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Transboundary Waters Assessment Programme

Note by the secretariat

Summary

The present note sets out the background and results of the Transboundary Waters Assessment Programme (TWAP) of the United Nations Environment Programme and the Global Environment Facility. The project presents the first global assessment of international waters and consists of five water-category-specific assessments that cover a total of 758 international water systems: 199 transboundary aquifers and groundwater systems in 42 small island developing States, 204 transboundary lakes and reservoirs, 286 transboundary river basins, 66 large marine ecosystems and the open ocean. With the exception of the open ocean assessment, the four water system category assessments are comparative, providing a quantitative indicator-based means of classifying water systems into five risk categories ranging from very high to very low risk. A cross-cutting analysis that brings together the five water components provides a high-level summary of patterns and trends.

The TWAP assessment is the first global assessment that uses quantified indicators of system states, pressures and impacts under three broad themes: biophysical, socioeconomic and governance. Results are summarized into five relative levels of system risk (lowest, low, moderate, high and highest), which are open to system- and regional-scale comparisons. As such, TWAP is poised to help identify core indicators to support national monitoring and reporting of targets required to realize the Sustainable Development Goals for the period 2015–2030. TWAP freshwater indicators map to Sustainable Development Goal 6, on clean water and sanitation, notably target 6.6 (protection and restoration of mountains, forests, wetlands, rivers, aquifers and lakes). TWAP marine indicators support Sustainable Development Goal 14, on oceans, seas and marine resources, and all its targets.

* UNEP/EA.2/1/Rev.1.

I. Introduction

1. The water systems of the world, namely aquifers, lakes, rivers, large marine ecosystems and the open ocean, sustain the biosphere and underpin the health and socioeconomic well-being of the world's population. Many such systems are shared by two or more nations. These transboundary waters, stretching over 71 per cent of the planet's surface, in addition to subsurface aquifers, make up the water heritage of humanity.

2. Recognizing the value of transboundary water systems and the reality that many of them continue to be overexploited, degraded and managed in fragmented ways, the Global Environment Facility (GEF) initiated the Transboundary Waters Assessment Programme (TWAP).

3. GEF approved a full-sized project, entitled "A Transboundary Waters Assessment Programme: Aquifers, Lake/Reservoir Basins, River Basins, Large Marine Ecosystems, and Open Ocean to Catalyse Sound Environmental Management", in December 2012, following the completion in 2011 of the medium-sized project "Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme". The TWAP full-sized project, started in 2013, has two major objectives: to carry out the first global-scale assessment of transboundary water systems that will help GEF and other international organizations to improve the setting of funding priorities, and to formalize partnerships with key institutions to ensure that transboundary considerations are incorporated in regular assessment programmes to provide continuing insights on the status and trends of transboundary water systems.

4. The five water-category-specific assessments cover a total of 758 international water systems: 199 transboundary aquifers and groundwater systems in 42 small island developing States, 204 transboundary lakes and reservoirs, 286 transboundary river basins, 66 large marine ecosystems (and the western Pacific warm pool) and the open ocean. The assessed waters cover over 70 per cent of the planet's oceans and landmass, and about 16 per cent of the planet's landmass that is also underlain by transboundary aquifers. As the first global comparative assessment of transboundary waters (those shared by two or more countries), TWAP provides quantified assessment results that can inform the setting of priorities for intervention by GEF and others, as well as the development of strategies on how nations and regions can meet their Sustainable Development Goals and targets by 2030.

5. TWAP delivers the first baseline assessment of all the planet's transboundary water resources, providing benchmarks of the current state of water systems to inform policy, encourage knowledge exchange, identify and classify water bodies at risk and increase awareness of the importance of protecting transboundary waters at relatively low risk and mitigating the state of systems at moderate to highest risk.

6. The TWAP assessment is the first global assessment that uses quantified indicators of system states, pressures and impacts under three broad themes: biophysical, socioeconomic and governance. Results are summarized into five relative levels of system risk (lowest, low, moderate, high and highest), which are open to system- and regional-scale comparisons. As such, TWAP is poised to help identify core indicators to support national monitoring and reporting of targets required to realize the Sustainable Development Goals for the period 2015–2030. TWAP freshwater indicators map to Goal 6, on clean water and sanitation, notably target 6.6 (protection and restoration of mountains, forests, wetlands, rivers, aquifers and lakes). TWAP marine indicators support Goal 14, on oceans, seas and marine resources, and all its targets.

