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Guest Editorial, part of a Special Feature on Restoring Riverine Landscapes

Restoring Riverine Landscapes: The Challenge of Identifying Priorities, Reference States, and Techniques

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ABSTRACT. This special issue of Ecology and Society on restoring riverine landscapes draws together nine presentations from the Second International Symposium on Riverine Landscapes, convened in August 2004 in Storforsen, Sweden. We summarize three themes related to river restoration: (1) setting priorities, (2) identifying relevant reference conditions, and (3) choosing appropriate techniques. We discuss ways of developing river restoration and provide examples of future needs in sustaining functioning river ecosystems that can support human societies.

Key Words: *reference conditions; restoration objectives; restoration techniques; river restoration.*

INTRODUCTION

Worldwide, rivers are the type of ecosystem most affected by humans. This high level of impact has a number of reasons. Rivers provide ecosystem goods and services that sustain human societies; therefore, the history of impacts on rivers is as long as human history; dating from early civilizations, e.g., the Nile in ancient Egypt, the Euphrates and Tigris in Mesopotamia, and the Yellow and Yangtze in China (Duan et al. 1998, Shaw 2003, Korn 2004). Rivers occupy the lowest positions in landscapes; thus, collecting and integrating impacts occurring over entire catchments (Naiman et al. 2002). Consequently, rivers are excellent indicators of environmental change. Further, natural rivers have the capacity to harbor a large variety of habitats and species (Ward et al. 1999, Naiman et al. 2005). This is because they act as conduits for varying amounts of water in more or less unstable channels, making them naturally dynamic (Leopold et al. 1995). Human-related impacts on natural as well as artificial river flows or channels, therefore, result in immediate ecosystem responses.

Humans have only recently started restoring or rehabilitating impacted rivers (Bernhardt et al. 2006, Palmer and Allan 2006, Jansson et al. 2007). Researchers are closely following this development as evidenced by the increasing number of articles addressing river restoration ecology in the last two decades (Fig. 1), and the billions of dollars spent annually on restoration (Bernhardt et al. 2005). Nevertheless, better coordination among research efforts and improved communication are needed for restoration efforts that are effective (Poff et al. 2003, Palmer et al. 2004, Wohl et al. 2005). In order to meet this demand, the Second International Symposium on Riverine Landscapes (SISORL) was convened in August 2004 in Storforsen, Sweden. The theme was river restoration and a group of more than 80 prominent researchers from 17 countries, representing a broad array of disciplines, met for a week to exchange information and to provide their views. A subset of the contributions from this symposium is presented in this Special Feature, offering several basic themes related to river restoration. One theme is setting priorities. This is vitally important because currently development emphasizes human requirements to the detriment of natural ecological processes in rivers, thus causing deterioration of natural environments. Another theme addresses undertakings to mitigate or reverse these effects, i.e., the techniques of river restoration. In this context ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER 2004). A third theme is the challenge of identifying relevant reference conditions at which to aim. In reality, this challenge is the equivalent of hitting a moving target in a constantly changing world.

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SETTING PRIORITIES: EMPHASIS ON HUMAN REQUIREMENTS

The maintenance of most natural environments has always had a relatively low priority in many of the world's societies. However, as a result of increasing prosperity, growing urbanization, declining aquatic-related diseases, and escalating human impacts such as pollution, regional water diversions, and mega dams, the public's position on rivers in many industrialized countries has shifted in favor of a better environmental balance. As a result, legislation has been introduced to assist in achieving this goal. Even though the development of the ecosystem concept has been important, and progress within hydrology and geomorphology has offered new tools, there has been reluctance by many academic ecologists to accept humans as integral parts of ecosystems (Reuss 2005). It is important to appreciate this history if one is to understand present-day situations. Nevertheless, today most ecologists recognize the necessity to work with planners and engineers in creating environmentally responsible solutions for water resources.

