Informational Requirements for a Lake Basin Management Programme

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I. Introduction

Water remains the essential medium for life on our planet. In its various forms of vapor, liquid and ice, it is a fundamental component in a vast array of complex linkages involving our planet's biotic and abiotic components, such that changes in one part of the Earth system can impact other parts on varying temporal scales, ranging from days or months, to decadal or millennial periods. To this end, the Millennium Ecosystem Assessment (MA 2005) has highlighted that our freshwater, coastal and marine ecosystems continues to decline on a global scale. Human activities are a particularly important element in this decline, both as a causative factor, as well as being impacted by human-derived disturbances to the natural environment.

Because of increasing population growth, increasing agricultural production to meet growing food needs, and increasing economic activity and industrialization to enhance human well-being, the world's freshwater resources are under ever-increasing pressure. Our planet also is becoming an urbanized world, with more than half of the global population now living in urban settlements. The process of globalization of world trade is further exacerbating pressures on our freshwater resources. Thus, because of their fundamental role in facilitating human survival and well-being, and for maintaining life-supporting ecosystems, the protection and management of these resources for their sustainable use also is also of fundamental importance.

II. Basis for Action

The need for adequate supplies of freshwater resources to meet human survival and economic development needs, as well as their role in maintaining the integrity of aquatic and terrestrial ecosystems, has been recognized and discussed in a number of international water fora over the last two decades, the 2000 United Nations Millennium Summit, with its development of the Millennium Development Goals (MDGs) and the 2002 World Summit on Sustainable Development being two important examples. The World Water Development Reports (WWDR1 and WWDR2 REFERENCES), and the Global Environment Outlook (GEO-4 REFERENCE), also highlight the generally deteriorating condition of our plant's freshwater resources. Their overall observations can be encompassed within the description of our planet's freshwater resources as: (i) finite; (ii) sensitive to human activities; and (iii) having no substitutes for their many uses. Thus, their protection and management also is of fundamental importance to continued human existence and economic advancement.

III. The Need for an Integrated Water Management Approach

Virtually all freshwater problems can be characterized as being those of water quantity, water quality, or both. The former typically involves both the impacts of the natural phenomenon of drought, as well as the anthropogenic effects of human overabstraction of freshwater to meet agricultural, industrial or drinking water needs. The result is water shortages of varying magnitudes, and temporal and/or spatial scales. In one sense, the situation is relatively more homogenous in regard to water quality, noting that the same water pollutants are generally identified throughout the world, whether in developed or developing countries. The major freshwater pollutants typically comprise some combination of microbes, nutrients, heavy metals, synthetic organic chemicals, oxygen-consuming materials, and sediments. Highly saline water also is a pollutant in some situations. In fact, the major differences regarding water quality concerns appear to lie in: (1) the perspectives of the individuals and/or areas affected by the pollutant (i.e., what is the specific problem(s) and how serious is it?), and (2) the range of available options for dealing with these problems (i.e., what can be done about it and how much will it cost?). Addressing the former problems is largely a matter of assessing the condition of the water resources, while the latter focuses more on water governance and financial issues. Whatever the basic perception, however, the fundamental issue to be considered is how humans can address the issue of ensuring the sustainable use of freshwater resources to meet human health and economic needs, while also protecting important ecosystems.

To this end, there is continuing agreement on a global scale of the need for a comprehensive, integrated approach to addressing the sustainability of freshwater resources. This notion is recognized within the concept of integrated water resources management (IWRM). Although several definitions of this concept exist, dating back to Agenda 21, one that is often cited for freshwater systems is provided by the Global Water Partnership, which defines IWRM as *"a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems"* (GWP, 2000). This approach was subsequently incorporated in the 2002 WSSD Plan of Implementation, which called for all countries to *"develop integrated water resources management and water efficiency plans by 2005, with support to developing countries"*(Jønch-Clausen, 2004).

