Annotated Bibliography of Technical References Pertaining to Restoration of Streams and Rivers, Riparian Areas and Floodplains
Version 1

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January 2003

Albert, S., and T. Trimble. 2000. Beavers are partners in riparian restoration on the Zuni Indian Reservation. *Ecological Restoration* 18: 87-92.

Amoros, C. 2001. The concept of habitat diversity between and within ecosystems applied to river side-arm restoration. *Environmental Management* 28: 805-817.

Since returning an ecosystem to its pristine state may not be realistic in every situation, the concept of habitat diversity is proposed to help decision-makers in defining realistic restoration objectives. In order to maintain habitat diversity and enhance the long-term success of restoration, process-orientated projects should be preferred to species-orientated ones. Because the hydrogeomorphological processes that influence biodiversity operate at different spatiotemporal scales, three scales are considered: ricer sectors, floodplain waterbodies, and mesohabitats within each waterbody. Based on a bibliographical review, three major driving forces are proposed for incorporation into the design of restoration projects: (1) flow velocity and flood disturbances, (2) hydrological connectivity, and (3) water supply. On the sector scale, increased habitat diversity between waterbodies can be achieved by combining various intensities of these driving forces. On the waterbody scale, increased habitat diversity within the ecosystem can be achieved by varying water depth, velocity, and substrate. The concept is applied to a Rhône River sector (France) where three terrestrialized side arms will be restored. Two were designed to be flood scoured, one having additional supply of groundwater, the other being connected to the river at both ends. The third cannot be scoured by floods because of upstream construction and would be supplied by river backflow through a downstream connection. Habitat diversity within the ecosystem is exemplified on one side arm through the design of a sinuous pathway combined with variation of water depth, wetted width, and substrate grain size. Self-colonization of the side arms is expected owing to the restoration of connectivity to upstream sources of potential colonizers.

Amoros, C., and G. Bornette. 1999. Antagonistic and cumulative effects of connectivity: a predictive model based on aquatic vegetation in riverine wetlands. *Large Rivers* 11: 311-327.

The effects of connectivity cannot be reduced to a simple gradient. River overflows disturb the vegetation of connected wetlands but, reducing competition, promote plant diversity. Overflows also bring nutrients, silt and plant propagules. Nutrients increase eutrophication and promote phytoplankton development, which reduces water transparency and impedes the growth of rooted plants. Silt inputs accelerate terrestrialization but provide regeneration niches that favour the recruitment of allochthonous propagules. These multiple effects are combined into a model that predicts diversity and life-history traits of aquatic plants (growth form, potential size, phenology and frequency of flowering, vegetative reproduction and defense against herbivores) in relation to the connectivity of the riverine wetlands.

Amoros, C., G. Bornette, and C. P. Henry. 2000. A vegetation-based method for ecological diagnosis of riverine wetlands. *Environmental Management* 25: 211-227.

The management of riverine wetlands, recognized as a major component of biodiversity in fluvial hydrosystems, is problematic. Preservation or restoration of such ecosystems requires a method to assess the major ecological processes operating in the wetlands, the sustainability of the aquatic stage, and the restoration potential of each riverine wetland. We propose a method of diagnosis based on aquatic macrophytes and helophytes. Plant communities are used because they are easy to survey and provide information about (1) the origin of a water supply (i.e., groundwater, seepage, or surface river water) and its nutrient content, (2) effects of flood disturbances, and (3) terrestrialization processes. The novelty of the method is that, in contrast to available typologies, it is based on the interference of gradients resulting from knowledge of the processes involved in terrestrialization, i.e., the influence of flood disturbances, occurence of groundwater supplies, trophic degree, and water permanency of the habitat during a yearly cycle. The method is demonstrated on five different river systems.

Anderson, B. W., and R. D. Ohmart. 1985. Riparian Revegetation as a Mitigating Process in Stream and River Restoration. Pages 41-79 in J. A. Gore, ed. *The Restoration of Rivers and Streams*. Butterworth Publishers, Stoneham, MA.

We present a promising technique for mitigation for southwestern riparian habitats in kind and place. We have described the various steps preceding revegetation efforts in the hope that our generalized procedure can be of use in other areas. The basic procedure involved six steps (Table 3.13), ranging from preliminary data collection to monitoring of results. Costs of revegetation may seem high to some individuals, but if a lesson is to be gleaned from our data it is this: Action agencies should explore all alternatives prior to destroying a reach of valuable riprian habitat. Should it be necessary to destroy it, they should be prepared to meet the high cost of replacing it in kind and in general proximity. More attention must be paid to losses of riparian vegetation because it consists of a distinctive and rapidly disappearing flora which supports a distinctive fauna. Proper watershed management practices, including the prevention of soil erosion, dictates that measures be taken now to preserve existing natural streamside vegetation and to replenish areas where it has already been destroyed.

Baker, J. A., K. J. Killgore, and R. L. Kasul. 1989. Aquatic habitats and fish communities in the lower Mississippi River. *Reviews in Aquatic Sciences* 3: 313-356.

The Mississippi River ecosystem is, and probably has been for millions of years, home to a large and diverse community of freshwater fishes. The river is also an important inland artery for commerce, and its floodplain supports extensive agriculture and many urban and commercial areas. The ecosystem and the distribution and abundance of its aquatic habitats have changed greatly over geological history. Recent attempts to control river have also produced changes in the ecosystem, and in many ways these changes are different from those that occurred naturally over the history of the river. Managing the aquatic ecosystem of the river requires an understanding of its ecological habitats, the biotic communities, and their interrelationships. This article examines the state of our knowledge of the lower Mississippi River ecosystem; it also delineates the aquatic habitats of the river and describes the communities of fish associated with them.

Bayley, P. B. 1991. The flood pulse advantage and the restoration of river-floodplain systems. *Regulated Rivers: Research & Management* 6: 75-86.

The 'flood pulse advantage' is the amount by which fish yield per unit mean water area is increased by a natural, predictable flood pulse. Evidence for this increase is presented from tropical and temperate fisheries. It is argued that increasing multispecies fish yield by restoring the natural hydrological regime is consistent with increasing production of other trophic levels and with restoration from ecological and aesthetic viewpoints. When applied to a river floodplain system, this restoration would provide a large, self-sustaining potential for recreation, commercial exploitation, and flood control. An interim "natural flood pulse' restoration approach is proposed for systems modified for navigation. This approach approximates the natural hydrological regime in a river reach and is intended as a first step in the long process of restoring the watershed.

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in acific northwest watersheds. *Fisheries* 24: 6-15.

We present an approach to diagnosing salmonid habitat degradation and restoring habitat-forming processes that is focused on causes of habitat degradation rather than on effects of degradation. The approach is based on the understanding that salmonid stocks are adapted to local freshwater conditions and that their environments are naturally temporally dynamic. In this context, we define a goal of restoring the natural rates and magnitudes of habitat-forming processes, and we allow for locally defined restoration priorities. The goal requires that historical reconstruction focus on diagnosing disruptions to processes rather than conditions. Historical reconstruction defines the suite of restoration tasks, which then may be prioitized based on local biological objectives. We illustrate the use of this approach for two habitat-forming processes: sediment supply and stream shading. We also briefly contrast this approach to several others that may be used as components of a restoration strategy.

Bendix, J. 1999. Stream power influence on southern Californian riparian vegetation. *Journal of Vegetation Science* 10: 243-252.

Mechanical damage by floodwaters in frequently invoked to explain the distribution of riparian plant species, but data have been lacking to relate vegetation to specific estimates of flood damage potential. This research uses detailed estimates of unit stream power (an appropriate measure of potential for mechanical damage) in conjunction with vegetation cover data to test this relationship at 37 valley-bottom sites in the Transverse Ranges of Southern California. A computer program, HEC-2, was used to model the slope and the variation in flow depth and velocity of the 20-yr flood across the sites. Regression models tested the influence of stream power (and of height above the water table) on the woody species composition of 393 4-m cross-section segments of the valley-bottom sites. Results indicate that unit stream power does have a significant effect on the riparian vegetation, but that the amount of that influence and its importance relative to the influence of height above water table varies between watersheds. Some species are found primarily in location of high stream power, while others are limited to portions of the valley bottom that experience only low stream power.

Best, L. B., D. F. Stauffer, and A. R. Geier. 1979. Evaluating the Effects of Habitat Alteration on Birds and Small Mammals Occupying Riparian Communities. Pages 117-124. U.S. Department of Agriculture Forest Service.

Birds and small mammals were censused along stream segments in Iowa, representing a range of habitats from open fields to closed-canopy woodlands. Vegetation was sampled and general habitat types identified. The reciprocal of Simpson's index was used to express breadth of habitats selected and nest-site specificity. The general application of using an index of niche breadth in conjunction with conventional plant and animal sampling techniques to assess species' susceptibility to habitat alteration is discussed.

Bohn, B. A. and J. L. Kershner. 2002. Establishing aquatic restoration priorities using a watershed approach. *Journal of Environmental Management* 64: 355-363.

Since the passage of the Clean Water Act in 1972, the United States has made great strides to reduce the threats to its rivers, lakes and wetlands from pollution. However, despite our obvious successes, nearly half of the nation's surface water resources remain incapable of supporting basic aquatic values or maintaining water quality adequate for recreational swimming. The Clean Water Act established a significant federal presence in water quality regulation by controlling point and non-point sources of pollution. Point-sources of pollution were the major emphasis of the Act, but Section 208 specifically addressed non-point sources of pollution and designated silviculture and livestock grazing as sources of non-point pollution. Non-point source pollutants include runoff from agriculture, municipalities, timber harvesting, mining, and livestock grazing. Non-point source pollution now accounts for more than half of the United States water quality impairments. To successfully improve water quality, restoration practictioners must start with an understanding of what ecosystem processes are operating in the watershed and how they have been affected by outside variables. A watershed-based analysis template developed in the Pacific Northwest can be a valuable aid in developing that level of understanding. The watershed analysis technique identfies four ecosystem scales useful to identify stream restoration priorites: region, basin, watershed, and site. The watershed analysis technique is based on a set of technically rigorous and defensible procedures designed to provide information on what processes are active at the watershed scale, how those processes are distributed in time and space. They help describe what the current upland and riparian conditions of the watershed are and how these conditions in turn influence aquatic habitat and other beneficial uses. The analysis is organized as a set of six steps that direct an interdisciplinary team of specialists to examine the biotic and abiotic processes influencing aquatic habitat and species abundance. This process helps develop an understanding of the watershed within the context of the larger ecosystem. The understanding gained can then be used to identify and prioritize solely on site-level information, a common problem with historic restoration efforts. When the watershed analysis process was used in the Whitefish Mountains of northwest Montana, natural resource professionals were able to determine the dominant habitat forming processes important for native fishes and use that information to prioritize, plan, and implement the appropriate restoration activities at the watershed scale. Despite considerable investments of time and resources needed to complete an analysis at the watershed scale, the results can prevent the misdiagnosis of aquatic problems and help ensure that the objectives of aquatic restoration will be met.

Boon, P. J. 1998. River restoration in five dimensions. *Aquatic Conservation: Marine and Freshwater Ecosystems* 8: 257-264.

1. This paper provides a synthesis of the information presented at *River Restoration '96* under a series of headings--described here as five 'dimensions'. 2. The conceptual dimension addresses the motivation for restoration, and whether intervention by restoration would happen at all. Even when river restoration projects are motivated by particular sectoral interests, they should be set within a broader environmental framework. 3. The spatial dimension considers the lateral, longitudinal, and vertical connectivity within river systems, and the relationship between restoration and the spatial functioning of rivers. There is a growing acceptance of the importance not only of connections between river channels and their adjacent floodplains, but also of the need to take account of river processes operating at the catchment scale. 4. The temporal dimension describes both the importance of river history when attempting to reconstruct past river landscapes, and the requirement of post-project appraisal once a scheme is completed. Systems of river classification and evaluation are essential for pre-project planning and for post-project appraisal. 5. River restoration often focuses on the technological dimension, and a wide array of engineering techniques are currently used both on river channels and the adjacent land. Analytical techniques such as mathematical modelling and GIS are now commonly applied to restoration projects, but it is important that sophisticated analysis is matched by a base of sound scientific data. 6. The presentational dimension plays a valuable role in river restoration, as restoration is unlikely to succeed without the support of a wide cross-section of society. However, whilst river restoration can bring a range of benefits, it must never be portrayed as an alternative to maintaining high quality in undegraded rivers.

Bornette, G., C. Amoros and N. Lamouroux. 1998. Aquatic plant diversity in riverine wetlands: the role of connectivity. *Freshwater Biology* 39: 267-283.

Summary:
1. The hypothesis was tested that intermediate connectivity to a river results in propagule inputs to wetlands, whereas excessive connectivity impedes recruitment, and insufficient connectivity causes less competitive species to be eliminated, with no recruitment of new species. As a consequence, very low or very high nutrient levels should decrease species richness by selecting specialized species, whereas intermediate nutrient levels should favor the co-occurrence of species with contrasting nutrient requirements.
2. Among cut-off channels with high sinuosity and which are infrequently flooded by the river (low flood scouring), on example possesses high species richness because most species are saved from extinction by long-term isolation of the channel and cold groundwater supplies. Other channels are poorly supplies with groundwater and show richness of species, because of low propagule inputs and low recruitment potential.
3. Cut-off channels with low sinuosity and which are flooded at intermediate frequencies were divided into three groups. The first group was species-poor, being closely connected to the river through downstream backflows which maintain nutrient-rich turbid water, in keeping with the hypothesis. The second group presents intermediate richness caused by: (i) lower river backflows; and (ii) floods that partly scour substrate and plants, and afford regeneration niches for transported propagules. The third group was species-poor because of excessive groundwater supplies, which probably acted as a limiting factor for species growth and recruitment.
4. The most frequently flooded channel shows the highest species richness, and occurrence of rare fugitive species, because of floods which compensate competition by scouring sediments and

plants, and afford regeneration niches for propagules. In this case, conservation of biodiversity necessitates propagule sources at the level of the river landscape.

Boulton, A. J. and L. N. Lloyd. 1991. Macroinvertebrate assemblages in floodplain habitats of the lower River Murray, South Australia. *Regulated Rivers: Research and Management* 6: 183-201.

Macroinvertebrates were sampled in seven microhabitats (submerged woody debris, reeds, sedges, inundated grass, floating aquatic vegetation, lignum, and the unvegetated littoral) at thirteen sites representing six macrohabitats (single temporary and permanent ox-bow lakes (billabongs), fast and slow-flowing anabranches, backwaters, and the main channel) of the River Murray, and the Australian lowland river. Sites were sampled in spring 1988, shortly after floodwaters had receded. Most of the 95 taxa collected were aquatic insects. Detritivores were most abundant in all macrohabitats except the temporary billabong where predators predominated. Scrapers were only abundant in the permanent billabong. The temporary billabong harbored the most species and individuals whereas slowly-flowing anabranches contained the fewest species and individuals. At the microhabitat level, most taxa and individuals occurred in stands of aquatic vegetation. The unvegetated littoral zone was the most depauperate microhabitat. Multivariate analyses illustrated the distinctiveness of the faunal assemblage found in the temporary billabong. Subsequent analyses of the permanently inundated macrohabitats indicated gradients related to current velocity and the extent to which the sites were continuous with the main river. Current velocity apparently determined assemblage composition at the macrohabitat scale whereas the structural complexity of submerged vegetation operated at the microhabitat scale. The relatively large number of taxa collected from this area emphasizes the importance of a range of macrohabitats and microhabitats to faunal diversity in a floodplain ecosystem. Although there was little faunal overlap between billabongs and the main river, billabongs probably serve as refuges for many lentic taxa that rely upon regular inundation to survive. Surveys of floodplain rivers for management purposes must include samples from aquatic habitats adjacent to the main channel because the fauna of the floodplain is potentially most threatened by regulation and alteration of the flooding regime.

Bren, L. J. 1993. Riparian zone, stream, and floodplain Issues: a review. *Journal of Hydrology* 150: 277-299.

In the last two decades, the effects of forest management on streams, riparian zones, and floodplains have become of much interest. In general, there is agreement that such areas should be maintained in a state approximating naturalness, although it is recognized that definition of this state is usually difficult or impossible. A diversity of management effects has been recognized and, in some cases quantified. For upland catchments, issues particularly relate to direct disturbance of the zone, changes in the flow of woody debris into the stream, or disturbance to the environment by effects generated upstream or downstream. For many areas, a particularly important commercial aspect is the definition of a 'stream', as this can impose many expensive and severe restrictions on management of the land. For large rivers, a common issue is the effect of river management on flooding forests. In each case, the issues are complex, information is difficult to collect, and there are fundamental difficulties in going from anectotal observation to data. Currently, most information appears to be at a relatively local level, and there is a very inadequate knowledge base to give a more holistic overview, although the concept of 'cumulative effects', with the effects accumulated over both space and time, has much potential value. There are many opportunities for work in this field.

Brinson, M. M., H. D. Bradshaw, and E. S. Kane. 1984. Nutrient asssimilative capacity of an alluvial floodplain swamp. *Journal of Applied Ecology* 21: 1041-1057.

Nitrate, ammonium and phosphate were added to the forest floor of an alluvial swamp at a weekly rate of 1 g of nitrogen or phosphorus per m^2 for nearly 1 year. The experimental design allowed examination of nutrient assimilation and accumulation under field conditions that cannot be duplicated in the laboratory and produced results relevant to management of these swamps for wastewater treatment. Nitrate loss by denitrification was rapid and persistent; only slight accumulation occurred in surface water, and soil water accumulation was undetectable. Ammonium accumulated on cation exchange sites but was transformed to nitrate during drydown of sediments in summer and autumn. As nitrate did not accumulate, a tight coupling of nitrification and denitrification is inferred. Phosphate accumulated in sediments principally in acid-extractable form with little evidence of loss after the additions ceased. At these high loading rates, uptake of nitrogen and phosphorus by vegetation and accumulation in tree stem-wood was small in comparison with disappearance by denitrification and accumulation in sediments. The capacity of the swamp for nutrient removal was highest for nitrate, intermediate for ammonium, and lowest for phosphate. Annual drydown of sediments would be required for sustained ammonium removal in swamps with prolonged flooding, as in this case. It appears that swamps of this type could be managed for inorganic nitrogen removal from sewage effluent, but their usefulness for tertiary treatment of phosphate is limited by the capacity of sediments for phosphorus storage. Management considerations not evaluated by this study, but deserving further investigation are possible health impacts related to sewage effluent and competing ecological services such as wildlife production.

Brookes, A. 1992. Recovery and Restoration of Some Engineered British River Channels. Pages 337-352 in P. J. Boon, P. Calow, and G. E. Petts, eds. *River Conservation and Management*. John Wiley & Sons Ltd, Chichester, UK.

Channel maintenance offsets stream recovery, while lack of such maintenance permits gradual stream recovery. The nature and rate of adjustment following channel works depends not only on the available energy or stream power but also on the sediment supply from the catchment upstream or from channel erosion. The plan shape of a modified reach is also important: even in relatively low-energy rivers a bend may cause the flow lines to converge locally and scour a shallow pool. A variety of morphological adjustments have been identified for modified reaches of high-energy gravel drawn from upstream was responsible for reducing the capacity of many of the enlarged channels. Use of allowable mean velocity as an engineering design criterion in gravel-bed rivers means that, while erosion may be prevented in most cases, no attention is paid to deposition . Clearly, sediment-laden streams will deposit if maximum velocities are insufficient to keep the sediment in motion. However, the maximum average value obtained for the reduction of the enlarged capacity by adjustment was 35% for the River Caldew (in a period of 35 years), and at the majority of sites the value was less than 12%. This relatively small amount of adjustment could be attributed to a number of factors, including an insufficient source area for gravel above the scheme, associated structural works to prevent infill, or channel maintenance. Shoals and shallow pools developed as reaches infilled. The reduction of the enlarged channel capacity at resectioned lowland sites was also insignificant, with a maximum value of 9% being obtained for the River Cherwell in Oxfordshire in the absence of regular maintenance over a period of 14 years. In view of these findings, it is concluded that the modified channels studied were not significantly affected by morphological adjustment and that this is, therefore, unlikely to have a major impact on the conveyance of flood flows or arterial drainage. By undertaking further hydraulic modeling studies the significance of re-formed deposits on flood flows could be calculated for these channels. It is recommended that these types of recovery be allowed to continue, where hydraulic performance is not endangered, until a new equilibrium is attained. Where a widened reach adjusts by sediment deposition then this may be beneficial to both the flora and fauna by creating a more natural low-flow width (e.g. Brookes, 1987b). Maintenance or management plans should be drawn up to protect such features where feasible. In exceptional circumstances, where a straightened channel has naturally regained its original sinuosity, a corridor could be designated to accommodate that adjustment. Channel recovery occurs across a wide range of stream powers in England and Wales. Lack of natural adjustment at low-stream sites means that restoration of morphological features may be required. It is essential to establish for each individual stream the restoration design which is hydraulically and biologically appropriate. Some indication of the physical constraints which have determined the success or failure of restoration designs can be obtained from projects already implemented in similar environments. As yet, there are relatively few documented examples, and it is difficult to make accurate predictions and recommendations. Particular problems arise when attempting to enhance a straightened reach of channel through reintroduction of substrate or channel narrowing. Even in lowland clay rivers, the potential for scour in straightened reaches means that materials must be appropriately sized and located.

Brookes, A., J. Baker, and C. Redmond. 1996. Floodplain Restoration and Riparian Zone Management. Pages 201-228 in A. Brookes and J. F. Douglas Shields, eds. *River Channel Restoration: Guiding Principles for Sustainable Projects*. John Wiley and Sons, Ltd., Chichester, UK.