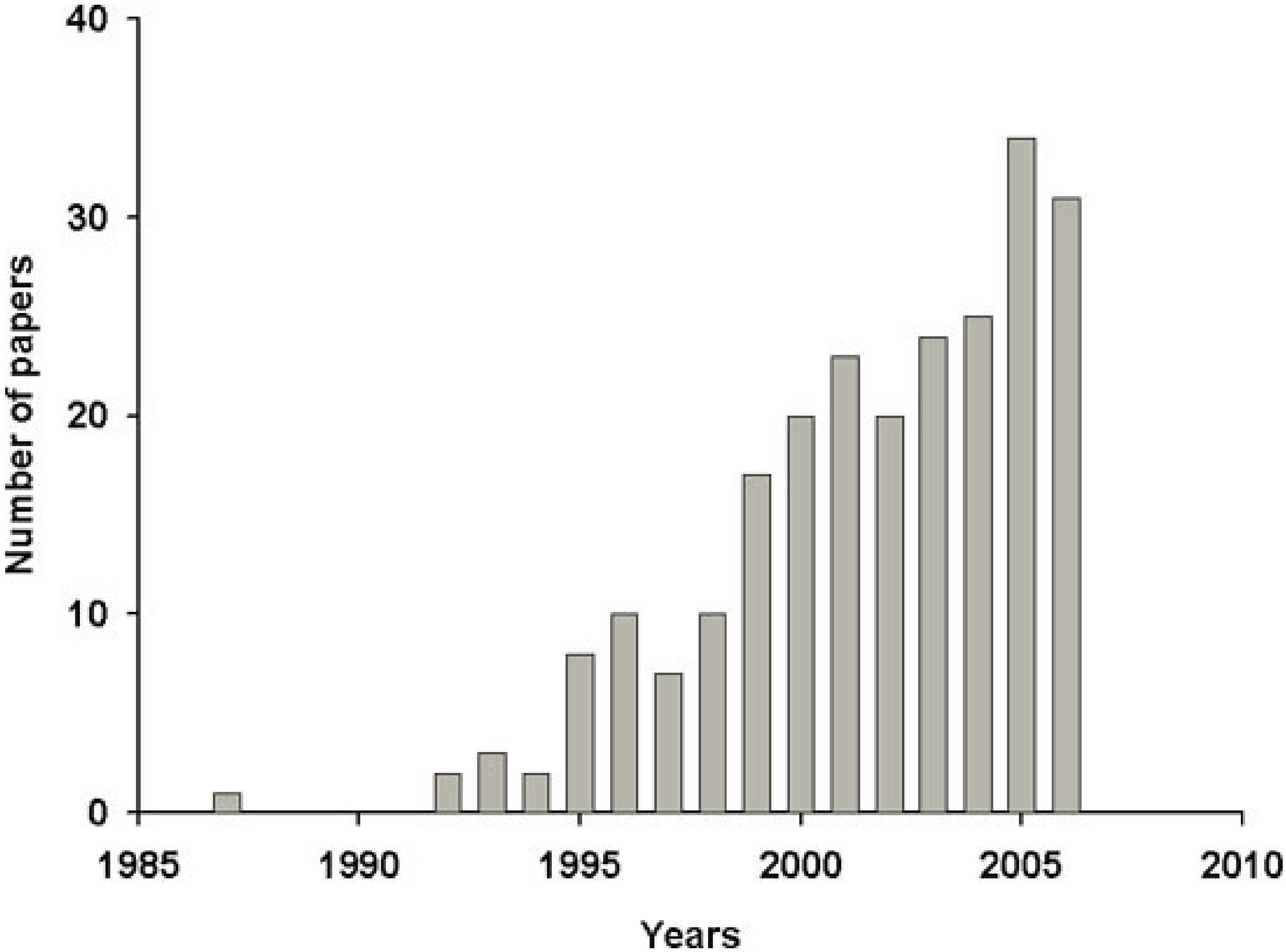
Human interference with freshwater ecosystems has severely affected their natural physical characteristics and biological complexity, thus undermining their productivity and resilience. For example, in North America by year 2000, 27 species of freshwater fish had gone extinct in the previous century and 37% of the more than 1200 freshwater fish species were at risk of extinction. Ten species of mussels were known to have gone extinct during the same period and 188 of the remaining 281 mussel species were considered rare or imperiled (Abell et al. 2000). Strikingly similar erosion of biodiversity is underway in other parts of the world experiencing rapidly increasing economic growth (Dudgeon et al. 2006). For example, in tropical Asia where there is no legislation specifically regulating environmental protection or conservation to protect biodiversity, overexploitation of rivers has caused many fish populations to collapse (Dudgeon 2005). Legislation has been introduced throughout Asia to control water pollution, primarily because of the danger it poses to human health. Where enforced, existing legislation can be effective against point-source polluters, but it has been ineffective against the organic contamination from non-point agricultural and domestic sources that severely affect rivers such as the Ganges and Yangtze. As in North America (Reuss 2005), Asian river scientists have had little influence on policy makers in implementing an effective environmental perspective in water development projects. Finding avenues for such collaboration is of utmost importance for developing sustainable catchment management (Naiman 1992, Falkenmark et al. 2004). South Africa provides an encouraging example where management of environmental flows has been successful in this way (e.g., King and Brown 2006), but there remain many challenges ahead (Arthington et al. 2006).

