Abstract: Despite warnings that clean freshwater is becoming increasingly scarce throughout the World; freshwater ecosystems continue to be under increasing threat from economic development, and this threat is worse in countries that are trying to build their economies and lack resources to protect their environment. Many economists have warned that economic development that destroys environmental resources is unsustainable.

Local expertise capable of evaluating the water quality of lakes and flowing water systems is often missing. Many countries need capacity building programs to help train young scientists in techniques that are commonly used in biomonitoring of aquatic ecosystems in the US, Europe, Japan and South Korea. Biomonitoring of major groups of organisms can be less costly relative to sophisticated instrumentation, and the presence of even tolerant biological organisms is more dependable than chemical concentrations that vary continuously. The most effective groups of organisms for biomonitoring include the diatoms that are often dominant forms of algae in both lakes and riverine systems, aquatic insects, in particular the mayflies, stoneflies and the caddisflies, often referred to as the EPT, and fishes. Biological methods can be used with an adaptive management approach that provides guidance for remediation of polluted water systems by studying levels of degradation or of recovery of ecosystems to or from a more normal state, but this can only be effective as long the skills exist to properly identify lake and river flora and fauna.

Keywords: Capacity Building, Biomonitoring, Rivers, Lakes

“The world economy is inextricably linked to the environment because societies must extract, process, and consume natural resources. All those resources must end up as waste through the principles of mass and energy conservation.” (p. 3-4; Pearce and Warford, 1993, World without End).

1. Introduction

Freshwater ecosystems, lakes and rivers, are being degraded by point and non-point source pollution. The chemical composition of this pollution is complex because it includes organic and nutrient rich effluents from cities, toxic discharges from industries, warm water discharges from electric power plants, and many different non-point source runoffs from agricultural lands containing plant fertilizers, pesticides, animal wastes, and silts and clays from soil erosion. Moderate discharges may only alter physical-chemical conditions and affect only a few biological species, but as the human population has increased in size and resource use, a more complex situation has occurred wherein multiple discharges are seriously disrupting ecosystem services by reducing aquatic biodiversity, eliminating top level fish predators, and altering species’ dominance by changing ratios of nutrients, skewing competitive advantage to specific kinds of algae. In addition, the resultant change in food webs and species’ interactions allows the invasion of exotic species. All of these factors diminish the benefits people derive from aquatic ecosystems. Most major rivers and lakes of the world are threatened by pollution, and as a result, clean freshwater is increasingly scarce, causing serious human illnesses due to contaminated water and causing a serious burden on the economic growth of nations. Clean water is rapidly becoming the most important resource limiting economic development.

Since the early 1980s many economist have cogently argued that environmental protection is an essential component of sustainable economic development. Realization of this is
now evident in many Asian and African nations. The goals of “Sustainable Resource Use” and “Sustainable Ecosystems” and their corollary the protection of “Ecosystem Services” are argued to be the primary pathway towards facilitating economic development, protecting the health of its people and maintaining stable social-ecological systems (Pearce and Warford 1993, Millennium Ecosystem Assessment Synthesis 2005).

1.1 Ecosystem Services

The concept of Ecosystem Services is easily understood by Policy makers and the Public who can appreciate what is lost when an ecosystem’s ability to perform services is damaged due to pollution associated with development. However, to place a dollar figure on the value of “Services” and utilize cost estimates for purposes of arguing for remediation may not be appropriate, particularly when considered as possible end points in remediation of a river or lake (Norton, 2005).

Protection of environmental resources and ecosystem services requires the protection of an ecosystem’s biodiversity. As long as lakes and rivers are used as a means to eliminate human waste and toxic byproducts of industry, biological monitoring of aquatic systems will remain essential as a tool to anticipate future problems or to remediate systems that are already seriously damaged. Monitoring cannot be based solely on technology because applications of technology in the absence of understanding the basis of the problem will lack direction, and as a result could be very expensive but ineffective. Biomonitoring requires analysis of the physical, chemical and biological conditions of aquatic ecosystems. Physical and chemical conditions are highly variable because they are related to immediate discharges into a lake or river. In contrast, biological organisms are part of the system and have generation times that span many discharge cycles from an industry or a city’s sewage treatment facility. Therefore, they provide information on the condition of an ecosystem.

2. Biomonitoring of lakes and rivers

Biomonitoring applies knowledge of the biology of aquatic ecosystems to evaluate conditions of water bodies. Seger and Martens (2005) stated it very succinctly: “Freshwater organisms … reflect quality of water bodies and can thus be used to monitor changes in ecosystem health.”