Clearly restoration of floodplains raises extremely complex and often unanswered questions. A not for optimism is that in the 1980's and 1990's the river corridor environment has become a major theme of interdisciplinary research (Malanson 1993; Gurnell 1995). If projects are to be sustainable over the longer term then more comprehensive approaches may be necessary. Floodplain restoration may be critical to true restoration of river channels for a number of reasons, whilst conversely restoration on floodplains cannot be successfully achieved in isolation from consideration of the hydraulics and geomorphology of river channels themselves (Chapters 2 and 3) and without appraisal of the upstream catchment conditions (Chapter 6), including the impacts of water quality (Chapter 7). There are also a large number of channel and floodplain types around the world (Chapter 5) which may compound the uncertainties for river managers working at a particular site. Chapters 9 to 13 provide further case studies of particular river-floodplain types form witch river managers can draw analogies.

Brunet, R. C., G. Pinay, F. Gazelle, and L. Roques. 1994. Role of the floodplain and riparian zone in suspended matter and nitrogen retention in the Adour River, south-west France. *Regulated Rivers: Research & Management* 9: 55-63.

The retention capacity of the floodplain and riparian zone for suspended matter and nitrogen has been investigated in the Adour River, a seventh order stream in south-west France. Suspended matter and nitrogen fluxes through a 25 km meandering stretch of the river were measured during two flood events and compared with the amount of sediment trapped in the riparian zone (1.1 km2) and the major floodplain (16.8 km2) of the studied area. It was estimated that the floodplain and the riparian zone together retained between 10 and 20% of the suspended matter entering the stretch under study during the two main floods (138,700 Mg). Moreover, they retained about 11% of the total particulate nitrogen fluxes (640Mg). Although the riparian zones are 15 times smaller than the major floodplain, the total suspended matter and particulate nitrogen deposition were, 50 and 17 times, respectively, larger in the riparian zone. The results obtained on the Adour River floodplain show that large river systems should not be considered only as export systems as riparian zones can retain a significant amount of suspended organic and mineral matter during floods.

Burt, T. P. 1997. The Hydrological Role of Floodplains Within the Drainage Basin System. Pages 21-32 in N. E. Haycock, T. P. Burt, K. W. T. Goulding, and G. Pinay, eds. *Buffer Zones: Their Processes and Potential in Water Protection*. Quest Environmental.

Floodplains play several important roles within the drainage basin system. In small to medium-sized basins (<10,000 km^2), floodplains are usually quite narrow (1 km^2) and may act either as a conduit or a barrier to water movement - and associated sediment and solute transport - from hillslopes to the river channel. Indeed, it is generally acknowledged that, for low-order streams especially, the condition of the river and the condition of the riparian zone are intimately linked. However, the ability of a floodplain to act as a pollution buffer between farmland and the river depends fundamentally on the hydrological properties of the floodplain sediments, providing opportunity for processes such as denitrification and deposition of suspended sediment load from surface runoff. Impermeable alluvium tends to deflect influent groundwater through aquifers below the alluvium or across the floodplain surface; in either case, the buffering capacity of the floodplain is greatly restricted. In large basins, floodplains may be several kilometers wide and hillslope inputs become less important compared to overbank flooding and storage of flood waters generated in the catchment headwaters. This paper will consider the topographical and sedimentological controls of floodplain hydrology, using results from modelling studies and field experiments in southern England to illustrate general themes.

Campbell, I. C., P. J. Boon, B. L. Madsen, and K. W. Cummins. 1997. Objectives and approaches in lotic and restoration projects. *Meanders* 8.

Restoration is becoming increasingly necessary as more and more ecosystems suffer from excessive human use or misuse. Although restoration of ecosystems has been discussed in the scientific and management literature for at least 20 years (e.g. Cairns et al., 1977; Holdgate and Woodman, 1978; NRC, 1992) much of the early attention on aquatic ecosystems focused on restoring eutrophic lakes (e.g. Lake Washington see Edmondson, 1991) with stream restoration limited to actions designed to improve water quality (e.g. see Gameson and Wheeler, 1977). More recently restoration of lotic aquatic systems has been recognized as needing a more comprehensive approach incorporating concerns about water quality, physical habitat and biota as well as the influence of catchment processes, especially riparian influences (e.g. Gardiner, 1991; Boon et al., 1992, NRC, 1992). Various approaches to the restoration of riverine and riparian ecosystems have developed indifferent countries. The approach most suited to any given situation will depend on a range of factors including the condition of the stream, the circumstances which have caused the deterioration, physical constraints, the cultural environment and the funds available for restoration. Many of the scientific principle involved appear to be universally applicable, but other factors (especially economic and cultural ones) necessitate a unique approach in each region, if not each individual restoration project. At the SIL meeting in Sao Paulo, Brazil (August, 1995) the SIL Working Group on the Conservation Management of Running Waters convened a meeting to discuss the objectives and approaches to restoring streams and rivers and their riparian zones. Four case studies from different countries were presented, highlighting different approaches adopted. This paper includes a brief summary of the case studies and an outline of some of the discussion points which were raised by the Working Group participants.

Charbonneau, R., and V. H. Resh. 1992. Strawberry Creek on the University of California, Berkeley Campus: A case history of urban stream restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems* 2: 293-307.

1. Strawberry Creek (37degrees 52 mins N; 122 degrees 15 mins W) is the major focus of open space on the University of California, Berkeley (Alameda County, California, USA) campus; it provides visual amenity and variety, riparian and wildlife habitat, and educational and recreational opportunities. 2. Since the beginning of this century, urbanization of the catchment, channel alteration and water quality degradation combined to cause deterioration of the creek's habitat and overall environmental quality; this was manifested by a marked absence of flora and fauna, obvious water pollution and severe erosion. 3. In 1987 a restoration project was undertaken that focused on water-pollution and erosion-control measures. In 1989, native three-spined sticklebacks (*Gasterosteus aculeatus*) were successfully reintroduced. Family Biotic Index scores for the macroinvertebrate community indicated a change from the 'poor' water quality conditions in 1986 to 'good' water quality in 1991. 4. Environmental education programmes now involve over 1500 students who use the creek each year in laboratory exercises; a popular natural histroy and conservation walking-tour guidebook has also been prepared. 5. On-going restoration efforts include additional reintroductions of other native species, further environmental education efforts and monitoring. 6. Obstacles and key factors that led to the successful implementation of this project are presented to assist in implementing similar ecological restoration projects of urban streams.

Clausen, J. C., K. Guillard, C. M. Sigmund, and K. M. Dors. 2000. Water quality changes from riparian buffer restoration in Connecticut. *Journal of Environmental Quality* 29: 1751-1761.

One-half of a 35- by 250-m riparian buffer cropped in corn (*Zea mays* L.) was seeded with fine leaf fescue (*Festuca* spp.) and allowed to remain idle to determine water quality changes resulting from riparian buffer restoration. A corn control was also used in this paired watershed design located in Connecticut. Water, N, and P fluxes were determined for precipitation, overland flow, and ground water. Also, an N mass balance was calculated. Total Kjeldahl nitrogen (TKN) and total phosphorus (TP) concentrations significantly ($P<0.05$) increased as ground water flowed through the restored buffer. Nitrate N (NO_3-N) concentrations declined significantly but most (52%) of the decrease occurred within a 2.5-m wetland adjacent to the stream. An N mass balance for the 2.5-m strip indicated that denitrification only accounted for 1% of the N losses and plant uptake was from 7 to 13% of the N losses annually. Ground water was the dominant source of N to the buffer and also the dominant loss. Restoration of the riparian buffer decreased ($p<0.05$) overland flow concentrations of TKN by 70%, NO_3-N by 83%, TP by 73%, and total suspended solids (TSS) by 92% as compared with the control. Restoration reduced ($p<0.05$)

NO_3-N concentrations in ground water by 35% as compared with the control. Underestimated denitrification and dilution by upwelling ground water in the wetland area adjacent to the stream were believed to be primarily responsible for the decreasing NO_3-N concentrations observed.

Cohn, J. P. 2001. Resurrecting the dammed: A look at Colorado River restoration. *BioScience* 51: 998-1003.

Collins, B. D., and D. R. Montgomery. 2002. Forest development, wood jams, and restoration of floodplain rivers in the Puget Lowland, Washington. *Restoration Ecology* 10: 237-247.

Historically in Puget Lowland rivers, wood jams were integral to maintaining in anastomosing channel pattern and a dynamic channel-floodplain connection; they also created deep pools. In the late 1800s, wood was removed from most rivers, rivers were isolated from their floodplains, and riparian forests were cut down, limiting wood recruitment. An exception to this history is an 11-km-long reach of the Nisqually River, which has natural banks and channel pattern and a mature floodplain forest. We use field and archival data from the Nisqually River to explore questions relevant to restoring large rivers in the Pacific Northwest and other forested temperate regions. In particular, we focus on the relation between recovery of in-channel wood accumulations and valley bottom forest conditions and explore implications for river restoration strategies. We find that restoring large rivers depends on establishing riparian forests that can provide wood large enough to function as key pieces in jams. Although the frequency of large trees in the Nisqually valley bottom in 2000 is comparable with that of 1873 land surveys, many formerly more abundant *Thuja plicata* (western red cedar) were cut down in the late 1800s, and now hardwoods, including *Populus trichocarpa* (black cottonwood) and *Acer macrophyllum* (bigleaf maple), are also abundant. *Pseudotsuga menziesii* (Douglas fir) and fast-growing *P. trichocarpa* commonly form key pieces that stabilize jams, suggesting that reforested floodplains can develop naturally recruited wood jams within 50 to 100 years, faster than generally assumed. Based on the dynamic between riparian forests, wood recruitment, and wood jams in the Nisqually River, we propose a planning framework for restoring self-sustaining dynamic river morphology and habitat to forested floodplain rivers.

Conine, K. H., B. W. Anderson, R. D. Ohmart, and J. F. Drake. 1978. Responses of riparian species to agricultural habitat conversions. Pages 248-262 in *Stategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems*. U.S.D.A. Forest Service, Callaway Gardens, Georgia.

Approximately 1100 ha of agricultural land and 540 ha of riparian habitats were censused over a 14 month period in the lower Colorado River Valley to examine relative use of these areas by riparian birds. We found that many species did not use agricultural lands at all; insectivorous species suffered severe losses through agricultural conversions, whereas fringillids, doves, some flycatchers, and the Brown-headed Cowbird used agricultural areas to a high degree. Riparian birds seemed to travel either very short distances into agricultural areas on rare occasions, or they frequently traveled great distances into those areas. Distance traveled from riparian vegetation was correlated with density and number of riparian species as were weedy margins, canals, and alfalfa (Medicago sativa). Also, agricultural-riparian edge was beneficial to certain species.

Copp, G. H. 1989. The habitat diversity and fish reproductive function of floodplain ecosystems. *Environmental Biology of Fishes* 26: 1-27.

Fish reproduction in floodplain ecosystems, based on relative abundance and total biomass of 0+ juveniles, was studies using the synchronic approach to typological analysis in conjunction with Point Abundance Sampling by modified electrofishing. In 3 different flood plains of the Upper Rhône River, 1015 point samples yielding 4573 juveniles (0+) from 21 species were collected from 48 ecosystems of various geomorphological origin. The results demonstrate the lotic-to-lentic succession of floodplain ecosystems to be a series of non-sequential reproductive zones, with spawning conditions being reflected by the specific composition and guild structure of the YOY fish assemblages. The habitat diversity and the fish reproductive potential of floodplain ecosystems are strongly influenced by geomorphological origin and by past and present hydrological conditions. The YOY assemblages of autogenically driven ecosystems (usually of anastomorse or meander origin) tend to differ both in composition and in quantity from those found in allogenically driven ecosystems (generally braided origin). Ecosystems of intermediate character, and fish reproduction thereof, occur as the result of either ecosystem rejuvenation or senescence: autogenically driven ecosystems by allogenic mechanisms, or allogenically driven ecosystems by anthropic and/or autogenic mechanisms, respectively. Because of co-occurrence of ecosystems at similar and at different successional status, the flood plain as an entity is seen as 'stable' with respect to fish reproduction.

Crance, J. H. and L. S. Ischinger. 1989. Fishery functions and values of forested riparian wetlands. *American Water Resources Association; Water: Laws and Management*: 14A-9 - 14A-16.

This paper focuses on freshwater forested floodplain wetlands in the southeastern United States. Relationships between these wetlands and the associated riverine fishery resources are reviewed, and management implications and research needs are discussed. Forested riparian wetlands provide spawning and nursery habitat for more than 90 species of fish, and the annual fishery harvest from some of the most productive wetlands has exceeded 8,000 kg/km2. These wetlands also import, store, produce, and recycle materials used in food chains in situ, and are a source of residual materials used in downstream food chains. Wetland characteristics that respond to hydrologic regimes include productivity, species diversity and structure, nutrient cycling, and fish habitat quality and quantity. Thus, anthropogenic changes that affect hydrologic regimes and the fishery resources of these wetlands should be considered when stream corridor developments are evaluated.

Decamps, H. 1996. The renewal of floodplain forests along rivers: a landcape perspective. *Verh. Internat. Verein. Limnol.* 26: 35-59.

Floodplain forests are integral parts of river ecosystems. Their importance interest as transition zones is well established, and thus they cannot be ignored in river conservation or restoration schemes. At the same time, fragmentation and flow regulation of river systems are general (Dynesius & Nilsson 1994), and examples throughout the world indicate that this phenomenon often produces unexpected changes in floodplain forest dynamics. There is still the need for further information therefore on the mechanisms by which floodplain forests regenerate. Progress has been made during the last few years in two main areas. Firstly, if reference is made to the three major disciplines involved - hydrology, geomorphology and ecology - links can be made with model processes which depend on water, landform and riparian plant species (Murray & Paola 1994). Secondly, if ecology is considered on its own, then spatially explicit models can be used to predict the effect of landscape configurations on ecosystem and population processes (Kareiva & Wennergren 1995). Indeed, a strong conceptual basis is being put together to enable us to understand and predict floodplain forest renewal.

Dijk, G. M. V., E. C. L. Marteijn, and A. Schulte-Wulwer-Leidig. 1995. Ecological rehabilitation of the River Rhine: plans, progress and perspectives. *Regulated Rivers: Research & Management* 11: 377-388.

The River Rhine has suffered because of numerous drastic environmental changes-for example, the regulation of the river bed and the construction of weirs and dams. Furthermore, discharges of agricultural, industrial and municipal wastewater have caused deterioration in the water quality. This problem became particularly acute in the 1960's and 1970's. After the Sandoz accident in Basle in November 1986, the states bordering the River Rhine agreed the Rhine Action Programme for its ecological rehabilitation. This programme has the following four aims, which should be realized by the year 2000: (1) to create conditions which will enable the return of higher species (such as salmon); (2) to safeguard Rhine water as a source for the preparation of drinking water; (3) to abate the contamination of sediments due to toxic compounds; and (4) to fulfill the requirements of the North Sea Action Plan, as the River Rhine flows into the North Sea. Water quality criteria have been developed for about 50 contaminants or contaminant groups and for phosphorus and ammonium. Early signs of the ecological recovery of some aquatic communities in the River Rhine have been observed, but eutrophication and pollution by micropollutants, in particular polychlorinated byphenyls found in suspended matter, sediments and biota, still form a serious threat. In addition to further improving the water quality, river habitats must be improved, reversing the artificial river control measures taken in the past for the return of a number of characteristic riverine organisms such as migratory fish. The 'Ecological Master Plan for the River Rhine' aims to restore the mainstream, along with the main tributaries, as habitats for migratory fish (e.g. salmon). This involves protecting, preserving and improving ecologically important reaches of the River Rhine and the Rhine valley. The first steps for realizing the hydrological and morphological modifications have been taken, starting with the development of a specific ecological network focusing on the most important floodplain areas along the Rhine. Habitat improvement measures started later than the pollution abatement measures and, so far, the relatively few studies on the effectiveness of the ecological rehabilitation techniques concerning habitat improvements in the Lower Rhine have been published. A major task for research programmes will be to identify the detailed quantifiable and verifiable ecological objectives (e.g. water quality criteria, hydrological and morphological targets) to guarantee the actual ecological rehabilitation of the River Rhine.

Dister, E., D. Gomer, P. Obrdlik, P. Petermann, and E. Schneider. 1990. Water management and ecological perspectives of the Upper Rhine's floodplains. *Regulated Rivers: Research & Management* 5: 1-15.

The diverse Upper Rhine floodplains (with regard to geomorphology, hydrology, vegetation, and fauna) have undergone far reaching changes over the last 170 years, intensified from 1955 to 1977, especially as a result of water engineering measures. Far reaching and serious disturbances of the ecological balance (flood problems, lowering of the water table, etc.) and the drastic reduction of biotic communities, as well as the increasing demands of society, call for a newly oriented policy with regard to the future development of the Upper Rhine floodplains. This should be based on a critical review of the recent history of the landscape and recognition of the ecological importance of these floodplains.

Dobkin, D. S., A. C. Rich, and W. H. Pyle. 1998. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin. *Conservation Biology* 12: 209-221.

Riparian habitats are centers of biological diversity in arid and semiarid portions of western North America, but despite widespread loss and degradation of these habitats there is little quantitative information concerning restoration of native riparian biota. We examined the recovery of a riparian meadow system in the context of long-term versus short-term release from livestock grazing. We compared the structure and dynamics of plant and avian communities on 1.5-ha plots inside a long-term (>30 years) livestock exclosure ("exclosure plots"), with adjacent plots outside the exclosure ("open plots") for 4 years following removal of livestock from open plots. Throughout the study, sedge cover, forb cover, and foliage height diversity of herbs were greater on exclosure plots; bare ground, litter cover, shrub cover, and shrub foliage height diversity were greater on open plots. Forb, rush, and cryptogamic cover increased on open plots but not on exclosure plots. Grass cover increased, whereas litter and bare ground decreased on all plots but not on exclosure plots. Grass cover increased, whereas litter and bare ground decreased on all plots in conjunction with increased availability of moisture. Sedge cover did not change. Avian species richness and relative abundances were greater on exclosure plots; species composition differed markedly between exclosure and open plots (Jaccard Coefficient = 0.23-0.46), with exclosure plots dominated by wetland and riparian birds and open plots dominated by upland species. The appearance of key species of wet-meadow birds on open plots in the third and fourth years following livestock removal signaled the beginning of restoration of the riparian avifauna. We interpret the recovery of riparian vegetation and avifaunal composition inside the exclosure as a consequence of livestock removal, which led to a rise in the water table and an expansion of the hyporheic zone laterally from the stream channel. The lack of change in sedge and shrub cover on open plots suggests that restoration to a sedge-dominated meadow will not happen quickly.

Dominick, D. W. S., and M. P. O'Neill. 1998. Effects of flow augmentation on stream channel morphology and riparian vegetation: upper Arkansas River Basin, Colorado. *Wetlands* 18: 591-607.

We characterized changes in stream morphology and riparian vegetation cover at eight field sites in tributary basins of the upper Arkansas River, Colorado, U.S.A. Three of these sites have experienced flow augmentation, while five others are responding to natural flow conditions. Data analyzed for the eight field sites included hydrologic data from U.S. Geological Survey gaging stations, extensive field surveys of riparian vegetation and channel and floodplain morphology, and land-cover maps compiled from historic aerial photographs of field sites. Hydrologic analyses indicated that augmented peak annual floods in the Lake Creek basin are more than double those of Clear Creek or Cottonwood Creek, similar tributaries where flow augmentation does not occur. Likewise, augmented peak floods on Lake Fork are roughly double those of a similar tributary basin with a natural flow regime. Flow duration curves from these basins also indicated that flows of a given magnitude are sustained over longer periods of time in the Lake Creek and Lake Fork basins than in comparable basins lacking flow augmentation. Historic

changes in the channel pattern at augmented sites indicated a shift from highly sinuous meandering channels. Data from field sites also indicated that along augmented reaches, bankfull channel width and width-depth ratios are greater than in comparable sections that lack flow augmentation. Similarly, substrate size on depositional bars at augmented sites is substantially coarser than on streams without flow augmentation. Median particle size for the three sites along augmented reaches ranges from 38-56 mm. By contrast, sites where natural flows occur have median particle sizes between 15 and 26 mm. Historic aerial photograph analysis indicated that over the last 56 years, loss of riparian vegetation cover at sites where flow augmentation occurs was greater than that at sites where natural flows occur. Bottomland area immediately adjacent to the active channel have experienced up to a 10% decrease in riparian vegetation cover at sites affected by augmented flows. These losses primarily occur along channel margins, with commensurate increases in exposed depositional bars and active channel features. By contrast, along reaches where natural flows occur, riparian vegetation cover generally shows a net increase or decrease of less than 2% of the bottomland area. Substantial change in channel and floodplain morphology suggests that augmented streams in the upper Arkansas River basin are continuing to adjust their shape and channel dimensions to achieve a new equilibrium. The complex response of mountain streams to flow augmentation over a relatively short geologic time period makes the prediction of future long-term condition difficult. Restoration planners working in this or similar watersheds must recognize the historic and potential future impacts of flow augmentation when evaluating sites for restoration efforts.

Dorris, T. C. 1958. Limnology of the middle Mississippi River and adjacent waters: lakes on the leveed floodplain. *American Midland Naturalist* 59: 82-110.

Douglas, I. 2000. Fluvial geomorphology and river management. *Australian Geographical Studies* 38: 253-262.

