Fish Passage through Dams in Large Temperate Floodplain Rivers: An Annotated Bibliography

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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is implemented by the Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi, Illinois, Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to improve understanding of how the system functions, determine resource trends, develop management alternatives, and manage information.

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http://www.umesc.usgs.gov/ltrmp_fish/fish_passage_biblio.html#lit. (Accessed June 2001.)

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Abstract

This report contains 474 annotated citations that are relevant to fish passage through dams in large temperate floodplain rivers. Our goal was to survey the literature to help define the potential ecological consequences of restricted fish passage through dams in the Upper Mississippi River System and to identify alternative engineering solutions for increasing fish passage in large temperate floodplain rivers. Consequently, topic coverage is broad, including theoretical concepts in large river ecology, engineering design of fish passage structures, ecological responses to river impoundment, fish swimming performance, and relations between freshwater mussels and fish. This report is served in searchable electronic format from the U. S. Geological Survey's, Upper Midwest Environmental Sciences Center web site (http://www.umesc.er.usgs.gov/).

Introduction

Twenty seven dams on the Upper Mississippi River System (UMRS) allow for the management of water levels during low flows. Most of these dams were authorized by Congress in 1930 to maintain a 9-foot navigation channel (Rivers and Harbor Act, July 3, 1930, H.R. 11781). Fish passage through these dams has been a long-standing concern on the UMRS (Coker 1929; Fremling et al. 1989). A report from the Chief of Engineers (War Department 1932) that served as the basis for authorization of the Upper Mississippi River 9-foot channel navigation project states the following:

"The strong currents through the gates, locks, and other openings will attract fish to these openings through which, the Board feels, they will be able to pass more readily than through any fishway. Fishways through the dams will, however, be installed if shown to be necessary."

Several studies have documented that some fish species can pass through UMRS dams (e.g., Bahr 1977; Holzer and Von Ruden 1982; Hurley 1983; Holland et al. 1984). However, it has recently become evident that passage opportunities vary in space and time because of hydrologic conditions at the dams, differences in dam design and operation, and differences in the swimming performance of fish species. Substantial questions remain about whether UMRS dams, as they are operated presently, impart a significant influence on fish movement, and if restricted fish passage has significant ecological consequences. This report compiles literature sources for assessing ecological consequences associated with restricted fish passage in the UMRS and for evaluating fish passage alternatives.

This report is not a complete bibliography on fish passage. We excluded most of the prodigious literature pertaining to Pacific salmon (Onchorhynchus spp.), Atlantic salmon (Salmo salar), and shad (Alosa spp.). We reasoned that problems

and solutions for those species were distinctly different from those of interest in large floodplain rivers in general and the UMRS in particular (e.g., different life history characteristics—anadromy versus potadromy—and different dam characteristics—high-head hydroelectric versus low-head navigation dams). Rather, we took a broad view of fish passage concerns in the UMRS and included citations on theoretical concepts for large rivers; species-specific behavior and swimming performance; engineering, design, and performance of various fish passage devices; and case history studies from around the world. Additionally, we included citations related to freshwater mussels because mussel distribution and dispersal are directly related to movement of fish that act as hosts for the juvenile parasitic stage of most freshwater mussels.

We searched Aquatic Sciences and Fisheries Abstracts (1978–present), Conference Papers Index (1982–present), Water Resources Abstracts (1967–present), and Fish and Fisheries Worldwide (1971–present) as well as various other sources housed at the U. S. Geological Survey (USGS), Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. Dr. Mufeed Odeh (USGS, Leetown Science Center, S. O. Conte Anadromous Fish Research Center, Turner Falls, Massachusetts) graciously provided access to a bibliographic database on anadromous fish passage developed at the S.O. Conte Anadromous Fish Research Center.

Most abstracts included in this report are the original author's abstracts. If an abstract was not provided, we wrote one. An underlined citation number indicates the abstracts we wrote.

No attempt was made to standardize units of measure across citations. In all abstracts, units of measure are from the original paper. Titles in brackets indicate that the reference was previously translated by other sources.

This report is served in searchable format on the World Wide Web, through the USGS, Upper Midwest Environmental Sciences Center's web site (http://www.umesc.er.usgs.gov/).

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We thank Daniel B. Wilcox (U.S. Army Corps of Engineers, St. Paul District) and Mark A. Cornish (U.S. Army Corps of Engineers, Rock Island District) for their assistance in planning this work. We also thank Mike A. Caucutt and Dave A. Bergstedt (USGS, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin) for their assistance in serving this database on the World Wide Web. This report was developed with funding provided by the U. S. Army Corps of Engineers during Fiscal Year 2000.

Literature Cited

Bahr, D. M. 1977. Homing, swimming behavior, range, activity patterns, and reaction to increasing water levels of walleyes (*Stizostedion vitreum vitreum*) as determined by radio-telemetry in Navigation Pools 7 and 8 of the Upper Mississippi River during spring 1976. M.S. Thesis. University of Wisconsin, La Crosse.

Coker, R. 1929. Studies of common fishes of the Mississippi River at Keokuk. U.S. Department of Commerce Bureau of Fisheries. Fisheries Document No. 1072. Bulletin of the Bureau of Fisheries XLV.

Fremling, C. R., J. L. Rasmussen, R. E. Sparks, S. P. Cobb, C. P. Bryan, and T. O. Claflin. 1989. Mississippi River fisheries: A case history. Pages 309-351 *in* D. P. Dodge, editor, Proceedings of

the International Large River Symposium (LARS). Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Holland, L., D. Huff, S. Littlejohn, and R. Jacobson. (1984). Analysis of existing information on adult fish movements through dams on the Upper Mississippi River. Report to the St. Paul District, U. S. Army Corps of Engineers. U.S. Fish and Wildlife Service, National Fisheries Research Laboratory, La Crosse, Wisconsin. 193 pp.

Holzer, J. A., and K. Von Ruden. 1982. Walleye spawning movements in Pool 8 of the Mississippi River. Pages 1-40 *in* Wisconsin Department of Natural Resources. Mississippi River Work Unit Annual Report 1981-1982. Madison, Wisconsin.

Hurley, S. T. 1983. Habitat associations and movements of shovelnose sturgeon in Pool 13 of the Upper Mississippi River. M.S. Thesis. University of Iowa–Ames. 82 pp.

War Department. 1932. Survey of Mississippi River between Missouri River and Minneapolis. Part 1: Report. House Document 137. 72nd Congress, 1st Session. U.S. Government Printing Office, Washington, D.C. 120 pp.

List of Annotated Citations

1. Adam, B. and U. Schwevers (1998). Positioning fish migration facilities - behavioural investigations on fish in a hydraulic flume. Wasser und Boden. **50**:55-58.

We investigated typical behavioural patterns of rhithral fish in a hydraulic flume (18 m x 1,5 m x 1 m deep), in order to determine how fish migration facilities should best be installed. By comparing different discharges and various entrance locations of a simulated fishway, we found that the most effective position for the entrance is parallel to the tailwater flow and directly at the obstacle. In contrast, entrances at right-angles to the flow can hardly be found by the fish. On their way upstream, they pass the zone of turbulence and assemble immediately in front of the migration barrier.

2. Adams, S. R., G. R. Parsons, J. J. Hoover and K. J. Killgore (1997). Observations of swimming ability in shovelnose sturgeon *Scaphirhynchus platorynchus*. Journal of Freshwater Ecology. **12**:631-633.

Swimming performance and behaviour of five adult (57 - 69 cm fork length) shovelnose sturgeon, *Scaphirhynchus platorynchus*, were studied in a 945-L swim tunnel at 16^{o} C. Fifteen-minute critical swimming speeds ranged from 65 to 116 cm s^{-1}. Sturgeon swam volitionally at low speeds (5-30 cm s^{-1}), but at higher speeds (40 - 120 cm s^{-1}) sturgeon alternated between active swimming and appressing themselves to the bottom of the tunnel. This second behaviour is enhanced by sturgeon morphology - streamlined body shape, flat rostrum, and large pectoral fins. It allows shovelnose sturgeon to exploit river bottoms as a refugia from current and maintain position in high velocities.

3. Ahmed, F. and N. Rajaratnam (1997). Three-dimensional turbulent boundary layers: A review. Journal of Hydraulic Research. **35**:81-98.

The nature of three-dimensional turbulent boundary layers (3DTBL) are discussed with the intention of applying them to the problems encountered in hydraulic engineering. After introducing the basic concepts of 3DTBL, various cross-flow and near-wall similarity models are described. A comparison between the flow situations commonly encountered in hydraulic engineering and in some other branches of fluid mechanics (which initially prompted the development of 3DTBL theories) is made to explore the possibilities of utilizing the 3DTBL theories in hydraulic engineering. There appears to be numerous opportunities to fruitfully apply 3DTBL theories in hydraulic engineering. One such application is presented in a companion paper.

4. Alexander, T. W. (1992). Discharge rates for tainter and roller gates at Lock and Dam No 25 on the Mississippi River near Windfield, Missouri. U.S. Geological Survey, Water-Resources Investigations Report 92-4118.

The water surface elevations on the Inland Waterway Navigation System of the Upper Mississippi River are controlled during normal operating conditions by various flow controls located at 29 locks and dams. The headwater (navigation pool) and

tailwater elevations at Lock and Dam No. 25 near Windfield, MO, are controlled by the regulation of 14 tainter gates and 3 roller gates. Stage discharge ratings for these tainter and roller gates were developed for use in computing discharge through Dam No. 25 and to aid in regulating the navigation pool within its normal operating limits of 429.70 to 434.00 ft. A total of 57 measurements of discharge that ranged from 370 to 9,220 cu ft/sec were made in the tainter and roller gate forebays. The measured discharges were used to define flow regimes as a function of static-headwater depth (h1), static-tailwater depth (h3), and vertical height of tainter or roller gate opening (hg). Submerged orifice flow is the predominant flow regime at lock and Dam No. 25. Thirty-seven discharge measurements defining coefficients of discharge (Cgs) ranging from 0.087 (hg=1 ft) to 0.731 (hg=14 ft) were used to develop the submerged orifice discharge coefficient relation for the tainter gates. Seventeen discharge measurements defining coefficients of discharge ranging from 0.038 (hg=1 ft) to 0.534 (hg=14 ft) were used to develop the submerged orifice discharge coefficient relation for the roller gates. Also, three discharge measurements were made with the gates closed (hg=0) to evaluate the tainter and roller gate leakage discharge relations. Theoretical equations that express discharge per gate (Q) as a function of discrete hydraulic control variables were developed from these discharge coefficient and gate leakage discharge relations. The resulting equations of discharge area applicable to gate openings of 1 ft to 14 ft and for orifice submergence ratios (h3/hg) ranging from 1.4 to 11.0; thus, these equations can be used to compute discharges for regulated flow conditions not otherwise defined by the current meter discharge measurements. Discharge rating tables for the tainter and roller gates are given for selected combinations of headwater and tailwater elevations.

5. Allan, J. D. and A. S. Flecker (1993). Biodiversity conservation in running waters. Bioscience. **43**:32-43.

In this article, the authors describe the biological diversity of running waters and its state of imperilment, and we identify six major factors that threaten the destruction of these species and ecosystems. Finally, although few steps are being taken to protect river ecosystems, their potential for recovery is considerable, and we close with a discussion of measures to enhance the health of flowing waters.

6. Allendorf, F. W., N. Ryman and F. M. Utter (1987). Genetics and fishery management, past, present and future. Pages 1-19 *in* N. Ryman and F. Utter, eds. Population Genetics and Fisheries Management, University of Washington Press, Seattle, Washington (USA).

A review is made of the genetic management of fisheries, examining characteristics of fish which make them unique from a genetic perspective and thus have resulted in the delayed application of basic genetic principles to fisheries management. Future directions for genetics in fisheries management are indicated, discussing the need for education, application of existing techniques and the development of new techniques.

7. Anderson, R. V. (1989). Environmental aspects of river control in the Upper Mississippi River. Pages 74 *in* M. D. Games, ed. National Meeting of the American Association for the Advancement of Science, New Orleans, Louisiana (USA), AAAS Annual Meeting Abstracts.

The first lock and dam on the Mississippi River was completed in 1913 at Keokuk, Iowa. The resulting impoundment and flooding and leveling of the floodplain

forest have substantially modified the river environment. The annual hydrologic regime has been changed with increasing flood frequency and elevation. The loss of floodplain habitat has altered energy flow and nutrient cycles by removing extensive floodplain/riverine interactions and thus altering food web structures. Bottom substrate has become finer grained with a shift in benthic organisms from cling and sprawling to burrowing forms. As silt accumulates in impounded river reaches aquatic vascular plants begin to grow dramatically reducing benthic production and shifting community composition. Macrophyte beds further accelerate siltation which results in a succession of plant communities ultimately reducing the permanent aquatic habitat. Present management programs in the Upper Mississippi River are being developed which should mitigate some of these environmental effects.

8. Anderson, R. V., J. Eckblad, T. Claflin, S. Cobb and L. Sanders (1987). Habitat diversity and utilization by invertebrates and fish along the Mississippi River continuum. Pages 241 *in* M. P. Lynch and K. L. McDonald, eds. Estuarine and Coastal Management, Tools of the Trade, New Orleans, Louisiana (USA).

The Mississippi River from Minnesota to the Gulf of Mexico represents the higher orders (8-12) of the stream classification system arranged along an increasing continuum. Theory suggests that a change in community composition of fish and macroinvertebrates should occur along this continuum. However, little changes in species composition of fish and trophic guilds of benthic invertebrates was found when comparing these communities from similar habitat types down the length of the Mississippi River. Density did decline in the lower reaches of the river and much higher densities of the Asiatic clam did occur in the lower river reaches. More differences were found in fish and macroinvertebrate communities along a lateral gradient throughout the system than a longitudinal gradient. The highest densities and biomass of macroinvertebrates and fish were found associated with potential availability of particulate organic matter.

9. Anderson, R. V., J. W. Grubauch, R. E. Sparks and K. W. Blodgett (1989). Mussels of Pool 19, 75 years behind a dam. Pages 13 *in* J. Rasmussen, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

The river reach presently designated Pool 19 has long been an area of known mussel beds with history notes dating to the early 19th century. In association with commercial harvest for the pearl button industry and construction [sic] of Dam 19, early researchers predicted a reduction in the mussel populations of the river. Qualitative construction and quantitative records for the past 75 years were examined to determine if changes have occurred and to evaluate those changes in the mussel community. While commercial mussel harvest rapidly declined in the 30's and 40's it has again become a prevalent activity on the river with tons of mussels being removed from the river annually. In 1930, 21 species of mussels were collected from this Pool while in the mid-1980's 29 species were present. Sampling effort and the number of habitats examined increased in the 1980's. Even though simple diversity may have increased, density has decreased. Though more species are presently reported from this river reach, shifts in density and composition have occurred with previously abundant species becoming rare.

10. Angermeier, P. L. and J. R. Karr (1994). Biological integrity versus biological diversity as policy directives. BioScience. **44**:690-697.

The authors argue that resource policy would be most effective if the goal were the protection of biological integrity. Biological integrity is defined as biological diversity plus the processes that support that diversity. Thus, it is a truer systems approach to resource management than just managing for the greatest different types of organisms. In their argument, the authors stress the importance of understanding organizational heirarchies in ecosystem management. Objective recognition and assessment of changes in integrity are critical for the concept's use in resource policy. Thus, appropriate benchmarks need to be established against which future system states can be compared and contrasted. Variation in elements attributable to natural processes does not represent a variation in integrity, but variation caused by humans does. The authors argue further that evolotionary history should provide the primary basis for assessing biological integrity. A keystone concept in their argument is that ecological processes are buffered from perturbation by redundancy among ecosystem elements and processes. Anthropogenic influences often simplify systems, reducing their redundancy, and thus negatively impair system integrity. In essence, the goals of biological conservation and restoration should focus on protecting integrity, especially the organizational processes that generate and maintain all elements, rather than focusing on the presence or absence of particular elements.

11. Anonymous (1972). Upper Mississippi River Comprehensive Basin Study: Volume I, Main Report. Upper Mississippi River Comprehensive Basin Study Coordinating Committee.

This study was prepared at field level and presents data for a framework program for the development and management of the water and related land resources of the Upper Mississippi River Basin. The main report summarizes the findings of the 17 supporting appendices. The water and related land resources of the basin are ample. There are opportunities for further resource development. Conservation and development of the resources are needed if the basin is to maintain its relative position in the national economy. The study presents the needs for water and related land resources and a framework for development of such resources. The estimated total first cost of the recommended framework for development is $28.5 billion of which $13.2 billion is federal and $15.3 billion is non-federal. The annual investment ranges from $31 per capita in 1980 to $44 per capita by 2020. The current annual rate of investment is about $27 per capita. Recommendations include approval and adoption of the framework by the federal government and the seven basin states, further studies to develop details of the framework, periodic review of the framework, and continuation of the present coordinating committee pending organization of the Upper Mississippi River Basin Commission.

12. Anonymous (1978). Culvert guidelines: recommendations for the design and installation of culverts in British Columbia to avoid conflict with anadromous fish. Canadian Fisheries and Marine Service, Technical Report of the Fisheries and Marine Service 811.

This report examines the hydraulic criteria that should be satisfied at a culvert installation to ensure that fish can migrate through the facility with a minimum of stress. The report also outlines guidelines that, if incorporated into the culvert design, should produce a facility that will permit the free passage of fish in most situations. The design

of auxiliary fish passage structures such as culvert baffles and tailwater control facilities are discussed and exampled by drawings. Consideration is also given to the installation of culverts to avoid conflicts with fish use in the stream both during and after the construction period. Guidance is also given concerning the procedures to follow for necessary approval of a proposed culvert installation by the Fisheries and Marine Service.

13. Anonymous (1978). Environmental issues in river basin development. Pages 1163-1172 *in* U. Nations, ed. Water Management and Development, Proceedings of the United Nations Water Conference, Mar del Plata (Argentine), Pergamon Press.

Environmental effects of dam construction in river basins and methods of minimizing such effects are described. Large dams tend to have particularly significant and complex effects on aquatic ecosystem which must be carefully evaluated prior to construction. Rational development involves: (1) a comprehensive basinwide assesment of social, economic, and ecological characteristics and of the effects of development; (2) evaluation of development alternatives reflecting social, economic, and environmental factors to provide the basis for environmental management. Dam construction can provide the water supply, hydroelectric power, and flood control, and can greatly improve agriculture, forestry, and livestock management. Excessive use of water and agricultural chemicals can however, cause waterlogging and salinization, and can affect water quality and quantity. Dams produce a permanent physical transformation, inundating settled areas and destroying habitats , affecting the groundwater regime and water table, possibly increasing seismic tendencies, and often leading to explosive aquatic weed growth and the spread of schistosomiasis and other communicable diseases. Dams in tropical areas tend to favor weed propagation and vectors of parasitic diseases, while temperate-zone dams often interfere with fish migration. Resettlement of population displaced by dams often leads to housing, disease, and social problems. Loss of wetlands endangers many plant and animal species.

14. Anonymous (1978). A review and resolution of fish passage problems at culvert sites in British Columbia (2nd edition). Fisheries and Marine Service, Technical Report of the Fisheries and Marine Service 810.

The success or failure of a fish in migrating through a culvert depends upon the swimming ability of the fish and the hydraulic conditions present. In culverts stream flow velocities are maximized and usually constant throughout most of the culvert length as opposed to the variety of conditions in a natural stream channel. From documentation of swimming ability of salmon (Oncorhynchus) it is possible to determine hydraulic criteria that must be satisfied to ensure free fish passage, especially throughout the spawning migration period. Since detailed stream flow records for small streams in British Columbia have not been taken, a general system must be used. Some recommendations for culvert design are given.

15. Anonymous (1978). A study of model and prototype culvert baffling for fish passage. Fisheries and Marine Service, Technical Report of the Fisheries and Marine Service 828.

Most streams, crossed by roads or highways, are culverted. Many such crossings are impassable to migrating fish because of the culvert length and the high water velocities in them. A hydraulic model study tested and developed devices to aid fish passage through culverts. Based on the model study recommendations, Offset baffles and

Spoiler baffles were designed and installed at the Mackenzie Highway crossing of the Redknife River. Field testing showed good agreement, between model and prototype results. The effectiveness of both baffle types is inversely proportional to culvert slope. Maximum recommended slope is 5%. A method of judging baffle adequacy is provided. The Offset and Spoiler baffles are recommended, primarily for correcting existing culvert installations and for proposed stream crossings where alternative designs are neither practical nor economical. Minor problems were presented by ice, debris and sediment. Unsuccessful attempts by Arctic grayling *Thymallus arcticus* and longnose sucker *Catostomus commersoni*, to enter the Redknife River culverts, were observed; their failures were attributed to overwhelming water velocities associated with elevated culvert outlets.

16. Anonymous (1979). Anadromous fisheries management. Massachusetts Division of Marine Fisheries, Completion Report .

During the project period AFCS 14-1 through AFCS 14-5 (1974-1979), eight fish passage facilities were constructed, four fishways were improved and another 217 were adjusted and cleaned. A total of 151,550 alewives were stocked in 34 areas where passage improvements were made or anticipated. Smelt eggs (113.7 million) were planted in Millcreek, Sandwich; Bull Brook, Rowley, and Jones River, Kingston. Shad eggs were stocked in Charles River (5,337,100), Taunton River (11,908,200) and Merrimack River (12,104,700) in an effort to establish shad populations. A total of 2237 pre-spawning adult shad were transplanted from the Holyoke Fish Lift to four Massachusetts rivers.

17. Anonymous (1989). Long-term resource monitoring program for the Upper Mississippi River system. U.S. Geologic Survey, Environmental Management Technical Center, Annual Report EMTC-89/02.

The First Annual Report of the Long Term Resource Monitoring Program for the Upper Mississippi River System covers the period from September, 1986 through January 1989. The report includes: program activities information concerning cooperation between member states and agencies; a summary of the past year's data collection effort for water quality; deviations from the Operating Plan; critical paths and funding requirements through 1999; plans for the coming year, and; management of the Environmental Management Technical Center. Technical Center Staff are divided between Ecology and the Computerized River Information Center. Ecology is responsible for the analysis of significant resource problems and for long term resource monitoring of the Upper Mississippi River System. The Computerized River Information Center is responsible for supplying the necessary computer hardware and software for geographical information systems, data base management, modeling and statistical analysis.

18. Anonymous (1990). Environmental management program: Long term resource monitoring program, Upper Mississippi River system. U.S. Geological Survey, Environmental Management Technical CenterEMTC-90/05.

The Second Annual Report of the Long Term Resource Monitoring Program for the Upper Mississippi River System covers the period from January through December 1989. The report summarizes program activities; information concerning cooperation between member states and agencies; program management information concerning

staffing and budgeting; variances from the Annual Work Plan and task scheduling for current and future fiscal years. Environmental Management Center and Field Station operations are described and accomplishments for the year are summarized. A listing of completed publications is provided.

19. Anonymous (1992). Bibliographical materials related to navigation project. Long term resource monitoring program. U.S. Geological Survey, Environmental Management Technical Center, Report EMTC92S012.

The strategy to quantify physical impacts of commercial traffic is included in the Long Term Resource Monitoring Program (LTRMP) Operating Plan (USFWS 1992) as Strategy 1.2.2, and to determine effects of navigation on selected components and processes of the Upper Mississippi River System. Future navigation studies under the LTRMP will continue in conjunction with environmental studies yet to be described by the U.S. Army Corps of Engineers. The bibliography is intended as a reference document for researchers interested in retrieving reports prepared by the Illinois State Water Survey while under contract to the U.S. Fish and Wildlife Service between 1986 and 1992.

20. Anonymous (1998). National strategy for the conservation of native freshwater mussels. Journal of Shellfish Research. **17**:1419-1428.

On April 1995, representatives from several federal and state natural resource agencies, the commercial mussel industry (Shell Exporters of America), academia, and The Nature Conservancy met to discuss freshwater mussel declines and gather information on freshwater mussel trends, research, and recovery activities (Appendix I). As a result of the magnitude and immediacy of the nationwide threats to the freshwater mussel fauna, the group agreed that a coordinated effort of national scope was needed to prevent further mussel extinctions and population declines. To address this need, the group decided to (1) draft a National Strategy for the Conservation of Native Freshwater Mussels (National Strategy) and (2) establish a national ad hoc committee with broad-based representation from state, tribal, and federal agencies, the mussel industry, private conservation groups, and the academic community to help implement mussel conservation at the national level. A draft National Strategy was presented at the second Symposium on the Conservation and Management of Freshwater Mussels organized by the Upper Mississippi River Conservation Committee, in St. Louis, Missouri in October 1995. Comments received at and subsequent to the symposium were incorporated into another draft dated September 16, 1996. The September 1996 draft was presented at a February 1997 meeting of the newly formed National Native Mussel Conservation Committee in St. Louis, Missouri. Comments from the February 1997 meeting have been incorporated into this current document.

21. Anonymous (1999). A comparison of genetic variability in artificial and natural populations of brown trout in a regulated river system. Regulated Rivers: Research & Management. **15**:159-168.

Brown trout *Salmo trutta* were sampled from tributaries of Glomma, the largest river system in Norway. Brown trout were formerly known to migrate long distances, but several dams and river regulations have made migration difficult, as fishways constructed at the dams are not efficient. To compensate for the resultant reduction in brown trout, the river system has been stocked with hatchery fish reared from native brown trout.

Genetic analysis by enzyme electrophoresis was conducted to monitor possible genetic effects on native fish. Brown trout were obtained from a fishway at Lopet in the South Rena River, and from a section at Deset, 16 km upstream of the fishway. One sample was taken from a cohort of first generation hatchery fish, based on only six spawning fish collected in the fishway, and one sample was taken from the second hatchery generation, bred from a mixture of two cohorts of first generation hatchery fish. The pooled broodstock of these two first generation cohorts numbered five females and five males. Eight samples were taken from second-, third- and fourth-order streams containing populations differing in size and degree of isolation. Tissue samples taken from eye, liver and muscle were analyzed using starch gel electrophoresis for protein polymorphism to determine genetic population structures. Allele frequencies, heterozygosity and polymorphism were compared. The fraction of heterozygosity ranged from 3.3 to 13.5% in the wild populations, and the lowest fraction was found in the most isolated population. Heterozygosity was 8.0% in the first generation of hatchery reared fish and 7.3% in the second generation. The number of detected polymorphic loci ranged from one to seven, with a mean of 4.5, in wild populations, but was three in the first generation and four in the second generation of hatchery fish. Polymorphism seemed to be lost at three loci in the first generation, but one locus was restored in the second generation, probably due to breeding with another hatchery cohort.

22. Arrhenius, F., B. Benneheij, L. G. Rudstam and D. Boisclair (2000). Can stationary bottom split-beam hydroacoustics be used to measure fish swimming speed in situ? Fisheries Research. **45**:31-41.

We used split-beam hydroacoustics (Simrad EY500, 70 kHz) as a method for estimating fish swimming speed in situ. The method was first evaluated in the field using underwater video cameras (stereocinematographic method, SCG) to estimate accurate fish swimming speeds. The mean and distribution of swimming speeds of 15-cm brook trout (*Salvelinus fontinalis*) obtained by the two methods were not statistically different (average 17.8 cm s^{-1} with split-beam and 18.6 cm s^{-1} with SCG). We then used the split-beam technique to measure swimming performance in situ for fish assumed to be yellow perch (*Perca flavescens*) and alewives (*Alosa pseudoharengus*) in two lakes in New York State, USA. The measured swimming speeds ranged from 0.5 to 6 body length (BL) per second for juvenile and adult fish. Other laboratory studies on swimming speeds have reported values in the same range. However, measured swimming speeds for smaller fish were unrealistically high (2-32 BL s^{-1}) Advantages of the split-beam method are the ability of measuring swimming speed independently of visibility, with minimal disturbance and at large distances. Disadvantages are the inability to distinguish species observed and some variance in target location, which results in calculated average swimming speeds of 2.6 cm s^{-1} even for a stationary target.

23. Arseneault, M. (1994). Salmon saga: Murphy's law as a fish story. Ceres. Rome. **26**:10-12.

For thousands of years salmon (Salmonidae) and 7 other species of fish migrated up the Dordogne in France. At the turn of the 20th Century hydroelectric dams were constructed along the river, impeding salmon reproduction; despite the construction of fish ladders at the dams, by 1920 the salmon had disappeared from the Dordogne. A salmon restoration project was initiated but 15 years and 40 million FF later the salmon have still not returned. The various problems encountered in trying to ensure the return of the salmon to the river are discussed.

24. Assis, C. A. (1990). Threats to the survival of anadromous fishes in the River Tagus, Portugal. Journal of Fish Biology. **37 (Suppl. A)**:225-226.

Most European anadromous fish are threatened species. This investigation concerns the River Tagus (Iberian Peninsula). Four anadromous fish spp occur in this basin but they no longer reach the upper (Spanish) part. In Portugal, the sea lamprey, *Petromyzon marinus* (Petromyzontidae), and the twaite shad, *Alosa fallax* (Clupeidae), are still common, the allis shad, *Alosa alosa* (Clupeidae), is rapidly declining and the river lamprey, *Lampetra fluviatilis* (Petromyzontidae), is rare. The sturgeon, *Acipenser sturio* (Acipenseridae), no longer occurs in the River Tagus. In the Tagus basin there are countless sources of all types of industrial and urban pollution. Although most anadromous fish species used to live in the whole Tagus basin, reaching its Spanish portion, they are now limited to the lower 200 km of the main Tagus River. This limitation is due to two dams which are impassable barriers, either because the fishways, when they exist, are not suitable for these anadromous species or because they are currently not in use. The reservoir at Castelo de Bode contains a land-locked population of allis shad. This population, due to its lower condition, size and weight has a low commercial value. The impact caused by fishermen on the anadromous fish stocks is important at two levels, both leading to low recruitment.

25. Auer, N. A. (1994). Effects of change in operation of a small hydroelectric facility on spawning characteristics of lake sturgeon. Lake and Reservoir Management. **9**:52-53.

Migratory lake sturgeon, *Acipenser fulvescens*, which spawn below a small hydroelectric facility located on the Sturgeon River, Michigan have responded to a change in facility operation negotiated during recent relicensing. Spawning characteristics of this stock of fish have been monitored for 6 years. The facility operated as a peaking facility from 1987 through 1989, generating electricity from 0800 to 1700 hrs. Near run-of-the-river flows were provided in 1991 and 1992. The facility closely matched discharge from the plant to that received into the reservoir 24 hrs/day. The change in facility operation and therefore water discharge pattern, created changes in several characteristics of the spawning lake sturgeon population. There has been a reduction in time adult lake sturgeon are observed on site, an increase in total number and size of adults, an increase in spawning-ready fish, and a change in location of capture. Constant and non fluctuating water flows now produced by run-of-the-river operation appear to be triggers to reproductive readiness and allow more and larger fish to move onto spawning grounds. These changes in operation are beneficial to spawning lake sturgeon, a species threatened in the state of Michigan. These changes may be applied to other small hydropower facilities and fisheries to improve multiple use of water resources.

26. Auer, N. A. (1996). Importance of habitat and migration to sturgeons with emphasis on lake sturgeon. Canadian Journal of Fisheries and Aquatic Sciences. **53 (Suppl. 1)**:152-160.