Biological monitoring, or biomonitoring, is the systematic use of living organisms or their responses to determine the quality of the aquatic environment (Rosenberg et al. 2005). But it must include regular studies of existing organisms in a receiving water body to characterize and evaluate impacts and changes in an ecosystem. Biomonitoring includes the collection and identification of specific individual taxa or of taxonomic groups of plants and animals that are considered to be sensitive indicators of physical and chemical parameters that characterize specific ecological systems, e.g., a section of a river, a lake, or terrestrial habitats. The presence, number and relative abundance of biological species of particular groups (species diversity); groups of algae, aquatic insects and fishes are most commonly used in riverine studies. Expertise in the identification of taxa is necessary to apply these techniques; unfortunately, this knowledge is often based on a cursory training of individuals to perform these studies.

Algae—diatoms and Cyanobacteria are commonly used in biomonitoring. Diatoms are a very diverse group with substantial information available about their distribution and diversity in riverine systems. Cyanobacteria or the blue-green algae are very important in studies of lake eutrophication. Good taxonomy is critical because some forms of the bluegreens accumulate toxic compounds and can cause serious problems when abundant in lakes and reservoirs used as a drinking water source, as occurred in Lake Tai in eastern China in 2007. Three groups of aquatic insects are very good indicators of water quality in streams; the Ephemeroptera (mayflies), Plecoptera (stoneflies) and the Trichoptera (caddis flies). Fishes also are sensitive indicators of water quality both in rivers and in lakes.

The parameters used to characterize water quality in biomonitoring are described in several publications (e.g., Rosenberg and Resh 2008) and will not be repeated here. The Rapid Bioassessment Protocol developed by the US Environmental Protection Agency is widely used and is amenable for use in Asian streams and rivers, assuming individuals have some training in this method. It is particularly important to use similar biomonitoring techniques in longitudinal studies of large river systems such as the Yangtze or Mekong so that comparisons among sites can be made among
polluted sections in comparison with undisturbed and recovery sections of the river.

The real benefits of biomonitoring lie in the ability to determine when aquatic habitats are being destroyed or during recovery from prior pollution events.

3. The need for Capacity Building:

Capacity building refers to training individuals by introducing them to the problems, to the theory and to means of studying the problem and its resolution. Capacity building for biomonitoring of lakes and streams is not about providing water resources for citizens but about maintaining clean water resources and restoring damaged aquatic ecosystems to ensure that freshwater is available for continued use. Understanding the concepts associated with biomonitoring can be most effective with training in the theory of Ecology and the ability to identify organisms of specific groups of organisms that are sensitive to pollutants.

3.1 Theory of Ecology

The theory of ecology is highly relevant to environmental protection and remediation of polluted and disturbed systems because it can help detect deviations from an expected norm and define desirable futures or end points for ecosystem management leading to “sustainable” ecosystems. Theory represents concepts often developed mathematically and tested experimentally, though actual observational data are the foundation of theory as well as needed for tests of theoretical concepts. Theory tested with observational data and models is robust and can be very helpful in understanding critical measurements or tests needed for determination of the most effective approach to solving ecosystem problems.

We will briefly discuss three important theoretical community and ecosystem concepts relevant to understanding problem solving in managing ecosystems:

1. Ecosystem Services
2. Species richness and biodiversity
3. Alternative stable states

3.2 Ecosystem Services

In a broad sense, Ecosystem Services could be considered a part of the theory of ecosystem ecology. As defined by the Millennium Assessment (2005), ecosystem services are “the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial benefits.” Ecosystem Services also includes the need for decomposition of organic matter along with the recycling of nutrients; two processes critical to the maintenance or restoration of aquatic habitats.

3.3 Alternative Stable States

Alternative stable states represent the potential of a given habitat to be represented by more than one characteristic set of organisms. A very good example of this occurs in lakes that may be characterized either by Cyanobacteria blooms with very turbid water or by very clear water conditions with a lush growth of rooted aquatic plants (Scheffer et al. 1993). This can be relevant in our understanding of ecosystem remediation is that lakes with Cyanobacteria blooms are poor sources of potable water; whereas, the water of lakes with clear water and rooted aquatic plants is more likely to be potable. It should be feasible to shift the balance from one state to a second, more desirable state once we better understand the nutrient conditions of lakes.

