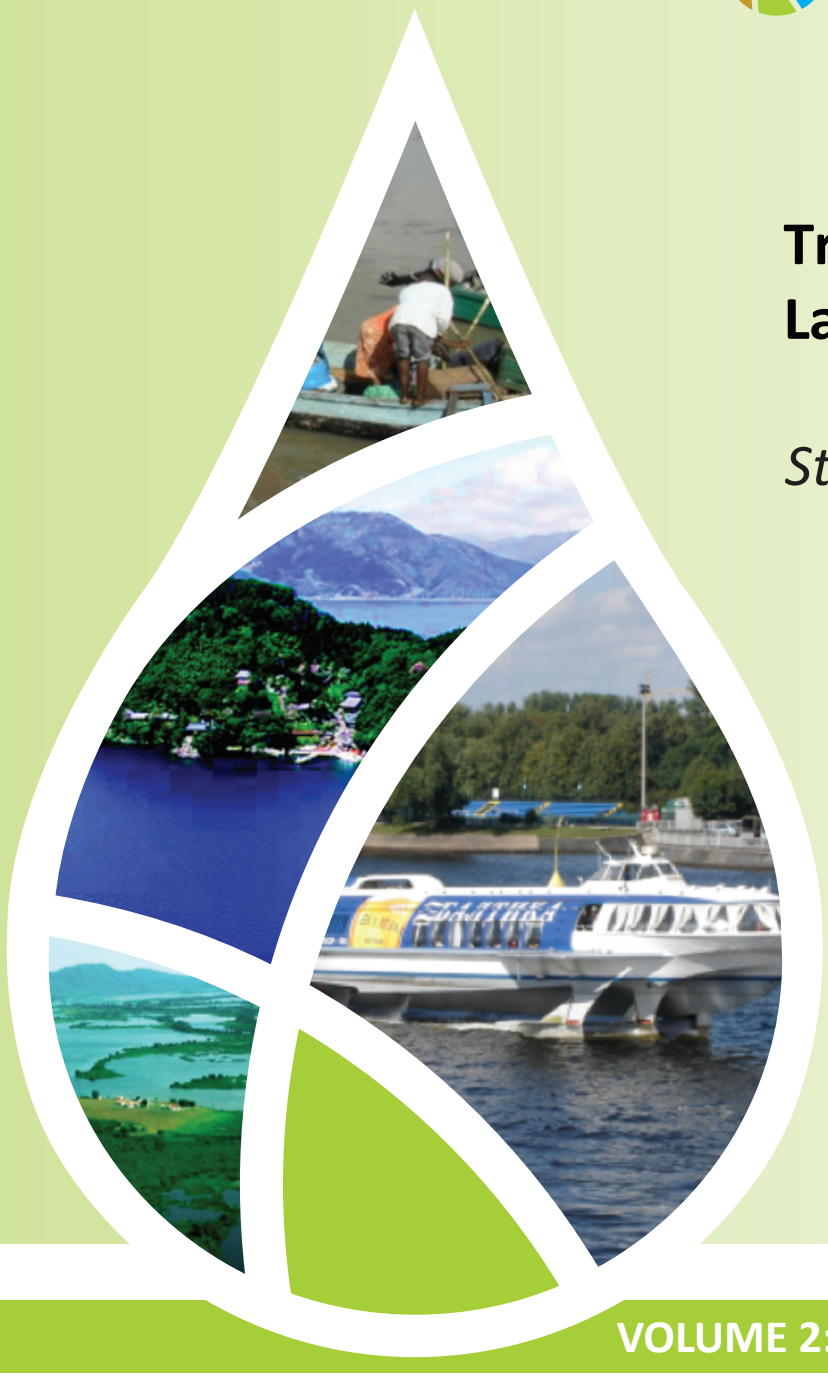
TWAP
TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME



Transboundary Lakes and Reservoirs

Status and Future Trends

VOLUME 2: LAKE BASINS AND RESERVOIRS

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Transboundary Lakes and Reservoirs: Status and Trends

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Source of administrative boundaries used throughout the assessment: The Global Administrative Unit Layers (GAUL) dataset implemented by FAO within the CountrySTAT and Agricultural Market Information System (AMIS) projects.

Unless otherwise noted, all photos and figures contained herein are provided by the authors, based on previously-prepared documents, projects and case studies

Preface

The Global Environment Facility (GEF) approved a Full Size Project (FSP), "A Transboundary Waters Assessment Programme: Aquifers, Lake/Reservoir Basins, River Basins, Large Marine Ecosystems, and Open Ocean to Catalyze Sound Environmental Management", in December 2012, following the completion of the Medium Size Project (MSP) "Development of the Methodology and Arrangements for the GEF Transboundary Waters Assessment Programme" in 2011. The TWAP FSP started in 2013, focusing on two major objectives: (1) to carry out the first global-scale assessment of transboundary water systems that will assist the GEF and other international organizations to improve the setting of priorities for funding; and (2) to formalise the partnership 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.