Sturgeons utilize a variety of habitat types throughout their life: rivers for spawning; rivers, lakes, estuaries, or the sea for feeding and wintering adults; and estuarine areas for feeding young. Distances covered by some sturgeons during spawning migrations show a positive relationship to average adult size. The lake sturgeon,

Acipenser fulvescens, is the only sturgeon endemic to the Great Lakes basin. Most remaining populations in the basin are restricted in movement, yet in a few, free-ranging populations still remain. Study of these populations will more adequately define range and habitat preferences of the species. Some state and federal agencies are now creating management plans for lake sturgeon. Those plans need to be based on information gathered from free-ranging groups. A barrier-free 250-300 km combined river and lake range is suggested as a minimum distance to support self-sustaining populations and distances of 750-1000 km should not be considered unusual. Fishery managers should give barrier removal or fish passage greater consideration than habitat enhancement for populations currently isolated and restricted in range.

27. Auer, N. A. (1996). Response of spawning lake sturgeons to change in hydroelectric facility operation. Transactions of the American Fisheries Society. **125**:66-77.

Spawning of lake sturgeon *Acipenser fulvescens* was documented from 1987 to 1992 below the Prickett hydroelectric facility on the Sturgeon River, a tributary to Portage Lake, Michigan. Lake sturgeons were captured at the spawning site with dip nets during periods of reduced flow. A change in the spawning characteristics of the population was noted that corresponded to a change in the operation of the hydroelectric facility. In 1987 and 1988 the facility operated in a peaking mode, which resulted in large daily fluctuations in river flows. The years 1989 and 1990 were years of transition, and in 1991 and 1992 the facility released near run-of-the-river (ROR) flows. Under near-ROR flows, which were more natural, adult lake sturgeons spent 4-6 weeks less at the spawning sites, 74% more fish were observed, weights were greater due to a 68% increase in number of females, and fish had increased reproductive readiness. The change in flow regime was the result of a Federal Energy Regulatory Commission relicensing action. The positive response observed in lake sturgeon spawning activity that resulted from the change of facility operation to near-ROR flows should be beneficial to the survival and perpetuation of this population. Similar results may be experienced in other lake sturgeon waters affected by manipulated flow regimes.

28. Auer, N. A. (1999). Population characteristics and movements of lake sturgeon in the Sturgeon River and Lake Superior. Journal of Great Lakes Research. **25**:282-293.

A 2.6-km reach of the Sturgeon River, containing two sets of rapids, is an important spawning site to a native population of lake sturgeon, *Acipenser fulvescens*, which ranges widely into southern Lake Superior. Similar spawning areas in other Great Lake tributaries may also be important to the protection and rehabilitation of lake sturgeon throughout this region. Information on range and habitat needs of this species, which is considered "threatened" in the State of Michigan, was obtained from the Sturgeon River spawning population from 1987 to 1995. Radio-tracking was employed to determine movements and habitat use by post-spawning lake sturgeon. Telemetry data from 25 fish were supplemented with data obtained through identification tag returns. During the study 925 lake sturgeon were handled; 86 returned to spawn 1 time and 12 returned 2 times. Spawning intervals for male lake sturgeon were commonly 2, 3, or 4 years; yearly spawning by males was never observed. Females returned to spawn after 3 to 7 years. From 1991 to 1995 the male:female sex ratio at the spawning site was 1.25 to 2.7. In 1990 13 of 18 adults fitted with transmitters moved out of the river within 9 days. Upon reaching Portage Lake nine individuals spent time in shallow (maximum depth, 6 m) Pike Bay. After 3 to 53 days (mean, 22) tagged fish moved into the deeper water of Portage Lake (maximum depth, 17 m) and ranged more widely. Three fish were located

in Keweenaw Bay, Lake Superior by late August. Identification tag returns reveal that lake sturgeon traveled 70 to 280 km from the spawning site throughout southern Lake Superior.

29. Bain, M. B., J. T. Finn and H. E. Booke (1988). Streamflow regulation and fish community structure. Ecology. **69**:382-392.

Many regulated streams are characterized by highly variable and unpredictable flow regimes. Since changes in streamflow directly modify physical habitat, streams with such highly variable flows provide highly unstable aquatic habitats. The authors evaluated the effect of artificial streamflow fluctuation on stream fish communities by comparing fish densities, in species and habitat groups, between two rivers differing in daily flow regime: one with a natural flow, and one with highly regulated flows.

30. Bainbridge, R. (1958). The speed of swimming as related to size and to the frequency and amplitude of the tail beat. Journal of Experimental Biology. **35**:129-153.

The author describes an apparatus in which it is possible to study and record the continuous swimming of fish at speeds up to 20 m.p.h. Records made of the swimming at different speeds of dace, trout, and goldfish measuring up to 30 cm in length are reproduced. Speed at any particular frequency of tail beat is shown to be directly related to the length of the specimen. Above a frequency of 5 tail beats per second, speed is directly dependent upon frequency up to the maximum values recorded. The results for all sizes and species recorded may be adequately expressed by the formula $V=1/4\{L(3f-4)\}$, where V = the speed in cm/sec, f = the frequency in beats per second, and L is the body length in cm. The distance travelled per beat (and hence the speed) is directly dependent upon the amplitude of the tailbeat.

31. Baldwin, C. K. and U. Lall (1999). Seasonality of streamflow: The Upper Mississippi River. Water Resources Research. **35**:1143-1154.

The understanding of seasonal variations in streamflow is important for water resource management. The dynamics of streamflow are often dominated by annual and intra-annual variations, and the global warming debate has also generated an interest in potential changes in the seasonal cycle of hydroclimatic variables. Thus there are mechanistic as well as policy motivations for an empirical analysis of the historical seasonal variations in streamflow. The seasonality of the upper Mississippi River streamflow is investigated in this paper using a 123-year record of daily flow. This long streamflow series provides an interesting look at the high- and low-flow seasons within the year, their interannual variation, and within-season attributes. Evidence for changes in the timing and amplitude of these seasons and the annual flow extremes is presented. Connections to similar trends in regional climate variables are noted. The upper Mississippi River streamflow exhibits bimodal probability distributions for monthly averages and for specific seasons. Transitions across the high- and low-flow regimes corresponding to these modes exhibit memory across seasons and over years. Thus an empirical basis for seasonal or longer prediction is provided. Needs for developing a mechanistic explanation of the empirical observations offered are also indicated.

32. Balon, E. K. (1978). Kariba: The dubious benefits of large dams. Ambio. **7**:40-48.

The ecological consequences of dam building extend far beyond the common cost-benefit analysis. On the Zambezi River for example, a unique and stable ecological system, which took millenia to develop, was rapidly changed by dams into less productive lakes. The process was accompanied by widespread destruction and misery. The production of the electricity required for a more profitable export of mineral resources rendered the local inhabitants dependent on external sources of food, water, etc, where they had formerly been self-sufficient. The surface of the lake reflects more solar energy than the old terrestrial system. As a consequence, fish production is lower than the lost production of plants and game. Species diversity may be increased by natural invasion and artificial introduction, but the production limits of the system can not be changed.

33. Balon, E. K., S. S. Crawford and A. Lelek (1986). Fish communities of the upper Danube River (Germany, Austria) prior to the new Rhein-Main-Donau connection. Environmental Biology of Fishes. **15**:243-271.

A study of fish communities in the upper Danube was carried out at 19 localities in 1976 and 1984, yielding 24 samples with over 23,000 specimens. Forty-two species - 8 of them new for this part of the Danube - and 6 cyprinid hybrids were identified. Two distinct regions, above and below Ulm, were recognized for the upper Danube on the basis of both abiotic (distance from source, elevation, river gradient) and biotic (species richness, species distribution) characters of the localities. Nine species were distributed over most of the upper Danube, while 10 and 23 species were limited mostly to the upriver and downriver sections, respectively. A factor analysis of ecomorphological attributes for 28 dominant species revealed a generalist-specialist pattern among their swimming behavior and feeding modes.

34. Banarescu, P. M. (1998). On the relations between hydrography and the ranges of freshwater fish species and subspecies. Italian Journal of Zoology. **65**:87-93.

Ranges of freshwater fish species depend on river basins. However, most species are confined to a limited area of a basin. Some limited distributions are determined by the ecology of the species, most have historical grounds. Many species are endemic to a restricted area of a river basin (e.g., 7 in the River Danube; more than 80 in the Mississippi river basin). Most non-endemics confined to a sector of a river basin also live in one or more adjacent basins. Cases are known of conspecific subspecies inhabiting distinct areas within a river basin, some of them being also present in a neighbouring basin. Restricted distributions are determined by the fact that river captures usually involve tributaries, not the main rivers and the inhabitants of the upper and middle reaches of the river do not disperse through the lower reaches.

35. Banneheka, S. G., R. D. Routledge, I. C. Guthrie and J. C. Woodey (1995). Estimation of in-river fish passage using a combination of transect and stationary hydroacoustic sampling. Canadian Journal of Fisheries and Aquatic Sciences. **52**:335-343.

We describe a hydroacoustic technique that uses both transect and stationary sampling to estimate numbers of fish migrating in a river. The technique includes refinements and additions to one developed by the International Pacific Salmon Fisheries Commission to estimate sockeye *Oncorhynchus nerka* and pink salmon *Oncorhynchus*

gorbuscha migrations in the Fraser River. The estimator is independent of the actual shape of the effective acoustic beam and the distribution of target strengths when the same hydroacoustic equipment and settings are used for both types of soundings. Thus, the method shares with the duration-in-beam method the advantages that equipment calibration requirements are minimal and that estimates remain valid when fish sizes vary over a wide range. We also provide formulae for the variance of the abundance estimate and illustrate the methods with example calculations of daily fish passage in the Fraser River at Mission, British Columbia. A correction procedure is proposed to compensate for bias arising from violation of the assumption that fish speed is negligible relative to boat speed.

36. Baras, E., H. Lambert and J. C. Philippart (1994). A comprehensive assessment of the failure of *Barbus barbus* spawning migrations through a fish pass in the canalized River Meuse (Belgium). Aquatic Living Resources. **7**:181-189.

This paper presents a comprehensive study of the impact of damming on the spawning migrations of *Barbus barbus* in the canalized River Meuse (Belgium). A Denil fish pass on the Ampsin-Neuville dam was controlled 251 times in 1989-1993. The most striking feature is the almost complete absence of barbel. Most captures of barbel in the fish pass in 1989 were clumped and related with spawning migrations. The variables involved in the attractivity condition set refer indirectly to the influence of water catchment by a hydroelectric plant and to the relative importance of the flow in the pass. The study concludes that this additional condition set significantly interfere with the natural environmental stimuli triggering spawning migrations in barbel and questions the effectiveness of the thermally related reproductive strategy of the species.

37. Barekyan, A. S., B. S. Malevanchik and M. A. Skorobogatov (1988). Promising designs of fishways. Hydrotechnical Construction. **22**:384-388.

The designing of fishways is based on the location of the fishway in the system of hydrologic development and optimization of the hydraulic regimes in various zones: in the fishway, in the fish attraction zone in the lower pool of the hydrologic development, in the fish release zone in the upper pool, etc. The effectiveness of a fishway largely depends on its design and on the technological scheme of passage of the fish to spawning grounds. To eliminate negative aspects of the operation of existing fishways, research and development studies were carried out to develop new promising designs and technological schemes of attracting, holding, and conveying spawners from the lower to the upper pool of a hydrologic development. The realization of these designs will make it possible to increase the number of fishes being passed to spawning grounds, to reduce injury during their conveyance from the lower to the upper pool, and to reduce the number of downstream migrants that pass into the upper pool. The main group of developments is aimed at increasing the duration of active attraction of fishes, i.e., attraction at speeds close to the optimal, by changing the technology of releasing fish into the upper pool. One of the possible ways of increasing the productivity of a fishway is to continuously attract fish with a constant current speed at the exit of the fish-holding chute. Also effective is to replace the exiting stimulating devices with netting requiring a reduction of the current speed in the fish-holding chutes during its movement by devices using an electrical field for fish stimulation. Use of these fishway designs will make it possible to increase the passage of spawners to spawning grounds and thereby to increase the number of valuable commercial fish species in inland water bodies.

38. Barinaga, M. (1996). A recipe for river recovery? Science. **273**:1648-1650.

The author outlines contemporary approaches to river recovery that are more holistic in nature than previous management initiatives; namely the restoration of the physical processes that shape a river's habitats. This contemporary management approached is guided by major advances in river ecology and theoretical concepts. However, the author also highlights that political issues may limit its application. Political roadblocks to river restoration are especially acute in regions of the United States experiencing water shortages. Competing water demands among agriculture, industry, and municipalities create a charged political environment in which to attempt large-scale river restoration.

39. Barry, T. and B. Kynard (1986). Attraction of adult American shad to fish lifts at Holyoke Dam, Connecticut River. North American Journal of Fisheries Management. **6**:233-241.

The movements of 18 radio-tagged American shad (*Alosa sappidissima*) were studied in 1980 and 1981 as they attempted to locate the upstream fish collection facilities of two fish lifts at Holyoke Dam on the Connecticut River in Massachusetts. Nine fish (50%) were passed by the lifts during the 2 years and, in 1980, the efficiency of the tailrace lift was estimated at 42%. The mean delay time of the seven fish passed by the tailrace lift during the two years was 3.3 d (range 2-5 d); the delay of the two fish passed by the spillway lift in 1981 was 6 and 7 d. Fish were repelled by the turbulence caused by the turbine discharge into the head of the tailrace and only entered the vicinity of the tailrace lift during 55% of all upstream trips in 1980 and 67% of the trips in 1981. During high river flows, fish were attracted to the spillage over the dam, not the flow from the tailrace. The inefficiency of either lift to pass early migrating American shad and of the tailrace lift to pass fish efficiently at any time may limit upstream passage during some years. The situation at Holyoke Dam, together with similar problems at other upstream dams, prevents many fish from reaching the historical upstream limits of their range and creates a poor or, at best, and unpredictable sport fishery upstream.

40. Barthem, R. B., M. C. L. B Ribeiro and M. Petrere (1991). Life strategies of some long-distance migratory catfish in relation to hydroelectric dams in the Amazon Basin. Biological Conservation. **55**:339-345.

Results of sampling from 1982 to 1989 indicated that the long-distance migratory catfish *Brachyplatystoma filamentosum*, *B. flavicans*, *B. vaillantii*, *Goslinia platynema*, and *Lithodoras dorsalis* spawn in the headstreams of the Amazon River and its tributaries and that the estuary of the Amazon is the main nursery ground utilized by their alevins. Hydroelectric dams are a potential threat to these fish, interrupting the downstream movement of catfish eggs or young (provided they do spawn in the upper tributaries) or obstructing the upstream migrations that annually restore catfish stocks upriver. The synergistic effects of flood control over the entire basin may also harm the species, since their hydrological requirements are drastically modified. The only hope for preserving migratory catfish stocks above the dams will be for them to spawn upstream from the reservoirs if their pre-recruits manage to survive in floodplains outside the estuary. Otherwise, artificial measures such as fish ladders or side channels would have to be employed. Stocking could also be tried, producing the alevins in fish culture stations, or

by transporting mature individuals when they stop below the barrage during their upstream migrations.

41. Bates, K. (1991). Pool-and-chute fishways. Pages 268-277 *in* J. Colt and R. J. White, eds. Fisheries Bioengineering Symposium, Bethesda, Maryland (USA), American Fisheries Society Bioengineering Section.

The pool-and-chute fishway is an economical means of providing fish passage over constructed barriers. Pool-and-chute fishways resemble pool-and-weir fishways at low flows and become baffled chutes at moderate to high flows. The economy of the concept is achieved by exceeding the usual criteria of fishway pool volume based on energy dissipation in each pool. The size and complexity of the structure are thus reduced. Design guidelines covering appropriate application and geometry ensure hydraulic conditions that allow fish passage. Cost comparisons based on actual and estimated construction costs of pool-and-chute and other styles of fishways verify the economic benefit of the concept.

42. Baxter, R. M. (1977). Environmental effects of dams and impoundments. Annual Review of Ecology and Systematics. **8**:255-183.

The morphology and physical and chemical limnology of man-made lakes, the biology of reservoir ecosystems and the downstream and other effects of impoundments are discussed. Reservoirs are probably best regarded as a distinct type of freshwater ecosystem distinct from both streams and lakes. Because they are frequently built on streams carrying a heavy sediment load, the deposition and distribution of this material is often more important than in natural lakes. Therefore constraints on the nature of the developing biological community are imposed when a new reservoir is constructed. The environmental changes below a dam may be as dramatic as those above it. The effects of future tropical impoundments should be predictable on the basis of the first great African impoundments. The development of reservoirs in temperate regions occurred more gradually and due to this and the lower rate of biological processes, the effects were less dramatic than in the tropics. Large-scale surprises are not expected from future temperate region impoundment. However, much remains to be learned of the importance to man at a more detailed scale, such as the effects on the fur bearing animals in the area, or on resources such as salmon.

43. Bayley, P. B. (1995). Understanding large river-floodplain ecosystems. BioScience. **45**:152-158.

Significant economic advantages and increased biodiversity and stability would result from restoration of impaired systems. Funding for experimental restoration and evaluation should take priority over ecological research on severely impaired ecosystems.

44. Beach, M. H. (1984). Fish pass design - criteria for the design and approval of fish passes and other structures to facilitate the passage of migratory fish in rivers. Fisheries Research Technical Report. **46**:1-47.

This report explains in simple terms how the fish and water control requirements can be reconciled and proposes design criteria to enable fish to negotiate structures such

as sluice gates, weirs and fish passes. It also explains the Ministry's legal position with regard to obstructions in migratory fish rivers and gives examples of the procedures necessary to obtain approval for satisfactory structures. The information on fish swimming speeds and endurance and the relation of three parameters to water control structures and fish passes is essential to the effective management of migratory fish in our rivers.

45. Beamesderfer, R. C. P., T. A. Rien and A. A. Nigro (1995). Differences in the dynamics and potential production of impounded and unimpounded white sturgeon populations in the lower Columbia River. Transactions of the American Fisheries Society. **124**:857-872.

White sturgeons *Acipenser transmontanus* were sampled in three lower Columbia River reservoirs from 1987 to 1991 to describe population dynamics, the ability of these stocks to sustain harvest, and differences among reservoir and unimpounded populations. Significant differences were observed among reservoirs in white sturgeon abundance, biomass, size composition, sex ratio, size of females at maturity, growth rate, condition factor, and rate of exploitation. No differences among reservoirs were detected in fecundity, natural mortality rate, or longevity, in part because of sampling difficulties. Recruitment rates and densities in reservoirs were inversely correlated with growth rate, condition factor, and size of females at maturity. Differences in population dynamics resulted in substantial differences in sustainable yields. Maximum yields per recruit were predicted at annual exploitation rates between 5 and 15%. Most characteristics of reservoir populations were less than or equal to optima reported for the unimpounded lower river; as a result, yield per recruit, reproductive potential per recruit, and the number of recruits were less in reservoirs than in the unimpounded river. Comparisons with pristine standing stocks suggest that the unimpounded river may approximate preimpoundment conditions for white sturgeon. We conclude that potential yield from impounded populations has been reduced by dam construction, which restricts populations to river segments that may not include conditions optimal for all life stages. Alternatives for enhancement of reservoir populations might include improved passage at dams, increased spring flow to improve spawning success, transplants from productive populations, hatchery supplementation, and more intensive harvest management.

46. Beamish, F. W. H. (1978). Swimming capacity. Pages 101-187 *in* W. S. Hoar and D. J. Randall, eds. Fish physiology, Academic Press, New York, New York (USA).

This book chapter presents a physiological account of swimming capacity in fishes. As such, it describes both field and laboratory methods for determining swimming capacity, paying particular attention to biological and environmental constraints on physiological processes responsible for defining species-specific swimming capacities. In addition, an account is provided the energetics of swimming in fishes. Numerous tables, containing species-specific swimming performance information, are presented along with citations to the original research conducted to determine swimming preformance. Finally, a discussion of the application of swimming performance data to management practices concludes the chapter.

47. Becker, G. C. (1983). Fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin (USA).

This book is a classical text on the fishes endemic to Wisconsin waters. In it, Becker discusses the biogeologic history of Wisconsin waters as well as stresses on Wisconsin freshwater systems at the time of publishing. Background on the management of Wisconsin fisheries is provided, including discussion on limnological studies, fish culture and stocking, fish rescue and transfer, fishkills, demands on the fishery resources, trends in management, nongame fishes, exotic introductions, and endangered or extirpated species. Additional information includes a key to Wisconsin fishes, a brief account of fish parasites in Wisconsin waters, and detailed species accounts that include among many things distributional maps.

48. Behlke, C. E. (1987). Hydraulic relationships between swimming fish and water flowing in culverts. Pages 112-132 *in* D. W. Smith and T. Tilsworth, eds. Proceedings of the Cold Regions Environmental Engineering Conference, Edmonton, Alberta (Canada), University of Alberta, Department of Civil Engineering.

Proper passage of fish through culverts is an important element of design of highways, railroads and pipelines for the North. Though several investigators have attempted to define swimming capabilites of fish, it does not appear that the swimming requirements for fish to pass through culverts and other fish passage structures have been properly analyzed and defined. This paper defines and analyzes the forces which fish are confronted with in entering and passing through barrels of sloping culverts flowing full and as open channels.

49. Behlke, C. E. (1991). Power and energy implications of passage structures for fish. Pages 289-298 *in* J. Colt and R. J. White, eds. Fisheries Bioengineering Symposium, Bethesda, Maryland (USA), American Fisheries Society.

Fluid mechanic equations are used to show effects of virtual mass force, non-Archimedean buoyant force, and profile drag force on fish in several fish passage structures. Example problems are worked to show computational procedures for calculating net propulsive force, net power, and net energy necessary for fish to swim in a lake, up a steep chute, and through the outlet, barrel, and inlet of a culvert.

50. Behlke, C. E., D. L. Kane, R. F. McLean and M. D. Travis (1993). Fundamentals of culvert design for passage of weak-swimming fish. Alaska Department of Transportation and Public Facilities, Report FH WA-AK-RD-90-10.

This manual presents design procedures to pass upstream-migrating, weak-swimming fish. The manual also displays criteria for retrofitting existing culverts.

51. Belaud, A., R. Labat, D. Trivellato and G. Tison (1987). [Hydraulic and ichthyological experiments with an automatic trapping system for migrating fish at Golfech]. Pages 73-80 *in* Definition and Efficiency Control of Fishways, Paris (France), de la Societe Hydrotechnique de France et l'Agence de Bassin Loire-Bretagne.

Previous studies relating to the frequent visits of migrating fish in the outlet of the Golfech complex have illustrated the need to build an automatic crossing device. To produce a current which would attract fish, experiments on a reduced model have been firstly carried out and are intended to define (installation, flowrate, speed and swell)

characteristics of the improvements required. After the partial completion of the automatic trap, the 1985 migration season has proved how efficient the system is for Salmonoidea and for Alosa during the peak migration period. As regards smaller affluxes, the jet remains attractive but the speed needs to be increased inside the passage of storage tanks in order to drive the alosa into the trap.

52. Bell, M. C. (1973). Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon (USA).

This report covers all aspects of fish behavior and passage through and around obsructions encountered during movements and migrations, man-made or natural. This report is widely considered the first full and detailed account of fish passage issues, fish behavior at obstructions, and engineering and mitigating measures.

53. Bell, M. C. (1986). Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, North Pacific Division, Fish Passage Development and Evaluation Program Report .

This report covers both fish facility design problems and the operation of fish facilities. Chapters on swimming speeds, spawning criteria, and food and oxygen requirement for several species of fish are included. The effects of temperature, water quality, silt and turbidity on fish are discussed. The toxicity on fish of elements and compounds, including metals, plastics, pesticides, and herbicides are reviewed. Hatcheries, rearing ponds and fish pumps are described. The subjects of fish behavior and diseases are addressed. Fishway structures at natural obstructions and dams are examined, as is the related subject of artificial guidance of fish.

54. Bellariva, J. L. and A. Belaud (1998). Environmental factors influencing the passage of Allice shad *Alosa alosa* at the Golfech Fish Lift on the Garonne River, France. Pages 171-179 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Since 1973, the operation of the hydropower facility Malause-Golfech on the Garonne River (south-west France) has prevented allice shad *Alosa alosa* from accessing upstream spawning grounds, thus endangering the population (Cassou-Leins & Cassou-Leins, 1981). From 1981 to 1986, allice shad were captured just downstream of the power plant during their spawning migration and manually carried and released above the weir. These measures resulted in significant population increases and led to the design and installation of a fish lift near the power plant, which began operating in 1987. Since 1981, data on both environmental factors and fish passage have been recorded daily. From 1987 to 1991 and in 1993, peak migration occurred in June. In 1992, 1994 and 1995 peak migration occurred in May. In 1994 and 1995 the earlier appearance of allice shad at the Golfech passage facility was due to the disappearance of an old dam which was a brake for the migration. There was a significant correlation between daily shad passage and water temperature. The Golfech fish lift provides the means to quantitatively control the allice shad migration.

55. Bemis, W. E., V. J. Birstein and J. R. Waldman (1997). Sturgeon biodiversity and conservation: An introduction. Environmental Biology of Fishes. **48**:13-14.

This volume includes many of the papers presented at the international Conference on Sturgeon Biodiversity and Conservation which took place at The American Museum of Natural History (AMNH), New York, on 28-30 July 1994. The main goal of the conference was to attract attention to sturgeons and paddlefishes, still the most speciose group of 'living fossil' fishes, but now fast disappearing from our planet (Birstein 1993, Bemis and Findeis 1994, Waldman 1995). Some presentations at the conference described basic aspects of acipenseriform biology, including evolution, genetics, and life cycles. Others focused on the contemporary status of a particular species or a few species inhabiting the same basin or region; most of these contributions also addressed ongoing conservation efforts. Still other speakers examined current controversies at the interface between science and society, bringing information from a variety of sources to enrich our meeting. These three approaches are reflected by the three part organization of this volume: part 1, Diversity and evolution; Part 2, Biology and status reports; and Part 3, Controversies, conservation and summary. We hope that the included papers offer a broad perspective about contemporary work on the phylogeny of Acipenseriformes, as well as a review of the worldwide status of almost all of the species constituting this order.

56. Bemis, W. E. and B. Kynard (1997). Sturgeon rivers: An introduction to acipenseriform biogeography and life history. Environmental Biology of Fishes. **48**:167-183.

We present an overview of the global distribution of all 27 living species of Acipenseriformes in an attempt to understand their biogeographic history and the range of life history patterns displayed by different species. Our biogeographic analysis (based on the most recent phylogenetic analysis including fossil Acipenseriformes) suggests that Acipenseriformes originated in Europe, and that early diversification took place in Asia. Acipenseriformes do not have a common life history; variation within and between species is the rule rather than the exception. The few relatively well-known case studies (e.g. Caspian Sea sturgeons, European Atlantic sturgeons in the Gironde system, and shortnose and North American Atlantic sturgeons in rivers of the east coast of America) greatly influence what we think we know about sturgeon biology. Our present level of phylogenetic understanding does not allow us to determine whether anadromy or potamodromy is the plesiomorphic life history pattern for Acipenseriformes. We propose that rivers in which spawning occurs must be the central unit for biogeographic analysis of living Acipenseriformes. After mapping these rivers, we recognized nine biogeographic provinces for acipenseriforms. Some repeated historical patterns emerge from this analysis, but, again, we are limited by our current understanding of phylogenetic relationships within the genus Acipenser in particular. Distribution and biogeographic data are central to deciding where to make new efforts to update existing status information for acipenseriform species. We single out a widely ranging and highly variable species, Acipenserruthenus, as particularly intriguing, for it spans three of our nine biogeographic provinces, and apparently has different life history patterns in different river systems. Finally, we note new areas in need of basic research, particularly the need for more detailed descriptions and analyses of life histories of different populations of sturgeons.

57. Bender, M. J., C. Katopodis and S. P. Simonovic (1992). A prototype expert system for fishway design. Pages 115-127 *in* A. H. El-Shaarawi and D. C. L. Lam, eds. Expert systems and statistical methods in water resources, Burlington, Ontario (Canada), Environmental Monitoring and Assessment.

The design of structures for fish passage in rivers and streams provides an opportunity to apply expert system concepts to a design problem. Fishways contribute to the sustainable development of water resources projects by providing a path that allows fish migrations to be maintained. A prototype expert system (FDES) has been developed to recommend the most suitable fishway type for given design conditions. A recommendation is provided on the basis of fishway hydraulics, fish passage performance, and cost requirements. Fishway design demands expertise in various scientific disciplines such as hydrology, hydraulics, and fish biology. Expert system technology may be used to reduce design time requirements and to serve as a teaching aid to inexperienced engineers by organizing and accessing the cumulative knowledge of the most experienced designers. The rule-based expert system development tool, VP-Expert, supplies the backward chaining control structure for accessing the knowledge within the prototype.

58. Benke, A. C., C. A. S. Hall, C. P. Hawkins, R. H. Lowe-McConnell, J. A. Standford, K. Suberkropp and J. V. Ward (1988). Bioenergetic considerations in the analysis of stream ecosystems. Journal of the North American Benthological Society. **7**:480-502.

Most bioenergetics studies to date have been descriptive, and there is a major need to study those abiotic and biotic factors which control bioenergetics in streams across biomes and latitudes. The importance of floodplains and the role of dissolved organic matter have not been adequately incorporated into our understanding of stream bioenergetics. We need to determine if some generally applicable organismal-environmental relationships can be used to predict energetic characteristics across streams. Major new initiatives are required to answer some of the larger scale questions. Several approaches are possible: (1) synoptic analysis of multiple streams to compare within-region variance with between-region variance, (2) experimental manipulation of entire streams or their catchments to test factors that control bioenergetics, (3) the use of batteries of experimental streams to help isolate cause-effect relationships, and (4) the further development of computer models that incorporate abiotic forcings and bioenergetics. (DBO)

59. Benstead, J. P., J. G. March, C. M. Pringle and F. N. Scatena (1999). Effects of a low-head dam and water abstraction on migratory tropical stream biota. Ecological Applications. **9**:656-668.

Migration of large-bodied "macroconsumers" (e.g., fishes, shrimps, and snails) is an important functional linkage between many tropical rivers and their estuaries. Increasingly, this linkage is being severed by dams and water abstraction. The ecological impacts of these activities are poorly understood and are largely being ignored by dam operators. We investigated the direct effects of a water intake and low-head dam on the migration of amphidromous freshwater shrimps between the headwater streams and estuary of the Rio Espiritu Santo, Puerto Rico, USA. Both downstream migratory drift of larvae and upstream migration of postlarvae had strong diel patterns, with most activity occurring at night. Unlike large dams on the island, this low-head dam did not act as a complete barrier to the upstream migration of metamorphosed postlarvae. However, the dam did cause large numbers of postlarval shrimps to accumulate directly downstream of the structure. Mortality of drifting first-stage larvae by entrainment into the water intake during downstream migration averaged 42% during the 69-d study period. During low discharges, 100% of the drifting larvae were entrained by the intake. The rate of

nocturnal entrainmentinduced mortality averaged 233 larvae/s and peaked at 1167 larvae/s. We used our field data and a 30-yr discharge record to model the long-term impacts of different intake management strategies on the entrainment mortality at this dam. The simulation model estimated long-term mean daily entrainment mortality at 34-62%, depending on the amount of water extracted from the river. Monthly differences in mean daily entrainment mortality (27-76% depending on estimates of abstraction) were caused by seasonal variation in discharge. Modeling of mitigation options suggested that daily entrainment mortality of larvae could be reduced to 11-20% if water abstraction was halted for 5 h during evening periods of peak drift. Impacts of the dam and operations can be significantly ameliorated by 3-5 h stoppages in water abstraction during peak nocturnal larval drift, upkeep of a functional fish ladder, and maintenance of minimum flow over the dam. Since the impacts of dams depend on the hydrology and design of specific water intake systems, mitigation strategies must be tailored to individual dams and intakes. However, our approach and results are likely to apply to low-head dams throughout the range of amphidromous species.

