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IW:Science

*Enhancing the use of Science in International
Waters projects to improve project results*

SYNTHESIS REPORT

SCIENCE-POLICY BRIDGES OVER TROUBLED WATERS

Making Science Deliver Greater Impacts
in Shared Water Systems



GEF IW:Science Project

Science-Policy Bridges Over Troubled Waters

Making Science Deliver Greater
Impacts in Shared Water Systems

By Laurence Mee and Zafar Adeel



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Science-Policy Bridges Over Troubled Waters

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September 2012

IW: Science, or Enhancing the Use of Science in International Waters Projects to Improve Project Results is a medium-sized project of the Global Environment Facility (GEF) International Waters (IW) focal area, implemented by the United Nations Environment Program (UNEP) and executed by the United Nations University Institute for Water, Environment and Health (UNU-INWEH). GEF ID Number: 3343.

This report provides the overall synthesis of the findings of the GEF IW:Science project. It is based on a series of reports produced for each of five classes of global transboundary water system: River Basins, Lakes, Groundwater, Land-based Pollution Sources, and Large Marine Ecosystems and Open Oceans. Summarizing the key findings and recommendations from these underlying Synopsis and Analysis Reports, an integrated perspective on a broad range of transboundary water issues is provided.

This report was made possible through the dedication, input and authorship by the IW:Science Working Group Co-chairs, Group members and project partners for the GEF IW:Science Project. All reports can be found on the IW:Science, UNU-INWEH, IW:LEARN and GEF websites.

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Cover photo: Crossing the U Bein Bridge at sunset, Amarapura, Mandalay, Myanmar.

List of Acronyms and Abbreviations

ACRONYM	MEANING
AM	Adaptive Management
BENEFIT	Benguela Environment Fisheries Interaction and Training Programme
BEP	Benguela Ecology Programme
CBD	Convention on Biological Diversity
CCA	Causal Chain Analysis
CIC	Co-ordinating Committee of La Plata Basin Countries
DPSIR	Driver, Pressure, State, Impact and Response (Framework)
DPSWR	Drivers, Pressure, State, Welfare, Response (Framework)
EIMS	Environmental Information Management and Advisory System
ELME	European Lifestyles and Marine Ecosystems
ENVIFISH	Environmental Conditions & Fluctuations in Recruitment and Distribution of Small Pelagic Fish Stocks
EU FP6	European Union Sixth Framework Programme
FREPLATA	Environmental Protection of the Rio Del La Plata and its maritime front: Pollution Prevention and Control and Habitation Restoration
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information Systems
GIWA	Global International Water Assessment
ICM	Integrated Coastal Management
IIMS	Integrated Information Management Systems
IPCC	Inter-Governmental Panel on Climate Change
IUU	Illegal, Unreported and Unregulated
IW	International Waters
IW:LEARN	International Waters: Learning Exchange And Resource Network

ACRONYM	MEANING
IW:Science	Enhancing the Use of Science in International Waters Projects to Improve Project Results is a medium-sized project of the Global Environment Facility (GEF) International Waters (IW) focal area
LBPS	Land Based Pollution Sources
LME	Large Marine Ecosystems
LOICZ	Land-Ocean Interactions in the Coastal Zone
MEA	Millennium Ecosystem Assessment
NGO	Non-Governmental Organization
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PROCUENCA	Programme for the Integrated Management of Water Resources and Sustainable Development of the San Juan River Basin and its Coastal Zone
RA/RM	Risk Assessment/Risk Management
RICH	Regional Information Coordination House
SAP	Strategic Action Programme
SEP	Scientific Evidence Panel
SMART	Specific, Measureable, Achievable, Relevant and Time-bound
SRES	Special Report on Emissions Scenarios
STAP	Scientific and Technical Advisory Panel
TDA	Transboundary Diagnostic Analysis
TTT	Technical Task Team
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU	United Nations University
VIBES	Viability of Exploited Pelagic Fish Resources in the Benguela Ecosystems in relation to the Environment and Spatial Aspects
WFD	Water Framework Directive

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Foreword

The International Waters (IW) Focal Area of the Global Environment Facility (GEF) covers water systems shared by two or more countries; underground aquifers, river basins and lakes as well as marine coasts, large marine ecosystems and open oceans. These different water systems face complex issues where interactions are not always well understood or often inadequately recognised. In more than twenty years of its history the GEF has invested over 1.3 billion US dollars in transboundary projects and programmes, catalyzing 7 billion US dollars of investment in managing shared waters – fresh and marine – in almost every part of our planet, above and below its surface. This significant investment includes a large and valuable resource of scientific knowledge and results-based management improvement opportunities for GEF. The crucial role for science in determining the nature and priority of investments has largely been ‘taken for granted’ until now, its role and full potential have not previously been documented and scrutinized.

This publication is very timely since to date, no effort has been made to recognize, capture, analyze and integrate the scientific findings from these projects and to disseminate them across the IW portfolio and beyond. Similarly, until now, there has been little opportunity to inform IW project scientists and managers about broader global water science issues, in particular emerging challenges, new methodologies and science breakthroughs. There is a critical need for this cross-system comparative analysis for future strategic planning for the IW focal area. By making this knowledge widely available, GEF-eligible countries would be greatly able to strengthen their scientific capacity and use of science. The results presented here would broaden the IW science base through the integration of social and natural sciences into a systems approach that will, in turn, strengthen ecosystem-based, adaptive management within IW projects.

The IW:Science project, a GEF Medium-sized project ‘Enhancing the use of science in IW projects to improve projects results’, laid down a fundamental scientific understanding of the IW portfolio efforts to date and provided data and analysis underpinning the findings and recommendation of this report – one of the key outcomes of this project. The Executing Agency, the United Nations University Institute for Water,

Environment and Health (UNU-INWEH) should be praised for collating this report and for producing five sets of underlying, waters system specific reports, which provided understanding and documented, for future analysis and reference, the scientific experience and scientific best practices from the IW projects portfolio. The project results, including this publication, will enhance - through knowledge integration and information-sharing tools - the use of science in the GEF IW focal area to strengthen priority setting, knowledge sharing, and results-based, adaptive management in current and future projects.

This volume is significant proof that the science emerging from GEF projects contributes to our global knowledge on transboundary groundwaters, rivers, lakes, coastal areas, large marine ecosystems and the global ocean. It is an important step in raising the profile of GEF IW science globally. It provides an assessment and synthesis of science across the full IW portfolio, points out to emerging science issues, contemporary scientific challenges, research and science-policy gaps and global-scale impacts and research needs for action by the IW focal area. Documentation of use of science, the engagement of scientists, and the communication of scientific advice for results-based, adaptive management in the IW focal area as well as a policy-guidance overview which this report and the IW:Science project provides is invaluable for future GEF IW projects design.

Last but not least, all GEF recent and future projects will broadly benefit from further dissemination of this publication through the web page of IW:Learn – the GEF IW global knowledge management and learning platform. GEF will sustain the IW scientific learning network and its capacity for knowledge sharing, mutual learning in concert with global scientific community.



Ivan Zavadsky
GEF International Waters
Focal Area Coordinator

CHAPTER ONE

Summary for Decision Makers

The Global Environment Facility (GEF) has catalysed the largest investment of its kind in human history into shared water bodies. The GEF has catalysed more than US\$7 billion of investment in managing shared waters – fresh and marine – in almost every part of our planet, above and below its surface. The crucial role for science and scientific discovery in determining the nature and priority of investments has largely been taken for granted and its role and full potential have not previously been scrutinised. The present report is the culmination of a process that seeks to raise the profile of use and generation of science in the GEF International Waters (IW) portfolio and ensure that scientific advice is truly fit for purpose, gives greatest added value and that the science emerging from GEF projects contributes to our global knowledge base. In the IW:Science process, we have examined projects focussing on transboundary ground waters, rivers, lakes, coastal areas, large marine ecosystems and the global ocean and distilled the lessons learned in a series of synopsis reports and finally into the present document.

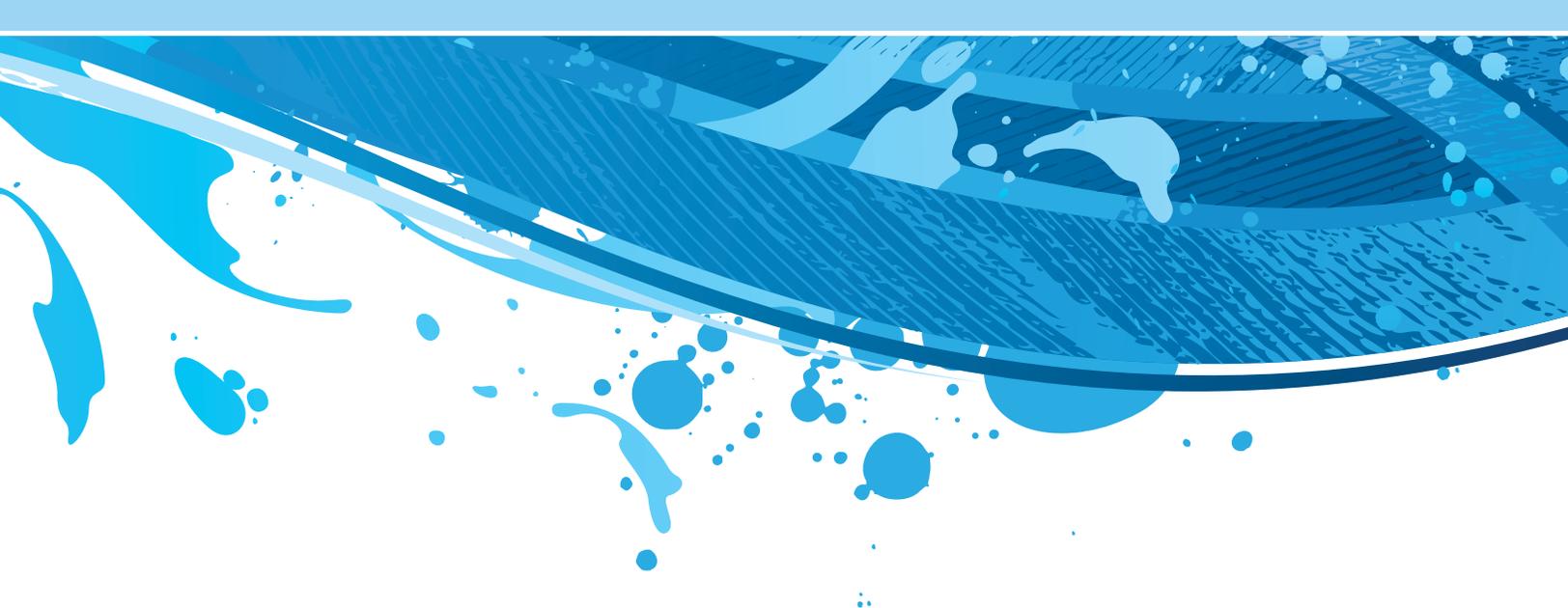
Insufficient and disjointed management of human demands on water and aquatic systems has led to situations where both social and ecological systems are in jeopardy and have even collapsed. It is important to understand that the relationship between global pressures and their impacts on aquatic systems requires a new scientific approach that embraces complexity. The management of groundwater, for example, remains isolated and limitations in recharge capacity of aquifers are not well understood by decision makers. Urbanization and economic activity are increasingly putting river basins under intense pressures, which are projected to increase further due to growing water scarcity and diminishing water quality. Entire river systems are changed by management measures such as flow regulation, fragmentation of river courses due to damming and water consumption in dry regions. On

a regional and global scale, multiple human drivers on marine ecosystems strongly affect all areas of the oceans. In some marine areas, dissolved oxygen – a critical ecological indicator for coastal marine ecosystems – has changed drastically over a relatively short time and has become a worldwide crisis. Overall, the huge increase in the stored heat in oceans does not bode well for impacts on climate, ecosystems, sea level and eventually human society.



Management of the Mekong requires significant social and natural science understandings / A. Dansie

The role of science and the scientist in addressing these huge management challenges is to primarily inform policy choices and ideally not to advocate a particular management solution. Most of the transboundary water problems tackled by the GEF projects can be



characterised as “wicked” problems that require management decisions involving human values and difficult trade-offs. The consequences of poor decision-making are dire: we face a “water bankruptcy” in many regions of the world with implications for food and energy security, adaptation to climate variability and change, economic growth and human security challenges.

While successful implementation of the Transboundary Diagnostic Analysis (TDA) approach has been the single most effective element in the success of transboundary management interventions, the science utilized for this is often omitted from key reports. The GEF IW Focal Area has developed innovative approaches for enhancing the information base for decision-making. The TDA, together with a closely-linked and politically negotiated Strategic Action Programme (SAP), has emerged as a major tool for better understanding complex shared-water resources and systems. We strongly recommend that all GEF initiatives should explicitly include use of science and engagement of scientific networks in ways that contribute to the regional and global knowledge base. Objectivity and freedom from political influence is the most important element in success of a TDA. Sufficient information exists on how successful TDA-SAP processes and their underlying information needs can be designed. There are some areas needing improvement and new scientific approaches however; on the general issue of horizon scanning for example, we note that very few GEF projects attempt to look into the future.

Targeted research and resulting scientific discoveries are a major way of reducing the uncertainties in the management of shared natural resources – investments in targeted scientific research have paid rich dividends for GEF. We examined new and emerging global issues; the ‘surprises’ that appear from time to time. Sometimes these ‘surprises’ are already in the scientific domain long



A groundwater pumping station servicing a rural community in the Lebombo Mountains, Swaziland near the Mozambique border / A. Dansie

before they become serious socio-political problems (this happened with the ozone hole, chlorinated pesticides, eutrophication in the Baltic, etc.). We examined how these early ‘alarm bells’ could be heard, and heeded, and how the GEF might foster this process. We have developed a framework for research in this area that can be utilized by new transboundary water projects. It includes an integrated roadmap for placing forward-looking scientific research squarely in strategic and project planning. It is clear that a better understanding of emerging issues would help the GEF design timely interventions in the future.

Scenario development – utilizing horizon scanning – must be used as a tool for comparing management alternatives and their outcomes. Linked to the problem of emerging issues is the need for horizon scanning and

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Guarani Aquifer System, a well in Uruguay / O. Tujchneider

a systems approach. There is a huge need to develop plausible social-ecological scenarios that can help frame our understanding of the state of the natural environment in the future and its capacity to deliver the much-needed services. We consider that development of standardized horizon scanning methodologies and their consistent application is essential to the success of transboundary water projects. Furthermore, systems science, involving natural and social science (including economics) is implicit for delivering the GEF's central objectives but has received little attention and there are only few examples of GEF projects that have taken a systems approach and examined future scenarios.

Considerable attention has to be placed on the optimum use of scientific expertise in the design and implementation of GEF projects. Scientific expertise can be applied in many ways to GEF projects as part of, and in addition to, the TDA-SAP process. Highlights of how expertise has been employed in GEF projects, and recommendation for future inclusion of expertise are: building Communities of Practice to stimulate innovation and optimize uptake of scientific information – using TDA as a tool; engaging scientists in capacity development endeavours; engaging the scientific community in dissemination and communications to general and policy audiences and decision makers; conveying future forecasts and scenarios to the general public; informing policy choices through effective risk communication; and engaging at regional level through forecasting, disaster management and preparedness. We

provide evidence of how these approaches have been employed and the need for making them more widely available.

Significant advances in the field of systems science should be incorporated into the scientific framework underpinning the International Waters focal Area. Effective solutions to today's and tomorrow's environmental problems will depend upon a 'joined-up' approach engaging the combined skill and energy of natural and social scientists working within a common framework. We focus on two aspects of systems science: conceptual modelling and adaptive management - a practical process for defining and achieving environmental objectives in the face of complexity. The Drivers-Pressures-State Change-Welfare-Response (DPSWR) model is presented as a useful basis for systematic analysis and formulation of potential solutions. It couples well with the existing GEF indicator framework where management action is often triggered by one or more indicators exceeding agreed values.

GEF IW programmes and projects provide good examples of the practical application of adaptive management and this has wider value as case studies for future policy making. Adaptive management may be particularly useful to deal with complex or "wicked" issues that cannot be resolved through 'first order fixes' (simple linear solutions or 'easy wins'). The most crucial aspect of this process is the feedback mechanism that is created. Adaptive management happens through failures as well as successes – but policymakers (and sometimes international organisations) are very reluctant about revealing negative experiences.

Scientific discovery must provide the bridge between research and management through which alternative solutions can be "test-driven." In the light of the new science-policy framework, we review some of the challenges in creating linkages between science and policy. It is particularly challenging to achieve long-term commitment beyond the life of the GEF intervention, although very important for successful adaptive management. It is also important to help policymakers to find viable solutions to environmental problems in transboundary waters. We illustrate how the DPSWR framework can help to identify solutions at various temporal and geographical scales. In particular, the SAP should contain a range of solutions to environmental problems at the Driver, Pressure, State and Welfare level as well as comprehensive schemes to improve

governance (policies, laws, institutions). Choices between alternative solutions are based upon a large number of factors including feasibility, durability (sustainability), public acceptance, cost effectiveness, social willingness and ability to pay, as well as political factors that reflect social choice.

