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THE ROLE OF RIPARIAN CORRIDORS IN MAINTAINING REGIONAL BIODIVERSITY[1]

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Abstract. Riparian corridors possess an unusually diverse array of species and environmental processes. This "ecological" diversity is related to variable flood regimes, geomorphic channel processes, altitudinal climate shifts, and upland influences on the fluvial corridor. This dynamic environment results in a variety of life history strategies, and a diversity of biogeochemical cycles and rates, as organisms adapt to disturbance regimes over broad spatio-temporal scales. These facts suggest that effective riparian management could ameliorate many ecological issues related to land use and environmental quality. We contend that riparian corridors should play an essential role in water and landscape planning, in the restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts.

Key words: biodiversity; fluvial ecosystems; hydrologic connectivity; landscape; policy; riparian corridor.

Natural riparian corridors are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth. Riparian corridors, as interfaces between terrestrial and aquatic systems, encompass sharp environmental gradients, ecological processes, and communities. Riparian corridors are an unusually diverse mosaic of landforms, communities, and environments within the larger landscape. As such, we believe they serve as a framework for understanding the organization, diversity, and dynamics of communities associated with fluvial ecosystems (Naiman et al. 1988, Gregory et al. 1991).

The riparian corridor encompasses the stream channel and that portion of the terrestrial landscape from the high water mark towards the uplands where vegetation may be influenced by elevated water tables or flooding, and by the ability of soils to hold water. The width of the riparian corridor, the level of control that the streamside vegetation has on the stream environment, and the diversity of functional attributes (e.g., information flow, biogeochemical cycles) are related to the size of the stream, the position of the stream within the drainage network, the hydrologic regime, and the local geomorphology. For example, the riparian corridor is often small in the numerous headwater streams that are almost completely embedded in the forest. In mid-sized streams the riparian corridor is larger, being represented by a distinct band of vegetation whose width is determined by long-term (>50 yr) channel dynamics and the annual discharge regime. Riparian corridors on large streams are characterized by well-developed, geomorphically complex floodplains with long periods of seasonal flooding, lateral channel migration, oxbow lakes in old river channels, a diverse vegetative community, and moist soils (Salo et al. 1986, Naiman et al. 1992).

Ecological investigations of riparian corridors have demonstrated them to be a key landscape feature with substantial regulatory controls on environmental vitality (Naiman et al. 1992). Streams are non-equilibrium systems with strong effects on habitat formation and stability, on the attributes of riparian vegetation, on local geomorphology and microclimate, and on the diversity of ecological functions. The riparian corridor is frequently disturbed by floods and debris flows, creating a complex shifting mosaic of landforms over a spatial scale ranging up to 10^7 m (Salo et al. 1986, Swanson et al. 1988). Consequently, plant species richness varies considerably in space and time along stream margins, and these variations have important influences on the in-stream biota and processes. It is well known that riparian vegetation regulates light and temperature regimes, provides nourishment to aquatic as well as terrestrial biota, acts as a source of large woody debris (which significantly influences sediment routing, channel morphology and in-stream habitat), regulates the flow of water and nutrients from uplands to the stream, and maintains biodiversity by providing an unusually diverse array of habitat and ecological services (Naiman and Décamps 1990). We believe that

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many of the ecological issues related to landuse and environmental quality could be ameliorated with effective riparian corridor management.