7. The TWAP full-sized project has been implemented by the United Nations Environment Programme (UNEP) as implementing agency, the UNEP Division of Early Warning and Assessment as executing agency, and the following lead agencies for each of the water system categories: the International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization (UNESCO) for transboundary aquifers including groundwater systems in small island developing States; the International Lake Environment Committee Foundation for lake and reservoir basins; the UNEP-DHI Partnership – Centre on Water and Environment for river basins; and the UNESCO Intergovernmental Oceanographic Commission for large marine ecosystems and the open ocean. The institutional partnerships forged in this assessment are also envisioned to seed future transboundary assessments.

8. The assessment results are organized into five technical reports and a sixth volume that provides a cross-category analysis of status and trends:
- (a) Volume one: *Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends*
 - (b) Volume two: *Transboundary Lakes and Reservoirs: Status and Trends*
 - (c) Volume three: *Transboundary River Basins: Status and Trends*
 - (d) Volume four: *Large Marine Ecosystems: Status and Trends*
 - (e) Volume five: *The Open Ocean: Status and Trends*
 - (f) Volume six: *Transboundary Water Systems: Cross-cutting Status and Trends*
9. A summary for policymakers accompanies each volume. In addition, all supporting data and publications are accessible via a central data portal (www.geftwap.org) that links the five water-category-specific websites.

II. Transboundary aquifers and groundwater systems of small island developing States: status and trends

10. Volume one sets out the first comprehensive indicator-based global assessment of status and trends in 199 transboundary aquifers and 42 groundwater systems of small island developing States. It was prepared by the UNESCO International Hydrological Programme and the UNESCO International Groundwater Assessment Center in partnership with Simon Fraser University (Canada) and Goethe University Frankfurt (Germany).
11. The overall objectives of the groundwater component of TWAP are to:
- (a) Provide a description of the present conditions of transboundary aquifers with areal extent > 5000 km² and aquifers in small island developing States that will enable the GEF international waters focal area to determine priority aquifers/regions for resource allocation;
 - (b) Bring the major issues, concerns and hotspots of these transboundary aquifer systems and aquifers of small island developing States to global attention and catalyse action.
12. The results of the TWAP groundwater assessment have provided elements to help GEF and other interested parties to find answers to the following questions, among others:
- (a) What human and ecosystem uses of water resources are currently affected or impaired (use conflicts, depletion and degradation)?
 - (b) How will water conditions and uses evolve over the coming decades? Global change is likely to lead to increased pressures over the coming decades, such as higher water demand for food security/irrigation and domestic use, more intensive use of fertilizers and nitrogen, and increasing seawater intrusion in coastal zones;
 - (c) Where will all these problems occur? Increasing droughts or floods have been observed in some areas and have been projected through modelling; such projections need to be incorporated and summarized in the assessment;
 - (d) Which international groundwater systems are likely to prevent, buffer or mitigate water-related problems under increasing stresses over the coming decades?
13. A major element in the TWAP groundwater component is information management. To facilitate storage, retrieval and visualization of results and underlying data, a dedicated information management system has been developed. Final results and underlying data from the transboundary aquifers and small island developing States subcomponent have been uploaded to the information management system database. These data can be visualized as maps in the information management system viewer. Results and underlying data can be downloaded in Excel format, and information sheets on transboundary aquifers and small island developing States can be downloaded in PDF format. The TWAP Groundwater Information Management System and its underlying database will facilitate the periodic update of the inventory and characterization, as well as the monitoring of trends and impacts.

Key messages: transboundary aquifers

1. **Groundwater is still a largely untapped resource.** Worldwide, the majority of transboundary aquifers with a surface expression that is greater than 5000 km² are located outside regions highly affected by groundwater development stress, and show very low depletion rates of less than 2 mm per year in most regions. Human dependency on transboundary groundwater is still generally low to very low in 193 out of the total 258 transboundary aquifer national segments analysed.

It is therefore possible to draw the conclusion that large amounts of groundwater resources are still potentially available for development in transboundary groundwater basins and aquifer systems. When considering that this assessment, largely based on modelling, has necessarily not taken into consideration the vertical dimension of aquifers, that is, the existence and thickness of multilayered systems and deep-seated aquifers, the quantity of those still unexploited reserves becomes very large indeed.