The IWRM concept has continued to evolve and expand over the past decade (Smith and Rast, 1998; Rast, 2003), with references being made in the literature to Integrated River Management (IRM), Integrated River Basin Management (IRBM), and Integrated Coastal Area and River Management (ICARM). Only recently has the concept of IWRM been applied to lake systems, as an equally important component of integrated water resources management. Building on the initial concepts promulgated within the Dublin Principles (Solanes and Gonzalez-Villareal, 1999), the International Lake Environment Committee (ILEC) has subsequently developed an integrated approach to lake systems; namely, Integrated Lake Basin Management (ILBM). The ILBM concept has been developed and applied by ILEC to the sustainable use of lakes, both natural or manmade, with the development of the World Lake Vision (WLV) and its seven WLV Principles (ILEC, 2003), the integrated lake management approach embodied in ILBM (ILEC, 2005; World Bank, 2005), and the "lessons learned" in application of the WLV Principles to a number of case studies around the world (ILEC, 2007).

IV. Information Needs for Integrated Lake Basin Management

Lakes as Freshwater Resources

Lakes have a fundamental role in nature's hydrologic cycle. Of course, they form parts of larger aquatic systems that can include rivers, wetlands and groundwater. At any given instant, however, lakes contain more than 90% of all the liquid freshwater on the Earth's surface. Further, from a landscape perspective, a lake consists of two closely interrelated, yet distinct, parts; namely, the waterbody itself and the surrounding surface area from which water drains into it (i.e., drainage basin). Both must be taken into account in lake management activities, since the former cannot exist without the latter.

Although some lakes are extremely deep (Lake Baikal; Lake Tanganyika), or contain huge volumes of water (Lake Baikal, Caspian Sea, Lake Superior), the vast majority of the millions of lakes are of much smaller size and volume, usually less than 20 meters deep. These latter lakes are particularly important because they are most accessible to the greatest number of people, being especially important to the lakeside communities that depend on them for water supplies, food and economic well-being. Further, lakes can be both natural and artificial, the latter comprising impounded water systems constructed by humans usually for various water storage purposes. In fact, nearly all the world's major river systems have been impounded, with an estimated 800,000 reservoirs now in operation worldwide, and another 1,700 more large reservoirs currently in construction, particularly in Asia, Latin America and Africa.

The Unique Resources Values of Lakes

Lakes, whether natural or artificial, are dramatic features of our global landscape. In contrast to the transport function of rivers, lakes represent water storage bodies. Depending on their specific mode of origin, their shapes, sizes and depths can vary considerably. A significant characteristic of lakes, compared to other water systems, is that they are subject to the widest range of human uses. They are storehouses for large quantities of water, which is an asset for ensuring water availability during periods of water shortage. This capacity is equally important as a means of storing the large water volumes generated during flood events, in order to reduce downstream loss of life and property. Lakes are sources of food and recreational possibilities for humans. They are home to an amazing range of aquatic biodiversity, as well as resting and feeding habitats for migratory birds. They also can be significant repositories of natural and human history, noting that ancient urban centers often arose on or near lakeshores. Further, development of the lifestyles of some indigenous cultures has been based on lakes, an example being those in the Lake Titicaca (Bolivia, Peru) drainage basin. Lakes Chapala (Mexico) and Manasarowar (Tibet, China) are considered sacred sites, as is Chikubu Island in Lake Biwa (Japan). Lakes with large water volumes can even moderate the local climate by reducing the range of atmospheric temperatures fluctuations. Not to be forgotten is the intrinsic beauty of some lakes, which can provide a sense of emotional, spiritual and even intellectual peacefulness not necessarily found with other landscapes (ILEC, 2003; 2005).

Three Unique Characteristics of Lakes

Although lakes of varying depths, sizes and volumes can be found throughout the world, virtually all share three fundamental characteristics - an integrating nature, a long water retention time, and complex response dynamics. These characteristics certainly are unique to lakes, since other water systems also can exhibit them; estuaries can exhibit complex dynamics, for example, while groundwater aquifers can exhibit long water retention times. Rather, it is the simultaneous combination of these three characteristics that is unique to lake systems. As discussed further in a later section, the importance of this observation lies in the influence of these characteristics on the integrated management of lakes for sustainable use (ILEC, 2005).

Integrating nature - The integrating nature of a lake refers to the mixing of the inputs of water and pollutants from its multiple inputs, including direct participation onto the lake surface, tributary inflows from the surrounding drainage basin, groundwater inflows, the long range transport of airborne pollutants, etc (Thornton et al., 1999). Various natural forces (sunlight, wind) also can affect the condition of lake systems. The integration of these various inputs and factors in a lake ensures that both its resources and problems are disseminated throughout the lake volume. In this regard, lakes have sometimes been referred to as sensitive 'barometers' or 'mirrors' of the degrading impacts of human activities in their drainage basin and beyond.

