

Bash, J. C. M. R. (2002). "Stream Restoration and Enhancement Projects: Is Anyone Monitoring?" Environmental Management **29**(6): 877-885.

Declines in salmon stocks and general watershed health in Washington State, USA, have led to an increase in stream restoration and enhancement projects initiated throughout the state. The increasing number of projects has also raised questions regarding the monitoring of these efforts. Project managers receiving hydraulic project approvals (HPAs) were surveyed to determine whether monitoring was taking place on their projects. About half the project managers surveyed reported the collection of baseline data and the use of biological, physical, chemical, or other water quality measures for their projects. Of those who reported collection of monitoring data, only 18% indicated that monitoring was required. Respondents were also asked to rank the importance of various project goals on a Likert scale. Project managers with projects focusing on "engineering" goals (e.g., roadbed stabilization) were less likely than other project managers to collect baseline monitoring data. Project managers with projects focusing on "restoration/ecological" or "fisheries" goals were more likely than other project managers to collect monitoring measures. Although monitoring appears to be taking place in slightly more than half of the projects surveyed, the nature of the data collected varies widely across projects, and in most cases the monitoring effort is voluntary. This suggests that project sponsors, funders, and managers must consider the issues involved in requiring appropriate monitoring, establishing standardized monitoring guidelines, the time frames in which to monitor, providing other incentives for conducting monitoring, and ensuring adequate funding for monitoring efforts.

Jungwirth M, M. S., Schmutz S (2002). "Re-establishing and assessing ecological integrity in riverine landscapes." Freshwater Biology **47**(4): 867-887.

1. River-floodplain systems are among the most diverse and complex ecosystems. The lack of detailed information about functional relationships and processes at the landscape and catchment scale currently hampers assessment of their ecological status.
2. Intensive use and alteration of riverine landscapes by humans have led to severe degradation of river-floodplain systems, especially in highly industrialised countries. Recent water-related regulations and legislation focussing on high standards of ecological integrity back efforts to restore or rehabilitate these systems.
3. Most restoration projects in the past have suffered from a range of deficits, which pertain to project design, the planning process, the integration of associated disciplines, scaling issues and monitoring.
4. The so-called 'Leitbild' (i.e. a target vision) assumes a key role in river restoration and the assessment of ecological integrity in general. The development of such a Leitbild requires a multistep approach. Including explicitly the first step that defines the natural, type-specific reference condition (i.e. a visionary as opposed to an operational Leitbild), has great practical advantages for restoration efforts, primarily because it provides an objective benchmark, as is required by the European Water Framework Directive and other legal documents.
5. Clearly defined assessment criteria are crucial for evaluating ecological integrity, especially in the pre- and postrestoration monitoring phases. Criteria that reflect processes and functions should play a primary role in future assessments, so as to preserve and restore functional integrity as a fundamental component of ecological integrity.
6. Case studies on the Kissimmee River (U.S.A.), the Rhine River (Netherlands and Germany), and the Drau River (Austria) are used to illustrate the fundamental principles underlying successful restoration projects of river-floodplain systems.

Muotka, T., R. Paavola, A. Haapala, M. Novikmec, P. Laasonen (2002). "Long-term recovery of stream habitat structure and benthic invertebrate communities from in-stream restoration." Biological Conservation **105**: 243-253.

Pedroli B, d. B. G., van Looy K, van Rooij S (2002). "Setting targets in strategies for river restoration." Landscape Ecology **17**(Suppl 1): 5-18.

