TWAP
TRANSBOUNDARY WATERS ASSESSMENT PROGRAMME

Transboundary Lakes and Reservoirs

Status and Future Trends

SUMMARY FOR POLICY MAKERS

VOLUME 2: LAKE BASINS AND RESERVOIRS

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Summary for policy makers

Key Messages and Recommendations

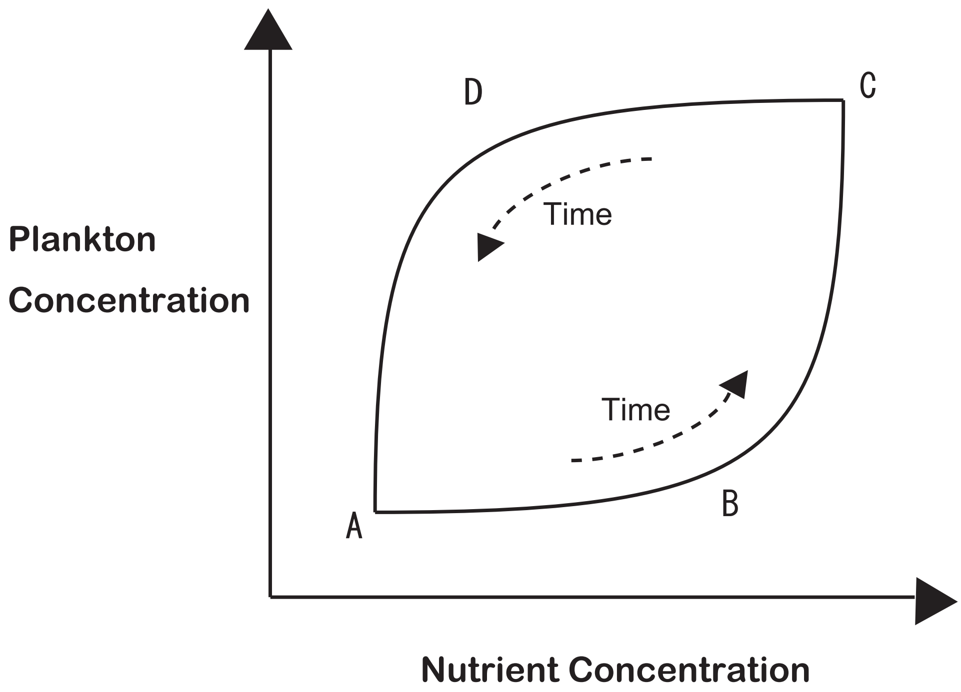
1. **Lakes and other lentic water systems contain more than 90% of the liquid freshwater on the surface of our planet, providing the widest range of water-based ecosystem goods and services.** Thus, degrading a lake translates into degrading a major freshwater resource;
2. **Lakes respond to environmental stresses in a slow, incremental and non-linear manner, constraining their accurate assessment.** Their characteristic buffer function can mask visible signs of both lake degradation and remediation;
3. **There is a serious deficiency of lake-specific information and data on a global scale.** Specific in-lake and near-lake scientific data needed for comparative analyses of stressed lakes are very scarce, making the assessment of their comparative conditions on a global scale extremely problematic.
4. **Based on their drainage basin characteristics, the African lakes as a group exhibit the greatest relative risks, expressed as Adjusted Human Water Security (Adj-HWS) threats rather than Incident Water Security (HWS) threats, followed by lakes in Asia and South America, while exhibiting lesser risks on the basis of their Incident Biodiversity (BD) threats.**
5. **Relative transboundary lake threat ranks can change markedly when considered from different perspectives.** Interpreting the threat ranks can be readily affected by the weights assigned to the parametric ranking factors, and specific criteria or preconditions considered important by the user of the rankings. Thus, the ranking order of lakes can be markedly different even for the same set of lakes, if sub-categorized on varying defining criteria.
6. **Lake management is often subsumed under river basin concerns that do not realistically consider the capacity of lakes to buffer environmental stresses within their basins.** Although reducing land-based stresses in a lake-river basin should eventually lead to an improved environmental status in and around a lake, focusing solely on river basin threats does not necessarily address the threats facing lakes and other lentic water systems lying within them.;
7. **Accurately ranking transboundary lake threats requires a detailed case-by-case assessment that considers a range of interlinked factors requiring funding levels far beyond the scope of the TWAP assessment.** Advancing assessment of transboundary lakes beyond TWAP will require a concerted effort to increase the quantity of lake-related information and data, with greater interagency and transnational cooperation.
8. **In assessing individual transboundary lake management intervention priorities, the GEF should also consider the possibility of addressing multiple lake needs and other related factors.** Lakes are not isolated waterbodies. Rather, some are linked or located in relatively close proximity to other lakes, for example, while others require consideration of their status within the context of the larger basins in which they are located. Still others require detailed consideration of their scientific and/or political situation prior to considering management interventions.
9. **Integrated Water Resources Management (IWRM) does not adequately address lakes and other lentic water systems.** Because IWRM does not adequately consider the global threats facing lakes and other lentic water systems, infusing it with an integrated lake management framework such as Integrated Lake Basin Management (ILBM), is needed to achieve sustainable use of their ecosystem goods and services. Integrated Lentic-Lotic Basin Management (ILLBM), as an extension of the ILBM framework, provides a virtual framework for assessing and strengthening river-lake-coastal basin governance, focusing on gradual, continuous and holistic improvement of basin governance. The GEF Transboundary Diagnostic Analysis / Strategic Action Programme (TDA/SAP) management approach also can be significantly advanced by infusing the ILLBM conceptual features as part of an overall basin management framework, regardless of whether they are pursued on the basis of IWRM or otherwise.

Conceptual Framework for Transboundary Lake Basin Assessment and Management

Lakes, wetlands, marshes, bogs and other impounded water systems, collectively designated as "lentic waters" contain more than 90% of the readily-available liquid freshwater on the surface of our planet. The Laurentian Great Lakes and Lake Baikal, for example, collectively contain nearly 40 per cent of all the liquid freshwater on the surface of our planet. Numbering in the millions, lakes are difficult to assess and manage because of their large water volumes, long water retention time and complex integrating nature, which collectively make their behavioral dynamics unpredictable and uncontrollable. Because of these characteristics, 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. The 'hysteresis' effect highlighted in Figure 1 regarding a lake response to increasing nutrient concentrations associated with increasing lake eutrophication provides an example. Lakes exhibit a slow, incremental response to such stresses (points A to B) until undergoing a fundamental trophic shift to a degraded condition (point C). For the same reason, a degraded lake will not necessarily exhibit signs of improvement in response to nutrient reduction programs until they have decreased to the point where it undergoes another fundamental trophic shift to a less-degraded condition (points C to D). Even then, a lake will not necessarily return to its original non-degraded condition, making it difficult to accurately determine the environmental status of a lake at any given time.

Lakes and other lentic water systems also provide the widest range of ecosystem services of all freshwater systems, including ***resource provision services*** (drinking water supply, agricultural irrigation, fisheries, recreation, transportation, hydropower generation), ***regulating services*** (flood and drought mitigation, self-purification, climate mediation, shoreline ecotone buffering, diverse food-chains), and ***Cultural services*** (aesthetics, spiritual, anthropogenic, and historical values) that can span human-delineated boundary systems of administrative and political nature, including both national and transboundary systems (MEA 2010).

Figure 1. Buffering Capacity of Lakes to Increasing Nutrient Concentrations, Illustrating Non-linear (Hysteresis) Responses to Degradation and Remediation Efforts.