The GEF can obtain considerable added value from use of science in its projects and contribute to the global knowledge base by focussing efforts on the quality and content of the resulting scientific findings and consistency in the way it is reported. Well-recorded science with scope for innovation will enhance the credibility of the IW Focal Area and buy-in from stakeholders.



Water collection, Tanzania / A. Dansie

We provide six specific recommendations for improvement:

1. All GEF IW projects should incorporate a scientific evidence panel (SEP) that includes local scientists, ensures data or metadata archiving and produces a separate summary report of the science used in the intervention.

2. During the preparation of the project proposal, a gap analysis should be undertaken to identify likely limitations in the scientific information to support project implementation. A strategy for bridging the gaps should be proposed and financial support for this should be part of final project design. Targeted research is a legitimate approach for bridging identified gaps.
3. One of the remits of each SEP should be to conduct a horizon scanning exercise. This should be part of every TDA-SAP process and include review of emerging science issues and future scenarios for key issues. We have proposed a useful classification framework to assist with the identification of emerging issues.
4. The GEF should develop a process for medium/ long term evaluation of the impact of interventions (i.e. well after the termination of the project), indicators developed using the DPSWR framework during the SAP process can provide the structure for this process. This role could be assigned to the GEF Evaluation Office and should include a review of tangible evidence of impacts. Such a long-term analysis by GEF would also help in evaluating the effectiveness of the adaptive management strategy adopted by the GEF's IW Focal Area, and lead to a stronger argument for employing SMART¹ indicators.
5. The GEF should empower its Scientific and Technical Advisory Panel (STAP) or a group of similar standing to examine the basic scientific principles underpinning GEF projects and to communicate them to implementing and executing agencies in order to ensure greater uniformity in terminology and overall methodology.
6. Greater attention should be paid to improve the storage and dissemination of the scientific data from GEF projects in order to make it more accessible for further analysis. This should not be limited to standard project reports but should provide an access route to the data and information that underpins them.

1 Specific, Measurable, Achievable, Relevant and Time-bound.

CHAPTER TWO

An Overview of Global Challenges to International Water Systems

The environment, natural and social, covered by the International Waters Focal Area of the GEF is unlike any other on our planet. This is because it tends to have open boundaries and operates at multiple scales. Aquifers spanning international boundaries interact with surface waters operating at different scales and these flow into lakes and regional seas that, in turn, form part of the global ocean. Many of the challenges each of these systems is facing are complex in nature, for which interactions are poorly understood or inadequately recognised.

THE STATE OF CHALLENGES IN INTERNATIONAL AND TRANSBOUNDARY SYSTEMS

Insufficient and disjointed management of human demands on water and aquatic systems has led to situations where both social and ecological systems are in jeopardy and have even collapsed. The underlying challenge is that many in the policy- and decision-making realm regard these systems and their resources as limitless and freely available

AN OVERVIEW OF PRESSURES ON IW SYSTEMS

Understanding the relationship between these global pressures and their impacts requires a new scientific approach that embraces complexity. Growth in the global population and the increasing demand for natural capital and ecosystem services (e.g., water for human consumption and irrigation, transport along rivers and seas, fish and aquatic plants and algae, waste disposal, renewable energy, recreation and tourism) is putting huge multiple pressures on aquatic systems.

The design of GEF groundwater projects tends to be limited in scope and linkages to other policy arenas are often not addressed, leading to limited understanding

by decision makers. For example, managers concerned about efficient use of groundwater resources, may not give much emphasis to the interdependency between recharge sites and biological diversity because this is beyond their remit – and this is sometimes reflected in sectoral system assessments, even though changes in evapotranspiration from biodiversity loss may have wider implications for human development. Similarly, priorities for river systems management may be altered if the downstream implications for associated coastal seas are taken into account.

Urbanization and economic activity are increasingly putting river basins under intense pressures, which are projected to increase further due to growing water scarcity and diminishing water quality. Rivers are particularly exposed to human pressures, due to the fact that most of the largest cities and areas with the highest population densities are situated on rivers, and often on river delta systems. The very recent report Exploring the links between water and economic growth² shows that ten river basins are home to a quarter of the world population, generating 10% of its GDP. Water scarcity is likely to be significant in seven of these basins by 2050 and this has serious implications for human development, the economy and basin/downstream ecosystems. The GDP in these basins – all located in developing countries, with the partial exception of the Danube – is estimated to be as large as the combined economies of the USA, Japan and Germany. The GEF has some level of involvement in almost all of these rivers and six are included in the IW portfolio.

² Frontier Economics (2012) Exploring the links between water and economic growth; A Report Prepared for HSBC. London, June 2012, 62pp

Table 1 The ten most populous river basins and the involvement of the GEF (river data from Ref 1)

RIVER	COUNTRIES	POPULATION IN 2010		BASIN GDP IN 2010		BASIN GDP IN 2050		GEF INTERVENTION	
		(million)	(% world)	(US\$ billion)	(%world)	(US\$ billion)	(% world)	IW	Non regional
Ganges	India, Bangladesh, Nepal	528	7.7%	690	1.1%	5,776	3.00%	No	Biodiversity
Yangtze (Chian Jiang)	China	407	5.9%	1,796	2.9%	14,810	7.80%	Yes	Multiple
Indus	India, China, Pakistan	254	3.7%	281	0.5%	1,522	0.8%	No	Small grants
Nile	North-East Africa*	207	3.0%	304	0.5%	3,035	1.6%	Yes	
Huang He (Yellow river)	China, see**	170	2.5%	751	1.2%	6,187	3.3%	Yes	IW
Huai He	China, see**	103	1.5%	457	0.7%	3,766	2.0%		Biodiversity
Niger	West Africa***	100	1.4%	105	0.2%	753	0.4%	Yes	
Hai	China, see**	96	1.4%	426	0.7%	3,511	1.9%	Yes	
Krisna	India	89	1.3%	126	0.2%	1,052	0.6%	No	
Danube	Central and E. Europe****	81	1.2%	1,305	2.1%	6,432	3.4%	Yes	Biodiversity
Total		2035	29.6%	6,241	10.1%	46,844	24.80%		

* Sudan, South Sudan, Burundi, Rwanda, Democratic Republic of the Congo, tanzania, Kenya, Ethiopia, Uganda and Egypt

** Tranboundary implications for the Yellow Sea

*** Guinea, Mali, Niger, Benin, Nigeria

**** Switzerland, Germany, Austria, Slovakia, Czech Republic, Hungary, Croatia, Serbia, FYR Macedonia, Bulgaria, Moldova, Ukraine, Romania

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Box 1. Lake Chad: A system with severe water stress

Lake Chad has shrunk considerably in the last 40 years due to a decrease in rainfall in its southern basin. The lake, with a maximum depth of 11 metres is bordered by Cameroon, Chad, Niger and Nigeria.

A study in *Regional Environmental Change*³ found that main activity of the population living around the lake during high lake levels were fishing, which provide food and income from the export of smoked and dried fish. However, they were first herders and farmers who developed flood-retreat farming and sophisticated irrigation systems. Since 1973 large areas with rich soils have allowed maize, cowpeas, sorghum and vegetable farming without irrigation and fertilizer, but there is a risk of soil exhaustion if the lake does not return.

The GEF has undertaken a study on the integrated environmental assessment and social assessment of the reversal of land and water degradation in the Lake Chad Basin⁴, with pilot projects on the Waza-Logone Floodplains (northern Cameroon), Komadougou-Yobe Integrated Wetlands (northern Nigeria), Transboundary Desertification Control (Niger and Chad), Lake Chad shorelines (Cameroon, Chad, Niger and Nigeria), Lake Fitri (Chad) and the Upper Chari Basin Transboundary Project (Central African Republic and Chad). The study made recommendations to take forward for the TDA-SAP process.

These suggestions were taken forward and GEF approved a US\$ 20.5 million grant, which will be run through the African development Bank (who will contribute another US\$ 146 million to the project) for the Lake Chad Basin Regional Program for the Conservation and Sustainable Use of Natural Resources and Energy Efficiency on the 9th of November 2011⁵. This project calls for conserving the water and agro-sylvo ecosystems of the Lake Chad Basin and ensuring sustainable use of resources while meeting the needs of energy efficiency and food security. The expected outcomes of the project are:

- Increased efficiency in approaches and tools related to natural resources and energy consumption
- Improved sustainability of productive landscapes
- Increased capacity and knowledge concerning integrated water resource management and water use efficiency
- Strengthened water and ecosystems management and riparian collaboration

3 Luxereau, A., Genthon, P., Ambouta Karimou, J-M. 2011. Fluctuations in the size of Lake Chad: consequences on the livelihoods of the riverian peoples in eastern Niger. *Regional Environmental Change* (DOI: 10.1007/s10113-011-0267-0)

4 <http://iwlearn.net/iw-projects/767/reports/lake-chad-basin-project-social-and-environmental-assessment-english-version.pdf>

5 <http://www.afdb.org/en/news-and-events/article/gef-approves-usd-20-5-million-grant-for-lake-chad-basin-regional-program-8582/>

River systems are changed by management measures such as flow regulation, the fragmentation and loss of lateral connectivity in river courses due to damming and water consumption in dry regions⁶.

Human interactions also cause sedimentation of river systems, chemical contamination, acidification, thermal unbalance, the introduction of invasive species, etc. Globally, river geochemistry have been altered by agriculture, deforestation, mining, urbanisation, industrialisation, irrigation and damming with the continental aquatic systems now being affected by hypoxia, eutrophication, salinization, contamination by nitrates, metals and persistent organic pollutants⁷. There are only a few typical management strategies that have been employed to deal with these issues. These management responses usually last between 10 and 50 years (if they are successful), while the reaction of the earth system to the changes such as major changes of fluxes via the continental waterscape, the land-ocean interactions, the water bodies-atmosphere interactions will take place over a much longer time scale of 100-1,000 years⁷. Lake Chad (please see Box 1) is an example of mis-balanced management.

Multiple human drivers on marine ecosystems strongly affect all areas of the oceans⁸. The science challenges dealing with marine international waters at a global, regional and transboundary level include multiple stressors such as eutrophication, overfishing, habitat destruction, pollution, harmful algal blooms and the movement of opportunistic invasive species. The interlinkages between the oceans and land-based activities include runoff of pollutants and nutrients into coastal waters, while the extraction of resources decreases the resilience of those ecosystems. Fisheries and the global seafood trade also impacts the health of



Erosion and Sand Bag Protection on the Inside Dam Wall of the Maga Dam (south of Lake Chad) (Lake Chad Basin GEF project).

the world population⁹. The overexploitation or collapse of most world fisheries are primarily the result of their mismanagement and it has been suggested¹⁰ that well-designed catch shares might prevent fishery collapse.

Dissolved oxygen – a critical ecological indicator for coastal marine ecosystems – has changed drastically over a relatively short time and has become a worldwide crisis. In a paper on the spread of eutrophication in marine systems Diaz and Rosenberg¹¹ suggest that “*hypoxia and anoxia are among the most widespread deleterious anthropogenic influences on estuarine and marine environments, and now rank with overfishing, habitat loss, and harmful algal blooms as major global environmental problems. We believe it would be unrealistic to return to preindustrial levels of nutrient input, but an appropriate management goal would be to reduce nutrient inputs to levels that occurred in the middle of the past century, before eutrophication began to spread dead zones globally.*”

A huge increase in the stored heat in oceans does not bode well for impacts on climate, ecosystems, sea level and eventually human society. All of these findings have

6 Meybeck, M. The global change of continental aquatic systems: dominant impacts of human activities. *Water Sci. Technol.* 49(7): 73-83 (2004).

7 Meybeck, M. Chapter 6: Global Alteration of Riverine Geochemistry under Human Pressure, p. 97-114 in: Ehlers, E. and Krafft, T. (Eds.) *Understanding the Earth System: Compartments, Processes and Interactions*. Springer, Berlin, (2001).

8 Halpern, B. S. et al. A Global Map of Human Impact on Marine Ecosystems. *Science* 319, 948-952, doi:10.1126/science.1149345 (2008).

9 Smith, M. D. et al. Sustainability and Global Seafood. *Science* 327, 784-786, doi:10.1126/science.1185345 (2010).

10 Costello, C., Gaines, S. D. & Lynham, J. Can catch shares prevent fisheries collapse? *Science* 321, 1678-1681, doi:10.1126/science.1159478 (2008).

11 Diaz, R. J. & Rosenberg, R. Spreading dead zones and consequences for marine ecosystems. *Science* 321, 926-929 (2008).

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to be framed in the context of an inexorable process of climate change. Two very recent studies^{12,13}, have confirmed the pace of change in the oceans and its human drivers. The oceans are the ultimate repository of heat that drives climate, weather, fertilisation of the oceans and global freshwater supply. Warming could also eventually shut down key circulation processes through stratification. Though the 0.6°C average warming of the sea surface since the Challenger Expedition in 1872 does not sound very large, it represents a huge increase in heat storage. The distribution of the temperature rise and change in seasonality is not uniform; the largest changes are in polar and equatorial systems including the areas of South-East Asia that harbour the highest marine biological diversity¹⁴.

MANAGEMENT CHALLENGES FOR COMPLEX SYSTEMS

The role of science and the scientist in complex management situations is to primarily inform policy choices in an understandable way by elaborating the consequences of each choice, and ideally not to advocate a particular management solution. The management of complex systems poses one of the most difficult challenges in modern times and one where relevant scientific evidence can provide key information on the trade-offs involved in alternative potential solutions. The role of the scientist involved in these analyses is to provide objectivity and not resort to advocacy positions; that is typically the role of the policy maker.

Most of the problems tackled by GEF IW projects can be characterised as “wicked” problems. In a recent scientific paper, Svein Jentoft and Ratana Chuenpagdee¹⁵ used a well-established management paradigm to define environmental issues as ‘tame’ or ‘wicked’. Tame- or ‘first order’ - problems have simple causes and a

linear relationship to them. They can often be ‘fixed’ using a straightforward piece of technology, change in practice, training, etc. Policymakers and investors like ‘tame’ problems because they are easy wins, sometimes even described as ‘low hanging fruit’. In the past, the GEF has often been driven towards focusing on the tame problems that can be ‘fixed’ with a clear-cut intervention¹⁶. The problem is that most issues affecting international waters are complex with no easy wins in sight and difficult trade-offs. These ‘wicked’ – or ‘second order’ - problems require value judgements. Science can provide information to help make decisions but these ultimately depend on complex social factors.

Many regions around the world face “water bankruptcy” with implications for food and energy security, adaptation to climate variability and change, economic growth and human security challenges.

Worsening water security – particularly in water-scarce regions – will adversely impact various parts of the global economic system, with the volatility of global food prices being one of the first indications of this issue. The Water Security report by the World Economic Forum Water Initiative^{17,18}, states that if we are to ensure sustained economic growth, human security, and political stability, water management is an urgent political issue that requires government engagement in its management and reform. Good regulation and integrated management of water resources is indispensable. The Report states that without proper adaptation or planning for change, hundreds of millions of people will be at greater risk of hunger, disease, energy shortages and poverty due to water scarcity, pollution or flooding. The risks, or consequences of making decisions under uncertainty, can be qualified and sometimes quantified. Providing decision-makers with tools that shows the broader water resource consequences of various decisions (actions, inactions) can substantially contribute to better overall resource management, and reduced threats and adverse impacts.

12 Gleckler et al. Human-induced global ocean warming on multidecadal timescales. *Nature Climate Change* DOI: 10.1038/NCLIMATE1553, 10 June 2012

13 Dean Roemmich, W. John Gould & John Gilson. 135 years of global ocean warming between the Challenger expedition and the Argo Programme. *Nature Climate Change* 2,425–428 (2012)

14 Michael T. Burrows, et al. The Pace of Shifting Climate in Marine and Terrestrial Ecosystems. *Science* 334, 652 (2011)

15 Svein Jentoft and Ratana Chuenpagdee, *Marine Policy*, Volume 33, Issue 4, July 2009, Pages 553-560

16 Mee, L.D., H. Dublin and A. Eberhard (2008) Evaluating the Global Environment Facility: A goodwill gesture or a serious attempt to deliver global benefits? *Global Environmental Change* 18(4): 800-810

17 Waughray, D. *Water security: the water-food-energy-climate nexus: the World Economic Forum water initiative*. Island Press, Washington (2011).

18 WWAP (World Water Assessment Programme). 2012. *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk*. Paris, UNESCO.



Rainfall runoff, laden with soil from recent coastal development, brings excess nutrients and contaminants into the marine environment / *Marine Photobank 2008, G. Bergsma*

USE OF SCIENCE IN UNDERSTANDING AND RESPONDING TO GLOBAL CHALLENGES

The Transboundary Diagnostic Analysis (TDA) has emerged as a major tool for better understanding complex shared-water resources and systems. The GEF IW focal area has been exemplar in pioneering the process of Transboundary Diagnostic Analysis (TDA) to reach a consensus on the scientific evidence base for each system where an intervention was proposed. This was coupled with a political and technical process of evaluating cost effective solutions and agreeing on a Strategic Action Programme (SAP) to cover the entire system. Sufficient information exists on how successful TDA-SAP processes and their underlying information needs can be designed.

