Pacific Warm Pool, using a set of core indicators (stress, status, socio-economic and governance/response indicators) for which data are available globally. This will be a baseline assessment of current ecosystem state, trends, and stressors (drivers), with future projections and likely impacts to 2030 and 2050 where possible. The objective of the Level 2 assessment is to derive a set of indicators and assessment best practices by examining transboundary waters assessments in selected developed and developing regions (two LMEs in each type of region) where data are available. These best practices could be used by GEF as guidance for its IW projects. The LMEs for the level 2 assessment will be identified during development of the full size project (FSP), in consultation with GEF and appropriate regional partners. Depending on the availability of funds, consideration would be given to conducting a pilot project with advanced assessment of selected LMEs, in collaboration with Regional Seas programmes, based on data availability and ongoing monitoring and assessment programmes and initiatives.

CONCEPTUAL FRAMEWORK

The existing approach to the assessment and management of LMEs is based on five modules, with corresponding suites of indicators: Productivity, Fish and Fisheries, Pollution and Ecosystem Health, Socio-economics, and Governance. A central theme of TWAP is the vulnerability of ecosystems and human communities to natural and anthropogenic stressors, and impairment of ecosystem services. A conceptual framework was developed that explicitly shows the links between human vulnerability and natural and anthropogenic stressors, ecosystem services and consequences for humans (with governance as an overarching concept), so that cause and effect can be better identified. This framework also accommodates other ecosystem services in addition to fish and fisheries. Further, it incorporates the five LME modules and integrates ecological, socio-economic, and governance indicators into a unified LME assessment framework.

DATA SOURCES

The assessment will be based on existing data and information available from a large number of global and regional programmes, and, where appropriate, national sources. A summary of the major types of data and information to be used in TWAP and a list of key agencies and data sources are included in the report.

MAJOR STAKEHOLDERS AND PARTNERS

While TWAP is expected to have a large number of stakeholders, the main user of the TWAP assessment results will be the GEF. Key stakeholders will include countries involved in GEF LME projects, UN organizations such as UNEP and others with global and regional programmes dealing with assessment and management of the marine environment, Regional Seas Programmes, other relevant regional institutions and programmes, non-governmental organizations (NGO) and national governments.

Among the key institutional partners are: Food and Agriculture Organization of the United Nations (FAO), Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP), GRID-Arendal, IOC-UNESCO, International Geosphere Biosphere Programme (IGBP), Land-Ocean Interaction in the Coastal Zone Programme (LOICZ), National Center for Ecological Analysis and Synthesis (Univ. Santa Barbara, California, USA), US National Oceanic and Atmospheric Administration (NOAA), Regional Seas Programmes, UNEP, UNEP-World Conservation Monitoring Centre (UNEP-WCMC), University of British Columbia (UBC) Sea Around Us Project, University of Miami Rosenstiel School of Marine and Atmospheric Science (Division of Marine Affairs and Policy), University of Rhode Island (URI), University of the West Indies Centre for Resource Management and Environmental Studies (CERMES), and University of Dalhousie Marine Affairs Programme.

INDICATORS

For the purposes of TWAP, four categories of indicators are identified:

- Transboundary stress indicators;
- Transboundary ecosystem status indicators;
- Socio-economic indicators (include indicators of anthropogenic drivers of ecosystem change and socio-economic impacts of these changes); and
- Governance/response Indicators.

Where possible, projections of stress indicators will be made to 2030 and 2050 using available modelling approaches. Projected transboundary stress indicators include: Climate change impact on fisheries; Sea-level rise; Nutrients and freshwater discharge; Threats to coral reefs; and Human population density in coastal areas.

Core indicators

A number of indicators were proposed, from which the following sub-set of core indicators was selected:

PRODUCTIVITY	FISH & FISHERIES	POLLUTION & ECOSYSTEM HEALTH	SOCIOECONOMICS
(1) Primary productivity; (2) Chlorophyll a; (3) Sea surface temperature (SST);	(4) Reported landings; (5) Value of reported landings; (6) Marine Trophic Index (MTI) and Fishing in Balance Index (FiB); (7) Ecological Footprint of Fisheries; (8) Stock-status catch plots;	(9) Mercury; (10) Nutrients; (11) Persistent organic pollutants (PoPs) (Plastic resin pellets); (12) Shipping density; (13) Seamounts at risk; (14) Change in Protected Area coverage; (15) Change in extent of mangrove habitat; (16) Reefs at risk index; (17) Deltas at risk index;	(18) GDP fisheries; (19) % GDP international tourism; (20) Urban and rural populations living within 10 m coastal elevation; (21) Human Development Index (HDI); and (22) Deaths per 100,000 caused by climate related natural disasters.

For each indicator, the following is described: relevance, methodology and data availability, and institutions/experts involved in developing the indicator. More detailed descriptions of the indicators are provided in a separate document on the TWAP website.

Socio-economic assessment

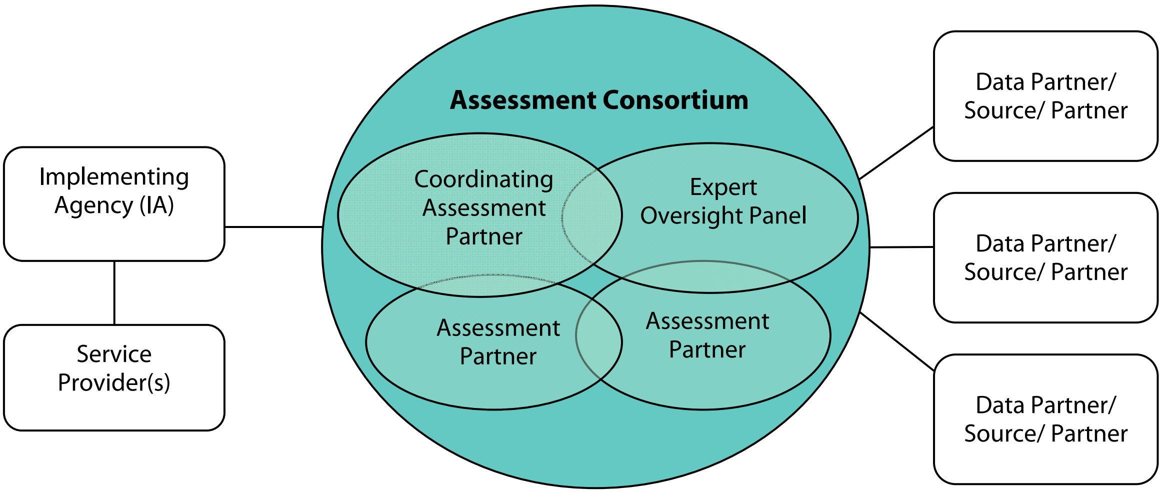
The approach to socio-economic assessment in transboundary waters was developed by the TWAP Socio-economics and Governance Correspondence Working Group (CWG), led by one of the LME experts. Using the conceptual framework, indicators to describe marine-based livelihoods, such as fishing and tourism, and the well-being of marine livelihood-dependent communities are identified at national and sub-national (geopolitical subdivisions to households) scales. Level 1 socio-economic assessment for LMEs will quantify water resource-based livelihoods in terms of GDP, as well as the vulnerability of these to climate related disasters. The core socio-economic indicators are given in the above table.

TWAP common approach to governance assessment

Development of a common approach for all five TWAP transboundary water systems was led by one of the LME WG experts and his colleagues, in collaboration with the TWAP Socio-economics and Governance CWG. The TWAP methodology will address governance assessment in two stages. Stage 1, to be conducted in the TWAP Level 1 assessment, will consist of a preliminary assessment of the extent to which a transboundary governance framework is in place to address the key issues relevant to LMEs: water quality, fisheries, biodiversity, and habitat destruction. It is expected that as the arrangements are examined, the vulnerabilities to climate change will be made explicit in each issue. The stage 1 assessment will provide: a picture of the extent to which governance issues are covered (and allow identification of gaps); the match between governance arrangements and issues; the extent to which arrangements extend outside the system; the extent to which issues are covered by multiple arrangements that could result in conflict; and how well arrangements are clustered to make best use of existing institutions and organizations. The stage 2 assessment (see Volume 1 for details) will assess the functionality and performance of governance arrangements in terms of a broad range of criteria such as effectiveness, inclusiveness, efficiency, and equitability. This methodology remains to be developed. Other approaches to governance evaluation in LMEs are described in Annex 8.

IMPLEMENTATION OF THE ASSESSMENT

TWAP will be carried out through a partnership between key institutions. A proposed institutional arrangement for the assessment of LMEs is shown in the following schematic. The LME assessment will be coordinated by IOC-UNESCO (Coordinating Assessment Partner). The expert oversight panel will be named by the partners in the TWAP LME assessment and GEF.



It is important that the assessment results are validated and accepted at regional/national levels. A mechanism will be established to engage regional and national entities throughout the assessment process, including reviewing the assessment results, to ensure credibility and acceptability at these levels. Validation of the assessment is also contingent on the acceptability of the assessment methodology itself by stakeholders. To this end, the draft LME methodology was presented at three forums for discussion. Feedback was generally positive, with some constructive criticism provided.

CAPACITY-BUILDING NEEDS

A comprehensive assessment of capacity needs will be required under the TWAP FSP. This will take into consideration the goals and the main target groups for capacity building. Areas in which capacity should be developed for TWAP purposes include:

- Integrated ecosystem-based assessment;
- Monitoring and data collection, exchange and management;
- Adaptive management;
- Modelling; and
- Capacity of project scientists, managers, practitioners and stakeholders to address national priorities and implement action plans.

ASSESSMENT TIME FRAME AND PRODUCTS

The TWAP assessment of LMEs could be conducted on average every three to five years, with the first assessment to consist of a baseline assessment. The main assessment products will include:

- Summary for decision makers with the main findings of the assessment;
- Technical report containing a Fact Sheet for each LME, assessment results and indicators, ranking of LMEs, maps, tables, etc.;
- Other products to be considered: State of transboundary estuaries/deltas report, Small Islands Developing States (SIDS) report; and
- Interactive online database and information system.

NEXT STEPS

The next steps include:

- External review of the final methodology reports;
- Identification of opportunities to promote TWAP and raise awareness;
- Identification of other potential partners for the full size project; and
- Preparation of the GEF full size project to conduct the assessment.

GENERAL INTRODUCTION

TWAP PROJECT BACKGROUND

The methodology for assessment of Large Marine Ecosystems (LMEs) was developed under the GEF MSP 'Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme (TWAP)'. The overall objective of the TWAP MSP was to develop methodologies for conducting a global assessment of transboundary groundwater aquifers, lakes/reservoirs, river basins, LMEs and open ocean areas, and to catalyse a partnership and arrangements for conducting the assessment. The MSP was executed by UNEP DEWA in Nairobi, Kenya, together with a number of partners. The IOC of UNESCO executed the LME component between September 2009 and November 2010.

The project arose out of the need for a systematic and scientifically robust methodology and institutional arrangements for assessing the changing conditions of transboundary water systems resulting from human and natural causes, which would allow the GEF, policy makers and international organizations to set science-based priorities for financial resource allocation. Such a methodology would also facilitate identification and assessment of positive changes in the environmental and resource situations in the transboundary water systems resulting from interventions by national authorities and international/regional communities. Except for a very limited number of transboundary water bodies, there is no baseline, regular global monitoring or assessment programme for transboundary waters. There is therefore a need to develop a methodology to establish the baseline as well as to track changes periodically in a subsequent FSP.

APPROACH TO DEVELOPING AN LME ASSESSMENT METHODOLOGY

A Working Group (WG) of natural and social science experts and institutional partners (Annex 1) was established and coordinated by the IOC to develop the methodology for assessment of LMEs. Two WG meetings were held, in February 2010 at IOC-UNESCO, Paris, France and in June 2010 at UNEP-GRID/Arendal, Arendal, Norway. The meeting reports are available on the TWAP website (http://twap.iwlearn.org/).

Following the first WG meeting, task teams were set up within the WG to develop particular aspects of the methodology. Background working papers were also prepared by WG experts to guide the development of the methodology (available on the TWAP website): R. Mahon and others (Governance); L. Talaue-McManus (Socio-economics); R. Klaus (Review of Transboundary Diagnostic Analyses); F. Kershaw (Marine habitats); B. Halpern (Tool for mapping of cumulative human impacts in LMEs); Z. Chen (Coastal interlinkages); K. Sherman and others (existing LME methodologies). Development of the methodology was also based on an extensive literature on LMEs. In addition to the LME WG, an Information Management and Indicators Working Group was established at the project level, as well as three CWGs with representatives from each of the five WGs (Socio-economics and Governance; Data and Information management; and Publications). See Volume 1 for further details on these groups.

The LME coordinator prepared a draft of the LME assessment methodology based on outcomes of the two meetings, written inputs from WG experts and discussions with WG members (by electronic means). The initial drafts were reviewed by the WG and other experts. In addition, the draft methodology was presented at three meetings for feedback from participants and validation:

- Twelfth Annual LME Consultative Committee Meeting, 8 – 9 July 2010 at IOC Headquarters in Paris, France;
- Twelfth Global Meeting of the Regional Seas Conventions and Action Plans, 20 – 22 September 2010, Bergen, Norway; and
- Conference: 'A Unified Approach for Sustainability in a Changing World: From Ocean Policy to Observations', held in Lisbon on 7 – 8 October 2010 and sponsored by Luso-American Foundation, NOAA, IOC-UNESCO, and ISPA University Institute.

The draft was revised to produce the final LME assessment methodology report based on the expert review and feedback from the three external meetings. It should be mentioned that there was some disagreement by certain WG experts on a number of proposed new aspects of the methodology. This was addressed through consensus among the majority of the WG members and guidance from the GEF and the TWAP project secretariat.

PART 1. CONCEPTUAL FRAMEWORK

1.1 OBJECTIVE

The overall objective of the TWAP MSP was to develop the methodologies for conducting a global assessment of transboundary groundwater, lake/reservoir and river basins, LMEs, and open ocean areas for GEF purposes, and to catalyse a partnership and institutional arrangements for conducting such a global assessment. This assessment will help GEF in setting priorities for its resource allocation based on an understanding of baseline environmental and water resource conditions and tracking the longer-term relative results of its interventions. In this manner, GEF can make more effective use of its resources for addressing higher priority transboundary systems and can report the impact of the use of its funding.

The expected outputs of the MSP were:

- Feasible, ecosystem-based methodologies for a global assessment of the five transboundary water systems categories; and
- Recommendations for partnerships and institutional arrangements among agencies and organizations to conduct the global assessment.

The ultimate goal of TWAP is to establish, in a follow-up phase, a programme for continuous assessment of major transboundary aquatic systems and to provide a platform for the international community to evaluate and monitor the impacts of interventions in international waters. The sustainability of the programme's benefits and financing will be partially addressed by its links with existing and planned regional and international research, monitoring, and assessment initiatives and programmes around the globe.

1.2 SCOPE

The scope of the MSP is to develop the methodologies for assessment of transboundary water systems based on existing data/information and approaches, and to propose an appropriate partnership and institutional arrangement for conduct of the assessment. The methodology consists of a number of major elements and approaches for two levels of assessment as described below. These are common to all five transboundary water categories.

i. **Conceptual framework**: A conceptual framework for the assessment that incorporates interlinkages between transboundary water systems, human vulnerability, and impairment of ecosystem services.

ii. **Indicators**: Indicators, which should be SMART[1], include *transboundary environmental state, stress (pressure), socio-economic and governance/response indicators*, with overarching impairment of *ecosystems goods and services*. Data and information for the indicators should be available from other organizations and existing programmes and databases.

iii. **Priority and emerging issues and hotspots**: The *priority current transboundary* and *emerging issues* should be identified and criteria proposed for identification of *hotspots with transboundary significance*.

[1] Specific, Measurable, Achievable, Relevant, and Timely

iv. **Interlinkages between water systems**: Interlinkages between the five transboundary water systems are crucial for the assessment. The interlinkage concept should incorporate the hydrological, geo-chemical, ecological, governance, and socio-economic interlinkages between the water bodies. Interlinkages could also be captured by an appropriate assessment conceptual framework. The focus should be on the *major transboundary concerns*, and could be described by simple *input/output analysis* and key indicators.

v. **Cross-cutting issues**: Issues that should be addressed by all groups where possible, as they are highly relevant to all five transboundary water systems, with likely transfer of stressors/impacts between water systems. Nutrients and mercury have been identified as cross-cutting issues to be addressed.

The TWAP assessment will be conducted at two levels:

Level 1

Level 1 will consist of a global comparative assessment of all 64 LMEs (including their transboundary estuaries/deltas where these occur) and the Pacific Warm Pool, using a set of core indicators for which data are available globally. This will be a baseline assessment of current ecosystem state, trends, and stressors (drivers), with projections and likely impacts to 2030 and 2050 where possible. This will help to identify LMEs in need of immediate attention and provide a baseline for subsequent assessments to help GEF and others track incremental changes to determine whether the conditions of the LMEs and associated coastal areas are improving or declining.

The Level 1 assessment will involve:

- A global comparative assessment of the current state, including for supporting biodiversity and ecosystem services, of all 64 LMEs and the Pacific Warm Pool, using a suite of specific core indicators - transboundary stress indicators, transboundary status indicators, socio-economic indicators, and governance/response indicators;
- Projections of the major transboundary stress indicators to 2030 and 2050 where possible;
- Combining multiple indicators for the individual LMEs to provide relative ranking of the status for each LME to differentiate those at greatest risk of degradation. An overall index of LME health is not readily available and needs to be developed (during the FSP); and
- Assessment of the status of major habitats of transboundary importance such as coral reefs and deltas, with the development of appropriate indices such as 'Reefs at risk index' and 'Deltas at risk index', and identification of hotspots.

Other indicators and metrics that are considered as important 'descriptors' would be included in a fact sheet for each LME. Supplementary LME-specific information and data that complement the core indicators by pointing at particular issues of concern for the LME and that help in interpreting the indicators in a broader LME context will be included in the fact sheets.

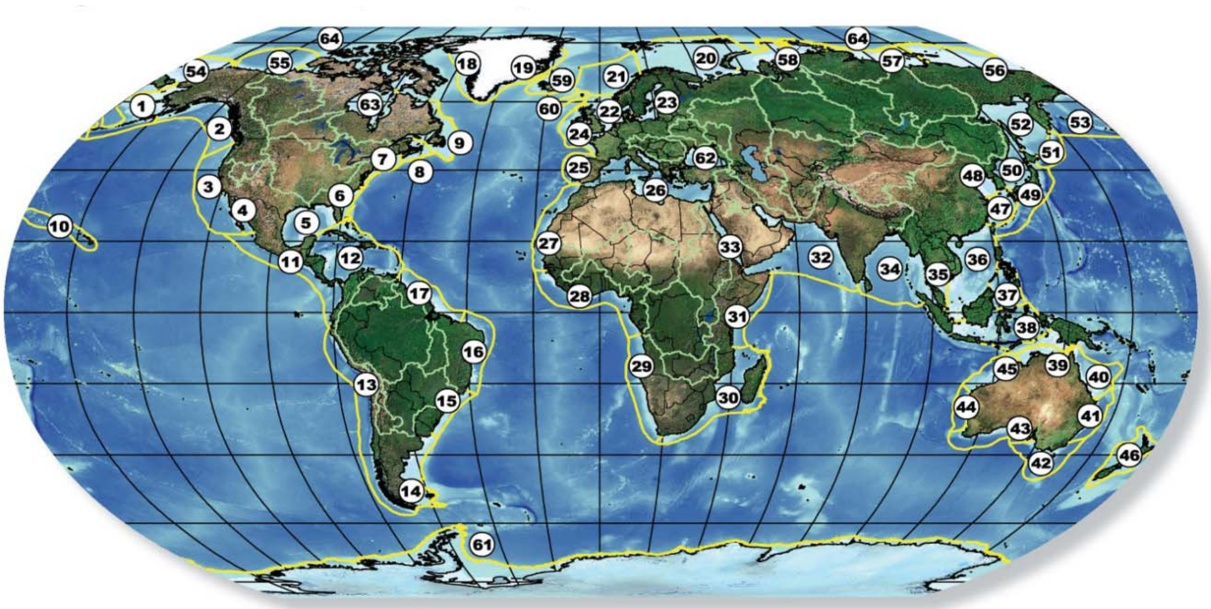
Level 2

The objective of the Level 2 assessment is to derive a set of indicators and assessment best practices by examining transboundary waters assessments in selected developed and developing regions (2 LMEs in each type of region) where data are available. These best practices could be used by GEF as guidance for its IW projects. Level 2 will be conducted as case studies by an experts group(s) and will also take into consideration completed transboundary diagnostic analyses (TDAs) and interlinkages between different transboundary water systems. The LMEs for the level 2 assessment will be identified during development of the full size project, in consultation with GEF and appropriate regional partners. Depending on the availability of funds, consideration would be given to conducting a pilot project with advanced assessment of selected LME(s), in collaboration with the Regional Seas programmes and other regional partners, based on data availability and ongoing monitoring and assessment programmes.

1.3 FRAMEWORK

Large Marine Ecosystems

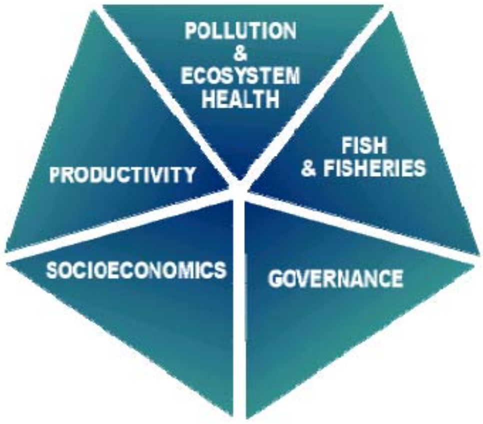
Large marine ecosystems are natural regions of coastal ocean space encompassing waters from river basins and estuaries to the seaward boundaries of continental shelves and seaward margins of coastal currents and water masses (Fig. 1). They are relatively large regions of 200,000 km^2 or more, the natural boundaries of which are based on four ecological criteria: bathymetry, hydrography, productivity, and trophically-related populations (Sherman, 1994; Duda and Sherman, 2002).



1 East Bering Sea
2 Gulf of Alaska
3 California Current
4 Gulf of California
5 Gulf of Mexico
6 Southeast U.S. Continental Shelf
7 Northeast U.S. Continental Shelf
8 Scotian Shelf
9 Newfoundland-Labrador Shelf
10 Insular Pacific-Hawaiian
11 Pacific Central-American Coastal
12 Caribbean Sea
13 Humboldt Current
14 Patagonian Shelf
15 South Brazil Shelf
16 East Brazil Shelf
17 North Brazil Shelf
18 West Greenland Shelf
19 East Greenland Shelf
20 Barents Sea
21 Norwegian Shelf
22 North Sea
23 Baltic Sea
24 Celtic-Biscay Shelf
25 Iberian Coastal
26 Mediterranean Sea
27 Canary Current
28 Guinea Current
29 Benguela Current
30 Agulhas Current
31 Somali Coastal Current
32 Arabian Sea
33 Red Sea
34 Bay of Bengal
35 Gulf of Thailand
36 South China Sea
37 Sulu-Celebes Sea
38 Indonesian Sea
39 North Australian Shelf
40 Northeast Australian Shelf-Great Barrier Reef
41 East-Central Australian Shelf
42 Southeast Australian Shelf
43 Southwest Australian Shelf
44 West-Central Australian Shelf
45 Northwest Australian Shelf
46 New Zealand Shelf
47 East China Sea
48 Yellow Sea
49 Kuroshio Current
50 Sea of Japan
51 Oyashio Current
52 Okhotsk Sea
53 West Bering Sea
54 Chukchi Sea
55 Beaufort Sea
56 East Siberian Sea
57 Laptev Sea
58 Kara Sea
59 Iceland Shelf
60 Faroe Plateau
61 Antarctic
62 Black Sea
63 Hudson Bay
64 Arctic Ocean

Figure 1. Map of the world's 64 Large Marine Ecosystems and their linked watersheds. (Source: Sherman and Hempel, 2008)

The existing LME approach to the assessment and management of marine resources is based on five modules, with corresponding suites of indicators for monitoring and assessing changing conditions in marine ecosystems: Productivity, Fish and Fisheries, Pollution and Ecosystem Health, Socio-economics, and Governance (see the following schematic). The application of these modules to the assessment and management of marine resources has been the focus of the NOAA LME Programme since its inception. The first four modules are intended to support the TDA process while the Governance module is associated with the SAP, which sets out reforms and interventions needed for sustainable management of the LME.



Modular approach for assessment and management of LMEs (Source: Sherman and Hempel, 2008)

Productivity

Productivity relates to both phytoplankton and zooplankton. Primary productivity is pertinent to the carrying capacity of an ecosystem for supporting fish resources (Pauly and Christensen, 1995) as well as to the problem of coastal eutrophication. The ecosystem parameters measured and used as indicators of changing conditions in the productivity module include zooplankton biomass, water-column structure, photo-synthetically active radiation, chlorophyll a, and primary production.

Fish and fisheries

Fish populations are important in the trophic transfer of energy within LMEs and in providing an important ecosystem service in the form of fish catch. LMEs produce 80per cent of the world's annual marine fisheries catch, providing a significant source of food, livelihoods, employment, and foreign exchange to bordering countries. Achievement of the Millennium Development Goal (MDG) to eradicate hunger will be partly dependent on the capacity of marine ecosystems to supply animal protein to the populations of most developing countries. Overexploitation is a widespread problem, and most severe within LMEs. Changes in biodiversity and species dominance within fish communities of LMEs have resulted from pressures such as excessive exploitation, naturally-occurring environmental shifts caused by climate change, and coastal pollution. Ongoing GEF LME projects are attempting to reverse overfishing and restore depleted fish stocks.

Pollution and ecosystem health

Included in this module are pollution (marine and land-based) as well as marine habitats and biodiversity. Pollution and degradation of habitats resulting from human activities are of major concern in many LMEs. Pollution is often transboundary as hydrological interlinkages between river basins, marine ecosystems, and the atmosphere often result in effects far from the source of the emissions. The risk of transboundary impacts tends to be highest for POPs, and particularly substances that readily migrate between water and air (such as Dichlordiphenyltrichloroethane (DDT) and mercury). In many coastal areas, pollution and eutrophication have been important driving forces of change in biomass yields. Marine habitats provide a broad range of ecosystem services with direct and indirect benefits to humans. In the light of human population growth, coastal habitats are increasingly under threat from a range of stressors including overfishing, pollution, invasive species, nutrient over-enrichment, and climate variability.

Socio-economics

The economic value of an LME can be considered as equivalent to the net present value of the goods and services it provides. Costanza, *et al*. (1997) estimated that the coastal waters encompassing LMEs annually contribute US$12.6 trillion to the global economy. Although this estimate is more than ten years old and does not reflect the benefits or costs of marginal changes in marine ecosystem goods and services, it highlights the critical importance of LMEs to the world's economies. The socio-economic module emphasizes the practical application of scientific findings to managing LMEs and the explicit integration of social and economic indicators and analyses with all other scientific assessments to ensure that prospective management measures are efficient. In order to respond adaptively to enhanced scientific information, socio-economic considerations should be closely integrated with science.

Governance

The LME Governance Module engages multiple scales of national, regional, and local jurisdictional frameworks needed to select and support ecosystem-based management practices leading to the sustainable use of resources. Through GEF LME projects, countries are moving towards joint governance arrangements to address the priority transboundary issues identified in the LMEs they share. The process used to make determinations on priority issues relating to governance include the joint preparation by participating countries of TDAs to prioritize issues, and Strategic Action Programmes (SAPs) to resolve issues within the framework of a governance mechanism. The SAPs serve as agreed documents guiding the implementation of actions identified and prioritized in the TDAs for ensuring maintenance of robust productivity, recovery of depleted fisheries, conservation of biodiversity, restoration of degraded coastal habitats, reduction and control of pollution and nutrient over-enrichment, and actions to mitigate and adapt to climate change. The actions are taken under the framework of the SAP to optimize the socio-economic benefits obtained from LME goods and services.

1.4 VULNERABILITY

A central theme of TWAP is the vulnerability of ecosystems and human communities to natural and anthropogenic stressors, and impairment of ecosystem services. All four categories of ecosystem services[2] identified by the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment, 2003) are provided by LMEs, with food provisioning in the form of fish catch and cultural services that support lucrative tourism activities being among the most valuable. Some ecosystems, such as coral reefs, are particularly vulnerable to external perturbations and are increasingly being subjected to a range of stressors, with potentially serious consequences for the services they provide. In turn, coastal human communities around the world are vulnerable to changes in ecosystem services because of their heavy dependence on these services for their survival and well-being. This is of particular concern in poor communities that have few alternatives for food security and livelihoods in the face of declining living marine resources.

Further, human communities are increasingly being exposed to the impacts of global climate change through the associated increase in frequency and intensity of extreme weather events (such as storms

[2] **Provisioning services**: The products obtained from ecosystems, such as food, fuel, fibre, fresh water, and genetic resources.

Regulating services: The benefits obtained from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, water purification, and protection from extreme events such as storms and tidal surges.

Cultural services: The non-material benefits obtained from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences.

Supporting services: Services that are necessary for the production of all other ecosystem services, such as primary production and production of oxygen.

and droughts). In coastal areas this vulnerability increases when the protective function of coastal habitats such as coral reefs and mangroves is lost. Humans can also be directly affected by contaminants in the marine environment, through direct physical contact and consumption of contaminated marine products. Assessing social well-being and vulnerabilities in addition to economic well-being provides a more complete picture of human-environment interactions. This concept underpins the approach to socio-economic assessment developed as part of the methodology.

The vulnerability of ecosystems to external stressors and of humans to ecological and environmental changes is captured in the following conceptual framework.

1.5 CONCEPTUAL FRAMEWORK

At the first TWAP LME meeting in February 2010, most members of the WG felt that a conceptual framework was required that more explicitly showed the links between human vulnerability and natural and anthropogenic stressors, ecosystem services and consequences for humans (with governance as an overarching concept), so that cause and effect could be better identified, and ecosystem services other than only fish and fisheries could be accommodated. Such a framework would also incorporate the five LME modules and integrate ecological, socio-economic, and governance indicators into a unified LME assessment.

A conceptual framework was subsequently developed (Fig. 2), which is centred on the vulnerability of both natural systems to external pressures and consequences for the sustainable production of ecosystem services, and humans to ecological changes.

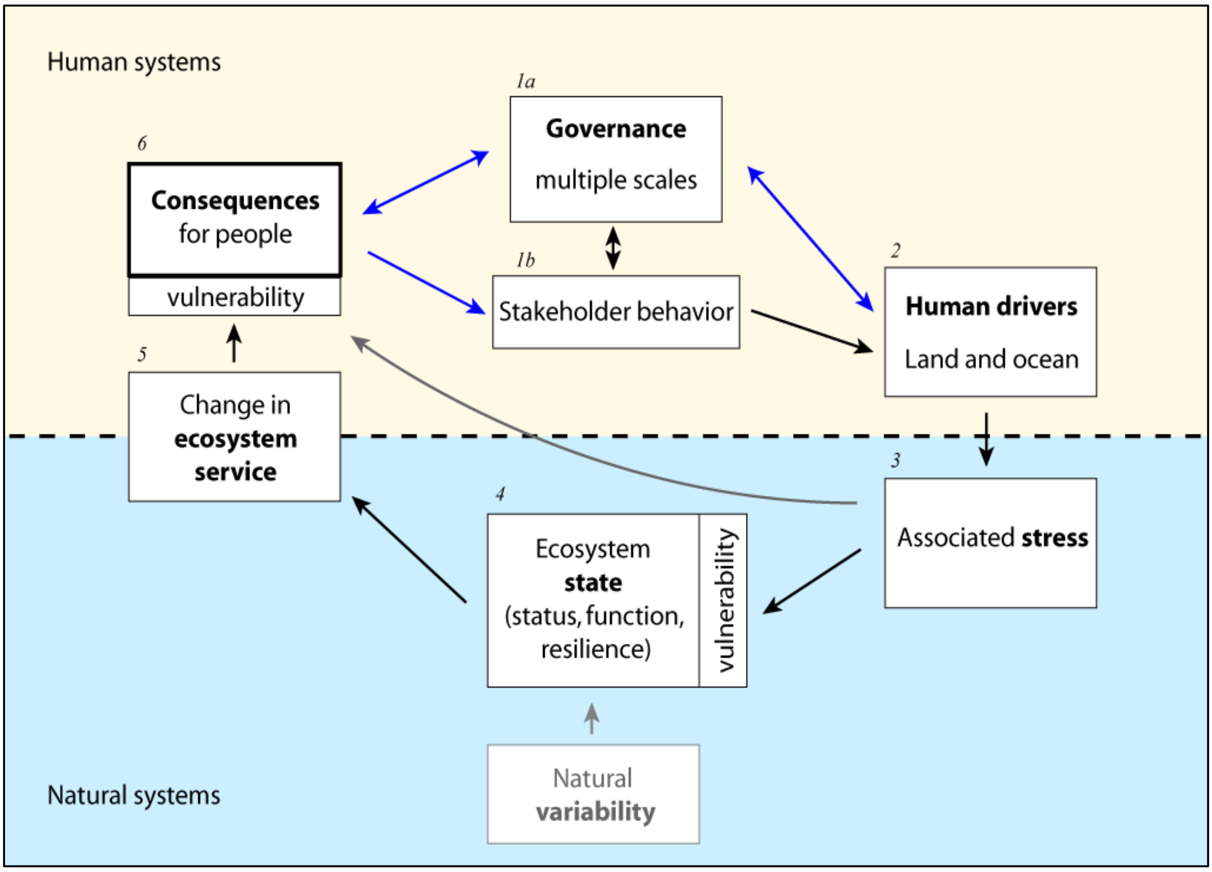


Figure 2. Overarching conceptual framework

The top part of the diagram represents the human system and the bottom the natural system. The framework tries to merge several existing conceptual frameworks: the Driver-Pressure-State-Impact-Response (DPSIR) framework, indicator science, an emerging focus on ecosystem services, and cumulative impact modelling, all with a strong focus on governance and socio-economics - on how to manage the human-natural system interaction.