2. **Areas of high groundwater development stress are presently limited but will more than double by 2050** The number of transboundary aquifers suffering from medium to very high groundwater development stress resulting from combinations of high human dependency, low renewable groundwater per capita and high extraction/recharge ratios is rather limited. Under the worst-case climate and irrigation scenario, the national segments of transboundary aquifers showing high risk of groundwater stress are expected to increase between now and 2050 from 20 to 58. New hotspots, largely driven by population pressure, are projected to develop mainly in sub-Saharan Africa, China and Mexico. The highest future groundwater development stress values and the largest increases in groundwater development stress of up to 40 per cent are projected for transboundary aquifers located in Botswana, the Middle East and North Africa, South Asia, Uzbekistan and Yucatán. Eight new transboundary aquifer country units with economic groundwater stress are projected for the future, all of them in West or East Africa.

3. **Alarming lack of modern data and of governance frameworks.** The assessment has evidenced an alarming lack of knowledge and modern data on groundwater in general, and transboundary aquifers in particular. It is a fact that without the help of modelling this assessment would not have been possible. Notwithstanding the highly appreciated efforts of hundreds of national and regional experts, the information received through widely distributed questionnaires reflects the lack of quantitative, modern standardized data on many key groundwater parameters and the generalized limited knowledge of the subsurface and its water resources.

The lack of adequate groundwater governance at the local, regional and global levels hinders the achievement of groundwater resource management goals such as resource sustainability, water security, economic development and equitable access to benefits from water and conservation of ecosystems. This statement is even more valid when applied to transboundary groundwater. The assessment has in fact confirmed that governance and institutional frameworks for transboundary aquifers are absent, with few albeit notable exceptions.

Key messages: groundwater systems in small island developing States

1. **Many island States are facing dramatic choices.** The situation that emerges from the assessment calls for immediate attention. In the absence of coordinated, sustained remedial national and international action, low-lying islands in the Pacific, highly dependent on scarce, polluted and growingly saline groundwater resources and impacted by climatic variability and change, are facing dramatic choices. In many other islands, degradation of groundwater quality and growing demands are posing short- to medium-term threats to human health, and impairing the provision of ecosystem services of great economic relevance.
2. **Water scarcity, pollution and high human dependency threaten sustainability.** Population density appears to be the main driver of water stress in all but one of the 42 representative islands object of the assessment. This is reflected in the high number of islands (71 per cent) that are at risk of water scarcity, with a peak of 91 per cent for low-lying islands. Risk due to groundwater anthropogenic pollution affects 73 per cent of all islands, compounded in many cases by seawater intrusion and natural salinization. High human groundwater dependency represents a risk factor in 10 per cent of the Caribbean and Atlantic/Indian Ocean islands, and 72 per cent of the Pacific islands for which data was available. This marked difference among regions likely reflects differences in the availability of alternative water resources, either surface water or seawater desalination (for example, the Bahamas), and/or different stages of socioeconomic development.

III. Transboundary lakes and reservoirs: status and trends

14. Volume two focuses on a global-scale assessment of transboundary lake and reservoir basins that considers their unique defining features, the stresses on their life-supporting ecosystem goods and services, and the assessment and management implications of their interlinkages with other water systems. It was prepared by the International Lake Environment Committee, in cooperation with the Texas State University Meadows Center for Water and the Environment ; the Shiga University Research Centre for Sustainability and Environment; Corazón de la Tierra (Guadalajara, Mexico); and International Environmental Management Services (Wisconsin, United States of America).

15. The activities for preparation of the assessment included the collection and dissemination of information and data on environmental aspects of lakes; the promotion of technical and management training and workshops on the lake environment; and collaboration with governmental agencies, research institutes and non-governmental organizations throughout the world, particularly in developing countries, on environmentally sound lake management directed at the sustainable use of life-supporting lake ecosystem goods and services.

16. The transboundary analysis of lakes clearly indicated that ranking lakes with regard to the nature and magnitude of the threats facing them is not simply a number-crunching exercise. Rather, it requires a detailed case-by-case assessment that considers a range of interlinked factors, including their current in-lake status; their geographic location; their linkages with other flowing and pooled water systems in their basins; the range of defining institutional, policy and socioeconomic issues; the adequacy of the governance framework under which they are managed; and the magnitude of the threats to the sustainable use of their ecosystem services. Identifying the “worst” transboundary lake in a given region is also problematic because the very definition of degradation in a given case, whatever its cause, is a function not only of the lake itself, but also of the perspective of those using the ranking results and the factors they consider most important with regard to the rankings.