The recently-agreed Sustainable Development Goals (SDGs) contained in the 2030 Agenda for Sustainable Development contains specific goals germane to sustainable water resources for human health and ecosystem integrity (Open Working Group, 2015). Target 6.6 of SDG Goal 6 (*"Ensure availability and sustainable management of water and sanitation for all")* includes the need to protect and restore water-related ecosystems by 2020, including rivers, aquifers and lakes, thereby expanding the original MDG water goal to encompass the entire global water cycle. Lakes are identified as a specific component in an agreed sustainability agenda pursued on a global scale. UN-Water (2015) also identified water at the core of sustainable development, with strong links to all the SDGs. Thus, achieving these goals will substantially improve our ability to achieve most other 2030 Agenda targets, with lakes and other lentic waters assuming important roles in this global goal because of the large quantities of readily-available freshwater they contain.

The lakes component of the Transboundary Waters Assessment Program (TWAP) was undertaken to compare the relative threats to transboundary lakes (and implicitly all "lentic waters"). Because of the greater complexity characterizing transboundary lake basins and their ecosystem services, compared to other freshwater systems, adopted management approaches must lead to a well-coordinated global process to address such challenges if their sustainability is to be attained. The assessment methodology must not only identify transboundary lake basin threats, but also help all involved basin stakeholders fully understand the need for collaborative efforts directed to gradual, incremental and long-term lake basin governance improvement.

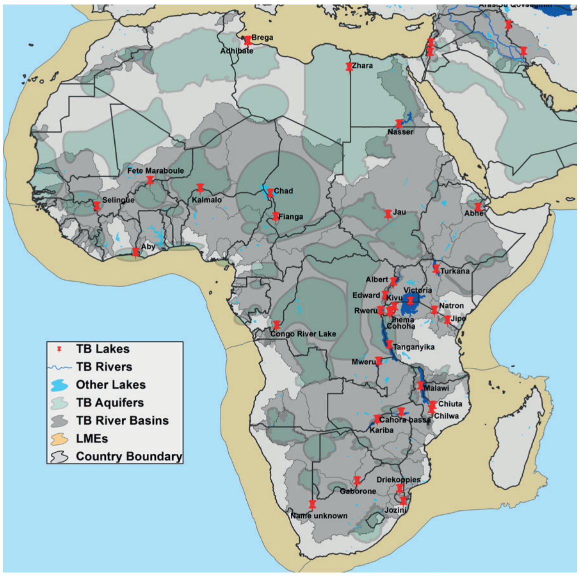
Identifying Transboundary Lakes and Basins

The lakes component of the TWAP originally comprised more than 1 600 transboundary lakes around the world. GIS-based spatial analysis of primarily NASA and USGS global-scale databases reduced this initial list to approximately 160 transboundary lakes, with 44 lakes in developed countries also included in the study list. The final study list totalled 204 transboundary lakes and reservoirs, including 33 in Africa, 51 in the Asia region, 30 lakes in South America, 70 in the European region, and 20 in North America (Figure 2).

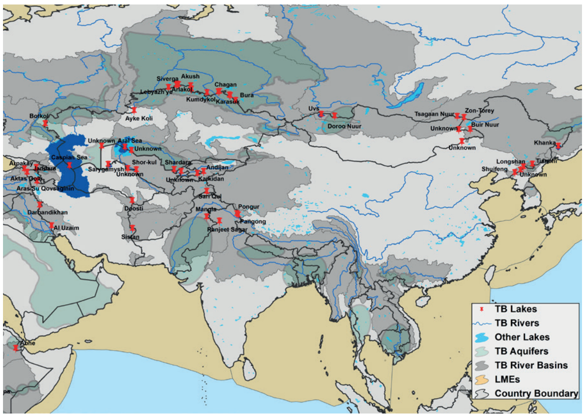
There was a serious lack of uniform, global-scale data for the vast majority of the TWAP transboundary lakes on: (1) their in-lake conditions, or (2) the areal extent of their drainage basins. The areal extent of the TWAP transboundary lake basins was delineated with GIS-based spatial analysis techniques, in combination with a digital elevation model (DEM).

The scarce global-scale data regarding the in-lake conditions of the study transboundary lakes would produce a skewed picture of the threats to the lakes. Thus, a global-scale dataset on river basin human water security and biodiversity threats was adapted to derive the transboundary lake threat ranks. It is emphasized that this latter dataset focused on drainage basin characteristics, rather than in-lake conditions, thereby serving as a surrogate for ranking the relative lake threats. This database, uniformly applied to all the transboundary lake basins, comprised 23 basin-scale drivers grouped under the thematic areas of catchment disturbance, pollution, water resource development, and biotic factors (Figure 3). Based on specific criteria meant to eliminate small lakes with sparse basin populations and/or frozen over for major portions of the year, the initial list of 204 transboundary lakes was reduced to a final list of 53 priority transboundary lakes for more detailed scenario analysis, comprising 23 lakes in Africa, eight in Asia, nine in Europe, six in South America, and seven in North America (Appendix 1);