IDENTIFYING REFERENCE CONDITIONS

When deterioration has reached states in which rivers are heavily compromised, restoration might be the only option if rivers are again to provide useful environmental services. In an ideal world, one may want to restore rivers to what one perceives as a "pristine state." However, identification of such states requires knowledge about previous human impacts. In many cases, ignorance about historical land use and about the associated effects on rivers makes it impossible to discover the degree to which rivers have been altered from natural conditions and to conclude what kinds of restoration are needed (Wohl 2004). Therefore, restoration attempts may set goals that are too idealistic or ones that are based on incorrect assumptions. Many rivers may give a false impression of naturalness although they have been significantly impacted during the last few centuries by multiple human activities, e.g., beaver removal, placer mining, log transport, flow regulation, to an extent that their present ecological integrity is heavily compromised (e.g., Wohl 2004).

Although historic land use can be revealed, and the understanding of pristine ecosystem states enhanced, it is, however, not self-evident that restoration should try to mimic attributes of previous ecosystems. There are six reasons for caution with respect to reference systems: (1) Often there are no suitable reference systems to mimic; (2) many catchment qualities have changed since the time period chosen for a historic reference system; (3) changes in climate and biota have been continuous throughout the Holocene; (4) expected climate change is of uncertain magnitude; (5) non-native species cannot be avoided; and (6) landscape context changes through time (Hughes et al. 2005). To reduce the risk for mistakes, Hughes et al. (2005) recommend that restoration projects should moderate the ambition of identifying specific target states and instead formulate trajectories that

Fig. 1. Diagram showing the increase in number of articles including “river,” “restoration,” and “ecology” over the last 20 yr. Data were extracted from the Web of Science by 23 January 2007. In total, 237 journal articles were found. Note that this graph is intended to show the trend. The real number of papers is certainly higher because authors can use equivalent terms, other than those used in the search.



accommodate some levels of both variability and unpredictability, i.e., inherent conditions of natural systems. For obvious reasons, this would provide an increased scope for adaptive management.

One apparent, but easily forgotten, reason why pristine ecosystem states are unrealistic targets for restoration is that the human involvement is much more influential now than ever before. Restoration copes with historic conflicts between needs of humans and needs of natural ecosystems. As the future unfolds, there will be shifts in the ways water is managed, from less command and control to more integration and adaptation (Pahl-Wostl 2006). For example, instead of fighting floods, humans can relearn how to live with them. Social learning has an important role in the transition toward the adaptive management necessary to restore multifunctional riverine landscapes, especially in a world experiencing increasingly changing climates.

So, in order to achieve successful river restoration, it is necessary to identify and target ecosystem states that would be able to interact with current surrounding landscapes, including other parts of the river, and that would be appreciated, or at least accepted, by human societies.