The conceptual framework (which has also been adopted by the TWAP Open Ocean component) is meant to reflect the relationship between human and natural systems and helps to identify why particular indicators are proposed and their relevance. The framework focuses on the idea of 'causal chains', which is consistent with causal chain analysis (CCA) conducted in GEF LME projects. In brief, human activities have associated stressors that in turn impact natural systems and this in turn affects the delivery (and value) of ecosystem services to people (starting in box 1 below and going clockwise). Ultimately we want to know how people are affected (box 6 in bold), but developing indicators for these ultimate responses may not be easy and may require much time, so there is value in having rapid ‘early indicator’ metrics.

On the human system side, all the interactions between boxes are strongly mediated by socio-economic factors. Governance is defined broadly as including government, markets, and civil society, operating at global, regional, national, and local scales. Governance factors influence each other across scales, including through to personal behaviour, and determine, for example, which people benefit from the delivery of ecosystem services (i.e. equity) and what kinds of activities people engage in (e.g. regulations, social norms). One could reasonably and conceivably have indicators for any of these boxes, but the ideal indicators would connect directly to ‘Consequence for people’ (box 6).

Effective governance is fundamental to achieving healthy ecosystems (inclusive of people), and in this context, should focus on sustaining ecosystem services (box 5) in addition to other politically-negotiated goals. Governance affects what activities people pursue and with what intensity, and if or how value derived from natural systems reaches human communities and is or is not distributed equitably among community members.

On the natural system side, the framework concentrates on human activities (box 2, which can come from both sea-based activities like fishing and land-based activities like agriculture and nutrient inputs), associated stresses (box 3), how they affect the state of the ecosystem under consideration (box 4, modulated by ecosystem vulnerability), which may lead to changes in the ecosystem services (box 5, for example, fish catch). Finally, crossing the natural-human system boundary, the changes can lead to consequences for people, buffered or exacerbated by their vulnerability (surrounding box 6). Natural variability, whether a regular seasonal change or more complex nonlinear interaction within the natural system, will need to be evaluated separately from the interaction with the human system, so that the impact of a change in the human system - through a change in governance or a particular GEF intervention - can be separately identified. It is also important to characterize natural variability in order to understand which ecosystem state changes require or can be subjected to management.

There are a few additional pathways depicted that are peripheral to this central framework, but should also be mentioned. Depending on the problem being examined, an associated stress may have a direct consequence for people without being mediated through an ecosystem service (arrow connecting box 3 to box 6 directly), such as in the case of human-induced sea-level rise and its direct physical impact in displacing coastal human populations.

While this conceptual framework identifies the protection of ecosystem services as the main pathway to mitigate consequences for people, under some other internationally-recognized value systems for management (protection of biodiversity, endangered species, natural heritage sites), the goal of management is not focused on sustaining ecosystem services but on directly conserving ecosystem state. In systems where thresholds might exist but uncertainty is high, and where future benefits are unknown, such a conservative approach has been politically negotiated.

The way that indicator science fits into this framework is through the need to select indicators that actually reflect what we care about. We ultimately care about human well-being, so long-term indicators should focus on this box. But all the preceding boxes can give us insights into likely outcomes for people, and often respond on much shorter time frames. We should therefore clearly articulate our management goals and the reasons for wanting to track particular information, and then design indicators that meet those goals. For example, we might want to track the amount of area set aside in Marine Protected Areas (MPAs), the human activity of protection, because it gives us an easy-to-measure indicator of changes in stressors (fishing pressure) that we assume improves the status of ecosystems (which is much harder to measure), and this has been shown to provide benefits to humans. The indicator is indirectly connected to the element we care about (benefit to people) through a number of assumptions. Making clear all these assumptions and how directly or indirectly an indicator connects to our ultimate goal is critical so that we can get a sense of the amount of uncertainty in how our indicator tracks what we ultimately care about, and clearly articulate exactly what the indicator is tracking within the broader framework.

The framework allows and is useful for assessing the potential consequences of different management scenarios within a context of changing human activities and associated stressors (through the addition of new stressors and the changing intensity of existing stressors). A given management decision (or change in the intensity of a stressor due to other reasons) will lead to a changing pattern of human activities and stressor intensities, which will in turn alter the attributes of the following boxes in the framework. These changes can be predicted, and then monitored to test the validity of the predictions.

There is an implicit temporal component to this framework, in that it takes time to move from box to box, and this time will vary depending on the human activity and ecosystem service that are of interest. For political and practical reasons, GEF may need to focus primarily on attributes within this framework that respond more quickly, but it is important to keep the longer timeframe and relevant consequences in mind.

Within the context of the TWAP assessment, indicators for all elements of the human and natural systems cannot be developed - as the systems and their interrelationships on different time and space scales are complex. But the framework allows some clarity in TWAP on where data is available to assess or capture in an indicator/descriptor, and what assumptions have to be made to link that indicator with its ultimate consequences. In the context of a future GEF intervention, the full framework could be useful in deciding the main points of intervention in the human system to help manage a positive outcome via the environment (the natural system). Some of these assumptions and scenarios will have to be scientifically tested and validated.

1.6 CONTRIBUTION TO EXISTING GLOBAL ASSESSMENTS

The TWAP methodology has direct relevance for ongoing and developing assessment efforts, some of which are briefly described below.

GEF LME projects

While not considered as global assessments, GEF LME projects are conducted throughout the world and are expected to make a significant contribution to TWAP and in turn to benefit from TWAP methodology and assessments. In fact, these projects will be among the key TWAP partners. Since 1995, the GEF has provided substantial funding (currently about US$3.1 billion) to support country-driven projects for introducing multi-sector, ecosystem-based assessment and management practices for LMEs to recover depleted fish stocks, reduce coastal pollution, restore damaged habitats, and adapt to climate change. At present, 110 developing countries and 16 industrialized countries are partners in 17 GEF LME projects. In most of these projects, the overarching strategic framework for developing the TDAs and SAPs is guided by the geographic area of the LMEs and the application of the five modules.

In 2008, the first global assessment of changing conditions in LMEs was published (Sherman and Hempel, 2008). This report originated from the results of the Global International Waters Assessment (GIWA) for GIWA sub-regions that coincided with LMEs, and was subsequently expanded to include other data and information.

The UN Regular Process

At the 2002 World Summit on Sustainable Development (WSSD), States agreed in the Johannesburg Plan of Implementation to 'establish by 2004 a regular process under the UN for global reporting and assessment of the state of the marine environment, including socio-economic aspects, both current and foreseeable, building on existing regional assessments' (the 'Regular Process'). In November 2005, the UN General Assembly launched the start-up phase of the Regular Process, called the 'Assessment of Assessments' (AoA), which was led by UNEP and IOC. The modalities for the implementation of the Regular Process are being developed. There is scope for development of valuable synergies in designing TWAP methodologies for the marine transboundary systems in such way that it contributes to the Regular Process. It is expected that close links will be established between TWAP LMEs and Open Ocean components and the Regular Process (http://www.un.org/Depts/los/global_reporting/global_reporting.htm).

UNEP Global Environment Outlook

The UNEP Global Environmental Outlook (GEO) is UNEP's global assessment process on the state of the environment that provides a link between science and policy. The UNEP GEO has a world-wide network of Collaborating Centres and experts that provide input to the assessment. In addition, an online GEO data portal has been developed, and is regularly updated (http://www.grid.unep.ch/data/geodataportal.php. One of the thematic areas of GEO is 'water', which includes status and trends in both marine and freshwaters and their ecosystem services. The TWAP assessment could benefit from the GEO data and knowledge base. The outcome of the TWAP assessment can also be used in the GEO assessment of aquatic ecosystems and the services they provide. The indicator maps, ranking basin status, could be of particular interest to GEO.

Regional Seas Programmes

The Regional Seas Programme (RSP) covers 18 world regions, making it one of the most globally comprehensive initiatives for the protection of marine and coastal environments (http://www.unep.org/regionalseas/default.asp). Currently there are six UNEP-administered RSPs, seven non-UNEP administered RSPs and five independent RSPs. The RSP, an alliance between RSCAPs, constitutes a unique approach to the protection of the coastal and marine environment, mandated by the Governing bodies of the individual RSCAPs. The RSP is UNEP's central mechanism for the implementation of activities relevant to Chapter 17 of Agenda 21 referring to the 'Protection of the Oceans and Seas'. The RSP also provides an important platform for co-ordinated regional implementation of many of the governance outcomes and SAP activities of GEF under LME projects, as well as the Global Programme of Action for Protection of the Marine Environment from land-based sources of pollution (GPA), among other global initiatives, programmes and Multilateral Environment Agreements. The RSP fosters regional cooperation in the marine and coastal environment, which it accomplishes by stimulating the creation of 'Action Plans' for each region. These include a series of regional Conventions - unique legal instruments designed to protect shared environmental interests.

Global International Waters Assessment

The Global International Waters Assessment (GIWA) was a worldwide assessment executed in 66 sub-regions, 46 of which included LMEs (http://www.unep.org/dewa/giwa). The project was funded by the GEF and other major donors, and implemented by UNEP. The overall objective of GIWA was to develop a comprehensive strategic assessment of the environmental conditions and problems in international waters (marine, coastal and freshwater areas, and surface waters as well as groundwaters) that may be used by GEF and its partners to identify priorities for remedial and mitigatory actions in international waters. GIWA focused on five major problem areas (freshwater shortage, pollution, overfishing and habitat modification, and global change), which included 23 specific environmental and socio-economic issues. A methodology was developed for the GIWA assessment and included causal chain analysis to identify and better understand the links between perceived problems and their societal root causes. The GIWA methodology and reports will be valuable for the TWAP LME methodology and global assessment.

Others

A large number of other global and regional programmes and initiatives exist that are relevant to TWAP (see the UN Regular Process Global and Regional Marine Assessment Database at http://www.unep-wcmc.org/GRAMED).

PART 2. INVENTORY AND CHARACTERIZATION OF LARGE MARINE ECOSYSTEMS

2.1 ASSESSMENT UNITS AND BOUNDARIES

The major assessment unit for the TWAP LMEs component will be the LME, 64 of which have been designated in the coastal areas around the margins of the Atlantic, Pacific, and Indian Oceans (Fig. 1). For TWAP purposes, coastal areas such as deltas and estuaries will be included within LMEs, and not in the transboundary rivers component. In addition to the 64 LMEs, the TWAP assessment will also include the Western Pacific Warm Pool, which contains many islands states with extensive Exclusive Economic Zones.

Sub-LME scale

Smaller assessment units within LMEs will also be considered. These will include SIDS, particular habitats and transboundary hotspots (e.g., coral reefs, mangroves, seamounts, deltas and estuaries), which can be assessed and reported by LMEs as well as across LMEs. Transboundary hotspots will be identified during the FSP.

The need to develop smaller assessment units within the boundaries of LMEs has been acknowledged, in order to better capture the diversity of habitats, support an ecosystem-based approach to marine management, and facilitate the assessment of domestic and transboundary issues. To apply an ecosystem-based approach, planning units based on natural regions must be defined on a range of hierarchically-nested scales, depending on the purposes. In this regard, classification and mapping of benthic habitats has been identified as a gap which needs to be addressed.

2.2 INVENTORY OF AGENCIES, PROGRAMMES, DATASETS AND SOURCES

A summary of the major types of data and information to be used in TWAP and a list of major agencies and data sources is given in Annexes 2 and 3. A large number of other global and regional programmes and data sources exist that could potentially contribute to TWAP. These are presented in the UN Regular Process Global and Regional Marine Assessment Database (http://www.unep-wcmc.org/GRAMED/). In addition, national datasets will be invaluable for TWAP, and should be used where available and as appropriate.

2.3 IDENTIFICATION OF MAJOR STAKEHOLDERS AND PARTNERS

While TWAP is expected to have a large number of stakeholders, the main user of the TWAP assessment results will be the GEF. Among other key stakeholders will be countries involved in GEF LME projects, UN organizations such as UNEP and others with global and regional programmes dealing with assessment and management of the marine environment, Regional Seas Programmes, other relevant regional institutions and programmes as well as NGO and national governments. Many of these stakeholders will benefit from the assessment results and from the availability of data and information for indicators of interest to their respective situations.

Potential TWAP partners have been selected on the basis of the following criteria:

- Those already maintaining, or with access to, databases with global coverage for one or more indicators;
- Those with expertise, and/or strong networks, relevant to one or more indicators; and
- Those with expertise in transboundary waters, natural resource indicators and assessments.

Other partners could be added as the FSP is developed and as the needs or opportunities arise.

Some of the stakeholders will themselves be among the key partners in that they will also play a role in the assessment, for example by contributing data. A list of proposed key partners and their respective roles in the TWAP assessment is given in Table 1. This list is based on the indicators and approaches included in the current methodology, and could be subject to change depending on the final indicators and approaches selected for the FSP. A number of these partners have been involved in the development of the LME assessment methodology under the MSP (indicated by *). It should be noted that each of these partners will be working in collaboration with their own partners and data providers. Among the major partners in the TWAP assessment will be the Regional Seas Programmes, particularly with respect to implementing the assessment and providing data and information through their respective monitoring programmes as well as helping to engage countries in TWAP.

Table 1. Proposed key partners and their respective roles in TWAP. (* Involved in TWAP MSP to develop the LME assessment methodology)

PARTNERS	PROJECT COMPONENT AND METHODOLOGY	EXISTING DATASETS, PROGRAMMES AND METHODOLOGIES	ROLE IN FSP	CONTACT PERSON
*IOC-UNESCO	Coordination; all components	Relevant expertise, programmes and databases; Global Ocean Observing System (GOOS), International Oceanographic Data and Information Exchange (IODE), HABs programmes, UN Regular Process, etc.	Implementation, Coordination of LME component	J. Barbiere
*UNEP	All components	Relevant expertise, programmes and databases; Regional Seas Programmes, UN Regular process, etc.	Advisory and oversight	J. Alder; S.Diop
Regional Seas Programmes	All components, pilot projects	Expertise, data and information	Pilot projects, engaging countries, data provider	J. Alder
GEF LME projects	All components, pilot projects	Data and information, including TDAs	Data provider, implementation, engaging of countries	GEF Sec; project coordinating units
*NOAA; University of Rhode Island (URI)	Satellite remote sensing, primary productivity	Mean annual values for chlorophyll-a and primary productivity; available for all 64 LMEs. Published in Sherman and Hempel (2008).	Update data for all 64 LMEs to 2010.	K. Sherman
URI Graduate School of Oceanography	Physical Oceanography: Fronts and Temperature	Completed SST gradients, anomalies and front locations for all 64 LMEs. Published in Sherman and Hempel (2008).	Update data for SSTs and fronts, all 64 LMEs, to 2010.	I. Belkin
*University of British Columbia (UBC), Sea Around Us Project	Fisheries assessments in LMEs	For all 64 LMEs: (i) time-series, reported landings by species by LME, 12 categories of fish; (ii) value of reported landings by major commercial groups, per LME; (iii) amount of primary production required to sustain fisheries within LMEs; (iv) the marine trophic index and the FiB index, by LME; and (v) stock-status plots, by LME. Published in Sherman and Hempel (2008).	Validate the time-series, trends and data already produced and update data for all LMEs to 2010; Development of Deltas at Risk Index	V. Christensen

PARTNERS	PROJECT COMPONENT AND METHODOLOGY	EXISTING DATASETS, PROGRAMMES AND METHODOLOGIES	ROLE IN FSP	CONTACT PERSON
	Fisheries ecosystem modelling	Indicator approach. *Ecopath with Ecosim* to determine LME carrying capacity. Spatial and temporal databases, including FishBase, SeaLifeBase, and other database developed by the *Sea Around Us* project. The models are formulated using the Ecopath/ Ecosim modelling approach and software. Models are first-generation database-driven ecosystem models. Summary of information on fisheries catch and value in the LMEs. Results published in IOC technical report 80.	Further the model development and validation with more time-series trend information, and data on spatial fishing effort. GEF/LME projects can enrich the models through addition of more local and regional data.	
	Fisheries Economics and Fishing Effort in LMEs	UBC Fisheries Center has already published a catch, price, and small scale fisheries database. Economic valuation during climate change completed for all LMEs of Mexico.	Develop cost of fishing and fishing effort databases by LME, a first version of a database of economic multipliers, as well as ECOST, ecological and socio-economic models that are being developed as part of the Ecopath with Ecosim modelling framework. Evaluate LME carrying capacity/MSY, cost of fishing/fishing effort for LMEs.	
FAO	Fish and fisheries	Databases on fish catches, socio-economics, etc; Ecosystem approach to fisheries; State of World Fisheries and Aquaculture; Forest Assessment (mangroves)	Contribute to fisheries and habitat assessment	K. Cochrane
*UNEP-WCMC	Habitats: coral reefs, seagrass beds, mangroves, seamounts, etc. Deltas at Risk Index	Extensive experience in handling, developing and managing spatial databases. Databases compiled from various sources of information; World Atlas of seagrass, mangroves. 'Bottom-up' individual habitat mapping/delineation approaches, through a range of methodological approaches, including predictive and observation-based approaches.	Extent of critical habitats (seagrasses, mangroves, coral reefs, seamounts, saltmarsh, etc) within LMEs; Habitat classification and mapping. Development of Deltas at Risk Index.	L. Wood

PARTNERS	PROJECT COMPONENT AND METHODOLOGY	EXISTING DATASETS, PROGRAMMES AND METHODOLOGIES	ROLE IN FSP	CONTACT PERSON
*GRID-Arendal	Habitat classification and mapping; Data management/GIS	Extensive experience in handling, developing and managing spatial databases. 'Top-down' hierarchical classification approaches, typically through modelling based on surrogate data such as biophysical data.	Data and information management; habitat classification and mapping; communication and publication.	J. Fabres
*International Geosphere Biosphere Programme (IGBP)	Nutrient over-enrichment methodology and baseline	(i) Nutrient Export from Watersheds (NEWS) model for assessing levels of nitrogen, phosphate and acidification. (ii) NEWS model for assessing change in DIN yields from watersheds between 2000 and 2030, using two scenarios (Global orchestration & Adapting Mosaic)	Mean annual values, 1970-2010. Model for hindcasting and forecasting nutrient loadings in the world's LMEs. NEWS model forecast to 2050 for nitrogen, phosphate, and acidification. Development of Deltas at Risk Index.	S. Seitzinger
*National Center for Ecological Analysis and Synthesis, Univ. Santa Barbara, CA, USA	Mapping of cumulative human impacts on marine ecosystems; Deltas at Risk Index	Methodology developed for mapping of cumulative human impacts on marine ecosystems	Cumulative human impact mapping in LMEs; Development of Deltas at Risk Index.	B. Halpern
*LOICZ/IGBP	Land-ocean interaction, Deltas at Risk Index	Extensive experience and data and information on land-ocean interaction in coastal areas	Contribute to link assessment; Development of Deltas at Risk Index.	H. Kremer
*GESAMP	Pollution	Expertise, data and information for assessment of marine pollution. WG established in 2006 proposes to address issues relating to management of methyl mercury.	Conduct marine pollution assessment.	M. Huber; T. Bowmer
* Division of Marine Affairs and Policy, University of Miami Rosenstiel School of Marine and Atmospheric Science	Socio-economics	Methodology developed under TWAP MSP for socio-economic assessment in all five transboundary water systems, in collaboration with the TWAP Socio-economics and Governance CWG.	Conduct Level 1 socio-economic assessment (quantify water resource-based livelihoods in terms of GDP, as well as vulnerability of these to climate-related disasters; measure levels of human well-being and its vulnerability to climate-related disasters)	L. Talaue-McManus

PARTNERS	PROJECT COMPONENT AND METHODOLOGY	EXISTING DATASETS, PROGRAMMES AND METHODOLOGIES	ROLE IN FSP	CONTACT PERSON
* Centre for Resource Management and Environmental Studies (CERMES), Univ. West Indies Marine Affairs Programme (MAP), Dalhousie University	Governance assessment (governance architecture and performance in LMEs)	CERMES has developed the multi-scale-level, policy cycle-based, LME Governance Framework which is the basis for the CLME Project, the only LME Project with a primary focus on governance. This framework is the basis for the two-stage approach developed under the TWAP MSP. CERMES has carried out a governance assessment of all 64 LMEs which has been published in Marine Policy (2010). It has an LME governance database. CERMES is an active partner in the Fisheries Governance Network based at Amsterdam University and its Faculty are Associates of the Earth Systems Governance Project. MAP has been involved in projects on Principled Ocean Governance in several areas of the world, notably the PROGOVNET Project in the Caribbean.	Implement methodology for assessment of governance in LMEs (TWAP Level 1).	R. Mahon
University of Rhode Island, Coastal Resources Center	Governance mechanisms in ecosystem-based management	Four orders of coastal governance outcomes. Methodology for assessing management process in relation to management outcomes (Handbook on Governance and Socio-economics of LMEs, 2006).	Measure progress in LME management through four orders of outcomes. Examination of LMEs that have developed governance mechanisms (e.g. Yellow Sea, Benguela Current, Baltic).	
University of Rhode Island	Mapping LME Governance profiles	Indicator approach. Published article, Governance profiles and the management of the uses of LMEs	Mapping of Governance profiles for all 64 LMEs	

2.4 PRIORITY ISSUES, EMERGING ISSUES AND HOTSPOTS

Priority and emerging issues or impacts within LMEs that should be prioritized for further examination were identified through a scoping exercise. These issues reflect anthropogenic and natural pressures and impacts on environmental state and ecosystem services as well as socio-economic impacts. No attempts were made to assign a score to the issues during development of the TWAP methodology (as done in GIWA). This will be done in the Level 1 assessment using the relevant core indicators.

Priority issues

Previous work has identified a number of overarching issues of concern in LMEs and has driven the development of the five LME modules and associated indicators. In addition, TDAs developed in GEF LME projects have also identified a number of priority environmental issues. During the development of the TWAP LME assessment methodology, priority and emerging issues were identified through a comprehensive review of TDAs and SAPs produced by GEF LME projects (See background paper on TWAP website). To date GEF has supported projects in 21 of the 64 LMEs and two regions not recognized as LMEs. These projects provide a potentially valuable source of information for the development of the TWAP LME methodology and for conduct of the global LME assessment. Only those projects for which completed (or nearly completed) TDAs and/or SAPs were available were selected for inclusion in the review.

The review captured a wide range of priority transboundary issues (Annex 4). In some cases, the allocation of the issues among the LME modules was challenging. While some of the issues were easily assigned to one of the five modules, others cut across two or more modules. All of the TDAs identified one or more priority transboundary concerns associated with 'Fish and Fisheries' with the exception of the project 'Addressing land-based activities in the Western Indian Ocean' (WIO-LaB), which is understandable given that this is not the project's focus. Only two of the TDAs identified a priority transboundary issue associated with 'Productivity', although there were other cross-cutting issues of relevance to this module. The majority of issues identified in the TDA/SAP process fell within the 'Pollution and Ecosystem Health' module. Notably, only one of the TDAs identified a socio-economic issue as a transboundary concern (Benguela Current LME: '*Inadequate human and infrastructure capacity to assess the health of the ecosystem as a whole (resources and environment, and variability thereof)*'. Similarly, only one of the TDAs (WIO-LaB) directly identified '*Governance (and awareness)*" as a transboundary issue. Several of the transboundary issues identified could be considered as socio-economic or governance related, and these were subjectively assigned to these categories.

The priority issues identified in the review are summarized according to the five LME modules, with indication of where these issues fit into the overarching conceptual framework (shown in parentheses) as follows:

Productivity

- Loss of ecosystem integrity (changes in community composition, vulnerable species and introduction of alien species) and yields in a highly variable environment including effects of global climate change (change in ecosystem state and services).
- Ecosystem (primary and secondary production and benthos) (change in ecosystem state and services).
  - Increase in frequency of harmful algal blooms (HABs).
  - Change in species composition.
  - Change in biomass or abundance.
  - Loss of benthic habitat in coastal areas.
- Uncertainty regarding ecosystem status and yields in a highly variable environment (governance?).

Fish and Fisheries

- Decline in commercial marine capture fisheries due to over-fishing (change in ecosystem services).
- Shift in species dominating commercial marine capture fisheries, including change in catch composition from high to low value species (fishing down the foodweb).
- Increased by-catch due to use of non-selective gears (stress).
- Change in the use of destructive fishing methods to compensate for declining catches (human driver; stress).
- Decline of large pelagic 'game' species due to increase in recreational fishing (change in ecosystem services).
- Conversion of natural habitats for use in mariculture (human driver; stress).
- Conflicts over resources between artisanal and industrial fisheries (human well-being/governance).
- Conflicts over resources between fisheries and marine mammals (stress).

Pollution and Ecosystem Health

Pollution

- Contamination from offshore oil and gas activities (stress – this and the following 11 issues).
- Contamination from urban sources.
- Contamination (including discharge of solid waste and sewage) from ship-based sources.
- Contamination from agricultural sources.
- Contamination from industrial sources.
- Contamination from atmospheric sources.
- Contamination with faecal matter from land or ship-based sources.
- Cooling water discharge (stress).
- Oil spills from exploration, production, and transport.
- Sedimentation (including from agriculture and livestock grazing).
- Change in nutrient balance / over-enrichment / eutrophication / depletion (ecosystem state).
- Oxygen depletion (ecosystem state).

Habitats

The transboundary habitat issues identified in the TDAs variously included:

- Physical alteration and destruction of habitats (five sub-categories: Degradation of mangrove forests; Degradation of seagrass beds; Degradation of coral reefs; Degradation of coastal forests; Shoreline changes) (stress; ecosystem state);
- Habitat destruction and alteration including modification of seabed and coastal zone, degradation of coast-scapes, coastline erosion (stress; ecosystem state);
- Habitat and biodiversity changes - including alien species introduction (ecosystem state); and
- Modification of habitats (stress): Destruction of mangroves, coral reefs, and seagrasses.

Biodiversity

The TDAs reviewed generally identified transboundary concerns relating to marine biodiversity including issues associated with the general decline in species richness, threats to endemics, and invasive and alien species. Although biodiversity is not explicitly identified as one of the five LME modules, it could be placed under the Pollution and Ecosystem Health module or the Fish and Fisheries module. The TDAs often specifically identified the following issues associated with biodiversity:

- Loss / decline of native, endemic, flagship, and globally endangered species due to loss of habitat or overexploitation (ecosystem state); and
- Increase in alien / invasive / nuisance species and associated loss / decline of native species, increased incidence of marine diseases due to pathogens, and loss of economic potential (stressor; change in ecosystem services; human well-being).

Socio-economics and Governance

Very few of the TDAs reviewed identified socio-economic or governance concerns as priority transboundary issues, although the Caspian Sea, Mediterranean and Benguela Current LME project identified the following issues:

- Decline in human health (Caspian Sea LME) (human well-being);
- Damage to coastal infrastructure and amenities (Caspian Sea LME) (change in ecosystem service; human well-being);
- Human health risks (Mediterranean LME) (human well-being); and
- Inadequate human and infrastructure capacity to assess the health of the ecosystem as a whole (resources and environment, and variability thereof) (governance).

The WIO-LaB TDA identified Governance/Awareness as a transboundary issue.

Emerging issues

TDAs do not always capture emerging issues, and since they become outdated, they need to be periodically updated to include emerging issues and to provide information where needed (e.g. deltas, which are not included in any global assessment or database of significance). Among the issues considered to be emerging issues in the TDAs reviewed are: a shift in the dominant species; influence of foreign fishing fleets; impact of recreational fishing; impact of mariculture; conflicts between humans and other species for fish and other marine resources; and impact of global climate change and variability.

UNEP-WCMC identified a number of emerging issues related to marine habitats arising from unprecedented human population levels and anthropogenic climate change: ocean acidification, carbon storage in the ocean, deep seabed mining, extraction of gas hydrates, and diseases in the marine environment.

Other emerging issues include climate-related shifts in species distribution, and melting of sea ice (covered in the Open Ocean methodology).

Hotspots

Hotspots represent geographic areas where issues are of particular importance and stressors and impacts very pronounced. For the TWAP assessment, hotspots to be considered will be those that are transboundary in geographic scope and/or with transboundary issues and impacts. A number of transboundary hotspots are already known within LMEs, especially related to pollution and habitat degradation as well as impacts of climate change. These include transboundary estuaries and mega-deltas. In addition, hotspots also include geographic areas of particular global importance, for example, areas with high biodiversity/endemism of global significance. The TWAP Level 1 assessment will confirm or identify transboundary hotspots.

2.5 IDENTIFICATION OF DEMONSTRATION/PILOT PROJECTS INVOLVING INTERLINKAGES AND TRANSBOUNDARY HOTSPOTS

LMEs or smaller areas such as transboundary deltas where demonstration or pilot projects can be developed will be selected during development of the FSP. LMEs for implementation of pilot projects could include, for example, LMEs from the North and South and from among those with GEF projects.

As one of the objectives of the pilot projects will be to demonstrate interlinkages between different transboundary water systems (e.g., between LMEs and Rivers), it is recommended that the development of pilot projects and selection of areas for their implementation are done in collaboration with experts involved in the other transboundary water systems. Pilot projects should be developed in regions where the boundaries or influence of two or more transboundary water systems converge, such as transboundary deltas.

An important consideration for selection of regions for the implementation of pilot projects is the availability of data and information as well as the presence and engagement of the appropriate national and regional institutions and ongoing monitoring and assessment programmes. Among these are the RSPs, which are seen as critical partners in the pilot projects as well as the overall TWAP assessment. The pilot projects should be developed in collaboration with RSPs and other agencies that are expected to be involved in their implementation.

PART 3. INDICATORS

The aim of the TWAP LME indicators is to understand the changing status of LMEs and their living resources. The assessment of LMEs therefore needs to provide the basis to answer questions that include *temporal* and *spatial* distributions. Among the questions the TWAP LME assessment will seek to answer are: What is the current environmental status and trends in LMEs and coastal areas? What and where are the main interlinkages between LMEs and other transboundary water systems? Which LMEs are most at risk and where is the ecological damage the worst? What are the drivers and stressors and their origin (e.g. anthropogenic, natural, land-based)? Where are human needs and dependence on LMEs and the socio-economic impacts of LME degradation the greatest? Are there LMEs with threats that are not yet serious but should be monitored closely? Are their irreversibilities, non-linearities, and greater risks if funding is not devoted now? Where do the experts project that future degradation will be serious with policy action needing to be implemented immediately? What actions are countries taking (individually and collectively) to address the priority environmental problems in LMEs including in their coastal areas? To provide answers to these, the assessment will consist of both a baseline and trend assessment to describe the changing condition of LMEs and associated stressors, and future projections of these stressors where possible.

3.1 TRANSBOUNDARY STATUS INDICATORS

To help assess project achievements, the GEF has adopted three levels of international water indicators: Process, Stress Reduction, and Environmental Status Indicators (Duda, 2002). These indicators are employed over the full life of the project, from project preparation, during the project development process, to the end of the project cycle. The indicators, particularly the environmental status indicators (renamed for the purposes of TWAP as ecosystem status indicators) that are agreed on by collaborating nations, usually remain in use beyond the GEF-funded interventions.

For the purposes of TWAP, four categories of status indicator are identified:

- Transboundary stress indicators (box 3, Fig. 2 above);
- Transboundary ecosystem status indicators (boxes 4 and 5, Fig. 2 above);
- Socio-economic indicators (include indicators of anthropogenic drivers of ecosystem change and socio-economic impacts of these changes) (boxes 2 and 6, Fig. 2 above); and
- Governance/response indicators (box 1, Fig. 2 above).

Ideally, the TWAP assessment should consider desired quantitative or qualitative targets or states against which the indicator could be compared, to help guide interventions and measure progress. However, targets would vary between LMEs (and countries) and would not be appropriate for a global comparative assessment. The indicator should be expressed as *change over time* in the parameter being measured. As the first TWAP assessment is expected to be a baseline assessment, expression as change over time will not be possible in this assessment for indicators for which historical time-series of datasets are not available. Sherman and Hempel (2008) present time-series for a number of indicators, which could be expressed as change over time in subsequent TWAP assessments. The indicator values should be validated where necessary by regional experts during the assessment.

3.2 PROJECTED TRANSBOUNDARY STRESS INDICATORS

Where possible, projections of stress indicators will be made to 2030 and 2050 using available modelling approaches. Stresses include natural drivers such as climate variability and anthropogenic drivers such as coastal human population density. The purpose of these projections is to allow identification of regions where these stressors and thus their impacts are predicted to become most pronounced, so that GEF and other donors could support the implementation of mitigatory and adaptation measures. Projected stress indicators will include:

Climate change impact on fisheries: Projected future changes in maximum fish catch potential from the global oceans by 2055 under various climate change scenarios have been modelled by Cheung, *et al*. (2009). Change in maximum catch potential (10-year average) from 2005 to 2055 is presented for ½˚ by ½˚ spatial cells (global coverage). Catch potentials can be aggregated by LMEs to evaluate projected climate change impacts at the LME level.