Long water retention time - Because lakes typically contain a large volume of water, with its diluting effects, they typically respond slowly to natural processes (e.g., atmospheric temperature changes) and to the polluting effects of material inputs (e.g., water pollutants), which is a defining characteristic of lentic (static) water systems. A long water retention time means the average time water spends in a lake is longer than for other surface water systems and, as a consequence, their water flushing rate also is slower. This observation has several important positive implications. One is that the water volume contained in lakes is relatively stable, compared to other water systems. Another effect of this long-term stability is that it has allowed some lakes to evolve unique ecosystems containing many endemic species of fish, some even unique to the lakes in which they are found. Long water retention times also allow for pollutants carried in flowing tributaries entering the lake to settle to the bottom of the lake, in effect making the lake a pollutant 'sink.' There are, however, also some serious negative impacts associated with a lake being a pollutant sink. Having a long water retention time, once a lake becomes degraded or polluted, it can take a very long time for it to recover. Further, necessary remedial programs can be difficult, costly and time-consuming. Even after remedial programs have been implemented, lakes that have received a large pollutant load over a long time can accumulate some of the pollutants (e.g. phosphorus, heavy metals) in the bottom sediments. Under certain chemical conditions, these pollutants will be released back into the water column after the major external inputs of the pollutants from the drainage basin have been controlled, thereby frustrating remedial efforts until the pollutants have essentially been flushed from the sediments. This can take many years in some cases.

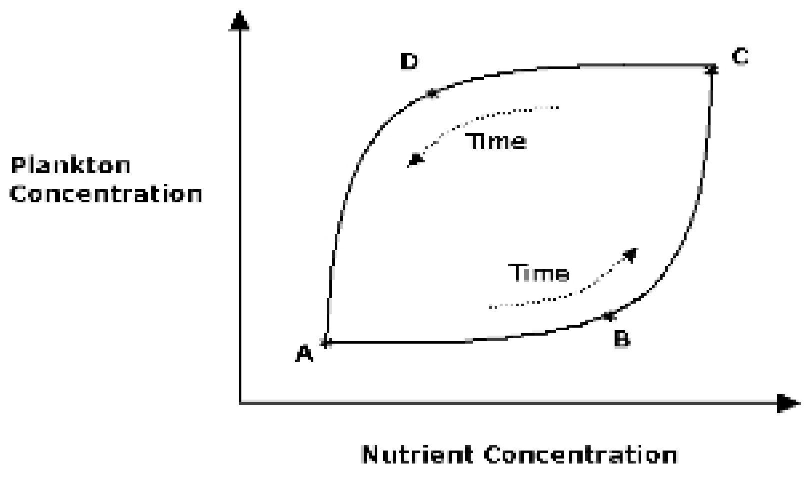
Complex response dynamics - In contrast to rivers, lakes do not necessarily respond to remedial programs in a linear manner. This is due in part to the above-noted 'internal loading' from bottom sediments of heavily polluted lakes. An example is illustrated below in the non-linear response of many lakes to excessive external nutrient loadings, and remedial programs subsequently implemented to reduce or eliminate them.

This example illustrates both the ability of a lake to resist the polluting consequences of excessive nutrient loads over a period of time (from point A to B), until the nutrient concentration finally becomes so large that the lake will experience a basic shift in its biological and chemical status, resulting in a significantly increased concentration of plankton, which is an indicator of increased eutrophication (from point B to C). Even when a remedial program is implemented to address the excessive nutrient loads (at point C), the lake may not exhibit any significant improvement until the nutrients that have accumulated in the lake bottom sediments over time have essentially been flushed from the system (from point C to D). Only when that point has been reached will the lake exhibit a significantly increased quality (point C back to point A). A major management implication of this hysteresis effect is that decisionmakers, lake stakeholders and the public may assume that a given remedial program (a potentially expensive undertaking) has not been successful, even though the lake is in fact undergoing a slow recovery.

In addition to the impacts of excessive nutrient loadings, other examples of the complex dynamics of lakes rests in the impacts associated with the introduction of alien species, which can displace native aquatic species, and the property of biomagnification of certain compounds in organisms (e.g., persistent organic pollutants) as one moves up the food chain.