EFFECTIVENESS OF SCIENCE IN GEF PROJECTS

We strongly recommend that all GEF initiatives should explicitly include use of applied science and engagement of scientific networks in ways that contribute to the regional and global knowledge base. Scientific knowledge underpins almost every GEF intervention but this is often ‘implicit science’ rather than ‘explicit science’ where the evidence is presented in a conventional format that is readily open to peer review and scrutiny by the stakeholders.

Successful implementation of the TDA approach has been demonstrated to be the single most effective element in the long-term success of transboundary management interventions. The comprehensive TDA collects and synthesizes existing information in order to provide a common pool of objective information for the subsequent SAP that establishes environmental objectives and evaluates options for achieving them. There were several components of rigorous project design that were important for enabling successful TDA-SAP processes including the use of appropriate replicates, baseline, and temporal and spatial representation. Projects were more successful if they focused on basin-level scientific analyses, reviews and assessments, set achievable and measureable targets, separated the technical and political influences on scientific design.

In turn, objectivity and freedom from political influence is the most important element in success of a TDA The TDA is a technical process that should be removed from political influence and include all available expertise and information whereas the SAP has to be a political and technical process, the technical part being support to decision makers to make informed choices (but recognising that their decisions may also involve a number of other criteria). TDAs can be subjected to rigorous scrutiny and review. We were not able to examine this aspect properly because projects do not generally incorporate independent science panels and we would regard their establishment as a matter of urgency.

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Box 2. La Plata River Basin

The La Plata River Basin (3.1 million km²), drains approximately one-fifth of the South American continent. Sub basins in the watershed have the highest numbers of endemic fishes (Paraguay River), the highest numbers of endemic birds (Parana River), and the highest number of major dams (Parana River)¹⁹. In addition, water that infiltrates into the groundwater system from within the Basin provides recharge for the Guarani Aquifer, one of the largest continental groundwater reservoirs in the world. Some 67 million people live in the basin (it includes the capital cities of Argentina, Brazil, Paraguay, and Uruguay) and this results in demands for river transport, irrigation, hydroelectric power, waste disposal and fisheries. Major climate-driven variability in the hydraulic regime and vulnerability to erosion add complexity to the transboundary management of water and habitat use.

GEF interventions developed in a piecemeal fashion that focussed on issues in the sub basins as well as the Pantanal, the estuarine Rio de la Plata and the Guarani aquifer. Each of these employed a mixture of local and foreign scientists to meet project objectives; indeed, the FREPLATA project (for the brackish and marine part of the system) and the Guarani project are exemplar. Our analysis revealed enthusiastic collaboration across the science community. This co-operation in an early stage contributed to a more comprehensive project design, ensuring a multi-disciplinary framework for linking results. Most of the work was done by local scientists, who contributed not only in the identification and provision of basic data, but also in wider scientific work.

The FREPLATA project is a good example of presentation of scientific results in a way that promotes discussion on trade-offs. The project made a huge effort to assemble scientific information on this area of transition waters between some of the largest rivers in South America and the open South Atlantic. Primary information was gathered in GIS format and some gaps in knowledge were filled with new scientific studies. The whole body of knowledge was finally condensed into a document explicitly written in a language accessible to policymakers. Some of the information was controversial and caused discomfort amongst some stakeholders (e.g. information on the declining fish stocks) but this highlighted the complexities of the management trade-offs and some of these are being dealt with in the subsequent GEF intervention (which would not have been possible without the open and rigorous assessment).

More recently, the GEF has supported a new project to integrate the jig-saw pieces to create a basin-scale programme executed by the Intergovernmental Co-ordinating Committee of La Plata Basin Countries (CIC), established in 1967²⁰. The project, which began in 2009, will include a 'mega TDA' for the basin and work on the implications of climate change including future scenarios. It is unfortunate that the project document makes no mention of the science that will obviously be needed to underpin this important work (the words 'science' and 'research' do not appear in the document). This is unfortunate; our study has revealed a huge diversity of science in GEF projects but this is difficult to find in official documents; the quality of science is difficult to determine and the way it cascades to a wider knowledge base seems haphazard and unplanned.

19 La Plata River Basin: A framework for the sustainable management of its water resources with respect to the hydrological effects of climatic variability and change. Water Project Series, No. 6 –October 2005. (http://www.oas.org/dsd/Events/english/Documents/OSDE_6LaPlata.pdf)

20 See Pochat, V. 2011. International agreements, institutions and projects in La Plata River Basin. *International Journal of Water Resources Development*, 27(3): 497-510 doi.org/10.1080/07900627.2011.597830



Lake Tanganyika provides a resource for fishing, livestock and domestic water use / S. Marjijnissen

Sufficient information exists on how successful TDAs and their underlying information needs can be designed. Other typical components of study design were important, especially consistency in sampling sites and with measurements and analytical methods. Some of the complicating factors influencing site selection included an uneven distribution of biodiversity associated with existing stressors, fragmented approaches that lacked coordination and consistency, the failure to consider the appropriate time frame for detecting changes or potential recovery or influence of mitigation. In the case of lakes for example, the location of a lake within the watershed also influenced the study design and aspects that needed to be considered; for instance whether the lake was positioned terminal versus headwater versus mid-basin was an important factor to consider.

On the general issue of horizon scanning, we note that very few GEF projects attempt to look into the future. The design of the TDA approach and the nature of GEF projects themselves tend to focus on the reactive approach to problems already identified. Given the length of the initial GEF project cycle (from problem identification to SAP implementation), it is often the case that the problems being tackled are those identified five years earlier. In some cases, this is perfectly adequate, but it is not in other cases when problems are dynamically evolving. In the Black Sea for example, eutrophication was well recognised as being the major cause of

system degradation, but it was not the only cause. A combination of economic collapse in the transition from centrally planned to market economies and regulatory actions reduced the nutrient input to the system. This revealed the secondary causes of degradation: overfishing, habitat destruction and invasive species, none of which had been the focus of GEF intervention. A 'systems approach' should have clearly identified these co-factors. The Black Sea TDA indeed described them but there was a GEF policy decision to 'fix' eutrophication first. There is abundant evidence that such linear logic does not resolve complex problems adequately. In stating this view, we are endeavouring not to be evaluative; scientific thinking has moved towards a systems approach since the time many of these projects were developed from earlier linear single cause/effect diagnosis.

Our review of TDAs associated with lakes concluded that the over-arching actions which are needed to address their transboundary problems are capacity development and training; policy development and harmonization; and the development of regional collaboration with respect to surveys and assessment of ecosystem status. There is a need for early engagement with stakeholders, and better use of appropriate science and best practices must engage the institutions in the region, who will be involved with the implementation in the end.



Signage to assist with traffic and transport on the Mekong Delta / A. Dansie

CHAPTER THREE

New and Emerging Global Issues

Emerging issues are the ‘surprises’ that appear from time to time. Sometimes these ‘surprises’ are already in the scientific domain long before they become serious social and/or political problems (this happened with the ozone hole, chlorinated pesticides, eutrophication in the Baltic, etc.). We examined how these early ‘alarm bells’ could be heard, and heeded, and how the GEF might help this process.

THE PROBLEM: WHY ‘NEW’ SCIENTIFIC RESEARCH IS NEEDED

Targeted research and resulting scientific discoveries are a major way of reducing some of the uncertainties in the management of shared natural resources. One of the criticisms that emerged regarding the use of applied and cutting-edge science in GEF projects has been the scarcity of new investments in developing applicable and relevant scientific evidence – and consequently using relatively out-dated or irrelevant scientific information. In some respects, the criticism that new data gathering and targeted research is taboo in GEF projects is unfair (though it may have been true a decade ago). However, in some cases the value given to science is still



Experts from the University of the Philippines conduct scientific studies on the indications of environmental stress due to Solar 1 oil spill as shown by shore mollusc and crustacean Assemblages in Guimaras Province, Philippines (PEMSEA).

limited and there are genuine concerns about how new discoveries are incorporated.

Investments in targeted scientific research have paid rich dividends in the GEF’s IW portfolio of project. This is not the same as the independently funded academic research that can be used to expand basic knowledge or contribute to the development of methodologies. Without targeted research, funded by the GEF, we would not have observed recovery of the Black Sea or understand how to remove water hyacinths that were choking Lake Victoria. But research can also be used to understand emerging issues and to peer into the future, as we will demonstrate in the following sections of this report. For example, GEF has focused attention on the role of coastal oceans in the nutrient and carbon cycles in the context of global change and related socio-economic drivers. Both aspects of science-for-policy could be incorporated into project design and into the TDA-SAP process.

UNDERSTANDING EMERGING ISSUES

This study provides frameworks for research that can be utilized by new transboundary water projects. A delineation of emerging issues related to: Water quantity; water quality, ecosystem stability; social benefits and global processes has enabled the development of a new framework that helps to identify and frame issues, stressors, science questions, outcomes and emerging issues in transboundary international waters. This constitutes a major contribution to new project design.

An integrated roadmap for placing science squarely in strategic and project planning has been developed. In Table 2, we present a summary of all science questions underlying the IW Focal Area in a useful classification scheme showing ‘Issues, stressors or drivers’; ‘Science questions’ (the scientific method requires questions or



hypotheses to address!); ‘Science integration’ (what science is needed to address the unresolved questions); the ‘outcome needs’ (what policymakers need to know and do); and the ‘Emerging issues’ (largely unaddressed by the GEF at this time). This table provides the basis for an integrated roadmap for the place of science in the GEF IW Focal Area and we recommend its adoption for that purpose.

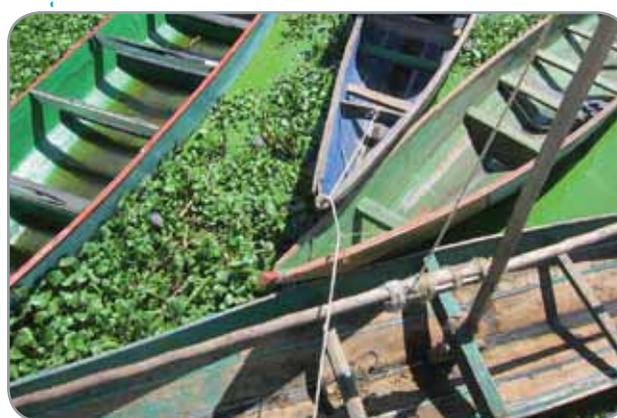
Table 2 classifies the type of problem addressed in an innovative way. We have grouped this into the following categories that apply, to a lesser or greater extent, to all components of the aquatic system:

- Water quantity
- Water quality
- Ecosystem stability
- Social benefits, and
- Global processes

The advantage of using this simple matrix is that it operates as a unifying mechanism for IW science and avoids the trap of compartmentalising everything into geographical units or specific water types. The framework emerged towards the end of the current project when we brought together the various strands of information and we have been unable to apply it to all of the projects in the portfolio but this could be the object of a follow-up study.

A better understanding of emerging issues would help the GEF design timely interventions in the future.

A typical issue raised through UN and independent



Eutrophication and increased nutrients in Lake Victoria cause algae blooms and encourage proliferation of the invasive water hyacinth, Kenya / A. Dansie

specialist bodies could be microplastics in the sea²¹. Recent evidence has shown that this material, derived from our careless disposal of plastic into rivers and seas, is becoming a massive problem²² throughout the oceans, choking marine life, damaging habitats and potentially affecting commercial production. Governments are just beginning to react to this problem and it has been given prominence during the Rio+20 process²³ but it is complex and transboundary, a true ‘smouldering fuse’.

21 GESAMP (2010), IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection); Bowmer, T. and Kershaw, P.J., 2010 (Eds.), Proceedings of the GESAMP International Workshop on plastic particles as a vector in transporting persistent, bio-accumulating and toxic substances in the oceans. GESAMP Rep. Stud. No. 82, 68pp.

22 Barnes, D. K. A., F. Galgani, R.C. Thompson and M. Barlaz, (2009). Accumulation and fragmentation of plastic debris in global environments. *Phil. Trans. R. Soc. B* 27 364(1526): 1985-1998

23 See <http://www.unep.org/newscentre/default.aspx?DocumentID=2688&ArticleID=9184&l=en> for further information.

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Table 2 Issues, stressors, science questions, outcomes and emerging issues in transboundary international waters.

	Issues, stressors or drivers	Science questions	Science integration	Outcome needs (solution development)	Emerging issues
Water quantity	Land use change, agricultural change, demographic changes, climate change and variability, or responses are present (i.e. land use subsidence)	<p>What are water inputs, outputs, storage, linkages between components and demands?</p> <p>What is the water balance and dynamics of the system?</p> <p>What are the trends, resilience and elasticity of the system?</p> <p>How do people behave?</p>	<p>Better assessment, monitoring and models of water, erosion, flooding,</p> <p>Define uncertainty</p> <p>Integrated analysis of physical and social and economic systems (social ecosystems approach).</p>	<p>Conflict management, trade-offs and options for allocation decisions, impacts of allocation decisions on the changes in availability, decisions about mining non-renewable sources, identifying new sources, protection of ecological flows in rivers and coastal systems (including diadromous needs)</p>	<p>Population growth – increased water demand.</p> <p>Changing diets – more meat</p> <p>Terrestrial biofuels</p>
Water quality	Land use change, agricultural change, industrial development, acid rain (precursors), population growth and urbanization, or responses are present (i.e. water salinization, eutrophication, sedimentation, poor water quality)	<p>What are the sources, and the origins of the contaminants (within processes)</p> <p>What is the loading, assimilative capacity, and dynamics (nutrients, contaminants, ratios)</p> <p>What are the trends, impacts of extreme events on levels</p> <p>What are the ecological impacts – productivity, etc. (see ecosystem stability)</p>	<p>Better models of environmental fate, linkages between components and interfaces, and long range transport of contaminants</p> <p>Understand emerging chemicals and ecological risk</p> <p>Understand impacts on food web including fish stocks</p> <p>Understand salinization impacts</p> <p>Linkages to dynamics in water quantity</p> <p>Understanding assimilative capacity and biogeochemical cycles</p> <p>Harmful algal blooms</p>	<p>Consideration of waste disposal needs, regulations, responses to introductions of new technologies, better methods of controlling chemicals (linked to origins and mechanisms), nutrient management, waste treatment</p>	<p>Changes in irrigation, new crops, chemical use</p>

	Issues, stressors or drivers	Science questions	Science integration	Outcome needs (solution development)	Emerging issues
Ecosystem stability	Habitat destruction (including sound), invasive species, ecosystem services, unsustainable exploitation	Critical habitat availability, biodiversity, species abundance, fecundity, maturity, biomass, Nursery areas, genetic diversity, predator-prey interactions. Implications for coastal mammal populations	Identification of threatened or new species. Identification of critical habitat Calculate ecological thresholds Measurements of habitat conversion Stock assessments	Sustainability and vulnerability assessments, protected area designation, shipping restrictions, harvest and export quotas Mariculture best practices Remediation priorities Eradication assessments	Impact of deep sea fishing, alternative fisheries, mining of methane hydrates
Social benefits	Ecosystem services Governance Ecological economics	Public awareness and perception surveys Valuation of critical components Census data Water use data Trade data Resource use statistics Study human values Traditional knowledge collection	Evaluation of costs and benefits, and cost-benefit analysis Trade-offs and inter-generational assessment Social system analysis Resilience of coastal social-ecological systems Modelling of social-ecological systems Macroeconomics - discounting and trade-offs	Payment for ecological services including water value pricing Behavioural change incentives Awareness campaigns Economic incentives Communication to stakeholders Holistic approach to policy development Zoning changes – marine spatial planning	Changing energy policies
Global processes	Climate change, temperature change, sea level rise, atmospheric CO ² increase, marine acidification, Climate variability	Water level, salinity, temperature, CO ² and nitrogen processes, pH, carbon drawdown, water flow, meteorological variables, climate variables, land stability, subsidence, erosion, coral bleaching, coral exposure	Changes in hydrologic cycle, rainfall patterns, biogeochemical cycle, coastal systems functioning, ocean atmospheric processes, Calculation of extreme events, definition of uncertainty around climate Model development, saltwater intrusion, climate,	Community adaptation and mitigation Vulnerability assessment to extreme events Coastal systems vulnerability assessment	Climate adaptation, changing salinity

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Eutrophication in Vembanad Lake / IOM, Anna University

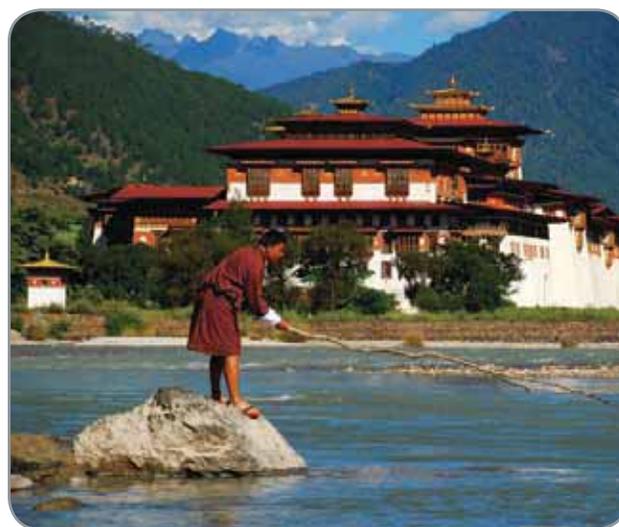
HORIZON SCANNING

Scenario development must be used as a tool for comparing management alternatives and their outcomes. Though scientists cannot predict the future, we can simulate alternative scenarios that help to frame future realities and test the effectiveness of potential interventions, answering the question “are they likely to work?” Use of these techniques will help the GEF to prioritise and plan more effective interventions.