60. Berg, D. J., E. G. Cantonwine, W. R. Hoeh and S. I. Guttman (1998). Genetic structure of *Quadrula quadrula* (Bivalvia: Unionidae): Little variation across large distances. Journal of Shellfish Research. **17**:1365-1373.

North American freshwater bivalves of the families Unionidae and Margaritiferidae represent one of the endangered faunas of the world. Effective management of threatened and endangered species requires knowledge not only of abundances of these species but also the degree of variation within species and the geographic distribution of this intraspecific variation. We used allozyme electrophoresis to examine the genetic structure of seven *Quadrula quadrula* populations from the Ohio, Tennessee, and Tensas Rivers. We then considered the implications of our results for the development of effective bivalve conservation strategies. Descriptive measures of genetic variation within populations are quite high (2.1 plus or minus 0.1(se) alleles per locus; 61.4 plus or minus 2.6% polymorphic loci; 0.24 plus or minus 0.01 heterozygosity) relative to other unionids. Genotype frequencies met Hardy-Weinberg expectations at all polymorphic loci. Among-population variation was low and mostly confined to differences between the Tensas River population (lower Mississippi River basin) and the Ohio River basin populations. Significant differences in allele frequencies among populations were only detected at 3 of 10 loci; no differences in allele frequencies were found among Ohio River basin populations. Genetic distances, though all small, were significantly correlated with geographic distance. Estimated gene flow was high among populations, but variation among populations did tend to follow the predictions of an isolation-by-distance model of dispersal. The low levels of among-population genetic variation are remarkable given that these populations are separated by distances as great as 2,500+ river kilometers. High levels of gene flow may ensure that within-population variation remains high and that populations do not become differentiated due to genetic drift. An optimum conservation strategy for this species in the mainstem of the Ohio River would center on the protection of a number of large populations and maintenance of corridors for dispersal of host fishes. Successful protection of threatened and endangered species requires conservation of both abundance and genetic diversity of unionids. Further work is needed to characterize general patterns of genetic structure within freshwater bivalve species.

61. Berg, D. J., W. R. Hoeh and S. I. Guttman (1997). Alternate models of genetic structure in unionid populations: Conservation and management implications. Journal of Shellfish Research. **16**:322-323.

North America is a region of immense freshwater mussel diversity. However, many of the endemic taxa are threatened with extirpation. To successfully conserve variation within taxa, management agencies must understand the genetic structure of populations. We used allozyme electrophoresis to characterize partitioning of genetic variation within-populations (w-p) and among populations (a-p) of unionids in the Ohio River system and within the Big Darby Creek system of central Ohio. *Quadrula quadrula* typically occupies large rivers, while *Elliptio dilatata* is a common resident of small streams such as Big Darby Creek. On average, populations of *Q. quadrula* contained greater w-p variation (2.1 alleles/locus, 61% polymorphic loci, 24% heterozygosity) than populations of *E. dilatata* (1.6, 32%, 10%, respectively). Patterns of a-p variation differed between species. Allele frequencies of *Q. quadrula* were not different among populations >1000 km apart. Populations of *E. dilatata* showed differences in allele frequencies between populations <100 km apart. Unionid species illustrate at least 2 models of the partitioning of genetic variation. Model I species such as *Q. quadrula* have a high gene flow among populations; each population contains much of the total variation present within a large geographic region. Model II species such as *E. dilatata* have restricted gene flow and large amounts of a-p variation; individual populations exhibit unique arrays of alleles. Large river habitats are more stable, capable of supporting larger populations of mussels, and may contain fishes with greater dispersal capability than small streams. The result of this combination is a single large metapopulation in big rivers. Preservation of several populations in big rivers will conserve most of a taxon's genetic diversity. Conservation of similar amounts of genetic diversity in small streams will require protection of a large number of populations within any geographic region. Such differences require that management agencies consider the genetic structure of mussel taxa when developing conservation plans.

62. Bertrand, B. A. (1997). Changes in the Mississippi River fishery along Illinois, 1976-1996. Journal of Freshwater Ecology. **12**:585-597.

In the 1970s the Great River Environmental Action Team (GREAT) proposed a long-range management strategy for the Mississippi River. GREAT predicted that backwater habitat would be lost and the fishery would decline riverwide over a 50-year period unless management changed. Twenty years into that 50-year period, long term data from fisheries monitoring along 581 miles of the river bordering Illinois has been gathered. From 1976-95, 483 electrofishing collections totaling 125,503 fish of 98 species were made at 33 locations. Species richness and catch per unit of effort analyses indicate that certain backwater fish species have declined, while river channel species have increased in number and frequency of occurrence.

63. Beumer, J. P. (1984). Lerderderg River fish-ladder. Aqua. **23**:16-17.

A study was undertaken to examine the movement of fish through a fish ladder installed in a diversion weir on the Lerderderg River. The River is a 60 km long tributary forming part of the Werribee River coastal drainage. The Merrimu Reservoir Project providing a domestic water supply for Melton and Bacchus Marsh involved construction of diversion weirs on Goodman Creek and the Lerderderg River. The ladder incorporates 42 steps with a trap bay at step 36. It has a slope of 1:10. A Nylex plastic screen covering

the ladder prevents fish escaping and reduces the amount of leaf-litter and other debris falling into the ladder. A two way trap covered by a fine mesh was installed in the trap bay to monitor fish usage of the ladder. Monitoring of the trap and electrofishing were carried out on a weekly basis for 21 weeks. A total of 69 specimens were taken in the trap during the monitoring period, about half in each trap section. While the fish ladder design was suitable for the larger river blackfish and larger brown trout, few smaller specimens of these two species were caught in the trap. The other three species, short-finned eel, roach and Australian smelt, were poorly represented in trap catches suggesting that they could not cope with the fish-ladder in its then existing design. A number of design modifications to the ladder and alterations to the flow pattern downstream of the spillway should improve the efficiency of the ladder.

64. Bhowmik, N. G. (1993). Commercial navigation in large rivers and the development of appropriate management alternatives. USGS Environmental Management Technical Center, Report EMTC93R017.

Large rivers of the United States of America such as the Mississippi River are used for the transport of goods and commodities as well as for recreational activities. The Upper Mississippi River System (UMRS) is used extensively by commercial barge traffic. The research involves collecting a comprehensive set of data and analyzing these data for the development of various functional relationships. These relationships will form the starting point for the determination of biological changes that may be associated with the frequent movement of commercial traffic within large river systems. Ultimately all the functional relationships will be used to formulate and develop comprehensive management alternatives for the UMRS.

65. Bhowmik, N. G. (1993). Physical changes due to navigation in the Upper Mississippi River system. Long term resource monitoring program. USGS Environmental Management Technical Center, Report EMTC93R019.

The Mississippi, Illinois, Ohio, and Missouri Rivers are used extensively for the transport of goods and commodities, as well as for recreational activities. The changes in the river environment resulting from the movement of such traffic may include creation of waves and drawdown, altered velocity and pressure regimes, resuspension and lateral movement of sediment, and temporary changes in flow direction due to the return flow. Research has been initiated to determine the physical changes associated with navigation within the Illinois and Mississippi Rivers. Field data on various hydraulic and sediment resuspension characteristics have been collected and analyzed to determine functional relationships. These physical relationships will be used in the biological models to identify and determine changes in the aquatic environment due to navigation traffic. The paper discusses some of the physical changes in a large river environment due to navigation traffic. Biological effects of navigation are given in a companion paper that follows this article.

66. Bhowmik, N. G. and J. R. Adams (1989). Successional changes in habitat caused by sedimentation in navigation pools. Pages 17-27 *in* P. G. Sly and B. T. Hart, eds. Sediment/Water Interactions, Melbourne (Australia), Hydrobiologia.

Upstream of St. Louis, Missouri, navigation on the Upper Mississippi River is made possible by a series of lock and dam structures. Many of the pools formed by these

navigation dams have nearly reached a new equilibrium condition for scour and deposition of sediment. Several pools with extensive backwater or channel border areas are still accumulating sediment at rates similar to those for man-made lakes. The original open-water habitats in these pools are changing to aquatic macrophyte beds and then to marsh or terrestrial floodplain conditions because of sediment deposition. Two pools are used as examples of this phenomenon. 1) Pool 19 on the Mississippi River was formed when the lock, dam, and power house at Keokuk, Iowa were completed in 1913; and 2) Peoria Lake which has been affected by the diversion of Lake Michigan water into the Illinois River in 1900 and the construction of a lock and dam in 1939. Both pools have had well over 50 percent of their original volume filled with sediment. Three areas in Pool 19 illustrate the successional changes that occur as sedimentation raises the river bottom into the photic zone. Sedimentation has made boating impossible on large areas of both pools. The continuing process is likely to change open waters to floodplains. Peoria Lake lacks aquatic plant beds because of excessive turbidity and frequent resuspension of bed material by wind- or boat-generated waves. It seems likely that these river reaches will become a narrow channel without any broad and highly productive channel borders.

67. Blaxter, J. H. S. and W. Dickson (1959). Observations on the swimming speeds of fish. Journal Du Conseil International pour l'Exploration de la Mer. **24**:472-479.

Swimming speeds have been measured in a number of ways: 1) Timing the movements of fish in tanks, culverts, fish passes, or from ships at sea, 2) Measuring the speed of lines running out after hooking fish, 3) Cine-photography of fish in aquaria, and 4) Measuring the speed of rotation of annular-shaped tanks in which fish are kept stationary relative to the ground.

68. Bogan, A. E. (1993). Freshwater bivalve extinctions (Mollusca: Unionoida): A search for causes. American Zoologist. **33**:599-609.

The freshwater bivalves (Mollusca: Order Unionoida) are classified in six families and about 165 genera worldwide. Worldwide rate of extinction of freshwater bivalves is poorly understood at this time. The North American freshwater fauna north of Mexico is represented by 297 taxa in two families. There are 19 taxa presumed extinct, 44 species listed or proposed as federally endangered, and there are another 69 species that may be endangered. A number of these endangered species are functionally extinct (individuals of a species surviving but not reproducing). Extinction of North American unionoid bivalves can be traced to impoundment and inundation of riffle habitat in major rivers such as the Ohio, Tennessee and Cumberland and Mobile Bay Basin. Damming resulted in the local loss of the bivalves' host fish. This loss of the obligate host fish, coupled with increased siltation, and various types of industrial and domestic pollution have resulted in the rapid decline in the unionoid bivalve fauna in North America. Freshwater communities in Europe have experienced numerous problems, some local unionoid populations have been extirpated, but no unionoid species are extinct. Three taxa from Israel are now reported as extinct. Other nations such as China that have problems with soil erosion and industrial pollution or have numerous dams on some of the rivers (e.g., South America: Rio Parana) are probably experiencing problems of local extirpation if not the extinction of their endemic freshwater bivalve fauna.

69. Borges Barthem, R., M. Brito Ribeiro and M. Petrere, Jr. (1991). Life strategies of some long-distance migratory catfish in relation to hydroelectric dams in the Amazon Basin. Biological Conservation. **55**:339-345.

In this paper, we present evidence that the long-distance migratory catfish *Brachyplatystoma filamentosum, B. flavicans, B. vaillantii, Goslinia platynema* and *Lithodoras dorsalis* spawn in the headstreams of the Amazon River and its tributaries and that the estuary of the Amazon is the main nursery ground utilized by their alevins. The impact of hydroelectric dams on their populations are discussed in terms of interruption to fish migration routes up river and to larvae moving down river, provided that the hypothesis above holds. Ways of mitigating the impact are also considered.

70. Borghetti, J. R., D. P. Chena and S. V. G. Nogueira (1993). Installation of a fish migration channel for spawning at Itaipu. International Water Power and Dam Construction. **45**:24-25.

A fish migration channel for spawning at the Itaipu (Brazil and Paraguay) hydroelectric station was installed to improve fish recovery downstream from the dam. The complex had caused a significant reduction in the spawning area, with a deleterious effect on the reproductive cycle of the native species. An experimental model of a fish migration channel was installed, having a system of 'tank steps' at the foot of the dam, a sheet-metal ladder, a serpentine-style channel for the spawning of the fish, and two marginal lagoons for incubation of the eggs and growth of the larvae. The return migration of the hatchlings will be made through a trough linking the marginal lagoons directly to the Parana River. The first phase of the project is formed by a 56-m-long ladder. Preliminary data from the first phase has proved that fish (3000/day) of tropical climates can ascend ladders exceeding 8 m. The results of the first phase indicate the efficiency of the experimental project, with the entry and ascendancy of fish in a migration channel ladder. These data now provide the technical basis for implementation of the complementary spawning channel stage.

71. Borghetti, J. R., V. S. G. Nogueira, N. R. B. Borghetti and C. Canzi (1994). The fish ladder at the Itaipu binational hydroelectric complex on the Parana River, Brazil. Regulated Rivers: Research & Management. **9**:127-130.

A study was carried out from 23 October to 19 November 1992 to determine the ability of fish to ascend the fish ladder at the ITAIPU dam, to identify the species attracted and to evaluate possible fish selection. The results show that some species of fish can ascend the latter during the migratory period; the dam is non-selective with respect to species, but selective with respect to fish size as a result of the presence of reduced openings. The ladder was ascended by both scaly species from surface waters (agile movers) and by deep water species which were characterized by slow movements. An average of 2892 fish ascended the ladder each day. The weight and length of fish recorded ranged from 336.0 to 3676.0 g and from 30.2 to 71.3 cm, respectively. The largest group of migrating fish was the curimba *Prochilodus scrofa*. The high ratio of 72% of fish in the gonadal development stage, classified as "maturing", indicates that the species caught in the ladder were migrating for reproduction purposes.

72. Brett, J. R. (1965). The relation of size to rate of oxygen consumption and sustained swimming speed of sockeye salmon *Onchorynchus nerka*. Journal of the Fisheries Research Board of Canada. **22**:1491-1501.

The relation of size (log weight, g) to metabolic rate (log O^2-uptake, mg O^2/hr) of sockeye salmon was found to have a continuous change in slope (0.78-0.97) with increasing activity at 15 ^oC. The slope of the equation relating the 60-min sustained swimming speed (log speed, cm/sec) to length (cm) had a value of 0.50, demonstrating a rapid decrease in relative performance with increasing size.

73. Brett, J. R. (1967). Swimming performance of sockeye salmon *Onchorynchus nerka* in relation to fatigue time and temperature. Journal of the Fisheries Research Board of Canada. **24**:1731-1741.

Further studies on the swimming performance of fingerling sockeye salmon at fixed velocities have been conducted in relation to fatigue time. The method of probit analysis, commonly used in dealing with bioassay data, was found to be suitable for determining times to 50% fatigue and in providing a measure of variance despite the presence of some erratic behaviour. For sockeye acclimated to 15 ^oC (mean length = 13.6 cm) the velocity at which 50% fatigued was 54.4 cm/sec of 4.0 lengths/sec (L/sec). The 5% and 95% fatigue velocities were 3.1 and 4.8 L/sec, respectively. Larger fish required longer exposure times for determining maximum sustained speeds, extending from approximately 120 min for fingerlings to 500 min for adults. Using the method of increasing velocity steps the effect of temperatures from 5 to 27.5 ^oC was examined. When acclimated to 15 ^oC fingerling sockeye exhibited only a 4% reduction in swimming speed at 10 and 20 ^oC. Temperatures above the lethal level caused a rapid decline in swimming ability approaching the extinction point at 27.5 ^oC. Recommendations for standard procedures in the study of swimming speeds are made.

74. Buckley, J. and B. Kynard (1985). Habitat use and behavior of pre-spawning and spawning shortnose sturgeon, *Acipenser brevirostrum*, in the Connecticut River. Pages 111-117 *in* F. P. Binkowski and S. I. Doroshov, eds. North American Sturgeons, W. Junk Publishers, Dordrecht, Netherlands.

Movements and ecology of pre-spawning and spawning shortnose sturgeon, *Acipenser brevirostrum* , were studied through 1979-1982 in a 2 km reach of the Connecticut River. Radio telemetry was used to monitor the movements of 18 sturgeon. An additional 165 sturgeon, captured by gillnets, provided information on spawning site selection, sex ratio, and reproductive condition. For 3 years the mean water velocities during the spawning period ranged from 0.36 to 1.2 m sec^{-1} in the spawning area. Substrate was cobble and rubble. Sturgeon spawned over a short time period (3-5 days), during decreasing river discharge of 679 to 301 m^3 sec^{-1} and rising water temperature between 11.5 to 14.0 ^oC. High river discharge over a prolonged period during the normal spawning season may preclude reproduction.

75. Buckley, J. and B. Kynard (1985). Yearly movements of shortnose sturgeons in the Connecticut River. Transactions of the American Fisheries Society. **114**:813-820.

Movements of shortnose sturgeon *Acipenser brevirostrum*, an endangered species, were studied for 5 years by radio telemetry and mark-recapture in the lower 140

km of the Connecticut River to Long Island Sound, Ninety fish (range, 54-97 cm fork length; 1.2-9.2 kg weight) were equipped with radio transmitters. The cycle of annual movement consisted of several up- and downriver migrations between four discrete areas that were used for summer feeding, spawning, and overwintering.

76. Budweg, F. M. G. (1980). Environmental engineering for dams and reservoirs in Brazil. Water Power Dam Construction. **32**:19-23.

The social and ecological impact of large dams in Brazil cannot easily be mitigated by procedures developed in other countries. Fish ladders for instance are very often inappropriate for the indigenous fish and other solutions have been adapted which have maintained or even enhanced the fishstocks. Major afforestation schemes are also needed for most projects, and a change in farming techniques is strongly recommended to keep reservoirs free from pollution and silt.

77. Bunt, C. M., C. Katopodis and R. S. McKinley (1999). Attraction and passage efficiency of white suckers and smallmouth bass by two Denil fishways. North American Journal of Fisheries Management. **19**:793-803.

We compared two Denil fishways, located on the west (low velocity, 10% slope) and east (high velocity, 20% slope) sides of the Mannheim weir, Grand River, Ontario, for use by upstream-migrating white suckers *Catostomus commersoni* and smallmouth bass *Micropterus dolomieu*. Mark-recapture and radiotelemetry were used to assess attraction and fish passage. Movement of 85 radio-tagged fish was monitored continuously during spring and early summer of 1995 and 1996. Attraction and passage efficiencies of white suckers at the west fishway were approximately 50%, and 55%, respectively. Attraction efficiency of white suckers at the east fishway was approximately 59%, and passage efficiency was 38%. The attraction and passage efficiencies of smallmouth bass at the west fishway were approximately 82% and 36%, respectively. At the east fishway, attraction efficiency of smallmouth bass was approximately 55%, and passage efficiency was 33%. There was an exponential decline in the numbers of both species that used each fishway relative to water velocity. The maximum water velocity used by white suckers was 0.96 m/s and that used by smallmouth bass was 0.99 m/s. Distracting flows near the west fishway appeared to affect attraction. Both fishways passed equal numbers of smallmouth bass per year, and smallmouth bass that used the east fishway were significantly larger than individuals that used the west fishway. In contrast, more than twice as many white suckers used the west fishway, and these fish were significantly larger than those that used the east fishway. Differences in passage were related to burst and critical swimming speeds and the use of velocity refugia within the fishways.

78. Burkhardt, R. W., M. Stopyro, E. Kramer, A. Bartels and M. C. Bowler (1998). Annual Status Report, 1997: A Summary of fish data in six reaches of the Upper Mississippi River System. USGS Long Term Resource Monitoring Program, Report LTRMP-98-P008.

The Long Term Resource Monitoring Program (LTRMP) completed 2,797 collections of fishes from stratified random and permanently fixed sampling locations in six study reaches of the Upper Mississippi River System during 1997. The six LTRMP study reaches are Pools 4 (excluding Lake Pepin), 8, 13, and 26 of the Upper Mississippi

River, an unimpounded reach of the Mississippi River near Cape Girardeau, Missouri, and the La Grange Pool of the Illinois River. A total of 66- 76 fish species were detected in each study reach. For each of the six LTRMP study reaches, this report contains summaries of: (1) sampling efforts for each combination of gear type and aquatic area class; (2) total catches of each species from each gear type; (3) mean catch-per-unit of effort statistics and standard errors for common species from each combination of aquatic area class and selected gear type; and (4) length distributions of common species from selected gear types.

79. Cada, G. F. (1998). Fish Passage Mitigation at Hydroelectric Power Projects in the United States. Pages 208-219 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Recent efforts of the US Department of Energy's (DOE) Hydropower Program have focused on the mitigation of adverse effects of dams on upstream and downstream fish passage. An initial study of 707 recently licensed hydropower projects in the United States indicated that approximately 11% were required to provide upstream fish passage and 28% were required to provide downstream fish passage. Despite considerable effort to design and install fish passage devices, many projects had no detailed performance criteria and no performance monitoring requirements. A follow-up study examined the effectiveness of fish passage mitigative measures at 16 hydropower projects that had conducted performance monitoring. Fish ladders and lifts can be very effective in moving fish upstream past a dam; some of the case study projects were nearly 100% effective. Three of the 12 case studies with downstream passage measures have successfully increased the survival of downstream-migrating fish. However, in other instances the devices have failed or, more commonly, operational monitoring has not been adequate to make a judgement about their effectiveness. As an alternative to downstream fish passage screening, the DOE Advanced Hydropower Turbine Systems Program has begun a phased effort to design, build and test fishfriendly turbines, i.e. turbine systems in which environmental attributes such as entrainment survival, instream flow needs, and/or water quality enhancement are emphasised. Such turbine systems could allow the efficient generation of electricity while miniraising the damage to fish and their habitats.

80. Cairns, J., Jr. (1995). Ecological integrity of aquatic systems. Regulated Rivers: Research & Management. **11**:313-323.

Focusing on the ecological integrity of large river systems has suggested the rethinking of the entire issue from a landscape perspective. Ecological integrity is impossible without biological integrity. However, it appears improbable that highly localized measures of biological integrity can be used for effective, scientifically justifiable extrapolations to landscape- or system-level ecological integrity. It may be more reasonable to make measurements at the level of organization of interest, i.e. larger spatial and temporal scales. In addition, human society and natural systems have been coevolving since the agricultural revolution and, arguably, well before then. Two types of coevolution between human society and natural systems appear possible: (1) an 'arms-race' in which human society ignores changes in natural systems-essential ecosystem services are lost, resulting in unpleasant consequences for society; or (2) mutualism in which environmental literacy and a feeling of responsibility for natural systems motivate rapid societal response to ecosystem changes and the preservation of ecological integrity. The simplest measures of ecological integrity may be the actions of human society likely to minimize or markedly reduce negative impacts on natural systems. This does not mean

substituting such measures for more customary ecological measures, but rather using both types of measurements simultaneously.

81. Cambray, J. A. (1990). Adaptive significance of a longitudinal migration by juvenile freshwater fish in the Gamtoos River system, South Africa. South Africa Journal of Wildlife Research. **20**:148-156.

After flooding of the Groot River, the major tributary of the Gamtoos River system, during March 1988 several species of freshwater fish underwent a mass upstream migration. The dominant group of fish consisted of juvenile moggel *Labeo umbratus* . There were also small-scale redfin minnows *Pseudobarbus asper* , Mozambique tilapia *Oreochromis mossambicus* and several chubbyhead barbs *Barbus anoplus* . Fish accumulated below a weir and began to migrate late in the morning. Migration activity continued throughout the afternoon until dusk when the fish dispersed downstream. The observed movement of fish was clearly a diurnal migration. The weir had altered the general riverine habitat and influenced the natural migratory movement of fish within the Gamtoos River system. Data are presented which would be useful in the design of a fishway at this weir.

82. Carter, B. T. (1954). The movement of fishes through navigation lock chambers in the Kentucky River. Transactions of the Kentucky Academy of Science. **15**:48-56.

This is an investigation of the extent to which fishes use navigation locks in the Kentucky River. It was initiated in response to possible discontinued operations at lock #7 of the Kentucky River. Discontinued operation of the lock and dam would result in a permanent, rather than a semi-permanent, barrier to fish passage above lock #7.

83. Casselman, J. M., T. Penczak, L. Carl, R. H. K. Mann and J. Holcik (1990). An evaluation of fish sampling methodologies for large river systems. Polskie Archiwum Hydrobiologii. **37**:521-551.

Fish sampling methodologies for large rivers were reviewed at the Large River Symposium by surveying 64 diverse sampling methods, their application and efficiency under various riverine conditions, diversity of habitat, and extreme environmental conditions in large rivers. Fishways and fish ladders are uniquely applicable for sampling migrating fish in rivers, especially those with large control dams or high flows. Remote sensing by stationary hydroacoustics has been used where spawning migrations are assessed. Trawling may be used where the current is relatively slow. There are no standardized sampling techniques for large rivers because environmental conditions are often extremely variable. Usually attempts are made to sample selectively only those parts of the river that have low flow and are amenable to bottom-set stationary gear such as gill nets, trap nets, and other fixed gear. Sampling riverine fishes at the community level is much more difficult and requires combining the results of several types of sampling gear (e.g., quantitative sampling using electrofishing or explosives, in combination with large lift nets or block off nets). Portable fish diversion systems exist that could make fish sampling in large rivers much more efficient. Some of these systems, such as portable marine fences, weak electric fields, bubble currents, and hydrosonic pulsers could be used to direct and concentrate fish to improve the actual sampling procedure. Because environmental conditions are more variable in rivers than in lakes, it is essential that if sampling efficiencies are to be compared, environmental

conditions must be the same. Sampling of fish populations in rivers where discharge is variable should be conducted in relation to velocity, rather than at fixed stations.

84. Cederholm, C. J., M. D. Kunze, T. Murota and A. Sibatani (1999). Pacific salmon carcasses: Essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries. **24**:6-15.

Pacific salmon and other anadromous salmonids represent a major vector for transporting marine nutrients across ecosystem boundaries (i.e., from marine to freshwater and terrestrial ecosystems). Salmon carcasses provide nutrients and energy to biota within aquatic and terrestrial ecosystems through various pathways. In this paper we review and synthesize the growing number of studies documenting this process in different localities. We also discuss the implications for maintaining the nutrient feedback system. Our findings show that future management will need to view spawning salmon and their carcasses as important habitat components for sustaining the production of fish as well as other salmon-dependent species within watersheds.

85. Chamani, M. R. and N. Rajaratnam (1999). Characteristics of skimming flow over stepped spillways. Journal of Hydraulic Engineering. **125**:361-368.

This paper presents the results of a laboratory study on the characteristics of fully developed skimming flow in a large model of a stepped spillway for two slopes, for a range of discharges with y_C/h in the range of 0.7-4.4. Fully developed aerated flow on a stepped spillway can be divided into lower and upper regions, similar to those for self-aerated flow in steep chutes. The air concentration distributions in these two regions agree with the equations developed by Straub and Anderson for flow in steep chutes. It was found that the depth at which the air concentration is equal to 90% can be considered as the depth of aerated flow on stepped spillways. In the lower region, the velocity profiles were described by the Karman-Prandtl equation for rough turbulent flow when an equivalent bed roughness was used. A correlation was developed for the skin friction coefficient to predict the Reynolds shear stress at the virtual bed of the stepped spillway. It was found that the relative energy loss in the stepped spillway is in the range of 48-63%. It was also found that the mean air concentration on a stepped spillway is larger than that in a corresponding chute.

86. Charlebois, P. M., R. G. Goettel, D. J. Jude, J. E. Marsden, R. K. Wolfe and S. Rudnika (1997). The round goby, *Neogobius melanostomus* (Pallas), a review of European and North American literature. INHS, Special Publication 20.

When a nonindigenous species becomes established in a new area, the scientific community often is asked to predict potential ecological effects and range expansion of the species. In order to make these predictions, scientists must have basic biological information on the organism. This document provides the scientific community with basic biological information on the round goby, Neogobius melanostomus (Pallas), which entered North America in 1990. We have reviewed the currently available European and North American literature and compiled a comprehensive bibliography of goby literature, including annotations and abstracts. We also have included a listing and examples of outreach materials available on the round goby. We have not attempted to evaluate the material. Obvious typographical errors (e.g., misspellings) in the published abstracts have been corrected.

87. Clancy, C. G. and D. R. Reichmuth (1990). A detachable fishway for steep culverts. North American Journal of Fisheries Management. **10**:244-246.

A fishway constructed of angle iron and reinforcing bar was installed in a high-gradient culvert to allow the passage of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* to upstream spawning areas. The structure was detachable from the culvert, inexpensive, and portable. The fishery was still effective 8 years after installation.

88. Cochran, P. A. (1993). The Fox River as an avenue for fish dispersal. Pages 116 *in* 36th Conference of the International Association for Great Lakes Research, De Pere, Wisconsin (USA), International Association for Great Lakes Research.

Dispersal of fishes and other organisms along the Fox River has been of interest for two reasons. First, concerns have been raised about the potential for exotic species to spread from Green Bay up to lower Fox River to Lake Winnebago and its tributaries. Indeed, closure of the Rapid Croche lock in 1988 has been followed by the appearance of white perch *Morone americana*, sea lamprey *Petromyzon marinus*, and zebra mussels *Driessena polymorpha*, in the lower river. Second, a canal dug in the 1800's at Portage, Wisconsin, connected the upper Fox River and the Wisconsin River of the Mississippi River drainage. A number of fishes and other organisms gained access to the Great Lakes drainage through this connection. Those that have dispersed all the way to Green Bay are typical large river species, whereas species typical of smaller streams have been "sidetracked" into the Wolf River drainage. The suitability of the Fox River as a dispersal route has apparently been enhanced through improvements in water quality. Over forty fish species have been collected in recent years in a sea lamprey assessment trap set in the lower river. These include several species typically associated with habitats of high quality.

89. Coker, R. E. (1929). Keokuk dam and the fisheries of the Upper Mississippi River. United States Department of Commerce, Bureau of Fisheries, Document 1063.

A detailed account of the Keokuk dam (the first dam on the Upper Mississippi River) is provided. Observations on the Keokuk dam as a possible obstruction to fish, an account of the migratory movements in the area of the dam, evidence of migration, and the effect of the dam on myriad physical properties of the river are tendered.

90. Coker, R. E. (1929). Studies of common fishes of the Mississippi River at Keokuk. United States Department of Commerce, Bureau of Fisheries, Document 1072.

Observations on the natural history of a wide range of fish species found in the area around the Keokuk dam during and after construction are presented. Taxon detailed include the sturgeons, gars, paddlefish, bowfin, several herring-like species, Americal eel, several catfish, bass, and sucker species, perches, buffalos, pike, lamprey, and drum.

91. Colavecchia, M., C. Katopodis, R. Goosney, D. A. Scruton and R. S. McKinley (1998). Measurement of burst swimming performance in wild Atlantic salmon (*Salmo salar* L.) using digital telemetry. Regulated Rivers: Research & Management. **14**:41-51.