Australian river landscapes offer many challenges for management. Much Australian river research is novel, but practical concerns have always had an influence on the research agenda. Australia's distinctive contributions to fluvial geomorphology include recognition of the great age of many fluvially eroded landscapes; understanding complex levee, terrace and valley fill sequences; analyzing the impacts of rare major floods; interpreting the effects of impoundment, mining and urbanization; and understanding the great anastomosing inland river systems. River restoration is now a major theme in the literature of river engineering, fluvial geomorphology and landscape design. Great achievements are occurring in geo-ecological river management and engineering. Changing people's thinking is becoming at least as important as gaining new scientific knowledge. The existing understanding needs to be more widely shared and enhanced by greater involvement with Asian countries where river management issues daily affect the lives of millions of people.

Duel, H., W. D. Denneman, and C. Kwakernaak. 1994. Ecological models for river floodplain rehabilitation. *Water Science Technology* 29: 383-386.

In The Netherlands, projects have been started by the government concerning ecological rehabilitation of rivers and river floodplains. Hydrological, morphological and ecological models

are indispensable tools to river basin management. In this paper a cluster of models is presented which have been used to predict and assess the effectivity of measures on improving the environmental quality and the ecological rehabilitation of the floodplains. The cluster of models consists of a simulation model for riparian vegetation development, habitat suitability evaluation models and an expert system concerning the contamination of river habitats and its ecological impact. This approach will result in an integrated ecological, environmental and water management in order to realize the ecological objectives for the rivers in The Netherlands.

Ewing, M. S. 1991. Turbidity control and fisheries enhancement in a bottomland hardwood backwater system in Louisiana (U.S.A.). *Regulated Rivers: Research & Management* 6: 87-99.

In response to a noticeable decline in recreational fishing in the formerly productive Larto-Saline backwater complex of east central Louisiana, a study was begun to identify causative factors for the decline and to determine effective methods to remedy the problem. To this end, water quality and fisheries surveys were conducted in the system for the study period 1 July, 1981 to 30 June, 1989. Data collected during the early years of the study indicated chronically high turbidity (>100 FTU) to be the major factor limiting game fish production. The high turbidity can be related to man-made alterations of natural flood patterns that had changed the major source of backwater flooding from Black River to the highly turbid Red River. In September, 1986, a construction project was undertaken to restore flood patterns to approximate natural conditions. Sampling subsequent to this construction has shown a significant decrease in turbidity and an increase in game fish production.

Fisher, S. A., and W. E. Kelso. 1988. Potential parasite-induced mortality in age 0 bluegills in a floodplain pond of the lower Mississippi River. *Transactions of the American Fisheries Society* 117: 565-573.

We assessed seasonal variations in endoparasite intensity (number per host) for six 1986 cohorts of age-0 bluegill *Lepomis macrochirus* collected from an overflow pond of the lower Mississippi River during March-December 1986. *Allacanthochasmus* sp. (Trematoda) was the predominate endoparasitic taxon infecting bluegills. We noted peaked intensity curves and declines in variance-to-mean ratios for total endoparasites and *Allacanthochasmus* sp. for three cohorts during pond flooding in October. Although changes in the distribution of parasite intensities during this period may have reflected bluegill mortality, declines in variance-to-mean ratios of parasite intensities were smaller than those predicted by theories of parasite-induced host mortality. We also examined bluegills of the previous (1985) year class in spring 1986; their endoparasite intensities and variance-to-mean ratios were substantially lower than those of 1986 cohorts in fall 1986. Because these data are from two year classes, they may not accurately reflect changes in the frequency distribution of endoparasites in age-0 bluegills during winter. However, there is little evidence of parasite mortality at low temperatures; if the pre-and postwinter intensity data are representative, overwintering mortality of parasitized bluegill may be substantial.

Ford, N. B., V. A. Cobb, and J. Stout. 1991. Species diversity and seasonal abundance of snakes in a mxed pine-hardwood forest of eastern Texas. *The Southwestern Naturalist* 36: 171-177.

Drift fences were used to live-trap snakes over a 4-year period in three habitats of a 32.2 ha forest preserve in northeastern Texas. The upland deciduous woodland had the most species (17 with 99 individuals) and the highest species diversity, but the lowland floodplain had the greatest number of snakes (15 species, 142 individuals). The upland coniferous woodland had the fewest snakes and the lowest species diversity (10 species, 72 individuals). The southern copperhead, *Agkistrodon contortrix*, was the dominant species in both upland habitats, and the western cottonmouth, *Agkistrodon piscivorus*, was the most abundant snake in the lowland habitat. The lowland floodplain had six species restricted to that habitat, the upland deciduous woodland had two, but no species were found only in the upland pine area. The Texas rat snake, *Elaphe obsolete* was the first species captured in the spring. *Agkistrodon controtrix* and the eastern coachwhip, *Masticophis flagellum*, were abundant in mid-summer, and *Agkistrodon piscivorus* was numerous in the fall. *Agkistrodon controtrix* was most abundant in the rocky upland deciduous woodland in the spring and increased its numbers in the other habitats in mid-summer. *Elaphe* showed the greatest habitat niche width, whereas *A. piscivorus* had the narrowest. The greatest niche overlap occurred between *M. flagellum* and *E. obsolete*, whereas the least overlap was between *M. flagellum* and *A. piscivorus*.

Frissell, C. A., and R. K. Nawa. 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management* 12: 182-197.

In recent years an increasing share of fishery management resources has been committed to alteration of fish habitat with artificial stream structures. We evaluated rates and causes of physical impairment or failure for 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington, following a flood of a magnitude that recurs every 2-10 years. The incidence of functional impairment and outright failure varied widely among streams; the median failure rate was 18.5% and the median damage rate (impairment plus failure) was 60%. Modes of failure were diverse and bore no simple relationship to structure design. Damage was frequent in low-gradient stream segments and widespread in streams with signs of recent watershed disturbance, high sediment loads, and unstable channels. Comparison of estimated 5-10 year damage rates from 46 projects throughout western Oregon and southwest Washington showed high but variable rates (median, 14%; range, 0-100%) in regions where peak discharge at 10-year recurrence intervals has exceeded 1.0 m2*s-1*km-2. Results suggest that commonly prescribed structural modifications often are inappropriate and counterproductive in streams with high or elevated sediment loads, high peak flows, or highly erodible bank materials. Restoration of fourth-order and larger alluvial valley streams, which have the greatest potential for fish production in the Pacific Northwest, will require reestablishment of natural watershed and riparian processes over the long term.

Gabbe, A. P., S. K. Robinson, and J. D. Brawn. 2002. Tree-species preferences of foraging insectivorous birds: implications for floodplain forest restoration. *Conservation Biology* 16: 462-470.

The tree-species composition of forests can be an important component of habitat selection by breeding birds. We examined tree-species use by observing the foraging behavior of 13 species of foliage-gleaning birds in floristically diverse floodplain forests in southern Illinois in 1997 and 1998. Twelve of 13 bird species foraged selectively with respect to tree species. The Yellow-throated Warbler (*Dendroica dominica*) and Cerulean Warbler (*D. cerulea*) were the most selective species, whereas the Yellow-throated Vireo, Red-eyed Vireo, and Eastern Tufted Titmouse (*Vireo flavifrons, V. olivaceus, and Baeolophus bicolor*, respectively) were the lease selective. Three tree species were strongly preferred by most of the bird community: kingnut hickory, bitternut hickory, and silver maple (*Carya laciniosa, C. cordiformis, and Acer saccharinum*, respectively). Less common bird species tended to be more selective foragers than the more abundant bird species. The four most preferred trees were relatively uncommon where we sampled. Heavy-seeded hickories are slow to recolonize forests traditionally restored with common oak species (*Quercus spp*.). Therefore, restoring floristically diverse floodplain forests by planting preferred heavy-seeded and uncommon trees will enhance habitat quality for birds in these forests.

Gaff, H., D. L. DeAngelis, L. J. Gross, R. Salinas, and M. Shorrosh. 2000. A dynamic landscape model for fish in the Everglades and its application to restoration. *Ecological Modelling* 127: 33-52.

A model (ALFISH) for fish functional groups in freshwater marshes of the greater Everglades area of southern Florida has been developed. Its main objective is to assess the spatial pattern of fish densities through time across freshwater marshes. This model has the capability of providing a dynamic measure of the spatially-explicit food resources available to wading birds. ALFISH simulates two functional groups, large and small fish, where the larger ones can prey on the small fish type. Both functional groups are size-structured. The marsh landscape is modeled as 500 X 500 m spatial cells on a grid across southern Florida. A hydrology model predicts water levels in the spatial cells on 5-day time steps. Fish populations spread across the marsh during flooded conditions and either retreat into refugia (alligator ponds), move to other spatial cells, or die if their cells dry out. ALFISH has been applied to the evaluation of alternative water regulation scenarios under the Central and South Florida Comprehensive Project Review Study. The objective of this Review Study is to compare alternative methods for restoring historical ecological conditions in southern Florida. ALFISH has provided information on which plans are most likely to increase fish biomass and its availability to wading bird populations

Gerhard, M., and M. Reich. 2000. Restoration of streams with large wood: effects of accumulated and built-in wood on channel morphology, habitat diversity and aquatic fauna. *International Review of Hydrobiology* 85: 123-137.

Large wood was added to regulated and straightened reaches of two third-order streams in Central Germany; the Josslkein and the Luder. In the Jossklein, the wood was a by-product of the forest management in the floodplain and accumulated in the channel during peak floods. In the Luder, logs were built-in as deflectors in regular intervals and fixed within the stream bank. In the Jossklein, the addition of large wood improved the channel morphology within four years. The variation in channel width and depth was considerably larger than in a regulated section. The extension of the riparian zone, especially of the semi-aquatic gravel and sand bars was strongly correlated with the amount of large wood that accumulated in the single sections. The number of microhabitats and their patchiness on the stream bottom was higher in restored sections, as well as the density of macroinvertebrates and the species number. In the Luder, some of the observed trends were similar, but not that clear. This difference can be explained by higher amounts of LWD in the Josslkein, organized in dynamic debris dams situated above the water level at low flow, in contrast to the single stacks of logs at the Luder, situated as stable deflectors within the low flow water level.

Gilbert, M., R. Leclair, and R. Fortin. 1994. Reproduction of the northern leopard frog (*Rana pipiens*) in floodplain habitat in the Richelieu River, P. Quebec, Canada. *Journal of Herpetology* 28: 465-470.

We studied the reproductive ecology and characterized the spawning habitat of northern leopard frogs (*Rana pipiens*) during the spring of 1986 on a floodplain of the Richelieu River, Quebec, Canada. Egg deposition began after the water temperature reached 8 C and lasted approximately 10 d in April. Habitats with the highest number of egg masses, in decreasing order of importance, were a wet meadow (*Phalaris arundinacea / Cornus stolonifera*), a shallow marsh (*Lythrum salicaria/ Scirpus fluviatilis*), and an abandoned meadow (*Ambrosia artemissifolia*/ *Poa* sp.). Egg masses were deposited at depths less than 65 cm. The number of female spawners present in this area in 1986 was estimated at 271. The number of eggs per egg mass varied between 982 and 5230. Fucundity varied between 1319 and 5270 ovarian eggs and correlated with female body size (length). Females reached sexual maturity at 2 yr and at lengths greater than 60 mm. In males, 55% of age 1 individuals were mature at a length greater than 51 mm.

Gippel, C. J. 1995. Environmental hydraulics of large woody debris in streams and rivers. *Journal of Environmental Engineering* 121: 388-395.

Although awareness of the habitat value of large woody debris in streams has promoted a more environmentally sensitive approach to its management, present guidelines are largely intuitive and do not contain advise for conducting quantitative hydraulic investigations. This review of the literature provides information to assist management, and highlights deficiencies in current knowledge. Hydraulically, debris act as large roughness elements that provide a varied flow environment, reduce average velocity, and locally elevate the water-surface profile. This can significantly increase flood travel time. The significance of debris is scale-dependent. For example, the hydraulic effects are often drowned out in a large flood on a large river. Some hydraulic models can be used to predict the effect of debris removal or reinstatement. A challenge for research is the development of a hydraulically and biologically meaningful definition of debris geometry that can be readily used in the field. When more is known about the physical and biological significance of debris in rivers, a detained cost-benefit analysis of its management should be undertaken.

Gore, J. A., and F. L. Bryant. 1988. River and Stream Restoration. Pages 23-38. *Rehabilitating Damaged Ecosystems*. CRC Press Inc., Boca Raton.

Though rivers and streams represent a small portion of available freshwater (<0.02%), the natural replenishment of this component of the hydrologic cycle (often 2 weeks) has caused humans to perceive this resource as more available and less destructable. In turn, overuse and misuse of streams and rivers have resulted in severe damage to the ecosystems associated with running water systems. Ecosystem damage can take on such subtle characteristics such as increased sediment loads, poor water quality from urban runoff, and unobserved declines of habitat and production of game and nongame species. Unlike terrestrial reclamation or restoration projects, river restoration must also account for systems that interact to produce the lotic ecosystem. That is, pollutant loads from surface runoff must be reduced or eliminated and riparian vegetation must be restored to control erosion and to provide habitat for riparian fauna that also use lotic resources. Within the restored channel, a number of hydrologic considerations must be examined. Because discharge patterns are fairly predictable, channel configuration can be designed to simulate meander and depositional patterns. In addition, bank and bed availability will be planned and structures built. Both fish and their food sources, mostly from the benthic community, must also be restored. Since river restoration rarely involves direct transplantation or introduction of animal species, habitat structures should be designed to attract residents from colonizers arriving from upstream and downstream areas. Thus 'reclamation' of the instream flora and fauna is a process of habitat and colonization enhancement.

Gregory, S., H. Li, and J. Li. 2002. The conceptual bais for ecological responses to dam removal. *BioScience* 52: 713-723.

Scientists and resource managers have proposed the removal of nonfunctioning dams or dams that cause environmental harm or present unsafe conditions (Poff et al. 1997, Hart and Poff 2002). The basis for assessment of the ecological responses to dam removal and for the design of ecologically effective removal practices is largely conceptual. Particularly in the Pacific Northwest, the adverse effects that large dams have on endangered anadromous salmon require extensive mitigation measures, such as transporting salmon around dams by barge (figure 1), and are a major factor driving dam removal proposals. The introductory article in this series by Hart and Poff (2002) identifies some of the general effects of dams and the responses to dam removal. This article will extend those issues and illustrate the challenges faced in western North America in the removal of high dams, such as the dams on the Elwha and Snake Rivers.

Although more than 75,000 dams have been built in the United States (Shuman 1995), fewer than 500 have been removed. Most dams that have been removed are less than 10 meters (m) high, and no dams higher than 30 m have been removed. Now, however, at least seven high dams in the Pacific Northwest are being reviewed for possible removal (table 1). Citizens and resource managers face a critical question: How much do we know about likely ecological responses to the removal of dams? Stanley and Doyle (2002) have described empirical studies of the ecological responses that follow removal of small dams, and Smith and colleagues (2000) reported on a regional study of those responses in the Pacific Northwest, but no empirical studies of the effects of removing high dams have been conducted.

This article provides a conceptual perspective of the ecological responses to large dam removal, based on our understanding of the structure and function of river ecosystems and on insights gained from small dam removals, where appropriate. We discuss geomorphic responses, hydrologic effects, and several major biological interactions that are affected by dams or their removal. These issues are illustrated in the scientific deliberations concerning removal of high dams in two river basins in the Pacific Northwest- the Elwha River and the Lower Snake River.

Gregory, S. V., D. W. Hulse, D. H. Landers, and E. Whitelaw. 1998. Integration of biophysical and socioeconomic patterns in riparian restoration of large rivers. Pages 231-247 in H. Wheater and C. Kirby, eds. *Hydrology in a Changing Environment*. John WIley and Sons, Exeter, UK.

Summary: Riparian resources and floodplains are some of the most dynamic elements of any landscape. At the same time, societies highly value streamside properties: and pressures for human development commonly require these lands to be stable and safe from disturbance. This inherent contradiction is the basis for management of world floodplains and riparian forests. Planning of river management or restoration rarely incorporates physical processes that shape river channels, hydrologic regimes, ecological patterns and processes, demographic change, or economic values of riparian lands and resources. Though data sources (e.g., TM, air photo, resource inventories, streamflow data, land use records, populations census, economic indicators) and the analytical tools (e.g., GIS, hydrologic models, ecological models) are readily available for larger scales, restoration projects are planned for limited reaches of rivers and often are based on locally favored practices or single types of responses (e.g., flood control, channel stability, flood flow, vegetation, fish, nutrient retention). Integrated regional evaluation of biophysical processes and socioeconomic factors provides greater potential for long-term persistence of river restoration efforts and increased likelihood of ecological effectiveness.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones: focus on links between land and water. *BioScience* 41: 540-549.

Riparian zones contain valuable water resources, plant communities, fisheries, and wildlife. Perspectives of riparian zones based on isolated components of the terrestrial-aquatic interface are ecologically incomplete and have limited application to understanding of ecosystems. Management of riparian resources requires a conceptual framework integrating the physical processes that create valley floor landforms, patterns of terrestrial plant succession, and structural and functional attributes of stream ecosystems. An ecosystem perspective of riparian management objectives, evaluating current land-use practices, and developing future resource alternatives.

Grift, R. E., A. D. Buijse, W. L. T. v. Densen, and J. G. P. K. Breteler. 2001. Restoration of the river-floodplain interaction: benefits for the fish community in the River Rhine. *Large Rivers* 12: 173-185.

In the lower River Rhine, canalization of the river and disconnection of floodplains from the river bed lead to the present low diversity of habitats. Spawning conditions for especially rheophilic cyprinids have declined dramatically. Nowadays, eurytopic species dominate the riverine fish community. In 1989, river restoration started by connecting water bodies in the floodplains to the main channel permanently. To evaluate the effect of these restorations on the fish community, four water bodies, which differ in connectivity with the main channel, flow velocity and presence of aquatic vegetation, were sampled to investigate their functions as spawning and nursery areas for riverine fishes. The hypothesis that density of rheophilic cyprinids is in accordance with flow and connectivity was tested by analysis of presence-absence data, using logistic model and by analysis of variance for abundance data using a generalized linear model. Presence and abundance of rheophilic cyprinids increased from the isolated oxbow lake (not connected, no flowing water present) to connected oxbow lake (permanently connected with the main channel, no flowing water present) and to both secondary channels (permanently connected with the main channel, flowing water present permanently). Connectivity of a water body with the main channel and the presence of flowing water are important factors driving the structure of the YOY fish community in floodplain water bodies. Only a few years after their creation, secondary channels provide a suitable habitat as nursery areas for rheophilic cyprinids.

Harris, S. C., T. H. Martin, and K. W. Cummins. 1995. A model for aquatic invertebrate response to Kissimmee River restoration. *Restoration Ecology* 3: 181-194.

When the Kissimmee River was channelized in the 1960's and 1970's and placed under stage-fluctuation management, the dynamic interactions between the river and the floodplain were essentially removed. Correspondingly, aquatic invertebrate life in the river and floodplain ecosystem shifted from a riverine to a more lacustrine fauna. A relinkage of the Kissimmee River with the floodplain following restoration will result in numerous changes to such ecologically important factors as streamflow, substrate composition, food quality and quantity, and water quality, all of which will influence invertebrate communities. These factors and their function in the ecosystem as the fauna shifts from predominantly lacustrine back to riverine are presented in a conceptual model. As an integral component of all aquatic ecosystems and a key link between primary producers and higher trophic levels, aquatic invertebrates are a valuable group with which to evaluate the recovery of the Kissimmee River. Utilization of a geographic information system mapping approach linking expected increased habitat heterogeneity and invertebrate richness with restoration efforts is suggested as an economical means of monitoring recovery of the Kissimmee River ecosystem.

Hasfurther, V. R. 1985. The Use of Meander Parameters in Restoring Hydrologic Balance to Reclaimed Stream Beds. Pages 21-40 in J. A. Gore, ed. *The Restoration of Rivers and Streams*. Butterworth Publishers, Stoneham, MA.

Hauer, F. R., and R. D. Smith. 1998. The hydrogeomorphic approach to functional assessment of riparian wetlands: evaluating imppacts and mitigation on river floodplains in the U.S.A. *Freshwater Biology* 40: 517-530.

Summary :
1. The 'hydrogeomorphic' approach to functional assessment of wetlands (HGM) was developed as a synthetic mechanism for compensatory mitigation of wetlands lost or damaged by human activities. The HGM approach is based on: (a) classification of wetlands by geomorphic origin and hydrographic regime (b) assessment models that associate variables as indicators of function, and (c) comparison to reference wetlands that represent the range of conditions that may by expected in a particular region. In this paper, we apply HGM to riparian wetlands of alluvial rivers.
2. In the HGM classification, riverine wetlands are characterized by formative fluvial processes that occur mainly on flood plains. The dominant water sources are overbank flooding from the channel or subsurface hyporheic flows. Examples of riverine wetlands substratum of the south-

eastern coastal plain and the alluvial flood plains that typify the high gradient, coarse texture substratum of western montane rivers.
3. Assessment (logic) models for each of fourteen alluvial wetland functions are described. Each model is a composite of two to seven wetland variables that are independently scored in relation to a reference data set developed for alluvial rivers in the western U.S.A. Scores are summarized by a 'functional capacity unit' (FCU). When HGM is properly used, compensatory mitigation is based on the FCUs lost that must be returned to the riverine landscape under statutory authority.
4. The HGM approach also provides a framework for long-term monitoring of mitigation success or failure and, if falling, a focus on topical remediation.
5. We conclude that HGM is a robust and easy method for protecting riparian wetlands, which are critically important components of alluvial river landscapes.