There is a huge need to develop plausible social-ecological scenarios that can help frame our understanding of the state of the natural environment in the future and its capacity to deliver the much-needed services. Over the past few decades, aquatic and hydrological systems have experienced a process of accelerated change, largely driven by human activities. We have entered the Anthropocene²⁴, with no historical precedents to predict the outcome of our actions and ‘no going back’ to repair many of our mistakes. Views of the future, ranging from apocalyptic scaremongering to the comfort of planetary homeostasis, are often based on selective use of data and their extrapolation using a

host of undeclared assumptions, including linear cause/effect relationships. We struggle to deal with complexity, particularly where complex systems span disciplines and include memory effects, non-linearities, variable scales, choke points and emergent properties.

Development of standardized horizon scanning methodologies and their consistent application is essential to the success of transboundary water projects. Horizon scanning involves a number of techniques that help peer into the future by using our knowledge of the way economic and social drivers co-conspire with natural environmental variability to bring about changes in the status of the natural system and in human welfare. It is not simply a matter of plotting trends in natural system indicators as these rarely change in a linear way, but is an examination of how the whole system responds to human drivers. Since economic forecasts have intrinsic uncertainties, we need to look at a number of plausible scenarios within which future realities are likely to be found. Therefore, most of our current understanding of future trends and changes to river systems and open seas is driven by the application of scenarios primarily designed for exploring climate change (SRES models of the IPCC developed in 2000²⁵) or ecosystem change (the Millennium Ecosystem Assessment (MEA) scenarios, published in 2006). The MEA scenarios have been



Local Man Keeps Bhutan's River Immaculate / UN Photo, G. Fickling

24 Will Steffen, Paul J. Crutzen, and John R. McNeill (2007). The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature? *Ambio*. 36(8): 614-621

25 Nakicenovic, N. et al (2000) Special Report on Emissions Scenarios : a special report of Working Group III of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York,



Below the surface, fishing village in Anilao, Batangas, Philippines / Marine Photobank, P. Paleracio

employed to examine past and future trends of global river nutrient export²⁶. There are modified versions of the SRES scenarios such as those developed for the 2004-2007 European Lifestyles and Marine Ecosystems (ELME) project under EU FP6 and hybrid scenarios such as those for the UNEP GEO process. Though the MEA examined terrestrial aquatic systems, there have been no consistent efforts to develop and apply explicit scenarios to examine the future of seas (the regional seas) and oceans for 2050 and 2080 time horizons.

Systems science, involving natural and social science (including economics) is implicit for delivering the GEF's central objectives but has received little attention.

Further, we saw only a few examples of systems science being applied across sectors. For example, energy is needed to generate, produce or make use of water, and vice versa; challenges in the two sectors need to be addressed together. They are closely interlinked and inefficiency in the management of one exacerbates problems in the other, such as shortages, waste and unsustainable use patterns. A particular challenge in this respect arises from conflicting objectives between land development and IW management following the Ecosystem Approach. It is still difficult to make

meaningful comparisons between the short term benefits of water abstraction for food production and the long term costs from water loss to downstream ecosystems and such work will require open and facilitated science and policy cooperation across sectors.

There are few examples of GEF projects that have taken a systems approach and examined future scenarios. Some insights in how to do take an overt social-ecological systems approach to transboundary processes have been gained from the EU sponsored project European Lifestyles and Marine Ecosystems (ELME)²⁷. ELME developed conceptual causality models for each of Europe's regional seas and from these produced Bayesian belief network models (based upon statistical relationships). These are relatively simple and can include expert opinion when time series data is unavailable. The models enable policy options to be tested, some of which were directly relevant to GEF IW projects and programmes. They demonstrated that the full implementation of the current EU Common Agricultural Policy in Eastern Europe for example, would risk a return of eutrophication in the downstream Black Sea²⁸.

²⁷ http://www.elme-eu.org/ELME_Results.pdf

²⁸ Langmead O, McQuatters-Gollop A, Mee LD et al. (2009) Recovery or decline of the northwestern Black Sea: a societal choice revealed by socio-ecological modelling. *Ecological Modelling*, 220, 2927–2939

²⁶ Seitzinger, S. P., et al. (2010), Global river nutrient export: A scenario analysis of past and future trends, *Global Biogeochem. Cycles*, 24, GB0A08, doi:10.1029/2009GB003587.

CHAPTER FOUR

4. Utilizing Expertise to Solve Global Challenges

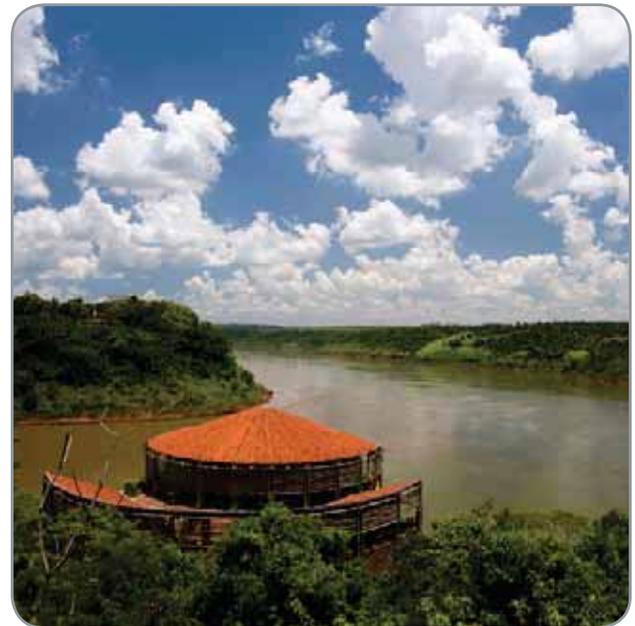
Scientific expertise can be applied in many ways to GEF projects as part of, and in addition to, the TDA-SAP process. Highlights of how expertise has been employed in GEF projects, and recommendation for future inclusion of expertise are: building Communities of Practice to stimulate innovation and optimize uptake of scientific information – using Transboundary Diagnostic Analysis as a tool; engaging scientists in capacity development endeavours; engaging the scientific community in dissemination and communications to general and policy audiences; conveying future forecasts and scenarios to the general public; informing policy choices through effective risk communication; and engaging at regional level through forecasting, disaster management and preparedness.

BUILDING COMMUNITIES OF PRACTICE TO STIMULATE INNOVATION AND OPTIMIZE UPTAKE OF SCIENTIFIC INFORMATION

Communities of Practice including local scientists and experts are critical to the success of transboundary projects. A central aspiration of the GEF IW Focal Area is to foster sustainable solutions to the problems afflicting transboundary waters. The scientific advice needed for this process should not be regarded as a ‘one off’ exercise; local experts will be required for the long term and fostering their skills development and networking should be regarded as an indispensable investment.

Scientists work in teams within respective Communities of Practice and investment are essential to enable their work within their realms and across disciplinary boundaries. The ‘cherry-picking’ of experts on an individual basis to meet project requirements neither stimulates innovation nor provides the best science for current and future needs. We have noticed a lot of work conducted by expert panels, often using retired

scientists or those that are no longer at the forefront of their research careers. These experts are hugely valuable but rely on knowledge from their more active colleagues in order to keep their own knowledge up-to-date. These generators of primary knowledge (in many cases research teams) often receive no support to maintain and encourage their work, other than support from national research councils – and these are often cash-strapped. There are few mechanisms, especially at an international level, to foster the kind of applied science that supports (and sometimes challenges) policymakers by providing an evidence base. We saw a few cases of IW projects that actively tried to build ‘communities of practice’ to encourage investment in science as a raw material for good policy making and two of these are illustrated in Box 3.



Borders of Paraguay, Argentina and Brazil at the confluence of the Parana River and Iguazu River.



Box 3. Using communities of practice in two IW Projects

A good example of the role and power of scientific communities is the Lake Tanganyika project, where effort was made early to look for local members of international (relevant) scientific societies or agencies that can provide the linkages to larger scientific efforts, groups, etc. After the 1989 International Limnological Society workshop on conservation and resource management in the African Great Lakes, a group of scientists concerned with conservation issues at Lake Tanganyika was organized. Their efforts led to the First International Conference on the Conservation and Biodiversity of Lake Tanganyika held at the University of Burundi in Bujumbura, Burundi from 11-13 March 1991. This meeting brought together key individuals from the fields of research, resource management (water, fisheries and agroforestry) and conservation to discuss the current state and the future of the Lake Tanganyika Basin.

In the case of the Black Sea Ecosystem Recovery Project, there was insufficient data to answer the key management question: ‘Is the Black Sea recovering?’ The only way to resolve this issue was to conduct new scientific expeditions and for this purpose an ‘International Science Group’ was established. Financial support was given to fund local vessels and scientists to work alongside international specialists where necessary. The research funded was targeted on key uncertainties and has proven highly valuable. All of this occurred at a time when local scientific infrastructure was in serious jeopardy and the project enabled earlier investment to be maintained and key expertise retained.

ENGAGING SCIENTISTS IN CAPACITY DEVELOPMENT ENDEAVOURS

Capacity building must go hand in hand with development of Communities of Practice. In some cases, the local cadre of expertise is insufficient to fulfil the needs of the TDA/SAP or subsequent project interventions. In those cases, capacity building may be the only viable way to ensure long-term scientific support. African lakes projects provide good examples of capacity building. Some effective steps were taken on the Lake Tanganyika project including training on environmental issues specific to the lake, and on project management and conflict management skills for the training officers and other project affiliates. Affiliates were trained to communicate and work with lakeside communities and the project invested in ‘Human capacity building and training’ in which the trainers learned how to effectively train members of

the communities. In addition, a multidisciplinary team was created to relate and translate special study findings to non-scientists. For the Lake Okavango project, the principal means of communication was through workshops with local and national governments, community leaders (including teaching community), NGOs and other relevant groups.

A number of projects also held capacity-building workshops with representatives from all relevant government agencies to transfer knowledge. In one case, a “Practices Manual” was produced that allowed experts in each country easy access to a variety of options for carrying out their objectives, and allowed them to gain an appreciation of why the policies and procedures were established as they were.

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Box 4. Capacity Development in Lake Okavango

For the Lake Okavango IW project, it was strongly recommended that a small number of suitably qualified graduates, preferably from the region, be employed by the project to strengthen the capabilities of the team. Previous experience has shown that this type of project can often attract funding for PhD and post-graduate studies, and this sort of support should be encouraged, but not at the expense of the education of the grass root stakeholders. For this project, scientific and technical experts were engaged right at the beginning in developing the environmental assessment and integrated management plan and to review the TDA and other relevant studies. Issues, concerns and ideas were inventoried and used to create an elaborate Strategic Action Programme (SAP). The Nile Basin project supported basin-wide networking among universities engaged in environmental education, with exchanges of information, teachers and students.

ENGAGING THE SCIENTIFIC COMMUNITY IN DISSEMINATION AND COMMUNICATIONS TO GENERAL AND POLICY AUDIENCES

Scientists must be at the forefront of knowledge dissemination to the general public as well as key stakeholders. ‘Faceless science’ does not inspire confidence in the information projects are producing and the advice that stems from them. Scientists should be encouraged to participate in the communication of their work and to engage in dialogue with the stakeholders, building trust and understanding.

Open communication channels between scientists and policy makers must be fostered to make science dissemination successful. We saw some good practice

among the projects that can set a general example. The Benguela Current LME series of projects is one case in point. It utilized the science obtained locally (BEP) and internationally (BENEFIT, ENVIFISH, VIBES) as well as the work published in the scientific literature, but by effective networking among stakeholders also succeeded in building the Benguela Current Commission as an effective management to coordinate management across three countries. There was a strong sense of open communication between scientists and policy makers in this project at all levels. Fishing within sustainable limits is key to the economy of countries like Namibia where it represents at least 15% of GDP. Good scientific advice is highly valued and scientists are given a prominent role in the communication of their findings.



The Okavango River Basin remains one of the least human impacted basins on the African continent, the GEF project ‘Environmental Protection and Sustainable Management of the Okavango River Basin’ partnered with the riparian countries Angola, Botswana and Namibia to tackle mounting socio-economic pressures on the basin, Cuito River, Angola (Lake Okavango project). OKACOM 2008



Fishing cages off the coast of Xiamen, China (PEMSEA)..

CONVEYING FUTURE FORECASTS AND SCENARIOS TO THE GENERAL PUBLIC

All contemporary and state of the art communication tools should be utilized for knowledge dissemination.

It is important to employ modern methods for communicating spatial data, forecasts of future environmental conditions and consequences for people. Advances in Geographical Information Systems (GIS) have improved accessibility and enable a large amount of information to be gathered and conveyed to policymakers in a manner that facilitates good decision-making. Many of the Land Based Pollution Sources projects have focused on forecast models and GIS-based approaches to prove the usefulness of future environmental conditions. GIS has been used as a predictive tool to combine multiple layers and has been applied within the model in the project on Persistent Toxic Substances, Food Security, and Indigenous Peoples of the Russian North. However, a more profound application of the underlying Arctic ecology could have been better applied.

Some of the PEMSEA projects have also used a wide range of ecological models, risk assessment studies and GIS. A few of the projects have used multiple causality

analysis in a GIS context with the advantage of allowing spatial visualization and better integration of different pollution indicators. Other LBPS projects that have effectively used models and GIS include PROCUENCA, in Nicaragua, where GIS-based maps and related land use information has been provided in atlas form to local governments and international agencies working in the country.

Information on trends in resource use, jurisdictions, environmental stresses and many other variables is obviously an essential component of effective management. In some cases such as the GEF FREPLATA project between Uruguay and Argentina, the information base has been extraordinary, providing enormous added value at a system scale and making it available to policymakers. Developing and institutionalizing systems for ensuring that the right data are gathered, analysed, stored and made available for easy retrieval and use is a complex enterprise. The lessons learned from the projects indicate that sound technical scientific cooperation strongly supports the basis for transboundary coastal management policy. There is a significant need for improved land based pollution regulations and management, better access



Congolese stakeholders using traditional communication methods to transfer and disseminate knowledge based on GIS-analysis of catchment characteristics as part of the GEF Lake Tanganyika project.

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to information and recognition for enhanced capacity development. Integrated pollution observation and monitoring systems as fostered by the PEMSEA project and implemented by government agencies provide a good model in which data can be generated at the local level and then utilized for management-related analysis.

INFORMING POLICY CHOICES THROUGH EFFECTIVE RISK COMMUNICATION

Risk analysis and its effective dissemination to stakeholders must be given a high priority. Most policy decisions on the environment require an analysis of risk. As yet there is no consistent procedure for incorporating risk analysis in the TDA-SAP process and this needs more attention. There are some valuable examples of risk analysis in some of the GEF projects however.

Risk assessment must provide the basis for identifying potential interventions and management measures. PEMSEA's risk assessment process was the technical basis for geographically larger and jurisdictionally more complex planning processes for Manila Bay, Bohai Sea and Gulf of Thailand. PEMSEA has made risk assessment and risk management a critical component of the planning for water bodies exhibiting transboundary environmental problems (e.g. Gulf of Thailand) and pollution "hot spots" (e.g. Manila Bay and Bohai Sea). The risk assessment process has been used in these contexts to identify the primary environmental concerns as well as potentially important data gaps. The concerns are then the basis for identifying potential interventions and management measures as part of the management framework. The data gaps are addressed as part of the environmental monitoring component.



Lakeside fishing community on the shores of Lake Victoria, Kenya / A. Dansie

Box 5. PEMSEA Case Study

The Partnership for the Management of the Seas of East Asia (PEMSEA) provides a useful example of forecasting. PEMSEA is addressing trans-boundary environmental issues in the Gulf of Thailand and pollution “hotspots” in Manila Bay and the Bohai Sea. In all three cases, the need for technical analysis of the underlying issues is essential. PEMSEA has used a risk assessment/risk management (RA/RM) framework to analyze these issues. In this process, they have first trained local counterpart staff in the RA/RM framework and then jointly conducted the analysis. This training provides both useful analysis and, equally important, builds key analytic skills among program staff.

In a coastal tourism project, a Regional Information Coordination House (RICH) has been planned, which would house a regional GIS-based coastal Environmental Information Management and Advisory System (EIMS) to store and manage information from existing tourism related initiatives, and from the demonstration activities in this project. RICH will also act as an information handling and dissemination centre for the project and the participating countries.

