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EDITORIAL

Ecological conservation and the restoration of freshwater environments in Korea

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Freshwater ecosystems worldwide are subjected to a variety of anthropogenic threats (Malmqvist and Rundle 2002). Inappropriate land use practices, pollutants, overexploitation, and overpopulation have simplified/fragmented aquatic habitats and degraded biodiversity and water quality. In fluvial systems, human threats result from relatively slight use, such as, sports activities (e.g., canoeing and rafting), to severe pollution of water quality (inflow of nutrient-enriched sewage and a large amount of nonpoint source pollution loads), and damage to stream morphology (e.g., channelization and straightening) and the flow continuum (e.g., impoundment by large dams and weirs). Thus, conserving and reviving freshwater health and biodiversity are increasingly becoming global aims to ensure ecosystem integrity and freshwater ecosystem sustainability.

Freshwater is a crucial resource for nature and man, and a biodiversity hotspot, which supports almost 10 % of all known animal species (Strayer and Dudgeon 2010), but they are much more vulnerable to disturbances than other ecosystems (Cushing and Allan 2001). Nevertheless, despite global attention on biodiversity imperilment in freshwater ecosystems for decades, increasing human pressures will accelerate species loss. Dudgeon et al. (2006) apprehended the extinction of freshwater animal species at a rate of 4 % per decade in North America, which exceeded by several fold that is expected of terrestrial species. In the case of Korean freshwater fishes, 63 of the 215 species (29.3 %) are endemic and 26 (12.1 %) are designated as 'Critically Endangered,' 'Endangered,' or 'Vulnerable' based on the IUCN (International Union for the Conservation of Nature and Natural Resources) red list, which portends a consistent decrease in their numbers (MOE/NIBR 2012). Intensive human-centered land use practices, such as, agricultural activities and urbanization, over decades have severely altered most stream and river ecosystems in Korea through excessive water use, which threatens water security and biodiversity (Jeong et al. 2010). Consequently, very few Korean streams and rivers remain undisturbed, and currently these compose only 5 % of reference streams listed in the National Aquatic Ecological Monitoring Program (NAEMP) database (Jun et al. 2012).

"Restoration of the ecological integrity of the nation's water" is one of the most important objectives of legislation concerning water environment management and conservation and related policies in many countries (e.g., US EPA 2011). This is also the case in Korea, where the Water Quality and Aquatic Ecosystem Conservation Act, and water environment management programs declare the importance of the health and integrity of aquatic ecosystems (MOE 2007). Given the implementation of national investment in water infrastructure and regulation, much work has been done to restore aquatic ecosystems, particularly rivers and streams. However, although major water quality improvements have been achieved (e.g., BOD) over the past three decades, many environmental challenges remain, such as, loss and destruction of habitat, altered

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hydrology, invasive species, stormwater management, eutrophication, and nonpoint source pollution. In the face of such challenges, it is important that water environment management programs be deployed to meet the vision encapsulated in the Water Quality and Aquatic Ecosystem Conservation Act to protect aquatic life.

Korea recently adopted biological criteria and the concept of ecosystem health given the recognition of the limitations of applying chemical parameters to the management of aquatic ecosystem integrity. Such biologically orientated activities have become important aspects of surface water management policy, and for this reason, NAEMP was established in 2007. This monitoring program includes evaluations of biological and habitat characteristics of river and stream ecosystems across the country at 960 sites. The four-class NAEMP assessment system designates ecosystem health as excellent (Class A), good (Class B), fair (Class C), or poor (Class D). Monitoring results collected over the 5-year period 2008–2012 show that 51, 44, and 28 % of total measured sites by benthic diatoms, fishes, and benthic macroinvertebrates, respectively, belong to the fair or poor classes (MOE/NIER 2013). Furthermore, the average of these proportions was about 2.7-fold higher than that measured and classified using the BOD standard. Similar results were also reported by Lee et al. (2011). These results indicate that many rivers and streams in Korea have been severely degraded and require active restoration.