Sea-level rise: See Open Ocean methodology. Projections of future sea-level rise are being produced by the World Climate Research Programme and assessed by the Intergovernmental Panel on Climate Change (IPCC). The vulnerability to this open ocean phenomenon is at the coast and particularly on low-lying SIDS. A global index will combine actual and projected local sea-level change (positive only) with human vulnerability.

Nutrients and freshwater discharge: Nutrient inputs to LMEs under future scenarios can be projected using the Global NEWS model. NEWS model experts are currently analysing a range of alternative scenarios for 2030 and 2050 to provide insights into how changes in technological, social, economic, policy, and ecological considerations could alter future nutrient export to coastal systems around the world (Mayorga, *et al*., 2010; Seitzinger, *et al*., 2010). The NEWS model could also be used for projections of freshwater discharge to coastal areas under different scenarios.

Threats to coral reefs: Estimates of threats to coral reefs from a number of factors (e.g., coastal development, land-based and marine-based pollution and damage, and overfishing/destructive fishing) are combined with modelled future estimates of thermal stress and ocean acidification to predict threat to coral reefs in 2030 and 2050 (the 'integrated local threat and future climate-related threat index'). All of these threat layers are combined with a map of coral reefs to show where reefs are at risk.

Human population density: Of particular interest to TWAP would be projections of human population density in coastal areas, including transboundary deltas, as a proxy for future stress on coastal ecosystems. In addition, coastal human population density evaluated along with projected sea-level rise and other climate change impacts would help identify areas where human vulnerability to these impacts would be greatest.

3.3 PROPOSED TWAP INDICATORS

The full list of indicators derived by the WG is given in Annex 5. A subset of indicators was subsequently selected for inclusion in the methodology. The following section describes core indicators (to be included in Level 1 global assessment), secondary indicators, and assessment approaches. For each indicator, the following is provided: relevance; methodology and data availability; a graphic showing visualization of the data (for some of the indicators); and institutions/experts who are involved in developing the indicator and are potential partners for the TWAP assessment. A more detailed description of each indicator is given in a separate document posted on the TWAP website. For each LME, a characterization sheet will be completed (see below). This will include general information about the LME as well as 'descriptors', which are indicators or metrics that are not included in the global comparative assessment but which are of particular relevance to the LME in question. It should be noted that a large number of indicators and approaches are presented, from among which a subset could be selected based on availability of data and financial resources during the TWAP FSP. Some of the indicators and approaches will also require further development.

Draft LME Characterization Sheet

TWAP LARGE MARINE ECOSYSTEM CHARACTERIZATION SHEET

[map]

Name of the LME: ____________________

Boundaries:____________________

Total area (km^2): ____________________

COUNTRIES	Relative share in LME area (%)
Country A	
Country B	
etc	

Socio-economic & Governance characterization

	Country A	Country B	Country C	Country X
Population in Coastal Zone				
HDI				
Fishing contribution to GDP				
Mariculture contribution to GDP				
Oil & gas contribution to GDP				
etc				
Regional Seas Convention				
Regional Fisheries Management Organisation (RFMO)				
LME Commission				
etc				

Biogeophysical characterization

Major Ocean currents & fronts	
% World coral reefs	
No. Seamounts (% world)	
No. (and area) major Estuaries & Deltas	
Primary Production Class (low, moderate, high)	
Major upwellings	
Etc.	

Descriptors: Indicators and metrics that are of particular relevance to this LME

Productivity

CORE INDICATORS

Primary productivity; chlorophyll a

Relevance: Primary productivity reflects ecosystem state but can also be considered a stressor at excessively high levels (e.g., algal blooms), when it could affect living marine resources. Primary productivity can be related to the carrying capacity of an ecosystem for supporting fish resources (Pauly and Christensen, 1995) (see Primary Production required to support fisheries in LMEs below). It has been reported that the maximum global level of primary productivity for supporting the average annual world catch of fisheries has been reached and that further large-scale increases in biomass yields from marine ecosystems are likely to be at trophic levels below those of fish. Measurements of primary productivity and chlorophyll *a* can also be useful indicators of the growing problem of coastal eutrophication.

Methodology and data availability: Primary productivity estimates (Fig. 3) are derived from satellite-borne data archived at NOAA's Northeast Fisheries Science Center, Narragansett Laboratory. These estimates originate from ocean colour sensors and satellites including the Coastal Zone Colour Scanner (CZCS) Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and Moderate Resolution Imaging Spectroradiometer (MODIS-Aqua and MODISTerra). Spatial and seasonal variability of near-surface chlorophyll and SST in all LMEs are presented in Sherman and Hempel (2008). The data allow the classification of LMEs into 3 categories: Class I, high productivity (>300 gCm^{-2} year^{-1}), Class II, moderate productivity (150-300 gCm^{-2}year^{-1}), and Class III, low productivity (<150 gCm^{-2} year^{-1}).

Institutions/experts: LME productivity descriptions available from NOAA and University of Rhode Island (J. O'Reilly, K. Hyde, and T. Ducas).

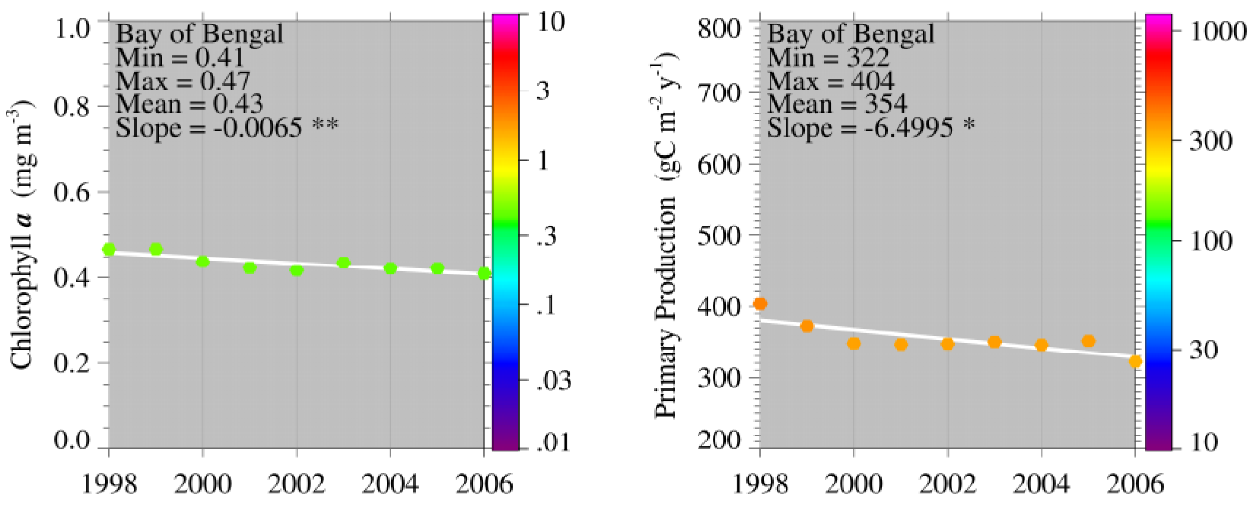


Figure 3. Chlorophyll (left) and Primary production (right) trends (1998-2006): Bay of Bengal. (Source: Sherman and Hempel (2008))

Sea surface temperature

Relevance: Changes in ocean conditions including water temperature are stressors that have direct and indirect impacts on the spatial distribution and productivity of marine organisms, which are vulnerable to increases in water temperature (outside their tolerance range). Increasing sea surface temperature (SST) is already significantly affecting marine ecosystems and their services (e.g., coral bleaching, shifts in species distribution). This impact is expected to increase in the near future owing to the current acceleration of warming that has already been observed in several of the LMEs (Sherman and Hempel 2008).

Methodology and data availability: Data from the UK Meteorological Office Hadley Centre SST climatology was used to compute 50-year time-series (1957– 2006) of SST and examine SST trends and anomalies in the world's LMEs (Belkin, 2009). The resulting plots of SST and SST anomalies are for 63 LMEs; ice cover precludes a meaningful assessment of the LME-averaged SST for the Arctic Ocean. SST time-series (1957 - 2006) for each LME are presented in Sherman and Hempel (2008) (Fig. 4 and 5).

Institutions/experts: University of Rhode Island (I. Belkin).

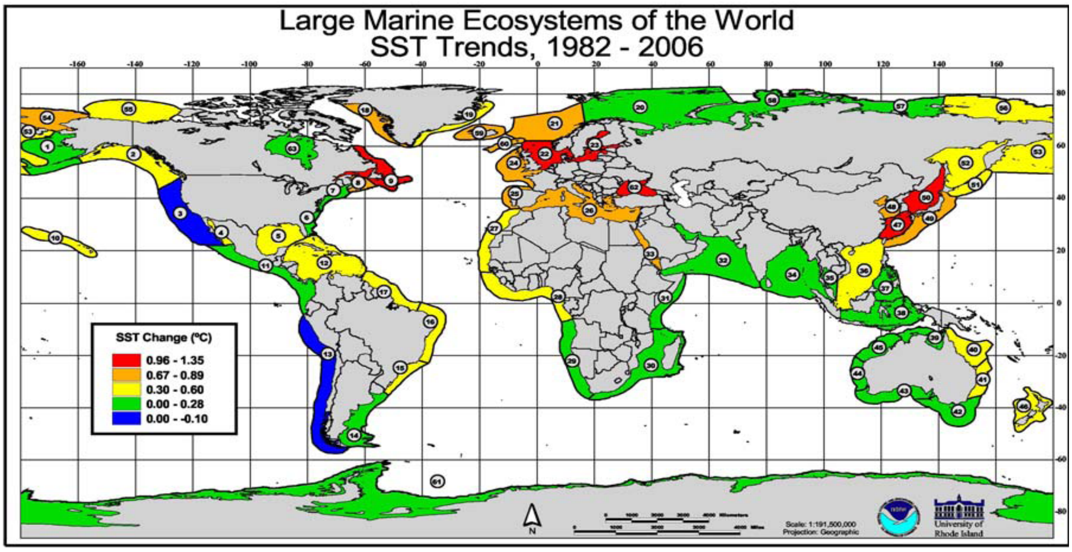


Figure 4. SST trends in the World's LMEs (1982-2006) modified after Belkin (2009).
(Source: Sherman and Hempel(2008))

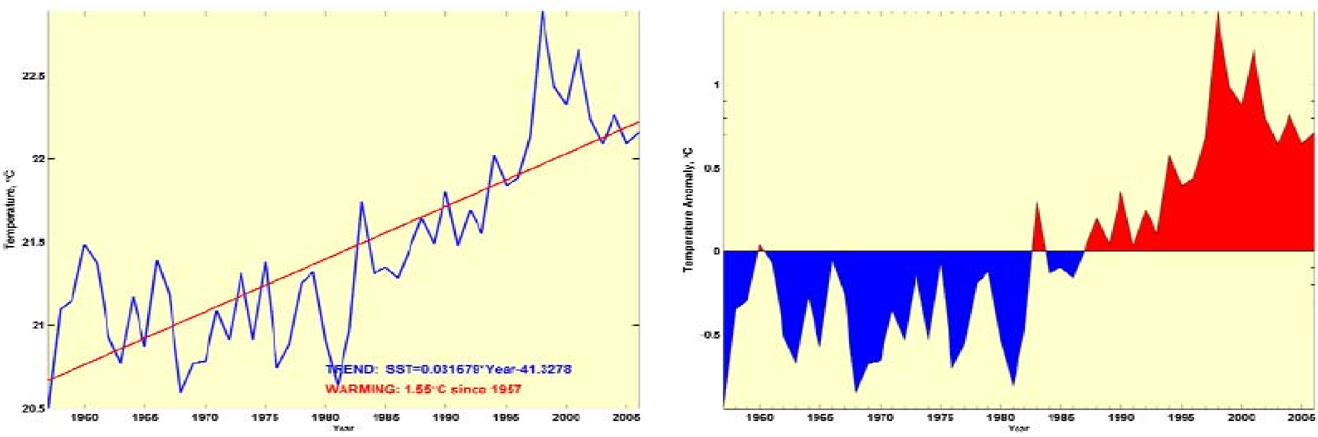


Figure 5. East China Sea LME annual mean SST (left) and SST anomalies (right), 1957-2006 (after Belkin, 2009).

OTHER INDICATORS

Oceanographic fronts

Relevance: An oceanographic front is a relatively narrow zone of enhanced horizontal gradients of physical, chemical, and biological properties (e.g., temperature, salinity, nutrients). Oceanic fronts affect ecosystem productivity and are subject to natural variability. They are important for a range of activities such as climate change monitoring and prediction as well as industries such as fishing and marine mining.

Methodology and data availability: Earlier descriptions and maps of LME oceanographic fronts in LMEs are presented in Sherman and Hempel (2008). The first global remote sensing survey of fronts in LMEs was based on a frontal data archive assembled at the University of Rhode Island. Since SST fronts are associated with chlorophyll fronts (Belkin and O'Reilly, 2009), frontal paths in these schematics, once digitized, lend themselves to studies of physical-biological correlations at fronts. Satellite-derived surface thermal fronts are typically co-located with hydrographic fronts determined from subsurface data.

Institutions/experts: University of Rhode Island (I. Belkin).

Fish and Fisheries

CORE INDICATORS

Reported landings

(Can be expressed by species, functional groups, commercial species, or fishing gear including bottom impacting gear)

Relevance: Catch time-series indicate fisheries status and trends (i.e. in the food provisioning service of LMEs). Most marine fisheries resources in the world are currently fully exploited, over-exploited or collapsed and the global marine catch appears to have reached or has exceeded its biological limits (Pauly, *et al*., 2008). Relevant policy frameworks include the FAO Code of Conduct for Responsible Fishing and the UN Convention on the Law of the Sea and its implementation agreement on straddling and highly migratory fish stocks.

Methodology and data availability: Time-series of reconstructed landings are provided by the UBC Fisheries Centre Sea Around Us Project using a method developed by Watson, *et al*. (2004). This relies on dividing the world oceans into more than 180 000 spatial cells of ½ degree lat.-long., and mapping onto these cells, by species and higher taxa, all catches that are extracted from such cells. These catches can then be regrouped by LMEs (Fig. 6). The Sea Around Us Project also reconstructed catch time-series for FAO Area 18.[3] Time-series (1950 – 2006) of reported landings by LMEs are presented in Sherman and Hempel (2008).

Institutions/experts: UBC Sea Around Us Project, FAO, FishBase, SeaLifeBase.

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[3] Contains seven LMEs: Kara, Laptev, East Siberian, Chukchi and Beaufort Seas, Hudson Bay, and the Arctic Ocean LME

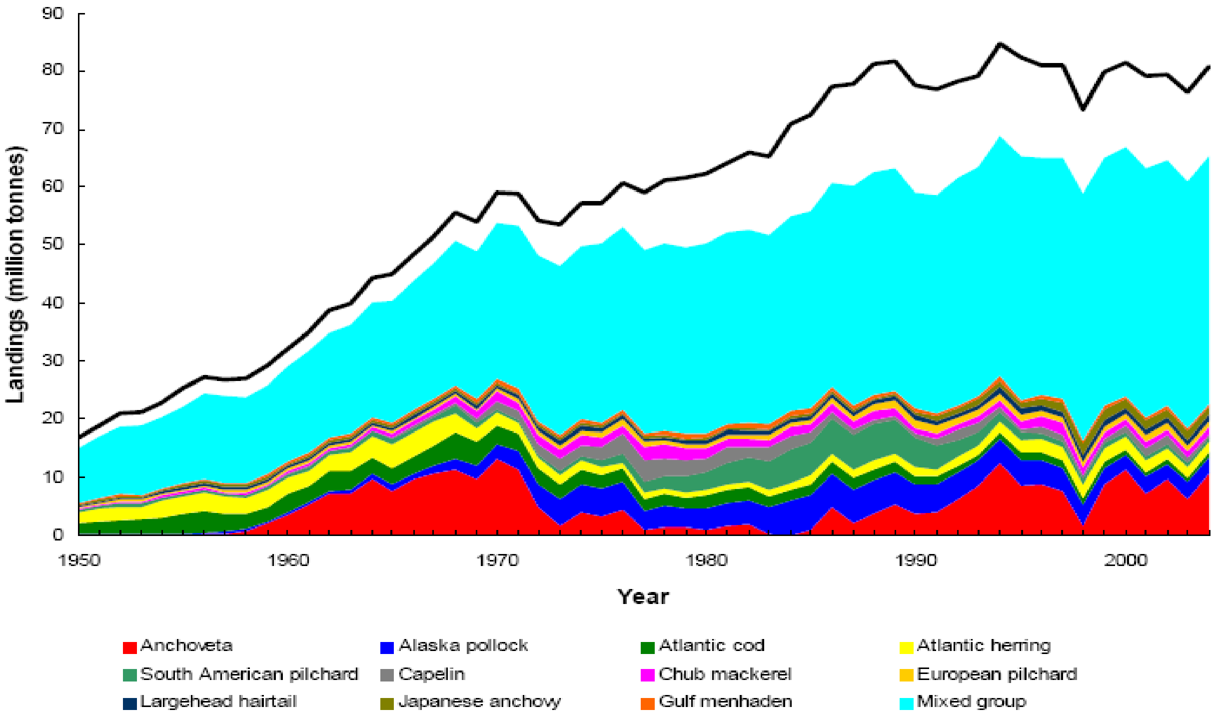


Figure 6. Landings by species in all LMEs (coloured time-series), and in the world ocean (black line). As this graph individually identifies only the 11 species with the highest global catch (with the remainder pooled into 'mixed group'), it exhibits more 'mixed group' landings (as the 12th category) than reported from any specific LME. The only major group not caught primarily in LMEs is large pelagic fishes, primarily tunas. (Source: Pauly, *et al*. (2008))

Value of reported landings

Relevance: Fishing effort is one of the major stress factors in marine ecosystems, and effort is in turn directly influenced by the value of the landings. This is a socio-economic indicator related to consequences for people and human well-being. Along with catches, catch values also indicate fisheries status and trends, e.g. through changes in species composition and catches. These relate strongly to the status of stocks in the LME.

Methodology and data availability: Time-series of the value of fisheries catches in year 2000 inflation adjusted prices are provided by the UBC Sea Around Us project. Catch value is the ex-vessel value of reported landings by LMEs, based on real 2000 prices (Sumaila, *et al*., 2007). A global database of ex-vessel fish price data has been constructed (Sumaila, *et al*., 2007). Time-series (1950 – 2006) of the value of fisheries landings are presented in Sherman and Hempel (2008).

Institutions/experts: UBC Sea Around Us Project.

Marine Trophic Index and Fishing in Balance Index

Relevance: The Marine Trophic Index (MTI) is an indicator of changes in ecosystem state (and as a consequence, in ecosystem services) brought about by fishing. Initially, a fishery usually targets the larger fish, turning to smaller, low-trophic level fish when these are depleted. Pauly, *et al*. (1998) were able to identify a worldwide decline in the trophic level of fish landings (a phenomenon now widely known as 'fishing down marine food webs'). The Convention on Biological Diversity (CBD) has adopted the mean trophic level of fisheries catch, which it renamed Marine Trophic Index, as one of eight biodiversity indicators for 'immediate testing' (CBD, 2004). The MTI is evaluated along with the Fishing in Balance Index (FiB) (Pauly, *et al*., 2000). The FiB index will decline when both the MTI and landings decline, as now happens in many LMEs. On the other hand, the FiB index will increase if increases in landings more than compensate for a declining MTI.

Methodology and data availability: Trophic levels (TL) are assigned to all catches from a given area (in the FAO landings data set), typically based on information in FishBase (www.fishbase.org) or SeaLifeBase (www.sealifebase.org) (Fig. 7). The weighted TL of the catch is then calculated by weighting the species/group TL with the corresponding catch level. The MTI, which may have declined at first, increases again, especially if the 'new' landings are high. Thus, at the scale of an LME, a trend reversal of the MTI may occur when the fisheries expand geographically. To facilitate this evaluation, a time-series of the FiB index is also presented (Fig. 7). Time-series (1950 – 2006) of MTI and FiB by LMEs are presented in Sherman and Hempel (2008).

Institutions/experts: UBC Sea Around Us Project, FishBase, SeaLifeBase.

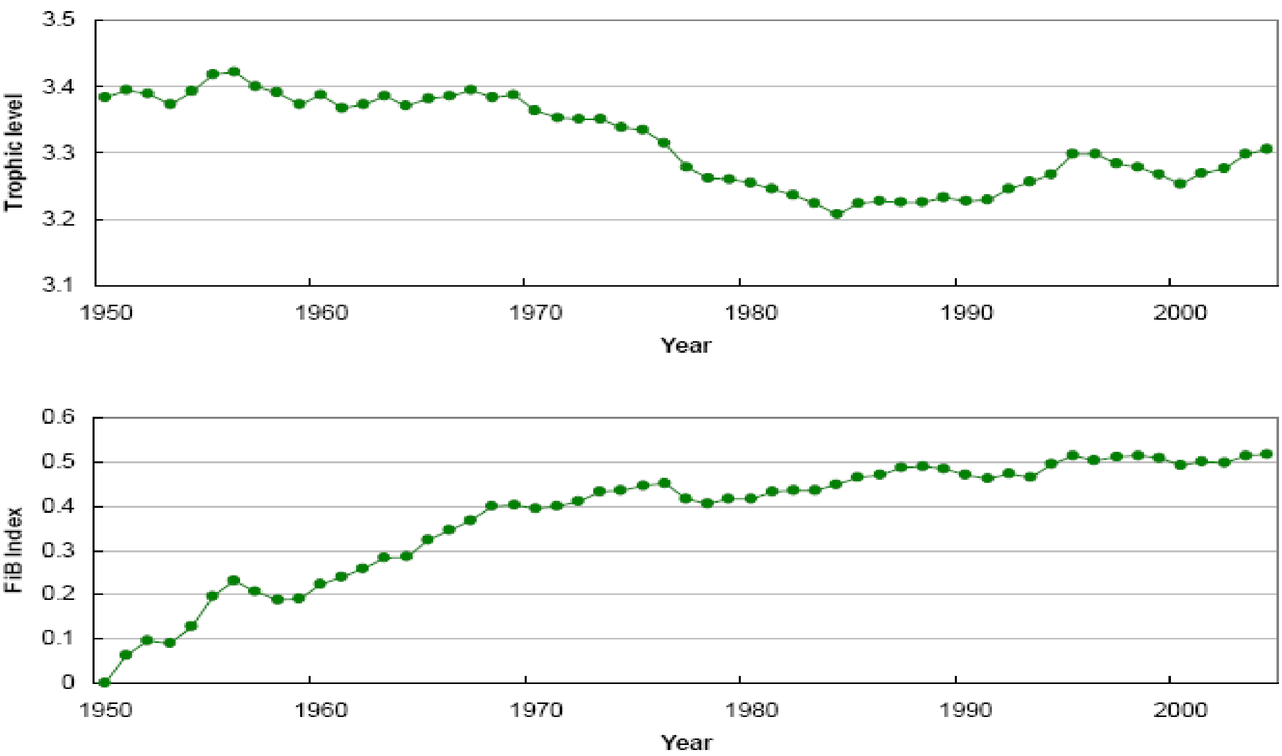


Figure 7. Top: trend of mean TL, indicating 'fishing down marine food webs', recently masked by offshore expansion of fisheries (Pauly, *et al*., 1998; Pauly and Watson, 2005). **Bottom**: corresponding trend of the FiB index, which is defined such that its increase in the face of stagnating or increasing MTI suggests a geographic expansion of the fisheries. (Source: Bhathal and Pauly (2008))

Ecological footprint of fisheries

Relevance: Primary Production Required (PPR) by fisheries corresponds directly to the ecological footprint of fisheries. PPR is estimated on the basis of the trophic level of the catches, and is often calculated as a fraction of the total primary production in the LME. PPR is an indicator of fisheries sustainability. When related to observed primary production, PPR provides another index for assessing the impact (stress) of the countries fishing within the LME in question.

Methodology and data availability: Landings data used to estimate footprints are those presented above. PPR is calculated separately for each species (or group of species) for the fleets of all countries operating in the LME in question, expressed in terms of the primary production in that LME (based on SeaWiFS data). The combined footprint of different countries fishing in a given LME area can thus be assessed. To facilitate comparisons between LMEs, the 'maximum fraction' (of PPR, in terms of primary production in each LME) is also assessed. Time-series (1950 – 2006) of PPR

by LMEs are presented in Sherman and Hempel (2008).

Institutions/experts: UBC Sea Around Us project.

Stock- status plots

Relevance: Unsustainable fishing has led to the overexploitation and/or collapse of fish stocks around the world, and the reduction in the ecosystem service (fish catch) provided by marine ecosystems. Stock-Status Plots document, for a series of years, the fraction of the reported landings that is derived from stocks in various phases of development (as opposed to the number of such stocks). Overall, 70 per cent of global stocks within LMEs are deemed overexploited or collapsed, and only 30 per cent fully exploited (Pauly, *et al*., 2008). However, the latter stocks still provide 50 per cent of the globally reported landings, with the remainder produced by overexploited and collapsed stocks.

Methodology and data availability: A newly proposed type of paired 'Stock-Status Plots' (percentage of stocks of a given status and percentage of catches extracted from stocks of a given status), wherein the status of stocks is assessed, based on Froese and Kesner-Reyes (2002). A 'catch by status plot' is proposed: percentage of stocks of a given status, by year and percentage of catches extracted from stocks of a given status, by year (Fig. 8).

Institutions/experts: UBC Sea Around Us project, FAO, University of Kiel.

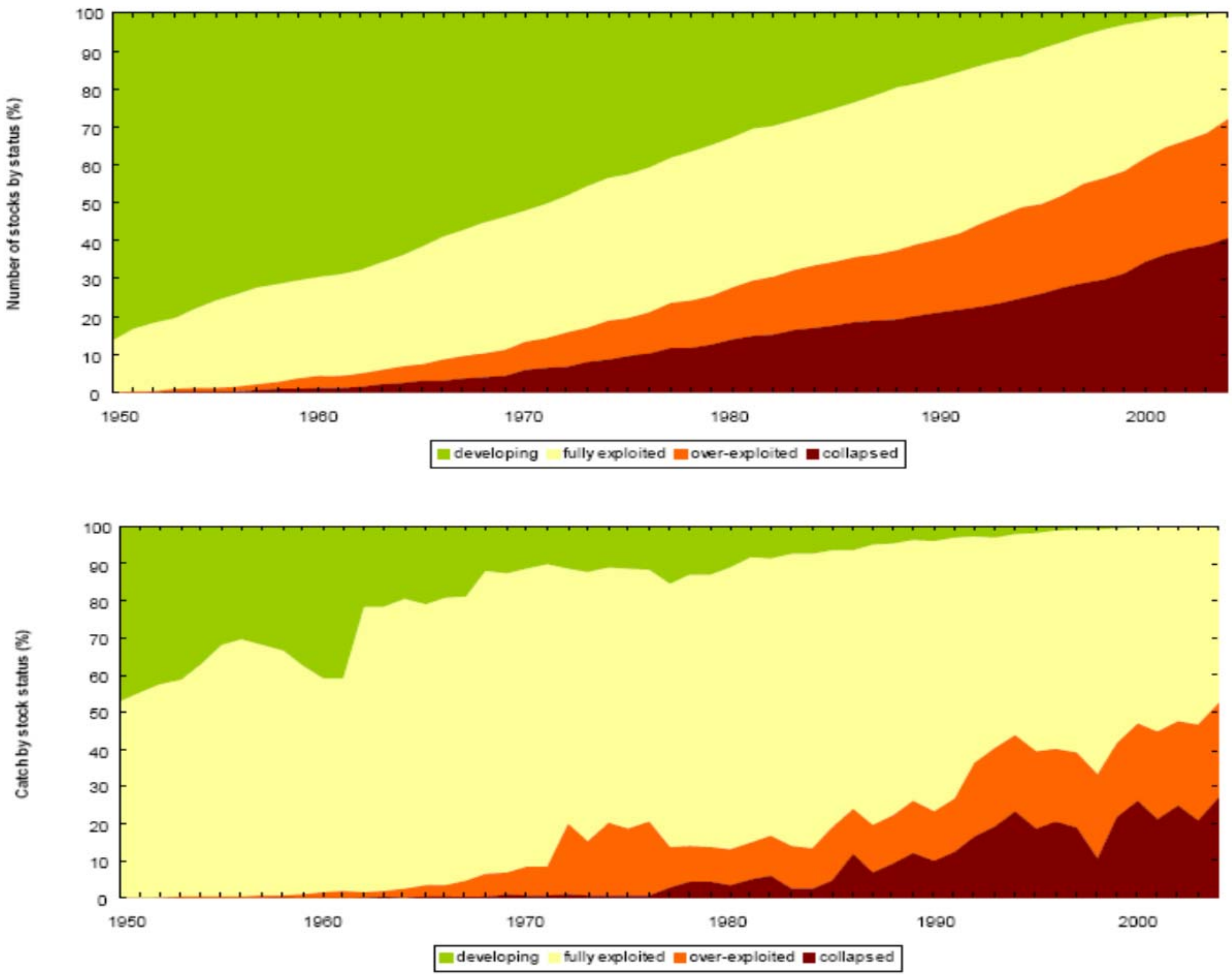


Figure 8. Paired 'Stock-Status Plots' for all LMEs. Top: percentage of stocks of a given status, by year, showing a rapid increase of the number of overexploited and collapsed stocks. Bottom: percentage of catches extracted from stocks of a given status, by year, showing a slower increase of the percentage of catches that originate from overexploited and collapsed stocks. Note that the number of 'stocks', i.e., individual landings time-series, only include taxonomic entities at the species, genus or family level, i.e., higher and pooled groups have been excluded. (Source: Pauly, *et al*., 2008)

OTHER INDICATORS

Catch from bottom-impacting gear

Catch from bottom-impacting gear (trawling and dredging) can be provided for each LME, as a proxy for destructive fishing practices (stressor). See description above for Reported landings.

Institutions/experts: UBC Sea Around Us Project.

Fishing effort (and cost of fishing)

Relevance: Globally, fishing is often the most important stressor in LMEs. The best measure of its intensity is the fishing effort that is exerted. Fishing gear such as trawls and dredges also modify bottom habitats, with negative consequences for the ecosystem services they produce.

Methodology and data availability: Effort is one of the key fisheries indicators, but while there is considerable information about effort available globally, there have only been limited attempts to summarize this at the national, regional, and global levels. The indicator is fishing effort (expressed as kilowatt days globally, by continents, by countries, by vessel tonnage class, and by vessel or gear types). A concerted effort is now underway to develop a comprehensive, spatially-explicit global effort database. The cost of fishing in relation to fishing effort can also be evaluated for each LME.

Institutions/experts: UBC Sea Around Us Project, FAO.

Projected catch potential (2005/2055)

Relevance: The projected change in maximum catch potential under climate change could have serious implications for global food security and achievement of the relevant MDG. If the decrease in catch potential in tropical countries is directly translatable to actual catches, climate change could have a negative impact on food security in many tropical communities that are strongly dependent on fisheries resources for food and revenues (Cheung, *et al*., 2009). This analysis illustrates the impact of natural variability on ecosystem state and hence on ecosystem services, and would help to identify where climate-change adaptation strategies might be most needed.

Methodology and data availability: Cheung, *et al*. (2009) projected future changes in maximum catch potential from the global oceans by 2055 under two climate change scenarios, based on analysis of 1 066 species of commercially exploited marine fish and invertebrates. Change in maximum catch potential from 2005 to 2055 is presented for ½˚ by ½˚ spatial cells (global coverage). This methodology could be restructured to reflect conditions in the world's LMEs.

Institutions/experts: UBC Sea Around Us Project; University of East Anglia; Princeton University.

LME carrying capacity in relation to maximum sustainable yield

Relevance: The two approaches described below are relevant to the recovery and sustainability objectives for degraded LMEs. The methodologies assist in the movement towards resilient and healthy LMEs.

Methodology and data availability: Two different approaches to carrying capacity in relation to maximum sustainable yield (MSY) are suggested: (i) This approach estimates fish biomass in LMEs using the Ecopath with Ecosim modelling approach and software, as described in Christensen, *et al*. (2009). It relies on a large number of spatial and temporal databases. (ii) This approach is based on the concept of ecosystem carrying capacity (ECC), as adopted in the SAP recently published by the Yellow Sea LME Project. ECC is defined as the capacity of an ecosystem to provide its services or the sum of all the ecosystem services it can provide. This approach takes into consideration indicators from all 5 LME modules. ECC will be determined by various ecological processes that are inter-dependent, which in turn are determined by ecosystem configuration and state. As such, ECC will change under different environmental conditions as the ecosystem structure and processes change. The environmental conditions will change as societal requirements increase and climate change accelerates.

Institutions/experts: UBC Sea Around Us Project; Yellow Sea LME Project.

Pollution and Ecosystem Health

This module includes indicators of pollution and those related to the health of the ecosystem as a whole (including critical marine habitats).

POLLUTION

A number of pollutants stemming from human activities on both land and in the sea act as stressors in the marine environment, with potential negative consequences for ecosystem state and services, and ultimately for humans. Further, certain contaminants in sea water and marine organisms can directly affect human health through direct contact or consumption. With an estimated 30 000 to 100 000 chemicals in commercial production, the choice of potential indicators of chemical pollution is vast. However a careful selection is required to represent the state of water and airborne emissions to LMEs. Therefore, a prioritization based on production/emission volume, environmental fate and hazard to human health and the environment is usually made.