In describing these characteristics, scientific knowledge has a particularly important role in integrated lake basin management (ILBM). The long water retention times of lakes means lake problem ideally should be anticipated as far in advance as possible. This is usually done via monitoring programs, and the development of indicators

Figure 1. Hysterisis and the Long-term Response of Some Lakes



and analytical studies. The complex dynamics means that detailed scientific studies may be needed to better understand and explain the observed response dynamics, and particularly their implications for sustainable use of a lake and its resources. As the sink for many pollutants, the notion of a 'mixing pot' that integrates the impacts of multiple material inputs to a lake from its drainage basin becomes a realistic vision. Scientific studies and the knowledge they impart also can help develop novel solutions to lake management problems.

V. Information Needs for Lake Basin Management

It should be no surprise that managing lakes for their sustainable use requires timely, accurate and understandable information and data. To this end, Principle 4 of the World Lake Vision (ILEC, 2003) states: *"Policy development and decision making for lake management should be based on sound science and the best available information."* In fact, managing lakes for sustainable use requires more than simply measuring the concentrations of specific chemicals and/or the numbers and types of aquatic communities present in a lake. Rather, a multidisciplinary approach is necessary, considering both the physical, chemical and biological sciences, and the socioeconomic, institutional, political, technological, historical and cultural factors. The former is essential for determining the status of lake-based water resources in a drainage, which provides information on their quantity and condition, and where they can be found. The latter, although less quantifiable than the former, is essential because it fundamentally determines ***how*** humans use the water resources. It also reflects people's values and associated goals for their water resources, as well as social and cultural relationships that can facilitate the sustainable use of these resources. This type of information and data is preferred in lake basin management efforts because, it is usually testable, reproducible, and essentially accessible to all lake stakeholders. As discussed further below, developing and implement sound lake management practices for a given lake requires systematic, continuous and up-to-date monitoring and evaluation of both the environmental and socioeconomic conditions unique to a lake and its basin.

As a general observation, local or traditional knowledge and customs, sometimes contained in legends, oral histories and experiences of Indigenous Peoples, also can be considered in developing lake management programs. Such information may comprise long-term personal observations in some situations, and also can be used to augment existing information. Further, such information may sometimes be the only source of available information for a given lake or basin, where no previous monitoring information exists. To this end, the World Lake Vision (ILEC, 2003) encourages new or continuing monitoring and assessment of the state of lakes and their basins, and subsequent dissemination of such information and data to decision-makers and all lake stakeholders. Depending on the circumstances, and the type of information and data being sought, such monitoring can be undertaken by a range of entities, including individuals, governmental and non-governmental agencies, academic institutions, and the private or. Such monitoring activities should be designed to recognize and incorporate the hydrologic, biological, chemical and physical characteristics of lakes. It is noted that citizen monitoring programs can be useful in some situations, as a relatively simple, low-cost approach to collecting lake-relevant data. If properly organized and supervised, citizen monitoring can be done independently of, or in collaboration with, other monitoring and assessment activities conducted by governmental or other organizations. It also can have the complementary effect of increasing public awareness and participation in lake management programs. At the same time, reliable information on existing institutions, regulations and policies, financial considerations, political realities, cultural perspectives, etc., is equally important in formulating effective management programs for sustainable use.

VI. Coupling Scientific Information and Lake Basin Management

Reliable, easily-understood and readily-accessible information and data is fundamental for effective lake basin management. Without such information, lake management policies can be misdirected, institutions can be inefficient and ineffective, rules and regulations can be unfair, inequitable and ineffective, and lake basin stakeholders may base their management perceptions on incorrect knowledge. According to the World Bank (2005), scientific information has three purposes: (1) it identifies the limits of lake basin resources (e.g., establishing fish-catch limits; setting water quality standards); (2) it identifies and quantifies processes operating in lake basins (e.g., establishing water balances; predicting effects of proposed hydraulic structures; identifying the role of pollutants); and (3) it provides novel solutions to problems (e.g., assessing the impacts of introducing alien species into a lake; modeling the benefits of alternative management options).