Because streams and rivers are important economically and ecologically, the restoration of fluvial ecosystems is receiving much attention worldwide (Dobson et al. 1997; Palmer et al. 2007). Ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration International, SER 2004). Furthermore, in addition to addressing ecological systems, restoration practices require consideration of the "socio-ecological ecosystems" on which societies depend (van Andel et al. 2012), and thus, successful restoration is a multifaceted issue. Moreover, ecological restoration draws knowledge, ideas, and data from disciplines as diverse as landscape ecology, including geomorphology and hydrology, community ecology along with considerations of soil and water physics, chemistry at the ecosystem scale, and physiology and genetics at organism and population levels. However, to address and engage the entire restoration process, we must incorporate socio-economic and human science (Mascia et al. 2003).

From the practical perspective, it is important to develop and apply sound suitable technologies that are applicable to disturbed ecosystems. Aquatic ecosystems, particularly fluvial systems, are ultimately set by regional climate, geology, and vegetation, but disturbances are likely proximated by human use. Thus, to ensure good results from restoration programs, sound restoration technologies that embrace the geological and environmental properties of target aquatic ecosystems and their watersheds should be incorporated. To meet the governmental vision of ecosystem health depicted by the national Act of aquatic ecosystem conservation and subsequent implementation strategies, the Korean government (Ministry of the Environment) established the Center for Aquatic Ecosystem Restoration (CAER) in 2007, as a part of the national Eco-STAR project. The main goal of CAER is to develop eco-friendly, practical, commercial technologies for aquatic ecosystem restoration that is commensurate with the regional and national characteristics of Korean aquatic ecosystems. Through the development of such technologies, the government intends to expand the restoration industry to support the green growth concept and to recover aquatic ecosystem health, and thus, to contribute to Korean quality of life.

The research and development conducted at CAER for more than 6 years since 2007 under the project name "Development of technologies for aquatic ecosystem restoration and management" consists of 5 areas and 17 unit projects (Table 1). The total budget of the whole project is ~80 billion KRW (80 million USD), and to date, 650 research staff representing fields as diverse as ecology, biology, limnology, toxicology, landscape architecture, environmental engineering, civil engineering, hydrology and hydraulics, environmental economics, and education and environmental law have participated. Almost 7 years of achievement by CAER have substantially improved technical and scientific understanding of aquatic ecosystem restoration; a total of 189 unit technologies have been developed, and some have already been applied in commercial restoration projects in Korea and overseas. In particular, the CAER project has contributed to the growth of aquatic ecosystem restoration enterprises in Korea, and provided valuable opportunities to understand aquatic ecosystems, particularly fluvial system structures and functions.

The results described in this special issue provide an overview of the project led by CAER over the past 6 years. This issue contains 19 papers (18 articles and 1 technical note) that deal with scientific and technological information related to restoration practices and covers a variety of subjects and disciplines. The presented works can be arbitrarily divided into four groups, as follows: (1) techniques for monitoring, assessing, and modeling aquatic ecosystems and watersheds, (2) techniques for restoring and improving riparian green space, lakeside land, fishways, sediment continuity, and water quality, (3) geomorphic parameters and their effects on flow, soil erosion, the ecological conditions of rivers, and (4) techniques and parameters used to construct and manage wetlands.

Table 1 Major R&D areas and projects led by the Center for Aquatic Ecosystem Restoration in Korea between 2007 and 2014

Major areas of R&D	Individual projects included in each major area
Habitat physical continuity	(1) Habitat restoration technology in aquatic ecosystem
	(2) Land-forming management techniques in stream
	(3) Natural riparia creation and management techniques
Water environment	(4) Water purification ecotechnology
	(5) Effective nonpoint source control technology
	(6) Water supply technology for ecological river rehabilitation
Riverine ecosystem	(7) Riparian greenspace and eco-corridor establishment technology
	(8) Waterfront and ecotone maintenance technology in the lake
	(9) Wetland construction and management technology with low greenhouse gas emission
Aquatic ecosystem health	(10) Risk assessment and management technology in aquatic ecosystem
	(11) Evaluation of ecological integrity in lake ecosystem
	(12) Development and application of stream naturalness evaluation method
Project foundation	(13) Communication program for aquatic ecosystem restoration
	(14) Legal system improvement and policy alternatives for aquatic ecosystem restoration and management
	(15) Strategic plan for aquatic ecosystem restoration project
	(16) Case-study project of river ecological restoration
	(17) Development of manual for aquatic ecosystem restoration and management