Swimming performance of wild Atlantic salmon (*Salmo salar* L.) was investigated in an experimental flume using coded radio signals. To calculate swimming speed, distance moved and time elapsed were measured with a digital spectrum processor using near real-time spectrum analysis. This device was designed to be used in a coprocessing arrangement with a receiver, thereby providing pulse position code discrimination, verification and continuous data storage. Radio-tagged adults (48.3 to 54.8 cm long) voluntarily swam against water velocities, ranging from 1.32 to 2.85 m s^{-1}, in an 18 m long flume at a mean water temperature of 10.1 plus or minus 1.6 ^{o}C. At water velocities of 1.32-1.55 m s^{-1}, individuals successfully ascended the flume at swimming speeds of 1.61-2.55 m s^{-1}, or 3.30-4.79 body lengths per second (l s^{-1}), respectively. At high water velocities ranging from 1.92 to 2.85 m s^{-1}, individual swimming speeds increased from 2.55 to 3.60 m s^{-1}, or 4.94-7.27 l s^{-1}, respectively. However, above a threshold value of 1.92 m s^{-1}, individuals traversed shorter distances and were unable to ascend the flume. The highest swimming speed observed was 4.13 m s^{-1}, or 8.35 l s^{-1}. The results of this study indicate that in addition to its applicability in the determination of burst swimming speeds, digital telemetry could prove a useful tool in the design and evaluation of future fishways and culvert installations.

92. Colt, J. and R. J. While, eds. (1991). Fisheries Bioengineering Symposium. American Fisheries Society, Bethesda, Maryland (USA).

Some 68 papers are presented in sections: habitats; fish passage; and fish hatcheries. Each contribution is abstracted and indexed separately.

93. Conley, S. (1990). Upstream downstream. Atlantic Salmon Journal. **39**:30-31.

The author describes the efforts of one man to manage anadromous fish, particularly with respect to Connecticut River Atlantic salmon *Salmo salar* and the complicated problem of fish passage -- how to get fish around the many formidable barriers blocking their annual migrations to and from the sea.

94. Conover, G. A. and J. M. Grady (2000). Mississippi River Basin paddlefish research coded-wire tagging project - 1998 Annual Report. Mississippi Interstate Cooperative Resource Association, Annual Report .

This most recent MICRA report provides some preliminary analyses of paddlefish movements in the Mississippi River Basin based on mark-recapture studies using coded-wire tagging methods. Both hatchery reared and wild fish have been marked since 1995. The authors report on paddlefish growth and movements, tagging and sampling effort, recaptures, and the progress made to date on the deveolpment of a GIS database that will permit spatial analysis of paddlefish movements throughout the Mississippi River Basin.

95. 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 studied using the synchronic approach to typological

analysis in conjunction with Point Abundance Sampling by modified electrofishing. In 3 different flood plains of the Upper Rhone 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.

96. Cowx, I. G. (1998). Fish passage facilities in the UK: issues and options for future development. Pages 220-235 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypass Channels Symposium, Fishing News Books, Vienna (Austria).

Provision for the migration of fish has a long tradition in the UK. However, the mechanisms by which it has been achieved have varied greatly as has the degree of success in maintaining migratory pathways. Most attention has focused on upstream migration of salmonids past medium and large impoundments (weirs and reservoir dams). More recently, attention has focused on using alternative channels, such as canoe slaloms, to bypass weirs and barrages, and improving access to natural spawning beds past small man-made obstructions such as road culverts and badly designed or located low weirs which impede upstream movement. In recent years, in the face of declining European eel Anguilla anguilla stocks and emphasis on improving fishing for other non-salmonid fishes, provision has been made for improving upstream migration of elvers and non-salmonids over difficult and insurmountable man-made obstructions. Legislation and provision for the design of fish passage facilities for migratory salmonids are under the direct control of the Environment Agency. They impose strict guidelines for designing passes and require that facilities at new barrages, particularly in estuaries, are adequately tested before they are given approval. With increasing pressure on improving river fisheries and the environment, there are many rivers now being considered for rehabilitation. This includes providing fish passage facilities at the many weirs built on rivers in the industrial past to providing renewed access to the headwater spawning and nursery areas. To date, little attention has been paid to the economics of such activities but this situation is changing rapidly and demands for cost benefit analysis are being imposed. An example is described where the decision to build fish passes on the many weirs impeding upstream migration was deferred on economic grounds. Finally, there are some controversial situations, where passage past natural barriers to previously inaccessible spawning and nursery grounds are discussed.

97. Curtis, G. L., J. S. Ramsey and D. L. Scarnecchia (1997). Habitat use and movements of shovelnose sturgeon in Pool 13 of the Upper Mississippi River during extreme low flow conditions. Environmental Biology of Fishes. **50**:175-182.

We monitored habitat use and movement of 27 adult shovelnose sturgeon in Pool 13 of the Upper Mississippi river, Iowa-Illinois, by radio-telemetry in April through August 1988. Our objective was to determine the response of this species to unusually low water conditions in the Upper Mississippi River in 1988. Most (94%) telemetry contacts were made in 3 habitat types: main channel (50%), main channel border where wing dams were present (29%), and tailwaters of Lock and Dam 12 (15%). Habitat use in spring was affected by the extreme low flows. We often found tagged shovelnose

sturgeon in the main channel and tailwaters during the spring period (11 March-20 May) where water velocities were highest. This was in contrast to other sites where shovelnose sturgeon did not occupy those areas during years with normal spring flows. Shovelnose sturgeon were typically found in areas with a sand bottom, mean water depth of 5.8 m, and mean bottom current velocity of 0.23 m sec^{-1}. They occupied areas of swifter current but were not always found in the fastest portion o f the pool, and we observed no emigration from the study pool. Linear total range of movement from the tagging site ranged from 1.9 to 54.5 km during the study period.

98. Dahlberg, M. L., D. L. Shumway and P. Doudorff (1968). Influence of dissolved oxygen and carbon dioxide on swimming performance of largemouth bass and coho salmon. Journal of the Fisheries Research Board of Canada. **25**:49-70.

The final swimming speed of juvenile largemouth bass, *Micropterus salmoides*, was reduced markedly at oxygen concentrations below 5 or 6 mg /liter in tests at 25 ^{o}C in a tubular chamber in which the velocity of water was increased gradually, at 10 minute intervals, until the fish were forced by the current permanently against a screen. At levels above 6 mg per liter, the final swimming speed was virtually independent of the oxygen concentration. The performance of bass that had been acclimated overnight to elevated carbon dioxide levels was not materially affected by the highest tested concentrations of free current dioxide, averaging 48 mg per liter, at any tested level of dissolved oxygen. For juvenile, coho salmon, *Onchorynchus kisutch*, at temperatures near 20 ^{o}C and carbon dioxide concentrations near 2 mg per liter, any considerable reduction of the oxygen concentration from about 9 mg per liter, the air-saturation level, resulted in some reduction of the final swimming speed. The performance of the salmon was impaired much more markedly than was that of the bass by the same reduction of the oxygen concentration. At oxygen concentrations near and above the air-saturation level, high concentrations of free carbon dioxide, averaging 15 and 61 mg per liter, had a depressing effect on the final swimming speed of coho salmon, even after overnight acclimation. However, this effect decreased at reduced oxygen and concentrations. No measurement effect of free carbon dioxide concentrations near 61 mg per liter was evident at 2 mg per liter dissolved oxygen, and concentrations near 18 mg per liter had little or no effect even at moderately reduced dissolved oxygen levels after overnight acclimation of the salmon to these carbon dioxide concentrations.

99. Daum, D. W. and B. M. Osborne (1998). Use of fixed-location, split-beam sonar to describe temporal and spatial patterns of adult fall chum salmon migration in the Chandalar River, Alaska. North American Journal of Fisheries Management. **18**:477-486.

Fixed-location, split-beam hydroacoustics was used to describe temporal and spatial patterns of upstream-swimming fall chum salmon *Oncorhynchus keta* in the Chandalar River, a tributary of the Yukon River, Alaska. Split-beam techniques allow for three-dimensional tracking of fish targets as they pass through the sonar beam. Elliptical-beam transducers were deployed from opposite river banks to optimize acoustic coverage and were aimed perpendicular to the current. Sonar systems were operated continuously from August 8 through September 22, 1996. Acoustic data on positional information of 204,153 upstream-traveling chum salmon were collected. Diel patterns in hourly passage rates differed between banks. On the left bank, chum salmon passage was highest during nighttime hours. On the right bank, fish did not show any consistent trend in diel passage rates. Chum salmon were generally shore oriented and swam near the river bottom.

During daylight hours, fish were further offshore and closer to the bottom than during night. Besides providing accurate counts of fish passage, riverine split-beam hydroacoustics proved a nonintrusive method for studying the migratory behavior of fish.

100. De Carvalho, J. L. and B. De Merona (1986). [Studies on two migratory fish from Lower Tocantins River before closure of Tucurui Dam]. Amazoniana. **4**:595-607.

Migratory fish species are generally the most important species for the fishing industry as well as for artesanal fishing. In the lower Tocantins, Brazil, two species of migratory fish dominate the captures: the mapara *Hypophthalmus marginatus* and the curimata *Prochilodus nigricans*. These species were studied before the damming of this river by the Tucurui hydroelectric dam as part of a larger study of commercial fisheries encompassing the Tocantins basin from the mouth to Maraba (Para). Based principally on landing records, this study describes the migration cycles of the two species. A classical and simple pattern of migration can be recognized: an upstream movement of immature forms and adults in the upper part of the distribution area, and the reverse or downstream movement of larvae and adults in a dispersion phase. The main difference between these two species lies in the size of the distribution area. The mapara is limited to part of the river downstream from the dam, and so would not be affected by its presence. The curimata has a much larger geographic range in the Tocantins basin. The part of the population living downstream will probably be profoundly perturbed by the dam due to the blockage of its migratory route.

101. Dominy, C. L. (1971). Changes in blood lactic acid concentrations in alewives *Alosa pseudoharengus* during passage through a pool and weir fishway. Journal of the Fisheries Research Board of Canada. **28**:1215-1217.

Blood lactic acid concentration of anadromous *A. pseudoharengus* sampled during their upstream migration through a pool and weir fishway was not extremely high (46.7 mg/100 ml) and the degree of exercise exhibited during ascent was judged to be moderate. for fish that were subjected experimentally to severe exercise, the concentration (108.7 mg/100 ml) was more than 5 times that for rested fish (18.9 mg/100 ml). of the 3 groups of fish sampled directly from the fishway pools, only 1 had an average concentration that differed significantly from that for the rested state.

102. Dominy, C. L. (1973). Effect of entrance-pool weir elevation and fish density on passage of alewives *Alsoa pseudoharengus* in a pool and weir fishway. Transactions of the American Fisheries Society. **102**:398-404.

A comparison of the rates of passage of alewives *Alosa pseudoharengus* into a pool and weir fishway throughout the peak of the alewife run (22 May - 6 June) in a Nova Scotia river revealed that one entrance weir, built at an elevation 0.21 m (8.0 in) lower than the existing conventional weir, passed alewives at a significantly greater mean rate (65.25/min) than the conventional weir (23.25/min). The mean rate of passage of alewives from pool to pool within the fishway (37.59/min) was not significantly greater or less than the mean rate for either of the entrance weirs. Density tests at two intermediate fishway pools revealed that the relationship between alewife density and exit rate may be described by a curve that rises to a peak exit rate of 80/min at a density of 75m^3 and then levels of to 70 /min at higher densities. It is concluded that crowding and delay is not likely to occur within the fishway at the peak of the alewife run. Values

for substitution in the formula of Clay (1961) for calculating fishway capacity determined for the alewife show that this species does not require any more time per fishway pool than Pacific salmon and that the demands of alewives on water volume are about six times less than for Pacific salmon. These determinations permit more general application, by fisheries resource biologists and engineers, of the data presented on crowding, delay and capacity for alewives in a pool and weir fishway.

103. Duncan, R. E. and P. A. Thiel (1983). A survey of the mussel densities in Pool 10 of the Upper Mississippi River. U.S. Fish and Wildlife Service, Fisheries Resource Office, Technical Bulletin 139.

Impoundment, water quality, and other factors have had an impact on the mussel fauna of the Upper Mississippi River. The primary objective of this survey was to quantitatively define the diversity and relative density of the mussel community in Pool 10 of the river. Pool 10 extends from Lock and Dam No. 9 near Lynxville, Wisconsin, to Lock and Dam No. 10 at Guttenberg, Iowa , a total of 32.8 river miles. Of the 309 sites sampled, mussels were found at 224 sites, or 72%. The East Channel near Prairie du Chien, Wisconsin had the richest mussel fauna with an average density of 2.964 mussels per square foot; and only 6% of the sites were nonproductive. The lower end of Pool 10 had the lowest mussel density at 0.655 per square foot and the highest percentage of nonproductive sites, 38%. The mussel density in the main channel border was two times greater than in the main channel and backwater. A total of 12,150 live specimens representing 31 species of freshwater mussels were collected from Pool 10; an additional 7 species were represented only by dead specimens. Threeridge, *Amblema plicata*, was by far the most abundant mussel species, comprising 52.9% of the catch and having an average density of 0.832 per square foot.

104. Durbin, A. G., S. W. Nixon and C. A. Oviatt (1979). Effects of the spawning migration of the alewife, *Alosa pseudoharengus*, on freshwater ecosystems. Ecology. **60**:8-17.

The influx of large numbers of *A. pseudoharengus* , into relatively small freshwater systems may have a considerable impact upon pre-established food chains and nutrient cycles. The total nutrient input to Pausacaco Pond, Rhode Island, USA, from alewives is estimated to amount to 0.43 g P, 2.7 g N, and 16.8 g C/m^2 over a 2-month period. This is largely through mortality of the spawning fish, and to a lesser extent through excretion. These inputs were much greater than the eventual nutrient loss to the system through emigration of juvenile fish. In tank experiments using pond microcosms, the initial response to the addition of the fish was a large phytoplankton bloom and an increase in litter respiration. The phytoplankton bloom was shortlived, and the most lasting effect was an increase in production and respiration in the leaf litter. This increased production in the litter community would support a long lasting supply of insect and benthic invertebrate food for young fish. The respiration rate of autumn leaves incubated in alewife streams during the migration was significantly higher than that of leaves incubated simultaneously in a stream which had no alewife run. Respiration rates of leaves incubated in the same streams before the arrival of alewives did not differ significantly. The increase in litter respiration, an indication of microbial and invertebrate activity on the leaf surface, was attributed to the additional nutrients supplied by the fish.

105. Dynesius, M. and C. Nilsson (1994). Fragmentation and flow regulation of river systems in the northern third of the world. Science. **266**:753-762.

Seventy-seven percent of the total water discharge of the 139 largest river systems in North America north of Mexico, in Europe, and in the republics of the former Soviet Union is strongly or moderately affected by fragmentation of the river channels by dams and by water regulation resulting from reservoir operation, interbasin diversion, and irrigation. The remaining free-flowing large river systems are relatively small and nearly all situated in the far north, as are the 59 medium-sized river systems of Norway, Sweden, Finland, and Denmark. These conditions indicate that many types of river ecosystems have been lost and that the populations of many riverine species have become highly fragmented. To improve the conservation of biodiversity and the sustainable use of biological resources, immediate action is called for to create an international preservation network of free-flowing river systems and to rehabilitate exploited rivers in areas that lack unaffected watercourses.

106. Eberstaller, J. and C. Gumpinger (1997). Low-gradient nature-like bypass channel on the river Pielach. Osterreichs Fischerei. **50**:47-51.

This low-gradient bypass channel at the "Tessmer-Wehr", on the river Pielach, is the first of its kind (i.e. without vertical drops) in the province of Lower Austria. The authors know of only one other such bypass constructed in Austria, located on the middle portion of the river Salzach. The morphology of the bypass channel resembles a natural, structure-rich tributary of the Pielach and the entrance to the bypass is located immediately beside the weir. Both factors help guarantee permanent passage for all occuring species and their corresponding life history stages. The discharge of the channel corresponds to the natural discharge regime of the Pielach, providing optimal conditions for passage during the spring spawning migrations of the dominant occurring species. Detailed plans of the construction were not made before hand, in order to allow more on-site flexibility whereby trained field consultants supervised the construction crew in creating a highly variable and more nature-like channel. Particulary important in reaching this goal were the fine adjustments made to the channel's structure after the flow inlet was opened and the consultants could observe potential problem areas for passing fish.

107. Eberstaller, J., M. Hinterhofer and P. Parasiewicz (1998). The effectiveness of two nature-like bypass channels in an upland Austrian river. Pages 363-383 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

In Austria, the construction of fishways had come to a virtual standstill for several decades because existing facilities did not operate effectively. However, an increasing number of nature-like bypass channels have now been built. These new bypass systems resemble natural streams with regard to morphology, gradient, hydraulic conditions and substrate composition. In order to evaluate the effectiveness of these new systems, two such constructions were studied on the Mur River, in southern Austria. With the exception of adult Danube salmon Hucho hucho, all occurring fish species and their respective life-history stages were documented passing through the channels. During and just prior to their spawning season, adult European grayling Thymallus thymallus ascended these bypass channels. The number of fish caught in traps at the top of the bypasses was equal to 17% of the estimated adult populations in the 5.5 and 4.5 km-long tailwater reaches below the weirs. Periodic sampling with backpack electro fishing gear demonstrated that both channels were colonised with a fish assemblage corresponding to natural tributaries of the Mur River. Because there are no generally accepted criteria for

evaluating fish passes, four criteria were established a priori to assess the efficiency of these bypass channels. Concerning upstream migration only, one bypass channel (Unzmarkt) was rated as 'effective' and another (Fisching) as 'effective to highly effective'.

108. Eicher, G. J. (1982). Fish passage in New South Wales. Fisheries. **7**:2-4.

The author investigated the fisheries of New South Wales in relationship to dams. It is recommended that fish be trapped and released above the dams.

109. Elvira, B., G. G. Nicola and A. Almodovar (1998). A catalogue of fish passes at dams in Spain. Pages 203-207 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

An inventory of fish passes at Spanish dams was made, and their effectiveness and level of maintenance were estimated. A total of 108 passes were catalogued, 31% of which were constructed after 1990. These passes are placed at weirs and dams of moderate height (1.5 to 25 m). Many of them are located in northern Spain and are mainly devoted to salmonid passage. Thus, 61% of the passes coincide with the occurrence of brown trout *Salmo trutta*, and 28% with the occurrence of both Atlantic salmon *Salmo salar* and brown trout. The most common fish pass design is the pool-and-weir (87%), followed by the Denil type (5%). With regard to effectiveness, it was estimated that 58% of surveyed facilities can be passed by target species. As for maintenance status, 61% of the passes are in good condition. A significant result of the survey is that a large majority of the approximate 1100 large dams built in Spain lack fish passes. Likewise, it was confirmed that alternative fish passage facilities, i.e. fish locks, fish lifts or bypass channels, are still absent from Spanish dams.

110. Enzenhofer, H. J. and G. Cronkite (1998). In-river accessory equipment for fixed-location hydroacoustic systems. , Canadian Technical Report of Fisheries and Aquatic Sciences 2250.

This report describes the design, construction and use of the in-river equipment that aids the operation of a fixed-location hydroacoustic system located near the confluence of Qualark Creek with the Fraser River near Yale, British Columbia, Canada. The equipment can be easily deployed by one person and is designed to withstand the forces created by strong current flow. This equipment is essential to the operation of the hydroacoustic system to maintain accurate and defensible enumeration of migrating salmon. Fish migrating in rivers with higher current flow tend to be shore and bottom oriented and require a shore based system aimed close to the river bottom and perpendicular to the flow. Specialised equipment must be used to move fish away from the shore so they can be counted. The operator must be able to aim the transducer precisely to ensure that the beam is close to the river bottom and covers the volume where fish passage occurs. The beam aim must be repeatable after moving the equiment. Since the detection characteristics vary between transducers, the ability to detect should be determined for each transducer in the environment where it is used.

111. Ewers, H. (1995). [Fishladder at the lower Wupper River]. Wasser und Boden. **47**:50.

The restoration of free fish passage along a river regulated with barrages is essential for the interactive environment of wild life. Fishladders will have to be installed, because the barrages are inevitable. Several types of fishladders constructed by the Wupperverband along the lower Wupper are introduced.

112. Farabee, G. B. (1979). Life histories of important sport and commercial fishes of the Upper Mississippi River. Pages 259 *in* J. L. Rasmussen, ed. A Compendium of Fishery Information on the Upper Mississippi River, 2nd edition, Upper Mississippi River Conservation Commission, .

This section of the Compendium presents a brief summary of the known life history characteristics of sixteen major sport and commercial fish species or species groups in the Upper Mississippi River. The life history of each species or species group has been divided into seven categories: fecundity and breeding habits, life history, age and growth, age and size at maturity, survival ability, relative importance to the fishery, and management implications. These categories are provided for the convenience of the reader, to enable a quick, brief review of existing information. Detailed information on the relative value of these species to the sport and commercial fishery can be found in Sections VI and VII of this Compendium, respectively. The data compiled in this Section has generally been gathered from surveys and research conducted on the Mississippi River by UMRCC biologists. However, in cases where Mississippi River data were (SIC) not available, other sources were used.

113. Farlinger, S. and F. W. H. Beamish (1977). Effects of time and velocity increments on the critical swimming speed of largemouth bass *Micropterus salmoides*. Transactions of the American Fisheries Society. **106**:436-439.

Critical swimming speed was measured for largemouth bass and found to be related to the increments of both time and water velocity. Critical speed decreased with increase in time interval, and reached a peak and declined thereafter with increasing velocity increment.

114. Farlinger, S. and F. W. H. Beamish (1978). Changes in blood chemistry and critical swimming speed of largemouth bass, *Micropterus salmoides*, with physical conditioning. Transactions of the American Fisheries Society. **107**:523-527.

Physical conditioning at swimming speeds of 2 and 3 body lengths per second for periods up to 30 days increased critical swimming speed by as much as 15% over that found for unconditioned fish. Haemoglobin increased significantly with conditioning, suggesting an enhancement of aerobic capacity. Conditioning did not, in general, increase the production of lactate dehydrogenase in blood serum. Following periods of swimming at critical speeds, blood volume decreased in unconditioned bass but with conditioning remained relatively stable.

115. Fausch, K. D. and M. K. Young (1995). Evolutionarily significant units and movement of resident stream fishes: A cautionary tale. Pages 360-370 *in* J. L. Nielsen, ed. Evolution and the Aquatic Ecosystem: Defining Unique Units in Population Conservation, Monterey, CA (USA), American Fisheries Society Symposium.

Many taxa of resident stream fishes are reported to be relatively sedentary throughout their lives. Such discrete populations would make identification and management of evolutionarily significant units (ESUs) straightforward. However, in contrast to this prevailing restricted movement paradigm, recent evidence indicates that even resident salmonids, such as interior stocks of cutthroat trout *Oncorhynchus clarki* living in headwater streams, move often, sometimes over relatively long distances. Resident stream fishes likely move in response to various ecological constraints, including the need to garner enough scarce resources or find a critical resource, or because the habitat they occupy becomes suboptimal or unsuitable. This emerging paradigm shift has important implications for defining and managing ESUs of resident stream fishes. For example, timing of sampling may affect which of several different "populations" mobile individuals are chosen to represent. Isolating small populations of native fishes above barriers to prevent invasion by exotic species may trade this risk for other environmental, demographic, or genetic risks caused by eliminating dispersal. Moreover, isolating small population fragments via natural or anthropogenic disturbances, or management actions, may create artificial ESUs. Biologists must understand not only the genetics and taxonomy, but also the spatial and temporal dynamics of component populations of species if they are to accurately identify and wisely manage ESUs.

116. Fremling, C. R. (1987). Human impacts on Mississippi River ecology. Pages 235-240 *in* M. P. Lynch and K. L. McDonald, eds. Estuarine and Coastal Management, Tools of the Trade, New Orleans, Louisiana (USA).

The Mississippi drains a basin of 4,759,049 km^2, about 12% of North America. It is the third longest river in the world, has the second largest drainage basin, and is the fifth largest worldwide in average discharge. For the purposes of this paper, the Mississippi River (MR) is delineated into three reaches: 1) the Lower Mississippi River (LMR) extending from the Head-of-Passes upstream to the mouth of the Ohio River, 2) the Upper Mississippi River (UMR) extending from the mouth of the Ohio to St. Anthony Falls, Minnesota, and 3) the Headwaters (HW) extending upstream to the river's source at Lake Itasca.

117. Fremling, C. R. and T. O. Claflin (1984). Ecological history of the Upper Mississippi River. Pages 17-18 *in* J. G. Weiner, R. V. Anderson and D. R. McConville, eds. Contaminants in the Upper Mississippi River: Proceedings of the 15th Annual Meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

The Upper Mississippi Valley, opened to Caucasians by Joliet 's explorations in 1673, was the site of rapid population growth and trading during the 1700's. This section of the river was surveyed in the early 19th century. The beginning of steamboat travel in 1823 led to navigation improvements by the Army Corps of Engineers starting in 1824. Settlements continued to grow in number and population, stimulating cutting of forests for lumber and agricultural activities, particularly steepland farming. These practices contributed to erosion and degradation of the river system. The Rivers and Harbors Acts of 1878, 1890, and 1907 resulted in channel deepening and other construction works in the section from Minneapolis to the Ohio River. These works used wing and closing dams, shore protection, and auxiliary dredging, permitting open-channel navigation. By 1870 the fisheries were rapidly declining as a result of wide fluctuations in water level which stranded fish in backwaters. Fish rescue operations were begun in 1879 and

continued until the 1950 's in a few locations. In the 1930 's more extensive channelization projects started. The channel was deepened to 9 ft by construction of locks and dams (29 built during this period), supplemented by dredging. As a result of the impoundments, the river habitat has changed, vastly increasing the marsh area and slack water area habitat available for invertebrates, periphyton, fish (139 species), furbearers, and waterfowl. Some long-term detrimental changes caused by the channel modifications include accelerated sedimentation (changing wetlands into floodplains), eutrophication, and accumulation of industrial wastes.

118. Fremling, C. R., J. L. Rasmussen, R. E. Sparks, S. P. Cobb, C. F. Bryan and T. O. Claflin (1989). Mississippi River fisheries: a case history. Pages 309-351 *in* D. P. Dodge, ed. Proceedings of the International Large River Symposium, Honey Harbour, Ontario (Canada), Canadian Special Publication of Fisheries and Aquatic Sciences.

The Mississippi River (MR) is severely regulated, mainly for transportation and flood control. Coastal wetlands are critical to marine fishes and invertebrates, and about 0.6% are being lost yearly to natural and human-induced forces, including levees which divert sediment directly into the Gulf of Mexico, instead of allowing it to build up the delta during annual floods. Distribution of 241 fish species reported from mainstream MR has been influenced mainly by glaciation, natural barriers and human activities; species diversity generally increases downstream.

119. Frost, S. L. and W. J. Mitsch (1989). Resource development and conservation history along the Ohio River. Ohio Journal of Science. **89**:143-152.

The 1578 km-long Ohio River has a rich history of natural resource use and abuse, starting with the development of the river itself for navigational purposes. There is a rich early record of natural history studies by Bartram, Michaux, Lesueur, Rafinesque and others. The navigational use of the river began with snag pulling and has progressed to modern high-lift dams. Flood control, navigational use of tributaries, and canal-building have been water resource development projects of the past. Early industries that developed around the availability and abundance of coal, oil, natural gas, salt, iron ore, timber, and clay in the valley ultimately led to the more recent pottery, iron and steel, chemical, and power generation industries along the river and its tributaries. There were also major horticultural developments of apple orchards, wine vineyards, and even silk worm farms along the river and a modest button industry from the mussels in the river itself. The pollution of the Ohio River has been a concern for decades, and the involvement of the federal government and the establishment of interstate compacts have led to the development of significant understanding of the science of water pollution and to the general improvement of the river's water quality.

120. Fruget, J. F. (1992). Ecology of the lower Rhone after 200 years of human influence: A review. Regulated Rivers: Research & Management. **7**:233-246.

Embankments of the last century and contemporary channelization and development of urban and industrial areas along the Rhone Valley have greatly changed the river. The impacts of these on three biological descriptors of the hydrosystem (benthic invertebrates, fish communities and aquatic birds) have been studied. A reduction in the morphological diversity of the regulated hydrosystem has caused a reduction in biological diversity. This system has become a slow potamic system as a consequence of

the more uniform environmental conditions: the benthic macroinvertebrate fauna has become eurytopic and pollution tolerant, with very localized potamic species; fish communities are dominated by limnophilic cyprinids; and water bird communities are limited by the absence of typical species of fluvial areas, such as terns.

121. Gebler, R. J. (1998). Examples of near-natural fish passes in Germany: drop structure conversions, fish ramps and bypass channels. Pages 403-419 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Since 1990, several different types of near-natural fish passes have been constructed by the author. This chapter presents a short compendium of near-natural fishways, including the design criteria, costs and comments concerning the practical experience gained in both the construction and monitoring phases. Addressed are engineers, biologists and other faculties involved in fish pass construction.

122. Gehrke, P. C., P. Brown, C. B. Schiller, D. B. Moffatt and A. M. Bruce (1995). River regulation and fish communities in the Murray-Darling River System, Australia. Regulated Rivers: Research & Management. **11**:363-375.

Fish communities from four catchments in the Murray-Darling river system were analysed in relation to climate, hydrology and river regulation. Using the annual proportional flow deviation as a measure of river regulation, the Paroo River catchment was assessed as unregulated, the Darling River catchment as mildly regulated and the Murrumbidgee River and River Murray catchments as highly regulated. A total of 11 010 fish, representing nine native and three alien species, was caught during high and low flow seasons in the four catchments. Native species, such as golden perch *Macquaria ambigua* (Percichthyidae), bony herring *Nematalosa erebi* (Clupeidae) and spangled perch *Leiopotherapon unicolor* (Terponidae), dominated fish communities in the Paroo and Darling catchments, but alien species, mostly carp, *Cyprinus carpio* (Cyprinidae), were also abundant. Both native and alien species were more abundant in these catchments after flooding, but there was little change in species composition between high and low flow seasons at the catchment level. Carp dominated communities in the Murray and Murrumbidgee catchments. There was a significant trend for reduced species diversity in increasingly regulated catchments. River regulation may alter the relative abundance of native and alien fish by desynchronizing environmental cycles and the reproductive cycles of native species. Ordination of species abundances showed discrete fish communities that reflect the geographical separation between catchments. Differences between communities are related to opportunities for dispersal, the environmental tolerances of dominant species and the modifying effects of river regulation. Fish communities in lakes exhibited less seasonal variation than riverine communities within the same catchment, indicating the greater seasonal stability of lakes compared with regulated and unregulated river reaches. Management of fish resources needs to include catchment-specific strategies within current State and basin-wide management programmes.

123. Godinho, H. P., A. L. Godinho, P. S. Formagio and V. C. Torquato (1991). Fish ladder efficiency in a southeastern Brazilian river. Ciencia e Cultura. **43**:63-67.

Fish were captured in the fish ladder of the Salto do Morais hydroelectric dam on the Tijuco River, part of the upper Parana basin, in the state of Minas Gerais, in order to evaluate their capacity to move up the ladder steps. The ladder has 25 steps (tanks), 78.3 m long and 10.8 m high. Over 41 species were captured in the region of the Salto do Morais dam, at least 34 of which were present in the ladder. However, there were few individuals of each species and only 2% of them reached the upper section of the ladder. This suggests that the ladder is selective for certain species, the most affected being the Pimelodidae family.