PEMSEA supports the development of integrated information management systems (IIMS) at each ICM site. PEMSEA continues to provide training, updated software and technical assistance to each site. The types of management support offered by IIMS vary among the sites, but the ultimate goal is a decision-support system. A regional network linking ICM sites and pollution hotspots is being developed.

Risk assessment is an important feature of PEMSEA. In Manila Bay, Bohai Sea, and the Gulf of Thailand risk assessment was the technical basis for much of the planning that occurred in all three contexts. In the Manila Bay project, the geographic scope included adjacent coastal provinces and the National Capital Region within the watershed. The planning processes included extensive consultation with multiple national agencies, littoral provinces and many local governments. Risk assessment was the technical basis for identifying priority environmental issues, an oil spill contingency plan and the Operational Plan for the Manila Bay Coastal Strategy. In the Gulf of Thailand, risk assessment was used primarily in the context of planning an oil spill contingency strategy embodied in an intergovernmental agreement involving Thailand, Cambodia and Vietnam. In the case of Bohai Sea, the risk assessment was the technical foundation for what ultimately became the Bohai Sea Sustainable Development Strategy.

REGIONAL ENGAGEMENT FOR FORECASTING, DISASTER
MANAGEMENT AND PREPAREDNESS.

*There is a need for wider use of emergency response
plans based upon predictive and real-time modelling.*

Although risk analysis, risk awareness and risk management are essential tools for policy making, environmental disasters are hard to predict and a response strategy is essential. We have seen surprisingly few examples of science informed disaster management frameworks. The first Black Sea project invested considerable effort on oil spill contingency planning and this led to contingency plans for every country in the region. These were put into practice during the Nassia oil spill in Turkey in 1995. Rapid support from the GEF Black Sea Environmental Project helped the Turkish authorities coordinate and mobilise national and international response efforts including compensation from the insurers.



Researchers engaged in Manila Bay clean up, Philippines (PEMSEA).

CHAPTER FIVE

A Framework for Science to Policy Translation

In parallel with the pragmatic approach employed to develop the IW Focal Area's TDA-SAP approach, there have been advances in systems science. The time has come to review progress in this area and incorporate some of the developments into the scientific framework underpinning the International Waters focal Area.

AN ANALYTICAL FRAMEWORK FOR AQUATIC SYSTEMS

Effective solutions to today's and tomorrow's environmental problems will depend upon a 'joined-up' approach engaging the combined skill and energy of natural and social scientists working within a common framework. Most of the actions we label as 'environmental management' are about managing human activities and yet the majority of scientists engaged in providing advice are trained in natural science.

The DPSWR approach (Box 6) provides a useful basis for systematic analysis. This is a refinement of the widely used DPSIR model in order to give greater clarity on the role of natural and social processes and the type of science that is needed to address them. It helps to move from thinking that is heavily dominated by natural science to a more balanced approach between natural and social sciences. It is not meant to be a quantitative model but a schematic diagram that helps to frame a problem and to understand the scale in which it operates. Each element of DPSWR has associated space and time scales. For example, an invasion by an opportunistic species, may cause a major State change at the sub-regional level and affect human Welfare by altering fisheries and aquaculture, damaging recreation, affecting human health (e.g. by introducing toxic species) and diminishing the non-use value of biodiversity and habitats. This may be the result of Pressure from ballast water discharges from ships operating across regional or even global scales as a consequence of national, regional

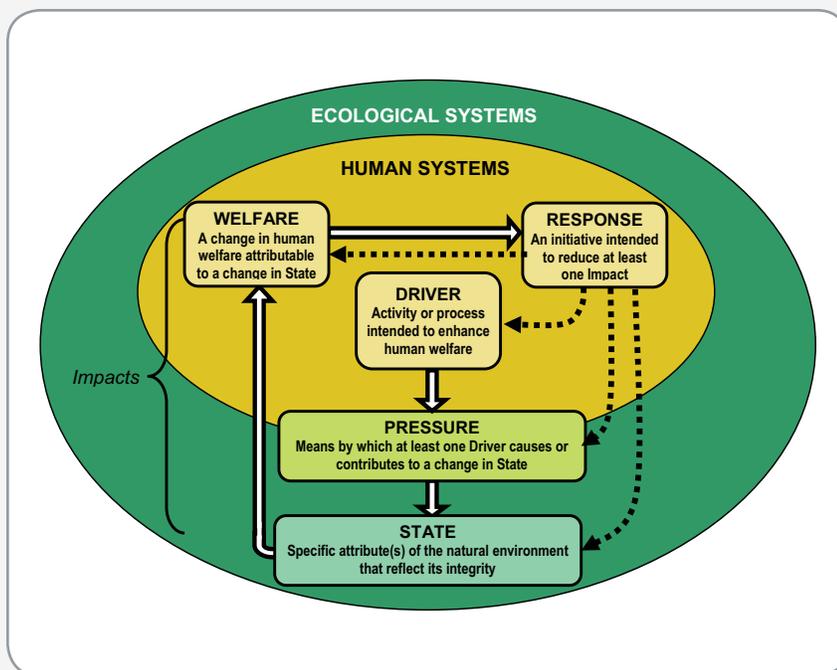
and global shipping policy, practices and markets. The Global Ballast Water Convention has already been negotiated though it is not yet (2012) in force. This is largely due to concerns about the practicalities and costs of measures that must be taken at geographical scales much larger than the sub regional and local scales in which the State and Welfare changes are felt. In many cases, countries and the national and transnational shipping industries are unwilling to act because of limited scientific and technical information, the need to ensure that costs are proportioned fairly and that measures are in place to avoid 'free riding' by those unwilling to comply. The GEF's Globallast²⁹ project was partly focused on filling this knowledge gap.

The DPSWR framework provides an opportunity to systematically review how drivers can be changed to achieve desired results. Each of the boxes in the DPSWR conceptual model contains a variety of elements and processes that operate on different temporal scales. There is no clear pattern of temporal scale characterizing each box, except perhaps for Responses which - in the absence of existing governance structures and policy - tend to occur in the range of years to decades. Drivers also tend to change quite slowly (except in the case of sudden market shocks and failure) and may be 'locked in' to broader issues of demography, major economic strategies, fixed infrastructure development and global markets. This is one reason why sustainable development is so difficult to achieve. Sustainable development often involves changing the nature of the Drivers, some of which may only be profitable because they are free riding the environmental economy and depleting natural capital. Given these difficulties, policy responses often focus on alleviating Pressures (for example by waste treatment plants or changes in fishing technology),

²⁹ <http://globallast.imo.org/>

Box 6. The DPSWR model

A widely employed framework for the analysis of the relationship between the economic activities, environmental degradation, human welfare and policy responses is the Driver, Pressure, State, Impact, Response (DPSIR) approach. The term ‘Impact’ frequently causes confusion however as it is applied differently by natural and social scientists. Recently, the EU KnowSeas project³⁰ developed the DPSWR model; a modified version of this conceptual model that is closer to the terminology currently employed in the GEF, avoids the term “Impact” and provides greater clarity for environmental accounting and policy development.



In the DPSWR, Drivers are the economic and social forces that result from government policies, markets and the activities of private industry, as well as demographic changes. These lead to Pressures which are the ways these drivers place demands upon ecosystem services (irrespective of whether these demands can be met in a sustainable manner). There are additional pressures caused by larger scale human induced climate change and extreme natural events. Pressures are the interface between the social and ecological components of the system. State changes are the changes in the ecosystem resulting from the Pressures (i.e. ecosystem impacts) and these in turn can result in changes to human Welfare (sometimes described as social and economic impacts). Response to a particular problem may be directed towards any of the other elements (D, P, S or W) in an effort to achieve a balance between the benefits of economic and social development and the ecosystem costs, usually determined by real or potential changes to human welfare. Welfare changes do not need to be dramatic in order to trigger a response; the current response to climate change is not driven by a huge change in the state of today’s ecosystems but by the perception that the level of change that is likely to occur could be catastrophic to humanity.

30 Cooper, P.W. (2012). The DPSWR Socio-Ecological Accounting Framework: Notes on its Definition and Application. KnowSeas Policy Briefs No 3. March 2012. Available on line at www.knowseas.com

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attempting to improve ecosystem State by protecting or building resilience (e.g. by marine protected areas), or by supporting Welfare by compensating for loss.

Gathering of long-term evidence needs to be supported by GEF so that gradual and “creeping” environmental changes can be identified and addressed in an adequate and timely manner. The relationship between Pressures, State changes and Welfare changes occur across a wide range of time scales from catastrophic change (e.g. the release of toxic mine tailings) to change over decades (e.g. the buildup of eutrophication or gradual loss of species and habitats). Governance systems tend to be more responsive to rapid change than those of a gradual but often more pernicious nature – sometimes termed as “creeping environmental changes” that are slow onset, low-grade, incremental but cumulative over time³¹. Gathering the science evidence base for such long term changes has proved particularly challenging because of the relatively short length of GEF interventions and because political attention is necessarily focused on the ‘quick wins’. Furthermore, State change is only detected when measurements reveal changes that exceed natural

variability in the system. In some cases, this may be by generating a solid baseline of evidence (the TDA) that incorporates governance and ecosystem resilience issues, and obtaining a commitment from governments to periodically revisit the original analysis.

DEVELOPING A UNIFIED APPROACH TOWARDS INDICATORS

Management action is often triggered by one or more indicators exceeding agreed thresholds. The development of a reliable suite of indicators is an essential element of GEF interventions and should be heavily reliant on good science and clearly described in the TDA-SAP process. There has been reluctance in the GEF to adopt the DPSIR framework. The newly formulated DPSWR may address some of the difficulties, several of which are a result of ambiguous terminology. Here we present a simple table showing the relationship between DPSWR and GEF terminologies and the general nature of indicators required, again noting that there are also larger-scale drivers and pressures resulting from such factors as demography, climate change and natural events.



Discharge of sediment load from a river into the Caribbean Sea / Marine Photobank, M. Naumann

31 Glantz, M.H. (2003) Climate Affairs – A Primer, Island Press, Washington DC.

Table 3 A unified approach to indicator development

INDICATORS	DPSWR	GEF ³²
Economic and social	Driver	Underlying drivers/Stress reduction indicators
Environmental and social	Pressure	Environmental status indicators/ stress reduction indicators
Environment and natural science indicators	State	Environmental status indicators (natural system)
Sustainable development (economic and social)	Welfare	Environmental status indicators (social system)
Governance	Responses	Appropriate process indicators

In all cases, indicators should follow the SMART approach: SMART indicators are:

- Specific,
- Measureable,
- Achievable,
- Relevant, and
- Time-bound.

These rather simple criteria are excellent filters when reviewing all indicators. Similar criteria apply to social and economic indicators as to natural science indicators. They also have the intrinsic difficulty of setting a baseline from which to measure change.

THE PARADIGM OF ADAPTIVE MANAGEMENT AS A TOOL TO CONNECT SCIENCE TO POLICY

GEF IW programmes and projects provide good examples of the practical application of adaptive management and this has wider value as case studies for future policy making. In its simplest form, adaptive management has been described as ‘learning by doing’. Its adoption in international processes however, represents an important paradigm shift that is closely linked to the ecosystem approach to management. Adaptive management (AM) is one of the key concepts underpinning the GEF International Waters Focal Area but has not been described in sufficient detail for it to

be useful at an operational level. In this section, we will elucidate the concept and then examine whether or not there are examples of adaptive management in GEF projects that can serve to test its effectiveness and to provide a baseline of best practices for the future. In doing this, we must make it clear that we regard AM as a powerful paradigm but not the only one to enable sustainable use of aquatic resources and their conservation.

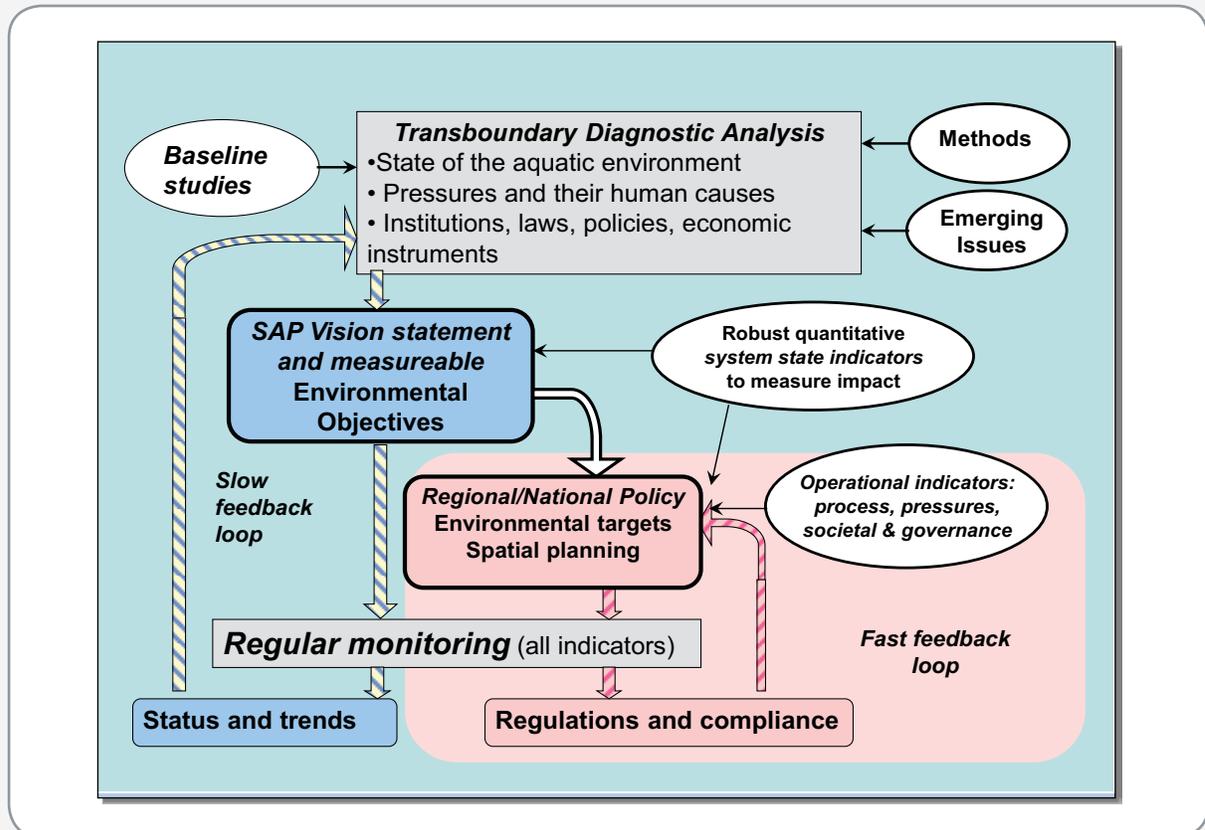
Adaptive management may be particularly useful to deal with complex or “wicked” issues that cannot be resolved through ‘first order fixes’ (simple linear solutions or ‘easy wins’). Complexity plagues water issues and many problems require solutions that involve value judgments and preference by society, often at a political level. The treatment of these complex problems in a simplistic or technocratic manner often leads to their recurrence.

32 Duda, A. (2002) Monitoring and Evaluation Indicators for GEF International Waters Projects, GEF Monitoring and Evaluation Working Paper 10. Washington

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Box 7. Adaptive management and the TDA/SAP approach.

The overall approach is illustrated here³³ but it should not be regarded as prescriptive; there may be alternatives. Scientific inputs are shown in oval boxes. The process begins with baseline studies (incorporating existing knowledge) followed by a TDA. Science helps to inform methodological design and this will obviously vary according to the state of knowledge in the region and the issues evaluated. Scientists should also be asked to review emerging issues so that the TDA is not simply based upon ‘old’ information.



Review of the TDA provides input for discussions on a common vision that is the first ingredient of the SAP. In some cases, scientists can model the information in the TDA to examine likely future scenarios, a process that is very informative for helping decision-makers and stakeholders to set long-term goals. The vision statement should include clear Environmental Objectives and these require robust system state indicators. The vision and its objectives are aspirational and long term, perhaps set for a decade into the future.

Having established a common long-term objective, measures are agreed as part of the SAP process at the appropriate administrative level, either national or at the provincial or state level (specifically in groundwater). They are like stepping stones towards the longer term vision and need to be assessed in a similar manner to a controlled scientific trial.

³³ Mee L. D. (2005). Assessment and monitoring requirements for the adaptive management of Europe's Regional Seas. In Salomons W, Vermaat J, K. Turner (eds), Managing European coasts: past, present and future. Environmental Sciences Series, Springer-Verlag, Berlin, Germany, pp 227–23

Although there is much work to be done in understanding the theory and practice of managing complex social-ecological systems³⁴, it is generally agreed that adaptive processes of decision making, learning, public participation, and the integration of knowledge across disciplinary/science/politician/manager/society divides are essential starting points.

There are a number of different interpretations of Adaptive Management (AM) and they can be used according to pertinent circumstances. We see this as a process of setting an agreed vision for the environment and implementing and testing practical approaches that move toward the vision. This is a 'learning by doing' process where careful monitoring is required of each intervention, as well as a periodic evaluation of overall progress towards the agreed vision and, adjustment of interventions that are found not sufficiently effective and, if necessary, a reevaluation of the vision itself.