Figure 2. Global Distribution of TWAP Transboundary Lakes and Reservoirs

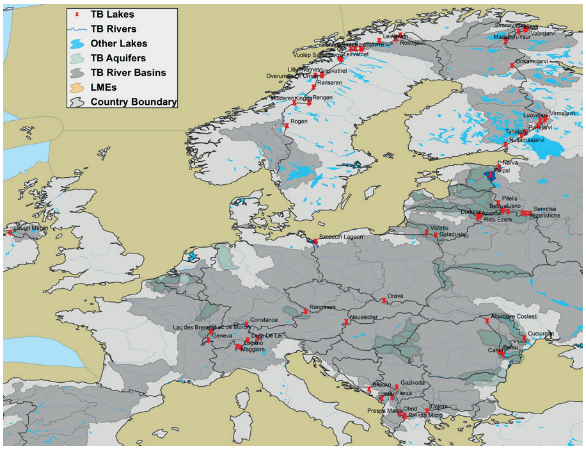


(a) African Transboundary Lakes

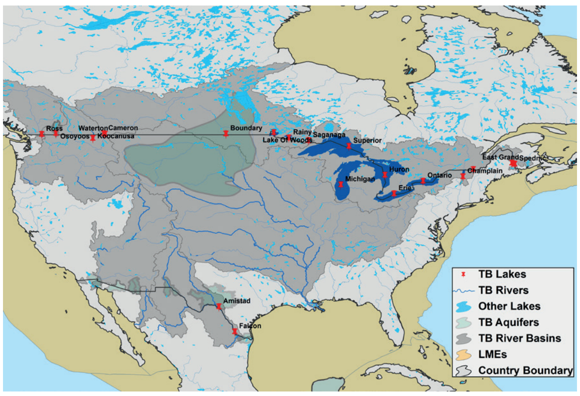


(b) Asian Transboundary Lakes

(c) South American Transboundary Lakes

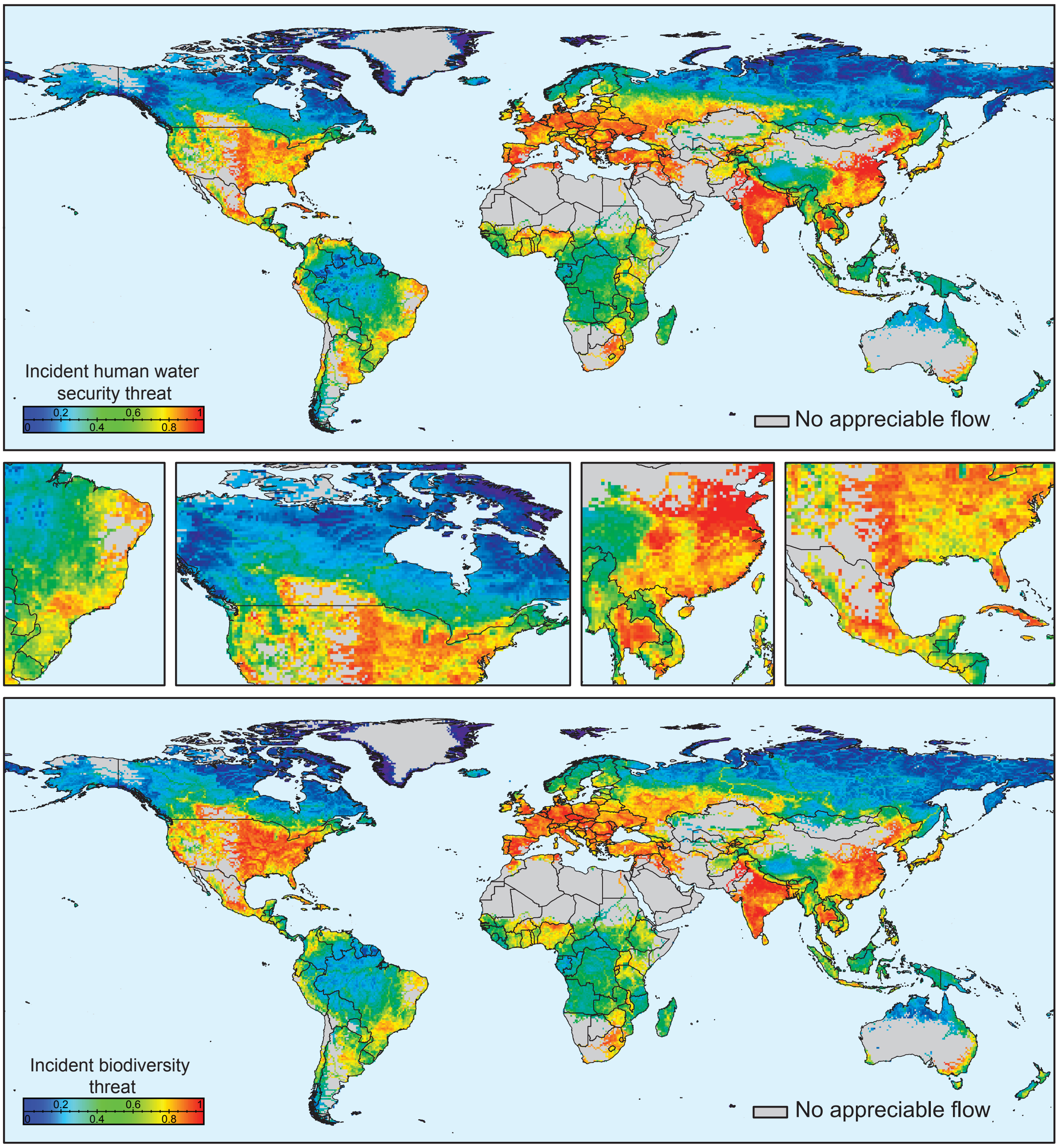


(d) European Transboundary Lakes



(e) North American Transboundary Lakes

Figure 3. Global Overview of Incident Human Water Security (HWS) and Biodiversity (BD) Threats (Vörösmarty *et al.* 2010)



Ranking Transboundary Lake Threats on Basis of Specific Ranking Criteria and Context

Limitations of Lake Ranking Process

There is no defensible way to unequivocally define the transboundary lake threats solely on the basis of their basin characteristics, making it very difficult to identify a unilateral and unconditional list of transboundary lakes requiring priority management interventions within the TWAP framework. The relative threats to the transboundary lakes were determined on the basis of an agreed set of indicators that can be translated into contextually-determined scores, and which consider the factors and preconditions most important to the user of the ranking results.

The calculated transboundary lake threats focus on the estimated risks facing the lake basin population in regard to Water Security ("Incident" and "Adjusted") threats. The biodiversity data are only available for the 'Incident' Biodiversity threats, rather than for an 'Adjusted' threat. Thus, the calculated transboundary lake threat ranks are highly human-centric, and likely highly skewed toward structural interventions for addressing short-term human water needs, while failing to address the need for long-term conservation and restoration for lake basin ecosystem cervices, particularly the "Regulating Service" component.

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The calculated threat ranks also do not take into account in-lake conditions because of a serious lack of in-lake data on a global scale. They also do not consider the capacity of lakes and other lentic water systems to assimilate or buffer basin-derived stresses. Thus, some transboundary lakes categorized as only moderately threatened on the basis of their basin characteristics, for example, may actually be seriously degraded, while some transboundary lakes experiencing serious threats may not be identified as such because of insufficient data, which is the prevailing situation for most of the TWAP transboundary lakes. Differing regional physical and socioeconomic perspectives can result in a lake being classified as threatened in one region may not be considered threatened elsewhere. Any of these factors considered alone or collectively can readily lead to erroneous conclusions regarding the comparative transboundary lake threats. Thus, the calculated lake threats presented in Table 1 represent only one approximation of the actual risks (although a high threat rank may signify future degradation under a 'business-as-usual' scenario). The reality is that more definitive conclusions can only be derived from more intensive lake data compilation and analyses on a global scale.

Lake Ranks Based Strictly on Calculated Threat Scores

Based on consideration of the Incident Human Water Security (HWS) and Biodiversity (BD) threats, ***the top dozen transboundary lakes exhibiting the greatest Incident HWS threats included five European, four Asian, two North American and one African lake*** (Table 1a). The African lakes as a group generally ranked in the bottom half of the 53 transboundary study lakes. An "Adjusted Human Water Security" (Adj-HWS) threat also was developed to account for the positive benefits expected to be derived from technological investments directed to water supply stabilization, improved water services, improved access to water sources, etc. Subsequent comparisons of the incident and adjusted HWS scores highlighted the significant positive impacts attributable to such investments, with the relative threats to the transboundary lakes in developed countries (e.g., Europe, USA) decreasing substantially, while those in many developing nations increased markedly. ***The top dozen lakes exhibiting the greatest Adj-HWS threats included ten African, one Asian and one South American lake*** (Table 1b), highlighting the greater need for catalytic funding for transboundary lake management interventions in many developing countries.

Regarding biodiversity, ***the top dozen lakes exhibiting the greatest Incident BD threats included five European, four North American and three Asian lakes*** (Table 1c). The African transboundary lakes again collectively exhibited lower Incident BD threats than those in the developed countries, meaning that although the developing nations typically lag behind the developed countries in terms of economic development, their biodiversity may exhibit a more robust condition, and suggesting much biodiversity in developed countries has already been significantly degraded because of their increased economic development activities and stakeholder affluence. There was insufficient global experience to develop an 'Adjusted' biodiversity threat analogous to the Adj-HWS threat.

Lake Ranks Based on Context of Threats

It also was noted that the significance of the calculated threat ranks in regard to both assessment and management intervention purposes can be misleading unless the goals and preconditions of the user of the threat rankings also are considered. Relevant factors can range from simple considerations such as lake or basin size, or basin population or density, to more involved considerations such as the ecosystem services being impacted, extent of preparedness to address the threats, and other non-transboundary and extra-boundary issues as well, all of which can influence the significance of the ranking results. Considered individually or in combination, such screening criteria could readily produce markedly different threat ranks, as noted by the relative ranks calculated for the Incident HWS versus the Adj-HWS transboundary lake threats (see Table 1). The responsibility for determining the appropriate context or screening criteria for interpreting the results is the responsibility of those using the ranking results, including lake managers and decision-makers.