With this background, there are desirable characteristics associated with scientific information, including:

- ***Reliable understanding*** - To effectively guide lake management efforts, scientific studies must be of high quality, including: (1) taking an integrated approach; (2) being conducted over sufficiently long time periods; (3) being integrated across disciplines; and (4) undergoing peer group scrutiny. Although previous single-issue approaches have proven valuable in the past (e.g., North American Great Lakes Basin), the complexity of current lake basin problems dictates a multidisciplinary approach to assess and address them. Where possible, previous studies can provide valuable management information, particularly where they illustrate changes over long time periods.

- ***Inclusion of monitoring*** - The reality is that there are few lakes for which continuous, or even periodic, diagnoses and surveys of the lake environment are carried out. Nevertheless, monitoring activities are invaluable in providing a baseline or reference against which: (1) changes in the condition or status of a lake can be measured, and (2) the effectiveness of management interventions can be assessed. Indeed, there is virtually no other way for assessing either the magnitude of changes, or how well specific lake management interventions are addressing a given lake basin problem. Unfortunately, however, consideration of the costs of monitoring can be problematic. In some instances, monitoring costs can be a small fraction of the costs of addressing a lake degradation problem after it has become apparent. In other cases, the costs have been a constraint to implementing a comprehensive monitoring program. To this end, restricting lake monitoring parameters to basic parameters (e.g. nutrient, dissolved oxygen and chlorophyll concentrations; water levels; turbidity; temperature) can reduce monitoring costs. Further, restricting monitoring efforts to record only parameters that will show the effectiveness of management interventions can be another means of monitoring management interventions.

- ***Communication with decisionmakers*** - To get the attention of decisionmakers, who typically make the fundamental decisions regarding whether or not to implement a lake basin management program, the knowledge and data gained from monitoring and other studies must be presented in a form they can understand and readily use. Indeed, strictly scientific reports often lose their value in guiding or advising lake management efforts. This has the double-edged effect of also dampening the enthusiasm of decisionmakers to provide necessary funding for scientific research and/ or related lake basin monitoring programs. Experience in some lake basins suggests the most effective means of ensuring research and monitoring results influence management decisions is to ensure the monitoring program is designed around the management objectives. This includes ensuring the information and data collected is relevant to management needs, and that it is provided to decisionmakers in a form and language they and other lake basin stakeholders can readily understand and use. This suggestion also applies to the use of models in lake management efforts. Although potentially very useful management tools, model application should be driven by lake basin management needs, rather than by scientific curiosity. It is noted that simple models often have proven more successful than complex models in management efforts, even if the latter are more scientifically rigorous. Nevertheless, the complexity of a given model should be matched with the capacity of the users, the available data, and the lake basin management needs.

- ***Accessibility of knowledge to lake basin management stakeholders*** - To be of maximum value, scientific knowledge and data gained in lake management programs must be disseminated to, and readily accessible by, a range of lake basin stakeholders, including national and local governments, lake management practitioners, non-governmental organizations, etc. Consistent with the same needs applied to decisionmakers, the scientific terminology and language level of such materials should be simplified for the audience. A number of avenues for disseminating this information and data have been documented, including lake museums and display centers, floating schools, web sites, and theater performances. Further, the communication can be in both directions. In some cases, stakeholder groups can actually benefit from, and even participate in, such efforts. An example is the valuable role artisanal fisher groups or association can play in monitoring and assisting with knowledge about fishing efforts and yields.

- ***Enhancing the Capacity for Acquiring Scientific Knowledge and Data*** - One other element meriting mention is the need to improve local scientific expertise for relevant lake studies and monitoring efforts, particularly in developing countries, as a component of sustainable lake basin management. This translates into long-term investment and capacity building to support the education of scientists and lake managers in the field of aquatic ecosystems, with a focus on lakes, their resources and their basins. Such capacity building must consider a range of skill levels in some cases.