17. Consideration of the context is fundamental to optimizing the meaning and significance of the transboundary lake threat rankings, and the responsibility for identifying the appropriate context rests with the user(s) of the ranks, being fundamentally important for maximizing their value and meaning. The scenario analysis program developed for compiling, analyzing and computing the transboundary lake threat scores, in combination with the integrated assessment and management approach encompassed within the Integrated Lake Basin Management framework of the International Lake Environment Committee Foundation provides a means of facilitating such considerations. As a complement to the widely used integrated water resources management approach, the integrated lake basin management platform process represents a virtual framework for identifying and assessing the many complicated interacting factors influencing effective lake basin management, particularly as related to sustainable lake ecosystem services. It represents a means of considering the significantly different assessment and management needs of lakes and other lentic water systems that comprise the vast majority of the readily available liquid surface freshwater of the planet.

Transboundary lake basins and reservoirs: key messages

1. **Lack of uniform lake data makes it difficult to accurately assess the status and trends of transboundary lakes on a global scale.** Lakes and other lentic (pooled) water systems contain more than 90 per cent of the liquid freshwater on the surface of our planet and provide the widest range of life-supporting ecosystem goods and services. However, there is a serious lack of lake basin data on a global scale, which seriously hinders our ability to make accurate assessments or realistic comparisons of the status and trends of transboundary lakes. The international water community must undertake significant development of knowledge bases focusing on lakes, their basins and other lentic water systems in order to address this serious deficiency.
2. **Based on their basin characteristics, the African transboundary lakes as a group exhibited the greatest (adjusted) human water security threats, following by lakes in Asia and South America. Transboundary lakes in developed countries exhibited the greatest incident biodiversity threats, with those in developing countries exhibiting comparatively better conditions.** An accurate assessment of the type and magnitude of transboundary lake threats requires an agreed set of indicators that can be translated into contextually determined weighted scores, based on the factors and preconditions that are most important to the user of the ranking results. The TWAP transboundary lake threats were based on their basin characteristics expressed as 24 basin indicators (drivers), categorized in four thematic subject areas and complimented by expert opinion and scenario analyses. Subsequent TWAP-scale assessments that include in-lake information and data will provide more definitive conclusions regarding transboundary lake threats. As for any prioritization decision-making process, however, it is difficult to identify a unilaterally agreed list of transboundary lake basins requiring priority management interventions within the TWAP framework.
3. **Integrated water resource management can best manage lakes and other lentic water systems for sustainable ecosystem services within the context of an integrated lake basin management framework for lake basins, their inflowing and outflowing rivers and other lotic waters.** Integrated water resources management has facilitated water resources policy reforms in many countries, but does not adequately consider the defining characteristics of lakes and other lentic water systems or their ecosystem goods and services, which require longer-term, incremental lake basin governance improvements directed to their sustainable use and conservation. Lakes are also usually linked hydrologically to upstream and downstream water systems. Infusing Integrated Lake Basin Management with integrated water resources management offers an effective means of sustainably managing lakes and reservoirs and their interlinked water systems, through gradual, continuous improvement of basin governance, including institutions, policies, stakeholder participation, scientific and traditional knowledge, technical possibilities and funding constraints. It also provides a standardized analysis process for enhancing the GEF transboundary diagnostic analysis / strategic action programme process for catalysing transboundary water management interventions, including being a framework for bilateral and multilateral actions and programmes. Further, integrated lentic-lotic basin management, as an extension of the integrated lake basin management framework, provides a virtual framework for strengthening river-lake-coastal basin governance.

IV. Transboundary river basins: status and trends

18. Volume three sets out the results of the first global assessment of transboundary river basins, prepared in partnership with UNEP-DHI, the International Union for the Conservation of Nature, the Stockholm International Water Institute, Oregon State University, The City University of New York Environmental CrossRoads Initiative, the International Geosphere-Biosphere Programme, the Columbia University Centre for International Earth Science Information Network, the Delta Alliance and the University of Kassel Center for Environmental Systems Research. The assessment aimed to be of use to a broad variety of stakeholders, including transboundary institutions of specific water systems (for example, river-basin organizations, bi-national and inter-State commissions), national institutions and Governments, regional and international agencies and donors.