A pragmatic approach has been chosen here to reduce the selection of indicator chemicals to those currently earmarked for action under international legislation, such as the Stockholm Convention on Persistent Organic Pollutants; this focuses mainly on chemicals that undergo long-range atmospheric transport[4] and the Mercury Convention scheduled for 2013. However, other Persistent Bioaccumulating and Toxic (PBT) chemicals are identified by many national and regional authorities and are highly likely to become subject to International legislation such as the Stockholm Convention in time, hence the addition of nine new substances in 2010 (See Box 1). Heavy metals, PAHs and many other organic compounds remain a cause for concern.

Box 1. Stockholm Convention: Persistent Organic

Pollutants

The entry into Force of the Amendments adding Nine Chemicals to the Stockholm Convention on POPs took place on 26 August 2010.

Annex A *(for elimination):*
Aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, heptachlor, tetra, penta, hexa and heptabromodiphenyl, hexachlorobenzene, alpha & beta hexachlorocyclohexane, lindane, mirex, pentachlorobenzene, toxaphene, polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF)**,** polychlorinated biphenyls (PCB).

Annex B *(for restriction):*
DDT, perfluorooctane sulfonic acid, its salts (PFOS)**,** perfluorooctane sulfonyl fluoride

Annex C *(unintentional production):*
Polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), hexachlorobenzene (HCB), polychlorinated biphenyls (PCB)

A ***primary substance indicator list*** should cover at least the following: PCB, DDT, HCB, PAHs, mercury, cadmium and lead, while ***a secondary list*** could cover PCDD, PCDF tributyltin, methyl mercury and 'newer' substances such as PFOS (see Box 1 for full names). Even the primary list requires multiple analytical instruments and validated methods in several media, including air, water, sediment and biota.

A similar tendency in terms of geographical distribution of data will apply to most contaminants, that is, coverage will be widespread in the Northern hemisphere and Mediterranean but will be far patchier elsewhere. All chemicals of concern can be expected to have geographical coverage problems and time-series can be expected to be fragmentary. Sustaining monitoring programmes for long enough to

[4] For Stockholm Convention POPs, see: http://chm.pops.int/Convention/The%20POPs/tabid/673/language/en-US/Default.aspx

obtain adequate time-series data is also a concern. The chemicals with the best coverage outside the relatively data-rich areas, in order of potential data richness, are: mercury, DDT, and PCBs and PAHs, and then the rest much less frequently.

Rather than listing a comprehensive set of indicators, the following potential indicators are presented to give an impression of what can be developed. They include input and output indicators of chemical contamination, as well as low-level and high-level indicators relative to the food-chain and potential effects. A further, rather novel indicator of contaminants in general has been added to provide an additional surrogate biota indicator.

CORE INDICATORS

Mercury

(see also POPs and marine mammals)

Relevance: Mercury contamination originating from industrial and combustion processes as well as natural sources is relevant to all five TWAP water systems. Mercury is of global concern owing to its long-range atmospheric transport, its persistence in the environment once anthropogenically introduced, its ability to bioaccumulate in ecosystems and its significant negative effects on human health and the environment (UNEP, 2002).

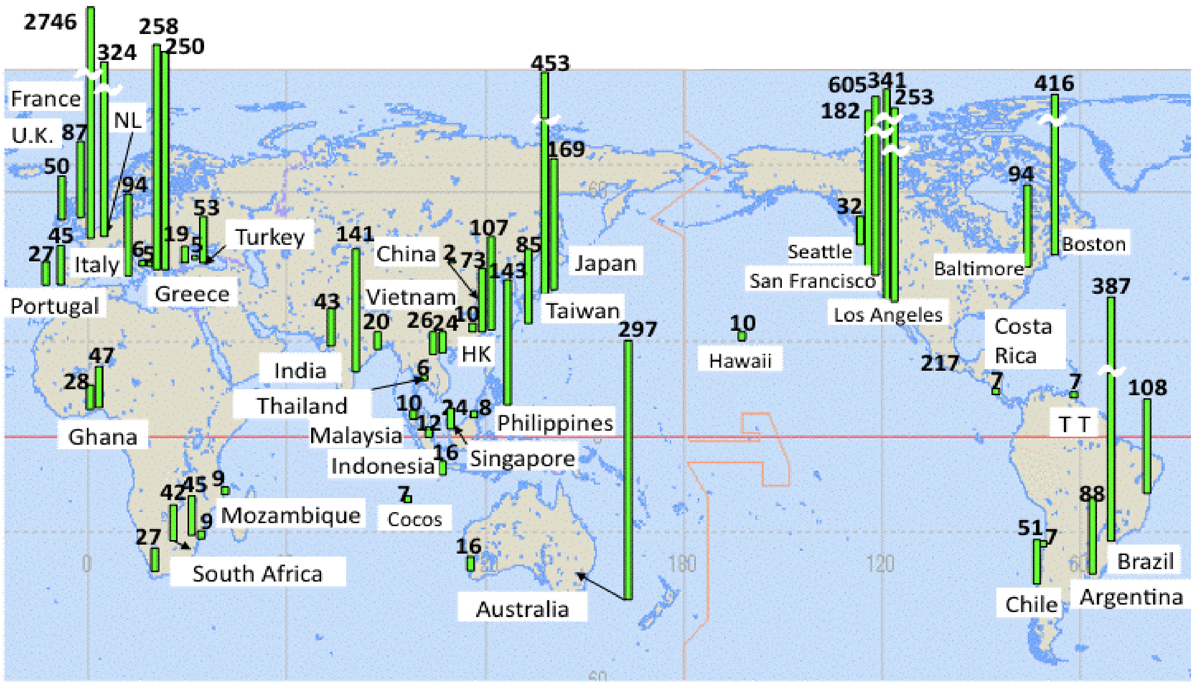
Methodology and data availability: A general input indicator is proposed, based on the change in mercury concentrations in environmental media, in particular atmospheric deposition, locally, regionally and globally, relative to background levels and/or appropriate environmental quality standards, through measurement and modelling. Sources of measured data (air, water, soil, sediment, and biota) are available mainly for Europe, North America, and Japan, with much less coverage elsewhere. Several multi-media models are available that predict to some degree the anthropogenic enrichment of mercury in the atmosphere, and deposition to land and the oceans (see UNEP 2008). There are no models that correlate inorganic mercury in various matrices to the production and accumulation of organic mercury in the aquatic environment.

Institutions/experts: GESAMP, UNEP Global Mercury Partnership, Regional Seas Programmes (HELCOM, OSPAR, Arctic Monitoring and Assessment (AMAP), COBSEA, and others) that monitor and assess mercury.

Plastic resin pellets

Relevance: Plastic resin pellets are ubiquitous in coastal waters, being derived primarily from accidental releases of pellets during transport or trans-shipment. The pellets have been shown to absorb hydrophobic compounds such as POPs present in the surrounding seawater, with a concentration factor of up to 1 000 000 (Smedes, *et al*., 2009). Concentrations of POPs in LMEs indicate both their status in coastal waters and variations in land-use and industrial development in the adjoining catchments. In addition there is evidence for the export of pellets to the open ocean (Lohmann and Muir, 2010).

Methodology and data availability: The International Pellet Watch programme has established a global network of volunteers and agencies that collect pellets from beaches and send them to a single laboratory for analysis (Ogata, *et al*., 2009). Pellets are sent from all over the world in sampling containers provided by the analytical laboratory to International Pellet Watch (www.pelletwatch.org), Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Tokyo, Japan. Global distribution of POPs as measured in beached plastic resin is shown in Fig. 9.



Concentration of PCBs* in beached plastic resin pellet (ng/g-pellet)

* sum of concentrations of CB#66, 101, 110, 149, 118, 105, 153, 138, 128, 187, 180, 170, 206
Measured by Polaris Q (Thermo Fisher Scientific)

Figure 9. Global distribution of POPs as measured in beached plastic resin pellets (ng g^{-1}).This very cost-effective global monitoring programme, using plastic pellets as a 'passive sampler', has revealed clear regional differences in the concentration of common POPs such as PCBs, DDT (dichlordiphenyltrichloroethane, insecticide for malaria control) and HCH (hexachlorocyclohexane, a pesticide), which can be linked to regional differences in land-use and other human practices (e.g. continued use of DDT as an insecticide). (Source: Takada, 2011)

Nutrients

Relevance: Many coastal LMEs are currently hotspots of nitrogen loading, and increases in the frequency of occurrence and extent of 'dead zones' from nutrient over-enrichment have been documented in coastal areas world-wide. The GPA recognizes the need for global, regional, and national actions to address nutrients impacting the marine environment. In 2002, WSSD identified substantial reductions in land-based sources of pollution by 2006 as one of their marine targets.

Methodology and data availability: An international interdisciplinary workgroup of IOC-UNESCO has developed a spatially-explicit global watershed model (NEWS) that relates human activities and natural processes in watersheds to nutrient and sediment transport by rivers to coastal systems throughout the world (e.g., Seitzinger, *et al*., 2005; Mayorga, *et al*., 2010) (Fig. 10). In addition to current predictions, the NEWS model is also being used to hindcast and forecast changes in nutrient, carbon, sediment, and water inputs to coastal systems under a range of scenarios. A full description of the data is given in Bouwman, *et al*. (2009). Data are also available in many regions at higher resolution (http://www.marine.rutgers.edu/globalnews/datasets.htm).

Total dissolved inorganic nitrogen (DIN) load to each LME was aggregated from all watersheds with coastlines along that LME for point sources and only those watersheds with discharge to that LME for diffuse sources (Fig. 11). This work was part of the GEF medium size project: Promoting Ecosystem-based Approaches to Fisheries Conservation and LMEs (Component 3: Seitzinger and Lee, 2007). Phosphorus, silica, carbon, and sediment loads are also available from the NEWS model (Seitzinger, *et al*., 2005 and 2010).

The TWAP assessment will also include projections of nutrient inputs to LMEs under future scenarios. Using the NEWS model, experts are currently analysing a range of alternative scenarios for 2030 and 2050 based on the Millennium Ecosystem Assessment (www.millenniumassessment.org) to provide insights into how changes in technological, social, economic, policy, and ecological factors could alter future nutrient export to coastal systems around the world (Seitzinger, *et al.*, 2010). These could be considered for inclusion in TWAP.

Institutions/experts: IGBP (S. Seitzinger), LOICZ, Utrecht University (A.F. Bouwman)

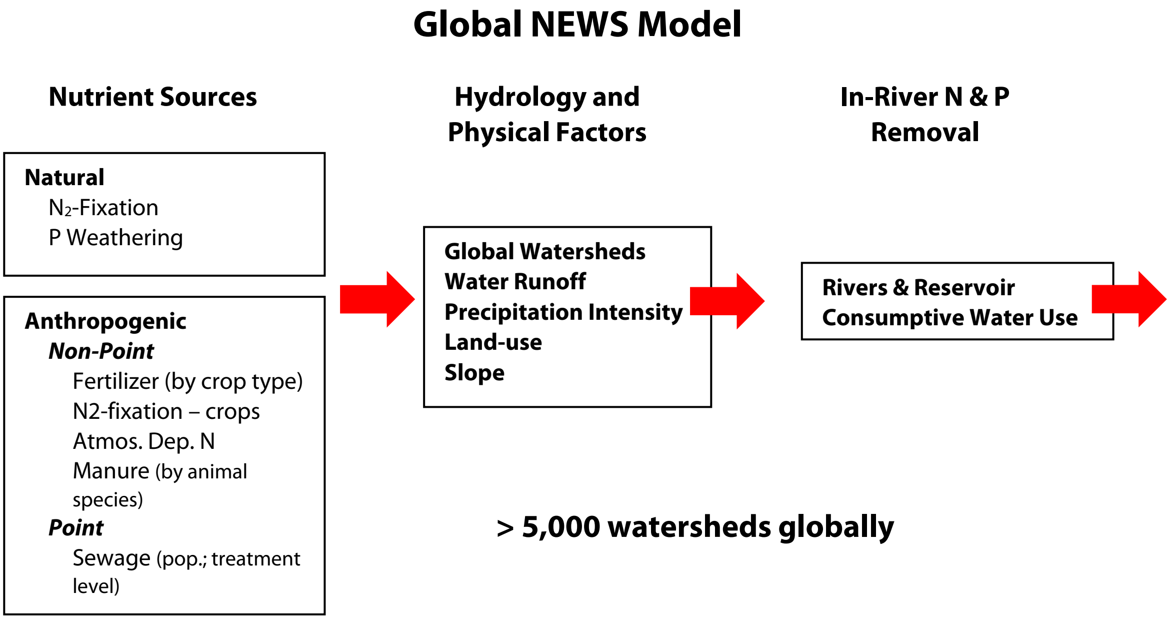


Figure 10. Schematic of some of the major inputs and controlling factors in the Global NEWS watershed river export model. (Source: Seitzinger and Lee, 2008)

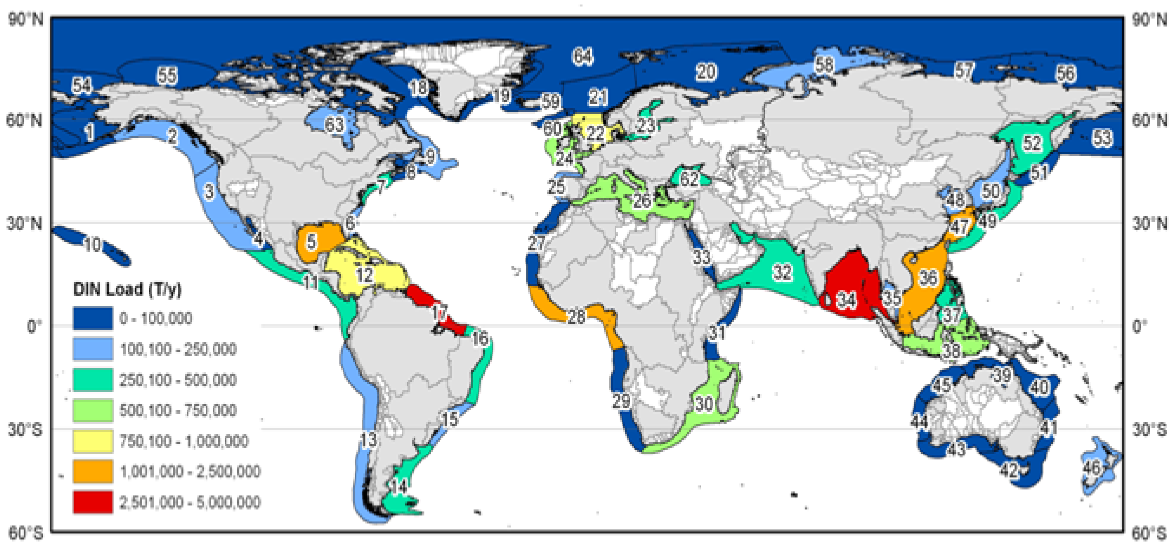


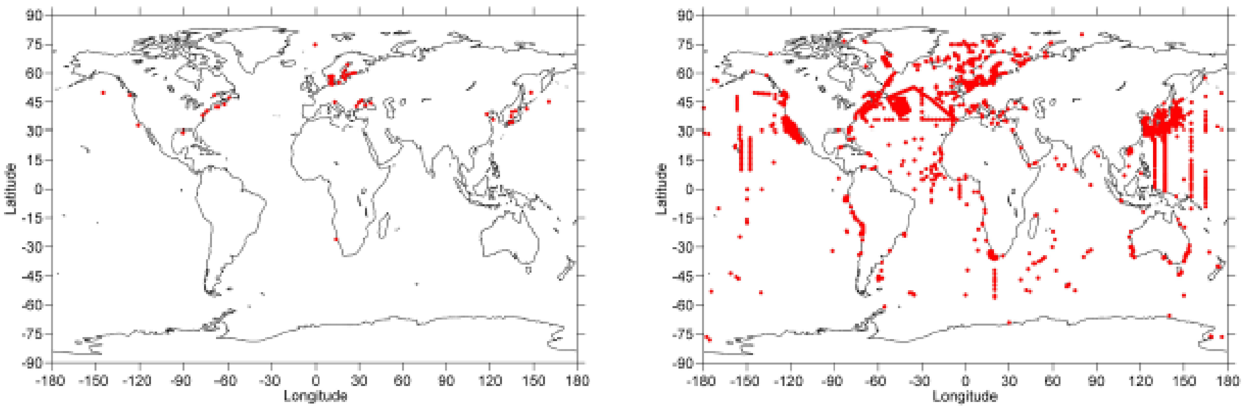
Figure 11. DIN inputs to LMEs from land-based sources predicted by the NEWS DIN model. Watersheds discharging to LMEs are grey; watersheds with zero coastal discharge are white. (Source: Seitzinger and Lee (2008))

Negative trends in dissolved oxygen concentration

Relevance: Permanent or seasonal dissolved oxygen (DO)-depleted or hypoxic (dead) zones appear to be increasing globally. Hypoxia has pronounced adverse effects on marine communities and fisheries, and also increases emissions from the ocean of the potent greenhouse gases methane and nitrous oxide. The development of hypoxic zones, particularly on the continental shelves and in enclosed basins, is strongly linked to eutrophication arising from input of nutrients from human activities, mainly on land. Global warming is also predicted to result in a generalized decrease in DO concentrations in the global ocean.

Methodology and data availability: The indicator would be calculated as the proportion of all data series within an LME that show a net negative trend in DO concentration. Scientific Committee on Ocean Research (SCOR) working group 128 has established a dataset based on (1) published time-series and (2) DO measurements, using time-series ≥10 years and using appropriate methods (Gilbert, *et al*., 2010) (Fig. 12). This is probably the best available global dataset on long-term DO concentration trends.

Institutions/experts: GESAMP; SCOR; US National Oceanographic Data Center; International Council for the Exploration of the Sea; Integrated Science Data Management, Dept. of Fisheries and Oceans, Canada; Institute of Ocean Sciences, Sidney, BC, Canada; Carbon Retention In A Coloured Ocean Project (CARIACO).



a. Station locations (red dots) of digitized oxygen concentration time series from refereed journal publications.

b. Station locations (red dots) of oxyen concentration time series calculated from a global oxygen database.

Figure 12. Oxygen concentration time-series. (Source : Gilbert, *et al*. (2010))

OTHER INDICATORS

Shipping density

Relevance: Shipping can be a significant or dominant source of several categories of pollutants, including tributyltin (TBT) and hydrocarbons, and in some areas of deposition NO_x and SO_2 from air emissions. Shipping is also the dominant source of distant anthropogenic sound in the ocean.

Methodology and data availability: Methodologies have been developed for quantitative estimation of ship-sourced inputs of some contaminants, including copper, TBT, and hydrocarbons as a function of ship traffic, but such estimates are generally a deterministic function of shipping volume/density or require more detailed information such as ship type and cargo. Shipping density captures all the information of deterministic methods needed to estimate contaminant inputs. More detailed information on shipping profiles is not likely to be widely available to support contaminant input estimation that requires such information, leaving shipping density as the best available indicator. This assumption requires further investigation during the FSP. Data on ship traffic are available for various time periods through the NOAA Voluntary Observing Ship (VOS) Program, through which volunteers provide weather observations from ships (www.vos.noaa.gov), automatic identification systems (AIS), which are primarily a short-range navigation and anti-collision tool (www.marinetraffic.com/ais), and Long-Range Identification and Tracking (LRIT), a satellite-based system that in 2009 became mandatory under the SOLAS convention. These systems provide accurate, spatially-referenced data on shipping traffic, ship type, ship size, and flag state. Indicator calculation to be determined.

Institutions/experts: GESAMP, International Maritime Organization (IMO).

Persistent Organic Pollutants and marine mammals

Relevance: An indicator with a high level of integration is proposed. The top levels of food chains have the tendency to biomagnify POPs from their food sources. Certain Arctic species, particularly those at the upper end of the marine food chain such as marine mammals as well as birds of prey, carry high levels of POPs (AMAP, 2004). Marine mammals and birds and their prey may therefore have great potential as high-level indicators of the status of POPs in the marine environment.

Methodology and data availability: Aguilar, *et al*. (2002) first provided a global overview of DDT and PCB levels in bottlenose dolphin, harbour porpoise, fin whale and harbour seals (Fig. 13). Their data covered mainly Europe and North America. Aguilar, *et al*. (2002) noted that the interpretation of the spatial and temporal patterns of variation in organochlorine concentrations in marine mammal populations is complex because of the lack of wide-scale, long-term surveys.

Institutions/experts: International Whaling Commission (IWC), AMAP, GESAMP New and Emerging Issues Correspondence group on: 'The biomagnification of contaminants in marine top predators and its ecological and human health implications'.

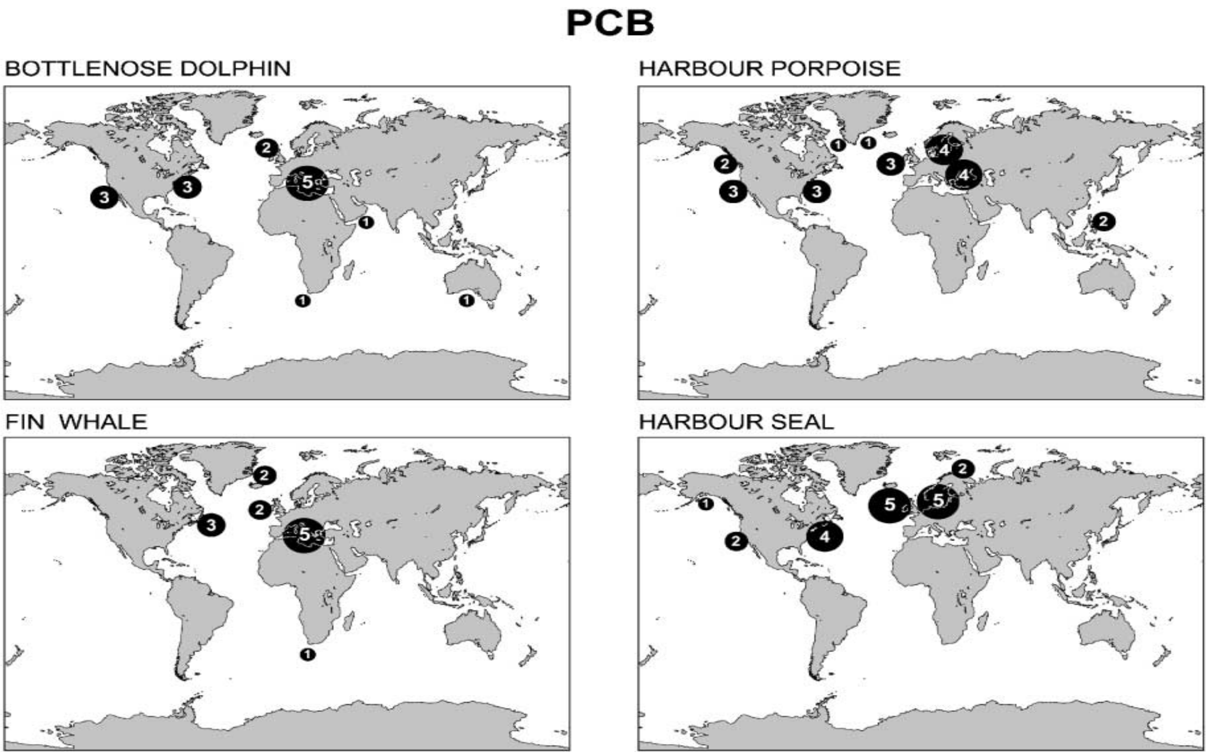


Figure 13. Relative PCB blubber concentration of selected marine mammal species:
Bottlenose dolphin: 1, <10 mg/kg; 2, 10–30 mg/kg; 3, 30–100 mg/kg; 4, 100–500 mg/kg; 5, >500 mg/kg.
Harbour porpoise: 1, <5 mg/kg; 2, 5–12 mg/kg; 3, 12–25 mg/kg; 4, 25–50 mg/kg; 5, >50 mg/kg.
Fin whale: 1, <1 mg/kg; 2, 1–2.5 mg/kg; 3, 2.5–5 mg/kg; 4, 5–10 mg/kg; 5, >10 mg/kg.
Harbour seal: 1, <2 mg/kg; 2, 2–5 mg/kg; 3, 5–10 mg/kg; 4, 10–20 mg/kg; 5, >20 mg/kg
(Source: Aguilar, *et al*. (2002))

Cadmium and lead

Relevance: Lead and cadmium are hazardous metals produced from natural as well as anthropogenic sources. Both metals have specific and significant hazards to human health and the environment, and are the subject of current consideration by UNEP's Governing Council. This is a broad-based indicator of pollution, based on the change in lead and cadmium concentrations in environmental media, locally, regionally, and globally relative to background levels and/or appropriate environmental quality standards.

Methodology and data availability: In both cases, the options for developing indicators would have to rely on long-term monitoring of air, water, sediment and/or biota, that is, tapping into existing monitoring programmes worldwide. UNEP (2008)[5] and GESAMP (2010) contain information on atmospheric and water-borne transport as well as residue levels in marine biota. For lead, there is only a handful of modelling studies, restricted to Europe and North America. The situation is similar for cadmium, although in this case atmospheric transport models are unknown.

Institutions/experts: Regional Seas Programmes, UNEP Division of Technology, Industry and Economics (DTIE) Chemicals Branch, UNIDO, GESAMP Metals Working Group.

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[5] http://www.chem.unep.ch/Pb_and_Cd/SR/Draft_final_reviews/Pb_Review/Final_UNEP_Lead_review_Nov_2008.pdf.

Harmful algal blooms

Relevance: The two most acute symptoms of eutrophication are hypoxia or 'dead zones' and HABs. Of the 415 areas around the world identified as experiencing some form of eutrophication, 169 are hypoxic and only 13 systems are classified as 'systems in recovery' (Selman, *et al*., 2008). Algal blooms can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems and their services, threatening the health and livelihoods of communities that depend on these services.

Methodology and data availability: Data on HABs are being compiled by IOC-UNESCO HABs programme (http://www.ioc-unesco.org/hab). Regional initiatives include NOAA Harmful Algal Blooms Observing System (HABSOS) for the Gulf of Mexico as well as GEF LME projects. An extensive literature review to catalogue systems experiencing any symptoms of eutrophication, including, but not limited to hypoxia, has been conducted by Selman, *et al*., (2008), and provides a global map of hypoxia events.

Institutions/experts: IOC HABs Programme.

Freshwater discharge

Relevance: Human activity (e.g., land-use changes, impoundment of natural water courses) and climate variability are altering the natural input of freshwater (along with nutrients and silt) to coastal areas, transforming coastal habitats such as deltas, estuaries, mangroves, seagrass beds, and coral reefs. Alteration of these habitats has serious consequences for their overall ecological function and for the provisioning of ecosystem services and the human communities and socio-economic activities that depend on them.

Methodology and data availability: Global NEWS model (Refer to methodology section on Nutrients)

Institutions/experts: IGBP; FAO Aquastat.

Sediment discharge

Relevance: Suspended sediment in a river basin serves as an effective carrier for exporting nutrients as well as contaminants such as pesticides and heavy metals to coastal areas. Excessive sediment loads smother critical habitats such as coral reefs and seagrasses. Human modification of basin-wide hydrography by dam construction, water diversion, and other activities, as well as by changes in land use, has largely altered the sediment load to coastal waters, inevitably affecting the nature of coastal ecosystems and their services.

Methodology and data availability: Global NEWS model (Refer to methodology section on Nutrients)

Institutions/experts: IGBP, LOICZ, others.

MARINE HABITATS

Marine habitats provide a broad range of ecosystem services with direct and indirect benefits for human well-being, including: food provisioning, coastline protection from weather and erosion events, recreation and tourism, water filtration, and soil formation (Nellemann, *et al*., 2009), as well as carbon sequestration. Coastal ecosystems form an extensive and highly biologically productive landscape that includes coral reefs, beaches and dunes, estuaries, lagoons, saltmarshes, mangrove forests, and seagrass beds. Approximately half of the world's cities with more than half a million inhabitants lie within 50 km of the coast and represent direct beneficiaries of the ecosystem services provided (Agardy and Alder, 2005; TEEB, 2009). Previous work undertaken by the 2010 Biodiversity Indicator Partnership (BIP) prioritized the development of an 'extent of assorted habitats' indicator to assess global progress toward the CBD's target to reduce biodiversity loss by the year 2010. This indicator is still in development and currently focuses on coral reefs, mangroves, and seagrass beds. Data limitations preclude the use of *change* in habitat extent as an indicator for a global comparative assessment.

The CBD represents only one of the many conventions established by the international community that is concerned with the protection of 'critical' marine habitats, i.e. those that provide essential ecosystem services and are also seriously threatened. A number of critical habitats have been identified through the review of biodiversity- and marine-related international conventions (Table 2), and they are proposed as indicators for the TWAP LME assessment. See background paper on TWAP website.

Table 2. Critical habitats identified through international Conventions and Frameworks.

HABITAT	CONVENTION AND FRAMEWORKS				
	CBD	MA	WSSD	Ramsar	IMO
Coral reefs	x	x	x	x	x
Mangroves	x	x	x	x	x
Seagrasses	x	x	x	x	x
Beaches and dunes		x			
Deltas				x	
Estuaries		x		x	
Tidal/mud flats		x	x	x	
Kelp forests		x			x
Lagoons		x		x[6]	
Saltmarshes		x		x[6]	
Shellfish reefs	x				
Cold water corals	x				
Cold seeps	x				
Hydrothermal vents	x				
Seamounts	x				
Sponge reefs	x				

CBD: Convention on Biological Diversity;
MA: Millennium Ecosystem Assessment;
WSSD: World Summit on Sustainable Development;
IMO: International Maritime Organization

The following core indicators were provided by UNEP-WCMC. Other potential indicators are included in the background working paper prepared by UNEP-WCMC (see TWAP website).

[6] near-shore marine areas

CORE INDICATORS

Seamounts at risk

Relevance: Seamounts represent key areas for biodiversity in the open ocean, supporting a range of vulnerable habitats, such as cold-water corals, and providing habitats for a large number of species including commercial fish. Seamounts are seriously threatened and disproportionately targeted by destructive fishing practices, such as bottom trawling, compared to other areas of the continental slope. Seamounts provide secondary habitats for cold-water corals and sponge beds, in addition to also being associated with hydrothermal vents and cold seeps. Seamounts are of interest to the CBD.

Methodology and data availability: SeamountsOnline (http://seamounts.sdsc.edu) holds data on species that have been recorded from seamounts. Global data layer has been compiled from multiple data sources. The data set represents one of the most up-to-date information sources available for hydrothermal vent and cold seep locations. Both hydrothermally-active and non-active seamounts are included, though the coverage is better for non-venting seamounts.

Institutions/experts: UNEP-WCMC; Census of Marine Life – Censeam/OBIS; National Institute of Water and Atmospheric Research; University of California, San Diego; UBC.

Change in protected area coverage

Relevance: Terrestrial and Marine Protected Areas have been identified by the international community as a key indicator of success towards reaching the 2010 Biodiversity Target implemented by the CBD. It is acknowledged that the existence of protected areas does not necessarily mean that they are effectively managed. Therefore, the assessment should also consider the effectiveness of protected areas (based on a clear definition of effectiveness).

Methodology and data availability: Global data layer has been compiled by UNEP-WCMC from multiple data sources. This indicator is derived from the World Database on Protected Areas (WDPA), considered the most comprehensive global spatial dataset on marine and terrestrial protected areas. Data is submitted by national governments or approved NGOs in a variety of formats. It is then processed into a standard GIS format and published online.

Institutions/experts: UNEP-WCMC, IUCN-World Commission on Protected Areas (WCPA)

Change in extent of mangrove habitat

Relevance: Mangrove forests have been identified as extremely valuable in terms of their ecosystem services and benefits, supporting coastal populations directly through a wide array of timber and non timber-related products, as well as adjacent seagrass and coral habitats via supporting and regulating services. Mangroves are currently under serious threat from deforestation and land-use change, as well as anthropogenic climate change. Mangroves are included in the following international frameworks: CBD; MA; WSSD; RAMSAR; and IMO.

Methodology and data availability: Global extent of mangrove coverage is available globally and change in extent (area) of mangrove habitat is possible for limited locations. Global data layer has been compiled by UNEP-WCMC from multiple data sources at a wide range of scales, in collaboration with the International Society for Mangrove Ecosystems, and recently published in the new World Atlas of Mangroves of the World.

Institutions/experts: UNEP-WCMC; International Society for Mangrove Ecosystems; FAO; International Tropical Timber Organization; United Nations University Institute for Water, Environment, and Health; The Nature Conservancy.

OTHER INDICATORS

Percentage extent of saltmarsh habitat

Relevance: Saltmarshes are largely sub-tropical and temperate in distribution, and provide a geographical complement to other available habitat datasets that are largely tropical. They are also critically important ecosystems for a range of ecosystem services, including carbon sequestration, wastewater processing, and shoreline protection.

Methodology and data availability: Data on saltmarshes are compiled from a range of sources, including published and grey literature, databases, conference proceedings, and direct communication with experts. The primary database was built in Microsoft Access with the spatial database components also compiled into a map using ArcGIS 9.0. There are five main tables: location, species, protected areas, international protected areas, and estuaries. Data are for indication of state in 2005, with no time-series component. Currently, it is point-based only and needs to transition to polygons (LMEs). Remote sensing may assist the development of polygons, but there are substantial technical challenges to implementing this, making the process time-consuming and costly.

Institutions/experts: UNEP-WCMC; The Nature Conservancy

Extent of seagrass habitat

Relevance: Seagrass beds are currently under serious threat from land conversion, as well as anthropogenic climate change. They are closely linked and interdependent on the functioning of other tropical, coastal marine ecosystems including mangrove forests and warm water coral habitats. Seagrasses are included in the following international frameworks: CBD; MEA; WSSD; RAMSAR; and IMO.