Since about 90% of the natural floodplain area of rivers in Europe has been reclaimed and now lacks river dynamics, nature rehabilitation along rivers is of crucial importance

for the restoration of their natural function. Flood protection, self-purification of surface water, groundwater recharge, species protection and migration are all involved in this process. It is now generally recognised that rivers form natural arteries in Europe but are also of economic importance and are recognisable cultural landscape. Many examples are already available of successful small river restoration projects. Several species thought to be extinct have now reappeared and characteristic species have also expanded in recent years. This paper concentrates on the concept of setting targets for river restoration as exemplified by the Meuse River. A modelling exercise shows the restraints of current habitat configuration and the potential for habitat restoration along the river. A policy analysis, using a strategic approach, illustrates the influence of the decision making process on the targets for natural river development. River dynamics play a key factor in determining the potential for persistent populations of target animal species along the river, with the help of an expert system (LARCH, Landscape ecological Analysis and Rules for the Configuration of Habitat). The potentials for the increase of dispersion and biodiversity and the maximisation of ecological benefits at different scales, are also considered.

Roni P, B. T., Bilby RE, Leonetti FE, Pollock MM, Pess GR (2002). "A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific northwest watersheds." NORTH AMERICAN JOURNAL OF FISHERIES MANAGEMENT **22**(1): 1-20.

Millions of dollars are spent annually on watershed restoration and stream habitat improvement in the U.S. Pacific Northwest in an effort to increase fish populations. It is generally accepted that watershed restoration should focus on restoring natural processes that create and maintain habitat rather than manipulating instream habitats. However, most process-based restoration is site-specific, that is, conducted on a short stream reach. To synthesize site-specific techniques into a process-based watershed restoration strategy, we reviewed the effectiveness of various restoration techniques at improving fish habitat and developed a hierarchical strategy for prioritizing them. The hierarchical strategy we present is based on three elements: (1) principles of watershed processes, (2) protecting existing high-quality habitats, and (3) current knowledge of the effectiveness of specific techniques. Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed.

SER, S. f. E. R. S. P. W. G. (2002). The SER Primer on Ecological Restoration.

Shields FD, C. C., Knight SS, Moore MT (2003). "Stream corridor restoration research: a long and winding road." Ecological Engineering **20**: 441-454.

Stream corridor restoration research and practice is presented as an example of the application of ecology and engineering to solve a class of environmental problems. Interest and public investment in stream corridor restoration has increased sharply in developed nations over the last two decades, as evidenced by the volume of technical and refereed literature. However, real progress at the regional and national scale depends on successful research outcomes. Research addressing problems associated with stream corridor ecosystem restoration is beset by numerous problems. First, terms referring to restoration are loosely defined. Secondly, stream ecosystems are not amenable to rigorous experimental design because they are governed by a host of independent variables that are heterogeneous in time and space, they are not scalable, and their response times are often too long for human attention spans. These problems

lead to poorly controlled or uncontrolled experiments with outcomes that are not reproducible. Extension of results to other sites or regions is uncertain. Social factors further complicate research and practice—riparian landowners may or may not cooperate with the experiment, and application of findings normally occurs through a process of suboptimal compromise. Economic issues, namely assigning costs for present and future ecosystem services that provide off-site benefits, further impede progress. Clearly, the situation calls for a hybrid approach between the rigor of the ecologist and the judgment and pragmatism of the engineer. This hybrid approach can be used to develop creative, low-cost approaches to address key factors limiting recovery.

Ward, J. V. (1998). "Riverine landscapes: Biodiversity patterns, disturbance regimes, and aquatic conservation." *Biological Conservation* **83**: 269-279.

The term riverine landscape implies a holistic geomorphic perspective of the extensive interconnected series of biotopes and environmental gradients that, with their biotic communities, constitute fluvial systems. Natural disturbance regimes maintain multiple interactive pathways (connectivity) across the riverine landscape. Disturbance and environmental gradients, acting in concert, result in a positive feedback between connectivity and spatio-temporal heterogeneity that leads to the broadscale patterns and processes responsible for high levels of biodiversity. Anthropogenic impacts such as flow regulation, channelization, and bank stabilization, by (1) disrupting natural disturbance regimes, (2) truncating environmental gradients, and (3) severing interactive pathways, eliminate upstream-downstream linkages and isolate river channels from riparian/floodplain systems and contiguous groundwater aquifers. These alterations interfere with successional trajectories, habitat diversification, migratory pathways and other processes, thereby reducing biodiversity. Ecosystem management is necessary to maintain or restore biodiversity at a landscape scale. To be effective, conservation efforts should be based on a solid conceptual foundation and a holistic understanding of natural river ecosystems. Such background knowledge is necessary to re-establish environmental gradients, to reconnect interactive pathways, and to reconstitute some semblance of the natural dynamics responsible for high levels of biodiversity. The challenge for the future lies in protecting the ecological integrity and biodiversity of aquatic systems in the face of increasing pressures on our freshwater resources. This will require integrating sound scientific principles with management perspectives that recognize floodplains and groundwaters as integral components of rivers and that are based on sustaining, rather than suppressing, environmental heterogeneity