19. The report was released following the entry into force of the United Nations International Watercourses Convention (2014) and provides a solid baseline for the Convention and for international and regional institutions with an interest in water and food security. It was also designed to be relevant to groups of countries managing shared resources, and to individual countries to broaden their understanding of the current situation and future outlook. The state of water resources in any

location depends on a complex array of natural circumstances, stressors and management responses. Measuring differences within each basin involves assessment of the transboundary nature of the issues and links between locations. In the assessment, the transboundary nature of basins was highlighted through the use of basin country units – the portions of each basin belonging to the respective country – and for deltas through delta country units.

20. Using basin country units (and delta country units) helps to show how each country contributes to the overall picture of risk in a given basin. It also illustrates that basin-wide problems and solutions in transboundary basins are often directly linked to individual countries. Thus, the basin country unit approach contributes to identifying countries that may need to be proactive or may need more assistance in solving problems that have transboundary implications. For both individual indicators and for combinations of indicators, the assessment provides a global perspective on the magnitudes of risk, a framework for comparative analysis of risks among basins, and identification of basins that are most and least at risk. Overall, this provides a context for policy responses at the global and regional levels but also at the basin and country levels, and facilitates inter-basin learning. TWAP river basin results can also be used in combination with detailed studies on individual basins.

21. The transboundary river basins assessment is an indicator-based assessment that identifies and classifies river basins at risk from a variety of issues, encourages knowledge exchange and increases awareness of the importance and state of transboundary waters. As activities in river basins often affect their deltas, 26 deltas have also been assessed. Fifteen core indicators across five thematic groups were assessed. Projections were made for five of these indicators and linkage indicators cover lakes and deltas.

Key messages: transboundary river basins

1. **The threat to freshwater biodiversity is global. Extinction risk is moderate to very high in 70 per cent of the area of transboundary river basins.** However, local-level tailored solutions are needed to address species extinction risks.
2. **The construction of dams and water diversions is in progress or planned in many transboundary river basins, often without adequate international water cooperation instruments.** While many transboundary agreements exist, more effort is needed to update them to reflect modern principles of transboundary water management, such as the obligation not to cause significant harm and the principles of cooperation and information exchange.
3. **Risks are projected to increase in the next 15–30 years, particularly for four hotspot regions: the Middle East, Central Asia, the Ganges-Brahmaputra-Meghna basin, and the Orange and Limpopo basins in Southern Africa.** Action should be taken now to reduce future costs and impacts.

22. The results and analysis in the report, and the tools available in an interactive data portal, allow users to examine a range of issues to obtain a more nuanced picture (<http://twap-rivers.org/indicators>).

V. Large marine ecosystems: status and trends

23. Volume four sets out the results of the comparative assessment of large marine ecosystems, which was conducted by a working group of institutional partners and experts under the leadership of the UNESCO Intergovernmental Oceanographic Commission. It includes an assessment of the western Pacific warm pool, using a subset of the indicators used in the large marine ecosystem assessment. The first global comparative assessment of large marine ecosystems provides a valuable snapshot of large marine ecosystem conditions with respect to a number of priority issues, such as unsustainable fishing, pollution, habitat destruction and climate change, identified in transboundary diagnostic analyses conducted as part of the GEF large marine ecosystem projects. The patterns of risk among large marine ecosystems (based on single as well as multiple indicators for both human and natural systems) have highlighted those large marine ecosystems at highest potential risk of degradation and contributing factors, as well as where human dependence on large marine ecosystems services and vulnerability to large marine ecosystem degradation and natural phenomena are greatest.

24. The assessment explores human–environment interactions, with a focus on human dependence on ecosystem services and vulnerability to environmental degradation and climate-related natural phenomena, and reveals patterns that are relevant for management and provides a multidimensional basis for determining risk. Management and response options can be tailored to suit the specific socioeconomic and environmental conditions in each large marine ecosystem.

25. Assessment results based on single indicators and indices, as well as on multivariate indicators, are fairly consistent. They show that, in general, large marine ecosystems in developing regions (GEF-eligible) are at highest potential risk. However, large marine ecosystems are impacted to different degrees by each issue assessed, and the factors accounting for high risk vary across large marine ecosystems. These factors are largely anthropogenic and local and regional in scale. But global threats (warming seas and acidification) are projected to play an increasing role in determining large marine ecosystem conditions, as seen in changes in fish catch potential under future warming, reefs at risk of warming and acidification, and the cumulative human impacts index. Furthermore, in a business-as-usual scenario, risk levels in a number of large marine ecosystems are projected to rise due to factors such as increasing nutrient inputs from watersheds and increasing coastal populations. While this assessment focuses attention on large marine ecosystems at relatively high risk, large marine ecosystems at low and medium moderate risk should not be ignored, as appropriate actions will be necessary to ensure that risk levels do not increase.