The most crucial aspect of this process is the feedback mechanism that is created through the AM process. By monitoring the effectiveness of the interventions and sharing this knowledge (irrespective of the success or failure of each intervention), learning occurs and new interventions can be designed or the most successful ones replicated. Every 5-6 years, or at longer intervals if the inertia of the systems concerned is large (groundwater) the TDA can also be repeated and the overall vision and its Environmental Objectives reappraised. As learning occurs and new knowledge emerges, old visions and objectives may no longer be appropriate.

Although all TDA-SAP-based projects are on a pathway to adaptive management, few have yet matured into a full iteration of repeated cycles with evidence of learning between the cycles. The Black Sea³⁵ (Box 8), Danube and the South China Sea projects are three examples where this has happened. In each case, the TDA has been repeated after a number of years of SAP implementation and the direction of the SAP has changed as a result of new knowledge or 'learning by doing'. In the case of the Danube programme, the GEF interventions neatly flowed into the implementation of the EU's Water Framework Directive (WFD). During

the implementation of the SAP, a large number of riparian countries had acceded to the EU and therefore had to adopt the WFD, a directive that also follows the principles of adaptive management.

Adaptive management happens through failures as well as successes – but policymakers (and sometimes international organisations) are very reluctant about revealing negative experiences. A good example of adaptive management of this kind in Lakes is found in Lake Victoria where there was a huge problem of ecosystem choking caused by massive growth of alien water hyacinths. The first GEF intervention was unsuccessful in resolving this central problem but the situation later improved through recognition of the reasons for failure and the adoption of alternative strategies. A Lake Commission was also created but this initially attracted some bad publicity. There was a technical problem with the initial project: World Bank consultants believed that water hyacinths would be dealt with through harvesting machines. The local community were unconvinced about this approach. Two types of machines were used: harvesting and chopping. The chopping machines could not keep up with the harvesting, and the chopping made the situation worse. A local institution successfully experimented with an alternative idea; biological control through the introduction of a kind of weevil. The weevils that can deal with this were not introduced by the GEF project, but by a local research institute. The GEF learned from this success story and adapted the overall strategy for the second intervention.



Bycatch from prawn trawling comprises up to 2 to 10 times the weight of the retained catch / *Marine Photobank 2008, S. McGowan*

34 Rogers K H (2008) Limnology and the post-normal imperative: an African perspective. *Verh. Internat. Verein. Limnol* 30, Part 2, p. 171-185.

35 <http://www.blacksea-commission.org/tda2008-document.asp>

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Box 8. A second iteration for the Black Sea TDA (2007)

This second TDA was developed in order to update the Black Sea Strategic Action Programme. Its objective was to be the background for the formulation of the specific actions (policy, legal, institutional reforms or investments) that had to be adopted nationally, usually within a harmonized multinational context, to address the major priority transboundary problems identified and over the longer term, enable the sustainable development and environmental protection of the Black Sea.

The original TDA was developed in 1996, the first of its kind for the GEF. The 1996 Black Sea TDA was a technical document which examined the root causes of Black Sea degradation and options for actions which could be taken to address them. The first time round, an initial series of thematic analyses were conducted at a national level and then integrated by a group of regional and international specialists in order to construct the Transboundary Diagnostic Analysis (TDA) of the Black Sea. The 2007 Black Sea TDA was expected to build on the existing 1996 document and it was anticipated that it wouldn't adhere to the previous TDA development process (the general model used in 1st phase International Waters projects). However, the developed document has followed the GEF IW TDA/SAP "best practice" approach.

The methodology adopted has been presented in the document and the process proceeded according to the 'Best Practice' steps including: identification and initial prioritisation of transboundary problems; gathering and interpreting information on environmental impacts and socio-economic consequences of each problem; causal chain analysis (including root causes); and completion of an analysis of institutions, laws, policies and projected investments.

During the process of TDA development, a series of thematic reports and a Causal Chain Analysis (CCA) were drafted through an iterative and consultative process, with several versions being developed after successive consultations with the international consultant and CCA National Experts. Based on the national reports, a Joint Survey of the Black Sea environment and the technical inputs from the international experts, the TDA identified the priority transboundary problems and included a hot spot analysis, governance and institutional analysis and stakeholder analysis. Based on the prioritisation exercise, four priority transboundary problems in the Black Sea were identified for further detailed study. These were a) nutrient over-enrichment/eutrophication; b) decline in natural resources (e.g. fisheries); c) chemical pollution; and d) habitat and biodiversity changes - including alien species introduction. For each of these four priorities, specific measures aimed to reduce the transboundary impact have been identified.

The TDA document provided a large amount of information either at the national or regional level. Its development had been carried out with the involvement of all stakeholders using scientific cruise data, existing monitoring information at the national level, expert meetings, international expertise, and local knowledge from different stakeholders. And the TDA used a clear methodology, presented in the document and contributed to the updated SAP.

CHALLENGES IN CREATING LINKAGES BETWEEN SCIENCE AND POLICY

It is challenging to achieve long-term commitment beyond the life of the GEF intervention, although very important for successful adaptive management.

Although adaptive management provides a valuable process for the sustainable management of transboundary waters, it is not without pitfalls. In particular, it requires a long-term commitment by

stakeholders – particularly governments and scientific communities of practice – that must extend far beyond the length of the GEF intervention; GEF's enabling investments can go a long way in facilitating this post-project analysis. This commitment includes the continued and transparent provision of scientific evidence for the effectiveness of management actions. The SAP should reflect this commitment.

A number of vulnerabilities in the adaptive management schemes remain. The scheme presented in the previous section seems logical and intuitive but it has a number of vulnerabilities that can impede successful implementation and the current review has sought to explore some of these. Examples are:

- The TDA could be partial or constrained in its objectivity;
- The vision and its objectives could be manipulated as the result of a process that is not open and inclusive;
- Decision makers may be uncomfortable with the lack of evidence that normally exists when setting long-term goals and may insist that these are strictly evidence based (and therefore in many cases unambitious). They may have their own ‘hidden’ agendas that will heavily influence processes poor in evidence;
- Indicators could be ‘soft’ and speculative rather than challenging and S-M-A-R-T;
- The success or failure of interventions may not be reported in a transparent manner that allows learning to occur;
- Long term monitoring systems may not be established or data shared;
- Interventions may be limited to ‘quick fixes’ or so called ‘low hanging fruit’ that do not resolve core causes;
- Partners may be reluctant to really cooperate and implement measures.

FINDING VIABLE SOLUTIONS TO ENVIRONMENTAL PROBLEMS IN TRANSBOUNDARY WATERS

Scientific discovery must provide the bridge between research and management through which alternative solutions can be “test-driven.” The role of science is not restricted to problem identification and indicator development; science has a major role in the development and testing of alternative solutions, some of which will be incorporated into strategic programmes of action. A simple classification scheme presented in this report helps to develop an integrated approach towards solutions. ‘Solutions planning’ requires increased engagement of economists, an area that often remains deficient in GEF IW projects.

The SAP should contain a range of solutions to environmental problems at the Driver, Pressure, State and Welfare level as well as comprehensive schemes to improve governance (policies, laws, institutions). Figure 3 illustrates some of the available solutions (these are only intended to be examples and the list is not comprehensive). Some of the solutions are quite similar between different classes of water body and others are more explicit (see recent publications on oceans³⁶ and lakes³⁷ for example). All require the input of multidisciplinary science. The figure also illustrates the need for careful evaluation of a wide range of solutions. Evaluation of viable options for improving governance may require support through the combined efforts of political scientists, lawyers, social scientists (including management specialists) and economists. This aspect of the ‘solutions matrix’ is often ignored when developing Strategic Action Programmes. Some reforms may be a matter of common sense, others, particularly those involving ‘wicked’ problems, may require innovative and novel approaches that are fit for purpose and culturally sensitive.

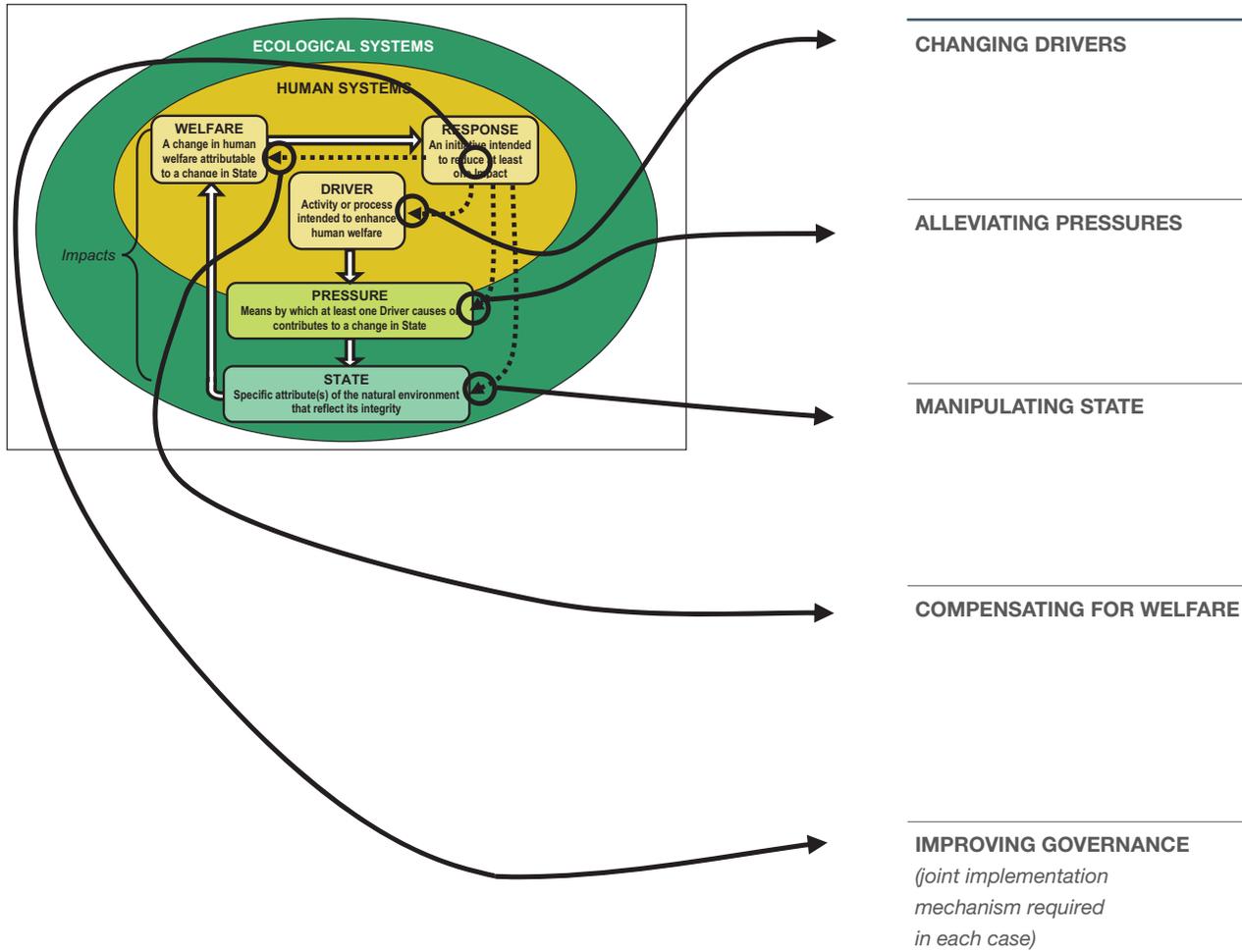
Choices between alternative solutions are based upon a large number of factors including feasibility, durability (sustainability), public acceptance, cost effectiveness, social willingness and ability to pay, as well as political factors that reflect social choice. The role of analyses of costs and benefits is important in this process but we have been unable to find a good example of how this work has been conducted in GEF IW projects, partly because this has not been fully reported in the project documentation. If reporting were improved, it would be possible to build a library of such studies and then apply ‘benefits transfer’ economic techniques to assist projects that suffer from insufficient social and economic data. The issue of limited expertise in environmental economics is not restricted to the GEF however; it is argued that this field is not sufficiently lucrative or attractive and suffers from a chronic shortage of manpower and research. The GEF might consider it appropriate to commission a review of how to improve the effectiveness of social science support to IW projects as this is a chronic problem that was emphasized during all IW Science workshops.

36 Jacquet J. et al. (2011) Scanning the oceans for solutions. *Solutions* 2: 46–55.

37 World Bank (2004). *Water Resources and Environmental Management Briefing Notes Series; Briefing Note 14 – Management of Lakes*. 40 pp.

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Figure 3. Solutions Matrix



This is not a comprehensive list but illustrates some of the key solutions that may be evaluated and applied in the transboundary aquatic systems reviewed

GROUNDWATER	RIVERS	LAKES	COASTAL/LMES	Ocean/Global
<ul style="list-style-type: none"> • Water pricing • Change crops/irrigation system • Location of population 	<ul style="list-style-type: none"> • Location and efficiency of major water users • Revise urban planning 	<ul style="list-style-type: none"> • Control fish demand by pricing and regulation • Actions as per rivers 	<ul style="list-style-type: none"> • Remove perverse fishing subsidies • Incentivize low-waste production 	<ul style="list-style-type: none"> • Exclude IUU fish from the marketplace • Levy disposable plastics
<ul style="list-style-type: none"> • Minimize unregulated pumping • Effluent discharges 	<ul style="list-style-type: none"> • Treat wastewater • Improve/regulate fishing techniques 	<ul style="list-style-type: none"> • Treat wastewater • Improve/ regulate fishing techniques 	<ul style="list-style-type: none"> • Regulate fishing effort • Treat effluent • Limit underwater noise 	<ul style="list-style-type: none"> • Treat ballast water • Require selective fishing gear
<ul style="list-style-type: none"> • Aquifer restoration • Vegetation cover restoration 	<ul style="list-style-type: none"> • Wetland/habitat & species restoration • Flood plain rehabilitation • Dam removal 	<ul style="list-style-type: none"> • Protection • Restocking • Aeration • Bioremediation 	<ul style="list-style-type: none"> • Protected areas for conservation/ rehabilitation • Restoring ecosystems 	<ul style="list-style-type: none"> • Create network of marine protected areas • Reintroductions • Removing floating waste
<ul style="list-style-type: none"> • Compensate and relocate displaced people • Improve understanding of water issues 	<ul style="list-style-type: none"> • Alternative life skills support • Relocation of displaced people • Build awareness • Compensation 	<ul style="list-style-type: none"> • Alternative life skills support • Relocation of displaced people • Build awareness • Compensation 	<ul style="list-style-type: none"> • Alternative skills support/employment • Build awareness through education/ recreation • Compensation 	<ul style="list-style-type: none"> • Build awareness through education/ recreation
<ul style="list-style-type: none"> • Aquifer management commissions. • National policies and laws • Joint/coordinated investment funds 	<ul style="list-style-type: none"> • River basin commissions • Integrated river basin management 	<ul style="list-style-type: none"> • Joint lake conventions and commissions • Lake basin management 	<ul style="list-style-type: none"> • Regional seas conventions and commissions • Marine spatial planning • Integrated coastal zone management 	<ul style="list-style-type: none"> • Revise Law of the Sea • Issue-based conventions • Global trade deals • Development of new or strengthened global institution(s)

CHAPTER SIX

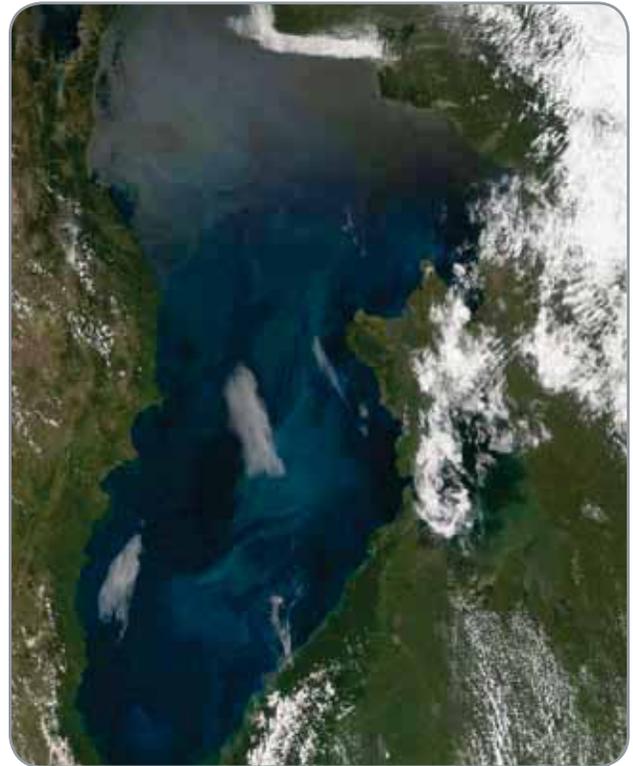
Recommendations for Connecting Science in GEF IW Projects

The role of science is crucial in GEF IW projects but it is seriously understated. By focussing more effort on the quality and content of the science and consistency in the way it is reported, the GEF can obtain considerable added value from it and contribute to the global knowledge base. Well-recorded science with scope for innovation will enhance the credibility of the IW Focal Area and buy-in from stakeholders. We provide six specific recommendations for improvement.