Wissmar RC, B. R. (1998). "Restoration and management of riparian ecosystems: a catchment perspective." *Freshwater Biology* **40**(3): 571-585.

1. We propose that strategies for the management of riparian ecosystems should incorporate concepts of landscape ecology and contemporary principles of restoration and conservation. A detailed understanding of the temporal and spatial dynamics of the catchment landscape (e.g. changes in the connectivity and functions of channel, riparian and terrestrial components) is critical.
2. This perspective is based upon previous definitions of riparian ecosystems, consideration of functional attributes at different spatial scales and retrospective analyses of anthropogenic influences on river catchments.
3. Restoration strategies must derive from a concise definition of the processes to be restored and conserved, recognition of social values and commitments, quantification of ecological circumstances and the quality of background information and determination of alternatives.
4. The basic components of an effective restoration project include: clear objectives (ecological and physical), baseline data and historical information (e.g. the hydrogeomorphic setting and the disturbance regime), a project design that recognizes functional attributes of biotic refugia, a comparison of plans and outcomes with reference ecosystems; a commitment to long-term planning, implementation and monitoring and, finally, a willingness to learn from both successes and failures.

5. Particularly important is a thorough understanding of past natural disturbances and human-induced changes on riparian functions and attributes, obtained by a historical reconstruction of the catchment.

Arthington AH, Pusey BJ. 2003. Flow restoration and protection in Australian rivers. RIVER RESEARCH AND APPLICATIONS.

19 (5-6): 377-395

Since 1857 new Australians have constructed many thousands of weirs (3600 in the Murray-Darling Basin alone) and floodplain levee banks, 446 large dams (> 10 m crest height) and over 50 intra- and inter-basin water transfer schemes to secure water supplies for human use. Flow regulation has changed the hydrology of major rivers on three temporal scales: the flood pulse (days to weeks), flow history (weeks to years) and the long-term statistical pattern of flows, or flow regime (decades or longer). The regulation of **river** flows is widely acknowledged as a major cause of deteriorating conditions in many Australian **river** and floodplain ecosystems. In response to mounting environmental concerns, all states, territories and the Commonwealth Government have committed the nation to the principles of ecologically sustainable development and a process of national water reform. Rivers and wetlands are now recognized as legitimate 'users' of water, and jurisdictions must provide water allocations to sustain and where necessary restore ecological processes and the biodiversity of water-dependent ecosystems. Progress in the protection and **restoration** of **river** and wetland water regimes has been significant, with over half of mainland aquatic systems designated to receive water allocations of some sort. However, exactly how much water they will receive or retain is unclear from the data available. Moreover, the ecological outcomes and benefits of water allocations are not yet apparent in most aquatic ecosystems, with the exception of certain waterbird breeding events, the disruption of algal blooms in weirs and improved fish passage. After reviewing these issues, this paper addresses two vital questions: How much water does a **river** need? and How can this water be clawed back from other users? Studies conducted to date in Queensland rivers suggest that around 80-92% of natural mean annual flow (and other ecologically relevant hydrological indicators) may be needed to maintain a low risk of environmental degradation. In the Top End of the Northern Territory, some rivers are maintained at 80% of their natural flow, whereas two-thirds of various flow indicators has been proposed as the **restoration** target for the **River** Murray, and 28% of natural mean annual flow has been negotiated for the Snowy **River** in Victoria. To validate these estimates, ecologists are seeking opportunities to turn **river restoration** projects into long-term hypothesis-driven experiments in ecological **restoration**, and the funding, time and institutional support to do so. The paper ends with some suggestions to advance the water reforms and achieve higher levels of water allocation for the environment.