Table 1. TWAP Transboundary Lakes Ranked on Basis of (a) Incident Human Water Security [HWS] Threats, (b) Adjusted Human Water Security [Adj-HWS] Threats, and (c) Incident Biodiversity [BD] Threats (Cont., continent; Eur, Europe; N.Am, North America; Afr., Africa; S.Am, South America; Estimated risks: Red – highest; Orange – moderately high; Yellow – medium; Green – moderately low; Blue – low)

(A) Lakes Ranked on Basis of Incident Human Water Security (HWS) Threats					(B) Lakes Ranked on Basis of Adjusted Human Water Security (Adj-HWS) Threats					(C) Lakes Ranked on Basis of Incident Biodiversity (BD) Threats				
Rank	Lake	Cont.	Surface Area (km²)	HWS Threat	Rank	Lake	Cont.	Surface Area (km²)	Adj-HWS Threat	Rank	Lake	Cont.	Surface Area (km²)	BD Threat
1	Cahul	Eur	89.0	0.61	1	Sistan	Asia	488.2	0.98	1	Falcon	N.Am	120.6	0.62
2	Falcon	N.Am	120.6	0.61	2	Ihema	Afr.	93.2	0.97	2	Mangla	Asia	85.4	0.62
3	Mangla	Asia	85.4	0.59	3	Azuei	S.Am	117.3	0.96	3	Cahul	Eur	89.0	0.61
4	Galilee	Eur	162.0	0.59	4	Rweru/Moero	Afr.	125.6	0.96	3	Neusiedler/Ferto	Eur	141.9	0.61
5	Aras Su Qovsaginin Su Anbari	Asia	52.1	0.57	5	Cohoha	Afr.	64.8	0.96	5	Erie	N.Am	26560.8	0.57
6	Dead Sea	Eur	642.7	0.57	6	Edward	Afr.	2232.0	0.94	6	Michigan	N.Am	58535.5	0.56
7	Darbandikhan	Asia	114.3	0.56	7	Natron/Magad	Afr.	560.4	0.93	7	Galilee	Eur	162.0	0.55
8	Neusiedler/Ferto	Eur	141.9	0.54	8	Abbe/Abhe	Afr.	310.6	0.93	8	Darbandikhan	Asia	114.3	0.54
9	Szczecin Lagoon	Eur	822.4	0.54	9	Victoria	Afr.	66841.5	0.91	9	Aras Su Qovsaginin Su Anbari	Asia	52.1	0.53
10	Josini/Pongola-poort Dam	Afr.	128.6	0.52	10	Albert	Afr.	5502.3	0.91	10	Ontario	N.Am	19062.2	0.53
11	Shardara/Kara-Kul	Asia	746.1	0.52	11	Kivu	Afr.	2371.1	0.91	11	Szczecin Lagoon	Eur	822.4	0.51
12	Erie	N.Am	26560.8	0.51	12	Malawi/Nyasa	Afr.	29429.2	0.91	12	Maggiore	Eur	211.4	0.51
13	Macro Prespa (Large Prespa)	Eur	263.0	0.50	13	Dead Sea	Eur	642.7	0.90	13	Dead Sea	Eur	642.7	0.49
14	Azuei	S.Am	117.3	0.50	14	Turkana	Afr.	7439.2	0.90	14	Macro Prespa (Large Prespa)	Eur	263.0	0.49
15	Ohrid	Eur	354.3	0.49	15	Aras Su Qovsaginin Su Anbari	Asia	52.1	0.89	15	Ohrid	Eur	354.3	0.49
16	Michigan	N.Am	58535.5	0.48	16	Mangla	Asia	85.4	0.87	16	Champlain	N.Am	1098.9	0.49
17	Ontario	N.Am	19062.2	0.46	17	Galilee	Eur	162.0	0.87	17	Josini/Pongola-poort Dam	Afr.	128.6	0.48
18	Caspian Sea	Asia	377543.2	0.45	18	Darbandikhan	Asia	114.3	0.87	18	Huron	N.Am	60565.2	0.47
19	Amistad	N.Am	131.3	0.42	19	Selingue	Afr.	334.4	0.87	12	Shardara/Kara-Kul	Asia	746.1	0.46
20	Victoria	Afr.	66841.5	0.42	20	Shardara/Kara-Kul	Asia	746.1	0.86	20	Scutari/Skadar	Eur	381.5	0.45
21	Ihema	Afr.	93.2	0.41	21	Nasser/Aswan	Afr.	5362.7	0.86	21	Victoria	Afr.	66841.5	0.44
22	Sistan	Asia	488.2	0.41	22	Chilwa	Afr.	1084.2	0.86	22	Ihema	Afr.	93.2	0.44
23	Scutari/Skadar	Eur	381.5	0.40	23	Josini/Pongola-poort Dam	Afr.	128.6	0.85	23	Azuei	S.Am	117.3	0.43
24	Maggiore	Eur	211.4	0.40	24	Chiuta	Afr.	143.3	0.85	24	Rweru/Moero	Afr.	125.6	0.42
25	Huron	N.Am	60565.2	0.40	25	Chad	Afr.	1294.6	0.84	25	Itaipu	S.Am	1154.1	0.42
26	Rweru/Moero	Afr.	125.6	0.40	26	Aral Sea	Asia	23919.3	0.84	26	Cohoha	Afr.	64.8	0.41
27	Champlain	N.Am	1098.9	0.39	27	Tanganyika	Afr.	32685.5	0.84	27	Caspian Sea	Asia	377543.2	0.40
28	Cohoha	Afr.	64.8	0.39	28	Aby	Afr.	438.8	0.83	28	Amistad	N.Am	131.3	0.39
29	Chad	Afr.	1294.6	0.38	29	Cahul	Eur	89.0	0.82	29	Sistan	Asia	488.2	0.38
30	Itaipu	S.Am	1154.1	0.36	30	Chungarkkota	S.Am	52.6	0.82	30	Albert	Afr.	5502.3	0.37
31	Chungarkkota	S.Am	52.6	0.36	31	Titicaca	S.Am	7480.0	0.82	31	Chad	Afr.	1294.6	0.36
32	Natron/Magad	Afr.	560.4	0.36	32	Sarygamysh	Asia	3777.7	0.82	32	Aby	Afr.	438.8	0.35
33	Albert	Afr.	5502.3	0.35	33	Mweru	Afr.	5021.5	0.81	33	Edward	Afr.	2232.0	0.35
34	Aby	Afr.	438.8	0.34	34	Cahora Bassa	Afr.	4347.4	0.78	34	Kariba	Afr.	5258.6	0.34
35	Edward	Afr.	2232.0	0.34	35	Itaipu	S.Am	1154.1	0.75	35	Lago de Yacyreta	S.Am	1109.4	0.34
36	Kariba	Afr.	5258.6	0.33	36	Kariba	Afr.	5258.6	0.75	36	Natron/Magad	Afr.	560.4	0.33
37	Turkana	Afr.	7439.2	0.33	37	Lago de Yacyreta	S.Am	1109.4	0.75	37	Kivu	Afr.	2371.1	0.33
38	Titicaca	S.Am	7480.0	0.33	38	Lake Congo River	Afr.	306.0	0.75	38	Selingue	Afr.	334.4	0.32
39	Kivu	Afr.	2371.1	0.31	39	Caspian Sea	Asia	377543.2	0.73	39	Nasser/Aswan	Afr.	5362.7	0.32
40	Lago de Yacyreta	S.Am	1109.4	0.31	40	Salto Grande	S.Am	532.9	0.67	40	Malawi/Nyasa	Afr.	29429.2	0.32
41	Abbe/Abhe	Afr.	310.6	0.31	41	Scutari/Skadar	Eur	381.5	0.62	41	Chungarkkota	S.Am	52.6	0.31
42	Selingue	Afr.	334.4	0.30	42	Neusiedler/Ferto	Eur	141.9	0.58	42	Cahora Bassa	Afr.	4347.4	0.31
43	Aral Sea	Asia	23919.3	0.30	43	Szczecin Lagoon	Eur	822.4	0.53	43	Turkana	Afr.	7439.2	0.30
44	Salto Grande	S.Am	532.9	0.29	44	Erie	N.Am	26560.8	0.51	44	Salto Grande	S.Am	532.9	0.30
45	Nasser/Aswan	Afr.	5362.7	0.29	45	Macro Prespa (Large Prespa)	Eur	263.0	0.51	45	Chilwa	Afr.	1084.2	0.30
46	Malawi/Nyasa	Afr.	29429.2	0.29	46	Falcon	N.Am	120.6	0.50	48	Titicaca	S.Am	7480.0	0.29
47	Cahora Bassa	Afr.	4347.4	0.29	47	Amistad	N.Am	131.3	0.49	47	Abbe/Abhe	Afr.	310.6	0.29
48	Chilwa	Afr.	1084.2	0.28	48	Ontario	N.Am	19062.2	0.48	48	Tanganyika	Afr.	32685.5	0.29
49	Sarygamysh	Asia	3777.7	0.26	49	Ohrid	Eur	354.3	0.47	43	Aral Sea	Asia	23919.3	0.28
50	Chiuta	Afr.	143.3	0.25	50	Michigan	N.Am	58535.5	0.44	50	Mweru	Afr.	5021.5	0.28
51	Tanganyika	Afr.	32685.5	0.25	51	Huron	N.Am	60565.2	0.42	51	Chiuta	Afr.	143.3	0.26
52	Mweru	Afr.	5021.5	0.24	52	Maggiore	Eur	211.4	0.33	52	Sarygamysh	Asia	3777.7	0.25
53	Lake Congo River	Afr.	306.0	0.20	53	Champlain	N.Am	1098.9	0.29	53	Lake Congo River	Afr.	306.0	0.20