Discovering the utilization or generation of science in GEF IW projects is very difficult, in part due to the lack of a design to capture this information. During our workshops and thematic meetings, we gradually appreciated the huge amount of science that had been employed in GEF IW projects. It is unfortunate that we feel obliged to use the word ‘gradually’ however. This is because much of the science was implicit rather than explicit and rarely featured in the documents that are archived through the IW:LEARN and GEF websites. Even the individual project websites tended to be poor in science information and many TDAs only presented a synthesis of science and this makes it difficult to compare between project periods or to use the information to assemble a bigger picture at a larger scale. This was one of the problems found during GIWA (the Global International Water Assessment) and one of a number of causes of its patchy (from excellent to non-publishable) and poorly consistent analysis. Major efforts were made by the UNU project team to gather information but its paucity was the cause of frequent comments at almost all of the meetings.

The main questions remain: how to capture the science already employed or generated in GEF projects and how to use the best available science to enhance future projects and to leave a wider legacy? A unique feature of IW projects is the TDA-SAP process and we have demonstrated that this is an effective way of

initiating an adaptive management process. So the GEF is potentially conducting one of the biggest trials of adaptive management on the planet. It is important not to understate this contribution to ‘big picture’ science. There are a very large number of approaches taken by individual projects to articulate adaptive management and these could be viewed as major experiments that can be mutually compared, if the observations of success criteria are gathered consistently and for sufficient time.



Phytoplankton blooms in the Black Sea. Increased nutrient inputs into the world's seas and oceans as well as excessive harvesting of fish stocks, which cause a "trophic cascade" as described for the Black Sea, result in increased eutrophication of Large Marine Ecosystems / NASA Earth Observatory, 2006 using the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite



We have six specific high-level recommendations to improve the role of science and get the best results from the GEF's investment. A compendium of 'best practices' is also presented in this report as a means of offering specific suggestions for improvement.

RECOMMENDATION 1:

All GEF IW projects should incorporate a scientific evidence panel (SEP) that includes local scientists, ensures data or metadata archiving and produces a separate summary report of the science used in the intervention.

RECOMMENDATION 2:

During the preparation of the project proposal, a gap analysis should be undertaken to identify likely limitations in the scientific information to support project implementation. A strategy for bridging the gaps should be proposed and financial support for this should be part of final project design. Targeted research is a legitimate approach for bridging identified gaps.

RECOMMENDATION 3:

One of the remits of each SEP should be to conduct a horizon scanning exercise. This should be part of every TDA-SAP process and include review of emerging science issues and future scenarios for key issues. We have proposed a useful classification framework to assist with the identification of emerging issues.

RECOMMENDATION 4:

The GEF should develop a process for medium/long term evaluation of the impact of interventions (i.e. well after the termination of the project), indicators developed using the DPSWR framework during the SAP process can provide the structure for this process. This role could be assigned to the GEF Monitoring and Evaluation unit and should include a review of tangible evidence of impacts. Such a long-term analysis by GEF would also help in evaluating the effectiveness of the adaptive management strategy adopted by the GEF's IW Focal Area, and lead to a stronger argument for employing SMART³⁸ indicators.

RECOMMENDATION 5:

The GEF should empower its Scientific and Technical Advisory Panel or a group of similar standing to examine the basic scientific principles underpinning GEF projects and to communicate them to implementing and executing agencies in order to ensure greater uniformity in terminology and overall methodology.

RECOMMENDATION 6:

Greater attention should be paid to improve the storage and dissemination of the scientific data from GEF projects in order to make it more accessible for further analysis. This should not be limited to standard project reports but should provide an access route to the data and information that underpins them.

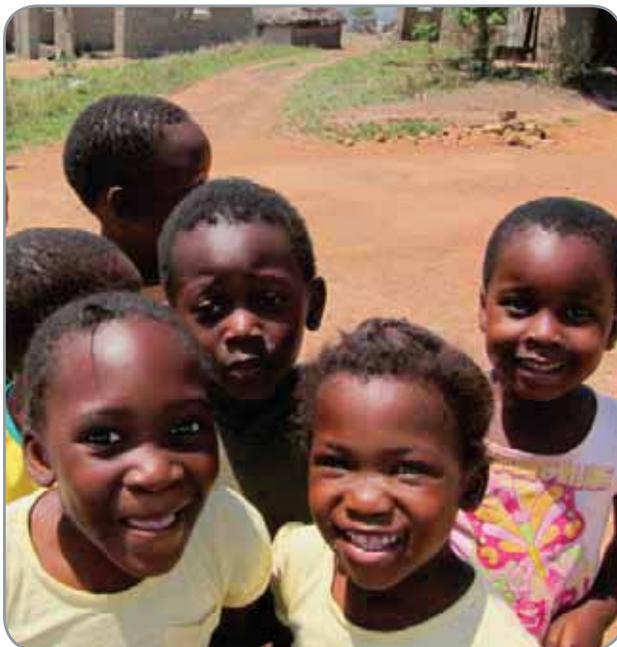
38 Specific, Measurable, Achievable, Relevant and Time-bound.

Compendium of Best Practices

The following core findings and recommendations on adaptive management were derived from the conclusions of individual panels and synthesized at the final project meeting at UNESCO in Paris. The group examined the wider use of science in GEF projects and the way science could be better engaged in the Adaptive Management process:

Best practices for science engagement

- A stakeholder analysis should be conducted as part of the TDA and the identified stakeholders should be invited to work together in 'constituencies' to nominate who will represent them as part of a joint technical task team (TTT).



Community life in the Lebombo Mountains near the border of Mozambique, Swaziland / A. Dansie

- Scientists should work together with stakeholder representatives in the TTT in an intentional joint process of scientific inquiry backed up by local data/information. This also achieves buy-in of the stakeholders on the outcomes of the analysis.
- The global community must be respectful and understanding of those engaged from the region, ensure inclusivity and take positive actions to overcome communication barriers including interpretation of local languages.
- Where possible, local approaches and traditional (or indigenous) knowledge should be incorporated (CBD principle of including traditional knowledge at the same level) to gather and interpret information and improve understanding of governance and value systems.
- Full use should be made of knowledge sources outside traditional UN processes and networks, understanding that these sources should be properly acknowledged and in some cases compensated.
- The contribution and expectations of science should be clearly outlined during project design to facilitate effective science involvement and properly budgeted for in the projects.
- A scientific evidence panel (SEP) should be incorporated in each project from the outset in addition to a widened involvement of scientists throughout the process. This should ensure the best use of all sources of evidence of appropriate quality and:
 - inventory and involve existing scientific networks and research on appropriate scales from the beginning



Incorporation of local and traditional knowledge, community engagement and mutual understanding between all levels of stakeholders is crucial to ensure IW intervention success and sustainability, Ghizou, China

- determine of the right scale to conduct the work in both geographic and scientific contexts
- establish Scientific Communities of Practice (comparable and transparent procedure) for thematic areas that will engage local communities
- identify gaps and incorporate investments in infrastructure and training of local scientists for local capacity building

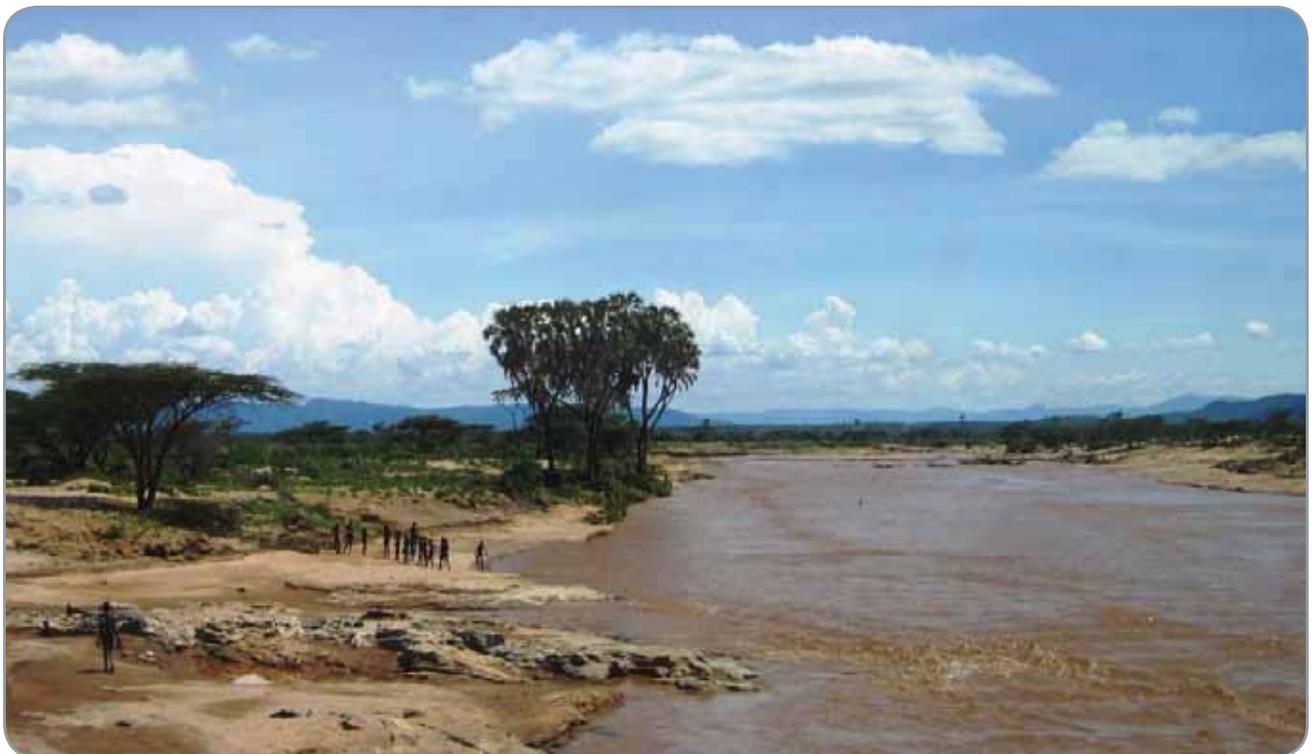
- Executing Agencies should establish independent review teams separate from the SEP.
- The SAP should incorporate a broadly-agreed platform for maintaining the evidence base, data sharing and databases created during the project.
- Where appropriate, prior to full-scale roll-out, adaptive management process and outcomes should be demonstrated in pilot sites (as a capacity building exercises).

Best practices for applying scientific expertise in IW projects

- Facilitate speedy implementation of the initiation phase, fully involving the scientific technical advisory panel (STAP).
- Bring international scientists together with local scientists early in the project to develop the most appropriate science strategy.
- Social science should not be an after-thought in the science underpinning projects and should be properly resourced (this may require capacity building in order to create an appropriate legacy).
- Invest effort early to look for local members of international (relevant) scientific societies or agencies that can provide the linkages to larger scientific efforts, groups, etc and provide the basis for building the Scientific Evidence Panel.
- Facilitate access for local science teams to relevant international workshops, training opportunities and courses, tours of similar projects, and include study tours of outside experts, exchanges.

Synthesis Report

- Give early consideration to ensuring the longer term legacy of projects by:
 - developing realistic and measurable indicators to describe the long-term vision for managing the system, and
 - understanding on-going monitoring requirements in terms of cost, logistics, and the sensitivity of time frames of projects
 - investing in building a repository in the beneficiary countries for monitoring long term impacts/welfare
 - Conduct demonstration, documentation and evaluation projects to allow for co-learning and reflection.
 - Look outside the project area for emerging issues and relevant proxies.
 - The international science peer review process needs to occur at regular intervals, including initial design, periodically during execution, reporting and in the follow-up process.
- Best practices for linking science and management, including policy formulation and broader governance issues*
- Develop clear focus on science-informed practical approaches for decision-making, addressing priority and strategic use and policy change.
 - Legal constraints and institutional barriers to engagement of the wider science community should be identified before the project fully develops.
 - Scientists need to be clear about the scientific uncertainties and be willing and able to policy makers/managers.
 - Projects should create platforms for engaging the governance triad between community (largely represented in organised civil society), policy and science (see figure). Use these platforms to get public support, community involvement and government support at all levels, and to demonstrate how science fits into the decision-making context.
 - Communication strategies and targeted workshops are necessary to translate science and study issues



Social and ecological considerations must be approached jointly for successful river basin management and, ultimately, IWRM / A. Dansie



Engagement of local science institutions, such as Universities, is important to the success and sustainability of IW projects. Here the next generation of scientists, policy designers and decision makers conduct a science experiment in the classroom / UN Photo, E. Debebe

- Document lesson learned with relevant indicators and establish a repository of scientific information³⁹.
- Improve access to all previous project documents to facilitate information flow.
- Encourage deliberate testing of solutions by pilot or demonstration programs focused on learning at multiple scales.
- Develop a mechanism for all GEF projects to include and disseminate scientific information through multiple instruments focused on end user communities and make the lessons learned available to as wide as possible a community in an appropriate format.
- Develop a communication plan involving the local target groups and a method for communicating to them, bearing in mind that lessons must be interpreted within the context of the socioeconomic, political, cultural and ecological characteristics of the region.

into relevant management decisions, and vice versa, and relevant targets need to be developed.

- Pilot projects can be effective models for creating a common understanding between all countries involved, leading to increased public involvement and achieving the program goals. Scaling-up can happen based on successes from pilots.
- An explicit adaptive management strategy helps to maintain a synergy between science and policy and ensure longer-term impacts. It can also be used for risk assessment and management.

How to better understand and effectively communicate the scientific dimensions of adaptive management to different user groups?

- Communicate the value of the ‘learning by doing’ process irrespective of whether the project was successful and improve the way in which all lessons are documented.

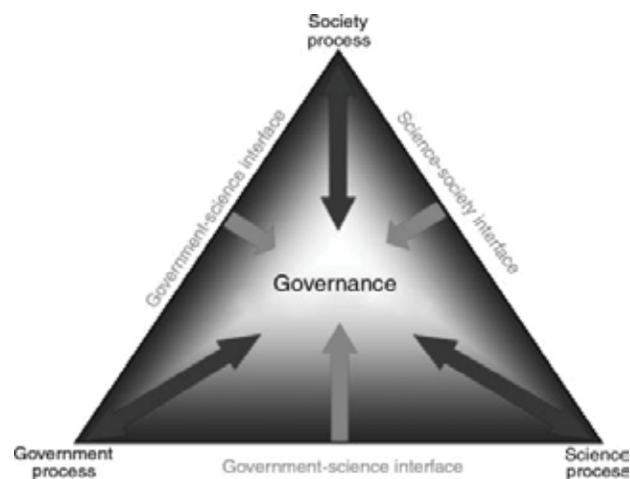


Figure 4. A triologue model for ecosystem governance (Source: Hattingh et al., 2007⁴⁰)

39 For instance, all documents related to the development and use of the Decision Support Framework, a comprehensive basin model package to support basin planning processes, are compiled in one place in the shared database of the Mekong River Commission.

40 J. Hattingh, G. A. Maree, P. J. Ashton, J. J. Leaner and A. R. Turton. (2007). A triologue model for ecosystem governance. Water Policy 9 Supplement 2: 11–18.

Annexes

1. AN OVERVIEW OF THE GEF IW: SCIENCE PROJECT

The overall objective of this project was to “enhance - through knowledge integration and information sharing tools - the use of science in the GEF IW focal area to strengthen priority setting, knowledge sharing and results-based, adaptive management in ongoing and future projects”. The GEF has been the largest funder in human history of projects to assist governments to sustainably manage transboundary International Waters. One of the key facets of transboundary systems is the large element of uncertainty in their management and this can only be reduced by monitoring and targeted research. Research was never an explicit goal of GEF projects however and this project was designed to capture the lessons learned from a number of disparate activities in a huge number of GEF interventions.

The report is based on a synthesis of work conducted by a number of sub-groups described in the online appendices to this report. The following meetings were held: Introductory meeting – Macau, 24-28 January 2010; Mid-term meeting of Steering Committee – Paris, 8-9 April 2010; WG meetings on Rivers, Lakes, Groundwater (aquifers), Land based pollution sources (coastal margins) and, Large Marine Ecosystems; Inauguration meeting for Scientific Synthesis Group– Bonn, 13-15 December 2010; Final meeting in Paris , 23-24 March 2011.

The conclusions of this report also deliver part of the fourth expected project output: Executive policy-guidance overview on key project conclusions and recommendations. We hope that these results will assist the overall project planning process within the GEF and in particular to clarify a common approach to adaptive management.

Intended recipients for this report are:

- Governments of the countries that implement GEF projects, the Implementation Agencies, and stakeholders benefitting from GEF projects;
- GEF STAP;
- IW:LEARN, including the whole portfolio of projects and the Communities of Practices; and,
- The GEF Secretariat, especially in terms of providing input to the TDA which will link to the tracking tool development.