Jakob C, Robinson CT, Uehlinger U. 2003. Longitudinal effects of experimental floods on stream benthos downstream from a large dam. AQUATIC SCIENCES 65 (3): 223-231

We examined the longitudinal effects of 3 experimental floods on seston, periphyton, and macroinvertebrates in a regulated river downstream from a large reservoir in the Swiss Alps. In addition, suspended organic sediments, in conjunction with conductivity and turbidity, were measured during each flood. Three study reaches were selected downstream from the reservoir: an Upper site ca 150 m, a Middle site at 1.2 km, and a Lower site at 2.3 km from the dam. The Upper site was located upstream of any

significant source of sediments. No flood effect was observed on water temperature, although river temperatures and diel amplitudes increased progressively downstream from the dam. Most organic sediments were mobilized and transported within the first few hours of each flood, with the pulse in sediments typically occurring later (after peak discharge) and being more prolonged at the Lower site. Turbidity generally decreased during the flood season, perhaps in response to lower amounts of fines and reductions in periphyton biomass. Seston concentrations (as chlorophyll a and AFDM) were lowest at the Upper site, and typically decreased following each flood. The flood response in seston was lowest at the Upper site and more pronounced at the Middle and Lower sites. Periphyton biomass also was lowest at the Upper site, and the flood effects were significant only in the Middle and Lower sites. In contrast, macroinvertebrate densities were similar between the Upper and Lower sites, and both sites exhibited a similar response to the floods. These results indicate a longitudinal response of **river** benthos to flooding below the reservoir that partly reflects the examined benthic constituent (periphyton or zoobenthos) and the longitudinal differences in the degree and type (e.g., flow in combination with sediment mobility and scouring) of disturbance.

Clarke SJ, Bruce-Burgess L, Wharton G. 2003. Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration. *AQUATIC CONSERVATION-MARINE AND FRESHWATER ECOSYSTEMS* 13 (5): 439-450

1. River restoration is now widely undertaken and may be considered an increasingly important aspect of river management. Recent developments in European legislation (Habitats Directive and the Water Framework Directive) should give further impetus to river restoration across EU member states, as this legislation places greater emphasis on the processes that support river ecology.
2. Traditional river restoration approaches have been reach-focused and opportunistic, capitalizing on flood defence works and the cooperation of sympathetic landowners.
3. Furthermore, many schemes have been species- or habitat-driven and, thus, have sought to recreate channel forms believed to be favoured by particular species or associated with particular habitats. Such approaches have not always given due attention to the underlying geomorphological processes that create channel form and, consequently, the schemes have not been self-sustaining, requiring continued management input.
4. Consistent with the ethos of the Water Framework Directive, an eco-hydromorphic approach to river restoration is proposed here. This approach views spatial and temporal heterogeneity as fundamental characteristics of fluvial systems and advocates recreating a framework within which natural processes, such as sediment transport and nutrient dynamics, can occur.
5. Mesoscale habitat approaches are considered as one possible way to plan and achieve this framework, providing the potential to link the wide range of spatial and temporal scales that characterize river systems.
6. It is argued that river restoration will only be sustainable if it is undertaken within a process-driven and strategic framework with inputs from a wide range of specialists. Such an approach needs to be reviewed constantly in light of appraisal and monitoring of previous river restoration schemes.