Ranking Transboundary Lake Threats on Basis of Multiple Ranking Criteria

In addition to single ranking criteria, the transboundary lake threats were also ranked on the basis of the product of multiple filtering criteria, including the Adj-HWS, Human Development Index (HDI), and RvBD, the latter representing an 'adjusted' BD threat surrogate. The final overall threat rank (Table 2) incorporates the cumulative ranking of the transboundary lakes based on all the filtering criteria.

As noted throughout the TWAP assessment, the African transboundary lakes are collectively the most threatened, comprising 21 of the top 25 most threatened lakes. The remaining lakes include three Asian and one South American lake (Table 2). The relative threat ranks differ when the Adj-HWS, BD or HDI are considered individually, however, with the developed countries generally exhibiting lower threat ranks.

GEF Intervention Possibilities

It also was possible to provide conclusions regarding potential GEF-catalysed management interventions (Table 3). Comparison of the threat ranks in Table 2 with ranks subsequently calculated by assigning differing weights to the Adj-HWS vs. RvBD threats (Case A) resulted in markedly different threat ranks in many cases (e.g., Lake Victoria in Africa; Lake Titicaca in South America). This result again highlight the importance of identifying appropriate screening criteria and context for considering the ranking results. Table 3 also suggests some GEF-facilitated management interventions could be considered from the context of addressing multiple lake needs, while others require further assessment of their scientific or political situation, or their basin characteristics, prior to considering management interventions. Lakes located in relatively close proximity to each other often exhibit similar characteristics and stresses, thereby meriting attention as a group ("cluster lakes," including non-transboundary lakes) for assessment and management purposes, including Africa's Rift Valley and western coast, and in the Himalayan and Andes mountain ranges.

Management Implications of Transboundary Lake Threats

Lakes are not isolated water systems, but instead typically exhibit hydrologic or jurisdictional linkages to other upstream and downstream water systems located within larger basins, thereby comprising a collection of nested flowing (lotic) and standing (lentic) water systems (Figure 4). This situation highlights the need for future global freshwater assessments to ensure experts representing such linked freshwater systems work collaboratively to design and undertake such assessments, with obvious synergistic possibilities.

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Table 2. Transboundary Lake Threat Ranks by Multiple Ranking Criteria

(Cont., continent; Eur, Europe; N.Am, North America; Afr, Africa; S.Am, South America; Adj-HWS, Adjusted Human Water Security threat; HWS, Incident Human Water Security threat; BD, Incident Biodiversity threat; HDI, Human Development Index, RvBD, surrogate for 'Adjusted' Biodiversity threat; Estimated risks: Red – highest; Orange – moderately high; Yellow – medium; Green – moderately low; Blue – low)

Cont.	Lake Name	Adj-HWS	HWS	BD	HDI	Adj-HWS Rank	HDI Rank	RvBD Rank	Sum Adj HWS + RvBD	Overall Rank	Sum Adj HWS + HDI	Overall Rank	Sum Adj-HWS + RvBD + HDI	Overall Rank
Afr	Abbe/Abhe	0.93	0.31	0.29	0.40	7	7	7	14	1	14	3	21	1
Afr	Turkana	0.90	0.33	0.30	0.41	13	10	9	22	2	23	10	32	2
Afr	Selingue	0.87	0.30	0.32	0.36	16	2	15	31	11	18	5	33	3
Afr	Malawi/Nyasa	0.91	0.29	0.32	0.42	9	12	14	23	3	21	9	35	4
Afr	Chiuta	0.85	0.25	0.26	0.41	23	9	3	26	5	32	15	35	4
Afr	Cohoha	0.96	0.39	0.41	0.38	3	4	28	31	2	7	1	35	4
Afr	Kivu	0.91	0.31	0.33	0.38	12	6	18	30	8	18	4	36	7
Afr	Rweru/Moero	0.96	0.40	0.42	0.36	4	3	30	34	16	7	2	37	8
Afr	Lake Congo River	0.75	0.20	0.22	0.34	35	1	1	36	18	36	19	37	8
Afr	Tanganyika	0.84	0.25	0.29	0.40	26	8	6	32	14	34	17	40	10
Afr	Edward	0.94	0.34	0.35	0.43	6	13	22	28	7	19	6	41	11
Afr	Chilwa	0.86	0.28	0.30	0.41	21	11	10	31	10	32	14	42	12
Afr	Mweru	0.81	0.24	0.28	0.38	33	5	4	37	21	38	20	42	12
Asia	Sistan	0.98	0.41	0.38	0.46	1	20	25	26	6	21	8	46	14
Afr	Natron/Magad	0.93	0.36	0.33	0.51	8	23	17	25	4	31	13	48	15
Afr	Nasser/Aswan	0.86	0.29	0.32	0.43	20	16	16	36	19	36	18	52	16
Afr	Albert	0.91	0.35	0.37	0.46	10	19	24	34	15	29	12	53	17
Afr	Ihema	0.97	0.41	0.44	0.44	2	18	33	35	17	20	7	53	17
S.Am,	Azuei	0.96	0.50	0.43	0.46	5	21	31	36	20	26	11	57	19
	Aral Sea	0.84	0.29	0.38	0.60	27	26	5	32	13	31	31	58	20
Asia	Sarygamysh	0.82	0.26	0.25	0.67	29	29	2	31	9	32	32	60	21
Afr	Cahora Bassa	0.78	0.29	0.31	0.43	34	15	13	47	25	25	25	62	22
Afr	Victoria	0.91	0.42	0.44	0.47	11	22	32	43	24	16	16	65	23
Afr	Chad	0.84	0.38	0.36	0.43	25	17	23	48	26	21	21	65	23
Afr	Kariba	0.75	0.33	0.34	0.43	36	14	19	55	30	28	28	69	25
S.Am	Titicaca	0.82	0.33	0.29	0.71	32	32	8	40	22	25	35	72	26
Afr	Aby	0.83	0.35	0.35	0.52	28	24	21	49	27	30	30	73	27
S.Am	Chungarkkota	0.82	0.36	0.31	0.71	31	33	12	43	23	34	34	76	28
Asia	Shardara/Kara-kul	0.86	0.52	0.46	0.65	22	28	35	57	31	27	27	85	29
Eur	Dead Sea	0.90	0.57	0.49	0.72	14	34	38	52	29	24	24	86	30
Afr	Josini/Pongola-poort Dam	0.85	0.52	0.48	0.61	24	27	37	61	34	29	29	88	31
S.Am	Salto Grande	0.67	0.29	0.30	0.74	40	38	11	51	28	39	39	89	32
Asia	Darbandikhan	0.87	0.56	0.54	0.68	17	30	46	63	35	23	23	93	33
S.Am	Lago de Yacyreta	0.75	0.31	0.34	0.73	38	36	20	58	32	38	38	94	34
Asia	Aras Su Qovsaginin Su Anbari	0.89	0.57	0.53	0.73	15	35	44	59	33	26	26	94	34
Asia	Mangla	0.87	0.59	0.62	0.54	18	25	53	71	39	22	22	96	36
S.Am	Itaipu	0.75	0.36	0.42	-.73	37	37	29	66	37	37	37	103	37
Asia	Caspian Sea	0.73	0.45	0.40	0.77	39	41	27	66	36	40	40	107	38
Eur	Galilee	0.87	0.59	0.55	0.88	19	46	47	66	38	36	36	112	39
Eur	Cahul	0.82	0.61	0.61	0.69	30	31	51	81	42	33	33	112	39
Eur	Scutari/Skadar	0.62	0.40	0.45	0.78	41	42	34	75	41	41	41	117	41
N.Am	Amistad	0.49	0.42	0.39	0.86	47	45	26	73	40	47	40	118	42
Eur	Macro Prespa (Large Prespa)	0.51	0.50	0.49	0.75	44	40	40	84	43	42	42	124	43
Eur	Ohrid	0.47	0.49	0.49	0.74	49	39	39	88	46	44	44	127	44
Eur	Szczecin Lagoon	0.53	0.54	0.51	0.83	43	43	43	86	44	43	43	129	45
N.Am	Huron	0.42	0.40	0.47	0.93	51	50	36	87	45	51	51	137	46
Eur	Neusiedler/Ferto	0.58	0.54	0.61	0.88	42	47	50	92	47	45	45	139	47
N.Am	Ontario	0.48	0.46	0.53	0.92	48	49	45	93	48	49	49	142	48
Eur	Lake Maggiore	0.33	0.40	0.50	0.89	52	48	42	94	50	50	50	142	48
N.Am	Falcon	0.50	0.61	0.62	0.85	46	44	52	98	53	46	46	142	48
N.Am	Erie	0.51	0.51	0.57	0.93	45	51	49	94	51	48	48	145	51
N.Am	Champlain	0.29	0.39	0.49	0.94	53	52	41	94	49	53	53	146	52
N.Am	Michigan	0.44	0.48	0.56	0.94	50	53	48	98	52	52	52	151	53