124. Gollmann, G., Y. Bouvet, R. M. Brito, M. M. Coelho, M. J. Collares-Pereira, A. Imsiridou, Y. Karakousis, E. Pattee and C. Triantaphyllidis (1998). Effects of river engineering on genetic structure of European fish populations. Pages 113-126 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Populations of cyprinid fishes from several rivers in Portugal -- *Chondrostoma polylepis*, France European chub *Leuciscus cephalus*, roach *Rutilus rutilus*, Austria nase *Chondrostoma nasus*, *R. rutilus* and Greece *L. cephalus* -- were investigated by allozyme electrophoresis to assess the effects of river engineering on their genetic diversity. No effects of dams on genetic variability were apparent in most places; this may be explained either by the permeability of dams to fish dispersal, by recent dates of isolation, and/or by the fact that the populations were large enough for genetic drift not to take place. However, a change in genotype structure caused by the dams may be suspected in the Lower Rhone. The chub and roach populations of the reservoirs and residual flow stretches show affinity with upstream lentic populations and not with upstream lotic populations as would be expected according to the mean gradient of their habitats. They are unstable populations in which extinction and colonisation from lentic upstream habitats presumably determine genetic structure.

125. Gowan, C., M. K. Young, K. D. Fausch and S. C. Riley (1994). Restricted movement in resident stream salmonids: A paradigm lost? Canadian Journal of Fisheries and Aquatic Sciences. **51**:2626-2637.

The restricted movement paradigm (our term) hold that resident stream salmonids are sedentary. Numerous studies have supported the restricted movement paradigm, but nearly all have relied on the recapture of marked fish from the same areas in which they were released, an approach we believe is biased against detecting movement. Substantial movement was found of trout in streams in Colorado and Wyoming using two-way weirs and radio telemetry. A review of the research on Lawrence Creek, Wisconsin, also showed that movement was important in the response of the trout population to habitat enhancement. Movement of resident stream fish has profound implications for research and management.

126. Grady, J. M. and G. A. Conover (1998). Mississippi River Basin paddlefish research coded-wire tagging project - 1997 Annual Report. Mississippi Interstate Cooperative Resource Association, MICRA Annual Report.

The Mississippi Interstate Cooperative Resource Association (MICRA) planned, organized, and initiated a long-term, multi-state, multi-jurisdictional paddlefish study to assess the status of paddlefish stocks throughout the Mississippi River Basin in 1994.

Two previous Interim reports contained information regarding fish tagging efforts in 1995 (Oven and Fiss 1996) and tag reading and database construction (Bettoli and Brennan 1997). This report summarizes progress made through 1997. MICRA participants participated in 420 sampling trips in 1996 and 1997 resulting in about 10,400 hours of effort. Biologists captured, tagged, and released 2,455 wild paddlefish in 1996 and 2,244 fish in 1997. More hatchery reared paddlefish were released to date in 1997 (127,743) than in 1996 (113,306). The total number of hatchery paddlefish released by MICRA cooperators is 437,022. Through January 1997, 701 paddlefish released by MICRA cooperators have been recaptured. Dossiers on each recaptured paddlefish were completed and provided to MICRA cooperators. Care and maintenance of the paddlefish databases were transferred from Tennessee Technological University to the U.S. Fish and Wildlife Service in March 1998. Changes in datasheet protocols were made after consultation with MICRA cooperators and are presented in Appendix B.

127. Graham, K. (1997). Contemporary status of the North American paddlefish, *Polyodon spathula*. Environmental Biology of Fishes. **48**:279-289.

North American paddlefish, *Polyodon spathula*, were once abundant in most large rivers and tributaries of the Mississippi River basin, but numbers have declined dramatically in most areas during the past 100 years. habitat destruction and river modification are the most obvious changes affecting their distribution and abundance. Although peripheral range has dwindled, paddlefish still occur over most of their historic range and are still found in 22 states. Populations are currently increasing in 3 states, stable in 14, declining in 2, unknown in 3, and extirpated in 4. Sport harvests presently occur in 14 states, however two states with traditionally important sport fisheries report decreased recruitment into the population and are planning more restrictive regulations. Commercial fisheries are reported in only six states. During the past 10 years, five states have removed paddlefish from their commercial list primarily because of declines in adult stocks due to overfishing or illegal fishing. Ten states are currently stocking paddlefish to supplement existing populations or to recover paddlefish populations in the periphery of its native range.

128. Grande, R. and D. Matzow (1998). A new type of fishway in Norway: how a regulated and acidified river was restored. Pages 236-245 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

To reduce the negative effects of a hydroelectric plant, a fish pass Facility was constructed at Rygenefossen, a 23 m-high waterfall on the Nidelva River at Arendal. The power plant, with a 6 m-high dam, is located on the upper portion of the waterhall. The fishway consists of a pool-and-weir pass in the lower part of the waterfall, linked to a pressure-chamber fishway (a kind of fish lock) in the dam. Between the dam and the powerhouse downstream, there is a 2 km-long residual flow stretch. Fishways were also built at three weirs within this residual flow stretch. The pressure-chamber fishway is new for Norway. Fish swim into a chamber at the base of the dam and when a sufficient number have entered, a diffuser closes and the pressure is increased to equal that found upstream of the dam. Another diffuser opens giving the fish access to a duct leading to the river above the waterfall. The system was constructed to take Atlantic salmon Salmo salar and sea-run brown trout S. trutta past the dam. Four years of trials have given positive results. This chapter describes the construction of this pressure-chamber fishway, how it works and our operating experience so far.

129. Gregoire, A. and F. Travade (1987). [EDF's experience relating to fish ladders and efficiency follow-up]. Pages 65-72 *in* Definition and Efficiency Controls of Fishways, Paris (France), Houille Blanche.

Since 1982, and in accordance with the provisions of the EDF/Environment Ministry/Energy State Secretariat agreement, EDF contributed to the national effort made to re-establish migrating fish populations, by providing measures intended to facilitate the crossing of a certain number of dikes. Currently, many undertakings have been completed. Amongst the main ones are those at Belleville in the Loire, at Bergerac in the Dordogne, at Poutes in the Haut-Allier and the fish lift in the Garonne and whose downstream part is currently in operation. Some research and follow-up activities concerning the effectiveness of these works are also being carried out.

130. Gurram, S. K. and T. Pohjamo (1999). Hydraulic assessment of a fish and boat pass channel. International Journal on Hydropower and Dams. **6**:65-67.

A concept has been proposed to combine a fishway and a boat channel at narrow sites where two separate channels cannot be constructed. This article describes the results of model and prototype studies of the combined channel structure recently built at Evijarvi, in central Finland. The baffles were designed to reduce the water velocities on the sides and bottom of the channel by reflecting the water current back on itself, so that both fish and boats can ascend the channel.

131. Gutreuter, S. (1992). Systemic features of fisheries of the Upper Mississippi River system: 1990 fisheries component annual report. United States Geological Survey, Report EMTC-92/T001.

During 1990, the fisheries component of the Long Term Resource Monitoring Program (LTRMP) conducted standardized sampling in Pools 4, 8, 13, and 26 of the Upper Mississippi River and La Grange Pool of the Illinois River. Fixed sampling sites from up to nine habitat classes were surveyed by seining, small 'minnow' fyke netting, electrofishing, fyke netting, and hoop netting during two fish community sampling time periods (June 25 to August 3 and August 1 to September 17) and three special efforts to sample black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and sauger (*Stizostedeon canadense*). Differences in fish community structure across pools and habitat classes were tested using multivariate analysis of variance models fitted to data from each sampling gear.

132. Gutreuter, S. (1997). Fish Monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990-1994. United States Geological Survey, Report LTRMP-97-T004.

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System (UMRS) conducts highly standardized monitoring of fishes in Pools 4, 8, 13, and 26, in a segment of the unimpounded Mississippi River, and in the La Grange Pool of the Illinois River. The mission of the LTRMP is to provide decision makers with information for managing the UMRS as a sustainable large river ecosystem given its multiple-user character. In the report, the author summarizes the initial 5 years of fish monitoring by the LTRMP. The report documents temporal variability that will be

critical to interpretation of future events and trends (consistent temporal changes), and documents important spatial patterns.

133. Gutreuter, S., R. W. Burkhardt, M. Stopyro, A. Bartels and E. Kramer (1997). Annual Status Report, 1992. A Summary of Fish Data in Six Reaches of the Upper Mississippi River System. Long Term Resource Monitoring Program. United States Geological Survey, Report LTRMP-97-P006.

The Long Term Resource Monitoring Program (LTRMP) completed 2,221 collections of fishes from stratified random and permanently fixed sampling locations in six study reaches of the Upper Mississippi River System during 1992. Collection methods included day and night electrofishing, hoop netting, fyke netting (two net sizes), gill netting, seining, and trawling in select aquatic area classes. The six LTRMP study areas are Pools 4 (excluding Lake Pepin), 8, 13, and 26 of the Upper Mississippi River, an unimpounded reach of the Mississippi River near Cape Girardeau, Missouri, and the La Grange Pool of the Illinois River. A total of 56-70 fish species were detected in each study area. For each of the six LTRMP study areas, this report contains summaries of: (1) sampling efforts in each combination of gear type and aquatic area class, (2) total catches of each species from each gear type, (3) mean catch- per-unit of gear effort statistics and standard errors for common species from each combination of aquatic area class and selected gear type, and (4) length distributions of common species from selected gear types.

134. Gutreuter, S., R. W. Burkhardt, M. Stopyro, A. Bartels and E. Kramer (1997). Annual Status Report, 1993. A Summary of Fish Data in Six Reaches of the Upper Mississippi River System. Long Term Resource Monitoring Program. United States Geological Survey, Report LTRMP-97-P008.

The Long Term Resource Monitoring Program (LTRMP) completed 1,994 collections of fishes from stratified random and permanently fixed sampling locations in six study reaches of the Upper Mississippi River System during 1993. Collection methods included day and night electrofishing, hoop netting, fyke netting (two net sizes), gill netting, seining, and trawling in select aquatic area classes. The six LTRMP study reaches are Pools 4 (excluding Lake Pepin), 8, 13, and 26 of the Upper Mississippi River, an unimpounded reach of the Mississippi River near Cape Girardeau, Missouri, and the La Grange Pool of the Illinois River. A total of 62-78 fish species were detected in each study reach. For each of the six LTRMP study reaches, this report contains summaries of: (1) sampling efforts in each combination of gear type and aquatic area class, (2) total catches of each species from each gear type, (3) mean catch- per-unit of gear effort statistics and standard errors for common species from each combination of aquatic area class and selected gear type, and (4) length distributions of common species from selected gear types.

135. Gutreuter, S., R. W. Burkhardt, M. Stopyro, A. Bartels and E. Kramer (1998). Annual Status Report, 1991. A Summary of Fish Data in Six Reaches of the Upper Mississippi River System. Long Term Resource Monitoring Program. United States Geological Survey, Report LTRMP-98-P001.

The Long Term Resource Monitoring Program (LTRMP) completed 2,053 collections of fishes from permanently fixed sampling locations in six study reaches of

the Upper Mississippi River System during 1991. The six LTRMP study areas are Pools 4 (excluding Lake Pepin), 8, 13, and 26 of the Upper Mississippi River, an unimpounded reach of the Mississippi River near Cape Girardeau, Missouri, and the La Grange Pool of the Illinois River. For each of the six LTRMP study areas, this report contains summaries of: (1) sampling efforts in each combination of gear types and aquatic area class, (2) total catches of each species from each gear type, (3) mean catch-per-unit of gear effort statistics and standard errors for common species from each combination of aquatic area class and selected gear type, and (4) length distributions of common species from selected gear types.

136. Haag, W. R. and M. L. Warren, Jr. (1997). Host fishes and reproductive biology of 6 freshwater mussel species from the Mobile Basin, USA. Journal of the North American Benthological Society. **16**:576-585.

Host fishes were identified for 6 species of freshwater mussels (Unionidae) from the Black Warrior River drainage, Mobile Basin, USA: *Strophitus subvexus*, *Pleurobema furvum*, *Ptychobranchus greeni*, *Lampsilis perovalis*, *Medionidus acutissimus*, and *Villosa nebulosa*. Hosts were determined as those that produced juvenile mussels from glochidial infestations in the laboratory. The following mussel-fish-host relationships were established: *Strophitus subvexus* with 10 species including Cyprinidae, Catostomidae, Fundulidae, Centrarchidae, and Percidae; *Pleurobema furvum* with *Campostoma oligolepis*, *Cyprinella callistia*, *C. venusta*, *Semotilus atromaculatus*, and *Fundulus olivaceus*; *Ptychobranchus greeni* with *Etheostoma bellator*, *E. douglasi*, *Percina nigrofasciata*, and *Percina sp. cf. caprodes*; *Lampsilis perovalis* with *Micropterus coosae*, *M. punctulatus*, and *M. salmoides*; *Medionidus acutissimus* with *Fundulus olivaceus*, *Etheostoma douglasi*, *E. whipplei*, *Percina nigrofaciata*, and *Percina sp. cf. caprodes*; and *Villosa nebulosa* with *Lepomis megalotis*, *Micropterus coosae*, *M. punctulatus*, and *M. salmoides*. *Fundulus olivaceus* served as hosts for 3 species and carried glochidia for long periods for 2 other species, suggesting that topminnows may serve as host for a wide variety of otherwise host-specialist mussel species. Host relationships for the species tested are similar to congeners. Methods of glochidial release, putative methods of host-fish attraction, and gravid periods are described for the 6 species.

137. Hackney, P. A. (1986). Research and development of fish passage technology. Tennessee Valley Authority, Report TVA/ONRED/WRF-8.

Any fish passage provided at TVA's John Sevier Fossil Plant (JSF) would involve only warmwater species. Although some anadromous (marine) warmwater species (e.g., American shad, blueback herring) are currently passed upstream and downstream through structures deliberately built for that purpose, effectiveness of this technology for passage of adults and young of potential target species (e.g., paddlefish and sauger/walleye) in Cherokee Reservoir is unproven. Downstream passage is by far the larger and more poorly understood subject of fish migration and should be investigated first. Currently, the Electric Power Research Institute (EPRI) is conducting research on downstream fish passage (Project RP 2694). It will ultimately be necessary to adapt this information to the target species and site specificity at JSF (DBO).

138. Hall, A. S. (1972). Migration and metabolism in a temperate stream ecosystem. Ecology. **53**:585-604.

Fish migration, total stream metabolism, and phosphorus were studied in New Hope Creek, North Carolina, from April 1968 to June 1970. Upstream and downstream movement of fish was monitored using weirs with traps. Most of the 27 species had a consistent pattern of larger fish moving upstream and smaller fish moving downstream. Diurnal oxygen series were run to measure the metabolism of the aquatic community. Gross photosynthesis ranged from 0.21 to almost 9 g O_2 m^{-2} day^{-1}, and community respiration from 0.4 to 13 g O_2 m^{-2} day^{-1} (mean of 290 and 479 g O_2 m^{-2} day^{-1}). Both were highest in the spring. Production per volume and respiration per volume were always much larger near the headwaters than farther downstream, apparently due to the dilution effect of the deeper water downstream. Migration may maintain young fish in areas of high productivity. Other effects of migration may include: prey control, recolonization of defaunated regions, genetic exchange, and mineral distribution. An energy diagram was drawn comparing energies of isolation, leaf inputs, currents, total community respiration, fish populations, and migrations. About 1% of the total respiration of the stream was from fish populations, and over 1 year about 0.04% of the total energy used by the ecosystem was used for the process of migration. Each calorie invested by a fish population in migration returns at least 3 calories. Analysis of phosphorus entering and leaving the watershed indicated that flows were small relative to storages and that this generally undisturbed ecosystem is in approximate phosphorus balance. Upstream migrating fish were important in maintaining phosphorus reserves in the headwaters.

139. Hammer, C. (1995). Fatigue and exercise tests with fish. Comparative Biochemistry and Physiology, A. **112A**:1-20.

The terminology and classification of swimming speeds are summarized. The physiological basis for the classification of swimming speeds is briefly explained with regard to burst, prolonged, cruising speed, and the velocity which is critical to fish. The protocols of fixed (fatigue) velocity tests and increased (incremental) velocity tests are reviewed. The experiments carried out by different authors are compared with respect to their methodological approaches, the main focus being on the different time intervals and velocity increments employed. From the comparison, it appears that time intervals between 2 and 75 min have been employed. Yet, it is shown that there is agreement that time intervals of longer than 15-20 min are not necessary if the critical velocity alone is needed. The dependency of the critical swimming speed (CSS) on factors such as race and population, size, season and temperature, sex, pollutants, light, food, training, and ambient gas content is outlined. The comparison shows that only the influence of pollutants and training on the CSS have been investigated in more detail, making further comparative studies on the dependence of the critical velocity on these factors necessary. Evaluation: since the CSS of fish depends on all these factors, it would appear to be a very sensitive measure for environmental or physiological factors. However, it is difficult to compare even intraspecific studies because of the individual variability and the dependence of swimming performance on the stock, population, gender and precondition level, making the calibration of the tests very complicated. It is shown that little is known about the mechanistic influence of internal or external factors on the CSS. Therefore, the CSS is of less interest for the physiologist than for the ecologist. Tests on the critical velocity have been successfully employed as an alternative to LD_{50} tests, although, once again, it is difficult to standardize the tests, and environmental factors, such as pollutants, may themselves influence the swimming performance since the metabolism can, in turn, in some cases depend upon the level of swimming performance itself.

140. Harden-Jones, F. R. (1968). Fish Migration. Edward Arnold Publishers, Ltd., London (England).

The author pursues a treatment of the biological aspects of migration in this early classical book on migration in fishes. Treatment is provided both environmental factors affecting migration as well as physiological adaptations that permit and aid fish migration. Means by which to study migration in fishes are presented and elucidated fully. The author then provides several "case history" examples of migration in fishes by discussing Salmonid, Anguillid, and Clupeid migrational strategies as anadromous examples. Two Gadiid examples, the cods and the plaice, are presented as examples of oceanic migration. Reactions to external stimuli, including temperature, current, chemical, and light, are presented based on findings from many scientific studies, both lab and field-based.

141. Haro, A. and B. Kynard (1997). Video evaluation of passage efficiency of American shad and sea lamprey in a modified ice harbor fishway. North American Journal of Fisheries Management. **17**:981-987.

Movement and behavior of adult American shad *Alosa sapidissima* and sea lamprey *Petromyzon marinus* were monitored by closed-circuit video at several locations within a modified Ice Harbor fishway. American shad ascended and descended the fishway exclusively by surface weirs, while sea lampreys used both surface weirs and submerged orifices. Upstream movement of American shad during the day was higher than at night at both lower and middle fishway observation sites. Peak downstream movement of American shad at both locations was associated with decreasing light levels in the evening. Sea lampreys moved primarily at night at the lower and middle fishway sites. Mean daily passage efficiency was low (1% for American shad, -2% for sea lamprey) at the lower fishway surface weir, but passage efficiency at the middle fishway surface weir was moderate (70% for American shad, 35% for sea lamprey). High water velocity, air entrainment, and turbulence of the modified Ice Harbor fishway design appeared to inhibit American shad and sea lamprey passage by disrupting upstream migratory motivation and visual and rheotactic orientation.

142. Haro, A., M. Odeh, T. Castro-Santos and J. Noreika (1999). Effect of slope and headpond on passage of American shad and blueback herring through simple Denil and deepened Alaska steeppass fishways. North American Journal of Fisheries Management. **19**:51-58.

Passage and transit time of adult upstream-migrant American shad *Alosa sapidissima* and blueback herring *A. aestivalis* were investigated in standard Denil and Alaska steeppass fishways with variable slope and headpond under semicontrolled conditions. Percent of American shad passed per unit time (percent passage) increased with temperature, while time required to ascend from the fishway entrance to the exit (transit time) decreased with increasing temperature for both species. Increasing fishway slope decreased percent passage of American shad, regardless of fishway type. Higher fishway slope decreased percent passage of blueback herring in the steeppass fishway only. Low headpond enhanced percent passage of American shad in the Denil fishway, but decreased percent passage of American shad in the steeppass fishway. Headpond level had no effect on percent passage of blueback herring in either fishway. Because headpond level in the steeppass fishway affected percent passage of American shad but

not the smaller blueback herring, the relatively small cross-sectional area of the steeppass fishway operated at low headpond may inhibit passage of larger species such as American shad. Transit time of American shad decreased with both increasing slope and high headpond, and American shad increased through-water swimming speed under these conditions. American shad appeared to regulate their swimming speed through Denil-type fishways below maximal values. Blueback herring ascended the fishways at speeds comparable to those of American shad. Shorter transit times were not associated with increased percent passage. Turbulence and air entrainment may influence percent passage of American shad more than longitudinal water velocity.

143. Haro, A., M. Odeh, J. Noreika and T. Castro-Santos (1998). Effect of water acceleration on downstream migratory behavior and passage of Atlantic salmon smolts and juvenile American shad at surface bypasses. Transactions of the American Fisheries Society. **127**:118-127.

Behavior and passage rate of smolts of Atlantic salmon *Salmo salar* and juvenile American shad *Alosa sapidissima* were compared between a standard (sharp-crested) and a modified surface bypass weir that employs uniform flow velocity increase (1 m s^{-1} m^{-1} of linear distance). Within the first 30 min after release, significantly more smolts passed the modified weir than the standard weir, but no differences in passage rate between weir types were noted for juvenile American shad. More Atlantic salmon smolts and juvenile American shad were passed by the modified weir in groups of two or more than were passed by the standard weir. Mean lengths of passed and nonpassed smolts were not significantly different between weir types, but American shad passed by the sharp-crested weir were significantly smaller than nonpassed fish. Most individuals of both species that passed the modified weir maintained positive rheotaxis and strong swimming throughout the length of the weir. In addition to acceleration, visual cues may be an important factor in avoidance behaviors near bypass entrances. The observed reduction of delay time before passage and maintenance of school integrity may facilitate appropriate timing of emigration and enhance passage survival.

144. Harris, J. H. (1984). Impoundment of coastal drainages of south-eastern Australia, and a review of its relevance to fish migrations. Australian Zoologist. **21**:235-250.

A study was carried out to estimate the proportion of the freshwater fish habitat in coastal drainages of south-eastern Australia that has been affected by stream impoundments. The results indicated that fish passage in about half of the aquatic habitat of Australia's south-eastern coastal drainages has been obstructed by dams, weirs and other man-made physical barriers. Migratory patterns of the region's fish species were reviewed. Ways in which impoundments affect the 26 species that were identified as migratory are discussed in relation to the ability of fish to bypass barriers, the nature of their migrations, and the role of flooding. The presence of about eight catadromous species in the region creates a special problem in fish passage. It is concluded that there is cause for concern over the status of the region's fish populations and that there is a need for a much greater awareness of the nature and extent of this problem.

145. Harris, J. H. (1984). A survey of fishways in streams of coastal south-eastern Australia. Australian Zoologist. **21**:219-234.

A survey has identified 29 fishways on coastal streams of south-eastern Australia, between the Mary River in southern Queensland and Lakes Entrance in eastern Victoria. Only 9.2% of 293 dams and weirs and 23 causeways surveyed had provision for fish passage. Among 37 fish species native to the study area, about 70% require passage within river systems, either for survival or for maintenance of population abundance and distribution. Despite this need for fish passage, the behavioural responses and physiological limits of Australian fish that control their use of fishways are poorly known. Of the 29 fishways recorded, 18 were of two metres or less in height, and none was higher than eight metres. Design, maintenance and water flow deficiencies resulted in 23 fishways failing to provide suitable conditions for fish passage at the time of the survey.

146. Harris, J. H., G. Thorncraft and P. Wem (1998). Evaluation of rock-ramp fishways in Australia. Pages 331-347 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Most of Australia's freshwater fish species are considered migratory, and all have some requirement for movement within streams. Many fish in coastal drainages are catadromous, while inland-drainage species are commonly potamodromous. Declining populations have been linked with fish-passage obstruction through water-supply development, with thousands of instream barriers. Attempts to restore fish passage are inhibited by the large numbers of barriers, and by the high cost of established technical fishways. The need for low-cost fishways has led to a test of rock-ramps, which use large rocks in transverse ridges, creating pools and small falls, to mimic stream riffles. Twelve rockramps have been built, generally sloping at 1:20. Some occupy only part of the width of the stream channel, but most are built full-width. Problems encountered included structural movement in unsupported ramps, excessive head losses, and fish missing the entrance of partial-width ramps. To assess the effectiveness of four rock-ramps of up to 1.5 m head loss, we compared species representation and length frequencies among fish arriving at the base of the ramps with those caught at the upstream exit. Preliminary results show rockramp fishways can be cheaper than technical fishways, and can provide passage for the species and sizes of native fish examined.

147. Harvie, C. J. and B. M. Jessop (1990). Evaluation of designs of periodic count surveys for the estimation of escapement at a fishway. North American Journal of Fisheries Management. **10**:39-45.

Counts of the number of alewives *Alosa pseudoharengus* migrating through the fishway on the Gaspereau River, Nova Scotia, were used to evaluate the accuracy and precision of various sampling schemes for estimating the population mean (true mean count/sample unit (15 min)). High variability in counts within day and season required more intensive sampling than suggested by previous studies to estimate the population mean to within a given percent relative error. Stratification in some cases doubled or trebled the precision of the estimated mean relative to the mean obtained from simple random sampling, whereas systematic sampling produced no gain in precision. Stratification to reduce the number of sample units required for a given precision may reduce the power of a test to detect differences between annual estimates of population means, depending on their variances. The importance of these interrelated factors should be determined before a particular scheme and level of effort are chosen for sampling.

148. Hatch, D. R., J. K. Fryer, M. Schwartzberg, D. R. Pederson and A. Wand (1998). A computerized editing system for video monitoring of fish passage. North American Journal of Fisheries Management. **18**:694-699.

We designed and tested a videotape editing system that selected and removed video frames not containing fish images from source videotapes previously recorded in 24, 48, or 72 h time-lapse modes. The system, based on image-processing software and a personal computer, compressed videotapes of the passage of Pacific salmon *Oncorhynchus spp.* by 75% (plus or minus 6.8%). The system reduced the length of tape that had to be reviewed without significantly altering fish counts made from the tapes. Fish counts made from visual review of both the edited and source videotapes were similar (P = 0.925). Using stratified random sampling, we selected and edited a sample of 200 d of recordings made at five different locations. The combined location and time data formed a 1,890-d statistical population of fish passage. This sample of source tapes was stratified post hoc into three different categories of fish-passage densities, measured by the number of fish on every 24 h of recorded tape (<100, 100-400, and >400 fish/d). Source tape compression was inversely related to fish passage density. The editing system processed and compressed source videotape recordings representing 24 h of monitoring at a particular site in approximately 2 h. The system was simple to use and did not require operator attention during the automated editing process. The videotape editing system can make it easier, faster, and less expensive to review videotapes of migratory fish passage and is most useful at locations or during times when relatively few fish will be observed per day.

149. Haymes, G. T., P. H. Patick and L. J. Onisto (1984). [Attraction of fish to mercury vapor light and its application in a generating station forebay]. Internationale Revue der Gesamten Hydrobiologie. **69**:867-876.

Laboratory and field tests were conducted to determine the effectiveness of filtered mercury vapor lights in attracting fish with possible utilization in a fish conserving scheme at an electrical generating station. In laboratory tests, alewife demonstrated an attraction to the mercury vapor light which was associated with an increase in swimming activity. This response was maintained over a 48 hour period. When the filtered mercury vapor lights were utilized in association with a fish pump in the Nanticoke Generating Station forebay, juvenile gizzard shad and smelt were attracted to the pump area. Although there was variation with time of day, turbidity and lighting array; the results suggested that the number of fish passing through the pump increased when the mercury lights alone or when the mercury lights in association with a white strobe light were employed.

150. Heggenes, J. and T. Traaen (1988). Downstream migration and critical water velocities in stream channels for fry of four salmonid species. Journal of Fish Biology. **32**:717-727.

Fry of brown trout, Atlantic salmon, brook trout and lake trout were tested for downstream migration and critical velocities with a method of stepwise increasing water velocities. Each velocity was tested for 15 min before increase to the next step. Critical velocities for fry entering the free-feeding stage, defined as the stage when the fry has resorbed its yolk sac and will have to ascend from the bottom to catch food, were between it 0.10 and 0.25 m/sec, varying among individuals and depending on species and water temperature. Downstream displacement started at lower velocities. Lake trout had the lowest critical velocity. Temperature influenced swimming performance

considerably. On average, a 7 ^{o}C increase in temperature resulted in a 0.05 m/sec increase in critical velocity. The fry actively search out the low-velocity niches in the channels. Flow-sensitivity gradually decreases with fry development; when the fry had reached a length of 40 - 50 mm they were able to tolerate water velocities higher than 0.50 m/sec.

151. Helfrich, L. A., C. Liston, S. Hiebert, M. Albers and K. Frazer (1999). Influence of low-head diversion dams on fish passage, community composition, and abundance in the Yellowstone River, Montana. Rivers. **7**:21-32.

The influence of three low-head irrigation diversion dams on the fish communities in the middle Yellowstone River was examined by down- and upstream electrofishing and trammel net comparisons of fish distribution, relative abundance, and size-structure. Fish passage at Huntley and Intake dams was evaluated by mark-recapture techniques in July and September following maximum annual discharge. Catostomids and cyprinids dominated the fish community at all sites. Mean relative abundance (CPUE) ranged from 1.58 to 5.13 fish/min, but no significant differences were detected between sites. Shovelnose sturgeon (*Scaphirhynchus platorynchus*) were consistently more abundant in the trammel net and electrofishing collections downstream of Cartersville and Intake dams. Species richness ranged from 7 to 24, depending on site and sampling method, but did not differ between down- and upstream sites. Of 4,430 fish (37 species) marked downstream of Huntley Dam, 13 fish (7 species) passed upstream and 3 fish (2 species) of the 1,032 fish marked upstream passed downstream during high flows in June 1997. Of 4,080 fish marked downstream of Intake Dam, 17 fish (4 species) passed upstream in June 1998. Fish species (swimming ability) appeared to be related to dam passage, but fish size was not an important variable. Our results suggest that fish passage was feasible at individual dams at high flows for some species such as sauger (*Stizostedion canadense*), white sucker (*Catostomus commersoni*), goldeye (*Hiodon alosoides*), shorthead redhorse (*Moxostoma macrolepidotum*), walleye (*Stizostedion vitreum*), and carp (*Cyprinus carpio*). However, the six dams in series on the Yellowstone River represent a cumulative fish passage challenge that, in combination, may ultimately restrict fish distributions and limit abundance, especially during low flows in dry years. Enhancing natural bypass channels and constructing artificial riffles may be useful strategies for promoting fish passage at low-head dams.

152. Hendershot, R. G., W. C. Acker and R. D. Sullivan (1984). Doppler techniques applied to fisheries hydroacoustics. Pages 15-20 *in* Oceans '84 Conference Record: Industry, Government, Education. Designs for the Future, Washington, DC (USA), ???

Fisheries management agencies are in need of better technologies to monitor the runs of migratory species in free-flowing rivers. This paper describes a long-pulse 420 kHz riverine Doppler sonar designed to detect upstream migrating fish in shallow waters and to reject false targets and large reverberations from the surface and bottom. The use of Hanning-shaped long pulses (30 msec) results in good spectral separation between reverberations and Doppler-shifted echoes from upstream migrants. A correlation detector rejects certain classes of false targets by comparing shapes of the transmit pulse and Doppler-shifted echoes. The correlation detector also improves the system's range resolution. In field tests the system has provided an accurate run timing index of the spring 1983 sockeye salmon *Oncorhynchus nerka* run on the Quinault River in Washington State. Current research includes investigating bistatic configurations for

monitoring fish passage through specific regions and the use of echo integration techniques to sum the total energy in the received signal.