To summarize the major points made by articles in this special issue, Han et al. (2014) determined the trophic status of agricultural reservoirs and provided a method for assessing lentic ecosystem health using multi-metric models of fish assemblages. The model shows that the health of agricultural reservoirs is directly affected by organic pollution and excessive algae production. Lee et al. (2014c) explored a model of integrated water quality indices for lakes and reservoirs using four parameters: total organic carbon, chlorophyll-*a*, total phosphorus, and turbidity levels. This model provides a relative evaluation system that can be useful for ecosystem management within an ecoregion or a jurisdiction. Seo et al. (2014) described a method for classifying plant species that provides indicators of lake eutrophication and ecosystem health based on trophic state indices. Global warming and subsequent climate change are increasingly becoming global issues in the context of water resource management, and adaptation to climate change requires assessments of potential disaster risks. Jung et al. (2014) used flood risk index to predict regional flood characteristics at the national level and to prioritize factors affecting flood risk. Shin et al. (2014) evaluate the impact of climate change on river hydrology by predicting future forest vegetation changes caused by a climate change scenario in Korea. Park et al. (2014a) addressed best management practices, such as, streambank stabilization, building recharge structures, conservation tillage, and terrace and contour farming, to reduce nonpoint source pollution loads under future climate change scenarios using SWAT modeling. Park et al. (2014b) examined seasonal variations in forest soil moisture, an important hydrologic component of water balance analysis, using remotely sensed information and SWAT modeling. Lee et al. (2014a) simulated bed form-induced hyporheic flow exchange using a fully coupled hydrodynamic model, and showed that upwelling and downwelling flow patterns are dominantly controlled by recirculation zones and stagnation points in the pool-riffle structures.

The riparian zone is a crucial part of river and stream restoration and management practices, as it makes important contributions to the mitigation of flood impact and soil erosion, to improvements of water quality and wildlife habitats, microclimate amelioration, and carbon sequestration. Jo and Ahn (2014) analyzed structures of natural riparia and explored planting models applicable to the establishment of riparian greenways. Jo et al. (2014) also addressed strategies for ameliorating problems existing in riparian greenspace by analyzing growth environments, vegetation structures, planting techniques, and tree growth and management conditions. Kim and Song (2014) explored the plant growth promoting ability of rhizobacteria in an effort to re-vegetate barren lakesides by enhancing wild plant growth. Kim et al. (2014d) addressed the problem of sediment deposition by investigating the use artificial transverse structures in rivers and examined the sediment exclusion efficiency of several types of modified labyrinth weirs to improve longitudinal sediment continuity. Kim et al. (2014b) also examined the efficacy of fishways constructed in large dams by analyzing the movement patterns of three freshwater species. Oh et al. (2014) described the mechanical properties and water purification characteristics of natural jute fiber-reinforced non-cement alkali-activated porous blocks in lakes and rivers with a view toward improving vegetation growth.

The geomorphology of waterbodies and watersheds affects all aspects of the water environment, such as, hydrology, hydraulics, water quality, and biological

conditions, and thus, is a critical consideration for restoration and management practices. In this regard, Kim et al. (2014a) concluded that a streamline geometry mediates the influence of urban land use effect on biological water quality as assessed by fish assemblages. In addition, Lee et al. (2014b) demonstrated that watershed slopes affect recharge/baseflow and soil erosion.

Wetlands are valuable ecosystems and serve as hot spots of biodiversity and places for improving water quality and sequestering carbon. Thus, the construction of effective artificial wetlands and sound management are important aspects of restoration practices. Kim et al. (2014c) sought to identify an effective means of planting *Sphagnum* to create a wetland in an urban ecosystem by analyzing the effect of nitrogen addition on its growth and decomposition. Hong and Kim (2014) confirmed the role of winter buds and rhizome morphology on winter survival and on the subsequent growth of reed. Hong et al. (2014) described interspecies competition between five emergent macrophytes in a constructed lentic wetland, and produced information useful for predicting the early succession and development of aquatic plants in constructed wetlands.

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