VII. Use of Scientific Information in Lake Basin Management

As noted above, science and scientific information is often used in three main ways to enlighten lake basin management decisionmakers. These are: (1) to show the limits of the resource; (2) to enlighten hard-to-see connections; and (3) to provide novel or innovative solutions, as follows (ILEC, 2005):

- ***Showing the limits to the resource*** - Scientific studies can provide considerable information on the status or condition of a lake basin. This includes identifying the limits or constraints on a given lake resource. An example is fishing, a major resource use for many lakes. Overfishing is a main constraint to sustainable fishing practices, thereby threatening both human livelihoods that depend on this resource, as well as the sustainability of the fisheries themselves. In such cases, scientific studies can be conducted to provide key information and data on sustainable fishing rates, which can be used by decisionmakers to decide whether or not to undertake some management interventions as restricting fishing efforts, setting fish catch limits, or designating acceptable fishing areas in a given lake. Another use of such information would be to set nutrient loading limits to a lake, as a means of identifying the lake's capacity to assimilate the nutrient inputs without exhibiting the water-degrading impacts of cultural eutrophication. Examples of other scientific studies useful in setting such limits include the modeling exercise undertaken by the United States and Canada to determine phosphorus loading targets for the North American Great Lakes, and modeling studies that illustrate how non-point pollutant sources could be transported to a lake from both in-basin waterborne pathways, and from outside a basin via atmospheric transport.

- ***Enlightening hard-to-see connections*** - Given the complex dynamics of lake ecosystems, another key role of science is to highlight hard-to-see, sometimes indirect, connections that are common to lake basin management efforts. A noteworthy example was the development and use of a simple model, utilizing long-term monitoring data, to indicate that, even though the Lake Naivasha water level exhibited natural fluctuations, water withdrawals for horticulture irrigation was responsible for water level declines in the lake over the past two decades. Scientific studies also indicated a proposed hydraulic control structure for stopping saltwater intrusion from the ocean into Laguna de Bay (Philippines) would negatively impact the lake's fisheries. Scientific studies also showed that decreasing snowfall in the Lake Biwa basin, combined with a weakened lake water overturn in the spring, resulted in lower dissolved oxygen concentrations in the lake which, in turn, caused phosphorus remobilization from the lake bottom sediments and potentially increased eutrophication of the lake. Studies on Lake Victoria suggested that atmospheric deposition was a much more significant source of phosphorus loading to the lake than was originally thought. None of these various connections or interrelations between lakes, their basins and the biotic and abiotic factors influencing them, would have been considered in the design and implementation of lake basin management efforts if such studies had been undertaken.

- ***Providing innovative solutions*** - Another benefit of scientific studies is to assist decisionmakers in developing innovative solutions to lake basin management problems. There are some excellent examples of this benefit, one being the use of modeling studies to determine that dredging a channel between Lake Chilika and the ocean could improve salinity conditions and, in turn, fisheries production. This action also would help alleviate potential conflicts among the local communities relying on the lake for fisheries. Detailed ecological studies in Kariba Reservoir in Africa provided valuable information in regard to how introducing a specific fish into the ecological niche that resulted from formation of the reservoir could support a commercially-valuable fishery. Studies on the Bhoj Wetlands (India) illustrated how high heavy metal concentrations were resulting from the practice of immersing idols during religious ceremonies. The study results also indicated that simply moving the immersion activity to another site was a possible solution to this pollution problem. The value of scientific studies to help solve or alleviate lake basin management problems is considerable, and more readily accepted by decisionmakers and lake basin stakeholders when provided in an understandable form and easily-utilized language.

Ironically, experience in many places suggests that constraints to use of scientific information and data rests in the perspective of some decisionmakers that scientific inputs are costly to obtain and time-consuming to utilize. And a common criticism of scientists, who are often cautious in their conclusions regarding the behavior of complex ecosystems, is that their inputs are often inconclusive. This latter factor is particularly problematic, given that decisionmakers often must make important decisions in a relatively short timeframe. Further complicating the situation is that scientists are often poor communicators with anyone other than other scientists and technically-competent colleagues, and have difficulty explaining their results to non-scientists. Finally, a particularly problematic issue regarding the use of scientific information and data is that effective lake management requires a comprehensive, integrated, multidisciplinary approach. This means experts from diverse disciplines (limnology, sociology, political science, economics, chemistry, etc.) must work together in analyzing lake problems and developing effective solutions to these problems. Although easily considered in a conceptual manner, the ability of such diverse individuals to work together in a coordinated, integrated manner continues to be a difficult goal to achieve.