Feist BE, Steel EA, Pess GR, Bilby RE 2003. The influence of scale on salmon habitat restoration priorities. *ANIMAL CONSERVATION* 6: 271-282 Part 3

Habitat loss and alteration is the leading cause of species' declines world-wide, therefore habitat restoration and protection is a prominent conservation strategy. Despite obvious connections between habitat and threatened or endangered species, conservationists have been hard pressed explicitly to link abundance or Population health with habitat attributes. Given that habitat relationships with species are often characterized at a spatial scale that does not account for the functional relationships between habitat and populations, it is not surprising that the habitat-population conundrum persists. In order to explore the influence of spatial scale on the apparent relationship between habitat and populations, we examined the relationship between GIS-based habitat data and spring/summer chinook salmon (*Oncorhynchus tshawytscha*) redd (spawning nests built by females) densities in the Salmon River basin, Idaho, at two very different spatial scales: stream reach and watershed. Redd density was strongly correlated with climate, geology, wetlands and terrain. However, our stream-reach scale models provided poor predictive power compared with the watershed scale models. Based on these results, we conclude that our perception of

which habitat attributes were important was clearly a function of our scale of observation, and that restoration efforts should focus on conditions at the watershed or landscape scale when attempting to do local or reach scale restoration projects.

Moerke AH, Lamberti GA. 2003. Responses in fish community structure to restoration of two Indiana streams. *NORTH AMERICAN JOURNAL OF FISHERIES MANAGEMENT* 23 (3): 748-759
Stream restoration has accelerated in the Midwestern United States during the past decade, but the effects of restoration on stream biota are rarely evaluated. From 1997 to 2000, we studied the responses in fish communities to the attempted restoration of two channelized streams (Juday Creek and Potato Creek) in northwestern Indiana, each of which received two new meanders to a 1-km reach of stream length. The restored meanders of Juday Creek also received major improvement to instream habitat, bank stabilization, and silt control. In contrast, Potato Creek received only reconnection of the stream to historical meanders. Fish were monitored for 3 years after reconstruction by use of electroshocking and salmonid redd surveys. In Juday Creek, trout size-class distribution broadened and redd construction increased in the restored reaches. However, most fish metrics for reconstructed reaches did not surpass the levels in the channelized reaches after 3 years. Continued sedimentation from upstream sources, which reduced habitat quality, likely counteracted the positive effects of the restoration. In contrast, unanticipated geomorphic changes in Potato Creek led to decreased current velocity and highly altered fish community structure. The American brook lamprey *Lampetra appendix*, a sensitive species, was not collected after restoration, and the fish community changed from rheophilic species to highly tolerant, slow-water species. Overall, changes in fish community structure revealed strengths and weaknesses in contemporary stream restoration approaches, findings that will aid future restoration efforts.

Shields FD, Knight SS, Morin N, Blank J. 2003. Response of fishes and aquatic habitats to sand-bed stream restoration using large woody debris. *HYDROBIOLOGIA* 494 (1-3): 251-257
Effects of habitat rehabilitation of Little Topashaw Creek, a sinuous, sand-bed stream draining 37 km² in northwest Mississippi are described. The rehabilitation project consisted of placing 72 large woody debris structures along eroding concave banks and planting 4000 willow cuttings in sandbars. Response was measured by monitoring flow, channel geometry, physical aquatic habitat, and fish populations. Initially, debris structures reduced high flow velocities at concave bank toes, preventing further erosion and inducing deposition. Physical response during the first year following construction included creation of sand berms along eroding banks and slight increases in base flow water width and depth. Fish collections showed assemblages typical of incising streams within the region, but minor initial responses to debris addition were evident. Progressive failure of the structures and renewed erosion were observed during the second year after construction.