153. Hesse, L. W. (1987). Taming the wild Missouri River: What has it cost? Fisheries. **12**:2-9.

The most significant legislation that authorized the alteration of the Missouri River is reviewed from a fisheries position. An outline of the dollar costs to achieve change along the river shows that the U.S. taxpayer has spent more than $6 billion in the Missouri River Basin. Broad ecological concern about lost riverine resources is raised. Mitigation, management, or enhancement of riverine resources has not been successfully completed. Alternatives to impoundment and channelization were not adequately discussed, and the extent of environmental damage was unknown, unexpected, and unstudied at the time these projects were planned. There was sufficient latitude in congressional action after 1944 to have provided some safeguard, had these laws been interpreted with a concern for wildlife.

154. Hesse, L. W. (1994). The status of Nebraska fishes in the Missouri River, 3. Channel catfish (Ictaluridae: *Ictalurus punctatus*). Transactions of the Nebraska Academy of Sciences. **21**:73-87.

The average size of Missouri River channel catfish *Ictalurus punctatus* has declined. The percentage 10 years old or older is 4.8% compared with an unexploited population in which 32% are 10 years and older. From 1944 through 1988 commercial harvest declined as much as 64%. Total mortality was 37% at age 4 and 79% at age 5. The increased mortality occurred as they reached 13 inches and became fully recruited to the commercial fishery. Harvest statistics are not wholly reliable because reports are not verifiable and commercial fishers do not return fish tags. Harvest exceeded a reasonable limit for maximum sustained yield. Commercial minimum-size limits have been ineffective due to their design and because they are not easily enforced. Commercial catfishing was closed in action taken by the Nebraska Game and Parks Commission in November 1990 to take effect 1 January 1992. Since then the mean size has increased from 286 mm total length (TL) to 324 mm TL in 25.4-mm mesh net samples from the channelized section of the Missouri River, and the percentage of fish longer than 330 mm TL increased from 8% in 1987 to 44% in 1993.

155. Hesse, L. W. (1994). The status of Nebraska fishes in the Missouri River, 4. Flathead catfish *Pylodictis olivaris*, and blue catfish, *Ictalurus furcatus* (Ictaluridae). Transactions of the Nebraska Academy of Sciences. **21**:89-98.

Flathead *Pylodictis olivaris* and blue *Ictalurus furcatus* catfish in the Missouri River have been over-exploited. Commercial harvest of both species ended in 1992, but commercial fishing was only part of the problem. The percentage of flathead catfish longer than 407 mm total length is very low. The density of flathead catfish in the upper unchannelized Missouri River is 6 to 10% of the density in the lower unchannelized reach, and channelized section density is six times greater than unchannelized density. Tagging studies have revealed that the population of flathead catfish in the upper unchannelized reach consists of less than 1,000 individuals. Blue catfish have been nearly extirpated and should be listed as endangered in Nebraska's portion of the Missouri River. Overharvest, reduced turbidity, and the removal of large woody debris has caused

the reduced population density. Management must include restricted harvest, closed areas, protected size classes, increased turbidity, and restoration of a floodplain with seasonal flooding. In the near term, large trees from the river bottom or from communities near the river should be placed in the channel to enhance in-stream cover.

156. Hesse, L. W. (1994). The status of Nebraska fishes in the Missouri River. 6. Sauger (Percidae: *Stizostedion canadense*). Transactions of the Nebraska Academy of Sciences. **21**:109-122.

Saugers *Stizostedion canadense* were once common representatives of the Missouri River fish assemblage. Prior to channelization and impoundment, they comprised from 10 to 65% of the main channel big-river fish group. They utilized the slower side channels and backwaters seasonally for feeding, resting, and maturing, but the main channel was important for breeding habitat. Since the onset of channelization and impoundment, saugers have been reduced by as much as 98% in some areas, and the trend toward extirpation continues unabated today. Recovery of native sauger stocks will require a complete cessation of harvest, recovery of the natural hydrograph, recovery of sediment transport, recovery of snags and organic matter dynamics, and re-connection of cut-off side channel morphology.

157. Hesse, L. W. and G. E. Mestl (1993). The status of Nebraska fishes in the Missouri River. 1. Paddlefish (Polyodontidae: *Polyodon spathula*). Transactions of the Nebraska Academy of Sciences. **20**:53-65.

The mean larval paddlefish density was 60 times higher in the upper unchannelized section of the Missouri River in Nebraska compared to the lower unchannelized section, and was three times higher than the channelized section's density. Within the upper unchannelized section, 96.2% of the larvae were collected in the discharge of two tributaries, which lie in the lower one-third of the reach. Survival from larval to young-of-the-year stage (June through August) was highest during 1991 due, in part, to the recent drought. Reduced fluctuation of river stages occurred as a result of reduced runoff, which minimized the need to reduce discharge to prevent flooding in the lower basin. The mean weight of paddlefish captured during the 1991 snagging season increased from 6.89 kg in 1990 to 7.45 kg, while the mean length increased from 739 mm (eye-to-fork length) to 753 mm. The percentage of snagged paddlefish 10 years old or older decreased from 15.3% in 1990 to 9.5% in 1991.

158. Hesse, L. W., J. C. Schmulbach, J. M. Carr, K. D. Keenlyne, D. G. Unkenholz, J. W. Robinson and G. E. Mestl (1989). Missouri River fishery resources in relation to past, present, and future stresses. Pages 352-371 *in* Conference International Large River Symposium, Honey Harbour, Ont. (Canada), Canadian Special Publications of Fisheries and Aquatic Sciences.

Nearly one-third of the Missouri River has been impounded, one-third channelized, and the hydrologic cycle, including temporal flow volume and sediment transport, has been altered on the remainder. The floodplain along the lower one-third has been converted from riparian forest and prairie to agriculture. The changes in basin and floodplain physiography and channel morphology have reduced commercial fish harvest by more than 80% and are implicated in the demise of native species. In some instances nonnative fish have replaced endemic species in the mainstream reservoirs, where

breeding and maturing habitat for riverine species has been eliminated. Suggested solutions include a holistic approach to future research and management.

159. Hillegass, K. R. and M. C. Hove (1997). Suitable fish hosts for glochidia of three freshwater mussels: strange floater, ellipse, and snuffbox. Pages 14 *in* M. Olekszyn and M. Steingraeber, eds. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

Of 297 freshwater mussels species living in North America, 213 are either endangered, threatened, or of special concern. The identification of fish hosts is listed in the National Strategy for Freshwater Mussel Conservation as an urgent research objective. We conducted laboratory studies to determine suitable fish hosts for three species of freshwater mussels: strange floater *Strophitus undulatus*, ellipse *Venustaconcha ellipsiformis*, and snuff box *Epioblasma triquetra*. Various fish species were exposed to mussel larvae via artificial infestation. A fish was considered a suitable hosed when larval metamorphosis to the juvenile stage was observed. Juvenile strange floater were collected from five of seven species tested: largemouth bass, green sunfish, black bullheads, bluegills, and yellow perch. Of nine fish species exposed to ellipse glochidia, only blackside darters were suitable hosts. Snuff box glochidia metamorphosed on log perch and blackside darters. Host requirements for strange floater glochidia appeared to be quite general, whereas the ellipse glochidia were more selective. Species-specific molecular markers are being developed for use in the identification of glochidia collected from naturally infested fish.

160. Hoggarth, M. A. (1992). An examination of the glochidia-host relationships reported in the literature for North American species of Unionacea (Molluske: Bilvalvia). Malacology Data Net. **3**:1-30.

This was an extensive list of many of the parasite-host relationships from the literature. It is valuable for its inclusion of the methods of infestation in each case: natural, artificial, transformed, etc... (from Watters 1994).

161. Holland, L., D. Huff, S. Littlejohn and R. Jacobson (1984). Analysis of existing information on adult fish movements through dams on the Upper Mississippi River. U.S. Fish and Wildlife Service, National Fisheries Research Laboratory, U.S. Government Report 84(14):37.

This report provides input towards the completion of the final feasibility report and draft Environmental Impact Statements for hydropower development at Locks and Dams 5 and 8 of the Upper Mississippi River (UMR), scheduled for completion by September 1985. This report has the following objective: to compile, review, and analyze existing information on movements of adult fish through dams on the UMR from St. Anthony Falls to Lock and Dam 14. Secondary objectives include (1) identification of information gaps about adult fish movements and UMR fisheries in general that would prevent an accurate assessment of the impacts of small-scale hydropower development on UMR fisheries; and (2) identification of impact assessment techniques, approaches, and methods for obtaining the necessary data for an assessment of the impacts of small-scale hydropower development on UMR fisheries. This report provides pool-by-pool reporting of available adult fish movement information and makes recommendations on representative, important fish species for future studies.

162. Holland-Bartels, L. E. (1990). Physical factors and their influence on the mussel fauna of a main channel border habitat of the Upper Mississippi River. Journal of the North American Benthological Society. **9**:327-335.

The habitats of mussel species in a portion of the main stem of Navigation Pool 10 of the Upper Mississippi River were examined. Population composition, abundance, and sediment and current preferences were measured at 186 sites in the East Channel of the pool. Although total mussel abundance varied significantly as a function of sediment and current ($P <= 0.05$), abundance could be predicted in only 44% of sites by discriminant analysis models. Accurate prediction of abundance for most species also was poor. Species showed little discrimination in choosing main channel habitats, but could be broadly classified into species preferring fine to medium-fine sands (e.g., *Truncilla truncata* and *Potamilus alatus*) or coarser sands (e.g., *Lampsilis cardium* and *Truncilla donaciformis*). The endangered *Lampsilis higginsi* was found in a broad range of habitats similar to those occupied by many of the more common species, suggesting factors other than loss of adult habitat for the rarity of this species.

163. Holland-Bartels, L. E. and T. W. Kammer (1989). Seasonal reproductive development of *Lampsilis cardium, Amblema plicata plicata,* and *Potamilus alatus* (Pelecypoda: Unionidae) in the Upper Mississippi River. Journal of Freshwater Ecology. **5**:87-92.

Adult specimens of three species of freshwater mussels common to the Upper Mississippi River were examined histologically to determine seasonal patterns of development in gametogenesis and release of glochidia. Full maturation of gonadal materials in *Lampsilis cardium* (formerly *L. ovata ventricosa*), a long-term breeder, occurred when ambient river temperatures reached 24 to 26 ^{o}C, between late-July and early-August. By mid-August, glochidia were present in the marsupia. Glochidia were released from late-May through mid-June of the following year once water temperatures reached 20 ^{o}C. The long-term breeder *Potamilus alatus* demonstrated full gonadal maturation earlier than seen in *L. cardium* with reproduction completed by late-July (26 ^{o}C). Glochidia of *P. alatus* were released over a period similar to that observed for *L. cardium*, late-May through early-July of the following year. Fully mature *Amblema plicata plicata*, a short-term breeder, were collected from late-May through early-July (18 to 21 ^{o}C).

164. Hooli, J. (1988). [Studies in the fishway models]. Aqua Fennica. **18**:171-178.

In order to conduct field experiments of fishways, scale models were constructed in Keminmaa and at the Kirakkakongas hydropower plant. The models were made for a fishway with vertical slots. The Kirakkakongas model was 30 m long with a vertical ascent of 2 m. The Keminmaa model was made on a scale of 1:4. The ascent behavior of fish was studied at discharges of 30-100 L/s. The depth of the basins was 30-60 m. The Keminmaa model allowed evaluation of different experimental designs, measuring equipment, and the methodology of fish behavior experiments. The Kirakkakongas model made it possible to carry out parallel and more detailed experiments. At Karakkakongas most fish swam up to the lower basin from the entrance downstream, in which the flow was strengthened by the flow from the lower channel. The flow velocity was 0.3-1.5 m/s, depending on the magnitude of the discharge used in the mouth of the fishway. In the Kirakkakongas fishway, fish swimming behavior was significantly affected by the

temperature of the water and the flows in the basins and openings. At the lowest discharge (33 L/s), most fish swam up and at the highest (100 L/s) only a few swam up. At the lowest discharge it was possible to obtain flow conditions in the model in which whitefish of different sizes were able to swim without difficulty. The suitable flow rate greatly depends on the species for which the fishway has been designed. For trout and salmon the flow can be very strong but whitefish require a calmer flow. In the Keminmaa models the greatest proportion of the fish swam up the fishway when the water temperature was 16-19 ^{o}C. The origin of the fish did not affect their rising activity. The best discharge for whitefish in this fishway model was 25-35 L/s. At lower discharges the whitefish also rose well. At discharges over 35 L/s, the swimming was uncontrolled and only a few whitefish were able to swim up. The rising activity of whitefish increased towards autumn, although the water was still warm. Fish swam up most actively in the morning.

165. Hove, M. C., R. A. Engelking, E. R. Evers, M. E. Peteler and E. M. Peterson (1995). Suitable fish hosts of six freshwater mussels. Pages 57 *in* M. Sandheinrich, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

Most freshwater mussels (unionids) must briefly attach to a fish in order to complete their life cycle. Management of rare unionids frequently demands knowledge of their fish host(s). Studies were conducted in 1994 to determine suitable fish hosts of the following unionids: purple wartyback *Cyclonaias tuberculata*, creek heelsplitter *Lasmigona compressa*, fluted-shell *L. costata*, black sandshell *Ligumia recta*, cylindrical papershell *Anodontoides ferussacianus*, and squawfoot *Strophitus undulatus*. Suitable fish hosts were determined by artificially exposing fish to mussel glochidia and determining if they facilitated glochidia metamorphosis to the juvenile stage. Six fish species were infested with *C. tuberculata* glochidia, but only the yellow bullhead *Ameiurus natalis* served as a suitable host. Four of ten fish species tested were found to be suitable hosts for *Lasmigona compressa*: spotfin shiner *Cyprinella spiloptera*, slimy sculpin *Cottus cognatus*, black crappie *Pomoxis nigromaculatus*, and yellow perch *Perca flavescens*. Juvenile *Lasmigona costata* were collected from one (slimy sculpin) of four fish species tested. Of eight fish species tested, *Ligumia recta* glochidia completely metamorphosed only on bluegill *Lepomis macrochirus*. Six of eleven species tested were found to be suitable hosts for *S. undulatus* glochidia: spotfin shiner, fathead minnow *Pimephales promelas*, bluegill, largemouth bass *Micropterus salmoides*, yellow bullhead, and black bullhead *Ameiurus melas*. Juvenile *Anodontoides ferussacianus* were collected from aquaria holding spotfin shiner and black crappie. Stuidies in 1994 combined with earlier studies at the University of Minnesota have identified several previously unknown suitable fish hosts for a variety of unionids.

166. Hove, M. C., R. A. Engelking, E. M. Long, M. E. Peteler and L. A. Sovell (1994). Suitable fish hosts of three freshwater mussels from the St. Croix River, Minnesota. Pages 11 *in* T. Naimo, M. Sandheinrich, C. Theiling and N. Mundahl, eds. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

Most species of freshwater mussels must briefly parasitize a fish in order to complete their life cycle. Management of rare mussel species frequently demands knowledge of the mussel's fish host(s). Suitable fish hosts of *Cyclonaias tuberculata*, *Lasmigona costata*, and *Ligumia recta* were determined by artificially exposing fish

species to mussel glochidia and then determining if juvenile mussels were produced. Fifty-one fish species were infested with *C. tuberculata* glochidia, but only the yellow bullhead (*Ameiurus natalis*) and channel catfish (*Ictalurus punctatus*) served as hosts. Six of eight fish species tested were found to be suitable hosts for *Lasmigona costata*: bowfin (*Amia calva*), northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum*). Juvenile *Ligumia recta* were collected from only two (largemouth bass and walleye) of thirteen fish species tested. Suitable fish hosts identified for *C. tuberculata* and *Lasmigona costata* were previously unknown. This is the first time the walleye has been identified as a suitable host for *Ligumia recta*.

167. Hoxmeier, R. J. H. and D. R. DeVries (1996). Status of paddlefish in the Alabama waters of the Tennessee River. North American Journal of Fisheries Management. **16**:935-938.

The Alabama waters of the Tennessee River have historically contained abundant populations of paddlefish *Polyodon spathula*. During the later half of this century, overexploitation has reduced the number of paddlefish in the Tennessee River. We attempted to determine whether paddlefish populations in the Tennessee River within Alabama had recovered from this overexploitation since the implementation of a statewide moratorium in 1988. We failed to collect paddlefish after an effort of 346 gill-net-hours and 20 h of electrofishing pedal time from November 1993 through June 1994. Low abundance of paddlefish in the Tennessee River is likely the result of a combination of continuing commercial harvest in bordering states, loss of habitat, and slow recruitment due to a relatively old age at maturity. Recovery may require additional time, stocking, or both.

168. Hubley, R. C., Jr. (1963). Movement of tagged channel catfish in the Upper Mississippi River. Transactions of the American Fisheries Society. **92**:165-168.

Results from a tagging study on Mississippi River channel catfish from Bay City, WI to Lansing, IO are presented. Greater than 6100 individual fish were tagged, with returns coming from both recreational and commercial fisheries operating on the river. Five "batches" of fish were tagged. Some of the batches were released at the site of capture (residents) while others were re-located greater than 100 miles from the capture site (transplants). Resident fish movements were described as principally downstream. A majority of transplanted fish were reported to move upstream, in contrast to resident fish. No evidence of homing was observed. The effects of obstructions (dams) are discussed. The author reported that the locks and dams on the Mississippi River did not present obstacles to channel catfish movements within the river. Nearly a quarter of the recaptured fish had moved through one or more dams. No information of the directionality of passage through the dams is provided (e.g., upstream vs. downstream passage).

169. Hurley, P. J. (1932). Letter from the Secretary of War transmitting report from the Chief of Engineers on survey of the Mississippi River between Missouri River and Minneapolis, with a view to securing a channel depth of 9 feet at low water, with suitable widths. Washington D.C., U.S. Government Printing Office: 120.

Dear Mr. Speaker: I am transmitting herewith a report dated December 9, 1931, from the Chief of Engineers, United States Army, on survey authorized by the river and harbor act approved January 21, 1927, of "Mississippi River between Missouri River and Minneapolis, with a view to securing a channel depth of 9 feet at low water, with suitable widths," together with accompanying papers and maps. Sincerely yours, Patrick J. Hurley, Secretary of War.

170. Hurley, S. T., W. A. Hubert and J. G. Nickum (1987). Habitats and movements of shovelnose sturgeons in the Upper Mississippi River. Transactions of the American Fisheries Society. **116**:655-662.

Habitats and movements of shovelnose sturgeons *Scaphirhynchus platorynchus* in Pool 13 of the Upper Mississippi River were ascertained during April-September 1982 by radiotelemetry, drifted trammel net, and mark-recapture methods. The fish were mostly sedentary, but sometimes they moved up to 11.7 km/d. Most movements occurred in May and July and the fewest in April and June. Long-range movements up to 17 km were noted between activity centers (areas occupied for 3-93 d). Among 22 radio-tagged shovelnose sturgeons, eight showed homing behavior.

171. Iversen, T. M., B. Kronvang, B. L. Madsen, P. Markmann and M. B. Nielsen (1993). Re-establishment of Danish streams: Restoration and maintenance measures. Aquatic Conservation: Marine and Freshwater Ecosystems. **3**:73-92.

Prior to 1983 the Danish legislation concerning streams gave priority to drainage of water. The revision of The Watercourse Act gave balanced priority to drainage of water and environmental quality, focusing on an ecologically more appropriate maintenance practice and giving special provisions for stream restoration activities. Different measures of single structure restoration have been used, the most common being replacement of weirs, dams or other obstacles by rapids, establishment of salmonid spawning grounds, and installation of new or improved fish ladders. The most common stream channel restoration method is integrated use of a number of single structure measures. Establishment of a two-stage channel and re-opening of small piped streams have also been used. Stream valley restoration includes restoration of old meanders or establishment of a new sinuous channel and involves the adjacent riparian areas. The changed stream maintenance practice involves a new strategy for dredging and cutting of weeds and bank vegetation in order to minimize the ecological damage caused by keeping a reasonable discharge capacity. In 1990, environmentally acceptable weed-cutting was performed in 37% of all municipal streams and the bank vegetation was left uncut in a third of the streams. Similarly, more than half of the county streams were maintained using hand scythes and in 74% of the streams the bank vegetation was left uncut. Quantitatively, stream restoration has contributed little to the general improvement of Danish streams compared with changed maintenance practice. Stream restoration projects create public interest in the environmental quality of streams, but major improvements in the physical properties of Danish streams depend on future maintenance practice. Due to major changes predicted in Danish agriculture many riparian areas and wetlands will reappear and the natural or semi-natural physical properties of streams will be re-established by natural processes or changed in maintenance practice. However, there will still be large areas with intensive agriculture, where environmental and agricultural interests must be balanced. The Danish experience has shown that this is possible.

172. Jackson, G. A., C. E. Korschgen, P. A. Thiel, J. M. Besser, D. W. Steffeck and M. H. Bockenhauer (1984). Problems on the Upper Mississippi River and its tributaries: Need for a long-term resource monitoring program. Pages 325-344 *in* J. G. Wiener, R. V. Anderson and D. R. McConville, eds. Contaminants in the Upper Mississippi River: Proceedings of the 15th annual meeting of the Mississippi River Research Consortium, La Crosse, WI (USA), Butterworth Publishers.

This paper outlines a general plan for implementing a comprehensive and totally integrated long-term resource monitoring program on the Upper Mississippi River and its major tributaries. This program is to ensure the productivity of the fishery and wildlife resources, while maintaining its multiple-use character through a coordinated process of data collection, analysis and interpretation.

173. Jennings, C. A., H. Bolton, M. J.M. and S. T. Yess (1992). Status and distribution of paddlefish in the Upper Mississippi River. Pages 28 *in* J. Wlosinski and M. Dewey, eds. 24th Annual Meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium, Inc.

In July, 1989, the U.S. Fish and Wildlife Service was petitioned to list the paddlefish *Polyodon spathula* as a threatened species. Data on the status and distribution of paddlefish populations in the Upper Mississippi River needed to respond to the petition data were scarce or lacking. Thus, a mail survey was conducted to assess the distribution and status of paddlefish populations in the upper river. During the summer of 1990, 705 questionnaires were mailed to fishery scientists and commercial fishermen from the five states bordering the Upper Mississippi. Thirty seven percent of the questionnaires (260 of 705) were completed and returned. A significant portion of the respondents (59%) indicated that they have caught paddlefish in the Upper Mississippi River. Of those, about half had caught paddlefish rarely, and one-third had commonly or frequently caught paddlefish. Most paddlefish were found in navigation Pools 8, 10, 13, and 19. Fishery classification status ranged from commercial to protected for the five states surveyed. The results of this survey suggest that paddlefish populations in the Upper Mississippi River still occupy much of their historic range. Moreover, many of the fishery biologists surveyed believed that paddlefish populations in the Upper mississippi River are stable and may be increasing.

174. Jennings, C. A. and D. M. Wilson (1993). Spawning activity of paddlefish *Polyodon spathula* in the lower Black River, Wisconsin. Journal of Freshwater Ecology. **8**:261-262.

We present indirect evidence of successful paddlefish *Polyodon spathula* reproduction in 1989 and 1991 in the lower Black River, Wisconsin, about 5 km upstream of the confluence with the Upper Mississippi River. This is the first indication of successful reproduction by paddlefish at the northern end of its range in the central United States.

175. Jens, G. (1983). [Upstream migrations via fishways]. Fischwirt. **33**:9-11.

In the Mosel River (Germany, Fed. Rep.) two kinds of fishways exist since 20 years which differ concerning construction and current conditions. Comparative studies

had been made, mainly using *Alburnus alburnus* and *Rutilus rutilus*, to investigate the time needed for passage and the fraction of fish which migrated upstream.

176. Jens, G. (1988). [Do fish passes really make no sense?]. Fischwirt. **38**:3-7; 9-11.

Critical evaluation in favour of fish passes in Moselle River concerning methodical approaches and conclusions of some other investigators.

177. Jernejcic, F. (1986). Walleye migration through Tygart Dam and angler utilization of the resulting tailwater and lake fisheries. Pages 294-300 *in* Reservoir Fisheries Management: Strategies for the 80's, Bethesda, Maryland (USA), American Fisheries Society.

Fish populations in 1740-acre Tygart Lake, West Virginia and its tailwater were sampled to provide information needed to evaluate impacts associated with the addition of hydropower facilities to the Tygart Lake projects. Walleyes *Stizostedium vitreum vitreum* dominate the sport fishery of the lake and migrate through the dam, providing a major tailwater fishery. Anglers caught 6042 walleyes from the lake and 8724 from the tailwater during a 1-year period. Walleye fishing success was higher in the tailwater than in the lake (0.56 vs. 0.32 caught per hour). Walleye fishing success was highest during the fall in the lake but during the spring in the tailwater. Tag returns indicated a 6% exploitation rate for lake walleyes during a 15-month period. Tailwater walleyes experienced a 25% exploitation rate during a 7-month period. Nine percent of walleyes tagged in the lake were caught by anglers in the tailwater from December through March. Age-0 and Age-1 walleyes migrated through the dam more readily than older walleyes. Walleye migration occurred during the winter, December through April, at times when the pool elevation was decreasing at a rate of at least 6-ft per 24 hours.

178. Jessop, B. M. and C. J. Harvie (1990). Evaluation of designs of periodic count surveys for the estimation of escapement at a fishway. North American Journal of Fisheries Management. **10**:39-45.

Counts of the number of alewives *Alosa pseudoharengus* migrating through the fishway on the Gaspereau River, Nova Scotia, were used to evaluate the accuracy and precision of various sampling schemes for estimating the population mean (true mean count/sample unit (15 min)). High variability in counts within day and season required more intensive sampling than suggested by previous studies to estimate the population mean to within a given percent relative error. Stratification in some cases doubled or trebled the precision of the estimated mean relative to the mean obtained from simple random sampling, whereas systematic sampling produced no gain in precision. Stratification to reduce the number of sample units required for a given precision may reduce the power of a test to detect differences between annual estimates of population means, depending on their variances. The importance of these interrelated factors should be determined before a particular scheme and level of effort are chosen for sampling.

179. Jirka, K. J. and R. J. Neves (1992). Reproductive biology of four species of freshwater mussels (Mollusca: Unionidae) in the New River, Virginia and West Virginia. Journal of Freshwater Ecology. **7**:35-44.

The gametogenic cycle, spawning and glochidial release periods, and age at sexual maturity were determined for four unionid species from the New River in Virginia and West Virginia: musket, *Actinonaias ligamentina* ; spike, *Elliptio dilatata* ; purple wartyback *Cyclonaias tuberculata* ; and pistolgrip, *Tritogonia verrucosa* . The mucket is a long-term brooder, spawning in mid-summer, brooding glochidia throughout fall and winter, and releasing them in spring. The spike, purple wartyback, and pistolgrip are short-term brooders. Spawning began in mid-March and continued into May for *T. verrucosa* , into June for *C. tuberculata* , and into July for *E. dilatata* . Glochidia were release upon maturation, beginning in mid-April and continuing through June for *T. verrucosa* , into August for *E. dilatata* , and extending from March through June for *C. tuberculata*. All four species are sexually mature at 4 to 6 years of age.

180. Johnson, B. L., B. C. Knights, J. W. Barko, R. F. Gaugush, D. M. Soballe and W. F. James (1998). Estimating flow rates to optimize winter habitat for centrarchid fish in Mississippi River (USA) backwaters. Regulated Rivers: Research & Management. **14**:499-510.

The backwaters of large rivers provide winter refuge for many riverine fish, but they often exhibit low dissolved oxygen levels due to high biological oxygen demand and low flows. Introducing water from the main channel can increase oxygen levels in backwaters, but can also increase current velocity and reduce temperature during winter, which may reduce habitat suitability for fish. In 1993, culverts were installed to introduce flow to the Finger Lakes, a system of six backwater lakes on the Mississippi River, about 160 km downstream from Minneapolis, Minnesota. The goal was to improve habitat for bluegills and black crappies during winter by providing dissolved oxygen concentrations > 3 mg/L, current velocities < 1 cm/s, and temperatures > 1 ^{o}C. To achieve these conditions, we used data on lake volume and oxygen demand to estimate the minimum flow required to maintain 3 mg/L of dissolved oxygen in each lake. Estimated flows ranged from 0.02 to 0.14 m^3/s among lakes. Data gathered in winter 1994 after the culverts were opened, indicated that the estimated flows met habitat goals, but that thermal stratification and lake morphometry can reduce the volume of optimal habitat created. This article is a U.S. government publication and is in the public domain in the United States.

181. Johnson, B. L., W. B. Richardson and T. J. Naimo (1995). Past, present, and future concepts in large river ecology. Bioscience. **45**:134-141.

How rivers function and how human activities influence river processes. Many important questions are likely to require natural experiments or large-scale manipulations that compare rivers or river reaches.

182. Johnson, J. H. and N. H. Ringler (1995). Estimating losses to predation of recently released American shad larvae in the Juniata River, Pennsylvania. North American Journal of Fisheries Management. **15**:854-861.

Predation on recently released larval American shad *Alosa sapidissima* was quantified in the Juniata River, Pennsylvania, on 10 occasions during 1991 and 1992. Of the four sites examined (the stocking site and 100, 200, and 350 m downstream) predation on shad larvae was highest at the stocking site; 44% of the total estimated losses occurred within this 30-m zone. Percentage predation mortality was weakly and

inversely related to the number of shad larvae released, and it ranged from 0 to 2.2% among sites. Overall percent mortality of larvae within the first 2 h of release was about 5% (range, 2-10%). Major predators included juvenile smallmouth bass *Micropterus dolomieu*, the spotfin shiner *Cyprinella spiloptera*, and the mimic shiner *Notropis volucellus*. Predation by these species varied among sites. Percent mortality of American shad larvae after nocturnal releases (0.17%) was significantly lower than after diurnal releases (1.18%). For most predators, the length of shad eaten increased with predator length. However, among predators of similar size, there were significant differences in the length of shad consumed. Estimated losses to predation were about equally divided among small (<50 mm, 30%) medium (50-99 mm, 37%), and large (>99 mm, 33%) predators. Because 30% of the estimated number of shad larvae lost to predation were eaten by predators less than 50 mm long, releasing slightly larger shad might reduce predation.

183. Johnson, J. H., R. C. Solomon, C. R. Bingham, B. K. Colbert and W. P. Emge (1974). Environmental analysis and assessment of the Mississippi River 9-ft Channel Project between St. Louis, Missouri, and Cairo, Illinois. Army Engineer Waterways Experiment Station, Report Y-74-1.

The Mississippi River 9-ft channel project was authorized by the River and Harbor Acts of 1927 and 1930. The purpose of the project was to maintain navigation from the confluence of the Missouri River to the confluence of the Ohio River. The main channel will be contracted to 1500 ft between riverward ends of dikes throughout the area to maintain the 9-ft depth during periods of low flow. A comprehensive study of the historical geomorphology supplemented by physical models of the river and side channels was made to determine the physica impact of river contraction works on river morphology and behavior. An intensive study of the terrestrial flora and fauna was conducted to inventory the existing organisms and communities located in the unprotected floodplain and to assess the impacts of operation and maintenance activities. The aquatic flora and fauna were studied to inventory the aquatic communities present in the study area and to assess the importance of side channels to the riverine ecosystem. The relative biological importance of each side channel, established by ranking procedures, provided a rational choice of those side channels that could provide maximum benefit to the river 's ecology. Operation and maintenance activities include maintenance dredging, disposal of dredged material, and construction and maintenance of levees, dikes, and bank revetments. The mentioned activities were examined, and the potential environmental impacts resulting therefrom were discussed. (Adams-ISWS)

184. Jokela, J. and P. Palokangas (1993). Reproductive tactics in Anodonta clams: Parental host recognition. Animal Behaviour. **46**:618-620.