Methodology and data availability: This indicator is derived from the most comprehensive global data set on seagrass habitat extent currently available. Major sources of data were scientific papers and collaborators in a wide range of formats. Data conversion was required and validation was undertaken through a global seagrass workshop comprising experts from 23 countries. All points in the dataset are fully documented with their own metadata, including individual reference.

Institutions/experts: UNEP-WCMC; Dr Frederick T. Short (University of New Hampshire).

ECOSYSTEM INDICES

Reefs at risk index

Relevance: Coral reefs face a wide and intensifying array of human-related local threats, including impacts from overfishing, coastal development, agricultural runoff, and shipping. The global threat of climate change has begun to compound these local threats in multiple ways. Coral reefs are included in the following international frameworks: CBD, MA, WSSD, RAMSAR and IMO.

Methodology and data availability: This indicator is derived from the most comprehensive global data set on coral reef extent currently available. The data set has been compiled from a number of data sources (including the Millennium Coral Reef Mapping Project of the Institute for Marine Remote Sensing, University of South Florida (IMaRS/USF) and Institut de Recherche pour le Développement (Centre de Nouméa), which have been compiled by UNEP-WCMC, the WorldFish Center, and the World Resources Institute (WRI). Local threats are combined with modelled future estimates of thermal stress and ocean acidification to predict threat to reefs in 2030 and 2050 (the 'integrated local threat and future climate-related threat index'). In the absence of complete global information on reef condition, this analysis represents a pragmatic hybrid of monitoring observations and modelled predictions of reef condition. Full methodology available at http://www.reefsatrisk.wri.org.

Institutions/experts: WRI; UNEP-WCMC; The WorldFish Center; The Nature Conservancy; NOAA; others.

Deltas at risk index

Relevance: Transboundary deltas will be treated as a smaller assessment unit within LMEs. Deltas are hotspots of anthropogenic and climate-change impacts, to which the human communities that inhabit them are highly vulnerable. Close to half a billion people live on or near deltas, with additional populations and activities in the upstream watersheds. Global climate change in combination with human activities will directly affect deltas, potentially producing catastrophic change on a decadal scale, with severe consequences for delta communities, particularly in developing regions. Deltas are areas where interlinkages between LMEs and Rivers are particularly pronounced, and are of special interest in TWAP.

Methodology and data availability: A working group (5 -10 people) will be formed to develop the Deltas at Risk Index. A number of the parameters are linked to the proposed TWAP Rivers, Lakes, LMEs, and Open Ocean indicators (in particular, population, nutrient loading, and fish and fisheries). This would provide consistency with the other major water systems in the TWAP process. See template for preliminary list of parameters.

Institutions/experts: IGBP/LOICZ (Lead); James Syvitski (University Colorado); V. Christensen (University British Columbia); B. Halpern (University California Santa Barbara); L. Wood (UNEP - WCMC).

Cumulative human impacts on marine ecosystems

Relevance: Effective management of marine ecosystems requires information on where and how much human activities are affecting the health of these systems, and these assessments need to be comprehensive, not just within a single sector. By comparing the relative impact of individual or sets of stressors within a given geography, one can, for example, determine the top threats to the region or the relative contribution of stressor(s) to overall ocean degradation. This in turn helps highlight hotspots of impact from different stressors, as well as where and how much different management actions might be able to mitigate cumulative impacts.

Methodology and data availability: See Annex 6 for a summary of the methodology. The cumulative impact assessment tool developed in collaboration with dozens of scientists from around the world (Halpern, *et al*., 2008) represents the only existing tool for comprehensively assessing the cumulative impact of all human activities on the state of all marine ecosystems at a global scale, in turn providing an assessment of ocean health. The tool allows one to produce results tailored to any area of interest, including LMEs, to provide a directly comparable assessment of human impacts in these areas. The cumulative impact tool requires three types of data: maps of each habitat, maps of the intensity of stressors (drivers) of interest, and vulnerability weights for each stressor-habitat combination. Data with global coverage are available for 20 different marine habitats and 17 human activities and associated stressors. If higher quality or additional data exist, these can easily be incorporated to ensure that the most current information is included in model analyses. Cumulative impact is calculated as the sum of the weighted impact of each stressor, at a given intensity, on each ecosystem, summed into a single, directly comparable measure of ecosystem condition. See Halpern, *et al*. (2008) and background paper on TWAP website for methodology description and data sources.

The mapping tool can be tailored to the priority regions of TWAP (LMEs, open oceans) as well as other UNEP/GEF priorities, such as SIDS, and can be expanded to account for forecast stressors, allowing for a powerful ability to evaluate different management scenarios. This tool has already been successfully applied to the Baltic Sea LME.

Institutions/experts: B. Halpern (University of California, Santa Barbara) and partners.

Ocean Health Index

Relevance: A large, multi-institution collaborative effort is underway to develop an Ocean Health Index (OHI). This will be a new, quantitative composite index that captures the state of ocean ecosystems, where health is defined as the combined status of natural systems and human communities that benefit from these systems. It is based very closely on the framework being adopted by TWAP due to individuals and organizations that are involved in both efforts. As such, most of the products from OHI will be directly relevant to TWAP, making incorporation of the data and indicators from OHI into TWAP fairly seamless. It will allow a very quantitative ranking across all aspects of TWAP, either in aggregate or for individual indicators, for LMEs and open ocean systems. This could become a core index when finalized.

Methodology and data availability: Individual indicators within the OHI will measure changes in the intensity of the most critical ocean stressors (climate change, ocean acidification, direct exploitation by fisheries, habitat destruction, eutrophication, chemical contamination, plastics pollution, sonic pollution, invasive species, etc.), their direct effects on the ocean, impacts on ocean subsidies and services, and consequences for human well-being. These various component indicators will then be synthesized into a single index that captures the overall health of the system. OHI will be global in scope but will also focus on a number of case study locations to test and validate the ability of the Index to capture the local-scale health of the system. Case study locations for the first several years are likely to include the following LMEs: U.S. Northeast Shelf and Scotian Shelf, Northeastern Australian Shelf-Great Barrier Reef, Benguela Current, Mediterranean Sea and Gulf of Mexico. Other regions of special interest include the U.S. Arctic, South China Sea, California Current, Patagonia, and the Eastern Brazil Shelf LMEs.

The completed index will be launched in June 2012. Indicator and index values will be recalculated and published annually (or as frequently as new data become available) and will continue indefinitely, depending on resources.

Institutions/experts: Conservation International, the National Geographic Society, and the New England Aquarium, and others.

Socio-economic

Capital, vulnerability and wellbeing

Previous work on the human dimensions and socio-economics of LMEs include that of Sutinen (2000) and Hoagland and Jin (2006) (Annex 7). Sutinen (2000) developed a framework for monitoring and assessment of the human dimension of LMEs and for incorporating socio-economic considerations into an adaptive management approach for LMEs. Hoagland and Jin (2006) used indices of socio-economic activity based on data from several marine economic sectors, including fish landings, aquaculture production, ship building, cargo traffic, merchant fleet size, oil production, oil rig counts, and tourism between 2002 and 2004, to compare marine industry activity with indices for socio-economic, fishing and aquaculture, tourism, shipping, and oil activities. A summary ranking of LMEs by area-adjusted marine industry activity was produced. These approaches were examined during development of the TWAP methodology.

Following discussions among all TWAP WGs, UNEP and GEF, it was agreed to develop a common approach to socio-economic assessment for all five TWAP water systems, that would focus on human vulnerability and livelihoods. This approach was subsequently developed by the TWAP Socio-economics and Governance Corresponding Working Group, led by one of the LME WG experts, Liana McManus (University of Miami). See Volume 1 for a detailed description of the approach.

<u>Conceptual framework and relevance</u>

Valuation of economic activities provides an incomplete picture of the real value of the ecosystem services that natural ecosystems provide. Assessing economic as well as social well-being and vulnerabilities provides a more complete picture of human-environment interactions. Using the conceptual framework in Fig. 2 above, indicators to describe marine-based livelihoods such as fishing and tourism (box 2), the ecological stresses these generate (box 3), and the well-being of marine livelihood-dependent communities (box 6) are identified at national and sub national (geopolitical subdivisions to households) scales. The availability of data to support the development of these indicators is also assessed.

It is important to note that the extent to which marine-based economic activities are developed varies across coastal states. Developing countries rely heavily on natural resources so that fishing and tourism at small and medium scales are major livelihoods in the coastal zone. For developed nations, heavy technology-based industries such as shipping and manufacturing as well as cruise tourism dominate. Furthermore, it is important to keep in mind that economic data are easier to obtain for industrial-scale economic activities than for small-scale livelihoods such as artisanal or small-scale commercial fisheries or ecotourism ventures. Thus, for developing countries where small-scale enterprises in fishing and tourism are critical for livelihood provision and poverty mitigation, the need for indicators should spur systematic and operational data collection to support integrated assessments.

Socio-economic indicators for integrated assessments of LMEs

Table 3 presents a preliminary but comprehensive list of socio-economic indicators, subsets of which may be used to: a) study the socio-economic correlates of fisheries exploitation; b) examine vulnerability and resource dependency of fishers and tourism operators or employees, especially in developing countries; and c) assess the socio-economic dynamics at local and national scales that determine the well-being of coastal communities and the sustainability of livelihoods in fisheries and tourism.

Each indicator consists of one or two metrics at the most to maintain clarity of measurement. Aggregate or composite indicators known as indices may be computed using a combination of at least two indicators, and weighted according to preference. An example of a widely-accepted index is the Human Development Index (HDI), which, in its most current version, includes four indicators: years of life expectancy, the adult literacy rate, the combined gross school enrolment ratio and the logarithm of the Purchasing Power Parity GDP per capita (McGillivray and Noorbakhsh, 2004).

National numeric indicators will be aggregated to the LME scale. While length of coastline was used by Hoagland and Jin (2006) to weight national-scale data, other weighting factors can be used such as proportion of coastal rural and urban populations. The use of population weighting factors also would allow for estimates to be expressed on a per capita basis where appropriate.

Data to support estimation of social indicators that measure human, social, physical and financial capital are not necessarily available at a national scale. However, case studies at local, regional and supranational scales provide narratives and data that may be coded and analysed alongside national-scale indicators and provide rich contexts for examining quantitative metrics. The use of case studies is an approach that has been used by the OECD (2000) in its study of transition trends to responsible fisheries, by Kronen, *et al*. (2010) in examining socio-economic drivers for artisanal coastal fisheries in the Pacific island countries, and by Béné, *et al*. (2010a, 2010b) to analyse fish trade in Africa.

By choice, only numeric indicators are included in the tabulation. While qualitative indicators are needed to supplement quantitative measures to achieve a holistic assessment of how policies impact marine based livelihoods, it is deemed important to concentrate on measured indicators during the current phase of method development. Narratives provided by case studies at local scales do include qualitative dimensions of policy impacts, and thus offer richer contexts beyond what can be captured by numeric indicators.

Methodology and data availability

The socio-economic assessment of LMEs will quantify water resource-based livelihoods in terms of GDP. It will measure levels of human wellbeing and its vulnerability to climate related disasters. Indicators of human well-being (e.g., life expectancy, adult literacy, disease) are combined in the HDI, which will be one of the core indicators. The distribution and growth of human populations relative to the coast along a rural and urban divide provides the spatial context for the socio-economic analysis. Bibliographic citations for examples of case studies that can be used in tandem with national scale indicators are given in Volume 1.

Institutions/ Experts: University of Miami Rosenstiel School of Marine and Atmospheric Science/ L.Talaue-McManus.

Table 3. Socio-economic indicators for measuring impacts of policy goals applied to marine-based livelihoods such as fishing and tourism. Indicators in black are those that require fine-scale case studies. Indicators in blue/green are core across the five TWAP transboundary water systems.

(See Volume 1 and background paper on TWAP website for details on this approach).

POLICY GOAL	COMPONENT	SCALE	INDICATOR / METRIC	DATA SOURCES
1. INCREASE CAPITAL WITHIN SUSTAINABLE LEVELS	**1.1 Social capital**	Local and national	Number of livelihood-based associations or cooperatives	Case studies
		Local and National	Number of NGOs/ civil society groups working on livelihood issues (e.g. fishing, tourism)	Case studies
	1.2 Human capital	Local	Adult employed or self-employed household members with primary education	Case studies
			Number of family members with marketable skills or with potential for employment outside of marine based livelihoods	Case studies
		National	Literacy rate among rural and urban populations	World Bank's Rural Development Indicators Handbook (World Bank, 2000)
	1.3 Natural capital	Local and National	Proportion of marine-based livelihood income to total household income	Case studies
	1.4 Physical capital	Local	Number of boats owned/fishing household	Case studies
			Number of fishing gear owned/ fishing household	Case studies
			Number of boats accessed as crew member/ fishing household	Case studies
			Area of agriculture land owned/ fishing household	Case studies
	1.5 Financial capital	Local	Total income from marine based livelihoods/ household	Case studies
			Total income from non-marine based activities/ household	Case studies
			Remittances/coastal household/year	Case studies
			% local tourism employees/ local population	Case studies
			% GDP fisheries	FAO and national databases
			% GDP international tourism	World Bank WDI

POLICY GOAL	COMPONENT	SCALE	INDICATOR / METRIC	DATA SOURCES
2. REDUCE VULNERABILITY	**2.1 To natural disasters**	Local	Urban and rural populations living within 10 m coastal elevation	SEDAC (Columbia University) Low Elevation Coastal Zone Urban-Rural Population Estimates
		National	Per capita damages in purchasing power parity from all natural disasters	Climate Risk Index 1990-2008 (National) (Other climate change indices may be considered – eg GAR 2009 report)
	2.2 To disease	Local and National	% households with improved potable water and sanitation	World Bank Data (Topic: Infrastructure)
	2.3 To economic fluctuation	Local	% households with marine based livelihoods providing at least 50% of income	Case studies
			Remittances received (USD/ coastal household/year)	Case studies
			Number of active microfinance loans per year	Case studies
			% non-marine based livelihood annual household income	Case studies
			% foreign owned tourist establishments	Case studies
		National	% population below $1/day	World Bank World Development Indicators
			Income inequality using WEALTH GINI coefficient	World Bank World Development Indicators
3. ENHANCE WELL-BEING	**3.1 Universal education**	National	Life expectancy at birth	WHO Global Burden of Disease in Disability-adjusted Life Year (DALY) rates
	3.2 Gender equality			
	3.3 Reduce child mortality			
	3.4 Improve maternal health			

OTHER INDICATORS

Marginal Economic Value of marine and coastal ecosystem services

Relevance: The use of Marginal Economic Value (MEV) will be of more relevance to policy-making decisions than Total Economic Value (TEV, see below). This is because the decisions to be made generally involve incremental changes (improvement or deterioration) in the provision of environmental goods and services, and it is these marginal changes that actually matter. Taking into account that the relationship between the economic value of marine and coastal ecosystem services and coverage areas tend to be non-linear (Barbier, *et al*., 2009), MEV provides a more useful tool to identify how small changes in the destruction of habitats will have an impact on the services provided by these ecosystems.

Methodology and data availability: It is possible to work out the TEV of a small change in a resource such as marginal TEV, which is the additional value gained or lost by a small change in the provision of a flow, or in the level of a stock. A demonstration project is being developed through the Southeast Pacific Action Plan.

Institutions/experts: UNEP Regional Seas Programme, McGill University, UN Economic Commission for Latin America and the Caribbean, the Andean Development Bank.

Total Economic Value of ecosystem goods and services and natural capital

Relevance: Costanza, *et al*. (1997) have calculated that the coastal waters encompassing LMEs annually contribute US$12.6 trillion to the global economy. Although this estimate does not reflect the benefits or costs of marginal changes in marine ecosystem goods and services, it highlights the critical importance of LMEs to the economies of the world. The economic value of an LME is equivalent to the net present value of goods and services that flow from uses and non-uses of its resources and environment.

Methodology and data availability: It is proposed that updated estimates of the value of the goods and services of all LMEs be produced under the TWAP full size project. The global estimate by Costanza, *et al*. (1997) was based on published studies and original calculations, based on 17 services, including climate regulation, hydrographic flows, water supply, erosion control, sediment retention, nutrient cycling, waste treatment, tropho-dynamics and biological control, habitats for resident and transient populations, food production, raw materials, genetic resources, opportunities for recreational activities, and the aesthetic, educational, cultural and scientific values of marine ecosystems.

Institutions/experts: Porter Hoagland and Di Jin (Marine Policy Center at Woods Hole Oceanographic Institution (WHOI).

Governance

TWAP common approach to governance assessment

Previous work on LME governance includes that of Juda and Hennessey (2001), who explored and mapped governance profiles of LMEs, and Olsen, *et al*., (2006), who developed an approach to track progress in ecosystem-based LME governance through four orders of outcomes (Annex 8).

Following discussions among all TWAP WGs, UNEP and GEF, it was agreed to develop a common approach to governance assessment for all five TWAP transboundary water systems, which could be adapted for each water system. This approach was subsequently developed by a group of experts, led by Robin Mahon and Patrick McConney (UWI CERMES) and Lucia Fanning (Marine Affairs Programme, Univ. Dalhousie), in collaboration with the TWAP CWG on Socio-economics and Governance. It is based on a governance working paper prepared for TWAP (Mahon, Fanning, and McConney, 2010) (available on the TWAP website) and discussions with the GEF Secretariat and the TWAP project secretariat on the need for a new and comprehensive approach to assessing governance in international waters. Governance fits into boxes 1a and 1b in Figure 2.

The TWAP methodology will address governance assessment in two stages. See Volume 1 for a detailed description of the approach.

Stage 1 Assessment: LME governance architecture

This stage will consist of a preliminary assessment of governance arrangements, that is, the extent to which a transboundary governance framework is in place to address the key issues relevant to LMEs: water quality, fisheries, biodiversity, and habitat destruction. Some or all of these issues were found by the CWG to be relevant to all TWAP water systems. In addition, climate-change vulnerability, adaptation to and mitigation of climate change are recognized as being a component of all these issues. It is expected that as these issues are unpacked and the arrangements are examined, the vulnerabilities to climate change will be made explicit for each issue. Similarly, it is assumed that governance responses will include adaptation.

It is expected that all arrangement-level issues will fit into the above categories to facilitate comparison among LMEs. However, the performance or functionality of the arrangements will not be assessed in this level. Several steps are required to determine the governance architecture in place for a particular water system (Table 4). This will provide a picture of: the extent to which governance issues are covered (and allow identification of gaps); the match between governance arrangements and issues; the extent to which arrangements extend outside the system; the extent to which issues are covered by multiple arrangements that could result in conflict; and, how well arrangements are clustered to make best use of existing institutions and organizations.

Table 4. Steps required to assess governance architecture.

STEP	KEY POINTS
Identify system to be governed	Begin with a clear definition of the system to be governed. In the case of the GEF IW programme the system is considered to be the entire LME or other IW area. Geographical boundaries of the system and the countries involved in the transboundary system must be clearly identified. In the case of the GEF IW programme the system to be governed is considered to be the entire river basin, aquifer, lake or reservoir, LME or other IW area, or portion of the open ocean.
Identify issues to be governed	In some IW systems the issues will already have been identified through a TDA and may have been further explored through CCA. Issues may have both a topical and a geographical component.
Identify arrangements for each issue	Determine the extent to which each issue is covered by an identifiable arrangement, whether formal or informal. Must be specific to the issue and have a complete policy cycle. Each arrangement should have functionality in three modes: (1) the meta-mode (articulation of principles, visions and goals, equating to policies in Integrated Lake Basin Management (ILBM) parlance); (2) the institutional mode (agreed ways of doing things reflected in plans and organizations; (3) the operational mode, if it is to be adaptive and effective. These modes may operate at different scale levels within the same arrangement, hence the need for links within arrangements.
Identify clustering of arrangements within institutions	Examine the way that arrangements are clustered for operational purposes and/or share common institutions/organizations at different levels. Similar issues may be covered by similar arrangements. There may be efficiency in clustering these arrangements. Alternatively, clustering may occur at higher levels for policy setting or institutional efficiency, but be separated at lower levels.
Identify links	Identify actual and desirable links within and among arrangements and clusters.

The above process will be used to reduce the governance architecture for each system to a set of scores (see Volume 1 for more details). These will be derived from separate assessments of the issue-specific arrangements. The approaches to evaluating the arrangements may vary between systems and arrangements, ranging from highly expert judgment-based to being based on extensive analysis of multilateral agreements, protocols, institutional constitutions and other instruments, supported by sound science and knowledge of stakeholder opinion. The clustering and links among arrangements will be reflected in a matrix showing interactions between them.

Stage 2 Assessment: Performance of governance arrangements

The stage 2 assessment (see Volume 1 for details) will assess the functionality and performance of governance arrangements in terms of a broad range of criteria such as effectiveness, inclusiveness, efficiency, and equitability. This methodology remains to be developed and can be pursued by further integrating the governance models reviewed and presented in the TWAP LME governance working paper (Mahon, *et al*., 2010) and others such as the Integrated Lake Basin Management guidelines for lake brief preparation (RCSE, Shiga University and ILEC, 2010) into a comprehensive assessment process.

The stage 2 assessment will focus on systems that are sufficiently complete that there is some level of planning and review, and thus the setting of goals and objectives against which to assess governance performance. It will assess the presence, appropriateness, completeness and functioning of policy cycles according to agreed criteria and against agreed objectives. Links within governance arrangements as well as between them are a critical component of the governance system. The nature of the interactions is also relevant. A discussion of the criteria that can be used in assessing functionality of governance arrangements is provided by Mahon, *et al*. (2010). Ehler (2003) provides a comprehensive list of governance performance indicators that can be applied as appropriate in assessing policy cycles, while RCSE, Shiga University and ILEC (2010) presents a series of diagnostic questions that can be considered in evaluating water resources governance.

It is proposed that a Governance Working Group be formed to develop and oversee the stage 2 assessment, which should then be applied to about 20-40 selected IW situations drawn from the five IW categories. Working Group members should be drawn from a diversity of individuals and organizations actively working on concepts and applications of governance in natural resource systems. Among these are the Earth System Governance Project, The Resilience Alliance, the Fisheries Governance Network and the Program in Water Conflict Management and Transformation (Oregon State University). This working group should include members from all five TWAP water system categories.

Institutions/experts: CERMES (R. Mahon and P. McConney), Univ. Dalhousie (L. Fanning)

Other approaches

See Annex 8 for other approaches to evaluation of governance in LMEs:

- Mapping of LME Governance Profiles; and
- Governance mechanisms in ecosystem-based management.

3.4 SCORING OF INDICATORS AND RANKING OF LMES

A comparative assessment of the condition of LMEs requires an appropriate, consistent indicator scoring system and an overall 'index' of LME health. Such an index does not currently exist, and needs to be developed based on a shortlist of core indicators (robust 'vital signs') that are sensitive to external stressors, to enable comparative assessments of LMEs, including nested marine ecosystems such as estuaries as well as MPAs. With the primary aim of TWAP being to help GEF identify transboundary water systems for priority intervention, the scoring system should have a sufficient number of categories to identify LMEs 'at risk' for any particular indicator or issue. This should be done in consultation with GEF in accordance with its priorities for transboundary waters. A scoring system of 1 – 5 is proposed, with '1' representing the lowest, and '5' representing the highest performance for each indicator. This has been adapted from the TWAP Rivers methodology. Ideally, the indicators should be scored based on set targets for each indicator. However, as targets (where they exist) will vary according to LME and even countries, they would not be practical for a global comparative assessment of LMEs.

For each indicator, the LMEs will be ranked consecutively from the highest to the lowest value of the indicator. The LMEs will then be grouped into five categories according to the indicator values, with each category representing a score (1 to 5, from lowest to highest performance of the indicator), as shown in the following table. Thus, for any indicator, the first five LMEs with the highest value will be assigned a score of 1; the next ten LMEs with the second highest values will be assigned a score of 2; and so on (see following table). *Note: The number of scoring categories and number of LMEs in each category could be modified in the FSP*.

SCORE	NUMBER OF LMES
1	5
2	10
3	15
4	15
5	20

The main rationale behind the 'asymmetrical' categories is to try to highlight those LMEs at greatest risk from existing and projected stressors or showing the highest level of degradation based on the relevant status indicators. This approach helps to identify the two most at-risk groups (scores of 1 and 2 – approximately 15 LMEs), that is, those requiring investment/intervention related to a particular issue(s). The individual indicator scores would be combined (rolled up) at the LME scale to provide an overall index of LME condition (to be developed under the FSP). Results of the scoring exercise could be presented using a stop light or similar approach.

PART 4. INTERLINKAGES WITH OTHER WATER SYSTEMS

This chapter discusses key interlinkages between water systems, including input/output analysis, and common (cross-cutting) issues.

4.1 INTERLINKAGES BETWEEN WATER SYSTEMS

An important component of the TWAP assessment will be the key interlinkages with the other transboundary water systems. Dynamic interactions exist between LMEs and open ocean and rivers, and to a lesser extent, groundwater aquifers and lakes/reservoirs. These interactions are manifested as drivers of change and/or impacts of one type of transboundary water body on the other. For example, a major influence of rivers on LMEs is the introduction of land-based pollution to coastal areas. Groundwater aquifers in coastal areas often experience salt water intrusion (as a result of over-abstraction of freshwater and sea-level rise). Oceanographic processes in the open ocean can be manifested in LMEs. Transboundary water systems may be also linked through socio-economic activities and governance in watersheds. TWAP will attempt to identify and assess the key interlinkages among adjacent transboundary water systems to provide a holistic picture of the interactions between water systems. This kind of analysis for LMEs (coastal areas) is of growing importance and relevance in view of GEF's increasing focus on Integrated Coastal Management (ICM).

Interlinkages were identified based on a number of issues that are considered to be common among two or more the TWAP water systems. Indicators related to interlinkages between LMEs and other TWAP water systems are shown in Table 5. Assessment of interlinkages will take these interactions into consideration to provide an integrated, more comprehensive picture of the origin of stresses and impacts in transboundary water bodies (e.g., upstream/downstream interactions) and hence development of integrated management approaches to address the problems identified. Use of a consistent dataset for common parameters would be advisable, and is highlighted in Table 5. In this regard, the Global NEWS model will be of great applicability in facilitating this kind of analysis in the TWAP assessment.

4.2 INPUT-OUTPUT ANALYSIS

Of particular interest in assessment of interlinkages are the indicators and data that describe the output from one water system into another (input/output analysis). For example, input of agricultural fertilizers in terrestrial areas and eventually to rivers becomes an output to adjacent LMEs through river runoff. Another example is rise in sea level leading to saline intrusion (input) into coastal aquifers. Therefore, data are required to describe these inputs/outputs between water systems, with adaptation in the spatial scale and measurement units made as necessary (e.g,. input of fertilizer in tonnes/m^2 of agricultural surface area and output of nutrients to estuaries/LMEs as tonnes/m3 of river water discharge).

4.3 CROSS-CUTTING ISSUES

Initially, all five TWAP WGs were asked to consider five cross-cutting issues (water quantity, nutrients/eutrophication, vulnerability to climate change, biological productivity and mercury) that are relevant to all five TWAP water categories. This list was subsequently reduced to two – nutrients and mercury- while the three other cross-cutting issues are included as potential interlinkages between water systems. Climate change is cross-cutting among all five water systems and is addressed in the appropriate issues and indicators.

Table 5. Issues and examples of indicators linking TWAP water systems A consistent use of datasets for common parameters would be advisable, for consistency. Indicated in yellow highlighting are those indicators that are input data or model calculations at the 0.5 x 0.5 degree (latitude/longitude) scale globally from the NEWS model.

ISSUE	RIVERS	LMES	OPEN OCEAN	GROUNDWATER	LAKES
Alteration of natural freshwater discharge to coastal areas	▪ Average discharge (modelled) ▪ Impoundment density ▪ Irrigation water withdrawal	▪ Average river discharge (volume/year) to delta/LME (Global NEWS)			
Nutrients/ Eutrophication (biological productivity)	Fertilizer consumption (t/ha/year) Soil balance indicator (P:N)	▪ Nutrients (N, P, Si, C) inputs to delta/LME (t/year) - focus on DIN ▪ Primary productivity; Ch a; HABs (hotspots)	Atmospheric deposition of nitrogen	Leaching of nutrients into groundwater	Atmospheric deposition of nitrogen
Climate change	Standard Precipitation Index	▪ Average discharge (volume/year) to delta/LME ▪ Sea-level rise (SLR) ▪ Acidification ▪ SST ▪ Population in vulnerable areas (coastal) ▪ Annual losses from extreme climatic events	▪ SST ▪ SLR Acidification	Salinity (saline intrusion to coastal aquifers from SLR)	
Mercury	Industrial effluent	▪ Mercury conc. in water and animal tissue	Mercury conc. in water and animal tissue (migratory species)		
Sediment loads	Soil erosion vulnerability	▪ Sediment load to delta/LME			

ISSUE	RIVERS	LMES	OPEN OCEAN	GROUNDWATER	LAKES
Water quality	▪ Water quality index (DO, Electrical Conductivity (EC), pH, Total Phosphorus (P) (or Ortho Phosphorus), Total Nitrogen (N) (or DIN, Nitrate/Nitrite, Ammonia) ▪ Industrial effluent: Proportion of industrial effluent produced compared to total basin discharge ▪ Municipal effluent: Combination of population (number), sanitation coverage (percentage), and likely level of effluent treatment (Water Quality Index score)	▪ Nutrient (N, P, Si, C) inputs to delta/LME (t/year) ▪ Other land-based pollutants		Salinity (saline intrusion)	
Exchange of biota (possible unavailability of data to quantify)	Movement of anadromous and catadromous fish species		Migratory fish and marine mammals that straddle LMEs and Open Ocean areas		
Socio-economics	Land-based human activities that impact on LMEs (e.g. coastal urbanization/ population in coastal zone, agriculture, industrial activities).				
Response	Adoption/implementation of frameworks and monitoring programmes to address interaction between terrestrial and coastal areas, such as Integrating Watershed and Coastal areas Management (IWCAM), ICZM, and GPA in countries bordering LMEs; Pesticide regulation index				

PART 5. DATA AND INFORMATION MANAGEMENT

5.1 DATA AND INFORMATION SOURCES

The TWAP assessment will be mainly based on existing data and information, through partnerships with data holders, and not on the collection of raw data. The data used by TWAP should meet basic quality requirements and represent the best measure available. Data partners should produce data of sufficient quality, coverage, and frequency for the purposes of TWAP, and are expected to do so for the foreseeable future. TWAP and data partners will develop a data quality assurance policy that ensures the reliability of information used as the basis for the assessment. Four essential properties of data to be used in TWAP are:

- Global coverage (relevant data at the regional/LME level will also be included where available);
- Spatial data;
- Publicly available; and
- Validated.

Whilst an extensive number of regional and national initiatives exist that can provide important sources of data, the emphasis at the global scale will be to reduce the possibility of inconsistency in results and conclusions in the assessment and comparison of LMEs. For a global comparative assessment of LMEs (Level 1 assessment), temporal and spatial datasets with global coverage are required for the key indicators. However, data resolution and coverage (spatial and temporal) could present some constraints to a global assessment. Nevertheless, TWAP will be based on the best available datasets. Although there are gaps, significant amounts of data are available for the five LME modules, with the natural science modules being more developed. Available datasets at smaller, sub-global scales will be useful as descriptors for individual LMEs. Data collected at the country level would also be utilized as appropriate.

A summary of the major types of data and information to be used in TWAP and inventory of data sources is given in Annexes 2 and 3.

5.2 DATA AND INFORMATION MANAGEMENT

Key concepts and considerations

Data and information management will require a multi-faceted tool, aimed at multiple user-types and will allow the following two core types of 'data':

a. ***Soft data***: this is defined as the broad range of information related to the theme or topic. Soft data assembles scientific literature, bibliographic information, mainstream knowledge, commentary, news, multimedia materials, amongst other types of information, all linked to an identified theme or related assessment unit.

b. ***Hard data***: this is defined as the real numerical-based datasets that represent the results of scientific and/or investigative research specific to a theme or topic. Hard data assembles datasets from experimental, field and instrumental observations, theoretical modelling and other scientific and applied technical data types from various sources.

This includes the results of the assessment such as the values for each indicator/indices for each LME. Such data can be geo-referenced and mapped.

A key component of a successful implementation of the TWAP methodology is the assurance of access to the scientific data and information necessary to produce the various indicators used to assess, predict and monitor the status of LMEs. The following core assumptions are made when considering the roadmap towards the development of a data and information management system:

1. Data providers are a combination of national focal points and international scientific institutions/organizations/entities that provide transboundary information and data for global, regional, sub-regional and national scale indicators;
2. Data providers for the TWAP LMEs are numerous and distributed globally;
3. Data providers have an interest in the maintenance and longevity of their own data systems;
4. Data providers have limited financial and human resources to dedicate to a technical process designed to adapt their system to an external standard;
5. TWAP may require access to historical, new and real-time (or near real-time) data, metadata and information from multiple sources; and
6. TWAP will require a credible, efficient and transparent data quality control mechanism.

Based on the above assumptions, a number of scenarios are possible, and will need to be further defined. One important factor that will influence data management options for LMEs and TWAP as a whole is the desired level of 'centralization' and 'decentralization' of data and information among partners and the TWAP Secretariat. A centralized approach is where data from the partners are transferred to a local system managed by one of the TWAP partners, while a decentralized approach focuses on compiling an 'inventory' of data sources (i.e. metadata) with some of the actual data remaining with the remote data holders.

A data and information system for TWAP should, at the least, enable regular, credible and salient assessment of LMEs through the use of:

a. Assembled, quality-controlled and archived indicator information based on a broad range of credible, well-documented, scientifically derived data; and
b. A mechanisms providing for timely dissemination of diverse types of data and information.