Riparian Corridors Require a Landscape Perspective

We view the term "biodiversity" as encompassing the presence of species *and* ecological processes, and it may be more properly referred to or thought of as "ecological diversity." The maintenance of biodiversity requires a landscape perspective, especially for fluvial ecosystems whose drainage networks are embedded in the landscape. We also view the riparian corridor as the heart of the drainage basin since it may be *the* ecosystem-level component most sensitive to environmental change (Naiman et al. 1988, 1989). It is our working hypothesis that delivery and routing of water, sediment, and woody debris are the key processes regulating the ecological characteristics of riparian corridors, and it is the dynamics of these materials that are affected by alterations to the landscape. Available evidence suggests that ecologically diverse riparian corridors are maintained by an active natural disturbance regime operating over a wide range of spatial and temporal scales. Ecologically diverse riparian corridors are dependent on the nature of the disturbance (e.g., floods, fire, landslides, debris torrents, channel migration) and the ability of the biotic system to adjust to constantly changing conditions (Kalliola et al. 1992). The natural disturbance regime imparts considerable spatial heterogeneity and temporal variability to the biophysical components of the system. In turn, this is reflected in the life history strategies, productivity, and diversity of the ecological community. In support of these statements we offer the following observations related to the biodiversity of riparian corridors.

Even though the riparian corridor has been recognized for its high levels of biodiversity, it is still not known how many species are present for any system (Nilsson 1992). This is remarkable, considering that >80% of the riparian corridor area of North America and Europe has disappeared in the last 200 yr. The general modification of this important habitat is continuing on a global scale, with little attention being paid to the ecological or human consequences of these changes (Décamps and Naiman 1989, Petts et al. 1989). Biodiversity is best documented for vascular plants, even though nearly 70% of vertebrate species in a region will use riparian corridors in some significant way during their life cycle (Raedeke 1989).

Studies of riparian vascular plants in Sweden (Nilsson 1986, 1992, Nilsson et al. 1989), in Finland (Kalliola and Puhakka 1988), in the Peruvian Amazon basin (Salo et al. 1986, Junk 1989, Kalliola et al. 1992), in southern France (Tabacchi et al. 1990, Décamps and Tabacchi 1993), and in the northwestern United States (Raedeke 1989, Gregory et al. 1991) all demonstrate unusually high levels of biodiversity. For example, Nilsson (1992) reports 13% (>260 species) of the entire Swedish flora of vascular plants occurring along a single river corridor; Junk (1989) reports that all periodically flooded forests in the Amazon basin may have ≈20% of the 4,000-5,000 estimated Amazonian tree species; and Tabacchi et al. (1990) report over 900 taxa of vascular plants along the Adour River riparian corridor in France.

The reasons for the high diversity of vascular plants are thought to be related to (1) the intensity and frequency of floods, (2) small-scale variations in topography and soils as a result of lateral migration of river channels, (3) variations in climate as streams flow from high to low altitudes or across biomes, and (4) disturbance regimes imposed on the riparian corridor by upland environments. The migration capacity of plants along riparian corridors is also an important factor explaining the high biodiversity observed along river courses. Collectively, these forces create a mosaic of habitats in a non-equilibrium system, which allows a wide variety of species to co-exist. It is well known that environmental heterogeneity, productivity, and resource diversity have major effects on functional diversity and species richness (Solbrig 1991). Floods destroy older patches and create new patches, resulting in an annual redistribution and sorting of sediment sizes and new channel configurations. Altitude affects the overall climate, while individual vegetative patches influence the microclimate. Species from upland habitats add to the species diversity in the riparian corridor although, in many cases, they are relatively rare. Finally, riparian corridors are productive systems because of the proximity of water and nutrients, but they are also subjected to regular and stochastic disturbance. These observations are consistent with the concepts of Huston (1979) and Solbrig (1991) related to the maintenance of high biodiversity in non-equilibrium situations where the process of competitive exclusion is retarded by periodic population reductions and environmental fluctuations.

Implications for Science and Policy

If the global body of evidence gathered to date is correct (there are no studies to the contrary), then the implications for science and policy are substantial and far reaching. Recognition of the riparian corridor as a significant landscape component in maintaining regional biodiversity also offers significant advances for resolving issues related to endangered species, cumulative effects, water yield and quality, and sustainability. However, to attain this level of recognition it will be necessary that policy makers have the desire and ability to address the following considerations:

The environment must be recognized as a legitimate consumer of water. The global alteration of hydrologic regimes is having devastating effects on fundamental processes maintaining the vitality of riparian corridors. In the conterminous United States only 2% of the total lengths of rivers are considered to be of sufficient quality for protection (Benke 1990); it is less in Europe and many developing countries. In many countries, especially those in arid regions, more than half the population lives within 1 km of a riparian corridor, using it for most of their daily needs (Turner et al. 1990). In addition, as of 1990 nearly 70% of the freshwater flowing to the oceans was controlled or modified in some manner (Petts 1984 and *personal communication*) with little understanding or appreciation of the ecological consequences. Finally, the supplies of freshwater in many parts of the world are severely over-subscribed, making water a key security issue in our collective future. A balance between immediate human water needs and long-term environmental and human requirements for water in the riparian corridor is essential.

The restoration of fluvial ecosystems will be a complex and expensive effort in this decade and beyond. Major efforts are already underway in the United States (Columbia and Connecticut rivers) and Europe (Rhine and Danube rivers). Clearly, complete restoration of the ecological diversity will be impossible. However, restoration efforts that consider disturbance regimes (frequency and intensity), hydraulic heterogeneity of the channel, and sediment dynamics, and that lessen human constraints on the channel, will be effective over the long term and at lower costs than engineering efforts directed at specified sites. In the past nearly all human influences on rivers (e.g., dams, irrigation, diking) have simplified the system; restoration requires management for connectivity and variability over broad spatial and temporal scales.

These considerations demand a broader perspective in planning. Planning based on isolated components (e.g., fish, vegetation, or restoration of specific stream sections) is ecologically incomplete. Consideration must be given to maintaining hydrologic connectivity and variability of riparian corridors from the headwaters to the sea. This means that better riparian corridor protection must take place in the numerous headwater streams as well as in the broad floodplains downstream. The area of land impacted by this recommendation is often <10% of the total land mass, but it offers an unusually diverse array of ecological services far in excess of its areal extent. We recognize, however, that management prescriptions are often made at the local level based on site-specific characteristics; but in the future they must be made within a basin-wide perspective. Attaining this broader planning perspective requires a close liaison between science and policy. It will be necessary to develop new applications of emerging technologies (e.g., geographic information systems and visual models) for basin-wide perspectives (Pastor and Johnston 1992, Swanson et al. 1992) and to couple social, economic, and environmental consideration with policy decisions at spatio-temporal scales and levels of complexity seldom before effectively demonstrated in human societies (Lee 1992, Lee et al. 1992, Naiman 1992).

A final consideration relates to political and institutional cooperation. International cooperation (IUCN 1980) and regional political cooperation (Naiman 1992) are frequently demanded since many river (riparian) corridors are shared by two or more political states or land owners. In addition, regulatory institutions usually have only jurisdiction for a portion of the resources in the riparian corridor, and often the institutional mandates are conflicting (e.g., fisheries vs. agriculture). Unless political and institutional cooperation can be achieved the rich array of biologically diverse resources and ecological services associated with riparian corridors will continue to be exploited or wasted. The consequences of existing practices for long-term environmental and human vitality will be severe.

Literature Cited

Benke, A. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society **9**:77–88.

Décamps, H., and R. J. Naiman. 1989. L'écologie des fleuves. La Recherche **20**:310–318.

Décamps, H., and E. Tabacchi. 1993. Species richness in riparian vegetation along river margins. *In* P. Giller, A. Hildrew, and D. Rafaelli, editors. Aquatic ecology: scale, pattern and process. Blackwell Scientific, *in press*.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience **41**:540–551.

Huston, M. 1979. A general hypothesis on species diversity. American Naturalist **113**:81–101.

IUCN. 1980. World conservation strategy. International Union for the Conservation of Nature and Natural Resources (IUCN), Gland, Switzerland.

Junk, W. 1989. Flood tolerance and tree distribution in central Amazonian floodplains. Pages 47–64 *in* L. B. Holm-Nielsen, I. C. Nielsen, and H. Balsley, editors. Tropical forests: botanical dynamics, speciation, and diversity. Academic Press, Orlando, Florida, USA.