We studied the reproductive behaviour of a common European freshwater clam, *Anodonta piscinalis* Nills., a generalist with respect to habitat and range of hosts. In a laboratory experiment, we found that female clams released more glochidia when in the presence of a fish, suggesting that they recognized its presence. In a second experiment, clams responded positively but nonspecifically to tactile, chemical and visual stimuli that might indicate the presence of a fish.

185. Jokela, J., E. T. Valtonen and M. Lappalainen (1991). Development of glochidia of *Anodonta piscinalis* and their infection of fish in a small lake in northern Finland. Archiv fur Hydrobiologie. **120**:345-355.

The development of glochidia in *Anodonta* , their seasonal patterns of infection in four fish species and their infection in relation to length and sex of the host individual were studied in a small hyper-eutrophic lake in Northern Finland. Glochidia development took place from June to August and they were fully developed when the water temperature began to fall in autumn. The glochidia were stored in the gill blades to be released in spring. All four fish species, the perch *Perca fluviatilis*, roach *Rutilus rutilus*, pike *Esox lucius* and ruffe *Lota lota*, were infected in spring. The prevalence of infection of the perch was high throughout the infection period whereas the roach had a high prevalence of infection only at breeding season. The larger roach were infected more often than smaller ones.

186. Jones, D. R., J. W. Kiceniuk and O. S. Bamford (1974). Evaluation of the swimming performance of several fish species from the Mackenzie River. Journal of the Fisheries Research Board of Canada. **31**:1641-1647.

Critical velocities of 17 species of fish from the Mackenzie River had been determined from increasing velocity tests in both field and laboratory, and the effects on critical velocity of different acclimation temperatures and of temperature shock were examined. In five species the relation between fatigue time and swimming speed was investigated. Critical velocity data from 10 species were analyzed by solving the regression equation $V = KL^e$ (where V = critical velocity in cm/s, L = fork length, K = constant, e = exponent). Neither acclimation to different temperatures nor temperature shock over a range of +/- 7 ^oC from acclimation temperature had a significant impact on critical velocity. Intraspecific variation was found to be unrelated to maturity, sex, or condition factor. From a graphical presentation of body length vs. maximum flow rate allowable in a 100 m culvert, it appears that culvert flow rates should be kept below 30-40 cm/s to allow successful passage of the majority of mature individuals of migratory species.

187. Jonsson, N. (1991). Influence of water flow, temperature and light on fish migration in rivers. Nordic Journal of Freshwater Research. **66**:20-35.

Water flow, water temperature and light are environmental variables that influence when fish migrate and the intensity of the migration itself. These variables apply both to up- and downstream migration, but their effects may among rivers and species. During the ontogeny, migratory fish in different life history stages are transported downstream by the water flow. Changes in water flow may influence when the fish migrate. To be carried downstream, the fish must position themselves within the water column and actively swim of out sloughs and backwaters. High water discharge may stimulate the river ascent. Water temperature is an important factor initiating up- and downstream migrations of several fish species. In particular, this may be the case in rivers where freshets do not regularly occur at the time when the environmental shift is favourable. Migrations of juveniles and adults are mainly nocturnal, but sometimes diurnal. When the migration occurs during dark hours this is expected to be an adaptation to avoid visual predators.

188. Jowett, I. G. and J. Richardson (1994). Comparison of habitat use by fish in normal and flooded river conditions. New Zealand Journal of Marine and Freshwater Research. **28**:409-416.

Floods are often considered one of the major regulators of fish populations, but there are few observations of fish behaviour or habitat use at such times. To investigate habitat use and fish movement during floods, two locations on the Pohangina River, North Island, were sampled at the peak of a small flood. Habitat use at normal flows was determined by repeating the same sampling procedure in runs and riffles on the Pohangina and two nearby rivers. The sampling procedure was to electrofish runs and riffles in lanes, stratified by depth (0-0.125 m, 0.125-0.25 m, 0.25-0.5 m, and 0.5-0.75 m). Water depths and velocities were measured in each sampling lane. Fish were most abundant along the river margins less than 0.25 m deep, both during the flood and in normal flows. Two days after the flood, these shallow areas, that had been occupied by fish during the flood, were dry again. This suggests that the edge-dwelling fish species in these rivers respond quickly to flow changes, moving with the river margins to minimise any change in depth. Response to changes in velocity were less apparent and the water velocity in the areas occupied by edge-dwelling fish during the food was sub-optimal in terms of normal habitat preference. The response of fish to flow and habitat change and the use of sub-optimal habitat for short periods of time highlights the difficulty of interpreting a time series of weighted usable area.

189. Jude, D. J. (1997). Round gobies: Cyberfish of the third millennium. Great Lakes Research Review. **3**:27-34.

The problem of transport of non-indigenous species from one place to another transacts boundaries, jurisdictions, and most of the efforts of humans to contain them. A recent study by Mills et al. (1995) lists 139 species that have made a substantial impact on Great Lakes ecosystems and they include organisms from bacteria, such as furunculosis, through purple loosestrife *Lythrum salicaria* and Eurasian watermilfoil *Myriophyllum spicatum*, to fish. The transfer of these organisms was brought dramatically to the attention of businesses and the public with the discovery of zebra mussels *Dreissena polymorpha* in 1986 (Herbert et al. 1986) as water intakes became clogged, power plant pipes became plugged, and boats and motors became covered with this species. The homogenization of our aquatic communities, loss of biodiversity, and amalgamation of our gene pools because of the introduction of exotic species is a worldwide problem of which the round goby *Neogobius melanostomus* is just another symptom. The round goby *Proterorhinus marmoratus*, are our latest uninvited piscine immigrants joining Great Lakes fish communities. These fish are cyberfish, because they came from a distant universe and have the unusual ability to attain high abundances in optimal rocky substrate areas in the face of native fish communities and they also are able to disperse rapidly using Great Lakes freighters as transport vectors.

190. Jude, D. J. and G. Crawford (1995). Impact and expansion of the latest exotic fish invaders, the tubenose and round gobies. Pages 61 *in* I. A. f. G. L. Research, ed. 38th Conference of the International Association for Great Lakes Research, Ann Arbor, Michigan (USA), International Association for Great Lakes Research.

The round goby, first noted in 1990 in the St. Clair River, is now found in high abundances in Lake St. Clair, near the Grand River in Lake Erie, and near the Grand Calumet River in southern Lake Michigan. The round goby now has access to the

Mississippi River system via the Grand Calumet River. Tubenose gobies (a small fish <120 mm) have only been found in the St. Clair River and Lake St. Clair, and maintain small to rare populations there. The round goby is much larger (up to 300 mm), is a multiple spawner, feeds almost exclusively on a relatively unutilized resource, zebra mussels, when it is >60 mm, and occupies depths to 10 m, but prefers nearshore areas. It has decimated populations of mottled sculpin and apparently depressed those of logperch in the St. Clair River, probably by driving competing species from prime feeding, security, and spawning sites. Many piscine predators eat gobies. Gobies are ideally suited for freighter transport because: (1) they can feed in the dark, (2) prefer holes or crevices, and (3) can tolerate degraded water quality conditions. We expect them to continue to spread and severely disrupt benthic fish communities in rocky, cobble, and vegetated areas, with the potential to also affect deepwater sculpin.

191. Jude, D. J. and S. F. Deboe (1996). Possible impact of gobies and other introduced species on habitat restoration efforts. Pages 136-141 *in* J. R. M. Kelso, ed. Workshop on the Science and Management for Habitat Conservation and Restoration Strategies (HABCARES) in the Great Lakes, Ottawa, Ontario (Canada), Canadian Journal of Fisheries and Aquatic Sciences.

Many fish habitat modifications involve riprap placement on sandy substrate. Because exotic species may be favored, a field experiment was designed to test differences in fish abundance in riprap, sand, and macrophyte-dominated substrate. A 3-m long seine was used to sample areas of sand, riprap and aquatic macrophytes three times during 1994 in the St. Clair River near Algonac, Michigan. Diversity was high, with 24 species of fish collected. Round gobies *Neogobius melanostomus* were most often collected in riprap and macrophyte habitat, with riprap habitat having a significantly greater mean catch on 16 August. On the other two dates, mean catches were not significantly different between macrophyte and riprap habitat, but both were significantly greater than the mean catch in sandy areas. Densities of tubenose gobies *Proterorhinus marmoratus* were similar between sandy and macrophyte habitats, but significantly greater in riprap habitat. Gizzard shad *Dorosoma cepedianum*, alewife *Alosa pseudoharengus*, and white perch *Morone americana* were mostly associated with open water sandy habitat. Zebra mussels *Dreissena polymorpha* were common on riprap substrate but were rarely seen on sandy substrate.

192. Jude, D. J., R. H. Reider and G. R. Smith (1991). First evidence of Gobiidae in the Great Lakes basin. Pages 124 *in* ???, ed. The 34th Conference of the International Association for Great Lakes Research, Buffalo, New York (USA), International Association for Great Lakes Research.

A tubenose goby *Proterorhinus marmoratus*, a European endangered species native to the Black and Caspian Seas, was recovered on 11 April 1990 from the travelling screens of the Belle River Power Plant located on the St. Clair River, south of St. Clair, Michigan. Subsequently on 28 June, 18 July, and 23 September, a Canadian and two American anglers each caught a round goby *Neogobius melanostomus* in the St. Clair River near Sarnia, Ontario. Three tubenose gobies and four round gobies were impinged on the Belle River Power Plant screens in fall 1990, and 17 round gobies and 27 tubenose gobies were trawled from an area near the Belle River Power Plant intake structure on 30 November, and 12 and 17 December 1990. These species are believed to have been transported to the Great Lakes in ballast water. They are expected to directly impact other

benthic fishes, such as sculpins *Cottus spp.*, darters *Etheostoma spp.*, and logperch *Percina caprodes*, and in turn act as prey for walleye *Stizostedion vitreum*.

193. Jude, D. J., R. H. Reider and G. R. Smith (1992). Establishment of Gobiidae in the Great Lakes basin. Canadian Journal of Fisheries and Aquatic Sciences. **49**:416-421.

A tubenose goby *Proterorhinus marmoratus*, a European endangered species native to the Black and Caspian seas, was recovered on 11 April 1990 from the travelling screens of the Belle River Power Plant located on the St. Clair River, Michigan. Subsequently, anglers caught three round gobies *Neogobius melanostomus* in the St. Clair River near Sarnia, Ontario. Thirty-one tubenose gobies and 11 round gobies were impinged or trawled at or near the Power Plant in the fall and winter of 1990-91. Nine round gobies (29-61 mm total length) are believed to be young-of-the-year. These species were probably transported to the Great Lakes in ballast water, may have successfully colonized the St. Clair River, and will probably spread throughout the Great Lakes.

194. June, F. C. (1977). Reproductive patterns in seventeen species of warmwater fishes in a Missouri river reservoir. Environmental Biology of Fishes. **2**:285-296.

The timing of ovarian maturation and spawning of 17 warmwater fish species in Lake Oahe (South and North Dakota) was estimated from changes in the mean ovary indices (ratios of ovary weight to fish length). The onset of vitellogenesis varied within species (up to 2 months). Maturation of the ova took from 7 . 5 to 10 months, depending on species. Annual variations in the mean date of peak spawning of individual species during 1964-71 were usually less than a week. There was little overlap of the annual mean peak spawning dates of the 17 species, and an established sequence of spawning among species was shown. A relatively high incidence of atresia in the shovelnose sturgeon, northern pike, and carp indicated that these species had apparently not yet adapted to the altered and variable spawning conditions in this reservoir. Regularity of spawning would seem to provide the best chance for spawning success in variable environments such as Lake Oahe.

195. Jungwirth, M. (1996). Bypass channels at weirs as appropriate aids for fish migration in rhithral rivers. Regulated Rivers: Research and Management. **12**:483-492.

In most cases, the design of currently deployed migration aids is based on technical concepts, e.g fish ladders, fish lifts, etc. These systems meet the swimming and migratory requirements of commercially interesting species such as salmonids, but not of a smaller fish species and/or juvenile stages. In this context, bypass channels designed to resemble natural stream channels-with a comparatively flat gradient and a high morphological, current and substrate diversity-are a viable alternative. The utility of such systems, in compensating for the interrupted river course and in supporting migrations of various rhithral fish species, has been demonstrated in an investigation of a bypass channel on the Mur River in Styria, Austria. This 200 m long system with a total of 30 pools and riffle-like connections was successfully navigated by all seven existing fish species and was additionally used by juvenile fish as habitat. During the main spawning periods April - June and September-December, a total of 3,658 fish ascended the bypass, 94% of which did so in the spring. In the 5.5 km stretch of river below the weir, the grayling *Thymallus thymallus* was the dominant species. From an estimated population of 13300 adults, 17% migrated through the pass.

196. Jungwirth, M. (1998). River continuum and fish migration- going beyond the longitudinal river corridor in understanding ecological integrity. Pages 19-32 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

One of the central ecological problems of running water systems, which are subject to multiple uses and therefore suffer disproportionate damage worldwide in comparison to other ecosystems, is the fragmentation of the longitudinal corridor by weirs of hydroelectric power plants and other water engineering measures. Restoring previously interrupted migratory pathways of fishes using bypass systems is one potential approach, but simply passing fish generally tends to overestimate the 'feasibility' and ultimate success of amelioration strategies in the framework of river revitalisation projects. This chapter attempts to show that running waters are far more than mere longitudinal river corridors. Modern concepts of ecology describe running waters as complex, four-dimensional systems. While longitudinal river corridors represent an important dimension, they are merely one of numerous factors whose interactions define ecological integrity. The long-term preservation and sustainable utilisation of running water ecosystems can therefore only be achieved by fully considering all four dimensions that contribute to overall ecological integrity.

197. Jungwirth, M., S. Schmutz and S. Weiss, eds. (1998). Fish Migration and Fish Bypasses. Fishing News Books, Vienna (Austria).

The symposium Fish Migration and Fish Bypass Channels was held on 24-27 September 1996 by the University of Agricultural Sciences, Department of Hydrobiology Fisheries and Aquaculture in Vienna, Austria. The meeting was attended by a diverse group of engineers and biologists primarily involved in various aspects of fish passage design and evaluation, river restoration or the study of migratory fish. This publication contains the majority of the oral presentations in article format, together with some poster material extended into articles. Since the publication of Charles Clay's The Design of Fishyways and Fishpass Facilities in 1961, the joint efforts of hydraulic engineers and fishery biologists have led to tremendous improvements in the technical design and efficiency of a whole array of fish passage facilities, together with an increased understanding, at least for a handful of well-researched species such as anadromous salmonids, of the complexities of fish migration and behaviour important to fish passage. This research has reached perhaps its zenith in cost, scale and complexity with the passage facilities on a series of dams on the Columbia River in the north-western United States. Here, one can boast of passing adult salmon through a staircase of concrete and metal baffles, orifices and louvres with an elevation gain of 35 m across 1300 m of length in under 4 hours (Williams, Chapter 13).

198. Junk, W. J. (1999). The flood pulse concept of large rivers: learning from the tropics. Large Rivers. **11**:261-280.

River-floodplain systems are specific ecosystems with very complex land-water interactions and a highly adapted flora and fauna. In temperate zones, they have been intensively modified by man for many decades, and only small areas are left in a relatively undisturbed condition. Furthermore, the impact of the flood pulse is often camoflagued by the annual temperature/light pulse. In the humid tropics there are still

large undisturbed river-floodplain systems, where the impact of the flood pulse can be studied without the interference of the temperature/light pulse. The flood pulse concept is presented and its implications for temperate river-floodplain systems are discussed.

199. Junk, W. L., P. B. Bayley and R. E. Sparks (1989). The flood pulse concept in river-floodplain systems. Pages 110-127 *in* D. P. Dodge, ed. Proceedings of the International Large River Symposium, Canadian Special Publication of Fisheries and Aquatic Sciences.

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 levied and drained by man. Because low-order stream pulses are brief and unpredictable, 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 nutrients, thereby resulting in higher 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 production. 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.

200. Kanciruk, P. and C. H. Penington (1985). Hydroacoustic fishery assessment techniques: A feasibility study on the Mississippi River. U.S. Army Corps of Engineers Waterways Experimental Station, Technical Report WES/TR/E-85-10.

This study was initiated to evaluate the usefulness of hydroacoustic techniques in large, alluvial river systems. The hydroacoustic equipment evaluated operated at a frequency of 420 kHz and included down- and side-facing transducers, dual-beam echo integrators, and digital recording equipment operated in mobile and stationary surveys. It was found to be reliable, fairly easy to use (with adequate training), and provided information of fish abundance, distribution, and behavior patterns not easily attainable using conventional fishery assessment tools such as netting or electrofishing.

201. Kapasa, C. K. and I. G. Cowx (1991). Post-impoundment changes in the fish fauna of Lake Itezhi-tezhi, Zambia. Journal of Fish Biology. **39**:783-793.

The fish fauna of the newly inundated Lake Itazhi-tezhi, Zambia was observed between 1980 and 1985. Marked changes in the community structure were identified. The most obvious were a decline in species diversity and a shift in species composition from a community with a preponderance of *Alestes lateralis* (Boulenger) (Characidae), to one dominated by cichlids. These changes were primarily due to members of the families Cyprinidae, Mormyridae and Schilbeidae being unable to adapt to the new environmental conditions, such as spawning and feeding grounds, and their inability to cope with fluctuating water levels in the lake. It was suggested that a sound fishery data collection system be implemented to provide reliable information on which to base management policy.

202. Karp, W. A., P. Nealson, D. J. Lispi and Q. Ross (1987). Behavior of adult blueback herring migrating upstream through Lock 2 of the Erie Canal. Pages 556 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Copper, eds. International Symposium on Common Strategies of Anadromous and Catadromous Fishes, Seattle, Washington (USA), American Fisheries Society.

Hydroacoustic techniques were used to observe movement of adult blueback herring *Alosa aestivalis* immediately upstream and downstream of the first lock on the Erie Canal at Waterford, New York, in May 1985. Objectives were to document fish movements in response to lockages, to develop recommendations for modified lock operations, and to evaluate hydroacoustic techniques for monitoring fish passage. At the lower gates, estimates of fish passage into the lock increased with duration of opening. At the upper gates, a pulse of fish was generally observed to move out of the lock immediately after the gates opened, and duration of opening did not appear to influence rate of fish passage from the lock into the canal. Fish were observed to move downstream, away from the lock gates, to avoid turbulence created by water dumping during the initial stages of drawdown.

203. Karr, J. R. (1991). Biological integrity: A long-neglected aspect of water resource management. Ecological Applications. **1**:66-84.

Water of sufficient quality and quantity is critical to all life. Increasing human population and growth of technology require human society to devote more and more attention to protection of adequate supplies of water. Although perception of biological degradation stimulated current state and federal legislation on the quality of water resources, that biological focus was lost in the search for easily measured physical and chemical surrogates. The "fishable and swimmable" goal of the Water Pollution Control Act of 1972 (PL 92-500) and its charge to "restore and maintain" biotic integrity illustrate that law's biological underpinning. Further, the need for operational definitions of terms like "biological integrity" and "unreasonable degradation" and for ecologically sound tools to measure divergence from societal goals have increased interest in biological monitoring.

204. Karr, J. R. (1999). Defining and measuring river health. Freshwater Biology. **41**:221-234.

Society benefits immeasurably from rivers. Yet over the past century, humans have changed rivers dramatically, threatening river health. As a result, societal well-being is also threatened because goods and services critical to human society are being depleted. 'Health' - shorthand for good condition (eg healthy economy) - is grounded in science yet speaks to citizens. Applying the concept of health to rivers is a logical outgrowth of scientific principles, legal mandates, and changing societal values. Success in protecting the condition, or health, of rivers depends on realistic models of the interactions of landscapes, rivers, and human actions. Biological monitoring and biological endpoints provide the most integrative view of river condition, or river health. Multimetric biological indices are an important and relatively new approach to measuring river condition. Effective multimetric indices depend on an appropriate classification system, the selection of metrics that give reliable signals of river condition, systematic sampling protocols that measure those biological signals, and analytical procedures that extract relevant biological patterns. Communicating results of biological monitoring to citizens and political leaders is critical if biological monitoring is to influence environmental policies.

205. Katopodis, C. (1994). Analysis of ichthyomechanical data for fish passage or exclusion system design. Pages 318-323 *in* D. D. MacKinlay, ed. International Fish Physiology Symposium, Vancouver, British Columbia (Canada), Fish Physiology Association.

Fish speed and stamina, locomotion and the mechanics of fish swimming, are key to the development and design of passage, exclusion, and guidance systems such fishways (including culverts), fish screens, fish barriers (including sea lamprey velocity barriers), and fish louvers. The large amount of data available, although primarily from laboratory respirometer studies and unevenly distributed between species, offered an opportunity to consider its systematic application to the development, design and testing of such devices. With this motive, comprehensive searches were made and literature on fish swimming performance tests was compiled, and published data were entered on spreadsheets. This data base includes the following information: scientific and common fish species name, swimming mode, fish length (l in m), swimming speed (U in m/s), endurance or time to fatigue (t in s), water temperature during testing, life stage (e.g. juvenile or adult), test method (e.g. constant or increasing velocity), number of fish tested, regressions of swimming speed versus fish length for specific endurance times as reported in the literature, publication reference (author and date), and relevant comments (Katopodis and Gervais 1991). The data base may be consulted for information on specific species, although many species either have very limited data or are not represented at all. The data base, which is available on request, is presently being revised and updated. Investigators with additional data which do not appear in primary publications, are encouraged to provide it for inclusion.

206. Katopodis, C., A. J. Derksen and B. L. Christensen (1991). Assessment of two Denil fishways for passage of freshwater species. Pages 306 - 324 *in* J. Colt and R. J. White, eds. American Fisheries Society Symposium, Bethesda, Maryland (USA), American Fisheries Society Symposium.

Fish movements through two Denil fishways were assessed by means of traps at the fish exit (upstream end) of each facility. Located in the Canadian prairies, the Fairford (Manitoba) and Cowan (Saskatchewan) fishways are similar in design and operation. At Fairford, 8,871 fish representing 13 species were caught in the trap. White suckers

Catostomus commersoni , walleyes *Stizostedion vitreum* , and saugers *Stizostedion canadense* made up 93.0% of the run. At Cowan fishway four species caught were white suckers, longnose suckers *Catostomus catostomus* , northern pike *Esox lucius*, and walleyes; 11,294 fish were trapped, although it was estimated that over 23,000 fish passed through the fishway. The size range of fish that passed through the fishways was 212-800 mm. The longest Denil fishway section negotiated was 9.5 m at a 12.6% slope. Headwater levels, water depths and water velocities were monitored. Although fish movements at both sites were likely obstructed by dams for several decades, all species present ascended the fishways readily.

207. Katopodis, C. and N. Rajaratnam (1983). A review and laboratory study of the hydraulics of Denil fishways. Canadian Technical Report of Fisheries and Aquatic Sciences. **1145**:1-181.

The development of Denil fishways is reviewed and the hydraulics of three Denil designs, referred to as Denil 1, 2 and 3, are studied experimentally and analytically. The very turbulent nature of the flow in the fishways is described and extensive velocity measurements are presented. Velocity profiles in the centerline of Denil 1 and 2 are distinct and display characteristic shapes amenable to similarity analysis, while velocity profiles for Denil 3 are inconclusive in this respect. Depth averaged velocities through the fishways are found to be only 11% to 14% of the average velocities expected in rectangular channels of the same dimensions. Energy dissipation in the three fishways is high. For slopes of 20% or more the fishways are more efficient than a hydraulic jump in dissipating flow energy. At lower slopes, the fishways create flow resistance conditions that are similar to those of boulder-filled headwater streams. A semi-empirical method is developed for the design of Denil fishways involving a fluid friction coefficient.

208. Katopodis, C. and N. Rajaratnam (1984). Similarity of scale models of Denil fishways. Pages 2.8-1 to 2.8-6 *in* H. Kobus, ed. International Association for Hydraulic Research Symposium on Scale Effects in Modelling Hydraulic Structures, Esslingen, West Germany, Technische Akademie.

This paper discusses scale effects on modelling Denil fishways. The overall objective of this research effort is to develop a general design method for Denil fishways.

209. Katopodis, C. and N. Rajaratnam (1990). Hydraulics of culvert fishways III: weir baffle culvert fishways. Canadian Journal of Civil Engineering. **17**:558-568.

The hydraulics of culvert fishways with weir-type baffles were studied in the laboratory. Weir baffles without slots would be less expensive to build than slotted-weir baffles and would resemble a pool-weir fishway. Baffles with heights equal to 0.15 and 0.1 times the diameter (D) of the culvert were studied with longitudinal spacings of 0.5D and 1.2D. Equations were developed to describe the relation between the discharge, slope, diameter, and the depth of flow. Using these equations it was possible to predict the barrier velocity that would exist at the baffles. The performance of the weir baffles was found to be as good as that of the slotted-weir baffles or slightly better by producing larger depths for smaller flow rates. A spacing of 0.6D was very effective, whereas a spacing of 1.2D appeared to be somewhat too large. During low flows, sediment may settle in the pools, but this might be eroded and transported by larger flows. A certain amount of maintenance of the culvert may be needed.

210. Katopodis, C., N. Rajaratnam, S. Wu and D. Tovell (1997). Denil fishways of varying geometry. Journal of Hydraulic Engineering. **123**:624-631.

This paper presents the results of an extensive laboratory study aimed at improving the design of Denil fishways. For the standard design of the simple Denil, an equation has been developed between the dimensionless discharge Q_* and the relative depth of flow d/b for d/b as large as 5.5. The normalized velocity distributions in the centerplane of the Denil were found to have certain shapes depending upon the d/b ratio. For the nonstandard designs of the Denil fishway, based on the results of about 660 experiments, a method has been found to predict not only the relation between Q_* and d/b but also the normalized velocity profiles in the centerplane of the Denil. The coefficient of friction between the central stream in the Denil and the circulating water on the sides as well as the bottom has been evaluated along with the equivalent Manning's n for the Denil fishway. These results are believed to be important in extending the depth range of the standard Denils as well as making changes to the standard Denil for passing different species of fish.

211. Katopodis, C., P. R. Robinson and B. G. Sutherland (1978). Study of model and prototype culvert baffling for fish passage. Department of Fisheries and the Environment Fisheries and Marine Service Western Region, Technical Report 828.

Most streams, crossed by roads or highways, are culverted. Many such crossings are impassable to migrating fish because of the culvert length and the high water velocities in them. A hydraulic model study tested and developed devices to aid fish passage through culverts. Based on the model study recommendations, Offset baffles and Spoiler baffles were designed and installed at the MacKenzie Highway crossing of the Redknife River. Field testing showed good agreement, between model and prototype results. The effectiveness of both baffle types is inversely proportional to culvert slope. Maximum recommended slope is 5%. A method of judging baffle adequacy is provided. The Offset and Spoiler baffles are recommended, primarily for correcting existing culvert installations and for proposed stream crossings where alternative designs are neither practical nor economical. Minor problems were presented by ice, debris and sediment. Unsuccessful attempts by Arctic grayling and longnose sucker, to enter the Redknife River culverts, were observed; their failures were attributed to overwhelming water velocities associated with elevated culvert outlets.

212. Keenlyne, K. D. (1997). Life history and status of the shovelnose sturgeon, *Scaphirhynchus platorynchus*. Environmental Biology of Fishes. **48**:291-298.

The shovelnose sturgeon, *Scaphirhynchus platorynchus*, is a freshwater sturgeon of the Mississippi and Missouri rivers and their tributaries. It is one of the smaller North American sturgeons, seldom weighing more than 2.5kg over most of its range except in the upper Missouri River, where individuals of over 7kg have been found. Spawning occurs in spring at temperatures between 17 and 21 ^{o}C over rock or gravel substrate downstream from dams, near rock structures, or in tributaries, most males reach sexual maturity at 5 years, most females at 7 years. Adults do not spawn every year. Shovelnose sturgeon are found in large, turbid rivers and frequently concentrate in areas downstream from dams or at the mouths of tributaries. Population densities range up to 2500 fish per km. They are commonly found in areas of current over sandy bottoms or near rocky

points or bars, where they feed primarily on aquatic invertebrates. The shovelnose sturgeon is classified as a sport species in 12 of 24 states where it occurs. Commercial harvest is allowed in seven states, where fresh shovelnose sturgeon sell for 55 to 88 cents per kg, smoked shovelnose for about $5.75 per kg, and roe from 33 to 110 dollars per kg. About 25 tons of shovelnose sturgeon are harvested commercially each year. Shovelnose sturgeon are considered extirpated in three states, fully protected in four states, and rare, threatened, or of special concern in eight states. Populations are considered stable throughout most of the upper Mississippi, lower Missouri, Red, and Atchafalaya rivers. Three states, Wyoming, West Virginia, and New Mexico, have developed plans to reintroduce the species into rivers where it has been extirpated.

213. Keenlyne, K. D., C. J. Henry, A. Tews and P. Clancey (1994). Morphometric comparisons of upper Missouri River sturgeons. Transactions of the American Fisheries Society. **123**:779-785.

Morphometric comparisons were made among three isolated populations of pallid sturgeon *Scaphirhynchus albus* and shovelnose sturgeon *S. platorynchus* from the upper Missouri River. Six measurements were made on 89 pallid and 204 shovelnose sturgeons. Means of several morphometric characteristics were statistically different between populations of both species. Pallid sturgeon means showed proportional trends relative to location on the river. Toward the headwaters, relative head and interrostral lengths were progressively shorter and outer barbel length relatively longer. The only trend observed for the shovelnose sturgeon was that relative head length became longer upriver. This was the opposite of the trend observed for the pallid sturgeon. Morphometric ratios commonly used to differentiate the two species were useful measures for live fish from isolated populations of Missouri River sturgeon but not for the overall sturgeon population. The exclusivity of morphometric ratios currently used to distinguish between the two species did not hold for our larger fish and large sample size. A cumulative morphometric characteristic index is described to aid managers in comparing individual fish within a composite sturgeon population, and the finding of three possible hybrids is discussed.

214. Keenlyne, K. D. and L. G. Jenkins (1993). Age at sexual maturity of the pallid sturgeon. Transactions of the American Fisheries Society. **122**:393-396.

Age at sexual maturity has not been described previously for the pallid sturgeon *Scaphirhynchus albus*, an endangered species. Age and reproductive data were obtained for five male and nine female pallid sturgeons collected from 1983 to 1991. Spawning bands were observed in pectoral fin ray sections of age-25 and age-41 females. Males reached sexual maturity at ages 5-7. Females began egg development at age 9-12 and first spawned at age 15. Eight of the specimens were collected from the head-waters of the Atchafalaya River, where pallid sturgeons had not been previously reported.

215. Kieffer, M. C. and B. Kynard (1993). Annual movements of shortnose and Atlantic sturgeons in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society. **122**:1088-1103.

We used biotelemetry to study the movements of 23 adult shortnose sturgeons *Acipenser brevirostrum* and 23 subadult Atlantic sturgeons *Acipenser oxyrhynchus oxyrhynchus* in the lower 46 km of the Merrimack River between 1987 and 1990.