CHOOSING APPROPRIATE RESTORATION TECHNIQUES

One of the most pressing river management questions is how water should be shared between humans and ecosystems (Falkenmark and Rockström 2004). Human-centered attitudes toward water have deteriorated many riverine ecosystems, implying that the derived benefits have brought considerable environmental and social costs. However, by modifying flow releases from dams, the environmental and social benefits afforded by natural ecosystems may be partially recovered. Worldwide, many attempts have been made to determine appropriate ways of making such releases (Tharme 2003). An assessment framework can be used to evaluate the benefits that might be restored through dam re-operation (Richter and Thomas 2007). This involves characterizing the dam's effects on the river flow regime, and formulating hypotheses about potential ecological and social benefits from restored natural flow patterns. These hypotheses are then tested by implementing re-operation, tracking the response of the ecosystem, and refining dam operations through adaptive management. It is not yet known how efficient such dam re-operations will be, but there are observations demonstrating that they can improve the ecological integrity of rivers (e.g., Bednarek and Hart 2005).

Re-operation of dams is especially challenging in the dry, water-stressed, and data-poor regions of developing countries. In South Africa, such problems have been tackled and worked into legislation that gives only two sectors rights to water: ecosystems and basic human needs. There are five major tasks underpinning the success of this approach: (1) transforming hydrologic data into a form that ecologists can use; (2) making holistic quantitative predictions of how flow manipulations can change rivers, especially in situations with few data; (3) describing how river changes can affect rural users of rivers; (4) informing and educating decision makers; and (5) guiding monitoring and adaptive management (King and Brown 2006). The need for realizing these tasks and approaching a holistic management of scarce water resources is most immediate in regions with rapidly growing demands on water (King and Brown 2006).

Human alteration of riverine ecosystems involves not only changes to flow regimes but also simultaneous changes in hydrologic connectivity. In general, physical fragmentation has a major impact on the world's rivers (Nilsson et al. 2005). Fortunately, there are indications that connectivity is prioritized in many restoration projects, but often over flow dynamics (Kondolf et al. 2006). Trajectories of degradation and restoration suggest that restoration measures to improve connectivity and flow dynamics are rarely parallel (Kondolf et al. 2006). This discrepancy obviously depends on political and economic factors; restoring connectivity is simply easier. Such restoration actions include removing dams to restore fish passage, reconnecting flow through artificially cut-off side channels, setting back or breaching levees, and removing fine sediment deposits blocking vertical exchange with the riverbed. Although restoration of natural connectivity is important, artificially increasing connectivity alone can have negative consequences, e.g., by facilitating invasion of nonnative species. Therefore, enhancements of connectivity require thorough analysis and, ideally, should be carried out in concert with rehabilitation of flow dynamics.

Many river restoration projects target heavily canalized reaches, thereby involving the creation of a new channel. In such cases, and especially in the United States, it has become fashionable to create stable, meandering channels, even if those were never a pristine feature of the river (Kondolf 2006). Although postproject appraisals of such restoration efforts show mixed results, they continue to be popular for practical as well as cultural, aesthetic reasons. Meandering channels are reasonably easy to construct and people find them attractive. This is an excellent example of how human preferences can ignore ecological principles showing that dynamically migrating channels have great ecological richness (Ward et al. 1999).

Many different factors combine to affect management decisions relating to river restoration (Findlay and Taylor 2006), thus challenging the development of restoration ecology. Restoration of river ecosystems increasingly challenges ecological science because of the growing human population and its mounting pressure on rivers, combined with the environmental adaptations required to effectively respond to global changes in climate and hydrology. Avoiding environmental and human tragedies requires that, in the future, rivers are able to sustain themselves as functioning ecosystems. It is therefore vital that scientists representing the various fields involved in river restoration develop interdisciplinary efforts among themselves, as well as form interactive collaborations with planners, engineers, and politicians. It is of utmost importance to expand the discussion on what should be the most appropriate targets for restoration and the most cost-effective means of achieving clearly stated goals. We hope that this special feature will contribute to this development.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol12/iss1/art16/responses/

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