Kalliola, R., and M. Puhakka. 1988. River dynamics and vegetation mosaicism: a case study of the River Kamajohka, northernmost Finland. Journal of Biogeography **15**:703–719.

Kalliola, R., J. Salo, M. Puhakka, and M. Rajasilta. 1992. New site formation and colonizing vegetation in primary succession on the western Amazon floodplains. Journal of Ecology **79**:877–901.

Lee, R. G. 1992. Ecologically effective social organization as a requirement for sustaining watershed ecosystems. Pages 73–90 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Lee, R. G., R. Flamm, M. G. Turner, C. Bledsoe, P. Chandler, C. DeFerrari, R. Gottfried, R. J. Naiman, N. Schumaker, and D. Wear. 1992. Integrating sustainable development and environmental vitality: a landscape ecology approach. Pages 497–519 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Naiman, R. J. 1992. New perspectives for watershed management: balancing long-term sustainability with cumulative environmental change. Pages 3–11 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Naiman, R. J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bisson, L. G. MacDonald, M. D. O'Connor, P. L. Olson, and E. A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. Pages 127–188 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Naiman, R. J., and H. Décamps, editors. 1990. The ecology and management of aquatic–terrestrial ecotones. Parthenon, Carnforth, England, and UNESCO, Paris, France.

Naiman, R. J., H. Décamps, and F. Fournier. 1989. Role of land/inland water ecotones in landscape management and restoration: proposals for collaborative research. MAB Digest **4**:1–93.

Naiman, R. J., H. Décamps, J. Pastor, and C. A. Johnston. 1988. The potential importance of boundaries to fluvial ecosystems. Journal of the North American Benthological Society 7:289–306.

Nilsson, C. 1986. Change in riparian plant community composition along two rivers in northern Sweden. Canadian Journal of Botany **64**:589–592.

———. 1992. Conservation management of riparian communities. Pages 352–372 *in* L. Hansson, editor. Ecological principles of nature conservation. Elsevier Applied Science, London, England.

Nilsson, C., G. Grelsson, M. Johansson, and U. Sperens. 1989. Patterns of plant species richness along riverbanks. Ecology **70**:77–84.

Pastor, J., and C. A. Johnston. 1992. Using simulation models and geographic information systems to integrate ecosystem and landscape ecology. Pages 324–346 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Petts, G. E. 1984. Impounded rivers: perspectives for ecological management. John Wiley & Sons, Chichester, England.

Petts, G. E., H. Möller, and A. L. Roux, editors. 1989. Historical change of large alluvial rivers: western Europe. John Wiley & Sons, Chichester, England.

Raedeke, K., editor. 1989. Streamside management: riparian wildlife and forestry interactions. Contribution Number 59. Institute of Forest Resources, University of Washington, Seattle, Washington, USA.

Salo, J., R. Kalliola, I. Häkkinen, Y. Mäkinen, P. Niemelä, M. Puhakka, and P. D. Coley. 1986. River dynamics and the diversity of Amazon lowland forest. Nature **322**:254–258.

Solbrig, O. T., editor. 1991. From genes to ecosystems: a research agenda for biodiversity. International Union of Biological Sciences, Paris, France.

Swanson, F., R. P. Neilson, and G. E. Grant. 1992. Some emerging issues in watershed management: landscape patterns, species conservation, and climate change. Pages 307–323 *in* R. J. Naiman, editor. Watershed management: balancing sustainability and environmental change. Springer-Verlag, New York, New York, USA.

Swanson, F. J., T. K. Kratz, N. Caine, and R. G. Woodmansee. 1988. Landform effects on ecosystem patterns and processes. BioScience **38**:92–98.

Tabacchi, E., A. M. Planty-Tabacchi, and O. Décamps. 1990. Continuity and discontinuity of the riparian vegetation along a fluvial corridor. Landscape Ecology **5**:9–20.

Turner, B. L., II, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews, and W. B. Meyer, editors. 1990. The Earth as transformed by human action. Cambridge University Press, Cambridge, England.