2. METHODOLOGY

The methodology employed for this project was the systematic analysis of project documents and outputs for a series of core questions. Work was conducted by individual specialist reviewers who came together on a number of occasions to synthesise their results. The experts were divided into a number of panels: Groundwater; Rivers; Lakes; Coastal margins (and transitional waters); and Large marine ecosystems. Where appropriate, the results of this analysis were benchmarked against information from the open scientific literature and reports from other integrated assessments. The questions were:

- What are the critical science challenges “on the horizon” specific to each ecosystem type?
- What is the significance of regional and global-scale drivers, in particular climate change, in the genesis of transboundary problems?
- Describe how understanding and managing multiple causality in a transboundary water context is undertaken?



- How are variable spatial and temporal scales in IW projects accounted for?
- What approaches were used to understand/asses the coupling of social and ecological systems?
- What scientific knowledge is available and/or used to evaluate trade-offs between the response options developed by IW projects?

In addition, there were questions on adaptive management and the use of indicators:

- Application of science for adaptive management
 - To what extent was engagement of both local and wider science communities utilised in IW projects? If not, how can improvements be made?
 - To what extent is scientific expertise and local knowledge well applied within the IW focal area, particularly in accessing existing baseline information, new findings on methodologies, science breakthroughs and scanning for emerging issues?
 - What lessons were identified for linking science and policy implementation, including policy formulation and broader governance issues?
 - To what extent is adaptive management happening? How to better understand and effectively communicate the scientific dimensions of adaptive management to different user groups?
 - How can newly-synthesized science knowledge be better communicated to stakeholders within and external to GEF?

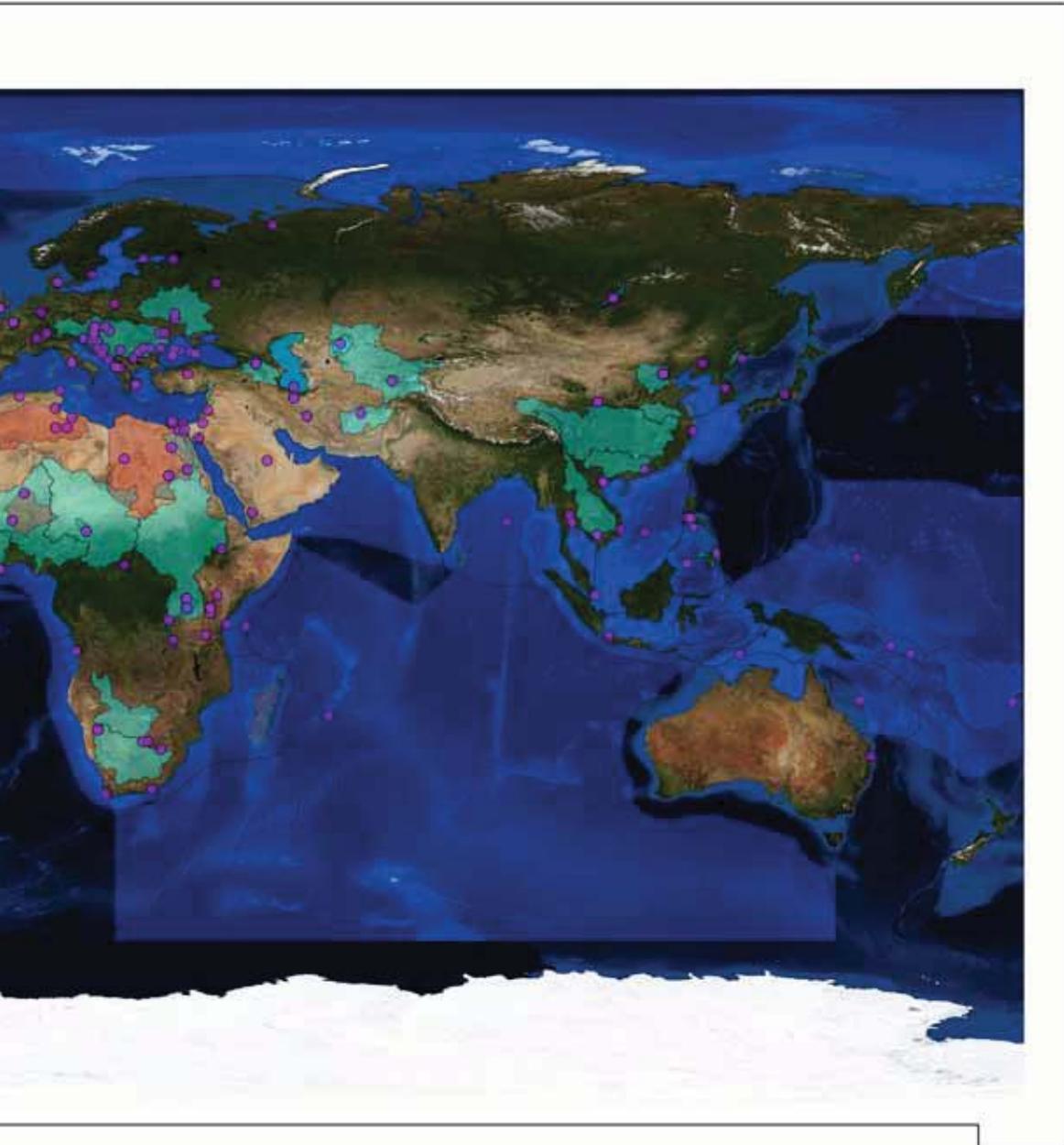
- Development and use of indicators to support IW projects
 - How did the projects help build and implement sound indicators and monitoring strategies to support SAP implementation and/or ultimately assess the achievement of environmental and social benefits?
 - How can we identify effective proxy indicators for use in IW projects?
 - How do we make better use of appropriate science and best practices for Transboundary Diagnostic Analysis?



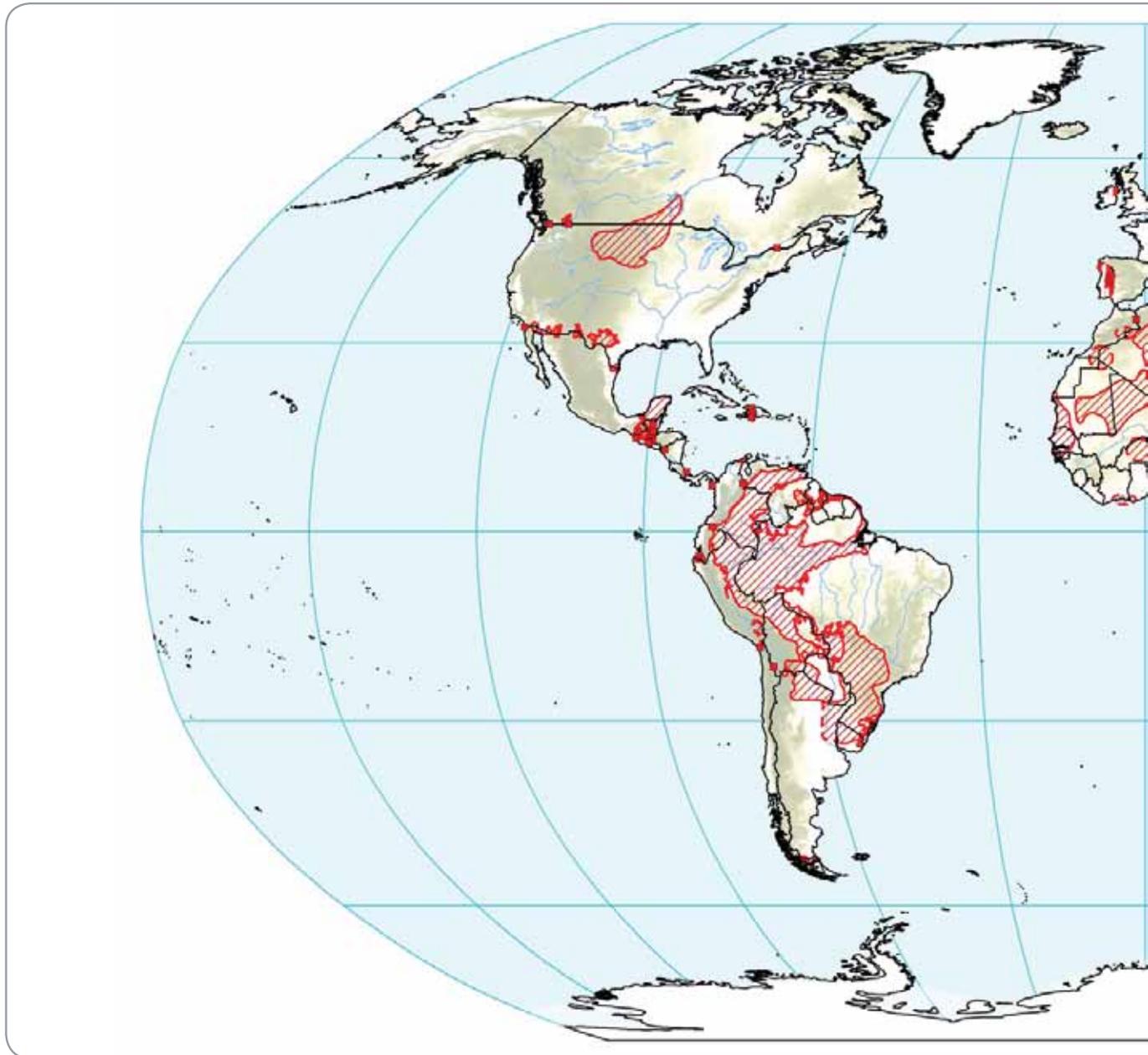
The growing human population and increasing demand for seafood worldwide places increasing pressure on the oceans / A. Dansie

The GEF International Waters Portfolio 1991 - 2012

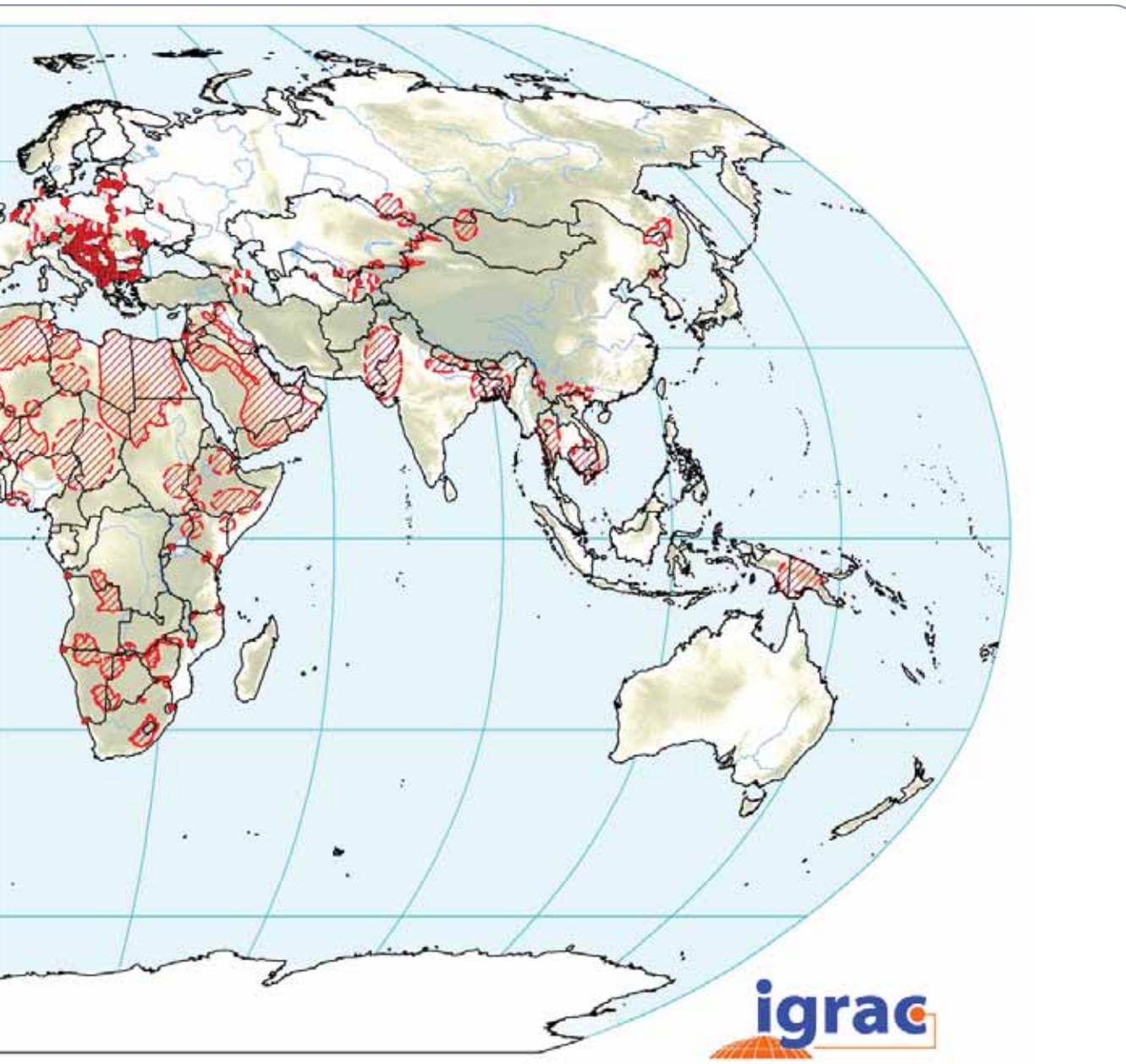




Transboundary Aquifers of the World - Update 2009 -

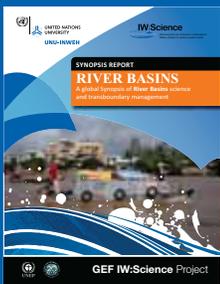
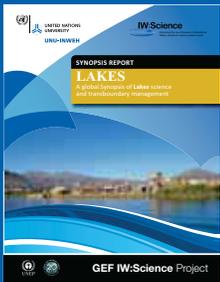
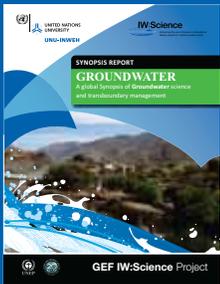


The map presented brings together information on transboundary aquifers as was known in 2009. The information is provided by various organisations and projects dealing with transboundary aquifer assessment and /or IGRAC compiled the available information in this TBA map based on the guiding principle to stay as close as possible to the information provided by the original sources, while presenting the information as appropriately as possible for the originally chosen scale of the map (1:50,000,000). The TBA map shows aquifer extent (if known), for aquifers with an area larger than 6,000 km². Smaller aquifers are represented with squares. If the exact aquifer boundaries are known and acknowledged by all sharing countries, they are delineated with solid red lines. If not, they are delineated with dashed red lines. Small (filled or half-filled) circles are used to depict aquifers whose extent is not known. A filled circle represents an aquifer whose occurrence is confirmed by all countries involved; if an aquifer is not recognized by all countries, it is depicted by a half-filled circle.

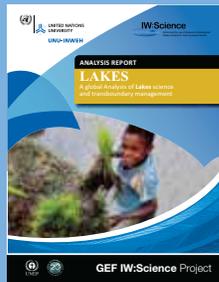


Synthesis Report

1. Synopsis



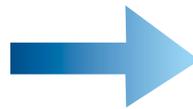
2. Analysis



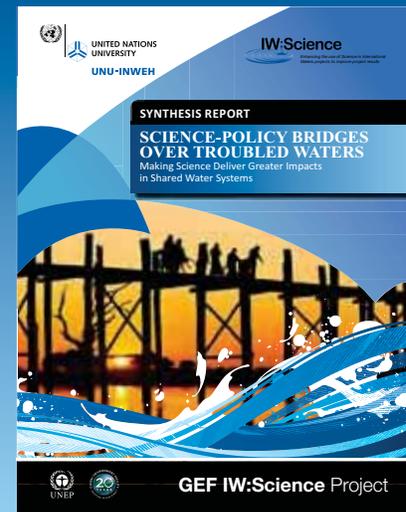
The IW:Science process; Synopsis → Analysis → Synthesis

The IW:Science Working Groups, each led by their Lead Institutions⁴¹, have completed the IW:Science Synopsis and Analysis process and reported on their findings. All reports are available on the GEF, IW:LEARN, IW:Science and UNU-INWEH websites.

The final stage of the IW:Science process is the preparation of this GEF IW:Science Synthesis Report, 'Science-Policy Bridges Over Troubled Waters, Making Science Deliver Greater Impacts in Shared Water Systems' bringing together the findings and efforts of the IW System Type Working Groups (Groundwater, Lakes, Rivers, Land-based Pollution Sources and, Large Marine Ecosystems and the Open Ocean). This report serves to provide a global perspective on the state of challenges and pressures facing transboundary water systems, both freshwater and marine. The context of this Synthesis is the need and effective use of science to address these challenges and the translation of such science use to policy for multi-country management of shared water resources.



3. GEF IW Synthesis Report



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Enhancing the use of Science in International Waters projects to improve project results



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