26. Because this was a global comparative assessment across all large marine ecosystems, it was not possible to examine cause and effect, which is likely to vary among and within large marine ecosystems. Detailed assessments, including at the sub-large marine ecosystem scale, are needed to link cause and effect in the conceptual framework for specific issues. More conclusive results can be obtained with improved data, including data at the sub-large marine ecosystem scale. While this assessment presents an approach for prioritization of large marine ecosystems based on multiple indicators, other types of indices can be created from the indicators based on stakeholder priorities and user-defined weightings.

Large marine ecosystems: key messages

1. **A wide range of natural and human stressors that have cumulative and synergistic environmental impacts are concentrated in large marine ecosystems and underscore the need for integrated and multisectoral environmental management approaches.** Human use of natural resources in large marine ecosystems and activities on land and sea are putting the health and productivity of large marine ecosystems at risk. Unsustainable fishing practices, floating plastic debris, persistent organic pollutants, nutrient inputs from watersheds, and coastal habitat destruction are some of the pressures experienced by large marine ecosystems around the world. This is compounded by climate change impacts, which are already evident in many large marine ecosystems. These pressures are projected to increase in the future under a business-as-usual scenario. Large marine ecosystems that are at the highest relative risk are mainly those in tropical regions. Addressing the diverse sources of pressures on large marine ecosystems requires, among others, integrated and multisectoral approaches and improvement in transboundary governance architecture.
2. **Ecosystem degradation has potentially severe consequences for the millions of people around the world who are dependent on large marine ecosystem services for their survival and well-being.** Future deterioration of ecosystem health coupled with climate change will exacerbate an already precarious state for coastal populations of some large marine ecosystems. These populations, particularly in highly populated tropical regions, are the most at risk from the combined effects of environmental threats, dependence on large marine ecosystem resources, and shortfalls in their capacity to adapt. Based on indicators of large marine ecosystem human development status and of large marine ecosystem health, the large marine ecosystems at highest overall risk are those fringed by developing countries in Africa and Asia. Measures need to be taken urgently to mitigate the risks to human communities arising from the combination of environmental degradation and climate change impacts.
3. **Management of large marine ecosystems can be considerably improved by improving the quality of data and information and by assessments at sub-large marine ecosystem scales.** The assessment has been constrained by limitations in the availability and quality of data, which are variable amongst large marine ecosystems. Much of the available data are characterized by varying levels of uncertainty as well as by spatial and temporal gaps, which can be addressed in the future through research and monitoring and observing programmes. Assessments are also needed at sub-large marine ecosystem scales, so that actions can be taken to address pressures and impacts at the appropriate scale. This requires the availability of data and information at the appropriate geographic scale. In addition, there is a need for maintenance and regular updating of the large marine ecosystems data portal developed under this phase of the TWAP so that interventions can be made in a timely manner as new data and information become available. It is crucial that adequate financial resources are made available to improve data availability and quality.

VI. The open ocean: status and trends

27. The open ocean is by international convention the largest transboundary space, with ocean areas beyond national jurisdiction covering about half of the surface of the Earth (ocean areas under national jurisdiction cover a further 20 per cent), under the ultimate governance of the United Nations General Assembly. Governance of the open ocean is mediated mainly through global international treaties based on particular themes (climate change, fisheries, pollution and biodiversity), as well as some regional conventions.
28. Global impacts on the ocean such as pollution and fishing come from human drivers on land and at sea. And global impacts on human society can be driven by the global open ocean through its role in the climate system. The oceans have a role in mediating patterns of rainfall and drought (an important input for the other TWAP water systems); global climate change is leading to sea-level rise and ocean acidification, with growing impacts on ocean ecosystems and on tourism and fisheries. Communicating these impacts remains a challenge.
29. There are many challenges to assessing how human well-being and stakeholder behaviour are affected by and linked to changes in the open ocean. A primary challenge relates to the limited scientific data on the state of the ocean: its physical state, chemical state, the state of ocean ecosystems and living marine resources. Systems monitoring the state of the physics of the upper ocean and the ocean carbon system related to climate are not fully implemented and have gaps in their adequacy. Monitoring of the state of ocean ecosystems in particular is lacking.