3.4 Biodiversity

Biodiversity refers to the richness of species in an ecosystem. In monitoring, it is the number of species found to represent an ecosystem. Theoretical and experimental ecological data unequivocally demonstrate that ecosystem stability and maintenance of ecological functioning are dependent upon species diversity or basically the number of species present and the degree of connectance among species (Tillman 1997). What this means for ecosystems is that when a disturbance occurs, species that are intolerant to the disturbance will be affected but tolerant species will maintain their populations and can expand to utilize the resources of the locally extinct intolerant populations, maintaining connectance within a food web. Productivity and many ecological services will be sustained and the ecosystem returns quickly to a stable state. However, if several different kinds of disturbances occur simultaneously, as usually occurs in rivers or lakes that receive numerous
kinds of wastes, several species’ populations are eliminated, making it impossible to replace components of a food web; connectance becomes unstable and ecosystem services are lost. Thus, understanding biodiversity is very relevant to monitoring the water quality and the need for reduction of discharges to a critical water resource.

4. Taxonomy of Aquatic Organisms

At a minimal level it is essential that evaluations of aquatic ecosystems depend upon knowing the number and kind of biological species present, or species richness. To accomplish this, it is necessary to develop local skills of individuals by training them to become specialist in the identification of specific groups of aquatic organisms. Many countries have the need for trained individuals but lack the expertise for training students. In a recent important review of freshwater biomonitoring with macroinvertebrates in East Asia (Morse et al. 2007), the authors summarized the problem as follows:

- “Japanese and Russian benthologists have conducted research on freshwater macroinvertebrates for over 50 years; similar studies have been undertaken in China, South Korea, Thailand, Malaysia, and Mongolia to a lesser degree.
- Current challenges to implementing macroinvertebrate biomonitoring in these countries include limited scientific knowledge of the fauna, few or no training opportunities, and poor understanding of the benefits.” (Morse et al. 2007, p. 33, Frontiers in Ecology).

There is a critical need for capacity building in the identification or understanding the taxonomy of at least the basic groups of organisms used most in biomonitoring: algae (Cyanobacteria, diatoms, aquatic macroinvertebrates and fishes). Where these skills are absent, the result of biomonitoring gives a false impression of species richness. In many regions, macroinvertebrate insects are identified only to genus or order; whereas, in other regions, a more exact identification to species may be possible. This makes it very difficult to establish generalized comparisons even within the same river system where the river crosses many boundaries.

In contrast, aquatic ecosystems that have economic value to governments, industry and the Public depend upon local governments to protect the benefits from these ecosystems. But for large rivers and lakes that span several provinces, states or nations, or have large cities and industries located nearby with poor sewage treatment facilities, serious damage is occurring to these ecosystems due to the absence of sufficient funding or consensus on how to protect these resources, to properly eliminate waste material or to protect rivers from non-point sources due to erosion. In the United States the greatest impact on rivers comes from agricultural non-point discharges and this must also be true throughout Asia.

The knowledge required and local expertise capable of evaluating water quality of lakes and flowing water systems is often inadequate, yet desperately needed. Advanced education is too often done without direction because poor countries lack financial resources to support graduate education or basic and applied research. Therefore, funding for graduate training for young scientists from poorer countries is often left to individuals and their families; the general and accepted pattern for young scientists is for them to travel abroad to study in a U.S. or European academic university. If they major in ecology or limnology, they may receive the essential training that will help in environmental remediation and may be introduced to relevant theoretical concepts. After receiving their degree they may or may not return to their home country to find a position in a university and help train other students who do not have the financial support to study abroad. Whether or not they are able to contribute new ideas to environmental protection and pollution abatement depends on the receptiveness of local government officials to new ideas.

5. Conclusions and Recommendations:

Biomonitoring is essential to understanding water quality conditions of lake and river water resources. Good taxonomic training is essential for biomonitoring; capacity building must be a critical part of this so that trained individuals can understand the elements of protection and remediation of aquatic habitats.

It is important to determine the optimal expertise required in biomonitoring. Capacity building to train individuals in biomonitoring through workshops followed by taxonomic training by specialist for individuals who in turn can train others and help build the critical mass of specialist for biomonitoring is very important. To accomplish this training,
international funds are needed for many countries to make capacity building possible. At a minimum, countries should adopt a standardized biomonitoring technique (e.g., Rapid Bioassessment Protocol of US EPA) as a beginning. The GEMS program would be a good example to follow or to help organize such a program if new funds were available. International guidelines for remediation of aquatic ecosystems would greatly help reduce the need for each country to develop their own methodology.

References

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