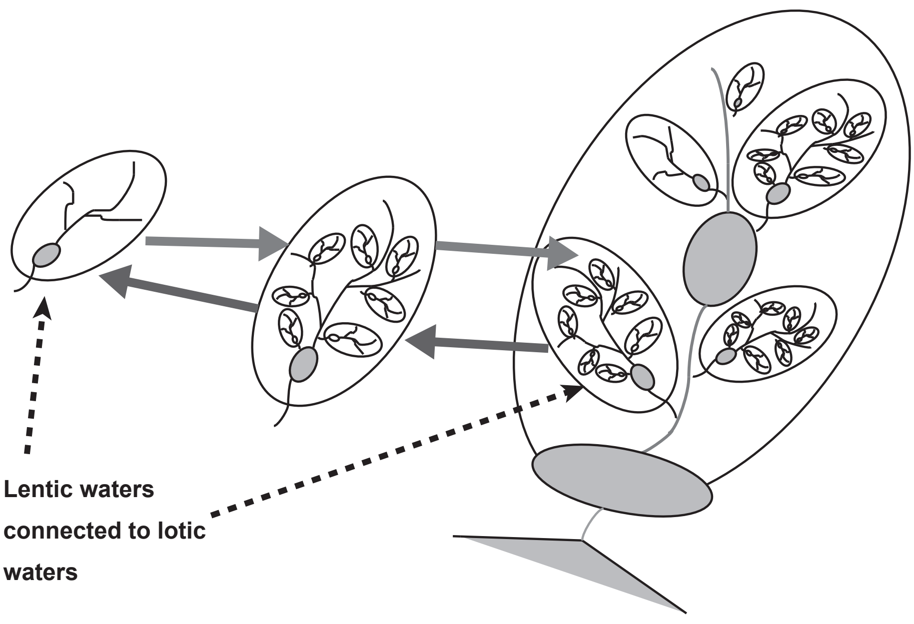
Table 3. Summary of Transboundary Lake Threats Related to GEF Intervention Possibilities

Lake	Lake Threat Rank			Key Observations for GEF Intervention Considerations
	Overall Threat Rank (*Taken from Table 2*)	**Case A** (*Average rank based on assigning increasing weight to Adj-HWS vs. RvBD threats; see text for definition of terms)*		
AFRICA				
Abbe/Abhe	1	11	Explore, Improve	Joint implementation with other Ethiopian and Djiboujtian highland lakes may be usefully explored.
Aby	27	15	Explore, Improve	Possibly consider together with Volta River and Lake Volta.
Albert	17	6	Explore, Survey	Joint implementation with Edward could be an option.
Cahora Bassa	22	2	Review, Defer	Need to confirm how lake is assessed within Zambezi River transboundary system.
Chad	24	12	Defer	Review current GEF status.
Chilwa	12	17	Explore, Improve	Joint implementation with Chiuta may be usefully explored. Examine viability of relating with Malawi/ Nyasa follow-up.
Chiuta	5	19	Explore, Improve	Joint implementation with Chilwa may be usefully explored. Examine viability of relating with Malawi/ Nyasa follow-up.
Cohoha	6	2	Explore, Improve	Consideration may be given to possible joint implementation with Ihema and Rweru/Moero as an option.
Edward	11	4	Explore, Survey	Joint implementation with Albert could be an option.
Ihema	18	1	Explore, Improve	Possibly consider together with Rweru/ Moero and Cohoha.
Josini/ Pongolapoort Dam	31	7	Defer	Current status of bilateral position is not clear.
Kariba	25	18	Explore, Improve	Need to confirm how lake is assessed within Zambezi River transboundary system.
Kivu	7	9	Defer	Political and social instability will have to be overcome before consideration.
Lake Congo River	9	23	Defer	Need to confirm how lake is assessed within Congo River transboundary system.
Malawi/Nyasa	4	10	Review	Review current GEF status, and relationship with Chiuta and Chilwa.
Mweru	13	22	Explore, Improve	Possibly consider together with Rweru/ Moero and Cohoha.
Nasser/Aswan	16	14	Review, Defer	Need to confirm how lake is assessed in Nile River transboundary system.
Natron/Magadi	15	8	Explore, Survey	Explore transboundary/non-transboundary framework.
Rweru/Moero	8	3	Explore, Improve	Consideration may be given to possible joint implementation with Ihema and Cohoha as an option.
Selingue	3	13	Defer	Need to undertake more preliminary scientific situation assessment.
Tanganyika	10	21	Review	Review current GEF status.
Victoria	23	5	Review	Review current GEF status.
ASIA				
Aral Sea	20	6	Review	Review current GEF status.
Aras Su Qovsaginin Su Anbari	35	1	Defer	Need assessment of current scientific and political situation.
Caspian Sea	38	7	Review	Review current GEF status.
Darbandikhan	33	2	Defer	Need assessment of current scientific and political situation.
Mangla	36	3	Defer	Current status of bilateral position is not clear.
Sarygamysh	21	8	Explore	Possibly consider together with Aral Sea follow-up, if that is realized.
Shardara/Kara-kul	29	5	Explore	Possibly consider together with Aral Sea follow-up, if that is realized.