30. However, a lack of sufficient monitoring and understanding should not rule out an assessment of the high uncertainty, long timescale and yet potentially very high-impact environmental problems associated with the global ocean. Indicators are key to communicating problems and tracking progress. The assessment provides a scoping analysis for looming future problems through development of indicators and an expert assessment of the latest scientific literature. It acts as an analogue to the assessment of the human relationship to climate by the Intergovernmental Panel on Climate Change of the World Meteorological Organization and UNEP, and complements the United Nations Regular Process and the World Ocean Assessment.
31. Quantifying uncertainty will always be a key part of the assessment of the ocean to support its management. The open ocean assessment has focused on where data are available, making extrapolations, assumptions and projections based on best scientific knowledge to generalize where data are lacking. It has also addressed key gaps for research and observations to point to a future path to reducing uncertainties about our knowledge.
32. The cost of management action to limit human impact on the open ocean, and of the open ocean on human lives, is often difficult to establish when the threats and benefits are not clearly monetized. Of the many ecosystem services provided by the open ocean (regulatory services, provision of food and energy, and recreational and cultural services), the only one that is traded on markets is fish. An assessment of changes in the valuation of natural capital with changes in the ocean could help inform debate.
33. The global governance arrangements for the open ocean are complex and therefore deemed a priority focus to better understand them through this assessment. In deciding where future interventions can help to mediate this relationship between human and natural systems and increase human well-being, GEF and other stakeholders will need to target these global conventions and work to ensure that links to lower-level policy cycles, including regional and local scales, are fully understood.
34. The TWAP open ocean assessment has addressed these challenges through a globally scoped analysis that directly considered six broad themes: governance, climate, ocean ecosystems, fisheries, pollution and an integrated assessment of these impacts on marine ecosystems. Rather than carving the open ocean into units based on natural system criteria, which can vary depending on the scientific discipline consulted and whether the surface, mid or deep ocean is being considered, the analysis took the cue from the human system side and the global governance arrangements already in place to focus on a global thematic assessment.
35. The assessment is aimed at clearly linking human vulnerabilities on land to the open ocean, and ecosystem vulnerabilities in the ocean to human threats. It addresses the political need for clear, high-level messages about the issues raised, and points towards interventions in governance that can help mediate the relationship between humans and the ocean, improving human well-being. A conceptual framework was used to organize the necessary simplifications and assumptions arising from the scientific work to achieve this goal.
36. The conceptual framework links human and natural systems and puts human well-being at the centre of concerns, but allows a focus on where data are available, in particular on indicators of human-related stress on ocean systems. For this assessment, the framework allowed clarity on where simplifications and assumptions were being made in the causal chain, and emphasized the vulnerability of human and natural systems. It put a broad definition of governance at the centre of the human system side to help guide future interventions.
37. The results provide a baseline of information on the state of the open ocean ecosystems, alongside projections of potential changes to 2050, and in some cases 2090. They also complement the Summary of the First Global Integrated Marine Assessment (2015) as part of the United Nations Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, otherwise known as the Summary for the World Ocean Assessment (2015).
38. It is clear, from the results of the TWAP open ocean assessment and considering the Summary for the World Ocean Assessment (2015), that urgent attention is required to sustainably manage open ocean ecosystems and services now and into the future. Understanding the impact of climate-ocean-human interconnections will help to inform and improve decisions for sustainable management. To do this, however, ongoing and improved monitoring of essential ocean variables, including physical, chemical and biological, is necessary. The United Nations Global Ocean Observing and Climate Systems can help drive this forward. Monitoring and management/policy interventions can be improved, guided by these results and the recommendations outlined in the

accompanying *TWAP Open Ocean Summary for Policy Makers: Status and Trends* (2015). In particular, issues linked to complex governance arrangements (and with many gaps), climate change impacts such as ocean acidification, de-oxygenation and ocean warming are threatening the health of open ocean ecosystems and related services and human well-being. Urgent reduction in greenhouse gas emissions, together with improved regulations for reducing pollution sources and overexploitation of fish stocks, could significantly improve the future health and sustainability of the open ocean ecosystems, services and human well-being.

39. The TWAP open ocean assessment provides a holistic overview of the state of the open ocean ecosystems and their connections with well-being. This can be used to guide a system of monitoring goals that could be set out within the Sustainable Development Goal framework, and should also be used to support future rounds of the World Ocean Assessment and subsequent targeted transboundary assessments for the ocean. Indeed, an ongoing and robust scientific support enterprise is essential to provide confidence to policymakers and decision makers that resources are being appropriately allocated for improved sustainable management and use of the ocean and its ecosystem services.