Hehnke, M., and C. P. Stone. 1978. Value of riparian regetation to avian populations along the Sacramento River system. Pages 228-235. *Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems*, Callaway Gardens, Georgia.

The purpose of this study was to determine the value of riparian habitat along the Sacramento River to birds. Comparisons of avian populations through the year on riparian and riprapped berms, and agricultural lands associated with each, were made. Avian diversity (species/ha) was 71 percent and avian density (total number of birds) 93 percent less, on riprapped than on riparian plots. Avian diversity was 32 percent and avian density 95 percent less, on agricultural lands associated with riprapped vegetation than on those associated with riparian. Spring and fall migratory peaks of bird density and diversity were higher in riparian and associated vegetation than in riprapped and associated vegetatoin. Riparian vegetation appears to control avian density and diversity in associated vegetation.

Henderson, J. E. 1986. Environmental eesigns for streambank protection projects. *American Water Resources Association Water Resources Bulletin* 22: 549-558.

Streambank protection projects are intended to prevent streambank erosion, thereby preventing streambank failure and maintaining a desirable channel alignment. Streambank erosion is a natural process of unaltered, dynamic river systems, and protection projects seek to impose stability on this natural system. The environmental impacts of such projects are primarily changes to terrestrial and aquatic habitats and to aesthetics. Adverse environmental impacts have been minimized and enhancement of existing habitat and aesthetics have been achieved through the development of new, innovative designs or modifications to existing designs and through use of construction and maintenance practices that promote habitat and aesthetics. Designs based on channel flow characteristics, e.g., revetments using a variety of structural materials, can result in preservation of wildlife habitat by reducing the use of structural protection by matching the erosion potential of flow at the bank with the protection capability of the materials used. Designs based on streambed stabilization prevent bank failure caused by bank undermining, result in preservation or establishment of streamside vegetation, and enhance aesthetics. Protection schemes that manage and preserve floodplains, berms and riparian areas preserve the natural condition of the floodplain area. Designs based on deflection of erosive flows, e.g., dikes, minimize disturbance to the bank vegetation and create low-velocity aquatic habitats. Use of vegetation for bank protection is most effective when used in combination with structural components. Construction and maintenance practices can be scheduled and modified to minimize

impacts to floodplain areas and to enhance wildlife habitat while preserving the integrity of the protection structure.

Henry, C. P., C. Amoros, and Y. Giuliani. 1995. Restoration ecology of riverine wetlands: II. An example in a former channel of the Rhone River. *Environmental Management* 19: 903-913.

Riverine wetlands, which provide numerous valuable functions, are disappearing in floodplains of a channelized European river. A restoration project has been proposed by scientists to restore a former braided channel of the Rhone River by the removal of fine organic sediments in order to enhance groundwater supply. A precise and intensive prerestoration monitoring program during one year (including comparison with a reference channel) has taken into account several variables and ecological performance indicators measured at various spatial and temporal scales. Three restoration techniques were then suggested, taking into account two charcteristics of ecosystem functions for increasing restoration success and self-sustainability: 1. the riparian forest as well as the shores must be preserved or disturbed as little as possible; and 2. the upstream alluvial plug must be preserved to prevent direct supply of nutrient rich water from the Rhone River. Among the three restoration options proposed, it was not possible to carry out the less ecologically disturbing one as it was considered too expensive, time consuming, and difficult to realize. A precise and intensive postrestoration monitoring program, conducted over two years, demonstrated restoration success but also unpredicted problems, such as a locally thick layer of fine organic sediment. As long as a self-sustainable state is not achieved, this monitoring should be continued. Afterwards, a less precise and less intensive long-term monitoring should enable the detection of future events that may influence ecosystem changes.

Herricks, E. E., and L. L. Osborne. 1985. Water Quality Restoration and Protection in Streams and Rivers. Pages 1-20 in J. A. Gore, ed. *The Restoration of Rivers and Streams*. Butterworth Publishers, Stoneham, MA.

Restoration and protection of stream quality are concepts basic to the formulation of water quality regulation in the United States. In practice, the goal of both restoration and protection is the return to or maintenance of some preconceived notion of an undisturbed state. Since few undisturbed streams and rivers exist, arbitrary measures of restoration effectiveness are often based on readily accepted criteria and standards of water quality. The success of restoration and protection efforts and the applicability of any technique or methodology that restores water quality or protects existing uses is dependent on physical, chemical, and biological characteristics of the stream ecosystem and prevailing use and disturbance in each watershed. Assessment of restoration and protection is dependent of the scientific validity of the criterion value used as an endpoint. Protection and restoration of stream water quality requires a knowledge, appreciation and proper juxtaposition of several fields of science.
The primary methods of restoration are isolation, removal, transfer, and dilution through space and time of substances which degrade water quality or affect ecosystem structure and function. Protection of stream water quality is often technology based. the applicationof treatment technologies typically meets protection requirements where point sources of effluents, containing high concentrations of substances that degrade water quality, are encountered. The potential for water quality degradation from nonpoint sources is greater (entire watersheds may be involved), but substance concentrations are generally less than point source effluents. Protection of stream

water quality affected by nonpoint sources of pollution is dependent on the implementation of best management practices that control substance entry into stream systems.

Hickman, S. 1994. Improvement of habitat quality for nesting and migrating birds at the Des Plaines River Wetlands Demonstration Project. *Ecological Engineering* 3: 485-494.

The Des Plaines River Wetlands Demonstration Project includes a series of man-made marshes constructed on degraded habitat (abandoned agricultural land, gravel quarrying pits, etc.) within the floodplain of the Des Plaines River in northeastern Illinois, USA. Avian use of the site was measured before wetland construction in 1985 and after construction from spring 1990 to summer 1991. Pre construction censusing indicated that no endangered or threatened species nested within the project site, and that use of the site by migratory waterfowl was minimal. Post-construction censuses revealed that wetland construction resulted in the arrival of two state endangered species, Least Bittern and Yellow-headed Blackbird, which nested on site and in three state endangered species, during the breeding season. Similarly, post-construction censusing indicated that the number of individuals and species of waterfowl using the site increased about 4000% and 400% respectively. These results demonstrate that the Des Plaines River Wetlands Demonstration Project has improved habitat quality for nesting and migrating birds.

Hilderbrand, R. H., A. D. Lemly, and C. A. Dolloff. 1999. Habitat sequencing and the importance of discharge in inferences. *North American Journal of Fisheries Management* 19: 198-202.

We constructed stream maps for a low-gradient trout stream in southwestern Virginia during autumn (base flow) and spring (elevated flows) to compare spatial and temporal variation in stream habitats. Pool-riffle sequencing and total area occupied by pools and riffles changed substantially depending on the level of discharge: reduced discharge resulted in an increase in total pool surface area with more numerous but smaller pools than during spring. In contrast, total surface area of riffles decreased with decreasing discharge as did total wetted surface area. These findings suggest caution should be exercised when comparing seasonal or annual surveys, applying habitat guidelines for assessment or management, evaluating fish standing crop potential from predictive habitat models, or predicting availiability of habitat or biological information at times other than when stream surveys are conducted. We demonstrate the potential dangers by intentionally applying biological sample results taken at one discharge level to the same stream reach at a different discharge level. Our results clearly illustrate the importance of acquiring physical and biological information during similar discharges.

Hill, M. T., and W. S. Platts. 1998. Ecosystem restoration: A case study in the Owens River Gorge, California. *Fisheries* 23: 18-27.

In 1991 the Los Angeles Department of Water and Power, in cooperation with Mono County, California, initiated a multiyear effort to restore the Owens River Gorge. The project aims to return the river channel, dewatered for more than 50 years, to a functional riverine-riparian ecosystem capable of supporting healthy brown trout and wildlife populations. The passive, or *natural*, restoration approach focused on the development of riparian habitat and channel complexity using incremental increases in pulse (freshet) and base flows. Increasing pulse and base flows resulted in establishment and rapid growth of riparian vegetation on all landforms, and the formation of good-quality microhabitat features (pools, runs, depth, and wetted width). An extremely complex, productive habitat now occupies the bottom lands of the Owens River Gorge. A healthy fishery in good condition has quickly developed in response to habitat improvement. Brown trout numbers have increased each year since initial stocking, 40% between 1996 and 1997. Catch rates increased from 0 fish/hr in 1991 to 5.8-7.1 fish/hr (with a maximum catch rate of 15.7 fish/hr) in 1996. Restoring the Owens River Gorge bridges the theoretical concepts developed by Kauffman et al. (1997) and the practical application of those concepts in a real-time restoration project.

Hill, M. T., W. S. Platts, and R. L. Beschta. 1991. Ecological and geomorphological concepts for instream and out-of-channel flow requirements. *Rivers* 2: 198-210.

Healthy fish populations are dependent on streamflow regimes that protect the ecological integrity of their habitat. Fish habitats are the consequence of linkage among the stream, floodplain, riparian and upland zones, and watershed geography. Fluvial-geomorphic processes form and control fish habitat. Because of this, multiple in-channel and out-of-channel flows are needed to maintain these processes. We present a conceptual methodology for measuring four types of streamflow regimes: instream flows, channel maintenance flows, riparian maintenance flows, and valley maintenance flows. The combination for these four streamflow types is designed to protect fish and their habitat. Using a case study of the Salmon River near Whitebird, Idaho, we demonstrate how the methodology could be used to develop a multiple flow recommendation.

Horton, J. S. 1970. Management problems in phreatophyte and riparian zones. *Journal of Soil and Water Conservation* 27: 57-61.

At present there is a great need for basic research on water losses from vegetation and ecology and life history of the plants involved. There is also a great need for resource managers and interested citizens to get together and decide what should be done to realize the greatest benefits from all resources in phreatophyte and riparian zones. Perhaps a resource classification aimed at optimum use of these lands could be developed. Natural values must not be sacrificed for immediate economic gains before sound management plans can be developed to use wisely the intrinsic resources of the lands. In some areas, immediate action is needed to preserve existing resources

Howard, A. D. 1992. Modeling Channel Migration and Floodplain Sedimentation in Meandering Streams. Pages 1-37 in G. E. P. P.A. Carling, ed. *Lowland Floodplain Rivers: Geomorphological Perspectives*. John Wiley & Sons Ltd, Chichester, UK.

The present model combines a model for flow and bed topography in meandering streams (Johannesson and Parker, 1989) with the assumption that bank erosion rates are related to the near-bank perturbations of downstream velocity and channel depth. This model provides realistic migration of simulated channels, although the simulated channels tend to be somewhat more asymmetric, sinuous and regular than natural channels.

The floodplain deposition model, which assumes that deposition rates decrease with distance from the closest channel and with increasing floodplain elevation, produces simulated topography that resembles that of natural floodplains, including point bars and oxbow lakes. Bank sedimentation is assumed to be initiated from the near-bank depths predicted by the flow-bed topography model. This produces linear depressions or sloughs at the downstram, inside margins of point-bar complexes in locations of sharp bends. Similar sloughs or mid-channel bars are found in natural channels at sharp bends, particularly at locations of confined meandering and recent cut-offs.

Both the meandering and depositional models can be modified in a number of ways to increase the range of features that are simulated (such as floodplain stratigraphy) or to improve the fidelity to natural processes. However, both existing model assumptions and suggested modifications will require validation through studies of natural meandering processes, particularly over reaches of several bends or more.

Huggenberger, P., E Hoehn, R. Beschta, and W. Woessner. 1998. Abiotic aspects of channels and floodplains in riparian ecology. *Freshwater Biology* 40: 407-425.

Summary:
1. The ecology of riparian zones is enormously influenced by the heterogeneous sedimentary structures and associated complex hydrologic flow paths that mediate surface- and groundwater exchanges. Sedimentary structures form a three-dimensional, dynamic framework that controls subsurface flow and the vertical and horizontal exchange of water between channels and floodplains in gravel bed rivers. The modern structure of the bed sediments reflects the legacy of cut and fill alluviation for a particular river basin.
2. Highly permeable sedimentary textures, particularly open framework gravels, allow rapid exchange between surface and groundwaters.
3. Ground penetrating radar provides high resolution information on the nature and three-dimensional distribution of the sediments within the shallow subsurface (4-25 m) of gravel bed rivers. Bed sediments can be mapped at the decimeter scale.
4. Exchange and mixing of ground and channel water occurs along losing, gaining and flow-through reached as determined by the hydraulic gradient and transmissivity of the bed sediments.
5. Spatial and temporal patterns of surface- and groundwater interactions can be quantified by mass flux measurements and by assessing geochemical contrasts. Natural tracers, such as temperature or radon, are well suited for mapping exchange sites and quantifying interactions. Artificial signals produced by injecting anions, like chloride, bromide, and organic dyes are also useful.
6. The study of riparian ecosystems requires an understanding of the geomorphic structures and processes that build and maintain bed sediments and flow pathways through them.

Hughes, F. M. R. 1997. Floodplain biogeomorphology. *Progress in Physical Geography* 21: 501-529.

Floodplains are unique ecosystems because of their linear form, the sometimes extreme dynamism of their geomorphology and because they process large fluxes of energy and materials from upstream areas. This article focuses on the importance of hydrological inputs to floodplains through 1) their influence on the arrangement of landforms and vegetation communities and 2) the connections between flooding regimes and the regeneration and turnover time of floodplain vegetation. Many researchers have demonstrated close links between the arrangement of vegetation communities and sedimentary landform types, elevation, soil characteristics, tolerance to flooding and availability of soil moisture. It is suggested that plants on floodplains are found along a combined gradient of available moisture and oxygen which can be viewed simultaneously as a flooding frequency gradient and a complex soil moisture gradient. Discussion of experimental work on floodplains demonstrates the importance of these gradients to a range of floodplain species in different environments. The relationships between these environmental gradients and the apparent high level of overlap between planform patterns of landforms and vegetation communities on floodplains are related to lag times in different parts of vegetation communities. Flood regimes greatly influence the availability of area suitable for vegetation regeneration from year to year and the age structure of floodplain communities over decadal time frames. Biotic factors also influence biogeomorphological relationships on floodplains and range from sediment-trapping by vegetation to the impacts of beaver and grazing animals on floodplain hydrology and vegetation. Restoration of floodplains is high on the agenda in many countries and it is argued that, for sustainable results, restoration of hydrological pathways is essential. Planned flood releases below dams in several African countries have had varied success rates but the development of models for managing flows to achieve different restoration targets is the start of an integrated approach to restoring complex floodplain ecosystems.

Hupp, C. R. 1983. Vegetation pattern on channel features in the Passage Creek Gorge, Virginia. *Castanea* 48: 62-72.

Vegetation zones were studied on longitudinal bars and upstream ends of islands within the Passage Creek Gorge, Virginia. These channel features, which are inundated approximately 10-15 percent of the year, support vegetation different in species composition and growth form from riparian vegetation typical of higher areas of the flood plain. Frequency of flooding and flood damage to vegetation are greater on channel features than on the adjacent flood plain, which suggests that the frequency of flooding is an integral factor in the formation and maintenance of vegetation patterns. Recognition of these patterns may be useful in detecting flood potential in areas where there are little or no flood data.

Hupp, C. R., and W. R. Osterkamp. 1996. Riparian vegetation and fluvial geomorphic processes. *Geomorphology* 14: 277-295.

Riparian vegetation and fluvial-geomorphic processes and landforms are intimately connected parts of the bottomland landscape. Relations among vegetation, processes, and landforms are described here for representative streams of four areas of the United States: high-gradient streams of the humid east, coastal-plain streams, Great Plains streams, and stream channels of the southwestern United States. Vegetation patterns suggest that species distributions in the humid east are largely controlled by frequency, duration, and intensity of floods. Along channelized streams, vegetation distribution is largely controlled by variation in fluvial geomorphic processes (cycles of degradation and aggradation) in response to increases in channel gradient associated with channelization. Similarly, riparian vegetation of Great Plains streams may be controlled by fluxes in sediment deposition and erosion along braided streams. Patterns of riparian vegetation in semi-arid regions may be most closely related to patterns of the coincident fluvial landform and attendant vegetation pattern throughout the continent. In most situation, riparian-vegetation patterns are indicative of specific landforms and, thus, of ambient hydrogeomorphic conditions.

Jackson, D. C., N. J. Brown-Peterson, and T. D. Rhine. 1993. Perspectives for rivers and their fisheries resources in the upper Yazoo River Basin, Mississippi. Pages 255-265 in L. W. Hesse, C. B. Stalnaker, N. G. Benson and J. R. Zuboy, editors. Proceedings of the Symposium on Restoration Planning for Rivers of the Mississippi River Ecosystem. Biological Report 19. U.S. Department of the Interior. National Biological Survey. Washington, D. C.

The upper Yazoo River basin is an integrated floodplain river ecosystem located in the Delta region of western Mississippi. The entire system has been modified for flood control purposes, primarily to protect and expand agricultural lands. These flood control measures encompassed upstream headwater impoundments and downstream channelization, including clearing, dredging, and snagging. Flood events, however, still occur, primarily during winter and early spring. In conjunction with soft alluvial soils and mild climate, this flooding encourages natural restoration of stream habitat features affected by the original flood control projects and promotes nutrient exchange dynamics conducive for development and maintenance of exploitable fish stocks. Fish stock assessments were conducted January-August 1990-91 using hoopnets (4.3 m long, seven hoops with 1.07 m diameters, 3.81 cm bar mesh netting) set overnight in the principal tributary streams of the Yazoo River (Coldwater, Little Tallahatchie, Tallahatchie, Yocona, and Yalobusha rivers). Overall mean catch rates were 3.5 +/- 0.22 kg/net-night (N=1,040 net-nights) for 1990 and 4.2 +/- 0.36 kg/net-night (N=810 net-nights) for 1991. Sport and commercially important species accounted for 91.6% of the catch for 1990 and 89.5% for 1991. Catches were dominated by longnose gar *Lepisosteus osseus*, smallmouth buffalo *Ictiobus bubalus*, flathead catfish *Pylodictis olivaris*, common carp *Cyprinus carpio* and channel catfish *Ictalurus punctatus*. Independent assessments conducted by the U.S. Army Corps of Engineers verify that these resources are similar to stocks supporting excellent riverine fisheries elsewhere in the Mississippi River system. Flood control projects and short interval (about 15 years) maintenance operations for existing projects proposed by special interest groups continue to threaten river fisheries resources throughout the upper Yazoo River basin. These projects, however, are being challenged by natural resources advocates, who contend that reformulation of project designs can address flood control needs while maintaining values associated with the river ecosystems in question.

Johnson, W. C. 1992. Dams and riparian forests: case study from the upper Missouri River. *Rivers* 3: 229-242.

This research examined the effects of altered flow and meandering rate of the Missouri River in central North Dakota on the compositional dynamics of floodplain forests. This was acomplished by estimating the rates of river erosion and deposition during predam and postdam periods from historical maps and aerial photographs. Future changes in forest composition were simulated using a simple mathematical model based on measured rates of forest succession and river meandering for pre- and postdam periods. Simulations indicated a future decline in the areal extent of pioneer forests (cottonwood, willow) due to river regulation. Later successional species (primarily green ash) will dominate the future forests. Experimentation is needed in order to regenerate pioneer forests to maintain current levels of species diversity on the floodplain.

Johnson, W. C., R. L. Burgess, and W. R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. *Ecological Monographs* 46: 59-84.

The study area, bounded north and south by two large reservoirs, includes the most extensive remnant of floodplain forest in the Dakotas. Structure and composition of the forest overstory are strongly related to stand age and horizontal and vertical position on the floodplain. *Populus deltoides* Marsh. and *Salix amygdaloides* Anders. predominate in young stands which generally occur on low terraces near the center of the floodplain. *Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg., *Acer negundo* L., *Ulmus americana* L., and *Quercus macrocarpa* Michx., which replace *Populus* and *Salix* through time, predominate in old stands on high terraces near the edge of the floodplain. Stands intermediate in composition are uncommon because of the discontinuous meandering pattern of the river across its floodplain.
Surface soil environment and species diversity change markedly during the course of succession. The soils of young stands are generally sandy and low in organic matter. Soil nutrient content and available water capacity are generally higher in older stands because of higher organic matter content and repeated inputs of nutrient-rich silt from past floods. Tree species diversity (H') initially increases as stands age, reaches a maximum in stands with mixtures of both pioneer and terminal species, and declines slightly in the oldest stands. Both variety and evenness follow a similar pattern.
Analyses of population structure indicate a recent decline in the establishment of small stems of *Acer* and *Ulmus*. Tree core analyses show a similar decline in diameter growth rate for *Acer, Ulmus*, and *Fraxinus*. Availabe data suggest that these changes can be attributed to the removal of periodic spring flooding caused by the presence and operation of the reservoirs. It is also hypothesized that the lack of seedling-sapling stands of *Populus* in the region is the result of a presumed reduction in the meandering rate of the river following reservoir construction and poor seedbed conditions in the absence of flooding.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Can. Spec. Publ. Fish. Aquat. Sci. 106: 110-127.