Lake	Lake Threat Rank			Key Observations for GEF Intervention Considerations
	Overall Threat Rank (*Taken from Table 2*)	Case A (*Average rank based on assigning increasing weight to Adj-HWS vs. RvBD threats; see text for definition of terms*)		
Sistan	14	4	Review	Review current GEF status.
SOUTH AMERICA				
Azuei	19	1	Recommend-able	Explore possibility and viability.
Titicaca	26	5	Review	Review current GEF status.
Chungarkkota	28	2	Defer	Review current status in relation to Titicaca.
Itaipu	32	3	Defer	Need assessment of current scientific situation.
Lago de Yacyreta	34	4	Defer	Need assessment of current scientific situation.
Salto Grande	37	6	Defer	Need assessment of current scientific situation.

Explore: *Explore feasibility of interventions with assistance of local experts. The available information on prevailing biophysical and limnological state of the lake environment warrants use of external interventions, although political climate, government readiness, and governance constraints are not clear, and a combined assessment is only possible with direct involvement of local experts;*
Survey: *Some scientific and managerial data and information are available, but insufficient for comprehensive, conclusive assessments. A reconnaissance survey conducted with local expert assistance may lead to necessary conclusions on desirability and feasibility of external interventions;*
Improve: *The quantity of information on scientific and managerial challenges is not sufficient to reach meaningful conclusions. A concerted effort is required to improve lake knowledge base;*
Defer: *It is premature to make positive assessment for external interventions;*
Review: *Review current GEF status;*
Recommendable: *Consider GEF intervention.*

Figure 4. Schematic of Linked Lentic and Lotic Water Systems in Lake Drainage Basin
(modified from Nakamura and Rast, 2014)



It is clear that assigning differing weights to the ranking criteria can result in significantly different ranking results (e.g., Table 3). An accurate and useful risk assessment, therefore, requires consideration of a range of interacting scientific, socioeconomic and governance issues, whose relationships can be very subtle and incremental in origin and impact.

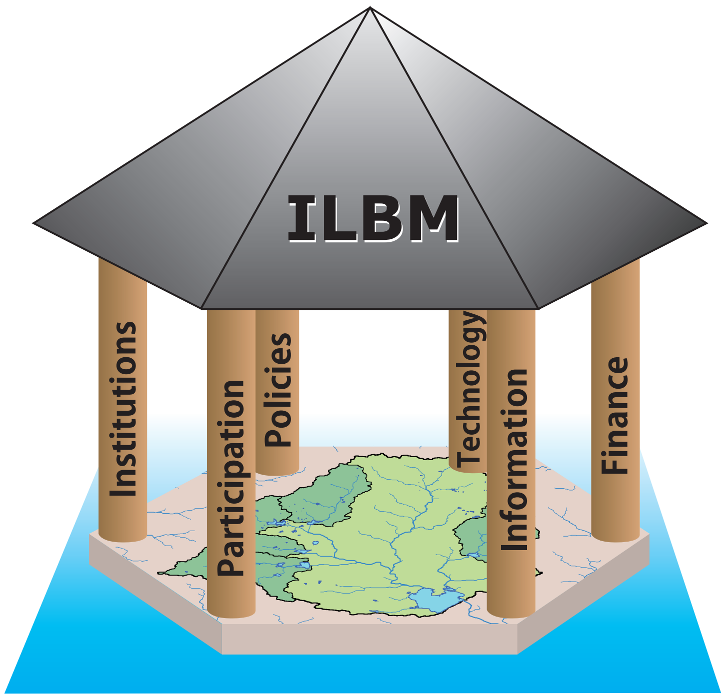
Further, the scarcity of uniform lake-specific data on a global scale highlights a serious need for the international water community to undertake significant knowledge-based development focusing on lakes and other lentic water systems. Understanding the importance and value of transboundary and other lakes will not change without concerted efforts directed to more data collection and analysis. The rare mention of lakes in international water agreements and fora reflects the lack of attention being paid to these freshwater systems, in spite of the range and magnitude of their ecosystem goods and services.

Another assessment consideration is that non-transboundary lakes and other extra-boundary factors can be important internal drivers influencing transboundary lake threats. Non-transboundary lakes located within transboundary river or lake basins can significantly influence the status of the latter, an example being lakes within the Rift Valley region of Africa. Further, many lakes, both transboundary and non-transboundary, are located along the continental or transcontinental flyways of migratory birds, with thousands often congregating in them for food and brooding during their annual migrations. Thus, non-transboundary factors can assume transboundary significance during portions of the year, with both assessment and management implications regarding their relative lake threats.

Integrated Management of Freshwater Lakes

How the collected data and knowledge are used to effectively manage the lakes also merits consideration. With few exceptions, virtually all transboundary lake threats are the result of various governance failures, highlighting the need for an integrated approach to facilitate their sustainable use. Integrated Water Resources Management (IWRM) has been widely used to address freshwater resource issues, facilitating water resources policy reforms, particularly in developing countries. Nevertheless, scientific and management experiences within the lake community have consistently demonstrated that 'operationalization' of IWRM principles has been difficult, partly because these principles do not appropriately consider the unique characteristics of lakes and other lentic water systems that fundamentally define and control their ecosystem services. These characteristics result in lake issues typically requiring longer-term, incremental lake basin governance improvements directed to sustainable use and conservation.

Figure 5. Overview of ILBM Governance Framework (Nakamura and Rast, 2014)



A lake-focused management approach, Integrated Lake Basin Management (ILBM), can address this deficiency. It focuses on the comprehensive management of lakes and other lentic water systems for sustainable use through a gradual, continuous and holistic improvement of basin governance, including sustained efforts for integrating institutional responsibilities, policy directions, stakeholder participation, use of both scientific and traditional lake-focused knowledge, technical possibilities and limitations, and sustainable funding prospects and constraints (Figure 5). The conceptual ILBM framework was developed in the form of ILBM 'Platforms' representing a virtual stage for collective stakeholder actions to improve lake basin governance, and complementing the existing IWRM approach (Nakamura and Rast, 2014).

The main stepwise activities comprising the ILBM Platform process include: (1) Describing the status of lake basin management; (2) Identifying and analysing the challenges regarding six primary governance elements (Figure 5); (3) Integrating the options for addressing these challenges, and (4) Implementing agreed actions to achieve them. An accompanying 'Lake Brief' framework also was developed to identify the type of data needed to accurately assess a lake basin and its linked water systems, and facilitate development of needed management interventions and governance actions.

ILBM also provides a standardized analysis process to enhance the flexibility of the GEF two-step process of undertaking a Transboundary Diagnostic Analysis (TDA) and Strategic Action Program (SAP) for catalysing transboundary water management interventions. It can facilitate activities regarding relevant national water issues outside the traditional scope of GEF-supported interventions, and also provides a firm foundation for bi- and multi-lateral actions regarding transboundary waters

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Concluding Remarks

Lakes and other lentic water systems are complex water systems that are difficult to assess and manage for sustainable use of their ecosystem services. As major stress points within a drainage basin, they integrate water and material inputs from many sources in their basins, and exhibit non-linear responses to degradation and over-exploitation. Their buffering capacity results in a 'lag' phenomenon that masks the incremental degradation of lakes, as well as making it difficult to observe the positive effects of remedial programs. In spite of their being the major stores of readily-available liquid freshwater on the land surface, there is little uniform lake data on a global scale, complicating the accurate assessment of transboundary lakes, and managing them for the sustainable use of the ecosystem services they provide. Inadequate attention paid to lakes and their ecosystem services in international water fora, and in international water agreements attests to the serious need for major attention regarding the sustainability of their ecosystem services.