For this, a proposed roadmap could include:

1. A centralized system, hosted by a TWAP partner, that can hold and share the 'hard' data on the final indicators plus the associated metadata (e.g. methodology) and derived products, linked to; and
2. A decentralized system set up for the discovery of the underlying data and information sources held by the data providers.

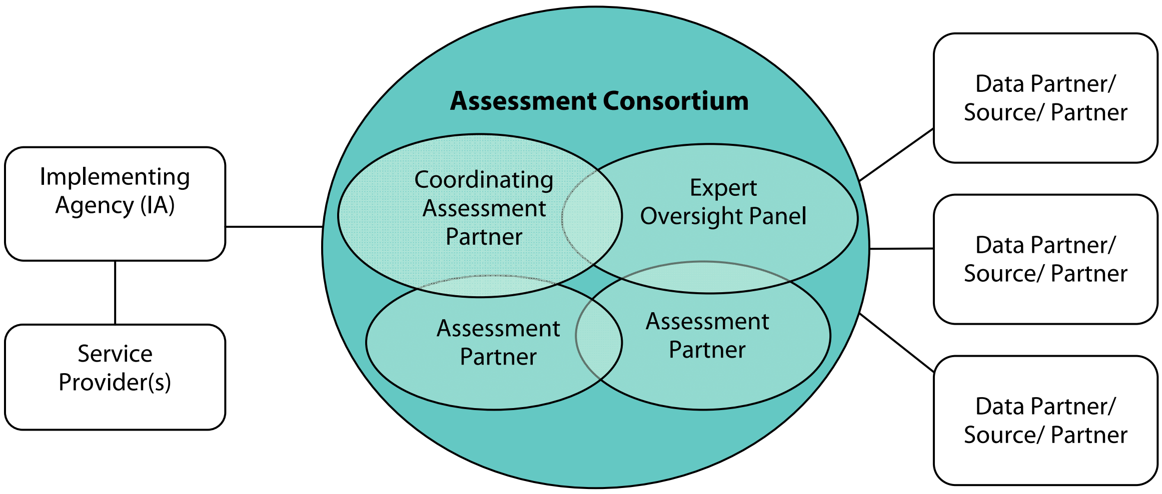
An advantage of having a centralized data system for the core indicators hosted and managed by a dedicated partner is the flexibility to perform further analysis and generate derived products (e.g. cartographic outputs, visuals of various forms, on-line services).

PART 6. TOWARDS IMPLEMENTATION OF THE ASSESSMENT OF LARGE MARINE ECOSYSTEMS

This section describes modalities for the conduct of the TWAP assessment. TWAP will be carried out through a partnership among key institutions, which is described along with the institutional arrangements for the actual assessment. A set of principles to guide the assessment is presented, based on the findings of the Assessment of Assessments report (see section 6.7 below).

6.1 PARTNERSHIPS AND INSTITUTIONAL ARRANGEMENTS

A proposed institutional arrangement for the assessment of LMEs is shown in the schematic below. This arrangement is adapted from that proposed by the TWAP Rivers Group. The LME assessment will be coordinated by IOC-UNESCO (Coordinating Assessment Partner). The assessment will have a coordinator and secretariat based at the IOC, advised by an expert oversight panel balanced between natural science, social science, and economic and legal experts as well as a representative of the GEF and representatives of relevant UN agencies and NGOs. The expert oversight panel will be named by the partners in the TWAP LME assessment and GEF.



***Assessment Consortium*:** The organizational core of the TWAP FSP will be the Assessment Consortium (AC). This consists of a Coordinating Assessment Partner (CAP) and Assessment Partners (APs). The AC will be collectively responsible for producing the final LME assessment report. It is expected that the AC has the expertise to produce global maps and graphical representation of results. To ensure consistency in the presentation of results (maps, tables, etc.) between the five water systems, it is recommended that a Service Provider specifies the formats to the AC and oversees this process.

- *Coordinating Assessment Partner (CAP)*: This has three primary functions:
    1. To provide specialist input and advice into the assessment process;
    2. To act as a coordinator for the APs; and
    3. To act as a liaison between the APs and Implementing Agency.

- *Assessment Partners (APs)*: The APs must have an established network to access data (or hold the data themselves) as well as the experience and capacity to undertake the TWAP assessment. The APs are each responsible for a sub-set of indicators and will collate data from their respective data sources or partners and score basins for each indicator. They are also collectively engaged in the cross-cutting assessment. Assessment partners could include institutions as well as projects and programmes such as the GEF LME projects and Regional Seas Programmes.

Data Partners**:** These may hold data for one or more indicators that need some processing, or hold data with temporal or spatial gaps that need addressing, or have data that needs to be updated. Formal arrangements will be made with Data Partners, which will include an agreement on fees for services provided. TWAP promotes open access to data and information, and transparency in their management and interpretation. This means that a data partner must commit itself to share, within the terms of the agreement, relevant data to which it has access. Data Partners will in turn have the benefit of access to all data managed under TWAP. The data partners will ensure quality assurance and quality control of data to be used in TWAP.

Data Sources**:** These produce data of sufficient quality, coverage, and frequency, which is freely available to the public, and it is expected to do so for the foreseeable future. If a data source does not me*et al*l the above criteria, it may be necessary for the data source to become a data partner, in order to ensure that data produced is suitable for TWAP. It is important to provide some benefit to Data Sources, which can be done in two ways: (i) in the form of recognition and visibility in the FSP report, and (ii) by granting Data Sources access to all data and results under the auspices of TWAP. Furthermore, in the interests of transparency of approach, these organizations may be given the opportunity to comment both on the approach, and on the results and findings based on their data, though the Assessment Consortium reserves the right to decide whether the comments provide a useful addition to TWAP.

This proposed approach has two main advantages:

- It utilizes the strengths of institutions with expertise in specific areas to undertake work in which they are world leaders. This enables TWAP to gain access to a high quality of data collection and analysis in a cost-effective manner; and
- It provides Assessment Partners with ownership of the indicators, as well as within the project, which contributes to achieving a high level of quality, as well as sustainability of the assessment.

Criteria

Partners and data sources will be selected based on the following criteria:

- Those already involved in assessment of LMEs and/or with expertise in transboundary waters, marine living resource indicators and marine assessments in general;
- Those already maintaining, or with access to, databases with global coverage for one or more indicators; and
- Those with expertise, and/or strong networks, relevant to one or more indicators.

Most of these institutions can provide data/expertise for multiple indicators, which represents a potential cost-saving for TWAP. Table 1 provides a list of key potential partners. While considerable effort has been made to make this list as comprehensive as possible, it is acknowledged that there are a number of possible approaches to a global assessment such as TWAP, involving a range of techniques and project partners.

6.2 VALIDATION

It is important that the assessment results are validated and accepted at the regional/national level. A mechanism will be established to engage regional and national entities throughout the assessment process, including in reviewing the assessment results, to ensure credibility and acceptability at these levels and address any disagreement and uncertainties. Validation of the assessment is also contingent on the acceptability of the assessment methodology itself by stakeholders and relevant experts. To this end, the draft LME methodology was presented at three forums for discussion and feedback: 1). Twelfth Annual LME Consultative Committee Meeting, IOC-UNESCO, Paris, 8 – 9 July, 2010; 2). Twelfth Global Meeting of the Regional Seas Conventions and Action Plans, Bergen, Norway, 20 – 22 September, 2010; and 3). Lisbon Conference, 7-8 October, 2010. A summary of the discussions is given in Annex 9.

Main outcomes of LME Consultative Meeting: The LME approach and five modules have been accepted by GEF and are already being widely applied in a number of GEF LME projects, which attests to the acceptability, validity and credibility of this approach. However, caution should be exercised in scaling-down the indicators from the global to the regional level. The use of the best science and inputs from the countries as well as peer review are critical for the success of the TWAP assessment.

Main outcomes of Regional Seas meeting: One of the major concerns centred on the perceived conflict/inconsistency between the Regional Seas and LME spatial scales and political versus ecological criteria and realities. As the meeting participants did not have sufficient time to review the draft methodology reports prior to the meeting, the reports, once completed, are to be sent to the UNEP officer responsible for the Regional Seas Programme for circulation to the Regional Seas coordinators for comments.

Main outcomes of Lisbon conference: The conference brought representatives from a number of independent assessment and indicator initiatives together to exchange information on their respective initiatives to facilitate synergy among them and initiate a process that will lead to coordinated evolution of a framework for sustainable use of marine ecosystem goods and services. A presentation was given on TWAP LMEs and Open Ocean indicators, many of which are similar to those of other initiatives. A number of recommendations arising from the conference are pertinent to TWAP. Among these is identification of a short list of core, scientifically sound indicators (robust 'vital signs') that are sensitive to external forcings (pressures) and enable comparative assessments of nested marine ecosystems from estuaries and marine protected areas to large marine ecosystems and the ocean basins (the high seas).

6.3 CAPACITY BUILDING NEEDS

For regional organizations and agencies to adopt the TWAP LME assessment methodology in their respective assessments, their capacity would need to be built or strengthened to use this methodology. A comprehensive assessment of capacity needs will be required under the TWAP full size project. This will take into consideration the goals and the main target groups for capacity-building. The areas in which capacity should be developed for TWAP purposes include:

- Integrated ecosystem based assessment;
- Monitoring and data collection, exchange and management;
- Adaptive management;
- Modelling; and
- Capacity of project scientists, managers, practitioners and stakeholders to address national priorities and implement action plans.

The new GEF-5 IW strategy recognizes the need to build capacity to enable LME projects to address broader global ocean issues and climate variability and change and to integrate new methodologies for shaping ecosystem management at both the regional and national level including ICM. A proposal is being considered for the establishment, with GEF support, of a Global Community of Practice (COP) to improve the Management of LMEs and their Coasts for learning and experience-sharing among LME Projects and related coastal and marine initiatives (LME/ICM-COP). The aim is to generate knowledge, build capacity, harness public and private partners, support South to South learning and improve performance of International Waters projects through this Community of Practice.

If real progress is to be made towards reversing coastal and marine degradation in the face of the accelerating effects of climate change on marine ecosystems there is an urgent need for States to adopt adaptive ecosystem-based management strategies that can respond to the changing circumstances. Meeting these new challenges will require the provision of coherent development assistance across the different scales of coastal and ocean governance and between transboundary water systems. The LME/ICM-CoP will establish a global support network for the GEF LME and ICM projects and practitioners and provide leadership and coherent development assistance to States to increase their capacity to address climate variability and change and incorporate ICM.

6.4 ASSESSMENT TIMEFRAME

The TWAP assessment of LMEs could be conducted on average every three to five years, with the first assessment to consist of a baseline assessment.

6.5 ASSESSMENT PRODUCTS

The main assessment products will include:

- Summary for decision-makers of the main findings of the assessment;
- Technical report containing a Fact Sheet for each LME, assessment results and indicators, ranking of LMEs, maps, tables, etc;
- Other products to be considered: State of transboundary estuaries/deltas report, SIDS report; and
- Interactive Online database and information system.

6.6 FINANCIAL RESOURCES REQUIRED

The following is a rough estimate of the cost of producing the first LME assessment (to be finalized during development of the FSP):

Total cost:	US$ 8.28 million
GEF funds:	US$ 1.88 million
Co-financing:	US$ 6.40 million

6.7 PRINCIPLES AND BEST PRACTICES

The Assessment of Assessments (AoA) (UNEP and IOC-UNESCO, 2009) identified three attributes as central to an assessment's influence:

- ***Relevance*** (also referred to as salience), which denotes the ability of an assessment to address the particular concerns of those using it;
- ***Legitimacy***, which is a measure of the acceptability or perceived fairness of an assessment; and

- ***Credibility***, which is concerned with whether the knowledge assembled in the assessment is believed to be valid. An assessment gains credibility and authority by virtue of its information, methods and procedures.

The AoA Group of Experts found that basic design features for an influential assessment include:

- clear goals and definitions of objective and scope;
- regular dialogue to improve the science/policy relationship;
- stakeholder participation;
- transparent criteria and procedures for the nomination and selection of experts;
- agreed procedures and quality standards for data and information included;
- guidelines for the treatment of a lack of consensus among experts;
- clear treatment of uncertainty;
- peer review;
- effective communication including appropriate products for each target audience;
- capacity-building and networking;
- post-assessment evaluation; and
- clear institutional arrangements.

See http://www.unga-regular-process.org/index.php?option=com_content&task=view&id=18&Itemid=20 for more details.

6.8 WAY FORWARD

Through the TWAP MSP, a methodology for assessment of LMEs has been developed, and partnerships proposed for the conduct of the assessment under a future FSP, in which the methodology will be fine-tuned and partnerships and institutional arrangements negotiated and formalized. The way forward until the FSP involves a number of steps, including (not in chronological order):

- Discussion among working groups to finalize interlinkages aspects of the methodologies;
- External review of the final methodology reports;
- Finalization, publication, and distribution of the methodology reports;
- Identification of opportunities to promote TWAP and raise awareness, and for future collaboration with ongoing and planned initiatives;
- Identification of other potential partners for the FSP and initiation of discussions in preparation for the FSP;
- Final project Steering Committee Meeting;
- Preparation of the GEF Project Implementation Framework and Project Preparation Grant, with input from the five WGs; and
- Project terminal evaluation.

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ANNEX 1
TWAP LME WORKING GROUP MEMBERS

NAME AND ADDRESS	AREA OF EXPERTISE
Zhongyuan Chen (LOICZ) State Kay Laboratory for Estuarine and Coastal Research, East China Normal University, Shanghai, 200062, China P.R. Email: z.chen@ecnu.edu.cn Tel: +86 21 62232706; Fax: +86 21 62232416	Land-ocean interaction; Environmental assessment from drainage basin to estuary
Villy Christensen Professor, University of British Columbia Fisheries Centre 2202 Main Mall, Vancouver, B.C. Canada V6T 1Z4 Email: v.christensen@fisheries.ubc.ca Tel: +1 (604) 822-5751 ; Fax: +1 (604) 822-8934	Trophic links and modelling; Fish and Fisheries
Benjamin Halpern Director, Center for Marine Assessment and Planning National Center for Ecological Analysis and Synthesis 735 State St., Santa Barbara, CA 93101, USA Email: halpern@nceas.ucsb.edu Tel: +1 805 892-2531; Fax: +1 805 892-2510	Ecosystem-based management; human impacts on marine ecosystems; developing methods for managing and conserving marine resources
Rebecca Klaus Consultant, United Kingdom rebecca.klaus@gmail.com Tel: +44 208 144 4 027	TDA/SAP
Robin Mahon Professor and Director, Centre for Resource Management and Environmental Studies (CERMES), University of the West Indies, Cave Hill Campus, Bridgetown, Barbados Email: rmahon@caribsurf.com; robin.mahon@cavehill.uwi.edu Tel: +246 417 4570 ; Fax: +246 424 4204	Governance
Sybil Seitzinger IGBP Executive Director, IGBP Secretariat, The Royal Swedish Academy of Sciences, Lilla Frescativägen 4a, SE-114 18 Stockholm, Sweden Email: sybil.seitzinger@igbp.kva.se Tel: +46 8 166 448 ; Fax: +46 8 166 405	Biogeochemistry and nutrients
Liana Talaue-McManus Scientist, Division of Marine Affairs and Policy, Rosenstiel School of Marine & Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149 USA Email: lmcmanus@rsmas.miami.edu Tel: +1 305 421 4760; Fax: +1 305 421 4675	Socio-economics; policy

NAME AND ADDRESS	AREA OF EXPERTISE
David Vousden Regional Director, UNDP GEF Agulhas and Somali Currents LME project, South African Institute of Aquatic Biodiversity, Private Bag 1015, 18 Somerset Street, Grahamstown 6140 South Africa Email: david.vousden@asclme.org; davidvousden@aol.com Tel: +27 46 636 2984; Fax: +27 46 622 6621	GEF Agulhas and Somali Currents LME project
Institutional partners	
GRID-Arendal **Joan Fabres**, Coordinator, UNEP Shelf Programme, GRID Arendal, P. O. Box 183, N-4804 Arendal, Norway Email: joan.fabres@grida.no Tel: +47 97 04 03 08 Fax : +47 37 03 50 50 **Jean-Nicolas Poussart** GRID Arendal, P. O. Box 183, N-4804 Arendal, Norway Email : Jean-Nicolas.Poussart@grida.no Tel : +47 92 04 76 26 Fax : +47 37 03 50 50	Marine geology and oceanography
NOAA **Kenneth Sherman** Director, Narragansett Laboratory, US Department of Commerce National Oceanic and Atmospheric Administration Northeast Fisheries Science Center 28 Tarzwell Drive, Narragansett, RI 02882, USA Email: Kenneth.Sherman@noaa.gov Tel: +1 401 782-3211 Fax : +1 401 782-3201	LME and Open Ocean Indicators
UNEP **Ole Vestergaard** Programme Officer, Marine and Coastal Ecosystem Branch, Division of Environmental Policy Implementation, UNEP P.O. Box 30552-00100, Nairobi, Kenya Email: ole.vestergaard@unep.org Tel: +254 20 762-4729; Fax: +254 20 762-4816 **Jacqueline Alder** Director, Marine and Coastal Ecosystem Branch, Division of Environmental Policy Implementation, UNEP P.O. Box 30552-00100, Nairobi, Kenya Email: Jacqueline.Alder@unep.org Tel : +254 20 762-4662	EBM tools and frameworks for integrated coastal and ocean management Integrated coastal and ocean management; fisheries

NAME AND ADDRESS	AREA OF EXPERTISE
UNEP-WCMC **Louisa Wood** Head, One Oceans Programme, UNEP-WCMC 219 Huntingdon Road, Cambridge, CB3 0DL, United Kingdom Email: Louisa.Wood@unep-wcmc.org Tel: + 44 1223 277314 ; Fax: +44 1223 277136	Habitats/biodiversity
IUCN **James Oliver** Global Marine Programme, IUCN, World Headquarters Rue Mauverney 28, CH-1196 Gland, Switzerland Email: james.oliver@iucn.org Tel : +41 22 999 02 17 ; Fax +41 22 999 00 25	Biodiversity
GESAMP **Tim Bowmer** (Chairman of GESAMP) TNO The Netherlands Organization for applied Scientific Research, P.O. Box 360, 3700 AJ Zeist, The Netherlands Email: tim.bowmer@tno.org Tel: +31 30 694 46 45; Fax: +31 30 694 40 99 **Mike Huber** 32 Cordelia St, South Brisbane, Queensland 4101, Australia Email: mhuber@bigpond.net.au Tel: +61 7 3026 8170; Fax: +61 7 3893 4522 **Lawrence F. Awosika** Nigerian Institute for Oceanography and Marine Research (NIOMR), P.M.B. 12729, Lagos, Nigeria Email: larryawosika@yahoo.com Tel: +234 8 06427 3881; Fax: +234 1 61 92 47	Marine pollution
IOC-UNESCO	
Julian Barbiere TWAP LMEs Coordinator/Task manager, Programme specialist Integrated Coastal Management/Marine Assessment, Ocean Science Section, Intergovernmental Oceanographic Commission, UNESCO, 1 rue Miollis,, 75732 Paris Cedex 15, France Email: j.barbiere@unesco.org Tel:+33 1 45 68 40 45; Fax:+33 1 45 68 58 12	
Sherry Heileman TWAP LMEs coordinator, Consultant, IOC-UNESCO 60 Rue Emeriau, Paris 75015, France Email : sh_heileman@yahoo.com Tel: +33 1 40 59 08 34	Fisheries and environment

ANNEX 2
SUMMARY OF THE MAJOR TYPES OF DATA AND INFORMATION SOURCES

The TWAP assessment will be based mainly on existing data and information, and not on the collection of raw data, through partnerships with data holders. The following is a description of major data and information sources at the global scale. It is recognized, however, that there are numerous sources of data and information at smaller scales (regional, sub-regional, national, sub-national) that will be valuable for TWAP. These include data from monitoring programmes, reporting under international conventions, and other sources, and are not included here.

REMOTE SENSING

Data from remote sensing, particularly satellite datasets, are ideally suited for regular global, large-scale, and regional assessments. A consistent application of satellite datasets will be a key feature of TWAP, especially related to the productivity module. NOAA is the major source of data, synthesis and assessment of productivity parameters, including chlorophyll, primary productivity, sea-surface temperatures and frontal locations. Most of these data are in the public domain; the rest can be freely accessed by researchers for non-commercial applications. Environmental satellites provide a viable option for quick (hence globally-synchronized) and cost-effective assessments of vast open ocean areas. The ability of some developing countries to conduct this assessment if funding is limited would be of concern.

Satellite-borne data archived at NOAA's Northeast Fisheries Science Center (Narragansett Laboratory) have already been used to quantify spatial and seasonal variability of near-surface chlorophyll and SST in the world's LMEs. The data originate from various ocean colour sensors and satellites such as CZCS SeaWiFS, Moderate Resolution Imaging Spectro-radiometer (MODIS-Aqua and MODIS-Terra) and satellite SST measurements made by Advanced Very High Resolution Radiometer (AVHRR) flown on various NOAA satellites. Space agency programmes in Asia, Europe, and the United States provide satellite borne ocean colour radiometry data to monitor chlorophyll concentrations, and temperature sensors for SSTs, and define fronts. The application of satellite-based monitoring of SST, chlorophyll, and ocean fronts within the LMEs of developing countries, where survey vessel operations are severely limited, is particularly important during the present period of global climate warming. *In situ* sensors add depth to the relatively shallow section of sea surface interpreted remotely from satellite sensors.

IN SITU MEASUREMENTS

In situ measurements are important sources of data, including for groundtruthing and calibrating observations from remote sensing. Plankton can be measured over decadal time scales by deploying continuous plankton recorder systems from commercial vessels of opportunity. The Mariner Shuttle, an advanced plankton recorder, provides the means for *in situ* monitoring and calibrating satellite-derived oceanographic data. This undulating oceanographic sampling system carries sensors for depth, temperature, salinity, chlorophyll, oxygen, and nitrate, for which vertical profiles are produced.

The Pollution and Ecosystem Health module measures pollution effects on the ecosystem through *in situ* sampling and monitoring, for example, of contaminants and contaminant effects in the water column, substrate, and selected groups of organisms. Where possible, bioaccumulation and trophic transfer of contaminants are assessed, and critical life history stages and selected food web organisms are examined for indicators of exposure to and effects of contaminants, effects of impaired reproductive capacity, organ disease, and contaminant-impaired growth.

FISHERIES-DEPENDENT DATA

Fisheries-dependent data are collected at the national level and usually submitted to FAO. There are concerns about the quality of these data, and further attempts are needed to collect accurate and timely national level data. A valuable source of fish and fisheries data and information for TWAP is the Sea Around Us Project (www.seaaroundus.org) of the UBC Fisheries Centre. The project was established specifically to assess the impacts of fisheries at an ecosystem level, and has developed tools and concepts to present available fisheries data via ½ degree spatial cells, allowing consideration of various spatial scales, such as LMEs. The project has also derived a standard set of indicators and graphical representations, presented on a global scale for all currently defined LMEs. Time-series of catches by species are available for over 180, 000 half-degree cells from 1950 to 2006. Data are harmonized to create a single dataset representing global catches since 1950. Data on capture landings from FAO (FISTAT) is the foundation for the global data as it has global coverage since 1950. Data are also obtained from regional organizations such as the International Council for the Exploration of the Sea (www.ices.int/fish/statlant.htm), the Northwest Atlantic Fisheries Organization (www.nafo.ca), as well as national datasets. For detailed description of data sources and analysis see http://www.seaaroundus.org/doc/saup_manual.htm#13.

The catch data by species, multiplied by ex-vessel price data and then summed, yield the value of the fishery for each LME. These catch data can be used to evaluate a number of other fisheries parameters and indicators.

FISHERIES-INDEPENDENT SURVEYS

Important sources of time-series data and information on changes in fish biodiversity and abundance levels for the fish and fisheries module are fisheries-independent bottom-trawl surveys and pelagic-species acoustic surveys. Included among these are acoustic and trawl surveys carried out by the R/V Dr. Fridtjof Nansen through the Ecosystem Approach to Fisheries (EAF)-Nansen Project (http://www.eaf-nansen.org/nansen/en), which is executed by FAO in collaboration with the Institute of Marine Research (Bergen, Norway) and funded by the Norwegian Agency for Development Cooperation (NORAD). A number of F. Nansen research cruises have already been conducted in several regions, including in LME areas. The Census of Marine Life and global monitoring programmes such as Reefcheck will also yield valuable information for TWAP.

MODELLING

Mathematical modelling will be an important tool for TWAP, including for compensating for data gaps and making future projections under different scenarios. Models should be those that are well-documented to ensure open access for further assessments. Models already used in LME programmes include Ecopath with Ecosim (EwE) and the Global NEWS model. Ecosystem modelling calls for integration and analysis of data from the entire ecosystem. There are increasing numbers of global databases that provide the basic biological and physical parameters to develop ecosystem models.

The Global Nutrient Export from Watersheds (NEWS) GIS-based model is a spatially explicit global watershed model that relates human activities and natural processes in watersheds to nutrient (N, P, and C) and sediment inputs to coastal systems throughout the world (Seitzinger, *et al*., 2005 and 2010). A full description of the data is given in Bouwman, *et al*. (2009). Data are also available in many regions at higher resolution (http://www.marine.rutgers.edu/globalnews/datasets.htm).

OTHER SPATIALLY-DISTRIBUTED DATASETS

TWAP will rely heavily on other spatial datasets (global and regional) including of land use, population, and marine habitats. Spatial datasets are most applicable for assessing changes in habitat extent, facilitating relatively simple overlay analysis using GIS, the results of which can be aggregated at a range of scales, including the level of LMEs, and also enabling the simple visualization of results through maps and graphics. Non-spatial data and more qualitative research can be used to add value to these spatial layers by assisting the interpretation of findings. Global data layers for marine habitats have been compiled by UNEP-WCMC from multiple data sources.

It is becoming increasingly apparent that, currently, the data sets required to underpin these large-scale assessments of habitats are of insufficient quantity and quality, and that there is a significant need to collaboratively integrate existing data with new information collected through standardized methodologies spanning multiple sectors in order to develop robust indicators of change. The majority of these challenges stem from a general lack of available, standardized, and validated data for many habitats at the global and regional scales. The following table summarizes these challenges using a hierarchical framework where data availability declines through the list. Performing the TWAP assessment using only existing data would be unlikely to substantively improve current understanding of the state of LMEs. For TWAP to contribute effectively and meaningfully to the GEF results-based framework, considerable investment will be required to improve the datasets that underpin the various indicators.

Hierarchical framework of data availability gaps in marine habitat data

SCORE	DATA AVAILABILITY GAP	DESCRIPTION
1	Spatial extent	Geographic coverage of data: the majority of data sets do not provide comprehensive global coverage, with biases in the location of research and reporting. Additionally many reporting entities represent small-scale initiatives with no comparable data collection/reporting methodology.
2	Spatial resolution	Inconsistencies in resolution of data: global data, often derived from satellite or remote-sensing techniques, tends to be relatively coarse with a higher probability of error. Data derived through small-scale activities tends to be much higher resolution with lower probability of error, but is not conducted at the scale appropriate for global/regional assessment and international decision-making.
3	Habitat quality/condition	Habitat presence/absence (and therefore extent) data do not provide information on the quality or condition of the habitat being measured which would provide a more accurate method to assess ecosystem health. Studies to assess habitat condition are generally conducted on a local scale and the data are not typically integrated into broad-scale, global assessments. Examples include the percentage of diseased colonies on a coral reef, or the tree diversity of a mangrove forest.
4	Temporal resolution	Inconsistencies and evolution in data-collection methodologies as well as time lags in data reporting have resulted in time-series data being almost non-existent for marine habitat extent. It is critical to establish validated baselines and develop approaches which will allow the timely compilation of data in order to measure change in habitat extent over time.

Population data are available in gridded population datasets. For example, the Socio-economic Data and Applications Center (SEDAC) of the Center for International Earth Science Information Network at Columbia University (CIESIN) has developed a digital database of global population distribution in 1990, 1995, and 2000. There are pre-prepared national-level data of coastal populations available at: http://sedac.ciesin.columbia.edu/es/csdcoastal.html.

Socio-economic and governance surveys and case studies

Data and information from surveys and case studies (especially at national levels) will be particularly important for the socio-economics and governance modules. Socio-economic and governance data are available through some of the LME projects and in national, regional, and global databases and reports (including UN reports such as the UNDP Human Development Report).

Expert judgment

Expert judgment will complement the indicator-based assessment, especially with regard to contextualizing observed status and trends, and where concrete data for the indicators are not available. Spatial and temporal gaps in data availability will have to be addressed using expert judgment. This will be particularly important for pollution, where global data-sets are limited.

Recommendations for future indicator development and data needs

These recommendations were put forward by UNEP-WCMC in relation to marine habitats, but could be applied in a more general sense to other LME components:

Data collection and management

- Greater uniformity in data collection methods, data processing, and data sharing has substantial potential for advancing knowledge, and standard protocols for sample collection and processing should be developed and adopted.
- Future research should target the current gaps in geographic and bathymetric coverage and focus on under-researched areas such as temperate and deep-sea habitats.
- The value of historical data should be promoted.
- Development of internationally-agreed frameworks and guidelines for future data collection is essential for undertaking robust, large-scale assessments and should be positioned as a high priority activity on the international assessment agenda.
- To ensure the most reliable data possible is being made available, data sets should continue to be subject to standard expert- and peer-review processes, and the precautionary approach should, as always, be adopted in any decision-making process.

Integrated marine habitat mapping

- An integrated approach to habitat mapping which combines historical data, existing data collection and mapping activities, with habitat modelling and remote-sensing information should be promoted. Groundtruthing should be carried out where possible.
- Robust methods of integrating information from multiple, small-scale sources is needed to provide standardized reporting at regional and global scales.
- Emphasis should be placed on reviewing historical data and developing methodologies for its integration with current data collection and management techniques in order to ensure that indicator development for baseline establishment, and ultimately analysis of trends, is built on as many previous efforts as possible.
- A more holistic, ecosystem-based approach to assessment and management which recognizes that ecosystem service provision is highly dependent of the 'flow' of these services from one habitat to another should be adopted. The development of a Composite Ecosystem Extent Index would contribute significantly to achieving this.

Collaboration and partnerships

- Future data collection and habitat mapping efforts should aim to benefit both small- and large-scale decision-making processes via a multi-scale approach. The ability to aggregate and disaggregate data over a range of hierarchical scales would provide a comprehensive information base for all members of the marine community, encouraging participation and collaboration across different sectors in its development.
- This integrated approach will require cooperation between many different organizations and sectors, often fostering unprecedented partnerships. Mechanisms to facilitate these working relationships, such as through a global data partnership, should be encouraged.