The principal driving force responsible for the existence, productivity, and interactions of the major biota in river-floodplain systems is the flood pulse. A spectrum of geomorphological and hydrological conditions produces flood pulses, which range from unpredictable to predictable and from short to long duration. Short and generally unpredictable pulses occur in low-order streams or heavily modified systems with floodplains that have been leveed and drained by man. Because low-order stream pulses are brief and unpredicatble, organisms have limited adaptations for directly utilizing the aquatic/terrestrial transition zone (ATTZ), although aquatic organisms benefit indirectly from transport of resources into the lotic environment. Conversely, a predictable pulse of long duration engenders organismic adaptations and strategies that efficiently utilize attributes of the ATTZ. This pulse is coupled with a dynamic edge effect, which extends a "moving littoral" throughout the ATTZ. The moving littoral prevents prolonged stagnation and allows rapid recycling of organic matter and nutrient, thereby resulting in high productivity. Primary production associated with the ATTZ is much higher than that of permanent water bodies in unmodified systems. Fish yields and production are strongly related to the extent of accessible floodplain, whereas the main river is used as a migration route by most of the fishes.
In temperate regions, light and/or temperature variations may modify the effects of the pulse, and anthropogenic influences on the flood pulse or floodplain frequently limit prodution. A local

floodplain, however, can develop by sedimentation in a river stretch modified by a low head dam. Borders of slowly flowing rivers turn into floodplain habitats, becoming separated from the main channel by levees.
The flood pulse is a "batch" process and is distinct from concepts that emphasize the continuous processes in flowing water environments, such as the river continuum concept. Floodplains are distinct because they do not depend on upstream processing inefficiencies of organic matter, although their nutrient pool is influenced by periodic lateral exchange of water and sediments with the main channel. The pulse concept is distinct because the position of a floodplain within the river network is not a primary determinant of the processes that occur. The pulse concept requires an approach other than the traditional limnological paradigms used in lotic or lentic systems.

Kajak, Z. 1992. The River Vistula and its Floodplain Valley (Poland): Its Ecology and Importance for Conservation. Pages 35-49 in P. C. P.J. Boon, G.E. Petts, ed. *River Conservation and Management*. John Wiley & Sons Ltd, Chichester, UK.

The River Vistula is a unique feature in Poland, and to a great extent also in Europe, as it is one of the last large rivers, and is almost wild for long stretches; it also forms an extremely important pathway for bird migration. The Vistula is important not only to Poland but to all Baltic countries who have interests in the abatement of Baltic Sea pollution. Most of the Vistula pollution undoubtedly comes from industry and towns. More and more villages are now getting a centralized water supply; unfortunately they are not also provided with sewage-treatment plants. There is an urgent need for sewage purification and modern technology, but owing to the present economic situation in the country this can only come about by international help. Diffuse pollution input is also important, and it is well known that this can be significantly diminished by vegetation belts along rivers. Fortunately, the Vistula has embankments up to hundreds of meters from the river along most of its length, with abundant vegetation cover between them and the river channel. This, together with the fertile soil, probably consumes most of the dispersed pollution flowing into the Vistula. Unfortunately, most of the tributaries do not have embankments; often agricultural areas adjoin the river banks. In addition, many small point sources from farms and villages enter the tributaries directly and finally reach the Vistula.

Karle, K. F., and R. V. Densmore. 1994. Stream and floodplain restoration in a riparian ecosystem disturbed by placer mining. *Ecological Engineering* 3: 121-133.

Techniques for the hydrologic restoration of placer-mined streams and floodplains were developed in Denali National Park and Preserve, Alaska, USA. The hydrologic study focused on a design of stream and floodplain geometry using hydraulic capacity and shear stress equations. Slope and sinuosity values were based on regional relationships. Design requirements include a channel capacity for a 1.5 year (bankfull) discharge and a floodplain capacity for a 1.5 to 100 year discharge. Concern for potential damage to the project from annual flooding before natural revegetation occurs led to development of alder (*Alnus crispa*) brush bars to dissipate floodwater energy and encourage sediment deposition. The brush bars, constructed of alder bundles tied together and anchored laterally adjacent to the channel, were installed on the floodplain in several configurations to test their effectiveness. A moderate flood near the end of the two-year construction phase of the project provided data on channel design, stability, floodplain erosion, and brush bar effectiveness. The brush bars provided substantial protection, but unconsolidated bank material and a lack of bed armour for a new channel segment led to some bank erosion, slope changes and an increase insinuosity in several reaches of the study area.

Kern, K. 1992. Restoration of Lowland Rivers: The German Experience. Pages 279-297 in G. E. Petts and P.A. Carling, eds. *Lowland Floodplain Rivers: Geomorphological Perspectives*. John Wiley & Sons Ltd., Chichester, UK.

Killgore, K. J., and J. A. Baker. 1996. Patterns of larval fish abundance in a bottomland hardwood wetland. *Wetlands* 16: 288-295.

Larval fishes were collected with light traps and ichthyoplankton nets for two consecutive years during spring and early summer in the channel floodplain (tupelo and oak forest) of the Cache River, Arkansas. A total of 8,113 individuals were collected between two gears. Twenty-eight species were confirmed, but total number of taxa, including genus and family level groupings, was 35. Pirate perch (*Aphredoderus sayanus*) was the most abundant species, with 21% of the total catch consisting of this fish. Percidae (darters) was the dominant family, comprising at least seven species and accounting for 57% of the total numbers of fish collected. The families Cyprinidae and Centrarchidae were also common. Specimens that could not be identified to species made up nearly 56% of the catch. Species richness was similar among the three habitats probably due to hydraulic mixing, but individuals in the families Centrarchidae, Cyprinidae, and Percidae were more abundant in tupelo and oak habitats than in channel for net and light trap catches. Mean catch of total individuals in nets and light traps was greater in floodplain habitats than in the channel, particularly during spring 1989. Large catches in spring 1989 corresponded t higher water levels that expanded the aquatic/oak forest transition zone compared to lower water levels in 1988. Thus, late winter and spring floods that inundate the oak forest appear to be a major factor in regulating abundance of larval fishes in this bottomland hardwood wetland.

Koning, C. W., M. N. Gaboury, M. D. Feduk, and P. A. Slaney. 1998. Techniques to evaluate the effectiveness of fish habitat restoration works in streams impacted by logging activities. *Canadian Water Resources Journal* 23: 191-203.

The Watershed Restoration Program (WRP) in British Columbia was initiated under the auspices of Forest Renewal B.C. to restore, protect and maintain fisheries, aquatic and forest resources adversely impacted by past forest-harvesting practices, by carrying out community-based remedial work on hillslopes and streams. Specific restoration components focus on impacted hillslopes, gullies, riparian areas, stream channels and fish habitat. Fish habitat restoration is typically carried out after an assessment of upslope risks (followed by rehabilitation) and instream conditions. Restoration techniques include restoring fish access, streambank stabilization, rehabilitating channelized reaches to provide fish holding pools and riffles, re-establishing instream cover and structure by addition of boulder clusters and large woody debris (LWD), restoring and creating off-channel habitat, and resupply of nutrients. After the restoration work is completed, research evaluation and operational monitoring are conducted to determine the overall success and ultimate benefit of the work. Research evaluation is not project-specific, but may involve evaluation of a specific technique (e.g., LWD placements), and synoptic studies and 'paired assessments' of experimental control and treatment streams. Routine and project effectiveness monitoring is project-specific and is carried out after the instream work is completed and has passed post-construction inspection. Routine monitoring is a low intensity activity to determine functionality and condition of the restoration works. It is mainly a visual activity, and may include simple measurements or indicators (e.g., for structural stability), and can be undertaken on an annual basis or after each major storm. Project effectiveness monitoring is of higher intensity, and is conducted on a selected sub-set of projects where there are uncertainties of outcome or adaptive management benefits. This monitoring typically includes fish sampling and physical measurements: pool widths and depths, stream gradient, channel form, and channel substrate characteristics. Engineering level surveys (to tie bed and water surface elevations and cross sections to a specific benchmark) are frequently required for quantitative comparisons of restoration works (before, as-constructed and post-restoration). Where possible, project effectiveness monitoring should be related to published estimates of increases in fish abundance due to habitat improvements (bio-standards) established during the planning and prescriptive phase. Evaluation and monitoring of fish habitat restoration projects, both in the shorter and longer term, are essential to improve biological, technical and cost effectiveness of projects, and to identify and incorporate innovations. Evaluation techniques described in the paper were developed to evaluate activities to restore streams impacted by past logging practices, but the underlying principles apply to stream restoration wherever forest, urban or agriculture practices have resulted in stream and riparian impairment

Kusler, J. A., W. J. Mitsch, and J. S. Larson. 1994. Wetlands. *Scientific American* 270: 64-70.

Variously dry, wet or anywhere between, wetlands are by their nature protean. Such constant change makes wetlands ecologically rich; they are often as diverse as rain forests. These shallow water-fed systems are central to the life cycle of many plants and animals, some of them endangered. They provide a habitat as well as spawning grounds for an extraordinary variety of creatures and nesting areas for migratory birds. Some wetlands even perform a global function. The northern peat lands of Canada, Alaska and Eurasia, in particular, may help moderate climatic change by serving as a sink for the greenhouse gas carbon dioxide. Wetlands also have commercial and utilitarian functions. They are sources of lucrative harvests of wild rice, fur-bearing animals, fish and shellfish. Wetlands limit the damaging effects of waves, convey and store floodwaters, trap sediment and reduce pollution--the last attribute has earned them the sobriquet "nature's kidneys."

Despite their value, wetlands are rapidly disappearing. In the U.S., more than half of these regions in every state except Alaska and Hawaii have been destroyed. Between the 1950's and the 1970's more than nine million acres--an area equivalent to the combined size of Massachusetts, Connecticut and Rhode Island--were wiped out. Some states have almost entirely lost their wetlands: California and Ohio, for example, retain only 10 percent of their original expanse. Destruction continues today, albeit at a slightly reduced rate, in part, because there are fewer wetlands to eliminate. No such numbers are available internationally, but we estimate that 6 percent of all land is currently wetlands. The extensive losses can generally be attributed to the same feature that makes wetlands so valuable: their ever changing nature. The complex dynamics of wetlands complicate efforts to create policies for preserving them. Their management and protection must incorporate a realistic definition, one that encompasses all these intricate ecosystems.

Lamouroux, N., H. Capra, and M. Pouilly. 1998. Predicting habitat suitability for lotic fish: linking statistical hydraulic models with multivariate habitat use models. *Regulated Rivers* 14: 1-11.

Quantitative estimates of habitat suitability in a stream reach generally result from coupling a hydraulic habitat model with a biological model of habitat use. The choice of each of these models has led to much controversy and discussion. Nevertheless, most habitat studies of lotic fish use a deterministic hydraulic model and univariate suitability curves. The objective of this contribution is to present a new, alternative method, which relates statistical hydraulic models to multivariate habitat use models.
Our statistical hydraulic models predict the frequency distributions of hydraulic variables such as velocity or water depth within stream reaches. Their main advantage is the simplicity of their input variables (mainly discharge and average characteristics of the reach). Our multivariate formulation of habitat us models takes into accout the local variabilty of fish habitat, prdicting habitat suitability as a function of the frequency distrbution of hydraulic variables within the local fish habitat. We demonstrate how these two model types can be linked to estimate habitat suitability in a stream reach as a function of discharge, focusing on two fish species (barbel, chub) in a regulated reach of the French Rhone River. The main limitations of this new method are a result of mathematical constraints associated with the linkage of the two modelling approaches and to uncertainties in transferring biological models from one stream to another because of insufficient data. Despite these limitations, the method provides solutions to several critical problems facing existing approaches and the simplicity of its input variables can accelerate the validation process of habitat models. Therefore, our first simulations strongly encourage: (i) the use of statistical approaches to describe hydraulic variables; and (ii) the study of multivariate habitat use models that apply to a large variety of streams.

Large, A. R. G., G. E. Petts, R. L. Wilby, and M. T. Greenwood. 1993. Restoration of floodplains: a UK perspective. *European Water Pollution Control* 3: 42-53.

Buffers offer a multi-functional role in river floodplain management. They offer considerable opportunities for enhancing conservation values and improving water quality, especially where problems are caused by overland or diffuse sub-surface flow, and in addition offer benefits for recreation and amenity. The FEG has identified a range of targets for reconstructed buffer zones in Britain, and has recommended that a number of pilot schemes be implemented in the UK to include representative examples of different river types and situations. Buffer zones should be introduced to protect he conservation value of river reaches having special scientific interest or conservation value. They should be enhanced whenever possible to create and diversify river corridors, particularly by developing the "habitat island" concept. All buffer zones irrespective of width, heterogeneity, and connectivity have a multi-functional role: especially for nature conservation, water-quality control and recreation. In terms of water pollution control, buffer zones should be created where land adjacent to the channel is cultivated to the river edge. However, the case for introduction of buffers solely for water-quality control is unclear as gaps in our knowledge exist, relating mainly to: the ability of different soils and vegetation types to absorb nutrients effectively; the long-term viability of buffers as nutrient sinks in relation to natural ecosystem development and succession; the shorter-term effects of seasonality and the resistance of buffers to perturbations such as flooding. Detailed studies will be necessary to fill these gaps, and it is recommended that site selection should take account of stream order, altitude as well as the habitat scale. On this scale, a variety of different sized and shaped strips and patches with varying structural characteristics and degrees of connectivity should be examined. Recreation of floodplain patch habitat will be necessary in many lowland situations. It is recommended that this should use as its basis relict hydrogeomorphological features such as abandoned channels, riparian woodlands and wet areas. These areas provide a logical strarting point for restoration and conservation measures. Finally, further detailed socioeconomic investigations are needed to elucidate financial implications of buffer zone creation, especially given the scale required for effective pollution control from farm land.

Layher, W. G., and K. L. Brunson. 1992. A modification of the habitat evaluation procedure for determining instream flow requirements in warmwater streams. *North American Journal of Fisheries Management* 12: 47-54.

The Kansas State Water Plan that was developed in the early 1980's provided means by which standards for minimum desirable stream flow (MDS) could be adopted. To develop and apply an expedient, defendable procedure for recommending MDS values for selected streams in Kansas, we used a modified habitat evaluation procedure (HEP). With this procedure, mean cross-sectional values for stream width, depth, and velocity were related to total fish standing crop. These values were converted to habitat suitability indices (HSI) and multiplied by stream area to estimate fish habitat units (HU) at different discharges. We adopted a standard policy of recommending MDS values that would yield 80% of the average HU's available at median discharge. Final MDS values achieved through negotiations with water management agencies were judged adequate overall. Subsequently, the Kansas legislature adopted this first set of MDS standards for the state.

Machado, A. A. 1990. Ecology of fishes of areas of the venezuelan llanos. *Interciencia* 15: 411-423. *In Spanish*

Martin, D. W., and J. C. Chambers. 2001. Restoring degraded riparian meadows: biomass and species responses. *Journal of Range Management* 54: 284-291.

Riparian meadows in central Nevada are highly productive and have been extensively utilized for livestock grazing. Consequently, many have been severely degraded resulting in changes in species composition and decreases in productivity. During a 3 year study, we examined the responses of mesic meadow systems to yearly nitrogen addition (100 kg ha^{-1}) and clipping (8-10 cm stubble height) to increase our understanding of grazing effects. We also examined the effects of a one-time, fall aeration (10 cm deep by 2 cm wide holes spaced 20 cm apart) and revegetation (removal of existing vegetation and reseeding) to evaluate the restoration potential of these sites. Changes in total biomass, species aerial cover and frequency, and surface basal cover were used to evaluate treatment responses. Clipping had no effect on total biomass, possibly because it was conducted late in the growing season. In contrast, nitrogen addition plus clipping increased biomass in all 3 years when treatments were compared across sites and for 1 out of 3 years when treatments were compared across a single site. Aeration had no effect on above ground biomass, but has been shown to increase rooting activity in these same meadows. Due to a dry, hot spring, early seral and weedy species had higher establishment than the seeded natives in the revegetation plots, and biomass was low the first year after treatment. Individual species varied in their treatment responses. The cover of low-growing forb species (western aster (*Aster occidentalis*

[Nutt.] Torrey and A. Gray), long-stalk starwort (*Stellania Longipes* Goldie), and common dandelion (*Taraxacum officinale* Wigg.) declined through time for all treatments, presumably due to increased grass cover and shading following release from grazing and above average precipitation and water table levels in 1998. Examination of the key graminoids showed that Kentucky bluegrass (*Poa pratensis* ssp. *pratensis* L.), an increaser species, did not increase in response to release from grazing, but increased in response to clipping and nitrogen addition. Nebraska sedge (*Carex nebrascensis* Dewey), a desirable native, increased in response to both release from grazing and nitrogen addition. The results were influenced by high spatial and temporal variability in water table elevations within these systems.

McCall, J. D., and R. F. Knox. 1978. Riparian habitat in channelization projects. Pages 125-128. *Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems*. U.S. Department of Agriculture, Forest Service, Callaway Gardens, Georgia.

Since 1970 construction has been completed on approximately 30 miles of PL-566 channels scattered throughout Indiana in 5 separate projects. Since 1973 a joint Memorandum of Understanding between the SCS, IDNR, and USFWS has fostered development and implementaton of project features designed and installed to protect or mitigate losses of fish, wildlife and riparian habitats. Successful implementation of such features has expanded their use to channel modification caused by highway bridge construction and legal county drain maintenance.

McIver, J., and L. Starr. 2001. Restoration of degraded lands in the interior Columbia River Basin: passive vs. active approaches. *Forest Ecology and Management* 153: 15-28.

Evidence for success of passive and active restoration is presented for interior conifer forest, sagebrush steppe, and riparian ecosystems, with a focus on the Columbia River basin. Passive restoration, defined as removal of the stresses that cause degradation, may be most appropriate for higher elevation forests, low-order riparian ecosystems, and for sagebrush steppe communities that are only slightly impaired. More active approaches, in which management techniques such as planting, weeding, burning, and thinning are applied, have been successful in forests with excessive fuels and in some riparian systems, and may be necessary in highly degraded sagebrush steppe communities. There is general agreement that true restoration requires not only reestablishment of more desirable structure or composition, but of the processes needed to sustain these for the long term. The challenge for the restorationist is to find a way to restore more desirable conditions within the context of social constraints that limit how processes are allowed to operate, and economic constraints that determine how much effort will be invested in restoration.

Middleton, B. A., ed. 2002. *Flood Pulsing in Wetlands: Restoring the Natural Hydrological Balance*. John Wiley and Sons, New York, NY.

Molles, M. C., C. S. Crawford, L. M. Ellis, H. M. Valett, and C. N. Dahm. 1998. Managed flooding for riparian ecosystem restoration. *BioScience* 48: 749-756.

Montgomery, D. R. 1997. River management: what's best on the banks? *Nature* 338: 328-329.

Morrison, M. L., T. Tennant, and T. A. Scott. 1994. Environmental auditing: laying the foundation for a comprehensive program of restoration for wildlife habitat in a riparian floodplain. *Environmental Management* 18: 939-955.

We analyzed the past and current distribution and abundance of vegetation and wildlife to develop a wildlife habitat restoration plan for the Sweetwater Regional Park, San Diego County, California. Overall, there has been a substantial loss of native amphibians and reptiles, including four amphibians, three lizards, and 11 snake species. The small-mammal community was depauperate and dominated by the exotic house mouse (*Mus musculus*) and the native western harvest mouse (*Reithrodontomys megalotis*). It appeared that either house mice are exerting a negative influence on most native species or that they are responding positively to habitat degradation. There has apparently been a net loss of 13 mammal species, including nine insectivores and rodents, a rabbit, and three large mammals. Willow (*Salix*) cover and density and cottonwoods (*Populus fremontii*) had the highest number of positive correlations with bird abundance. There has been an overall net loss of 12 breeding bird species; this includes an absolute loss of 18 species and a gain of six species. A restoration plan is described that provides for creation and maintenance of willow riparian , riparian woodland, and coastal sage scrub vegetation types; guides for separation of human activities and wildlife habitats; and management of feral and exotic species of plants and animals.

Muller, N. 1995. River dynamics and floodplain vegetation and their alterations due to human impact. *Arch. Hydrobiol. Suppl. 101 (Large Rivers 9)*: 477-512.

Within the last natural river floodplains of the northern and southern Alps, the regularities of river dynamics and floodplain vegetation are being investigated. By comparing different river stretches before and after civil engineering measures it is possible to examine the human impact on river dynamics and floodplain vegetation.
Summing up it becomes clear that especially the construction of hydroelectric power plants have led to a major change of flora and vegetation in river floodplains. This has led to a lasting change of the fundamental abiotic factors of floodplain ecosystems, especially in the morpho- and river dynamics. Therefore species and biozoenoses adapted on the special conditions of river ecosystems vanish even in natural stretches. Common communities of the central European rivers and communities characterized by man (ruderal communities) with euryoecious species increase in number and move as far as to the upper reaches.
Regarding the momentary situation, the conservation of the whole spectrum of the flora and vegetation typical for floodplains will be difficult. This is also true for the Alps. The success of restoration measures will depend to a large extent on the speed in which comprehensive conceptions are prepared and put into action, beginning in the catchment areas and proceeding to the estuaries.

Munn, M. D., R. W. Black, A. L. Haggland, M. A. Hummling, and R. L. Huffman. 1998. An Assessment of Stream Habitat and Nutrients in the Elwha River Basin: Implications for Restoration. Water-Resources Investigations Report 98-4223. U.S. Geological Survey.