Probably the most important conclusion arising from the transboundary lakes assessment is that ***ranking lakes in regard to the nature and magnitude of the threats facing them is not simply a number-crunching exercise.*** It requires a detailed case-by-case assessment considering a range of interlinked factors, including in-lake status, geographic location, linkages with other flowing and pooled water systems, defining institutional, policy and socio-economic issues, adequacy of the governance framework under which they are managed, and the magnitude of the threats to sustainable use of their ecosystem services. Identifying the 'worst' transboundary lake in a given region is also problematic because the definition of degradation is a function not only of the lake itself, but also of the factors and context that those using the threat ranks consider most important for lake basin stakeholders. Thus, as a complement to the widely-used Integrated Water Resources Management (IWRM) approach, the ILBM Platform process, and ILLBM as its extension, represents a virtual framework for identifying and assessing these complex interacting factors influencing effective lake basin assessment and management

Looking to the future, identifying and addressing transboundary lake assessment and management issues requires mainstreaming lakes in global water discussions. The scientific and management implications of their lentic properties and the assessment and management implications will continue to be largely ignored if not explicitly recognized in future transboundary water assessments. Some UN and other institutions can likely incorporate future transboundary assessments within their work programs.

No similar situation, however, exists for addressing transboundary lakes and other lentic water systems. Although ILEC and the other lead TWAP organizations will endeavour to sustain global-scale assessment activities, the availability of sufficient financial and institutional support remains a core requirement for sustaining future transboundary waters assessments for all five involved water systems (lakes, rivers, aquifers, large marine ecosystems, open oceans). More intensive efforts on the part of the international community to address the serious scarcity of accurate, meaningful data and information on lakes and other lentic water systems, combined with an integrated management framework of the type exemplified by Integrated Lake Basin Management (ILBM), and the more comprehensive Integrated Lentic Lotic Basin Management (ILLBM) platform, will greatly facilitate our ability to make more accurate assessments and science-based management interventions to address the conservation and sustainability of the range of ecosystem services they provide on a global scale.

Appendix A

Regional Distribution of 53 Priority Transboundary Study Lakes

Waterbody Name	TWAP Regional Designation	Lake (L) or Reservoir (R)	River Basin
AFRICA REGION			
Abbe/Abhe	Eastern & Southern Africa	L	Awash
Aby	Western & Middle Africa	L	Bia+Tano
Albert	Eastern & Southern Africa; Western & Middle Africa	L	Nile
Cahora Bassa	Eastern & Southern Africa	R	Zambezi
Chad	Western & Middle Africa	L	Chad (endorheic)
Chilwa	Eastern & Southern Africa	L	Chilwa (endorheic)
Chiuta	Eastern & Southern Africa	L	Chiuta (endorheic)
Cohoha	Eastern & Southern Africa	L	Nile
Edward	Eastern & Southern Africa	L	Nile
Ihema	Eastern & Southern Africa	L	Nile
Josini/Pongolapoort Dam	Eastern & Southern Africa	R	Maputo
Kariba	Eastern & Southern Africa	R	Zambezi
Kivu	Eastern & Southern Africa; Western & Middle Africa	R	Ruizizi
Lake Congo River	Western & Middle Africa	L	Congo
Malawi/Nyasa	Eastern & Southern Africa	L	Zambezi
Mweru	Eastern & Southern Africa; Western & Middle Africa	L	Congo
Nasser/Aswan	Northern Africa & Western Asia	R	Nile
Natron/Magadi	Eastern & Southern Africa	L	Southern Ewaso Ng'iro
Rweru/Moero	Eastern & Southern Africa	L	Nile
Selingue	Western & Middle Africa	R	Nile
Tanganyika	Eastern & Southern Africa; Western & Middle Africa	L	Congo
Turkana	Eastern & Southern Africa	L	Turkana (endorheic)
Victoria	Eastern & Southern Africa	L	Nile
ASIA REGION			
Aral Sea	Eastern & Central Asia	L	Aral (endorheic)
Aras Su Qovsaginin Su Anbari	Southern Asia; Northern Africa & Western Asia	R	Kura-Arkas
Caspian Sea	Northern Africa & Western Asia; Eastern & Central Asia; Southern Asia; Eastern Europe	L	Caspian (endorheic)
Darbandikhan	Northern Africa & Western Asia; Southern Asia	R	Tigris-Euphrates
Mangla	Southern Asia	R	Indus
Sarygamysh	Eastern & Central Asia	L	Amu Darya
Shardara/Kara-Kul	Eastern & Central Asia	R	Syr Darya
Sistan	Southern Asia	L	Helmand
EUROPE REGION			
Cahul	Eastern Europe	L	Danube
Dead Sea	Northern Africa & Western Asia; Southern Asia	L	Jordan
Galilee	Northern Africa & Western Asia	L	Jordan
Macro Prespa (Large Prespa)	Northern, Western & Southern Europe	L	Macro Prespa (endorheic)

Waterbody Name	TWAP Regional Designation	Lake (L) or Reservoir (R)	River Basin
Lake Maggiore	Northern, Western & Southern Europe	L	Po
Neusiedler/Ferto	Eastern Europe; Northern, Western & Southern Europe	L	Danube
Ohrid	Northern, Western & Southern Europe	L	Black Drin
Scutari/Skadar	Northern, Western & Southern Europe	L	Drin
Szczecin Lagoon	Eastern Europe; Northern, Western & Southern Europe	L	Oder
NORTH AMERICA REGION			
Amistad	Northern, Western & Southern America	R	Rio Grande
Champlain	Northern, Western & Southern America	L	St. Lawrence
Erie	Northern, Western & Southern America	L	St. Lawrence
Falcon	Northern, Western & Southern America	R	Rio Grande
Huron	Northern, Western & Southern America	L	St. Lawrence
Michigan	Northern, Western & Southern America	L	St. Lawrence
Ontario	Northern, Western & Southern America	L	St. Lawrence
SOUTH AMERICA & CARIBBEAN REGION			
Azuei	Central American & Caribbean	L	Azuei (endorheic)
Chungarkkota	Southern America	L	Titicaca-Poopo System
Itaipu	Southern America	R	La Plata
Lago de Yacyreta	Southern America	R	La Plata
Salto Grande	Southern America	R	La Plata
Titicaca	Southern America	L	Titicaca-Poopo System

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The water systems of the world – aquifers, lakes, rivers, Large Marine Ecosystems (LMEs), and the open ocean – sustain the biosphere and underpin the health and socioeconomic wellbeing of the world's population. Many of these systems are shared by two or more nations. The transboundary waters, which stretch over 71% of the planet's surface, in addition to the transboundary subsurface aquifers, and the water systems entirely within the boundaries of the individual countries, comprise humanity's water heritage.

Recognizing the value of transboundary water systems, and the reality that many of them continue to be overexploited and degraded, and managed in fragmented ways, the Global Environment Facility (GEF) initiated the Transboundary Waters Assessment Programme (TWAP) Full Size Project in 2012. The Programme aims to provide a baseline assessment to identify and evaluate changes in these water systems caused by human activities and natural processes, as well as the possible consequences of these changes for the human populations that depend on them. The institutional partnerships forged in this assessment are expected to seed future transboundary assessments. The final results of the GEF TWAP are presented in six volumes:

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.

This document – Volume 2 Summary for Policy Makers– highlights the main findings a global baseline assessment of 204 transboundary lake and reservoirs, including delineation of their drainage basins, and identifies 53 lakes and reservoirs that pose the largest threats to human water security and biodiversity on the basis of their basin characteristics.

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