The TWAP FSP was implemented by UNEP as Implementing Agency, UNEP's Division of Early Warning and Assessment (DEWA) as Executing Agency, and the following lead agencies for each of the water system categories: the International Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) for transboundary aquifers including groundwater systems in small island developing states (SIDS); the International Lake Environment Committee Foundation (ILEC) for lake and reservoir basins; the UNEP-DHI Partnership – Centre on Water and Environment (UNEP-DHI) for river basins; and the Intergovernmental Oceanographic Commission (IOC) of UNESCO for large marine ecosystems (LMEs) and the open ocean.

The five water-category specific assessments cover 199 transboundary aquifers and groundwater systems in 43 small island developing states, 206 transboundary lakes and reservoirs, 286 transboundary river basins; 66 large marine ecosystems; and the open ocean, a total of 758 international water systems. The assessment results are organized into five technical reports and a sixth volume that provides a cross-category analysis of status and trends:

Volume 1 -- ***Transboundary Aquifers and Groundwater Systems of Small Island Developing States: Status and Trends***

Volume 2 – ***Transboundary Lakes and Reservoirs: Status and Trends***

Volume 3 - ***Transboundary River Basins: Status and Trends***

Volume 4 – ***Large Marine Ecosystems: Status and Trends***

Volume 5 – ***The Open Ocean: Status and Trends***

Volume 6 – ***Transboundary Water Systems: Crosscutting Status and Trends***

A ***Summary for Policy Makers*** accompanies each volume.

Volume 2 focuses on the first global-scale assessment of transboundary lake and reservoir basins, including consideration of their unique features, the pressures and risks to their life-supporting ecosystem goods and services expressed in terms of human water security and biodiversity threats, and the assessment and management implications of these threats, including their links with other upstream and downstream water systems. It was prepared by the International Lake Environment Committee (ILEC), in cooperation with the Research Centre for Sustainability and Environment, Shiga University, Japan; The Meadows Center for Water and the Environment, Texas State University, USA; Corazón de la Tierra, Guadalajara, Jalisco, Mexico; and International Environmental Management Services (IEMS), Waukesha, Wisconsin USA

Executive Summary

Water is an essential requirement for all life, and the most important global integrator connecting aquatic and terrestrial ecosystems and the atmosphere in a continuing cycle of use and replenishment. Humans use freshwater systems to address the widest range of human health and socioeconomic development needs. Lakes and reservoirs are especially important in this context, numbering in the millions and existing on every continent (the term 'lakes' refers to both natural and artificial lakes [reservoirs]). The total number of lakes on our planet collectively cover approximately 4.2 million km^2 of land area, equivalent to half the land area of the contiguous United States. It is estimated that more than 90 per cent of all the liquid freshwater on the surface of our planet is located in lakes, reservoirs, wetlands and other lentic (standing) water systems.

Lakes possess unique characteristics that make it difficult to accurately assess their environmental status at any given time. In addition to a large water volume, these characteristics include long water-residence times, an integrating nature that ensures everything comes together in a lake, and non-linear responses to stresses that make their behaviour unpredictable and uncontrollable. Accordingly, lakes typically exhibit a 'lag' phenomenon characterized by slow, incremental non-linear responses to environmental stresses that can mask degradation until it has become a serious lake-wide problem. This buffering capacity (so-called 'hysteresis' effect) can also mask positive signs of remedial measures, making it difficult to accurately determine the status of a lake at any given time.

The TWAP Lakes Component originally comprised more than 1600 transboundary lakes, subsequently being reduced to 156 transboundary lakes, using GIS-based spatial analysis of NASA global-scale databases. The addition of 50 lakes in developed countries increased this list to 206 transboundary lakes for comparison purposes with the addition of 50 lakes in developed countries. The transboundary list used in this analysis initially comprised 30 lakes in the South America and Caribbean region, 34 in Africa, 70 in the European region, 52 in the Asia region, and 20 in North America. However, there was sparse data on the areal extent of the majority of the transboundary lake basins, necessitating combined GIS-based spatial analyses and digital elevation model (DEM) calculations to delineate the majority of the transboundary lake basins.