The Elwha River was once famous for its 10 runs of anadromous salmon which included chinook that reportedly exceeded 45 kilograms. These runs either ceased to exist or were significantly depleted after the construction of the Elwha (1912) and Glines Canyon (1927) Dams, which resulted in the blockage of more than 113 kilometers of mainstem river and tributary habitat. In 1992, in response to the loss of the salmon runs in the Elwha River Basin, President George Bush signed the Elwha River Ecosystem and Fisheries Restoration Act, which authorizes the Secretary of the Interior to remove both dams for ecosystem restoration. The objective of this U.S. Geological Survey (USGS) study was to begin describing baseline conditions for assessing changes that will result from restoration. The first step was to review available physical, chemical, and biological information on the Elwha River Basin. We found that most studies have focused on anadromous fish and habitat and that little information is available on water quality, habitat classification geomorphic processes, and riparian and aquatic biological communities. There is also a lack of sufficient data on baseline conditions for assessing future changes if restoration occurs. The second component of this study was to collect water-quality and habitat data, filling information gaps. This information will permit a better understanding of the relation between physical habitat and nutrient conditions and changes that may result from salmon restoration. We collected data in the fall of 1997 and found that the concentrations of nitrogen and phosphorous were generally low, with most samples having concentrations below detection limits. Detectable concentrations of nitrogen were associated with sites in the lower reach of the Elwha River, whereas the few detections of phosphorus were at sites throughout the basin. Nutrient data indicate that the Elwha River and its tributaries are oligotrophic. Results of the stream classification indicated that most of the habitat that would be usable by salmon is found in the mainstem of the Elwha River due to natural gradient barriers at the lower end of most tributaries. Habitat is diverse in the mainstem due to large woody debris accumulations and the existence of secondary channels. We concluded that restoring salmon runs to the Elwha River system will affect the ecosystem profoundly. Decaying carcasses of migrating salmon will tbe the source of large quantities of nutrients to the Elwha River. The complex instream habitat of the mainstem will enhance cycling of these nutrients because carcasses will be retained long enough to be assimilated thereby increasing primary and secondary production, size of immature salmonids, and overall higher salmon recruitment.

Mutz, M. 2000. Influences of woody debris on flow patterns and channel morphology in a low energy, sand-bed stream reach. *International Review of Hydrobiology* 85: 107-121.

In lowland areas, such as the glacial landscapes of eastern Germany, sand-bed streams are the most common stream type. They have low gradients and their hydrological regime is often subdued due to the frequent interruption by lakes. Very few is known about the influence of woody debris in these streams, since nearly all previous studies are from high-gradient conditions, where streams have coarse bed sediments and harsh hydrological regimes. The research objectives of this study were first to assess the quasi-natural quantity of wood in a lowland sand-bed stream and second to understand the influence of wood on the channel morphology and the flow patterns at base-flow.
The three-dimensional stream bed relief was surveyed by electronic distance measurement. The position and the size of large woody debris was assessed by close-up photography. An acoustic

Doppler velocimeter was used to record the patterns of flow velocity and turbulence. Overlay and analysis of the spatial data was done using a Geographic Information System.
The standing stock of wood was 1.9 m^3 and 39 woody elements per 100m^2 of stream bed. The flow pattern was clearly controlled by the wood. Woody elements elevated above the stream bed deflected flow and locally caused strong secondary current, high turbulence, and scour of the stream bed at base-flow. Wood resting directly on the stream bed, which contributed the majority of the wood inside the bank-full channel, determined the roughness of the stream bed. Near-bed flow patterns observed were isolated roughness flow and wake interference flow, which was registered inside the accumulations of wood.
68% of the stream bed had shear stress above critical. Hence, the secondary morphological structures of the sand-bed were controlled at base-flow by the flow which was determined by the woody debris distribution.

Nabhan, G. P. and T. E. Sheridan. 1977. Living fencerows of the Rio San Miguel, Sonora, Mexico: traditional technology for floodplain management. *Human Ecology* 5: 97-111.

In southwestern North America, agriculture is limited by both arable land and available water supplies. In the upper Rio San Miguel, as well as in other narrow river valleys of eastern Sonora, Mexico, floodplain farming is dependent upon living fencerows for its environmental stability. Propagated fencerows of willow and cottonwood maintain, extend, and enhance floodplain fields. These ecological filters also protect fields from cattle, harbor agents of biological control of pests, and provide renewable supplies of wood. Traditional Sonoran farmers do not perceive cottonwoods and willows as phreatophytic pests, as their Anglo-American neighbors do. The stability of the upper San Miguel agroecosystem contrasts with severely eroded conditions within the region's other arid watersheds.

National Research Council (NRC). 2002. *The Missouri River Ecosystem: Exploring the Prospects for Recovery*. National Academy Press, Washington, D. C.

Nunnally, N. R. 1978. Improving channel efficiency without sacrificing fish and wildlife habitat: the case for stream restoration. Pages 394-399. *Proceedings of the Symposium: Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems*. U.S. Department of Agriculture Forest Service, Callaway Gardens, Georgia.

Stream restoration is a means for improving the hydraulic efficiency of streams which is less expensive and less environmentally damaging than conventional channelization. Restoration creates a more stable channel by removing debris, providing fairly uniform cross sections, and stabilizing stream banks with minimal disturbance of the streambed and riparian vegetation.

Odum, E. P. 1978. Ecological importance of the riparian zone. Pages 2-4. *Opening address: National Symposium on Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems*. U.S. Department of Agriculture Forest Service, Callaway Gardens.

Riparian zones have their greatest value as buffers and filters between man's urban and agricultural development and his most vital life-support resource - water. Preservation based on public riparian rights provide an effective hedge against overdevelopment of urban sprawl and agricultural or forest monoculture.

Osterkamp, W. R., and C. R. Hupp. 1984. Geomorphic and vegetative characteristics along three northern virginia streams. *Geological Society of America Bulletin* 95: 1093-1101.

Geometry, sediment, and woody-vegetation data were collected from bottomland geomorphic surfaces at valley sections along three gaged perennial streams of northern Virginia. The basins of the streams differ widely in topography and physiography; mean discharges vary from 0.196 to 323 cubic meters per second. Prevalent surfaces identified were the depositional bar, active-channel shelf, flood plain, and terraces. The stages corresponding to active-channel-shelf levels were equivalent to flow durations of 5 to 13 percent. Stages corresponding to flood-plain levels were equivalent to discharges with 1.4- to 2.0- year recurrence intervals. The discharge data and statistical tests of geomorphic-surface, sediment, and vegetative data suggest that the various alluvial features are formed and maintained by hydraulically controlled sorting processes. Analysis of wood-plant and geomorphic data shows that each surface supports characteristic species, some of which are nearly unique to a surface. Tests of sediment type with species distribution showed lower correlation than that of geomorphic surface with species. It is inferred that plant distributions largely are controlled by flow frequency and intensity, and that plants may help identify geomorphic levels and potential for flood damage.

Paller, M. H., M. J. M. Reichert, J. M. Dean, and J. C. Seigle. 2000. Use of fish community data to evaluate restoration success of a riparian stream. *Ecological Engineering* 15: S171-S187.

From 1985 to 1988, stream and riparian habitats in Pen branch and Four Mile branch began recovering from deforestation caused by the previous release of hot water from nuclear reactors. The Pen branch corridor was replanted with wetland trees in 1995 to expedite recovery and restore the Pen branch ecosystem. Pen branch, Four Mile branch, and two relatively undisturbed streams were electrofished in1995/1996 to determine how fish assemblages differed between the previously disturbed and undisturbed streams and whether such difference could be used to measure restoration success in Pen branch. Fish assemblages were analyzed using nonparametric multivariate statistical methods and the index of biotic integrity (IBI), a bioassessment method based on measurement of ecologically sensitive characteristics of fish assemblages. Many aspects of fish assemblage structure (e.g. species richness, disease incidence, taxonomic composition at the family level) did not differ between distrubed and undisturbed streams; however, the disturbed streams were characterized by higher densities of a number of species. These differences were successfully detected with the multivariate statistical methods; whereas the IBI did not differ between most recovering and undisturbed sampling sites. Because fish assemblages are strongly influenced by instream habitat, and because instream habitat is strongly influenced by the riparian zone, fish assemblages can be used to measure restoration success. Nonparametric ordination methods may provide the most sensitive measure of progress towards restoration goals, although the IBI can be used during early stages of recovery to indicate when certain ecologically important aspects of structure and function in recovering streams have reached levels typical of undisturbed streams.

Parasiewicz, P. 2001. MesoHABSIM: A concept for application of instream flow models in river restoration planning. *Fisheries* 26: 6-13.

This paper describes the methodological concept for application of physical habitat models to restoration planning at a whole river scale. The design proposed here builds upon the Instream Flow Incremental Methodology but is focused at the need for managing large-scale habitats and river systems. It modifies that data acquisition technique and analytical resolution of standard approaches, changing the scale of physical parameters and biological response assessment to the micro- to meso-scale. In terms of technological process, a highly detailed microhabitat survey of a few, short sampling sites would be replaced by mesohabitat mapping of whole river sections. As with more traditional steam habitat models, the variation in the spatial distribution and amount of mesohabitats can provide key information on habitat quality changes corresponding to alterations inflow, channel changes, and stream improvement measures. However, the scale of simulations more closely matches restoration and system analyses, because it provides a solid base for quantitative assessment and simulation of habitat conditions for the whole stream.

Pearman, P. B., A. M. Velasco, and A. Lopez. 1995. Tropical amphibian monitoring: a comparison of methods for detecting inter-site variation in species composition. *Herpetologica* 51: 325-337.

Several methods have been proposed recently as standards for sampling and monitoring amphibians. This study sought to 1) compare several sampling methods during the establishment of a monitoring program and 2) describe differences in species composition among the method. The study was performed at the Jatun Sacha Biological Station in the Upper Amazon Basin in Ecuador. We established seven sites in primary forest and sampled amphibians four times over a 5 month period using transects searched during the day and night, artificial cover stations, and artificial ponds. Significantly more species were found during nocturnal searches of transects than with the other methods. In cluster analysis of species occurrences, both diurnal and nocturnal transect searches identified one floodplain site as being distinct from the rest. Sites appear most similar when artificial ponds were considered and consistently less similar in data from nocturnally searched transects. Data from both types of transect and from artificial cover indicated that one site in the reserve's interior was particularly rich in species of *Eleutherodactylus*. Additionally, nocturnal transect detected increased species richness of hylid frogs at the two floodplain sites. This is consistent with the aquatic mode of reproduction of hylid frogs. Higher species richness of *Eleutherodactylus* is characteristic of drier terra firme forest with low disturbance. These trends are most clear in data from nocturnally searched transects.

Petersen, R. C., L. B.-M. Petersen, and J. Lacoursiere. 1992. A Building -block Model for Stream Restoration. Pages 293-309 in P. C. P.J. Boon, G.E. Petts, ed. *River Conservation and Management*. John Wiley & Sons Ltd, Chichester, UK.

The purpose of this chapter has been to outline an approach for restoring the quality of small watercourses now being used as drainage ditches. We suggested that, as drainage ditches, these small streams were well engineered for removing water. This water-removal function was appropriate a centruy ago when the groundwater and the marine environment were not overloaded, and more land was needed for agriculture, but this engineering has turned out to be a clear case of not thinking of sustainable development. The large percentage of the landdscape devoted to modern agricultural practices, the loss of the self-cleaning capacity of streams, and removal of riparian wetlands has now resulted in an overload of freshwater systems, the groundwater and the sea with nutrients. For the marine environment, this is leading to the wholesale death of entire ecosystems (Nixon, 1990). In addition, the amount of land needed for crop production is now less than 25 years ago, and in fact too much food production is occurring in northern Europe. For this reason, it is time to start thinking about how to restore our streams. This reversal has to occur at the local and individual level and is already happening in many areas throughout Sweden, Denmark and Germany, but there is still a need for solutions to the problems in the form of new ideas, approaches, and technology. The building blocks described should be viewed as a series of suggestions to landowners and regional authorities on how to solve these problems. The foundation for this approach is to re-establish and then protect the riparian area. Once this is set aside, additioinal building blocks can be slelcted and added according to local needs. For this reason, the presentation in this chapter ahas been written in a format intended to be easily read. However, these suggestions are based on sound ecological principles and an understanding of the social and economic constraints placed on ecosystem restoration.

Poff, N. L., and J. V. Ward. 1990. Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management* 14: 629-645.

Spatial and temporal environmental heterogeneity in lotic ecosystems can be quantitatively described and identified with characteristic levels of ecological organization. The long-term pattern of physiochemical variability in conjunction with the complexity and stability of the substratum establishes a physical habitat template that theoretically influences which combinations of behavioral, physiological and life history characteristics constitute appropriate "ecological strategies" for persistence in the habitat. The combination of strategies employed will constrain ecological response to and recovery from disturbance. Physical habitat templates and associated ecological attributes differ geographically because of biogeoclimatic processes that constrain lotic habitat.

Prach, K. 1992. Vegetation, microtopography and water table in the Luznice River floodplain, South Bohemia, Czechoslovakia. *Preslia, Praha* 64: 357-367.

Relations between vegetation, elevation of topographic surface, and water table were studied along a cross-section transect in a representative part of the floodplain of the Luznice River in the Trebon Biosphere Reserve. The coenocline from aquatic macrophyte communities to mesic meadows was found in only 1.5 m range of elevation. Elevation could be used as the good measure of moisture gradient because of readily drained sediment; an exception being sites at terraces influenced by seepage. The information provided by this study is also used for recommendation of management practices for the floodplain.

Prach, K., and O. Rauch. 1992. On filter effects of ecotones. *Ekologia (CSFR)* 11: 293-298.

Filter ability of ecotones is briefly characterized in the general sense, and regional data are reviewed as a regional contribution to the SCOPE programme "Ecotones". Results of a case study are presented to demonstrate the filter ability of a floodplain segment, the Luznice river, South Bohemia, Czechoslovakia. The main conclusion is that the extremely high nutrient input from the crop field on the terrace is evident in the floodplain only up to about 20 m far from the margin of the field. Recommendations for further research are given.

Quinn, J. W., and T. J. Kwak. 2000. Use of rehabilitated habitat by brown trout and rainbow trout in an Ozark tailwater river. *North American Journal of Fisheries Management* 20: 737-751.

We evaluated instream and riparian habitat rehabilitation that was completed following catastrophic flooding in the White River, below Beaver Dam, Arkansas. Most rehabilitation structures were designed to stabilize the river banks and increase cover for trout (Salmonidae) during high flows associated with hydroelectric power generation. We quantified trout response to rehabilitation at two spatial scales--microhabitat and river reach. At the microhabitat scale, brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* occupied the deepest habitats available and were randomly associated with cover at low flow (about 1 m^3/s). Principal-components scores describing physical characteristics of brown trout and rainbow trout microhabitats were significantly different from available-habitat scores at high flow (about 215 m^3/s), when trout were strongly associated with velocity refugia near the river margins--habitats similar to those created by rehabilitation structures. At the reach scale, trout population size and structure were estimated in modified (700-m) and reference (800-m) reaches before and after rehabilitation. Total trout density and biomass in the modified reach increased after rehabilitation relative to that of the reference reach, evidence that the modified reach supported more fish after rehabilitation. Analyses stratified by salmonid species and size indicated that the observed effect was primarily due to rainbow trout and small trout (10.0-19.9 cm) of all species shifting their distributions into the modified reach. Our results suggest that instream and riparian habitat rehabilitation structures commonly applied to small streams are a valid management technique for large tailwater rivers. However, implementation in each system should be carefully evaluated, and management expectations for large trout should be conservative. Because of the observed benefit for small trout, placement of rehabilitation structures near spawning areas should be considered when management for wild trout is a priority. Finally, we suggest integration of instream and riparian habitiat rehabilitation into broader management plans when applied to regulated rivers.

Rundquist, L. A., M. ASCE, and J. E. Baldrige. 1990. Fish Habitat Considerations. Pages 579-613. *Cold Regions Hydrology and Hydraulics*. Technical Council on Cold Regions Engineering of the American Society of Civil Engineers.

Fish habitat has several inter-dependent physical and biological components that include channel structure, streamflow, water quality, and food-web relationships. The four major habitat components are evaluated collectively, since changes in one component can affect the other components. Each habitat component must have attributes within an allowable range for the habitat to be usable by a given species and life stage. The optimum means of maintaining fish populations is by preserving or maintaining existing fish habitat, since the art of restoring damaged habitat has not developed sufficiently to ensure success of the habitat features. Project definition, habitat feature selection, and habitat feature design are three steps of stream restoration design. Three categories of flows should be considered in the design of stream and riparian habitat restoration: 1) floodplain design discharges; 2) main channel design discharges; and 3) fish habitat design discharges. The optimum alignment for the stream is often its natural alignment. The design objective for the main channel is to provide sufficient channel conveyance for the bankfull flood while also providing habitat diversity. Habitat diversity is enhanced by providing 1) variability in channel depth and velocity; 2) pool and riffle cross sections; and 3) variability in substrate and cover. Habitat features should be monitored after floods and at a range of flow levels to evaluate their effectiveness and integrity. Examples of fish habitat features include rock islands, boulder clusters, submerged rock weirs, spruce tree revetments, rock wing deflectors, and overhanging bank cover.

Ryck, F. 1975. The effect of scouring floods on the benthos of Big Buffalo Creek, Missouri. Pages 36-45. *29th Annual Conference of the Southeastern Association of Game and Fish Commissioners*.

The effects of scouring floods on the diversity and density of the riffle benthic macroinvertebrate community of Big Buffalo Creek, and unpolluted Missouri Ozark stream, were evaluated from December, 1968 through December, 1969. A modified Hess sampler was used to collect the invertebrate samples. Flashfloods that scoured stream substrates had little effect on water quality assessments, although they did cause the temporary dislocation and dispersal of riffle benthic macroinvertebrates. The density and structure of this community were essentially identical to preflood conditions 1 month after floods. Diversity index values for samples collected 8 days after a flood were near normal. Apparently, riffle invertebrates were not dispersed over great distances and were therefore able to rapidly repopulate scoured areas. At the end of the study, after seven severe floods, the density, diversity, and species composition of the macroinvertebrate fauna were nearly identical to values observed at the start of the study.

Sabo, M. J., and W. E. Kelso. 1991. Relationship between morphometry of excavated floodplain ponds along the Mississippi River and their use as fish nurseries. *Transactions of the American Fisheries Society* 120: 552-561.

We sampled ichthyoplankton, zooplankton, and juvenile fish during May, August, and November 1988 from 15 excavated floodplain ponds along the Mississippi River. In May, densities of larval shad *Dorosoma* spp. ranged from 1.1 to 87.8/m^3 and densities of larval sunfish *Lepomis* spp. ranged from 0.3 to 19.3/m3 among ponds. Ponds with long (>1,800 m), sinuous shorlines, high volumes (>55,000 m^3), and variable depth had high ichthyoplankton densities (>50/m^3); smaller, low-volume ponds frequently had low ichthyoplankton densities (<10/m^3). Ponds that sustained high densities of larval sunfish during May had high numbers of young-of-the-year sunfish in August and November, which suggests that ponds with high ichthyoplankton densities ultimately contributed more fish to river population. Pond morphometry probably did not affect food availablily, because zooplankton densities were not correlated with ichthyoplankton densities and larval threadfin shad *D. petenese* grew faster in ponds with high shad densities. Morphometry may have regulated access of spawning adults to ponds or affected larval fish growth and survival in ponds. Future excavations should adhere to guidelines used by the U.S. Army Corps of Engineers to ensure that ponds function as viable fish nursery areas.

Sabo, M. J., W. E. Kelso, C. F. Bryan, and D. A. Rutherford. 1991. Physicochemical factors affecting larval fish densities in Mississippi River floodplain ponds, Louisiana (U.S.A.). *Regulated Rivers: Research & Management* 6: 109-116.

We collected water-quality data from 15 artificial floodplain ponds along the Mississippi River during May 1988 and quantified shoreline length, shoreline sinuousity, volume, and depth variation. Ponds regarded as high-quality nurseries (based upon larval fish densities) contained higher dissolved oxygen concentrations and lower total organic carbon concentrations than ponds of lower nursery quality ($p<0.02$). High-quality nurseries also maintained higher conductivity and turbidity than low-quality nurseries ($p<0.05$). Results indicated that dissolved oxygen and pH probably fluctuated less in high quality nurseries and therefore provided better conditions for survival and growth of larval fishes. Total organic carbon and conductivity were directly related to pond morphometry ($p<0.004$) and affected dissolved oxygen and pH in ponds. Large, high-volume ponds with sinuous shorelines and variable depths tended to contain both high conductivities and low total organic carbon concentrations. Pond morphometry may have affected water quality and subsequently determined the nursery value of artificial floodplain ponds.

Schiemer, F., C. Baumgartner, and K. Tockner. 1999. Restoration of floodplain rivers: the Danube restoration project. *Regulated Rivers: Research & Management* 15: 231-244.

Restoration concepts for large river systems are currently in an early stage of development. Possibilities for, and constraints of, rehabilitation--both from a process-oriented view as well as from the nature conservation perspective--differ strongly according to the degree of anthropogenic changes. This requires precisely formulated amelioration goals. Well-conceived and thoroughly analyzed case studies are necessary to better understand reversibility, direction and time scale of changes, and the sustainability of various scenarios. It is important to plan controllable set-ups with long-term monitoring in the pre- and post-implementation phases of restoration programmes. In order to achieve these goals, monitoring instruments have to be developed and calibrated that allow the definition and analysis of improvements. Finally, controlled restoration programmes offer the opportunity for large-scale experiments to test overall concepts and hypotheses and have an important heuristic value to improve the understanding of river ecology in general.

Schmetterling, D. A., C. G. Clancy, and T. M. Brandt. 2001. Effects of riprap bank reinforcement on stream salmonids in the western United States. *Fisheries* 26: 6-13.