Open ocean: key messages

1. The ocean climate is changing rapidly and will continue to change under multiple climate scenarios.
2. Climate change is projected to create critical hazards to key ocean ecosystems such as coral, to shrink habitat and to create significant direct sea-level risk.
3. Improved global governance of the open ocean and areas beyond national jurisdiction, linked to regional governance networks, is urgently needed to solve the majority of local risk posed by ocean ecosystems degradation.

VII. Transboundary water systems: cross-cutting status and trends

40. Volume six is a cross-cutting analysis that brings together the five water components and provides a high-level summary of patterns and trends. The analysis integrates the results of the five independent water-category-specific assessments where system risk is underpinned by interactions among system health, human well-being and governance, within the constraints of a changing climate.

41. System health is evaluated using selected directional biophysical indicators that include metrics that quantify water quantity, water quality, biodiversity for freshwater systems, and productivity, fish and fisheries, pollution and ecosystem health for large marine ecosystems. For the open ocean, measures of cumulative human impacts are used to assess waters beyond national jurisdictions, as these indicate relative risk. Socioeconomic indicators describe dependent human populations, including population sizes, incidence of poverty, human development levels and threats imposed by climate-related natural disasters. Governance risks are evaluated using governance architecture, with a view to subsequently analysing governance performance using more detailed analytical approaches. All indicators are assessed with 2000–2010 as the reference period, and several include projection scenarios to 2030, 2050 and 2100.

Cross-cutting analysis: key messages

1. Risk is generally lower in developed regions (Australia, North America and Europe) and higher in sub-Saharan Africa and South and South-East Asia. However, there are high- and low-risk systems in all regions, indicating the need for attention to transboundary water systems across the planet.
2. Risk appears spread across the three thematic areas (biophysical, socioeconomic, governance) and signifies the need for governance to address the integrated nature of risk in order to effectively sustain ecosystem health and human well-being.
3. There is a tendency for risk to increase “downstream” from aquifers to large marine ecosystems, with the exception of transboundary governance arrangements in aquifers, which are largely absent.
4. The assessment of governance arrangements and architecture is a novel aspect of this assessment, but does not yet reflect how effective the governance responses are in sustaining ecosystem health and human well-being. Subsequent assessments should focus on measuring effectiveness.

VIII. Way forward

42. TWAP has demonstrated the widespread incidence of the risk of unsustainability in transboundary aquifers, lakes, rivers, large marine ecosystems and the open ocean across the planet. To reduce and reverse the causes of risk in order to meet the Sustainable Development Goals by or before 2030, countries will need to continue developing and monitoring key indicators in order to identify and mitigate the sources of risk. Full details of the indicators used and the findings can be found in the five technical reports for the water system categories and their technical summaries for policymakers (www.geftwap.org).

43. In addition to having indicators that are specific to the transboundary water categories, it will be important to address the impacts of linkages among systems and the sources of risk in order to reduce risk. The approach of five separate assessments precluded a proper evaluation of the implications of the linkages between water systems in different water categories. Yet, it is well known that there are many biophysical linkages, such as the flow of water itself, pollution, movement of plants and animals and influences on climate. Seeking to understand and including these linkages must be a focus of the next global assessment.

44. Much has been learned in TWAP that can be applied to ensure a fuller suite of indicators that is focused on critical issues. As an example, the conjunctive use of surface and subsurface freshwater for food and energy production may require a nexus approach in which sustainable food and energy systems may need to be premised on the sustainability of surface aquatic systems (rivers and lakes) and subsurface aquifers, and which is constrained by a warming climate. Among saltwater systems, the downstream lateral flows of water, materials and pollutants alongside direct point sources of pollution and exploitation of marine living resources are undermining the health of coastal ecosystems. Moreover, in the open ocean and near the coast, climate impacts from intensifying processes of ocean warming, acidification and deoxygenation are exerting profound influences on changes in primary and secondary production, biodiversity and carbon storage. Sea level rise will be an intensifying source of risk where cause and effect spans millennia. When anthropogenic influence alters the ability of the ocean to modulate climate and planetary survival is at risk, human behaviour towards ocean-climate interactions will require more than risk minimization. It behoves a fundamental shift in policy time frame and targets where “now” has immediate as well as millennial consequences.