Another major challenge was very scarce uniform data for the large majority of the transboundary lakes, precluding direct comparison of in-lake conditions. Accordingly, the characteristics of the transboundary lake basins were used to estimate the relative threats to their basins, rather than directly using in-lake conditions. These characteristics were then translated into lake threat ranking criteria. Basin-scale data from a previous global-scale study conducted by Vörösmarty *et al.* (2010) on human water security and river basin biodiversity threats, comprising 23 basin-scale drivers grouped under the thematic areas of catchment disturbance, pollution, water resource development, and biotic factors, were adapted for the transboundary lake analyses.

A Scenario Analysis Program (SAP) was developed to compute the relative lake threat ranks on the basis of computed scores derived from the 23 drivers adjusted for their additive *vs.* non-additive characteristics, the areal extent of the basin stresses, the basin population and density, and the annual mean temperature. The list of 206 transboundary study lakes was reduced to a final list of 53 lakes on the basis of specific areal, population density and temperature criteria deemed suitable to identify the lakes meriting the most attention, including 23 African, 8 Asian, 9 European, 6 South American, and 7 North American transboundary lakes. A limitation of using basin characteristics, rather than in-lake conditions, however, was that a lake calculated as being threatened may not presently be experiencing serious degradation problems (although its basin characteristics suggest it may become threatened over the longer term). In contrast, some lakes not identified as threatened on this list may actually be experiencing significant degradation, but not be identified as such because of insufficient analysis data.

The transboundary lake threats were initially expressed in terms of incident Human Water Security (HWS) and Biodiversity (BD). The top five lakes exhibiting the highest incident HWS and BD threats included two European, two North American, and one Asian lakes. In contrast, the African lakes as a group generally ranked in the bottom half of the 53 study lakes.

This finding highlighted the great importance of determining the most appropriate context for considering the transboundary lake ranking results. In addition to the HWS and BD ranking scores, interpreting the threat ranks can also be readily affected by the weights assigned to the ranking factors, and specific criteria or preconditions considered important by the user of the rankings. Thus, the relative threat ranks of the transboundary lakes can be markedly different even for the same set of lakes, if sub-categorized on varying defining criteria. One major factor meriting consideration in this regard was the ability of the basin countries to undertake technological investments to reduce identified water threats (water supply stabilization, improved water services, etc.). This consideration resulted in the development of an Adjusted Human Water Security (Adj-HWS) threat criterion accounting for this possibility. Thus, even if initially exhibiting a high incident HWS threat rank, the more economically-developed countries (e.g., Europe; USA) exhibited lower Adj-HWS threats (Table 4.3). Countries less able to make such investments, mainly developing countries, exhibited higher relative Adj-HWS threats, highlighting a greater need for catalytic funding for management interventions than those with lower Adj-HWS scores. In fact, the relative threats to many African transboundary lakes increased substantially on the basis of the Adj-HWS threat, while those of European and North American countries decreased under this same criterion, with 11 of the 13 highest ranked transboundary lakes being located in Africa. The Adj-HWS threat ranks of the Asian lakes also generally increased, although not by the same magnitude as for the African lakes.

The importance of appropriate context for meaningful consideration of the transboundary lake threats was also substantiated with supplemental data and insights. Expert Group Meetings were conducted in Brazil, Ghana, India, Italy, Kenya, Malaysia, Mexico, Turkey and the Philippines, for example, to obtain on-the-ground information and data, and to discuss initial regional lake ranking results. A lake basin Questionnaire was also developed to obtain information about how lake basin stresses affected ecosystem services, and how the impacts affected lake basin stakeholder uses of the lake resources, being particularly useful when lake ranking results were confusing or contradictory. A knowledge-based system with an extensive literature resource base, LAKES-III *("Learning Acceleration and Knowledge Enhancement System"*), developed at Shiga University (Japan), was also used to substantiate more accurate conclusions regarding the status, potential and priority for addressing the lake threats. Used in conjunction with a Scenario Analysis Program for selecting specific filtering criteria for computing the threat rankings, it highlighted that the calculated ranks can be misleading for transboundary lake comparisons unless the most important factor(s) for the user of the rankings was also considered (lake or basin size, population number or density, socioeconomic condition, etc.). Considered individually or in combination, such factors could easily produce markedly different ranking results, with the ranks obtained with the Incident HWS versus the Adj-HWS providing a telling example.

The transboundary lakes also were evaluated with a parametric sensitivity analysis, assigning differing relative importance (weight) to the Adj-HWS and BD threats in the ranking process, as well as inclusion of the Human Development Index (HDI). Based on this sensitivity analysis, the African lakes as a group continued to exhibit the greatest threats, comprising 20 of the top 24 most threatened lakes. The remaining four lakes comprised three South American and one Asian lake. The ranking was not the same obtained using the Adj-HWS, BD or HDI alone, however, with the more developed countries exhibiting the lowest ranks.