ANNEX 3
DATA SOURCES INVENTORY

INDICATOR	AGENCY	DESCRIPTION
Primary productivity; chlorophyll *a*	NOAA Northeast Fisheries Science Center, Narragansett Laboratory; University of Rhode Island Sir Alistair Hardy Foundation for Ocean Science (SAHFOS)	Available for all LMEs from 1998 – 2006 in Sherman and Hempel (2008). Primary productivity estimates derived from ocean colour sensors and satellites including CZCS SeaWiFS, and Moderate Resolution Imaging Spectro-radiometer (MODIS-Aqua and MODISTerra). Large archive of *in situ* near-surface chlorophyll data and satellite SST measurements made by AVHRR flown on NOAA satellites available at NOAA. The Mariner Shuttle, an advanced plankton recorder, provides the means for *in situ* monitoring and calibrating satellite-derived oceanographic data. Continuous plankton recorder (CPR) systems deployed for the past 75 years from commercial vessels of opportunity by SAHFOS. CPRs can be fitted with sensors for temperature and salinity, to provide additional information on ecosystem conditions.
Sea Surface Temperature, SST anomalies	University of Rhode Island; UK Meteorological Office Hadley Centre	SST time-series (1957 - 2006) for 63 LMEs are presented in Sherman and Hempel (2008), based on UK Meteorological Office Hadley Centre SST climatology data (1 degree latitude by 1 degree longitude globally). Annual SST calculated for each 1° x 1° cell and the area-averaged annual 1° x 1° SSTs within each LME.
Ocean fronts	University of Rhode Island	Maps of LME oceanographic fronts for each of the 64 LMEs are presented in Sherman and Hempel (2008).
Fish and Fisheries	University of British Colombia (UBC) Fisheries Center Sea Around Us project (in collaboration with FAO; FishBase; SeaLifeBase)	Time-series (1950 – 2006) of annual reported landings and value by LMEs are presented in Sherman and Hempel (2008). Global catch database (30 min x 30 min spatial cells) has been prepared from a wide range of data sources. Landings can be expressed by species, functional groups, commercial species, total reported landings, gear types (including bottom-impacting gear). Catch data can also be used to determine other fisheries indicators. http://www.seaaroundus.org/lme/ The Global Ex-Vessel Fish Price Database contains a complete list of commodity (i.e. type of fish) and market-specific annual average ex-vessel prices for all marine fish taxa reported to have been caught from 1950 to the present.
	FAO	FAO maintains global time-series related to fisheries over 50 year time spans. Also available at regional and country levels. Data from each statistical collection are available through various formats, tools and information products. http://www.fao.org/fishery/statistics/collections/en; http://www.fao.org/fishery/statistics/en; http://firms.fao.org/firms/en (high-quality information on the global monitoring and management of fishery marine resources); http://www.fao.org/fishery/figis/en. Relevant publications include State of World Fisheries and Aquaculture (SOFIA) from 1994 - 2008: http://www.fao.org/fishery/sofia/en and Yearbook of Fisheries Statistics: http://www.fao.org/fishery/publications/yearbooks/en EAF-Nansen Project (http://www.eaf-nansen.org/nansen/en), which is executed by FAO in collaboration with the Institute of Marine Research (Bergen, Norway)

INDICATOR	AGENCY	DESCRIPTION
	Fishbase	A relational global database with information on practically all fish species known to science. Includes data and information on ecology, fish biology, taxonomy, biodiversity, etc. www.fishbase.org , version (03/2010).
	Sealifebase	An online information system with biological information on marine (and freshwater) species, necessary to conduct biodiversity and ecosystem studies. www.sealifebase.org
Fishing effort	UBC Sea Around Us project, FAO	An activity is now underway to develop a comprehensive, spatially explicit global fishing effort database.
Primary Production Required (PPR) by fisheries	UBC Sea Around Us project	Time-series (1950 – 2006) of PPR by LME are presented in Sherman and Hempel (2008). PPR is based on landings data (described above) and calculated separately for each species (or group of species) for the fleets of all countries operating in the LME in question, expressed in terms of the primary production in that LME.
Marine Trophic Index (MTI); Fishing in Balance Index (FiB)	UBC Sea Around Us project, FishBase; SeaLifeBase	Time-series (1950 – 2006) of MTI and FiB by LMEs are presented in Sherman and Hempel (2008).
Stock-Status Plots	UBC Sea Around Us project, FAO, University of Kiel	Stock-status plots presented in Sherman and Hempel (2008).
Carrying Capacity in relation to MSY	UBC Sea Around Us project	Estimate of fish biomass in the world's LMEs. Method relies on a large number of spatial and temporal databases, including FishBase, SeaLifeBase, as well as several other databases developed by the Sea Around Us project. The models are formulated using Ecopath with Ecosim modelling approach and software.
Predicted Catch Potential (2005/2055)	UBC Sea Around Us Project; University of East Anglia; Princeton University	Change in maximum catch potential from 2005 to 2055 derived for ½˚ by ½˚ spatial cells (global coverage). Could be restructured for LMEs.
Mercury	GESAMP; UNEP Global Mercury Partnership; Regional Seas Programmes (HELCOM, OSPAR, AMAP, COBSEA, etc.) that monitor and assess mercury	Sources of measured data (air, water, soil, sediment, biota) are available mainly for Europe, North America and Japan, with much less coverage elsewhere. Quality and context in which samples were originally taken may vary widely. UNEP (2002), Global Mercury Assessment, UNEP Chemicals, Geneva. http://www.chem.unep.ch/mercury/Report/Final%20report/final-assessment-report-25nov02.pdf UNEP (2008), Mercury fate and transport in the global atmosphere: measurement models & policy implications (Pirrone & Mason, eds.). Interim report of the UNEP Global Mercury Partnership. http://www.chem.unep.ch/mercury/Sector-Specific-information/Full_Report.pdf
Nutrients **(P, N, Si, C)**	IGBP, LOICZ, Utrecht University	Current and projections to 2030/2050 based on Global NEWS model and underlying datasets. Total DIN load to each LME. Data available in many regions at higher resolution (http://www.marine.rutgers.edu/globalnews/datasets.htm).

INDICATOR	AGENCY	DESCRIPTION
Concentrations of POPs (DDT, PCBs, HCH, PAHs) in beached plastic resin pellets	International Pellet Watch programme, Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Tokyo, Japan	International Pellet Watch programme (www.pelletwatch.org) has established a global network of volunteers and agencies that collect pellets from beaches and send them to a single laboratory for analysis. Global pollution maps available for selected POPs: http://www.pelletwatch.org/maps/index.html
POPs in marine mammals	IWC; AMAP; GESAMP New & Emerging issues Correspondence group on bio-magnification of contaminants	Annual State of the Cetacean Environment Reports (IWC, SOCER; http://www.iwcoffice.org/sci_com/socer.htm) summarize relevant scientific literature for marine mammals in general and some prey species. Global overview of DDT and PCB levels in bottlenose dolphin, harbour porpoise, fin whale and harbour seals produced by Aguilar, *et al*. (2002). IWC, AMAP, GESAMP New and Emerging Issues Correspondence Group on: '*The biomagnification of contaminants in marine top predators and its ecological and human health implications*'
Shipping density	GESAMP, IMO	Data on ship traffic available for various time periods through the NOAA Voluntary Observing Ship Program (www.vos.noaa.gov), automatic identification systems (www.marinetraffic.com/ais), and LRIT, a satellite-based system. These systems provide accurate, spatially-referenced data on shipping traffic, ship type, ship size, and flag state. Indicator calculation to be determined.
Cadmium and Lead	UNEP DTIE Chemicals Branch; GESAMP Metals Working Group; Regional Seas Programmes; UNIDO	Final draft review of scientific information on lead. http://www.chem.unep.ch/Pb_and_Cd/SR/Draft_final_reviews/Pb_Review/Final_UNEP_Lead_review_Nov_2008.pdf. GESAMP (2010) contains information on atmospheric and water borne transport as well as residue levels in marine biota.
Dissolved oxygen concentration	GESAMP; SCOR; US National Oceanographic Data Center; International Council for the Exploration of the Sea; Integrated Science Data Management, Dept. of Fisheries and Oceans, Canada (ISDM); Institute of Ocean Sciences, Sidney, BC, Canada; Carbon Retention in a Coloured Ocean Project (CARIACO)	SCOR working group 128 has established a dataset based on published time-series and DO measurements, using time-series ≥10 yr and using appropriate methods (Gilbert, *et al*., 2010). This is probably the best available global dataset on long-term DO concentration trends.

INDICATOR	AGENCY	DESCRIPTION
Atmospheric nitrogen deposition	JRC, Ispra	http://daac.ornl.gov/ (Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA)
Freshwater discharge	IGBP; FAO Aquastat	Global NEWS model - See Nutrients above. http://www.fao.org/nr/water/aquastat/dbases/index.stm
Sediment discharge	IGBP, LOICZ	Global NEWS model - See Nutrients above
Harmful Algal Blooms	IOC-UNESCO HABs programme and database; NOAA; GEF LME projects; WRI	http://www.ioc-unesco.org/hab; Harmful Algal Information System (HAIS); Harmful Algal Event Database (HAEDAT) is a meta database containing records of harmful algal events. HAEDAT contains records from the ICES area (North Atlantic) since 1985, and from the PICES area (North Pacific) since 2000. Regional initiatives include NOAA Harmful Algal Blooms Observing System (HABSOS) for the Gulf of Mexico as well as GEF LME projects (Benguela Current). Selman, *et al*. (2008) provide a global map of hypoxia events (WRI).
Extent of Saltmarsh habitat	UNEP-WCMC; The Nature Conservancy	http://www.unep-wcmc.org/; and http://www.nature.org/
Extent of Seagrass habitat	UNEP-WCMC; University of New Hampshire	Comprehensive global data set on seagrass habitat extent and world atlas of seagrasses available; compiled from scientific papers and collaborators. http://www.unep-wcmc.org/marine/seagrassatlas/index.htm
Seamounts at Risk	UNEP-WCMC; Census of Marine Life – Censeam/OBIS; National Institute of Water and Atmospheric Research (NIWA); University of California (San Diego)	SeamountsOnline (http://seamounts.sdsc.edu) holds data on species that have been recorded from seamounts
Change in Protected Area coverage	UNEP-WCMC, IUCN-WCPA	Global data layer compiled by UNEP-WCMC from multiple data sources. This indicator is derived from WDPA, http://www.unep-wcmc.org/; http://www.iucn.org/about/union/commissions/wcpa/
Extent of mangrove habitat	UNEP-WCMC; International Society for Mangrove Ecosystems; FAO; International Tropical Timber Organization; United Nations University Institute for Water, Environment, and Health; The Nature Conservancy	Global extent of mangrove coverage is available globally and change in extent (area) of mangrove habitat is possible for limited locations. Global data layer was compiled by UNEP-WCMC from multiple data sources at a wide range of scales and published in the new World Atlas of Mangroves of the World: http://www.unep-wcmc.org/. Includes interactive maps. See also FAO Global Forest Resources Assessment 2010 (http://www.fao.org/forestry/fra/fra2010/en/)

INDICATOR	AGENCY	DESCRIPTION
Reefs at Risk	WRI; UNEP-WCMC; The WorldFish Center; The Nature Conservancy; NOAA; others	Derived by UNEP-WCMC, the WorldFish Center, WRI and others from a number of data sources (including the Millennium Coral Reef Mapping Project of the Institute for Marine Remote Sensing, University of South Florida and Institut de Recherche pour le Développement. Full methodology available at http://www.reefsatrisk.wri.org
Coral reef diseases	UNEP-WCMC; NOAA	Global Coral Disease online database for coral disease information provides interactive maps and dynamic statistics of world-wide coral disease distribution. Of the 8 568 disease records, 1 140 records covering 19 260 m^2 of the global oceans comply with GCDD Data Standards and support dynamic statistics on the site. http://www.coraldisease.org/
Coral reefs	Global Coral Reef Monitoring Network (GCRMN); International Coral Reef Initiative (ICRI)	ReefBase is the online, central database of the GCRMN, and is developed and maintained by the WorldFish Center (http://www.reefbase.org/). ReefBase provides data and information on the location, status, threats, and management of coral reefs in over 100 countries and territories. Status of Coral Reefs of the World reports, based on data and information from coral reef experts around the world. http://www.gcrmn.org/ International Coral Reef Initiative, http://www.icriforum.org/
Populations within 10 m coastal elevation	CIESIN, Socio-economic Data and Applications Center (SEDAC), Columbia University	Center for International Earth Science Information Network (CIESIN), Columbia University. Low Elevation Coastal Zone (LECZ) Urban-Rural Estimates, Global Rural-Urban Mapping Project (GRUMP), Alpha Version. SEDAC, Columbia University. http://sedac.ciesin.columbia.edu/gpw/lecz. Available data are for 1990, 1995, and 2000.
Fisheries contribution to GDP	FAO, World Bank	FAO has compiled country profiles that include fisheries GDP where available. The World Bank includes agriculture GDP, which includes agriculture, forestry and fishing. http://www.fao.org/fishery/countryprofiles/search/en http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS
Tourism	World Tourism Organization	World Tourism Organization (2006*). Compendium of Tourism Statistics.* www.unwto.org
Damages from climate-related natural disasters	Germanwatch and Munich Re	Harmeling (2009) systematized a database including the total losses in US$ PPP for climate related natural disasters for the period 1990 to 2008. Germanwatch and Munich Re developed the Global Climate Risk Index. http://www.germanwatch.org/klima/cri.htm
Socio-economic data and information (various)	World Bank, UNDP	The World Bank, *World Development Report* 1990, 2000-2001, and 2006 editions The World Bank, *Word Development Indicators*, various years The World Bank, *Global Monitoring Report*, various editions UNDP Human Development reports

OTHERS	
IOC-UNESCO: GOOS, IODE, other relevant programmes (see IOC website)	GOOS is a permanent global system for observations, modelling and analysis of marine and ocean variables. Has a collection of ocean observing and information delivery systems providing near real-time measurements of the state of the oceans. Regional GOOS pertinent to LMEs. International Oceanographic Data and Information Exchange (IODE) system forms a worldwide service-oriented network consisting of 66 National Oceanographic Data Centres, Designated National Agencies, and Ocean Data and Information Networks. This network collects, controls the quality of, archives millions of ocean observations. http://ioc-unesco.org/
IOC-UNESCO, Census of Marine Life, Rutgers University	The Ocean Biogeographic Information System (OBIS) - the information component of the Census of Marine Life (CoML), is a web-based provider of global geo-referenced information on marine species. http://www.iobis.org/
UNEP GEO and GEO Data Portal	http://www.unep.org/geo/; data portal, http://geodata.grid.unep.ch/
UNEP Global and Regional Integrated Data *(GRID)* Centres (GRID-Arendal, GRID-Geneva, GRID-Sioux Falls	UNEP's major centres for data and information management, with a unique, 'value-adding' mandate in the handling of global and regional environmental data, which in turn support the environment assessment and early-warning activities of UNEP and its partners. Environmental data and information, vital graphics, publications. http://www.grida.no; http://www.grid.unep.ch/; http://na.unep.net/
GEF LME projects	Ecological and socio-economic data at LME/national scale.
GIWA	Databases and reports. http://www.unep.org/dewa/giwa/
IUCN	Global Invasive Species Database (GISD). Focuses on invasive alien species that threaten native biodiversity and covers all taxonomic groups in all ecosystems. http://www.issg.org/database/welcome/ Species Red List.
UN Regular Process	Global and Regional Marine Assessment Database. http://www.unep-wcmc.org/GRAMED
Space agencies	National Aeronautics and Space Administration (NASA), European Space Agency, Canadian Space Agency, and their counterparts in Japan, China, and India, among others.

ANNEX 4
MAJOR THREATS OR PERCEIVED PROBLEMS AND ISSUES IDENTIFIED IN TDAS

LME	NO. OF ISSUES	PRIORITY TRANSBOUNDARY ISSUE STATEMENTS
Caspian Sea TDA 2002	8	▪ Decline in certain commercial fish stocks, including sturgeon. ▪ Degradation of coastal landscapes and damage to coastal habitats. ▪ Threats to biodiversity. ▪ Overall decline in environmental quality. ▪ Decline in human health. ▪ Damage to coastal infrastructure and amenities. ▪ Introduced species. ▪ Contamination from offshore oil and gas activities.
Western Indian Ocean TDA 2009	4	▪ Water and sediment quality degeneration due to pollution; (5 sub-categories: Microbial contamination; High suspended solids; Chemical pollution; Marine litter/solid waste; Eutrophication). ▪ Physical alteration and destruction of habitats (5 subcategories: Degradation of mangrove forests; Degradation of seagrass beds; Degradation of coral reefs; Degradation of coastal forests; Shoreline changes). ▪ Alteration in freshwater flows and sediment loads from river basins (sub-categories: Alteration of river flows and water quality; Alteration of sediment loads). ▪ Governance / Awareness.
Caribbean LME TDA 2007	3	▪ Habitat and community modification. ▪ Pollution. ▪ Unsustainable exploitation of fish and other living resources.
Mediterranean LME TDA 2005	4	▪ Decline of biodiversity. ▪ Decline in fisheries. ▪ Decline of seawater quality. ▪ Human health risks.
Guinea Current LME TDA 2005	4	▪ Decline in GCLME fish stocks and unsustainable harvesting of living resources; ▪ Loss of ecosystem integrity (changes in community composition, vulnerable species and of alien species) and yields in a highly variable environment including effects of global climate change. ▪ Deterioration in water quality (chronic and catastrophic) from land and sea-based activities, eutrophication and harmful algal blooms. ▪ Habitat destruction and alteration including inter-alia modification of seabed and coastal zone, degradation of coastscapes, coastline erosion.
Bengula Current LME TDA 1999	7	▪ Decline in BCLME commercial fish stocks and non-optimal harvesting of living resources. ▪ Uncertainty regarding ecosystem status and yields in a highly variable environment. ▪ Deterioration in water quality - chronic and catastrophic. ▪ Habitat destruction and alteration, including inter alia modification of seabed and coastal zone and degradation of coastscapes. ▪ Loss of biotic integrity (changes in community composition, species and diversity, introduction of alien species, etc.) and threat to biodiversity/endangered and vulnerable species. ▪ Inadequate human and infrastructure capacity to assess the health of the ecosystem as a whole (resources and environment, and variability thereof). ▪ Harmful algal blooms.

<table>
<tr><th>LME</th><th>NO. OF ISSUES</th><th>PRIORITY TRANSBOUNDARY ISSUE STATEMENTS</th></tr>
<tr><td>Yellow Sea LME TDA 2007</td><td>7 / 4</td><td>The initial Yellow Sea LME TDA 2000 identified the following major perceived water-related environmental issues and problems:
□ Decline of commercial fisheries;
□ Degradation of biodiversity, loss of coastal habitats, loss or imminent loss of endangered species and their genomes.
□ Water quality deterioration;
□ Unsustainable mariculture;
□ Poor or unsatisfactory human health quality, unsanitary conditions in many beaches and bathing waters, contaminated fish and sea products;
□ Harmful algal blooms (emerging disease);
□ Inadequate capacity to assess ecosystem.

The issues were revised in the 2007 version of the TDA and the following 4 Regional Environmental Problem categories and 18 impact sub-categories were listed as follows:
▪ Biodiversity
□ Habitat loss and degradation.
□ Pollution.
□ Changes in river discharge.
□ Overexploitation of marine and coastal living resources.
□ Introduction of xenobiotic (alien species).
□ Decline of endemic species.
▪ Pollution
□ Eutrophication (Nitrogen (N) enrichment; Phosphorus (P) enrichment; Silicate (Si) depletion; Changed Si:N:P ratios; Oxygen depletion; Phytoplankton blooms including red tides).
□ Contamination (Faecal; Heavy metals; POPs; PAHs; Marine litter).
□ Increased risks to human health (seafood contamination, contaminated water).
▪ Ecosystem (primary and secondary production and benthos).
□ Increase in frequency of harmful algal blooms.
□ Change in species composition.
□ Change in biomass or abundance.
□ Loss of benthic habitat in coastal areas.
▪ Fisheries
□ Decline in landings of many traditional commercially-important species and increased landing of low-value species (including changes in dominant species).
□ Unsustainable maricultural practices.</td></tr>
<tr><td>Black Sea LME TDA 2007</td><td>4</td><td>The Black Sea LME TDA identified 4 problems:
▪ Nutrient over-enrichment/eutrophication;
▪ Decline in natural resources (e.g. fisheries);
▪ Chemical pollution; and
▪ Habitat and biodiversity changes - including alien species introduction.</td></tr>
<tr><td>South China Sea TDA 2000</td><td>4</td><td>The South China Sea TDA identified 4 MPPI and transboundary issues associated with these:
▪ Freshwater concerns;
▪ Modification of habitats;
□ Destruction of mangroves;
□ Destruction of coral reefs; and
□ Destruction of seagrasses;
▪ Overexploitation (marine, freshwater); and
▪ Pollution (sewage, freshwater contamination, agricultural loading, industrial waste, sedimentation, solid waste, hydrocarbon, ship-based sources, atmospheric).</td></tr>
</table>

ANNEX 5
PRELIMINARY LIST OF TWAP LME INDICATORS BY LME MODULE

Preliminary list of core indicators in **blue green**.

LME MODULE	STRESS INDICATORS	STATUS / IMPACT INDICATORS
PRODUCTIVITY	▪ **SST** (25 year trend and projections) - Ocean Fronts	▪ **Primary productivity** (gC/m²/yr) ▪ **Chlorophyl *a*** ▪ Zooplankton
FISH and FISHERIES	▪ **Primary Production Required** (Ecological Footprint) ▪ **Fishing effort** ▪ Bycatch/discards	▪ **Reported Landings**- also a stressor (by LME, countries, recreational, artisanal, commercial, and industrial fisheries) ▪ **Marine Trophic Index** ▪ **Fishing In Balance Index** ▪ **Catch-Stock Status and Trends** ▪ **Catch potential** (predicted): Map of predicted change in primary productivity and catch potential to 2055 ▪ Species distributions (Aquamaps) ▪ Fisheries carrying capacity ▪ Species invasion and extirpation ▪ Stock abundance and trends
POLLUTION and ECOSYSTEM HEALTH	▪ **Nutrient inputs: DIN, P, Si** (t/yr) to delta and LME (current & and projections) ▪ **Fertilizer application** (t/km²/yr) ▪ **Freshwater Discharge** ▪ **Sediment Flux** ▪ **Sea-level rise** ▪ **Catch from bottom-impacting gear** (trawling & dredging – proxy for fishing effort by destructive gear) ▪ **Mercury, other contaminants** ▪ Invasive species	▪ **N, P, Si concentration** (t/km³/yr) ▪ **Critical Habitat Extent** ▪ **Hypoxia, DO** ▪ **HABs** ▪ **Habitats at Risk Index: Reefs, Deltas, Seamounts** ▪ **Mercury in water and animal tissue** ▪ Coral bleaching/diseases ▪ Multiple Marine Ecological Disturbances ▪ Jellyfish Trends? ▪ Species listed (IUCN Red List) ▪ Ocean Health Index? ▪ Coastline at Risk Index?

<table>
<tr><th>LME MODULE</th><th>STRESS INDICATORS</th><th>STATUS / IMPACT INDICATORS</th></tr>
<tr><td>SOCIO-ECONOMICS</td><td colspan="2">

- **Value of fish landings** (industrial, commercial, artisanal)
- **Value of mariculture, recreational fisheries**
- **Employment in fishing sector** (industrial, commercial, artisanal, recreational, mariculture)
- **Economic value of ecosystem goods and services**
- **Forage Fisheries and Use (fish meal and oil/human consumption)**
- **Poverty in coastal areas (social conditions in coastal communities**
- **Per capita consumption fish; % protein source**
- **Population (density) in coastal areas (current and projected)**
- **HDI**
- **Losses from climate related events**
- Marine Activity Index (Hoagland and Jin 2006)
- Disease burden

Projections of stressors will be made to years 2030/2050, where possible.

</td></tr>
<tr><td>GOVERNANCE</td><td colspan="2">

- **Governance architecture**
- **Presence of legal frameworks/institutions (LME scale) and adopted ICM and rights-based fisheries laws (national scale)**
- **MPAs** (% coverage of EEZ; No-take vs the rest)
- **MARPOL** adoption (with required port-based reception of oily water)
- **Fishing subsidies**
- **FAO Code of Conduct compliance**
- **GPA** adoption, monitoring programme
- **ICM/IWCAM** adoption
- **LME Commission**
- **SAP adoption/implementation**
- **Regional Seas Conventions and Action Plans**
- Joint fishing agreements
- Management efficiency
- Management Response indicators - Eco-certification

</td></tr>
</table>

ANNEX 6
MAPPING OF CUMULATIVE HUMAN IMPACT ON MARINE ECOSYSTEMS

Background on cumulative impact tool

Any effective management of marine systems requires information on where and how much human activities are affecting the health of the systems, and these assessments need to be comprehensive not just within a single sector (for example, only fishing). We have developed the cumulative impact assessment tool over the course of four years in collaboration with dozens of scientists from around the world, leveraging millions of dollars of funding to collaborative institutions, to address this need. The work was published in the journal *Science* in 2008 (Halpern , *et al.*, 2008) and represents the only existing tool for comprehensively assessing the cumulative impact of all human activities on the state of all marine ecosystems at a global scale, in turn providing an assessment of ocean health.

Cumulative impact is calculated as the sum of the weighted impact of each stressor, at a given intensity, on each ecosystem, summed into a single, directly comparable measure of ecosystem condition. To date we have focused on the current level of cumulative impact, allowing us to answer a host of policy- and management-relevant questions, including where the most and least impacted areas are, which are the top threats, the most vulnerable ecosystems, and the relative impacts of different suites of stressors (e.g. climate change vs. pollution). These analyses can be conducted at regional and local scales to provide a directly comparable assessment of human impacts in these areas. In most cases these analyses account for differing rules and regulations within different regions of the oceans (e.g. country-level regulations within different LMEs) as the existence and effectiveness of these regulations is reflected in the modelled or measured intensity of stressors that the regulations are intended to affect. What is missing from these analyses, and what forms the core of the methodology proposed below, is the need to be able to evaluate the potential costs and benefits of different management scenarios on ocean health at different points in time in the future.

Management applications and implications

Management decisions about the use or protection of natural resources inherently require spatial decisions about who does and does not get access to a natural resource. Currently these decisions are generally made within a single sector (e.g. fisheries management decisions are made without regard to how other human activities affect the fish stocks) even though cumulative effects of human activities are the norm. Furthermore, management always requires tough resource allocation decisions as there is never enough time or money to achieve all goals, and so priority setting is one of the most common management activities. The cumulative impact tool, in its current form and even more so when developed to account for forecasted stressors, explicitly addresses these needs. The tool is already being used to inform marine spatial planning (MSP) efforts in Hawaii, California, Massachusetts, the U.S. Great Lakes, the Baltic Sea, the Coral Triangle, South Africa and the U.N. World Heritage programme, and is being considered in many other locations. Decisions being influenced in these regions include which stressors to address first, where to allocate money and resources, what types of management should be used to improve ocean health and sustainability, and where are the most vulnerable locations that deserve conservation protection.

In the context of the open oceans and in particular for areas beyond national jurisdiction (which account for nearly half the Earth's surface), the cumulative impact tool can serve to highlight human impact on a common resource, and the need to develop common global management instruments. It can help identify the most vulnerable regions now, and, with extension of the methodology, in the future. It will help identify the relative impact of stressors, which can potentially orient effort towards the development of particular management agreements.

Methodology

The details described below explain how the cumulative impact tool works and what it can provide. It is important to note that it does not replace the need for *in situ* measurements of ecosystem condition and the related indicators of ocean health that are derived from those measurements. The tool provides predictions about the state of the ocean that indicator assessments help validate. As the two processes (model predictions and indicator assessments) proceed and are refined, model predictions will become increasingly accurate and have finer resolutions.

General description and outputs

The cumulative impact tool requires three types of data: maps of each habitat, maps of the intensity of stressors (drivers) of interest, and vulnerability weights for each stressor-habitat combination. We have developed all of these for analyses at global scales, but have designed the tool to be fully adaptable and flexible so that if and when better data for any individual habitat or stressor become available, or new data for a previously unrepresented stressor are developed, they can easily be included and the model quickly (<1 day) rerun to reproduce all results of interest.

We initially focused on producing a global map of the cumulative impact of human activities. The tool also allows one to produce results tailored to any geography of interest, including LMEs and open ocean regions. By comparing the relative impact of individual or sets of stressors within a given geography, one can, for example, determine the top threats to the region or the relative contribution of stressor(s) to overall ocean degradation. This in turn helps highlight hotspots of impact from different stressors, as well as where and how much different management actions might be able to mitigate cumulative impacts. Which LME needs the most immediate conservation attention? Where within a given ocean region is climate change or fishing having the biggest impact? Which locations are most vulnerable and might therefore merit precautionary protection? These and many other management questions can be easily addressed with the cumulative impacts assessment tool.

Assumptions

There are a few key assumptions to our model, many of which we have tested and none which yet have enough scientific information to resolve. In all cases we can test the sensitivity of our results to these assumptions.

First, we assume linear relationships between increases in the intensity of stressors and the impact on ecosystems. In other words, we do not account for thresholds and nonlinearities in impact. Such thresholds are known to exist, but exactly where they occur and why is not known for most stressors, and in the few cases where they are understood they remain unpredictable at a global scale.

Second, we assume individual impacts of stressors are additive. Stressors are known to act synergistically in some cases (the whole is greater than the sum of the parts) and be mitigative in other cases (e.g. a small amount of nutrient input can increase productivity, helping buffer a system from other stressors). We have done a global meta-analysis of all empirical work evaluating what might lead to synergies or mitigative responses and found that results are completely unpredictable by any known variable (Crain, *et al*., 2008). Thus, an additive model serves as a conservative approach.

Finally, two additional aspects of reality are missing from the current maps due to insufficient data availability. First, in all cases we used annual averages for stressor intensities, but many stressors vary temporally, and the timing of the stressor relative to other variables (such as ecosystem productivity) can mitigate or exacerbate the impact of the stressor. Accounting for these temporal dynamics will be challenging, but more information on the nature of these dynamics for each stressor will at a minimum allow us to better quantify the uncertainty in the model output. Second, we treat ecosystem vulnerability as constant around the world, so that, for example, a coral reef in the Caribbean is equally vulnerable to each stressor as is one in the Great Barrier Reef. This may not be true, and so vulnerability estimates tailored to each region of the planet would improve accuracy of the maps. Given these assumptions, there remains a need to continue or improve efforts to monitor the state of natural systems and human stressors to the natural system, and to continue research on the relationship between the two, in order to validate and improve future versions of this tool.

Data included

We currently have data with global coverage for 20 different marine habitats and 17 human activities and associated stressors (see table below for full lists and data sources). If higher quality or additional data exist, these can easily be incorporated to ensure that the most recent information is included in model analyses. Available data and sources of raw data. All data were processed and tailored for this specific purpose within our project.

	DATA LAYER	NATIVE RESOLUTION	SOURCE
DRIVERS	Nutrients (fertilizer)	1km²	FAO, SRTM30, USGS
	Organic pollutants (pesticides)	1km²	FAO, SRTM30, USGS
	Inorganic pollutants (impervious surfaces)	1km²	FAO, SRTM30, USGS
	Direct human (population density)	1km²	FAO, SRTM30, LandScan
	Pelagic, low-bycatch fishing	half-degree	SAUP/UBC
	Pelagic, high-bycatch fishing	half-degree	SAUP/UBC
	Demersal, destructive fishing	half-degree	SAUP/UBC
	Demersal, non-destructive, low-bycatch fishing	half-degree	SAUP/UBC
	Demersal, non-destructive, high-bycatch fishing	half-degree	SAUP/UBC
	Artisanal fishing	1km²	FAO, ETOPO2, WRI, CIA
	Oil rigs	30 arc-second (~1km²)	NOAA National Geophysical Data Center (NGDC)
	Invasive species	1km²	WPI, many others
	Ocean pollution	1km²	VOS, WPI
	Shipping	lat/long data	VOS
	SST	21km²	UNC/NOAA collaboration
	UV	1 degree	Goddard Space Flight Center (GSFC) TOMS EP/TOMS
	Ocean acidification	1 degree	Guinotte, *et al.* (2003)
ECOSYSTEMS	Coral	1:250 000	UNEP-WCMC
	Seagrass	1:250 000	UNEP-WCMC
	Mangrove	1:250 000	UNEP-WCMC
	Rocky reef	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Shallow soft	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Hard shelf	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2

	DATA LAYER	NATIVE RESOLUTION	SOURCE
	Soft shelf	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
ECOSYSTEMS (cont.)	Hard slope	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Soft slope	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Hard deep	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Soft deep	lat/long data combined with 2 minute bathymetry	dbSEABED, ETOPO2
	Seamounts	14,287 point data with lat/long	Kitchingham and Lai (2004)
	Pelagic waters	derived from 2 minute bathymetry	ETOPO2
	Deep waters	derived from 2 minute bathymetry	ETOPO2

Proposed work

Despite the utility of this existing tool, there are a number of ways it can and should be improved to fully address the priorities of the TWAP process and the broader global marine assessment process of the UN. In particular, it can be tailored to the priority regions of TWAP (LMEs, open oceans) as well as other UNEP/GEF priorities, such as SIDS, and it can be expanded to account for forecasted stressors, allowing for a powerful ability to evaluate different management scenarios.

LME analysis

To date we have summarized our results at the global scale and by marine eco-region. With a relatively small amount of effort we can tailor results to be summarized by LMEs, providing the following output:

a. Mean, variance, and range of the overall cumulative impact and the cumulative impact of subsets of threats (e.g. all climate change, all land-based stressors) within each LME;
b. Top threats within each LME, measured by footprint (intensity only) or impact (actual consequence for ecosystems);
c. Percentage contribution of any given threat or subsets of threats to overall impact score within each LME;
d. Identification of least and most impacted areas within each LME;
e. Vulnerability maps for each LME (areas of least and greatest vulnerability to any given threat);
f. Distributions of land-based impacts and hotspots of these impacts; and
g. Specific maps (upon request) of cumulative human impacts and scores in LMEs.

The maps can then be decomposed into their component parts or analysed by subsets of stressors to produce results for each of the other types of output described above. For example, one can look at the cumulative impact of fishing vs. land-based pollution to show where hotspots of these impacts are, relative to the maps of cumulative impact.

SIDS/ open ocean analysis

With guidance on the relevant spatial boundaries of SIDS and open ocean areas of interest, we will also provide all of the above results for each SIDS and/or open ocean region. These results can be compared within these regions only, or if desired also with LMEs.

Future scenarios and forecasting

The critical missing piece from our work which, when developed, will allow managers, stakeholders, and policy-makers to evaluate the potential outcome of different management scenarios, is spatially-explicit forecasting of cumulative impacts. The cumulative impact model structure described above can easily be adapted to include forecasted stressor layers, allowing a full suite of powerful scenario analyses. With each individual stressor layer forecast into the future, one simply has to determine the number of years into the future of interest and slide maps of the layers at those time points into the cumulative impact model. Iteration of this analysis at successive time points allows for temporal trajectories to be analysed and presented graphically.

In order to complete these forecasting and scenario analyses each input data layer will need to be forecast into the future. This is true for both the stressor maps and the habitat maps – as species migrate or habitats are lost due to changing human stressors, the maps of where habitats exist will clearly change. In some cases (such as stressors associated with climate change) these forecast models exist, although they will need to be tailored to our purposes. In other cases we will need to develop novel forecast models. Table 2 provides some possible data sources for many of the stressors layers for which we anticipate developing spatially-explicit forecast models.

Ideally the effort to forecast these layers will involve several research scientists with expertise in different stressors (e.g. climate-change modelling, human population demographic modelling, fisheries modelling, land-use change modelling) and a GIS analyst to support the different research teams and the project as a whole.

Data visualization and dynamic user interface

We are currently working with the MarineMap (http://marinemap.org) development team to provide a dynamic, user-friendly interface for exploring the maps and data inputs for the cumulative impact tool. MarineMap was developed for the ongoing process in California to establish a network of MPAs along the entire coast. The visualization capabilities have proved powerful in helping communicate information about potential management goals to a wide variety of stakeholders and policy-makers. We are working to leverage this capacity for the cumulative impact analysis as governments move towards marine spatial planning. Incorporating this tool into the forecasting and scenario analyses described above will transform the work and capacity that we will develop in-house to something that is accessible (and dynamic) for any user anywhere in the world.