- ***The use of models*** - Models can range from very simple to complex, and can be a useful lake basin management tool under appropriate conditions. Models are mathematical representations of ecosystem behavior, linking natural processes and anthropogenic influences, in ways that we would not otherwise be able to consider. It is not possible to create a lake, for example, and manipulate it within the context of the Scientific Method, to try to determine the potential impacts of the manipulations. However, it is possible to attempt to construct these lake-based processes in mathematical terms. These mathematical terms, in turn can be manipulated in ways that allow one to consider the effects of changing parameters, magnitudes, timing, etc., on the characteristics of a lake, thereby also allowing one to analyze the predicted impacts of alternative management interventions. Models developed for Lake Peipsi/Chudskoe, Lake Victoria, and the North American Great Lakes, for example, were very useful to decisionmakers in considering alternative lake management interventions. Experience also suggests, however, that the design of a given model is best driven by the lake basin managers and stakeholders that will use them, rather than by the model developers themselves. Initial brainstorming sessions will further facilitate the development of models understood by the model users, so that the model can be readily utilized after the model developers have left the scene. A conceptual model developed at early stages in a lake basin management effort also can help identify data needs, thereby also facilitating the development of needed monitoring program (Jørgensen et al., 2005).

VIII. Sharing Lake Basin Management Scientific Information

As previously noted, scientific study results must be made available in a form and language readily utilized by decisionmakers and lake resource stakeholders. To this end, experience with good practices in involving stakeholders in lake basin management include the following characteristics: (1) all relevant stakeholders should be involved; (2) stakeholders must be allowed sufficient time to develop capacity to become familiar with the relevant issues; (3) existing representative structures (e.g., local governments, NGOs, traditional organizations) should be used to the maximum extent in disseminating relevant information and data; (4) the roles of stakeholders should be clearly defined, preferably in regard to government policy; and (5) stakeholders should have access to sufficient resources to become effectively engaged in the lake management process.

Involving People in the Lake Management Process

There are definite benefits in utilizing the public in gathering information and data useful for lake management efforts. These benefits include: (1) facilitating greater ownership on the part of lake basin stakeholders for management actions; and (2) augmenting the monitoring efforts of scientific staff with data (whose reliability must first be assured) from complementary citizen monitoring efforts. Examples include the use of local fishing communities to monitor water hyacinth control measures in Lake Victoria; citizen observations of the occurrence of increasing numbers of fireflies, as an indicator of environmental improvement in the Lake Biwa basin; and use of citizen-collected water quality data since 1979 related to eutrophication of Lake Champlain.

Dissemination of such information and data, as a means of facilitating ownership of lake basin management actions, is as important as collecting it in the first place. There are a number of useful avenues for this purpose, including lake-based museums and centers (e.g., Lake Biwa Museum; Chilika Lake Science Center; Balaton Limnological Research Institute; Leahy Center of Lake Champlain). Such centers can identify, compile, document, and disseminate information and data on specific lakes and their problems, including constraints to their sustainable use. Use of the public and private education system, the media, non-governmental organizations, and even the religious community, can be especially helping in facilitating lake management for sustainable use, including helping shape positive attitudes about the problems facing lakes, and the need for public participation in implementing practical solutions to them. Other dissemination avenues include instructional and descriptive brochures, use of the Internet, and relevant publications and documents. As noted before, the need to ensure the content and quality of the information and data is consistent with the understanding of the lake stakeholder audience remains a crucial factor in their use in lake basin management efforts.

In closing, it is noted that the World Lake Vision (ILEC, 2003) highlighted the need to manage lakes for their sustainable use, based on a vision that encompassed a number of goals, including *"...a future in which the understanding of lakes includes recognition of their inseparable connections to the drainage basins that surround and nourish them, and to the people whose activities control their health and vitality....*" and *"...a future in which research on lakes is initiated and pursued in a coordinated manner that increases human knowledge of their properties and functions, and benefits effective policy formation and management practices identified as important to the health and sustainable use of lake basin ecosystems....*" The acquisition and use of essential information and data on the characteristics of lakes, their basins and their uses, including both scientific/technical and socioeconomic, is fundamental to achieving these goals, all of which contribute to achievement of the broader goal of sustainable use of the important water systems represented by lake systems around the world. Indeed, one of the salient conclusions of the World Lake Vision is that if "*we are able to use lakes in a sustainable and responsible manner, there is much hope we can meet the needs of the human and natural communities that depend on them for clean freshwater resources, the key to life*."

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