Steinberger N, Wohl E. 2003. Impacts to water quality and fish habitat associated with maintaining natural channels for flood control. *ENVIRONMENTAL MANAGEMENT* 31 (6): 724-740
field investigation conducted on Boulder Creek in Boulder, Colorado evaluated impacts of flood control maintenance activities on flood conveyance, water quality, and fish habitat. Thirty-nine transects were monitored at one control site and two maintenance sites over a period of eight months. Each site was visited on more than 50 occasions in order to characterize pre- and post-maintenance conditions, and to monitor maintenance activities. Measurements along the transects included substrate composition, flow depth, velocity, and elevation. Reach-average values were assigned to variables such as in-stream vegetation, streambank stability, and woody vegetation before and after maintenance. Water temperature, dissolved oxygen, pH, specific conductance, and turbidity were sampled, and habitat suitability indices were developed pre- and post-maintenance for seven indicator fish species. Water quality impacts during maintenance consisted of high turbidity levels (> 400 NTU), which returned to background levels (0.1-15 NTU) overnight, as well as changes in mean temperature and pH. Alteration of physical channel characteristics as a result of maintenance had limited effects on habitat quality for four of seven fish species, but caused improvements in habitat quality for three fish species. The main implications of this study for floodplain management are that: (1) Flood control maintenance practices can be in direct conflict with water quality and fish habitat objectives, and should be carefully designed and implemented by an interdisciplinary team. (2) Physical habitat for some fish species can be improved as well as reduced by

maintenance activities. Habitat suitability curves may be useful tools for evaluating limiting factors of the habitat and for identifying opportunities for habitat improvements as part of maintenance.

Rood SB, Gourley CR, Ammon EM, Heki LG, Klotz JR, Morrison ML, Mosley D, Scopettone GG, Swanson S, Wagner PL. 2003. Flows for floodplain forests: A successful riparian restoration. *BIOSCIENCE* 53 (7): 647-656

Throughout the 20th century, the Truckee River that flows from Lake Tahoe into the Nevada desert was progressively dammed and dewatered, which led to the collapse of its aquatic and riparian ecosystems. The federal designation of the endemic cui-ui sucker (*Chasmistes cujus*) as endangered prompted a restoration program in the 1980s aimed at increasing spring flows to permit fish spawning. These flows did promote cui-ui reproduction, as well as an unanticipated benefit, the extensive seedling recruitment of Fremont cottonwood (*Populus fremontii*) and sandbar willow (*Salix exigua*). Recruitment was scattered in 1983 but extensive in 1987, when the hydrograph satisfied the riparian recruitment box model that had been developed for other rivers. That model was subsequently applied to develop flow prescriptions that were implemented from 1995 through 2000 and enabled further seedling establishment. The woodland recovery produced broad ecosystem benefits, as evidenced by the return by 1998 of 10 of 19 riparian bird species whose populations had been locally extirpated or had declined severely between 1868 and 1980. The dramatic partial recovery along this severely degraded desert river offers promise that the use of instream flow regulation can promote ecosystem restoration along other dammed rivers worldwide.

Champoux O, Biron PM, Roy AG. 2003. The long-term effectiveness of fish habitat restoration practices: Lawrence Creek, Wisconsin

ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS 93 (1): 42-54

Although many streams in North America have been rehabilitated to improve the habitat of salmonids, little is known about the long-term impacts of such practices on salmonid habitats and on river dynamics. The success of these improvement schemes is often assessed a short time after the work is completed and is usually based on changes in the targeted biological populations. This article examines the long-term effects of bank-cover deflectors on the physical fish habitat and on the channel morphology. The study was conducted on Lawrence Creek, a small stream in Wisconsin, where trout habitat had been affected negatively by intense cattle grazing. Data on the physical habitat and on channel morphology were collected on a 600-m-long reach in 1963 (immediately prior to the rehabilitation work), in 1966, and in 1999. In the upstream section, the channel flows through a moraine deposit where bed material is coarser than the material of the outwash plain found in the downstream portion of the reach. Results indicate that fish habitat in 1999 was better than in 1963 but has deteriorated substantially since 1966. Pool area increased from 267 m² to 625 m² between 1963 and 1966, but has decreased to 488 m² since then. Most of this deterioration, however, is concentrated in the morainic section. In the outwash plain, the deflectors are still in good condition, and the area occupied by pools has remained constant since 1966. In the morainic section, most structures are no longer efficient and the channel is unstable due to high bed-shear stress values, which entrain bed and bank erosion. Effective long-term rehabilitation schemes should therefore carefully consider the varying sensitivity of river reaches due to different geomorphic contexts.