Potential partners

We already have close working relationships with the global and regional offices of the Nature Conservancy based on data sharing, as we have both been aggregating and processing spatial data, albeit for different purposes. Future efforts would continue to depend on and benefit from this collaborative relationship. We have also worked closely with the climate offices of NOAA in processing climate data and would want to continue this relationship in producing and processing climate scenario data from existing climate-change models. As mentioned above, we view a working relationship with MarineMap as an important value-added relationship that will help make results and maps accessible to stakeholders and managers as they consider and pursue different management options.

Additional possible improvements to the cumulative impact tool

Ultimately the results from the cumulative impact tool are only as good as the input data, and the quality of these vary with stressor type and geography. Probably the most important improvement that could be made with regard to this issue, and an improvement that would have far-reaching implications beyond this tool, is better habitat data. Most notably in need of improvement is a suite of intertidal habitats, including salt marsh, rocky intertidal, and beach, and two shallow sub-tidal habitats, kelp forests and rocky reefs. These near-shore habitats provide a large suite of ecosystem services to people but are also subject to the largest number of human stressors. Better maps of these habitats would aid in assessments of how coastal areas are changing and the consequences for people.

Several of the stressor layers included in the analyses had to be modelled with little available data for validation. Effort to refine and better validate these layers would improve the current cumulative impact maps while also improving the ability to forecast the layers. Key layers to focus on improving are invasive species and coastal ocean acidification.

Finally, there are also a number of specific stressors layers that currently do not have globally-comprehensive data which, if developed, would help make the output of the cumulative impact tool more comprehensive and accurate. Most notably these include modifications to sediment regimes (from dam construction and land-use changes), aquaculture, shoreline modification, and recreational fishing (which is not captured by subsistence or commercial fishing).

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ANNEX 7
PREVIOUS APPROACHES TO ASSESSMENT OF SOCIO-ECONOMICS IN LMES

L. Talaue-McManus

Previous work on the human dimensions and socio-economics of LMEs include Sutinen (2000) and Hoagland and Jin (2006). Sutinen (2000) outline the steps for monitoring and assessment of LMEs to evaluate the human dimensions. Hoagland and Jin (2006) provide a first attempt to assess marine livelihoods at the LME scale globally. It is proposed in the NOAA contribution that these authors will update and complete estimates of activity levels of the relevant marine sectors (e.g. fisheries, aquaculture, tourism, shipping, oil and other goods and services) of countries bordering the world's LMEs.

Hoagland and Jin (2006) created a global database of five marine industry sectors (marine fisheries and aquaculture (metric tonnes), tourism (number of visitors), shipbuilding (gross tonnage), shipping (metric tonnes) and offshore oil (average barrel/day and number of offshore rigs) in each of 145 coastal states and 3 territories during the period 2003-2004. Metrics for each of the sectors are standardized into values ranging from zero to one, by ranking each nation's activity level relative to other countries. At the national scale, each sectoral index is given equal weight and then all five indices are summed to yield a national marine activity index (MAI), which provides a measure of the intensity of marine activity in a country relative to other countries in the database. The weights of each sector may be modified accordingly should additional data provide a basis to do so.

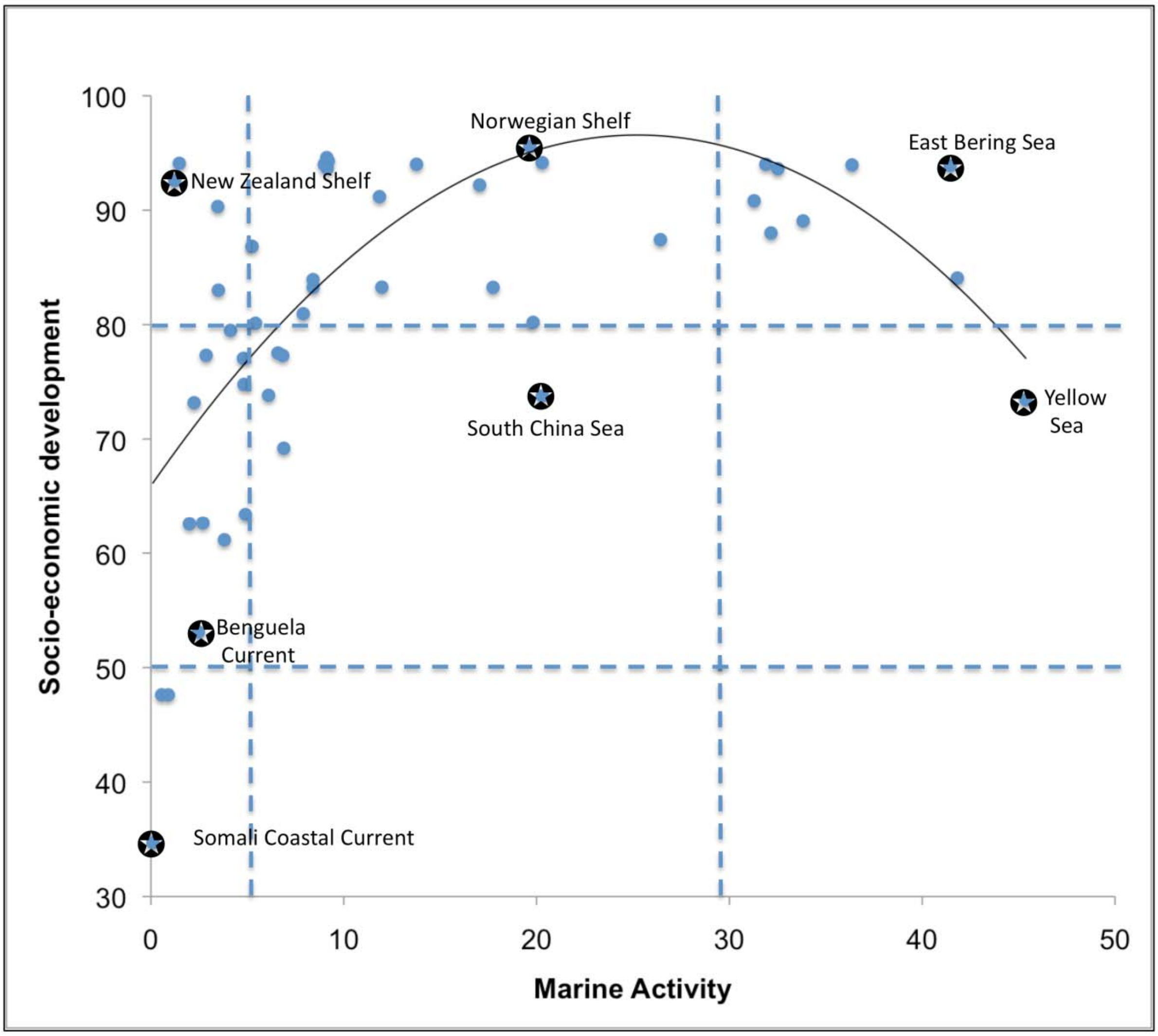
These authors used the 2004 HDI for each nation to indicate a nation's degree of socio-economic development. Both HDI and MAI are then weighted by length of country coastline associated with each LME to derive LME-scale indices. Using the latter, the authors provide a marine activity and socio-economic development classification of 64 LMEs as shown in the figure and table below.

Hoagland and Jin (2006) focused on across-country comparisons. The intensity of marine activities has to be assessed relative to the policy goals of each coastal nation in order to establish MAI as an indicator. In the case of the HDI, other measures of human well-being may articulate a coastal state's goals, so that a higher HDI, though implied as preferred to a lower HDI, cannot be assumed to encapsulate societal goals.

References

Hoagland, P. and Jin, D., 2006. Accounting for economic activities in Large Marine Ecosystems and Regional Seas. UNEP Regional Seas Reports and Studies 181. UNEP Regional Seas Programme, Nairobi, Kenya.

Sutinen, J. G. (Ed.), 2000. A Framework for Monitoring and Assessing Socioeconomics and Governance of Large Marine Ecosystems. NOAA Technical Memorandum NMFS-NE-158, 32p.



Classification of LMEs by intensity of marine activity and socio-economic development
(modified from Hoagland and Jin (2006)).

LMEs categorized by Marine Activity and Socio-economic development (Hoagland and Jin, 2006).

	LOW MARINE INDUSTRY ACTIVITY (MAI < 5)	**MEDIUM MARINE INDUSTRY ACTIVITY** (5 ≤ MAI < 30)	**HIGH MARINE INDUSTRY ACTIVITY** (MAI ≥ 30)
HIGH SOCIO-ECONOMIC DEVELOPMENT (SEI ≥ 80)	13. Humboldt Current 23. Baltic Sea 46. New Zealand Shelf 59. Iceland Shelf	4. Gulf of California 8. Scotian Shelf 9. Newfoundland-Labrador Shelf 14. Patagonian Shelf 20. Barents Sea 21. Norwegian Shelf 22. North Sea 24. Celtic-Biscay Shelf 25. Iberian Coastal 26. Mediterranean Sea 39. North Australian Shelf 40. Northeast Australian Shelf/ GBR 41. East-Central Australian Shelf 42. Southeast Australian Shelf 43. Southwest Australian Shelf 44. West-Central Australian Shelf 45. Northwest Australian Shelf 50. Sea of Japan 51. Oyashio Current 52. Sea of Okhotsk 53. West Bering Sea 54. Chukchi Sea 55. Beaufort Sea 63. Hudson Bay	1. East Bering Sea 2. Gulf of Alaska 3. California Current 5. Gulf of Mexico 5. Southeast US Continental Shelf 7. Northeast US Continental Shelf 10. Insular Pacific Hawaiian 47. East China Sea 49. Kuroshio Current
MEDIUM SOCIO-ECONOMIC DEVELOPMENT (50 ≤ SEI < 80)	12. Caribbean Sea 17. North Brazil Shelf 27. Canary Current 29. Benguela Current 32. Arabian Sea 33. Red Sea 34. Bay of Bengal 37. Sulu-Celebes Sea 56. East Siberian Sea 57. Laptev Sea 58. Kara Sea 62. Black Sea	11. Pacific Central – American Coastal 15. South Brazil Shelf 16. East Brazil Shelf 35. Gulf of Thailand 36. South China Sea 38. Indonesian Sea	48. Yellow Sea
LOW SOCIOECONOMIC DEVELOPMENT (SEI < 50)	28. Guinea Current 30. Agulhas Current 31. Somali Coastal Current	None	None

ANNEX 8
OTHER APPROACHES TO GOVERNANCE EVALUATION IN LMES

Mapping of LME governance profiles

Governance profiles of LMEs were explored to determine their utility in promoting long-term sustainability of ecosystem resources (Juda and Hennessey 2001). It is proposed to map governance profiles for all 64 LMEs in the TWAP assessment. In seeking to move toward governance arrangements that are more appropriate for ecosystem-based management, it is necessary to understand how existing institutional, economic and cultural systems operate, their implications for the natural environment and its resources, and how any needed change may emerge, given societal structures and norms. Ecosystem-based governance actions need to consider multiple legal jurisdictions and governance levels (e.g. municipal, state, regional, national, international) as well as the interests of multiple user sectors (e.g. fisheries, mining, oil and gas production, waste disposal, transportation, recreation) and stakeholders (e.g. fishermen, corporations, real-estate interests).

The LME Governance Module engages multiple scales of national, regional, and local jurisdictional frameworks needed to select and support ecosystem-based management practices leading to the sustainable use of resources. In each of the LMEs, governance jurisdiction can be scaled to ensure conformance with existing legislated mandates and authorities (Olsen , *et al*., 2006). Matrices have been employed in an effort to understand interactions between ocean uses. Governance efforts are important for two major reasons: (i) incompatible human uses of the LME and its goods and services that result in mutual interference; and (ii) human uses of the LME environment that interfere with natural processes and limit the potential for future use of the LME environment. The first two matrices (Juda and Hennessey 2001) directly address these matters.

Matrix 1
Use Interaction

Human Uses

Human Uses	Shipping/ ports	Fishing	Aqua-culture	Industrial siting	Re-creation	Waste Disposal	Housing	Military Uses	Agriculture	Forestry
Shipping/ ports										
Fishing										
Aquaculture										
Industrial siting										
Recreation										
Waste Disposal										
Housing										
Military Uses										
Agriculture										
Forestry										

scale:

1 2 3 4 5 6 7 8 9 10

compatible — conditionally compatible — incompatible

Matrix 2
Effects of Human Use on Ecosystems

Ecosystem alterations

Human Use	oxygen depletion	eutrophication	habitat destruction	turbidity increase	coastal erosion	change in biodiversity	pathogen contamination	introduction of alien species	change in water temperature
Fishing									
Aquaculture									
Dredging									
Navigation									
Military Uses									
Waste Disposal									
Recreation									
Industrial Siting									
Agriculture									
Forestry									
Off-Shore Oil									

scale:

1 2 3 4 5 6 7 8 9 10

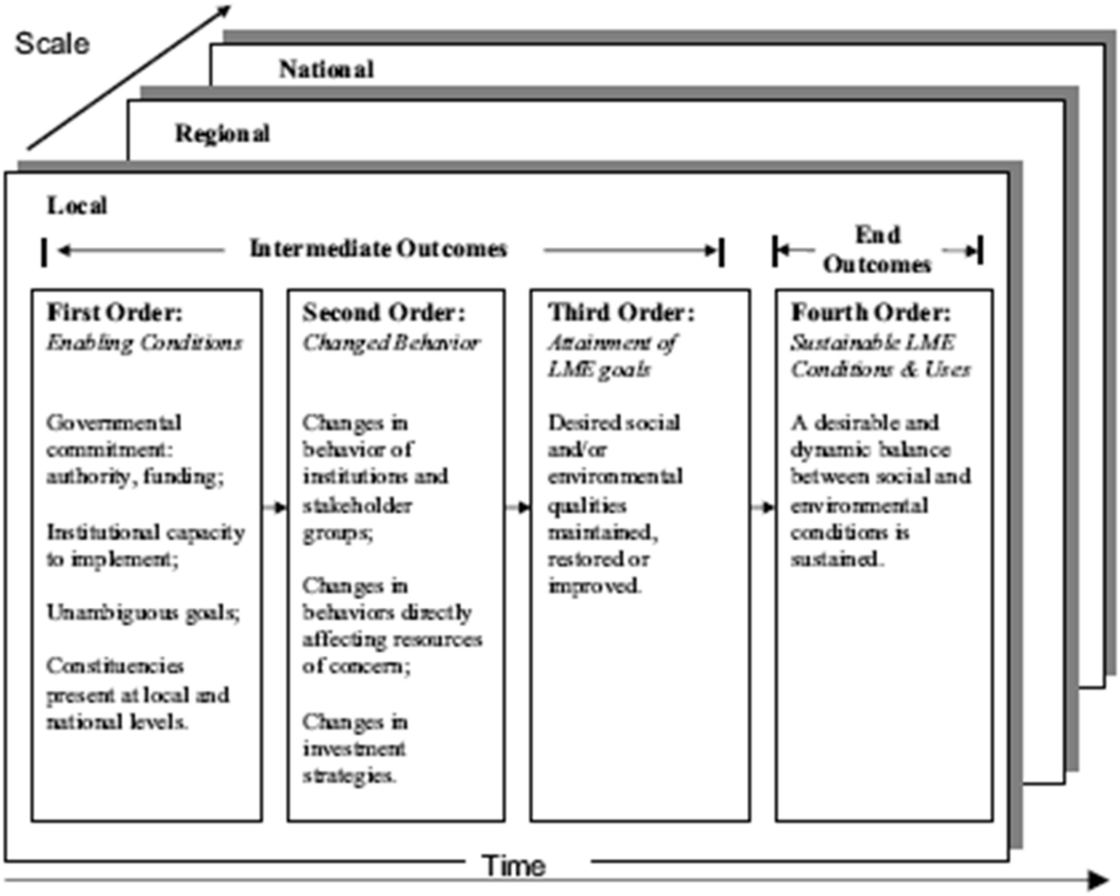
inconsequential — moderate — substantial

One matrix (not shown here) reflects the impact and feedback implications of ecosystem effects listed in Matrix 2 on outcomes of interest to stakeholders and the wider public. LME Governance profiles (Juda and Hennessey, 2001) can allow for comparisons and lessons learned in assessing whether an LME governance mechanism is progressing in its task. It is also important to consider the level at which a problem should be addressed. Another matrix provides an example of governance mechanisms in relation to LME uses (Gulf of Maine, a sub-area of the Northeast U.S. Continental Shelf LME).

Governance mechanisms in ecosystem-based management

Another approach to assessing governance is based on Olsen, *et al*. (2006), who have developed tangible indicators of progress in ecosystem-based LME governance through four orders of LME outcomes. This set of governance indicators can be used to follow the LME management system as it progresses from the baseline conditions documented by the GEF TDA and SAP process to more sustainable conditions and patterns of use. The first order (i) assembles the enabling conditions for ecosystem-based management. These conditions are created by a successful TDA/SAP process. The second order (ii) shows evidence of a successful implementation of an ecosystem based management program. The third order outcomes (iii) mark the achievement of the programme's goals, including targets achieved for the reduction of coastal pollution, the restoration of damaged habitats, the recovery of depleted fisheries, and improved local community incomes and social conditions (socio-economic benefits). The fourth order outcomes (iv) include achieving a dynamic equilibrium among both social and environmental indicators (see figure below).

Olsen and Sutinen propose to assess the management process in relation to management outcomes for all 64 LMEs, with special focus on the 17 LMEs where GEF is funding LME projects.



The Four Orders of Outcomes in Ecosystem-Based Management (Source: Olsen (2003))

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ANNEX 9
VALIDATION EXERCISES

Introduction

One of the requirements of TWAP is that the assessment methodologies are validated by key stakeholders and experts to ensure that they are acceptable and scientifically credible. The draft LME methodology was presented at three forums for discussion and feedback: 1). Twelfth Annual LME Consultative Committee Meeting; 2). UNEP Regional Seas Meeting; and 3). Lisbon conference – 'A Unified Approach for Sustainability in a Changing World: From Ocean Policy to Observations'. Powerpoint presentations included an overview of TWAP and the draft LME assessment methodology, specifically the overarching framework, indicators and approaches for assessment of socio-economics and governance of LMEs, as well as tools for integrating indicators to provide an overall index of ecosystem health and proposed institutional partners.

The following is a summary of the main outcomes of the discussions.

Validation exercises

1. TWELFTH ANNUAL LME CONSULTATIVE COMMITTEE MEETING

This meeting was held from 8 – 9 July, 2010, at IOC-UNESCO Headquarters in Paris, France. It was attended by representatives from GEF LME projects, GEF implementing and executing agencies, and national and regional organizations, among others. A presentation was given by the coordinator of the TWAP LMEs component.

Summary of discussions

The representative from Norway highlighted the issue of scientific credibility and the LME approach (whether right or wrong). He cautioned that the issue of indicator-based assessment is still an open one in terms of its utility and about the risk in downscaling indicators to regional levels. In this regard, he recalled the UNEP LME report and problems with the use of certain fisheries indicators, which did not reflect reality for Norway fisheries. It was suggested that it could be a useful exercise to assess the approaches currently in use in each LME to inform management. The Head of the IOC Marine Science Programme emphasized the importance of scientific credibility, reassuring participants that peer review and science will be at the highest level in IOC. He agreed with the challenges of indicators, especially extrapolating from the global to the regional level, which is an issue that the IOC was working on.

The representative from Mexico agreed that state and process indicators are needed to determine where we are compared to where we would like to be, and that socio-economic and governance indicators are also important. He suggested indicators such as GDP per capita if we want to improve livelihood, and of employment, tourism, infrastructure, index of human development, profit/loss, markets, conflicts, and people satisfaction. Governance is a little more challenging than socio-economics. It was proposed that an index or indexes be developed to rank countries, e.g. how countries are performing in the light of management. It was suggested that the TWAP group hold discussions with OECD and UNDP on socio-economics and governance.

Mr. Al Duda of the GEF Secretariat described the proposed TWAP Tier 1 and Tier 2 assessment, which GEF has called for and which is critically needed for all LMEs for results-based management. He pointed out that LMEs are not OECD countries – most countries do not have the luxury that countries like Norway and the US have. The Tier 2 level will be based on non-OECD TDAs, but we have been sitting on our hands for too long in the ocean realm in applying science to management, and we need both Tier 1 and 2 assessments because Tier 1 is not enough. He hoped that the Tier 2 process would help address any problems such as that which arose with the UNEP LME report and that Norway will be involved in the process. Furthermore, it was recommended that the subject of TDAs and the North's versions in terms of indicators being proposed/ used be included in the agenda of next year's consultation.

The Norway representative clarified that he and Norway have always been very supportive of LMEs and often point to them as examples. However, there is a scale issue and that is where the focus should be. It was understood that while the LME modules and indicators are important in data-poor situations, we need to be aware that a simple indicator-based approach may not be sufficient to *get al*l the management information that is needed.

Another participant was pleased to hear that there will be a Tier 2 assessment and hoped that TWAP gets the best science/ scientists. Results should be based on science results and not science opinion. The FAO representative asked if there was any attempt to look at indicators being developed elsewhere and at different levels. The LME TWAP coordinator responded that the TWAP indicators were selected according to priority transboundary issues and were being arranged under the five modules. Further, the Working Group (WG) has conducted a scoping exercise of what is available globally and regionally, including a review of existing TDAs, and has been evaluating the indicators.

One participant recommended that for the global Tier 1 assessment it would be useful to compare the indicators within comparable systems (e.g. upwelling systems), since the processes are different in different kinds of LMEs.

One of the UNEP representatives drew attention to ongoing discussions in UNEP to develop an IPCC-type programme for biodiversity and ecosystem services. The LME community should ensure that it is well connected to this work. He noted the importance of peer review and ensuring that science is well accepted and understood by policy-makers.

Conclusion

The LME approach and five modules are accepted by GEF and are already being widely applied in a number of GEF LME projects, which attests to the acceptability, validity and credibility of this approach. However, caution should be exercised in scaling down of the indicators from the global to the regional level. The Tier 2 assessment is expected to help address some of the issues associated with scaling. The use of the best science and inputs from the countries as well as peer review are critical for the success of TWAP.

2. TWELFTH GLOBAL MEETING OF THE REGIONAL SEAS CONVENTIONS AND ACTION PLANS

This meeting was held from 20 – 22 September, 2010, in Bergen, Norway. Participants included coordinators of the UNEP and non-UNEP-administered Regional Seas Programmes. A presentation on the TWAP LME (and Open Ocean) methodologies was given by the coordinator of the Open Ocean component.

Summary of discussions

Participants expressed the need for a more extended and broader consultation before being able to give concrete feedback on the methodology: the background document, which was provided to UNEP by the IOC a few weeks before the meeting, was not widely circulated in advance, and so participants felt they could not comment in detail on some of the questions posed to them about the applicability and appropriateness of the methodology for the Regional Seas.

There was considerable concern about the LME assessment and the 'LME approach' to environmental management: the LMEs were developed as areas based on ecological criteria, but regional cooperation is in fact based on political criteria. The Regional Seas coordinators felt that even basing the coastal assessment on LME assessment units predetermined outcomes that may or may not take into account the political realities within the regions. The UNEP staff and TWAP Open Ocean coordinator tried to reassure the coordinators with the following points:

- the TWAP methodology includes an updated conceptual framework that goes beyond the five LME modules;
- GEF has shown to be increasingly aware of the regional political mechanisms already in place in implementing LME projects, and not automatically forcing work through a new LME Commission; and
- The open ocean methodology takes a mapping approach and does not have assessment units, but for the issues that are global and include the open ocean, will provide a tool for zooming into a region and looking at the regional impact/vulnerability of a global issue.

There was some confusion as to whether TWAP as an assessment would incorporate all the regional assessment outputs as well as the relationship between TWAP, the UN Regular Process and the Assessment of Assessments. The Open Ocean approach which includes expert assessment of the scientific literature can take regional assessments into account, and the LME approach could do so. But the use of particular scientific groups to work on models at the LME scale could be seen as a barrier to the full incorporation of regional information, and as a barrier for assessing on scales other than the LME spatial scale.

There was also concern about the socio-economic indicator clusters that have been proposed by the TWAP Governance and Socio-economic CWG - the Millennium Ecosystem Assessment only looked at human well-being, and indicators based on national economies can fail to capture non-market-traded benefits or the scope of marine-related ecosystem services on local populations since they are averaged nationally.

Some additional thoughts on all the different assessments: the different assessment clients will need reduced high-level messages that are targeted to their concerns: they might be issue-based, they might be specific for a region; on the other hand all of the assessments will rely on the same basic monitoring tools whether they are monitoring human or natural systems. Thought and coordination should go into how to construct a common platform for assessments.

Conclusion

One of the major concerns centred on the perceived conflict/inconsistency between the Regional Seas and LMEs spatial scales and political versus ecological criteria and realities. As the meeting participants did not have sufficient time to review the draft methodology reports prior to the meeting, the reports, once completed, should be sent to the UNEP officer responsible for the Regional Seas Programme for circulation to the Regional Seas coordinators for comments.

3. LISBON CONFERENCE

The conference brought representatives from a number of independent assessment and indicator initiatives to exchange information on their respective initiatives to facilitate synergy among them and initiate a process that will lead to coordinated evolution of a framework for sustainable use of marine ecosystem goods and services. It was attended by members of the TWAP LME working group (J. Barbiere, B. Halpern, and L. Talaue-McManus). A presentation, specifically focusing on the proposed indicators, was given on TWAP LMEs and Open Ocean by L. Talaue-McManus.

Conclusion

Many of the indicators proposed for TWAP are similar to those being developed/monitored in other marine programmes and initiatives. A number of recommendations arising from the conference are pertinent to TWAP (see report of conference on TWAP website).

ANNEX 10
GLOSSARY OF TERMS*

Assessment unit: Geographic area or habitat being assessed and which will be used for reporting purposes (e.g. LME, delta).

Causal chain analysis: Traces the cause-effect pathways from the environmental impacts and socio-economic consequences back to their intermediate causes and sectoral influence through to the underlying root causes.

Core indicator: A well-developed, robust indicator preferably for which data are available globally (to be used in the level 1 assessment).

Ecosystem service: The benefit that humans obtain from an ecosystem. Include *provisioning services* such as food and water production, *regulating services* such as flood and disease control, *cultural services* such as spiritual and recreational benefits, and *supporting services* such as nutrient cycling.

Eutrophication: The process whereby waters are progressively enriched with nutrients such as nitrogen and phosphorus, leading to increases in the growth of aquatic plants and algae and accompanied generally by undesirable changes in ecosystem structure and function.

Governance: The whole of public as well as private interactions taken to solve societal or environmental problems. It includes the formulation and application of principles guiding those interactions and care for the institutions that enable them. *Governance* is broader than government and includes the full range of stakeholders and interactions.

Hypoxia: A condition in which natural waters have a low dissolved oxygen concentration, of less than 2-3 ppm.

Large Marine Ecosystem: A natural region of coastal ocean space encompassing waters from river basins and estuaries to the seaward boundaries of continental shelves and seaward margins of coastal currents and water masses. They are relatively large regions of 200 000 km^2 or greater, the natural boundaries of which are based on four ecological criteria: bathymetry, hydrography, productivity, and trophically-related populations.

Level 1 Assessment: A global comparative assessment of each transboundary water category based on existing data and information to identify systems that are most degraded or at greatest risk.

Interlinkage: The relationship between ecosystem components, hydrological elements, or other natural systems created by the mutual interactions of systems or the influence of one system on another in either a positive or negative fashion.

Transboundary: Crossing or existing across national boundaries; Transboundary waterbody means any body of water or its drainage basin that transcends international boundaries, including oceans, large marine ecosystems, regional seas, rivers, lakes, groundwater systems, and wetlands.

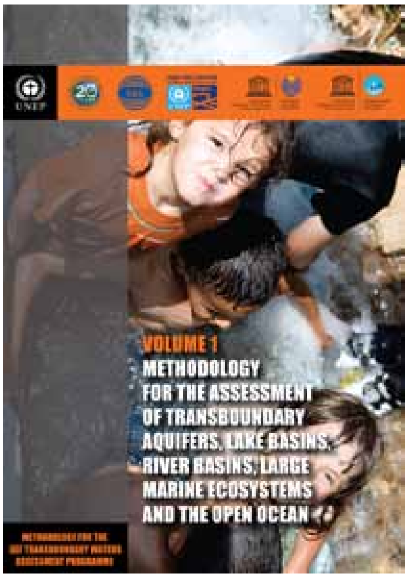
Transboundary Diagnostic Analysis (TDA): A rapid scientific and technical assessment of an international waters area that identifies and quantifies the priority environmental issues and problems and their socio-economic consequences.

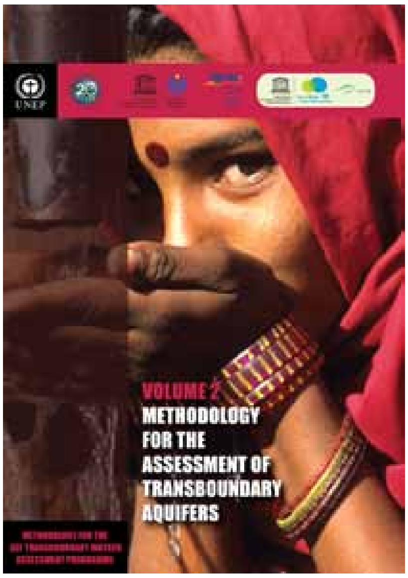
Vulnerability: The degree of exposure to risk experienced by human populations (including physical infrastructure), and to external perturbations by ecosystems.

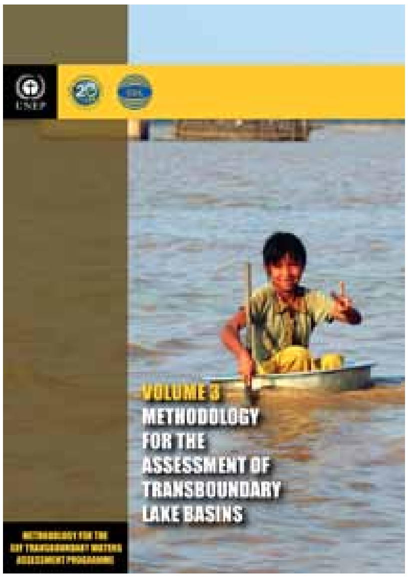
* See Volume 1 Annex II Glossary of terms for additional terms.

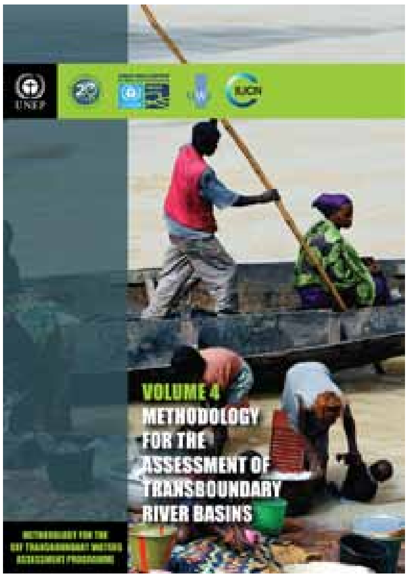
METHODOLOGY FOR THE GEF TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

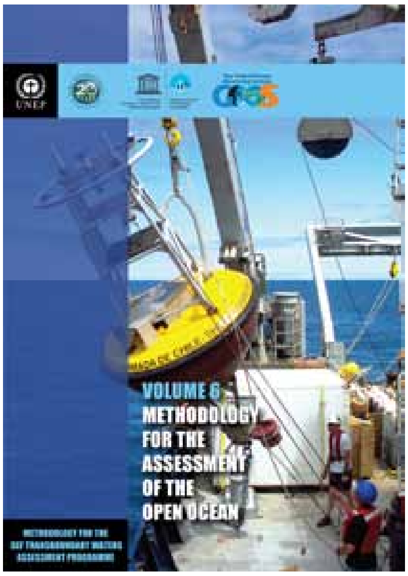
Volumes 1-6











www.unep.org

United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: uneppub@unep.org
www.unep.org

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The water systems of the world - aquifers, lakes, rivers, large marine ecosystems, and open ocean - support the socioeconomic development and wellbeing of the world's population. Many of these systems are shared by two or more nations and these transboundary resources are interlinked by a complex web of environmental, political, economic and security interdependencies. In order to address this challenge UNEP, under the auspices of the GEF, coordinated over a 2 years period from 2009 to 2011 the implementation of the Medium Size Project (MSP) entitled "Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme (TWAP)".

This Project produced methodologies for transboundary water systems. The final results of this Project are presented in the following six volumes:

Volume 1 - Methodology for the Assessment of Transboundary Aquifers, Lake Basins, River Basins, Large Marine Ecosystems and the Open Ocean;
Volume 2 - Methodology for the Assessment of Transboundary Aquifers;
Volume 3 - Methodology for the Assessment of Transboundary Lake Basins;
Volume 4 - Methodology for the Assessment of Transboundary River Basins;
Volume 5 - Methodology for the Assessment of Large Marine Ecosystems; and
Volume 6 - Methodology for the Assessment of the Open Ocean.

This Project has been implemented by UNEP in partnership with the following lead agencies for each of the water systems: the International Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) for transboundary aquifers including aquifers in small island developing states (SIDS); the International Lake Environment Committee (ILEC) for lake basins; UNEP-DHI Centre for Water and Environment (UNEP-DHI) for river basins; and Intergovernmental Oceanographic Commission (IOC) of UNESCO for large marine ecosystems and the open ocean.

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