Angular rock riprap is used to reduce riverbank erosion in developed riparian corridors. We reviewed peer reviewed as well as non-refereed literature to determine the effects of riprap on salmonid habitat and populations and to identify areas for future (applied) research. Although commonly used to armor banks, riprap affects salmonid populations and stream function. Riprap may provide habitat for juvenile salmonids and bolster densities on reaches of streams that have been severely degraded. However, riprap does not provide the intricate habitat requirements for multiple age classes or species provided by natural vegetated banks. Streambanks with riprap have fewer undercut banks, less low-overhead cover and are less likely than natural stream banks to contribute large woody debris to the stream. Lateral streambank erosion is a natural process that occurs in many stream types. However, most valley-bottom stream types, which have the greatest tendency to laterally migrate, lie within developed corridors. Although permitting of individual projects may attenuate localized negative effects to streambanks, it may not effectively curtail cumulative effects to a watershed. Our review further demonstrated that the practice of riprapping banks goes against current practices and philosophies of stream renaturalization and impedes future restoration work. Future research should determine the true effects of riprap banks on salmonid densities, the use of soft techniques using for stabilizing banks on rivers, and the cumulative effects of riprap projects on watersheds and fluvial processes. We foresee a continued struggle for resource managers trying to maintain natural fluvial processes while protecting public infrastructure and private property form those same processes

Schmidt, J. C., and R. H. Webb. 1998. Science and values in river restoration in the Grand Canyon. *Bioscience* 48: 735.

Discusses science and values in river restoration in the Grand Canyon. The importance of the river and the dam; The Colorado River ecosystem in the Grand Canyon; The potential for river restoration; Management resources and related processes of the Colorado River in the Grand Canyon; Science and societal choice about river-corridor resources.

Schnabel, R. R., and W. L. Stout. 1994. Denitrification loss from two Pennsylvania floodplain soils. *Journal of Environmental Quality* 23: 344-348.

Denitrification losses and dissolved nitrous oxide concentration within a well- and poorly -drained soil under ryegrass (*Lolium perenne* L.) were measured for ~12 mo. The soils received up to 252 kg N/ha as potassium nitrate in two equal amounts. Denitrification increased in March as the soil warmed to 5 to 7 degrees Celsius with the highest rates occurring soon after N was applied. Approximately 30% of annual loss occurred within 2 wk of fertilization. Dissolved nitrous oxide concentration peaks corresponded to periods with elevated denitrification. On average, the poorly-drained soil denitrified the equivalent of 40% of applied N (up to 110 kg N/ha). Less than 2.5 kg/ha was denitrified from the well-drained soil. The degree of anoxia in the measurement apparatus substantially effected measured denitrification rates. Consequently, it is important to know the relationship between redox in-situ and in the measurement apparatus.

Schroeder, R. L., and A. W. Allen. 1992. Assessment of Habitat of Wildlife Communities on the Snake River, Jackson, Wyoming. Pages 1-21. U.S. Fish and Wildlife Service National Ecology Research Center, Fort Collins.

The composition of the wildlife community in western riparian habitats is influenced by the horizontal and vertical distribution of vegetation, the physical complexity of the channel, and the barriers to movement along the corridor. Based on information from the literature and a workshop, a model was developed to evaluate the wildlife community along the Snake River near Jackson, Wyoming. The model compares conditions of the current or future years with conditions in 1956 are assumed to approximate the desirable distribution of plant cover types and the associated wildlife community and are used as a standard of comparison in the model. The model may be applied with remotely sensed data and is compatible with a geographc information systems analysis. In addition to comparing existing or future conditions with conditions in 1956, the model evaluates floodplain and channel complexity and assesses anthropogenic disturbance and its potential effect on the quality of wildlife habitat and movement of wildlife in the riparian corridor.

Sear, D. A., A. Briggs, and A. Brookes. 1998. A preliminary analysis of the morphological adjustment within and downstream of a lowland river subject to river restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems* 8: 167-183.

1. Geomorphological models developed from studies of alluvial river channel processes can be used to predict river channel response to restoration. These models suggest that restoration can significantly affect modified and unmodified reaches downstream and that sediment yields from these reaches may remain enhanced for some tive as the river system adjusts to restoration. A preliminary test of this model has been undertaken on a recently restored lowland river in the UK. 2. Adjustment is characterized by initially high rates of morphological change controlled by sediment type and stability. Specific adjustments include the growth of in-channel sediment stores and banks exposed by erosion that modify the geometry of the restored river. Downstream impacts show aggradation of the river bed and enhanced morphological diversity. 3. The results of the study indicate that whilst general geomorphological models are applicable to predicting impacts of lowland river restoration, the specific adjustments are controlled by the availability and type of substrate, the power available to transport the substrate, and the nature of the restored channel morphology. The study also shows the need for objective methods of assessing morphological diversity before and after restoration in order to assess the success of the morphological goals of river projects.

Shaffer, G. P., D. W. Llewellyn, N. J. Craig, D. Pashley, and L. A. Creasman. 1991. A Landscape Restoration Plan for the Forested Wetlands of the Mississippi River Alluvial Floodplain, USA. Pages 247. *76th Annual Ecological Society of America*, San Antonio, Texas.

Forested riparian wetlands perform a number of valuable services for humans, including moderation of downstream flooding, maintenance of good water quality, and provision of diverse habitats. Despite federal protection under Section 404 of the Clean Water Act, loss of forested wetlands continues at an alarming rate (over 23,000 ha per year in Louisiana alone) and threatens the functional integrity of entire wetland landscapes. This study was undertaken to determine the feasibility and cost of implementing a plan to restore, as functional ecosystems, eight targeted watershed in the lower Mississippi River Valley as part of the Mississippi River Alluvial Plain (MSRAP) Bioreserve Project of The Nature Conservancy. We also explore the feasibility of connecting the eight watersheds with a continuous forested corridor contiguous with the Mississippi River. Our initial efforts concentrated on placing two of the eight target sites (the Tensas basin in LA and Yazoo basin in MS) into a vector and raster based geographic information system (GIS) containing the following layers: (1) land cover, (2) hydrology, (3) soil type, (4) land ownership, and (5) prioritized forest patches and corridors. Forest patches and potential corridors were prioritized based on assembly rules combined with simple Boolean arithmetic and digtital subtraction. Detailed site-specific examples from each of the two watersheds demonstrate how the prioritization scheme operates and include optimal corridor linkages to the leveed floodplain of the Mississippi River by interfacing with a GIS of the U.S. Army Corps of Engineers.

Shields, F. D., A. J. Bowie, and C. M. Cooper. 1995. Control of streambank erosion due to bed degradation with vegetation and structure. *American Water Resources Association: Water Resources Bulletin* 31: 475-489.

Combinations of vegetation and structure were applied to control streambank erosion along incised stream channels in northwest Mississippi. Eleven sites along seven channels with contributing drainage areas ranging from 12-300 km^2 were used for testing. Tested configurations included eroding banks protected by vegetation alone, vegetation with structural toe protection, vegetation planted on re-graded banks, and vegetation planted on regraded banks with toe protection. Monitoring contiunued for up to 10 years, and casual observation for up to 18 years. Sixteen woody and 13 nonwoody species were tested. Native woody species, particularly willow, appear to be best adapted to streambank environments. Sericea lespedeza and Alamo switchgrass were the best nonwoody species tested. Vegetation succeeded in reaches where the bed was not degrading, competion from kudzu was absent, and bank slopes were stabilized by grading or toe protection. Natural vegetation invaded planted and unplanted stable banks composed of fertile soils. Designs involving riprap toe protection in the form of a longitudinal dike and woody vegetation appeared to be most cost-effective. The exotic vine kudzu presents perhaps the greatest long-term obstacle to restoring stable, functional riparian zones along incised channels in our region.

Shields, F. D., C. M. Cooper, and S. S. Knight. 1993. Initial habitat response to incised channel rehabilitation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 3: 93-103.

Incised stream channel aquatic habitats typically are severely degraded. After the primary knickpoints or knickzones have passed, base flows are limited to shallow channels flanked by sandy berms within the enlarged high-flow channel. Riparian vegetation, woody debris and pool habitat are in short supply, and stream systems become disengaged from their floodplains. We hypothesized that habitat recovery might be accelerated in channels that have incised and are regaining equilibrium through deposition of sandy berms by placing rock spurs in the channel and by planting woody vegetation on the berms. On the basis of literature review and a pilot study, planting designs were developed for a large-scale field experiment: 2550 1.5 m long cuttings of native willow (*Salix* spp.) 2-25 cm in diameter were planted 1-1.2 m deep along the base-flow channel of an incised stream. A ridge of stone was placed on the water side of the plantings, and 17 rock spurs were constructed by extending existing spur dikes from the opposite band. Woody cover along the treated bank increased from 38% to 66% of bankline after one growing season. Survival of individual plantings was reduced from an estimated 60% to an observed 34% by competition from the exotic kudzu vine, *Pueraria lobata.* Mean depth and mean scour hole depth, corrected for stage variation, increased 44% and 82%, repectively. Mean scour hole width increased 130%. The mean length of fish and the number of fish species approximately doubled, while the total weight of fish captured by a unit of sampling effort increased by an order of magnitude.

Shields, F. D., Jr., P.C. Smiley, Jr., and C.M. Cooper. 2002. Design and management of edge-of-field water control structures for ecological benefits. *Journal of Soil and Water Conservation* 57: 151-157.

Stream channel incision often triggers formation of tributary gullies. These gullies erode and extend into fields, generating sediments that pollute downstream waters and degrade aquatic habitats. Standard practice for gully treatment involves damming using an earthen embankment with drainage provided by and L-shaped metal pipe. To date, thousands of these structures, also known as drop pipes, have been constructed in riparian zones adjacent to agricultural areas, but environmental criteria have played no role in design. Sixteen drop pipe sites (defined as the region of temporary or permanent impoundment created by the structure) in northwestern Mississippi were sampled for fish, amphibians, reptiles, bids, and mammal; and physical habitat characteristics were assessed by sampling vegetation and surveying site topography. Speciose sites (those yielding 65-82 vertebrate species) were relatively large [= 0.09 ha (.22 ac)], with a significant pool area. Depauperate sites (only 11 to 20 species captured) were smaller, with no pool area and little woody vegetation. Considerable environmental benefits could be realized by slightly modified design and management of drop pipe structures. Results of this study suggest habitat benefits are minimal for sites smaller than 0.1 ha (0.2 ac), for sites lacking woody vegetation, and for sites that do not have at least 20% of their area below the inlet weir elevation.

Shields, F. D., S. S. Knight, and C. M. Cooper. 1998. Rehabilitation of aquatic habitats in warmwater damaged by channel incision in Mississippi. *Hydrobiologia* 382: 63-86.

Channel incision has major impacts on stream corridor ecosystems, leading to reduced spatial habitat heterogeneity, greater temporal instability, less stream-floodplain interaction, and shifts in fish community structure. Most literature dealing with channel incision examines physical processes and erosion control. A study of incised warmwater stream rehabilitation was conducted to develop and demonstrate techniques that would be economically feasible for integration with more orthodox, extensively employed watershed stabilization techniques (e.g., structural bank protection, grade control structures, small reservoirs, and land treatment). One km reaches of each of five northwest Mississippi streams with contributing drainage areas between 16 and 205 km^2 were selected for a 5 year study. During the study two reaches were modified by adding woody vegetation and stone structure to rehabilitate habitats degraded by erosion and channelization. The other three reaches provided reference data, as two of them were degraded but not rehabilitated, and the third was only lightly degraded. Rehabilitation approaches were guided by conceptual models of incised channel evolution and the third was only lightly degraded. Rehabilitation approaches were guided by conceptual models of incised channel evolution and fish community structure in small warmwater streams. These models indicated that rehabilitation efforts should focus on aggradational reaches in the downstream portions of incision watershed, and that ecological status could be improved by inducing formation and maintenance of stable pool habitats.
Fish and physical habitat attributes were sampled from each stream during the Spring and Fall for 5 years, and thalweg and cross-section surveys were performed twice during the same period. Rehabilitation increased pool habitat availability, and made the treated sites physically more similar to the lightly degraded reference site. Fish communities generally responded as suggested by the aforementioned conceptual model of fish community structure. Species composition shifted away from small colonists (principally cyprinids and small centrarchids) toward larger centrarchids, catostomids, and ictalurids. Fish density and species richness increased at one rehabilitated site but remained stable at the other, suggesting that the sites occupied different

initial states and endpoints within the conceptual model, and differed in their accessibility to resources of colonizing organisms. These experiments suggest that major gains in stream ecosystem rehabilitation can be made through relatively modest but well-designed efforts to modify degraded physical habitats.

Smith, G. F., and M. B. Badenhop. 1975. An evaluation of environmental quality: opportunity costs of channelization and land use change in the floodplain of the Obion-Forked Deer River Basin of West Tennessee. *Bulletin* 552.

The quality of the environment is a central issue in the controversy over the proposed channelization of the Obion-Forked Deer Rivers of Western Tennessee. Channelization would enhance agriculture production in the floodplain by providing some flood protection and land drainage and represents an enhancement of the environment to certain rural landowners and related agricultural interest. However, sportsmen and other environmentalists find the existing wetlands-forest desirable for their purposes; the transformation and loss of this environment through channelization and following land use changes represent a decrease in environmental quality to these interests. This report is an economic evaluation of these two alternatives.
The value of the development alternative was computed as the change in net agricultural returns attributable to channelization and following land use changes less the cost of channelization. The value of the preservation alternative was computed as the net values of forest products, fish, and wildlife which would be lost through development. These latter estimates were incomplete because of the current inability to predict the effects of channelization and land use change on potentially important parameters.
A project life of 50 years was assumed. Estimates were made for three levels of land use change at 8, 9, and 10% discount rates. Development values were estimated for six different sets of value, comparisons were made at the largest value set to reflect the loss of options which development entails.
The results indicated that the current environment should be maintained if crop prices were expected to approximate the three smaller sets used in the analysis. The better resource use would be a matter of judgment if crop prices were expected to approximate the two higher sets because of the incompleteness of the preservation value estimates. Development would be the better alternative if these unquantified, and perhaps unquantifiable, parameters were not judged to at least equal the difference between the development and preservation values.
Noticeable differences in the estimated development values were found when alternative assumptions regarding the benefits attributable to development were employed indicating the importance of proper benefit identification in project evaluation. Substantial differences between the public and the private costs and returns associated with development were also found suggesting that social control would be required if floodplain resources are to be allocated to the use which makes the greater contribution to society.
The analytical approach used in this study can identify the optimal alternative in a specified set but provides no information to evaluate the possible existence of a superior, unspecified alternative. A second limitation is that this approach does not consider the social acceptability of alternatives which may of necessity involve public restrictions on the rights of private property owners.

Sollers, S. C., A. Rango, and D. L. Henninger. 1978. Selecting reconnaissance strategies for floodplain surveys. *Water Resources Bulletin* 14: 359-373.

Multispectual aircraft and satellite data over the West Branch of the Susquehanna River were analyzed to evaluate potential contributions of remote sensing to floodplain surveys. Multispectral digital classifications of land cover features indicative of floodplain areas were used by interpreters to locate various flood prone area boundaries. The boundaries thus obtained were found to be more striking and continuous in the Landsat data than in the low altitude aircraft data. The digital approach permitted satellite results to be displayed at 1:24,000 scale and aircraft results at even larger scales. Results indicate that remote sensing techniques can delineate flood prone areas more easily in agricultural and limited development areas than in areas covered by a heavy forest canopy. At this time it appears that the remote sensing techniques can assist in effectively monitoring floodplain activities after a community enters into the National Flood Insurance Program.

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. *Fisheries* 26: 6-16.

Unlike conventional flood control systems that frequently isolate rivers from ecologically-essential floodplain habitat, California's Yolo Bypass has been engineered to allow Sacramento Valley floodwaters to inundate a broad floodplain. From a flood control standpoint, the 24,000 ha leveed floodplain has been exceptionally successful based on its ability to convey up to 80% of the flow of the Sacramento River basin during high water events. Agricultural lands and seasonal and permanent wetlands within the bypass provide key habitat for waterfowl migrating through the Pacific Flyway. Our field studies demonstrate that the bypass seasonally supports 42 fish species, 15 of which are native. The floodplain appears to be particularly valuable spawning and rearing habitat for the splittail (*Pogonichthys macrolepidotus*), a federally-listed cyprinid, and for young chinook salmon (*Oncorhynchus tshawytscha*), which use the Yolo Bypass as a nursery area. The system may also be an important source to the downstream food web of the San Francisco Estuary as a result of enhanced production of phytoplankton and detrital material. These results suggest that alternative flood control systems can be designed without eliminating floodplain function and processes, key goals of the 1996 Draft AFS Floodplain Management Position Statement.

Sparks, R. E., P. B. Bayley, S. L. Kohler, and L. L. Osborne. 1990. Disturbance and recovery of large floodplain rivers. *Environmental Management* 14: 699-709.

Disturbance in a river-floodplain system is defined as an unpredictable event that disrupts structure or function at the ecosystem, community, or population level. Disturbance can result in species replacements or losses, or shifts of ecosystems from one persistent condition to another. A disturbance can be a discrete event or a graded change in a controlling factor that eventually exceeds a critical threshold. The annual flood is the major driving variable that facilitates lateral exchanges of nutrients, organic matter, and organisms. The annual flood is not normally considered a disturbance unless its timing or magnitude is "atypical". The record flood of 1973 had little effect on the biota at a long-term study site on the Mississippi River, but the absence of a flood during the 1976-1977 Midwestern drought caused short-and long-term changes. Body burdens of contaminants increased temporarily in key species, because of increased concentration resulting from reduced dilution. Reduced runoff and sediment input improved light penetration and increased the depth at which aquatic macrophytes could grow. Developing plant beds exerted a high degree of biotic control and were able to persist, despite the resumption of normal floods and turbidity in subsequent years. In contrast to the discrete event that disturbed the Mississippi River, a major confluent, the Illinois River, has been degraded by a gradual increase in sediment input and sediment resuspension. From 1958 to 1961 formerly productive backwaters and lakes along a 320 km reach of the Illinois River changed from clear, vegetated areas to turbid, barren basins. The change to a system largely controlled by abiotic factors was rapid and the degraded condition persists. Traditional approaches to experimental design are poorly suited for detecting control mechanisms and for determining the critical thresholds in large river-floodplains. Large river-floodplain systems cannot be manipulated or sampled as easily as small streams, and greater use should be made of man-made or natural disturbances and environmental restoration as opportunistic experiments to measure thresholds and monitor the recovery process.

Stanturf, J. A., E. S. Gardiner, P. B. Hamel, M. S. Devall, T. D. Leininger, and M. E. Warren. 2000. Restoring bottomland hardwood ecosystems in the lower Mississippi alluvial valley. *Journal of Forestry*: 10-16.

Programs to restore southern bottomland hardwood forests to the floodplains of the Mississippi have been tested on federal land and are now being applied to private holdings. The initial goals were to provide wildlife habitat and improve water quality, but other benefits--possible income from biomass and carbon credits--may make restoration cost-effective, even for small landowners. One challenge is finding the right mix of tree species that are adapted to soil saturation and rood anoxia, can be planted and managed economically, and will produce a closed canopy and complex structure quickly. Bringing back the understory is another challenge.

Stauffer, D. F., and L. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. *Journal of Wildlife Management* 44: 1-15.

Avifauna of riparian communities were studied in Iowa during late spring and early summer. Birds were censused on 28 study plots representing a habitat gradient from hayfields to closed-canopy woodlands. An index of nesting niche breadth was determined for 18 open-nesting bird species on the basis of vegetation life form(s) used for nesting, and for 10 cavity-nesting species on the basis of type(s) of nest-cavity support. Cavity-nesters preferred soft snags as nest sites. Floodplain woodlands supported higher densities of breeding birds than upland woodland or herbaceous habitats. Birds species richness increased ($P<0.01$) with the width of wooded riparian habitats. Wooded habitats supported a maximum of 32 species; herbaceous habitats, 8. Observation frequencies of 41 bird species in 6 general habitat types were used to calculate indices of tolerance to habitat alteration. Microhabitat characteristics selected by each species were determined by comparing bird observation frequencies with 36 vegetation variables, using stepwise multiple regression. The potential effects of 6 alterations to wooded riparian habitats on the 41 species are predicted.

Stromberg, J. C. 2001. Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. *Journal of Arid Environments* 49: 17-34.

Riparian ecosystems in the south-western United States have undergone extensive physical and biological changes, due, in part, to alteration of natural flow regimes and suppression of fluvial processes. Many riparian ecosystem restoration projects are achieving success because they recognize the importance of restoring the hydrologic regime. In other words, these projects are restoring flows of water and sediment in sufficient quantities and with appropriate temporal and spatial patterns. Other projects have proceeded without recognition of the need to incorporate environmental stream flow requirements into management plans. Top increase success rate of riparian ecosystem restoration, this paper describes some changes that have occurred within riparian ecosystems of the southwestern United States, reviews the role of stream flow regimes in structuring riparian plant communities, and assesses various ways in which riparian plant communities can be restored by naturalizing ecological processes.

Swanson, S. D. 1978. The Flora of the Upper Mississippi River Floodplain. University of Wisconsin, La Crosse.

A search of 7 herbaria which contained specimens from the Upper Mississippi River Floodplain has been made. Eight hundred and seventy-nine species, 20 subspecific taxa, and 7 hybrids of vascular plants are here reported from the floodplain. This list is estimated to be two-thirds to three-fourths complete. All collection data was recorded from each of the herbarium specimens, i.e.; locality, date of collection, collector, phytosociolgy, etc., and at a future time will be computerized.
A portion of the University of Wisconsin-La Crosse general herbarium has been designated as the Upper Mississippi River Floodplain Herbarium (UMRF), and will be used to house all voucher collections made for this project as well as exchange specimens, from the floodplain, received for duplicate vouchers. Five hundred and ninety-eight of the 907 known taxa from the floodplain are presently deposited in the facility. Collections from Pools 1-10 and 24-26 are thus far the major representative localities. A program of exchange with other institutions bordering the floodplain has been initiated. Further herbaria searching, systematic collection, manual preparation, as well as the status of rare taxa and their habitats on the floodplain is discussed.
The most recent list of vascular plants from the Upper Mississippi River Floodplain will be available for all interested participants. Species are listed by family in systematic order with common names included. Notations are made with certain taxa indicating if they have rare, endangered, threatened, or extirpated status. Status was determined by the individual states bordering the floodplain, and therefore is based on the occurrence of the taxa throughout the state where designation was indicated.

Sweeney, B. W., S. J. Czapka, and T. Yerkes. 2002. Riparian forest restoration: increasing success by reducing plant competition and herbivory. *Restoration Ecology* 10: 392-400.

The reestablishment of riparian forest is often viewed as "best management practice" for restoring stream ecosystems to a quasi-natural state and preventing non-point sources contaminants from entering them. We experimentally assessed seedling survivorship and growth of *Quercus palustris* (pin oak), *Q. rubra* (red oak), *Q. alba* (white oak), *Betula nigra* (river birch), and *Acer rubrum* (red maple) in response to root-stock type (bare root vs. containerized), herbivore protection (tree shelters), and weed control (herbicide, mowing, tree mats) over a 4 year period at two riparian sites near the Chester River in Maryland, U.S.A. We started with tree-stocking densities of 988/ha (400/ac) in the experimental plots and considered 50% survivorship (i.e., a density of 494/ha [200/ac] at crown closure) to be an "acceptable or minimum" target for riparian restoration. Results after four growing seasons show no significant difference in survivorship and growth between bare-root and containerized seedlings when averaged across all species and treatments. Overall survivorship and growth was significantly higher for sheltered versus unsheltered seedlings (49% and 77.6 cm vs. 12.1% and 3.6 cm, respectively) when averaged across all species and weed control treatments. Each of the five tests species exhibited significantly higher 4-year growth with shelter protection when averaged across all other treatments, and all species but river birch had significantly higher survivorship in shelters during the period. Seedlings protected from weeds by herbicide exhibited significantly higher survivorship and growth than seedlings in all other weed-control treatments when averaged across all species and shelter treatments. The highest 4-year levels of survivorship/growth, when averaged across all species, was associated with seedlings protected by shelters and herbicide (88.8%/125.7 cm) and by shelters and weed mats (57.5%/73.5 cm). Thus, only plots where seedlings were assisted by a combination of tree shelters and either herbicide or tree mats exhibited an "acceptable or minimum" rate of survivorship (i.e., >50%) for riparian forest restoration in the region. Moreover, the combined growth and survivorship data suggest that crown closure over most small streams in need of restoration in the region can be achieved most rapidly (i.e., 15 years or less) by protecting seedlings with tree shelters and controlling competing vegetation with herbicides.

Tabacchi, E., D. L. Correll, R. Hauer, G. Pinay, A.-M. Plantly-Tabacchi, and R. C. Wissmar. 1998. Devlopment, maintenance and role of riparian vegetation in the river landscape. *Freshwater Biology* 40: 497-516.

Summary:
1. Riparian structure and function were considered from a longitudinal perspective in order to identify multiscale couplings with adjacent ecosystems and to identify research needs.
2. We characterized functional zones (with respect to vegetation development in association with various biogeochemical processes) within geomorphological settings using a delineation based upon erosional, transitional and depositional properties.
3. Vegetation dynamics within the riparian corridor are clearly influenced substantially by hydrological disturbance regimes. In turn, we suggest that vegetation productivity by hydrological disturbance regimes. In turn, we suggest that vegetation productivity and diversity may widely influence riverine biogeochemical processes, especially as related to the consequences of changing redox conditions occurring from upstream to downstream.
4. However, surface and groundwater linkages are the predominant controls of landscape connectivity within riparian systems.
5. The importance of riparian zones as sources and sinks of matter and energy was examined in context of structural and functional attributes, such as sequestering or cycling of nutrients in sediments, retention of water in vegetation, and retention, diffusion or dispersal of biota.
6. The consequences of interactions between different communities (e.g. animals and plants, micro-organisms and plants) on biogeochemical processes are notably in need of research, especially with respect to control of landscape features. Multiscale approaches, coupling regional and local factors in all three spatial dimensions, are needed in order to understand more synthetically and to model biogeochemical and community processes within the river-riparian-upland landscape of catchments.

Thoms, M. C., and K. F. Walker. 1992. Channel Changes Related to Low-level Weirs on the River Murray, South Australia. Pages 235-249 in P. A. Carling and G. E. Petts, eds. *Lowland Floodplain Rivers: Geomorphological Perspectives*. John Wiley and Sons Ltd., Chichester, UK.

Introduction: Lowland reaches in river systems are distinguished by their relatively low channel gradients and small particle sizes of sediment load and bed material. Long-term sediment storage occurs because flows are insufficient to accommodate the sediment load from high-energy reaches. The extent of deposition depends on the available storage space as well as the quantity of sediment supply. Storage is limited, for example, in the coastal rivers of eastern Australia, which fall steeply from the Eastern Uplands and deposit sediment over the remaining short distance to the sea (Erskine and Warner, 1987). In contrast, the rivers draining the western slopes have long, low-gradient profiles with extensive floodplains.

Lowland reaches are sediment sinks and potentially subject to continual change (Pickup, 1986). Alterations in the hydrological regimes, for example, may cause discharges and sediment loads in lowland reaches of the Murrumbidgee River. Australia, caused adjustments in sinuosity, meander wavelength and channel dimensions, although there was little bed degradation. Alterations to the river profile are not as common as changes in configuration, particularly over distances of more than 100 km (Richards, 1982, p. 222). Secular variations in climate also may initiate channel changes, as in the rivers of coastal New South Wales (Erskine and Warner, 1987), but the effects probably have not been significant in the larger catchments (> 30,000 meters squared) of southeast Australia (Riley, 1987).

Flow regulation also affects the dynamics of lowland river channels (e.g. Petts, 1984, p.114). In response, perhaps over several decades, the fluvial system tends towards a new equilibrium. The nature of the changes depends on many factors, including the size and location of the regulating structure. Most published studies concern the impact of large dams in headwater regions, and smaller regulators in lowland regions have received scant attention (e.g. Ahmad, 1951). As a result, it is not clear whether the fluvial processes of lowland rivers- and the nature of their response to regulation- are similar to those in headwater regions.

Thorne, C. R. 1992. Bend Scour and Bank Erosion on the Meandering Red River, Louisiana. Pages 95-115 in P. A. Carling and G. E. Petts, eds. *Lowland Floodplain Rivers: Geomorphological Perspectives*. John Wiley & Sons Ltd, Chichester, UK.

Studies of bank and bend processes were undertaken on the Red River between Index, Arkansas and Shreveport, Louisiana. The aims were to determine: the nature of the bank materials and the dominant mechanisms of bank failure; the role of outer bank type in affecting the scour depth of meander bends; and the implications for bank stabilization and river engineering schemes.
The results show that the banks are formed in materials of four different origins: meander belt alluvium and clay plug materials associated with the present floodplain; back-swamp deposits in a terrace left from the nineteenth century floodplain; and Pleistocene/Tertiary materials in the valley walls. Slab failures and rotational slips are the dominant failure modes. The Osman-Thorne analyses of bank stability were found to be useful in predicting the critical geometry for failure of banks formed in the different materials.
A relationship between outer bank type and bend scour depth was found. Generally, scour depth increases with outer bank resistance to erosion and failure, especially for tight bends of low radius

of curvature to width ratio. Maximum scour pool depths for revetted bends with nonerodible outer banks are 5-20% greater than those in an equivalent free, alluvial meander.
The U.S. Army Corps of Engineers is currently constructing a multi-million dollar scheme to make the Red River below Shreveport navigable. Concerns have been expressed regarding sedimentation problems in the navigation reach caused by the heavy sediment input from upstream. It is believed that bank erosion in the study reach between Index, Arkansas and Shreveport, Louisiana is a major source of this sediment. The results of this study suggests that some additional bend scour should be expected as a consequence of stabilizing the remaining free meanders in the study reach, promotion delta type deposition of coarse sediment at the head of pools in the navigation reach downstream, but reducing sedimentation of fines in the lock chambers and behind the dams.

Tockner, K., F. Schiemer, C. Baumgartner, G. Kum, E. Weigand, I. Zweimuller, and J.V.Ward. 1999. The Danube restoration project: species diversity patterns across connectivity gradients in the floodplain system. *Regulated Rivers: Research and Mangement* 15: 245-258.

The relationship between hydrological connectivity and species diversity patterns (alpha and beta diversity) of macrophytes, molluscs, odonates and amphibians was investigated in a semi-natural floodplain segment in the 'Alluvial Zone National Park' of the Danube River in Austria. Based on environmental variables, we distinguished four major channel types (inflow channel, parapotamal and palaeopotamal) that reflected a lateral connectivity gradient. In addition, a longitudinal environmental gradient along the parapotamal channel was found.

Connectivity rather that the surface area of individual floodplain water bodies, explained local species richness. Species diversity patterns among taxa: the highest species richness values for molluscs occurred in the parapotamal channels, for odonates in the para- and plesiopotamal channels, for macrophytes in the plesiopotamal channels and for amphibians in the palaeopotamal channels. Within the parapotamal channels, the species richness of odonates and amphibians increased moving upstream. Beta diversity displayed an almost inverse relationship with alpha diversity, with highest average values in isolated and fragmented floodplain channels. Habitat fragmentation favoured the beta diversity, of most groups, although connectivity favoured the beta diversity of amphibians. The highest proportion of endangered species (mainly rheophilic forms) was found in the parapotamal channels.

It is concluded that preservation of the high diversity of the alluvial flood plain would be more fully realized by individual groups or endangered species.

Tockner, K., F. Schiemer, and J. V. Ward. 1998. Conservation by restoration: the management concept for a river-floodplain system on the Danube River in Austria. *Aquatic Conservation: Marine and Freshwater Ecosystems* 8: 71-86.

1. One of the last remnants of a functional alluvial landscape on the Danube extends from Vienna to the Slovakian frontier. It is recognized as an ecosystem extremely worthy of protection and therefore has been designated as a National Park ('Alluvial Zone National Park')
2. However, surface connectivity has been reduced and floodplain habitats have been fragmented. At present, lateral exchange processes of matter are restricted to short-term flood pulses, while most of the year backwater processes are de-coupled from the river system.
3. A very high species diversity is recorded for this section, with a high proportion of endangered species in all groups, ranging from 16% of the riparian vascular plants to 100% for

amphibians and reptiles. High diversity is mainly a result of the remaining spatial array of water bodies of different age across the river-floodplain complex (between channel diversity).
4. A successful conservation strategy for this floodplain area requires a management scheme based on a solid conceptual foundation of the key processes in river-floodplain systems. Re-establishing hydrological dynamics is recognized as the most vital step, because other processes are influenced by the flow regime and resulting connectivity. Therefore, a large-scale project has been developed for a segment of the free-flowing section to restore gradually the hydrological connectivity between the river and it's floodplain.
5. The side-arm system will be reconnected to the main channel by lowering parts of the riverside embankments. After implementation, the side-arm system will be integrated with the flow regime of the river for more than half of an average year (at present: < 8 days per year).
6. A key challenge in the evaluation of the effects of restoration is the development and testing of an appropriate monitoring scheme, which has to include a wide range of physical, chemical, geomorphic, and ecological parameters.

Toth, L. A., and S. L. Melvin. 1998. Hydrologic manipulations of the channelized Kissimmee River. *Bioscience* 48: 9-14.

Historically, much of south-central Floida was domi-nated by a contiguous wetland system that extended from the headwater lakes of the Kissimmee River basin to Florida Bay. During the past half century, this wetland landscape has been compartmentalized with a network of canals, levees, and water-control structures (gated spillways; Figure 1). This network is used to manage hydrologic regimes of the regional hydrosystem, primarily for flood-control purposes (Light and Dineen 1994, Toth and Aumen 1994).

Trush, W. J., S. M. McBain, and L. B. Leopold. 2000. Attributes of an alluvial river and their relation to water policy and management. *Proceedings National Academy of Science* 97: 11858-11863.

Rivers around the world are being regulated by dams to accommodate the needs of a rapidly growing global population. These regulatory efforts usually oppose the natural tendency of rivers to flood, move sediment, and migrate. Although an economic benefit, river regulation has come at unforeseen and unevaluated cumulative ecological costs. Historic and contemporary approaches to remedy environmental losses have largely ignored hydrologic, geomorphic, and biotic processes that form and maintain healthy alluvial river ecosystems. Several commonly known concepts that govern how alluvial channels work have been compiled into a set of "attributes" for alluvial river integrity. These attributes provide a minimum checklist of critical geomorphic and ecological processes derived from field observation and experimentation, a set of hypotheses to chart and evaluate strategies for restoring and preserving alluvial river ecosystems. They can guide how to (*i*) restore alluval processes below an existing dam without necessarily resorting to extreme measures such as demolishing one, and (*ii*) preserve alluvial river integrity below proposed dams. Once altered by dam construction, a regulated alluvial river will never function as before. But a scaled-down morpholoy could retain much of a river's original integrity if key processes addressed in the attributes are explicitly provided. Although such a restoration strategy is an experiment, it may be the most practical solution for recovering regulated alluvial river ecosystems and the species that inhabit them. Preservation or restoration of the alluvial river attributes is a logical policy direction for river management in the future.

Vought, L. B.-M., J. O. Lacoursiere, and N. J. Voelz. 1991. Streams in the agricultural landscape? *Vatten* 47: 321-328.

In southern Sweden, changes in agricultural practices have affected the streamland interface increasing nutrient transport to the sea. Results from ongoing studies suggest that these areas surrounding Scanian streams are important in nutrient removal.

In artificially induced surface runoff through a riparian buffer strip, 66% of the PO_4-P (95%) had been removed. Results are less dramatic for NO_3-N. At 8 and 16m, 20 and 50% had been removed, compared to a similar experiment during winter where 11% of the nitrate was removed over a 30-m strip. Combining nutrient reduction with published faunal requirements and farming demands, a minimum of 10 m buffer strip seems to be a realistic suggestion.

A strong linkage between open channel and hyporheic zone was observed in a natural woodland stream. At low flow ($1.2\ L{\cdot}s^{-1}$), ca 50% of a continuously injected conservative-tracer was removed from the open channel after 572 m, indicating an exchange with the hyporheic. Monitoring of nutrient levels in an array of riparian pipes suggests that a reduction in nitrogen is occurring in the zone: NO3 levels were lower in the riparian pipes than in the stream channel or the groundwater, precluding a dilution factor. Given the extent of this mostly unknown dimension of stream system, it is crucial that any consideration of nutrient flow through the agricultural landscape takes into account the hyporheic zone.

Ward, J. V., K. Tockner, and F. Schiemer. 1999. Biodiversity of floodplain river ecosystems: ecotones and connectivity. *Regulated rivers: Research & Management* 15: 125-139.

A high level of spatio-temporal heterogeneity makes riverine floodplains among the most species-rich environments known. Fluvial dynamics from flooding play a major role in maintaining a diversity of lentic, lotic and semi-aquatic habitat types, each represented by a diversity of successional stages. Ecotones (transition zones between adjacent patches) and connectivity (the strength of interactions across ecotones) are structural and functional elements that result from and contribute to the spatio-temporal dynamics of riverine ecosystems. In floodplain rivers, ecotones and their adjoining patches are arrayed in hierarchical series across a range of scales. At a course scale of resolution, fringing floodplains are themselves complex ecotones between river channels and uplands. At finer scales, patches of various types and sizes form habitat and microhabitat diversity patterns. A broad spatio-temporal perspective, including patterns and processes across scales, is needed in order to gain insight into riverine biodiversity. We propose a hierarchical framework for examining diversity patterns in floodplain rivers.

Various river management schemes disrupt the interactions that structure ecotones and alter the connectivity across transition zones. Such disruptions occur both within and between hierarchical levels, invariably leading to reductions in biodiversity. Species richness data from the connected and disconnected floodplains of the Austrian Danube illustrate this clearly. In much of the world, species-rich riverine/floodplain environments exist only as isolated fragments across the landscape. In many large rivers, these islands of biodiversity are endangered ecosystems. The fluvial dynamics that formed them have been severely altered. Without ecologically sound restoration of disturbance regimes and connectivity, these remnants of biodiversity will proceed on unidirectional trajectories toward senescence without rejuvenation. Principles of ecosystem management are necessary to sustain biodiversity in fragmented riverine floodplains.

Washitani, I. 2001. Plant conservation ecology for management and restoration of riparian habitats of lowland Japan. *Population Ecology* 43: 189-195.

Conservation ecology is a new paradigm of ecology that aims at scientific contributions to maintaining earth's biodiversity and is committed to ecosystem management indispensable to intergenerational long-term sustainability. Population ecology plays a central role in conservation ecology. Persistence of the metapopulation rather than that of each local population should be pursued in species conservation management. Biological interactions essential to reproduction and soil seed bank components of the population should be investigated and applied to planning for the conservation of a plant population. Gravelly floodplains and moist tall grasslands are among typical riparian habitats containing many threatened plants in Japan. These riparian habitats are now subjected not only to heavy fragmentation but also to intensive invasion of highly competitive alien (nonnative) plants. Extreme habitat isolation may result in reproductive failure or fertility selection in a plant population without pollinators, as exemplified by a nature reserve population of *Primula sieboldii*. Biological invasions, which are facilitated by extensive changes in the river environment including decreased seasonal flooding, abandonment of traditional vegetation mangement, eutrophication, and extensive clearing of the land for recreational use, threaten endemic riparian species. To preserve safe sites and growing conditions for threatened plants such as *Aster kantoensis*, active management to suppress the dominance of alien invader plants is necessary. Population management and habitat restoration should be based on sound information on the population ecology of both threatened and alien invader plants, designed as an ecological experiment to clarify effective ways for management.

Welcomme, R. L. 1989. Floodplain Fisheries Management. Pages 209-233 in J. A. Gore and G. E. Petts, eds. *Alternatives in Regulated River Management*. CRC Press, Boca Raton, FL.

Williams, R. N., P. A. Bisson, D. L. Bottom, L. D. Calvin, C. C. Coutant, M. W. Erho, C. A. Frissell, J. A. Lichatowich, W. J. Liss, W. E. McConnaha, P. R. Mundy, J. A. Stanford, and R. R. Whitney. 1999. Return to the river: scientific issues in the restoration of salmonid fishes in the Columbia River. *Fisheries* 24: 10-19.

The Columbia River once was one of the most productive river basins for anadromous salmonids on the West Coast of North America; however, its current runs total less than 10% of historic levels. The Independent Scientific Group (ISG) of the Northwest Power Planning Council reviewed regional salmon management actions decribed in the Columbia River Basin Fish and Wildlife Program and concluded that the current program is unlikely to recover declining salmon and steelhead stocks. Adoption of a salmon life history ecosystem concept as a guiding foundation is needed to recover depressed stocks. Increasing natural ecosystem processes and functions should rebuild salmon populations to more abundant, productive, and stable levels. Elements of a salmon recovery program that increase these normative conditions include restoration of habitat for all life history stages (including migrations), reduction of mortality sources (including harvesters), planning of hydropower mitigation measures in the context of the normative river concept, and empirical evaluation of mitigation for effectiveness in reaching fish restoration objectives. Salmon need to be managed for population and life history diversity, not just for harvest. Reserves that protect remaining core populations and intact habitats are needed to foster a step-by-step rebuilding of salmon abundance and productivity.

Wissmar, R. C., and R. L. Beschta. 1998. Restoration and management of riparian ecosystems: a catchment perspective. *Freshwater Biology* 40: 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.

Wright, J. F., J. H. Blackburn, D. F. Westlake, M. T. Furse, and P. D. Armitage. 1992. Anticipating the Consequences of River Management for the Conservation of Macroinvertebrates. Pages 137-149 in P. C. P.J. Boon, G.E. Petts, ed. *River Conservation and Management*. John Wiley & Sons Ltd, Chichester, UK.

In Britain, the Nature Conservancy Council (NCC) has the task of selecting a national series of flowing waters for notification as Sites of Special Scientific Interest (SSSIs). The NCC uses a classification of river types based on aquatic and marginal wetland vegetation as a basis for SSSI selection. (Holmes, 1989; Nature Conservancy Council, 1989). When macrophyte surveys indicate that a river or section of river is of potential interest, the initial assessment is normally supplemented with a broad habitat survey (Nature Conservancy Council, 1985) together with further studies to determine the value of the river corridor for invertebrates, fish, birds, and mammals. In this chapter we report on a sampling programme to document the fauna of lowland rivers in summer. Information on the macroinvertebrates of a wide range of macrophyte and non-macrophyte habitats is being processed individually to provide the necessary database. A major objective is to combine current ability to predict the fauna of a site from environmental variables with detailed information on the habitat preferences of the fauna. In this way, it should be possible to anticipate the likely consequences for the fauna of management practices which alter the range of available habitat types.