Shortnose sturgeons used two freshwater reaches and one saline reach annually. Sexually mature fish began moving upriver from freshwater wintering areas to a spawning site in April, when increasing river temperature reached about 7 ^{o}C and decreasing river discharge reached about 570 m^3/s. Following spawning in late April-early May, fish moved downriver either to a freshwater reach where they remained all year or farther downriver to a saline reach where they remained for up to 6 weeks. After fish used the saline reach, they returned upriver to fresh water. Atlantic sturgeons entered the river from coastal waters by mid-late May, when increasing river temperatures reached 14.8-19.0 ^{o}C and decreasing river discharge reached 303-675 m^3/s, occupying a saline reach with 0.0-27.5% salinity. After using the same saline reach visited briefly in spring by shortnose sturgeons, Atlantic sturgeons emigrated from the river by October when maximum river temperatures were 13.0-18.4 ^{o}C. We observed no tagged Atlantic sturgeons in the river in successive years. Except for use of the saline reach during spring, the two species were spatially separate.

216. Kieffer, M. C. and B. Kynard (1996). Spawning of the shortnose sturgeon in the Merrimack River, Massachusetts. Transactions of the American Fisheries Society. **125**:179-186.

We tracked 10 ultrasonically tagged shortnose sturgeons *Acipenser brevirostrum* during spring in the Merrimack River to investigate spawning. Seven fish in 1989 and six fish in 1990 were tracked intensively to identify the timing and location of spawning and to characterize spawning habitat. In mid-April 1989 and 1990, fish moved upstream to just below head of tide, concentrating in a 2-km reach at river kilometers 30-32 (measured from the mouth) at Haverhill, Massachusetts. The estimated spawning time was a 5-d period (26-30 April) in 1989 and an 8-d period (22-29 April) in 1990. Spawning sites covered about 10.5 ha in 1989 and 13.5 ha in 1990. Fish spawned as river temperature increased from 9.6 to 14.0 ^{o}C and river discharge decreased from 390 to 240 m^3/s. Physical characteristics of spawning sites were boulder-rubble substrate, water depth of 1.8-5.5 m, and bottom water velocity of 0.3-0.7 m/s. We captured no ovulating females but verified successful spawning in 1990 by capturing two live embryos. Gill-net captures and telemetry during spring showed that some males moved to the spawning area annually. The low abundance estimates of spawning fish (9 in 1989 and 16 in 1990) indicate that the shortnose sturgeon population in the Merrimack River is the smallest yet identified as is likely vulnerable to extirpation.

217. Kline, T. C., Jr., J. J. Goering, O. A. Mathisen, P. H. Poe, P. L. Parker and R. S. Scalan (1993). Recycling of elements transported upstream by runs of Pacific salmon: II. Δ^{15}N and Δ^{13}C evidence in the Kvichak River watershed, Bristol Bay, southwestern Alaska. Canadian Journal of Fisheries and Aquatic Sciences. **50**:2350-2365.

Biota Δ^{15}N and Δ^{13}C values (deviations from recognized isotope standards) from Iliamna Lake (a major anadromous sockeye salmon *Oncorhynchus nerka* nursery lake supporting peak-year runs >10 million) and several other anadromous-salmon-free lakes in the Kvichak River watershed, Bristol Bay, southwestern Alaska, were compared to determine the significance of marine-derived nitrogen (MDN) delivered by returning adult salmon. Biota in Iliamna Lake had higher Δ^{15}N compared with control lakes, verifying a mixing model correlating Δ^{15}N with MDN. Periphyton Δ^{15}N values reflected localized input from populations of spawning salmon. Juvenile sockeye MDN varied in response to escapement size, suggesting the importance of large escapements (>10 million) for maintaining a predominantly MDN lacustrine N pool. Other resident fishes

showed shifts in $\Delta^{15}N$ between years of high and low escapement. The dual-isotope approach, using $\Delta^{15}N$ and $\Delta\ ^{13}C$ together, suggested that fish production is primarily dependent on limnetic primary and secondary production. The dual-isotope approach indicated that the coast range sculpin *Cottus aleuticus* was the only fish with an appreciable dietary component consisting of salmon eggs or emergent fry.

218. Klinge, M. (1994). Fish migration via the shipping lock at the Hagestein barrage: Results of an indicative study. Pages 357-361 *in* J. A. Van de Kraats, ed. Water Science and Technology, Tarrytown, New York (USA).

In the Dutch part of the Rhine many hydraulic works (sluices, barrages, etc.) are situated which are considered to be barriers for upstream fish migration. Because of intensive shipping these works are always combined with big shipping locks. Until recently no data were available concerning fish migration via this locks. This was studied in the river Lek at the Hagestein barrage. Due to the short length of the study period and few recaptured salmonids (salmon, sea trout, rainbow trout) no conclusive evidence about the effects of the shipping lock on salmonid migration was obtained. However, the results do suggest that the Hagestein barrage complex forms a serious barrier for upstream migration of salmonids. Several other fish species on other hand were observed to migrate through the lock. Therefore, depending on target species and management goals, the presence of shipping locks should be taken into account when considering improving fish migration possibilities.

219. Kolok, A. S. (1991). Photoperiod alters the critical swimming speed of juvenile largemouth bass, *Micropterus salmoides*, acclimated to cold water. Copeia. **4**:1085-1090.

The objective of this research was to determine whether the critical swimming speed of juvenile largemouth bass, *Micropterus salmoides*, was influenced by prolonged exposure to seasonally inconsistent photoperiods. To test this hypothesis, the critical swimming speeds (U_{crit}) of fish laboratory acclimated to 5, 10, 15, or 19 ^{o}C, and seasonally consistent or 12:12 light-dark photoperiods, were compared to that of field-acclimatized bass. In early winter the U_{crit} of largemouth bass laboratory acclimated to 5 ^{o}C and a 12:12 light-dark photoperiod was significantly reduced relative to that of fish field acclimatized to 5 ^{o}C but was not significantly different when compared to that of fish acclimated to 5 ^{o}C and a seasonally consistent 9:15 light-dark photoperiod. In early summer the U_{crit} of largemouth bass laboratory acclimated to 10 ^{o}C and a 12:12 light-dark photoperiod was significantly reduced relative to the U_{crit} of fish either acclimated to 10 ^{o}C and a seasonally consistent 15:9 light-dark photoperiod or field acclimatized to 10 ^{o}C.

220. Kolok, A. S. (1992). The swimming performance of individual largemouth bass *Micropterus salmoides* are repeatable. Journal of Experimental Biology. **170**:265-270.

Previous studies have shown that critical swimming speed (U_{crit}) of the largemouth bass, *Micropterus salmoides* Lacepede, is significantly influenced by a number of factors including body mass, training, water temperature and photoperiod. Recent research into locomotor performance of amphibians and reptiles has suggested that individual variation is substantial and repeatable. The results of this study suggests that variation in the swimming performance of individual and juvenile largemouth bass is substantial and repeatable for fish tested twice at one temperature, tested at different

temperatures, or tested after a 4 week acclimation to different temperature. These results strongly suggested that individual variation in U_{crit} is more than statistical noise and that it is a source of variation that can be exploited when designing future experiments.

221. Kolok, A. S. (1999). Interindividual variation in the prolonged locomotor performance of ectothermic vertebrates: A comparison of fish and herptofaunal methodologies and a brief review of the recent fish literature. Canadian Journal of Fisheries and Aquatic Sciences. **56**:700-710.

Physiological research of locomotor performance in fishes has traditionally adopted an approach in which the mean performance of a number of fish was considered `real' and variation around the mean was considered statistical noise. Drawing on advances made in herpetofaunal studies, an alternative approach has recently appeared in the fish literature in which variation among individual fish has been shown to be repeatable and statistically valid. The incorporation, rather than suppression, of individual variation in experimental design has revealed interesting and biologically relevant relationships between morphological and physiological traits and swimming performance that can be masked by the traditional use of group means. Considering the promising nature of these initial studies incorporating individual variability in fish performance, this paper has two primary objectives. The first is to compare methodologies that have been used in studies involving intraspecific variability in the locomotor performance of fish and herptofauna. The second is to review the fish literature regarding interindividual variation in prolonged swimming performance.

222. Kolok, A. S. and J. T. Oris (1995). The relationship between specific growth rate and swimming performance in male fathead minnows *Pimephales promelas*. Canadian Journal of Zoology. **73**:2165-2167.

The objective of this study was to test the hypothesis that the specific growth rate of male fathead minnows *Pimephales promelas* was positively correlated with swimming performance. Subadult fish were allowed to grow into adults over a period of 31-55 days, after which the critical swimming speed of each fish was determined. Variation in critical swimming speed was substantial (greater than 50%), and a significant positive correlation was found between number of growing days and critical swimming speed, whereas a significant negative correlation was found between specific growth rate and critical swimming speed. A multiple regression using specific growth rate and number of growing days explained over 47% of the variation in swimming performance. Fathead minnows that grow fast are poor swimmers, suggesting a trade-off between swimming performance and specific growth rate in this species.

223. Kolok, A. S., E. P. Plaisance and A. Abdelghani (1998). Individual variation in the swimming performance of fishes: An overlooked source of variation in toxicity studies. Environmental Toxicology and Chemistry. **17**:282-285.

A commonly used indicator of sublethal stress in fish *Pimephales promelas* is impaired swimming performance. Analysis of performance data usually employs a simple comparison, in which the mean of a stressed group of fish is compared to that of a control group. Although such a comparison is satisfactory in many cases, a comparison emphasizing individual variation in performance can yield valuable information unattainable by a means comparison. In this experiment, we determined critical

swimming speeds of subadult male fathead minnows before and after exposure to contaminated sediments from Devil's Swamp, Louisiana, USA. The data were then analyzed using a means comparison and an individual approach to illustrate the differences in explanatory power between the two approaches.

224. Kowarsky, J. and A. H. Ross (1981). Fish movement upstream through a Central Queensland (Fitzroy River) coastal fishway. Australian Journal of Marine and Freshwater Research. **32**:93-109.

A two-part study was made of fish movement past the Fitzroy River barrage at Rockhampton, Queensland, to assess the feasibilities of routes other than that through the simple pool and weir fishway situated at the barrage, and to monitor fish passage upstream through the fishway by placing a V-trap immediately above the fishway exit. It is concluded that while there is a need for facilitating fish movement upstream past the barrage, the present fishway does not seem to be particularly effective in this regard. Structural and management changes to the fishway which may improve its efficiency are proposed.

225. Kynard, B. (1997). Life history, latitudinal patterns, and status of the shortnose sturgeon, *Acipenser brevirostrum*. Environmental Biology of Fishes. **48**:319-334.

Historically, shortnose sturgeon inhabited most major rivers on the Atlantic coast of North America south of the Saint John River, Canada. Today, only 16 populations may remain. Major anthropogenic impacts on shortnose sturgeon are blockage of spawning runs by dams, harvest of adults (bycatch and poaching), dredging of fresh /saltwater riverine reaches, regulation of river flows, and pollution. The pattern of anadromy (adult use of salt water) varies with latitude. The pattern may reflect bioenergetic adaptations to latitudinal differences between fresh and salt water habitats for thermal and foraging suitability. The greater adult abundance in northern and north-central populations likely reflects a historical difference with southern populations that is currently accentuated by increased anthropogenic impacts on southern populations. Adult abundance is less than the minimum estimated viable population abundance of 1000 adults for 5 of 11 surveyed populations, and all natural southern populations. Across the latitudinal range, spawning adults typically travel to about river km200 or farther upstream. Dams built downstream of spawning reaches block spawning runs, and can divide amphidromous populations into up- and downstream segments. Conservation efforts should correct environmental and harvest impacts, not stock cultured fish into wild populations.

226. Kynard, B. (1998). Twenty-two years of passing shortnose sturgeon in fish lifts on the Connecticut River: what has been learned? Pages 255-266 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

The shortnose sturgeon *Acipenser brevirostrum* population in the Connecticut River has been physically separated into upstream and lower river groups by Holyoke Dam at river km 140 since 1849. Some lower river pre-spawning adults annually migrate to the dam, enter fish lifts and are passed upriver. I examined the passage pattern of 97 migrants lifted from 1975 to 1996. The annual number of fish passed was 0-16 (mean = 4.4, SE = 0.86, mode and median = 4 ind/yr). There was no trend in annual abundance during the 22 year period. Most fish (N = 67) were lifted individually during a day.

Adults were passed each month that the lift operated (April-October). Fish were lifted at water temperatures of 10 to 27 ^{o}C, with 86% lifted between 12 and 23 ^{o}C. River discharge may affect when fish migrate upstream, or enter the lift, or both, e.g. 60 of 71 dates that fish passed were within 23 days (mean -8.5 days, 95% CI = 6.9-10.2 days) following a river discharge > 600 m^3/s. Most fish entered during decreasing discharge of 200-450 m^3/s (mean = 312 m^3/s). Fish were passed by the spillway lift where water depth at the entrance is more shallow than at the tailrace lift entrance. Shortnose sturgeon passage can be enhanced by improving the approach route to the spillway lift, lifting migrants during late May-October when fish are in good physiological condition, increasing lift frequency and attraction flow during summer and fall, and increasing efforts to pass fish within 10 days following natural discharge that exceeds 600 m^3/s.

227. Kynard, B. and C. Buerkett (1997). Passage and behavior of adult American shad in an experimental louver bypass system. North American Journal of Fisheries Management. **17**:734-742.

We tested 436 adult American shad *Alosa sapidissima* in an experimental louver bypass system, which was similar to a system operating at Holyoke Dam, Massachusetts, to determine guidance and passage efficiency and to study fish response to stimuli from physical structures, light intensity, and water velocity. Groups of 5-29 fish were exposed to combinations of two bypass exits (wide-shallow and vertical-slot sharp-crested weirs) and two louver arrays (7.6- and 15.2-cm slat spacing) oriented 20 degree to water flow direction. Underwater video observations showed fish responded to louvers as a physical barrier during the day, when they stayed 30-55 cm (1.3 cm/5 klx) away from and oriented parallel to louvers, and as a behavioral barrier at night, when they moved closer to louvers and oriented into the current. Both louver arrays guided fish effectively, (i.e., prevented fish from passing through the slats) 100% for narrow spacing and 97% for wide spacing. Adults avoided moving closer than 0.5 m to either exit type; instead, fish remained 0.8-1.4 bodylengths upstream, depending on light intensity (farther upstream during daytime, similar to behavior at louvers). At exits, water velocity increased from 0.4 m/s to 0.8 m/s or more in a distance of 0.9 m (rate of velocity increase, 0.44 m/s per meter). This rapid velocity increase elicited an avoidance response by fish that resulted in few fish (5%) passing. Our results provide behavioral explanations for the efficient guidance of adult American shad by louvers and for the fishes' avoidance of the exit at the Holyoke Dam. From this, we provide suggestions on how to prevent fish avoidance of exits.

228. Kynard, B., M. Horgan, M. Kieffer and D. Seibel (2000). Habitats used by shortnose sturgeon in two Massachusetts rivers, with notes on estuarine Atlantic sturgeon: A hierarchical approach. Transactions of the American Fisheries Society. **129**:487-503.

Biotelemetry of shortnose sturgeon *Acipenser brevirostrum* and Atlantic sturgeon *A. oxyrinchus oxyrinchus* was used to study fish uses of habitat in several hierarchical classes in the Connecticut and Merrimack rivers. Hierarchical classes were geomorphological region (straight river run, run with an island, and river curve), river cross section (channel or shoal), and microhabitat (water depth, bottom current, substrate, and illumination). Coastal wandering juvenile Atlantic sturgeon were summer visitors to the Merrimack River, where they used a narrow range of habitat on all spatial scales, e.g., run-with-island, the channel portion of the cross section, and sand substrate. Shortnose sturgeon, year-round residents in both rivers, showed great individual variation in habitat use, and all ages selected a broad range of habitats on all spatial scales. However,

shortnose sturgeon in both rivers preferred curves with sand or cobble substrate and avoided runs regardless of substrate. Individuals used channel or shoal at rates ranging from 0 to 100% on a weekly time scale in an unpredictable manner. Connecticut River shortnose sturgeon increased their use of curves, channels (deep water), and sand substrate in the fall. This strategy may conserve energy because these conditions usually reflect slow water velocity. Winter habitat selection continued the fall pattern, but was less variable because habitat affinity was highest among wintering fish. Documenting individual fish use of large-scale habitat revealed habitat relationships that would not have been discovered if only fish use of microhabitat had been studied.

229. Kynard, B. and J. O'Leary (1993). Evaluation of a bypass system for spent American shad at Holyoke Dam, Massachusetts. North American Journal of Fisheries Management. **13**:782-789.

A bypass system for post-spawned American shad *Alosa sapidissima* began operation in 1980 on the Connecticut River canal system at Holyoke Dam. The purpose of the bypass was to enable downstream migrants that enter the canal to exit and avoid death due to delay or passage through hydroelectric turbines at water use facilities. The bypass system had the following elements: (1) an underwater AC electrical or acoustic barrier to prevent American shad from leaving the bypass area, (2) an underwater DC electrical field to immobilize fish for collection, and (3) a collection box with transfer pipe to carry fish to the river below the dam. During studies of the bypass system from 1979 to 1983, we found that the fish barriers were ineffective, the collection system was partially effective for American shad but not for anadromous species that passed through trashracks, and American shad could be immobilized and transported at high velocity through a pipe and have only low mortality (4-9%). Radio-tagged American shad, unwilling to pass through trashracks at water exits on the canal, behaved like trapped fish and were delayed an average of two or more days before dying or exiting the canal. An estimated 10 of 47 (21%) of the radio-tagged fish were passed. In 1980, when the greatest number of American shad were passed, an estimated 142,000 (37% of the fish lifted at the dam) survived spawning and used the bypass. After several years of operation, it was evident that, even with major improvements, the bypass could not pass the available American shad, and it was not useful for protecting other anadromous migrants that did not avoid trashracks.

230. Laasonen, J. (1994). Designing hydraulic structures using a 2-dimensional numerical model. Vesitalous. **5**:29-31.

A numerical model based on the finite-difference integration of non-linear equations for 2-dimensional unsteady flow in a horizontal plane is presented. Nearly horizontal flow and hydrostatic pressure are assumed in the equations. The algorithm used in the model has two parts. The one calculates the linearized terms, including resistance and bed forms, using the scheme of Abbott-Ionescu and the Alternating Direction (ADI) method; the other calculates the convective terms explicitly. An operator accurate to the third order for both space and time is employed. Use of this mathematical model for the lay-out of a hydraulic structure is described. Koivukoski hydro powerplant is on the River Kymijoki in Finland. It was found that fish migration through the fish ladder was better during the flood than at other times. To improve the operation of the fishway it was decided to release auxiliary water through the gates of the regulating dam. The area below the fishway was modelled to find the optimal flow pattern at the entrance of the fishway.

231. Laine, A. (1990). The effects of a fishway model hydraulics on the ascend (sic) of vendace, whitefish and brown trout in Inari, northern Finland. Aqua Fennica. **20**:191-198.

The behaviour of vendace, *Coregonus albula* , whitefish, *C. lavaretus, C. pidschian, C. wartmanni* , and brown trout, *Salmo trutta* , was studied in a 30 m long vertical slot fishway model in Inari, northern Finland. The discharge of the fishway was modifiable. Most of the fish ascended in the smallest test discharge. Improper energy dissipation, high drops between pools (20-30 cm), high velocities (over 1.4 m/s) and swirling of the water in the pools delayed or prevented the passage of vendace and whitefish. Water velocity at the most favourable resting areas corresponded to 1/2-1 fish body lengths per second (Bls^{-1}), but even areas with a velocity of 2-4 Bls^{-1} were used. Although the pool dimensions were similar, there were differences in the flow characteristics of the pools and slots. Certain pools seemed to be popular at each discharge rate, in some pools the flow conditions changed remarkably between discharge rates affecting the behaviour of the fish. Learning played an important role as the fish ascended the fishway.

232. Laine, A., R. Kamula and J. Hooli (1998). Fish and lamprey passage in a combined Denil and vertical slot fishway. Fisheries Management and Ecology. **5**:31-44.

A fishway (fish pass), consisting of vertical slot and Denil sections, was constructed at the lowest dam on the River Kemijoki, northern Finland, in 1993. The river was one of the best salmon rivers in Europe until 1949, when the dam and the hydropower plant were completed close to the river mouth. From 1993 to 1995, nearly 1000 adult salmonids passed through the fishway despite heavy fishing below the dam. Of environmental variables measured, water temperature, headwater level, and discharge through the power plant in relation to season changes explained most of the variation in Baltic salmon, *Salmo salar* L., numbers. They had a minor effect on trout, *Salmo trutta* L. Migratory whitefish, *Coregonus lavaretus* (L.), entered the fishway but were not observed in its uppermost pool. River lamprey, *Lampetra fluviatilis* (L.), passed through the vertical slot section of the fishway after plastic bristles were fastened into the bottom of the slots.

233. Lam, K. (1982). An ex-post benefit-cost analysis of the Meziadin Fishway. Canadian Manuscript Reports of Fisheries and Aquatic Sciences. **1643**:44.

Salmonid Enhancement Program facilities for sockeye salmon *Oncorhynchus nerka* are currently being evaluated using a multiple objective planning framework referred to as the Five Account Methodology. The five accounts to be assessed include National Income, Regional Development, Native People, Employment, and Resource and Environmental Preservation. The Meziadin fishway is evaluated using the same methodology. However, rather than relying totally on projected cost and production information, historical data is available for a number of years. By carrying out ex-post benefit-cost analyses on pre-S.E.P. facilities, their overall performance can be assessed and the information used to increase the net benefits of S.E.P. facilities.

234. Larinier, M. (1983). [Guide for planning passage facilities at dams for migratory fish]. Bulletin Francais Pisciculture, Tolosan, France.

The basic principles which can be used as a guide for planning fish passage facilities at dams or obstructions are outlined. Special reference is made to the attraction of fishway entrances. Information is presented concerning functional features and design parameters for different types of fish facilities: pool passes, Denil fishways, fish locks and fish lifts. A list of data required for planning fish facilities is included.

235. Larinier, M. (1983). [Let them swim upstream: Fishways for migrating species]. Adour Garonne Review Ear Midi Atlantic. **27**:5-10.

The different types of fishways are reviewed and analyzed. The choice must be made as a function of topography, existing works, river flow and possible flooding, and fish behavior. The fishway must also be accessible for cleaning. Examples of fishways built in the southwest of France are cited.

236. Larinier, M. (1998). Upstream and downstream fish passage experience in France. Pages 127-146 *in* M. Jungwirth, S. Schmultz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Plans for the restoration or enhancement of anadromous fish stocks were initiated in France more than 15 years ago. A 1984 law concerning freshwater fisheries requires that any obstruction in streams or parts thereof, in the list specified by decree, must include facilities to ensure the passage of migratory fish. As a result, more than 400 fish passes were built or improved, and significant advances in the design of upstream fish passage facilities have occurred during the last 15 years. This chapter provides an overview of the functional features and design parameters used in the different types of passage facilities: Denil fish passes, pool fish passes, fish elevators and natural bypass channels. The relative advantages and drawbacks of each type of fish pass are discussed, with reference to the requirements of specific migratory species and site-specific constraints. Emphasis is placed on the problem of maintenance. The various techniques used in France to evaluate the existing or newly constructed fish passes, as well as the topic of downstream migration at turbine intakes, are reviewed. Recent experiments have tested surface bypasses designed to provide a safe downstream route for smolts at small-scale hydroelectric plants. The efficiency of such bypasses is evaluated by radio telemetry and release-recapture tests. Results from some field studies are outlined. The effect of mercury lights to increase bypass attraction is discussed. The behaviour of fish in relation to the hydraulic flow patterns at the intake should be considered when designing a downstream bypass system. In conclusion, the author presents his view on the priorities for future research on fish passage facilities, insisting on the need for close collaboration between engineers and biologists, in particular fish behaviourists. Some priorities include the use of radio-telemetry to track Atlantic salmon *Salmo salar* on the migratory rivers, and research aimed at gaining a better understanding of downstream migration of salmon, brown trout *S. trutta*, and European eel *Anguilla anguilla*.

237. Larinier, M. and S. Boyer-Bernard (1991). [Smolts downstream migration at Poutes Dam on the Allier River: Use of mercury lights to increase the efficiency of a fish bypass structure]. Bulletin Francais de la Peche et de la Pisciculture. **323**:129-148.

Downstream migration of Atlantic salmon *Salmo salar* smolts was studied in 1989 at Poutes Dam on the Allier River to evaluate the effectiveness of mercury lights in modifying behavioral responses of smolts at a fish bypass structure. Daily and hourly passage of smolts was accessed by video recording. Migratory activity was mainly nocturnal, diurnal movements increasing at the end of emigration period. Analysis of results showed that the lights significantly increased the rate of passage. Visual observation showed that illumination duration, light location and intensity may be important parameters in effective application of mercury lights for attraction. Three to eight times as many fish were bypassed with the lights on than with the lights off.

238. Larinier, M. and A. Miralles (1992). The hydraulic characteristics of baffle-equipped fishways. Canadian Translations of Fisheries and Aquatic Sciences, Tolosan (France).

This brief report is a partial summary of the findings of research on baffle-equipped fishways that was conducted on a model system at the fish-farming facility in Pont Crouzet, in the department of the Tarn. The experimental setup consisted of 2 basins in which fish could be kept, connected by a glass-lined flume 0.30 m wide and 4.6 m long with a variable slope (ranging between 0 and > 20%).

239. Larinier, M., J. P. Porcher and F. Travade (1994). [Fishways. Valuation, conception of fish passes structures.]. Conseil Superieur de la Peche, Paris (France).

More than 10 years theoretical and applied research and a French experience of design and conception of fishways make these authors the French specialists of these hydraulic structures. This book is a technical document about conception, and design of fish passes including the biological approach of the users of these constructions: the migratory fishes. Numerous photographs and diagrams illustrate the document.

240. Larinier, M., J. P. Porcher, F. Travade and C. Gosset (1995). [Fish pass engineering.]. Conseil Superieur de la Peche, Paris (France).

This book presents the results of ten years of the French research on fish passes engineering for the migratory fish species.

241. Larkin, G. A. and P. A. Slaney (1997). Implications of trends in marine-derived nutrient influx to south coastal British Columbia salmonid production. Fisheries. **22**:16-24.

Marine nutrients and carbon transported by adult salmon are important to the productivity of the oligotrophic lakes and streams in which salmon spawn. Reduced carcass availability results in a decline in nutrient and carbon sources for stream-rearing salmonids. We examined 42 years of escapement records for five species of Pacific salmon for Georgia Strait, the west coast of Vancouver Island, and the mainland coast of British Columbia to estimate the status of this nutrient source. Salmon stocks from enhanced streams frequently dominated the total escapement of entire regions. As a result, most of the influx of marine nutrients is focused toward a few large stream systems already undergoing significant salmon enhancement, while nutrient influx to the more-numerous unenhanced streams is declining. In the large number of streams with smaller salmon escapements, stream-rearing species already in decline may decrease further from oligotrophication. Risk-averse escapement targets for wild salmon stocks

need to include sufficient spawners to provide the nutrient influx linked to the maintenance of stream productivity. Declining trends in nutrient influx to wild salmon streams in most regions are a cause for concern and more intensive examination.

242. Layzer, J. B. (1979). Transportation of adult American shad past dams on the Connecticut River, Massachussetts. Progressive Fish Culturist. **41**:7-9.

Adult American shad *Alosa sapidissima* were obtained from the Holyoke Dam fish lift, Massachusetts, and transported 68 km by truck to the pool above the Turners Falls Dam. From 1973 to 1976 , 6373 shad were transported; average annual mortality was 25%. Mortality of trucked fish was related to river temperature and the number of fish transported at any one time. During trucking a differential mortality occurred between sexes: 2.4 times more females died than males.

243. Layzer, J. B. (1996). The importance of habitat hydraulics in the restoration of native freshwater mussels. Journal of Shellfish Research. **15**:485.

Freshwater mussel populations in North America have been devastated by a wide array of physical and chemical perturbations. In some cases, habitat destruction and the loss of mussel populations is essentially permanent as in the case of the construction of dams which inundate riverine habitat, change water quality, and eliminate hosts fish populations. In many other cases, the factors responsible for the extirpation of mussel populations have largely been corrected and conditions may now be suitable for the reestablishment of mussels; however, it is suggested that during the intervening time between the extirpation of mussels and improvement in stream conditions other factors affecting stream hydraulics may prevent the successful reintroduction of mussels. In particular, land-use practices within watersheds may have profoundly affected stream hydrographs by increasing peak discharges following precipitation and decreasing base flows during dry periods. Lower base flows may expose mussel beds, eliminate settlement of juveniles from otherwise suitable habitat, and affect host fish population dynamics and movements. Conversely, results of recent research indicate that high shear stress associated with peak discharge is likely responsible for unsuccessful settlement of juvenile mussels in a headwater stream. Measuring or modelling simple hydraulic variables such as mean water column velocity is inadequate for assessing the affects of altered stream hydrographs on potential mussel habitat. In contrast, complex hydraulic variables such as shear stress and Reynolds boundary number are potentially better predictors of hydraulically suitable sites for mussel reintroductions.

244. Lee, H. L., D. DeAngelis and H. L. Koh (1998). Modeling spatial distribution of the Unionid mussels and the coresatellite hypothesis. Pages 73-79 *in* W. O. K. Grabow, M. Dohmann, C. Haas, E. R. Hall, A. Lesouef, D. Orhon, A. Van Der Vlies, Y. Watanabe, A. Milburn, C. D. Purdon and P. T. Nagle, eds. Biennial Conference of the International Association on Water Quality, Vancouver (Canada), Elsevier Science Ltd.

This paper discusses the spatial distribution patterns of the various species of the Unionid mussels as functions of their respective life-cycle characteristics. Computer simulations identify two life-cycle characteristics as major factors governing the abundance of a species, namely the movement range of their fish hosts and the success rate of the parasitic larval glochidia in finding fish hosts. Core mussels species have fish hosts with large movement range to disperse the parasitic larval glochidia to achieve high

levels of abundance. Species associated with fish host of limited movement range require high success rate of finding fish host to achieve at least an intermediate level of abundance. Species with low success rate of finding fish hosts coupled with fish hosts having limited movement range exhibit satellite species characteristics, namely rare in numbers and sparse in distributions.

245. Legault, A. (1992). [Technical note -- study of some selectivity factors in eel ladders]. Bulletin Francais de la Peche et de la Pisciculture. **325**:83-91.

Selectivity factors of eel ladders were studied just below an obstacle to eel *Anguilla anguilla* anadromous migration in Dordogne River. An experimental device caught 6 276 eels for 180,5 hours. The range size of eels varied from 120 to 395 mm (mean length: 223 mm) which is smaller than range size of eels caught by a neighbouring fish ladder. This result seems to show the selectivity of usual fishways. Various configurations of the experimental device allowed to test some selectivity factors. Slope and substrate factors seem to influence the efficiency. For a given slope, the eel size distribution depends on the substrate, more dense brushes involve a smaller average length of migrants. Selectivity also changes according to gradients. Slight slopes (15-30 degree) should be recommended for such devices and the substrate should be adapted to size distribution of eels in migration.

246. Lein, G. M. and D. R. DeVries (1998). Paddlefish in the Alabama River drainage: population characteristics and the adult spawning migration. Transactions of the American Fisheries Society. **127**:441-454.

Paddlefish *Polyodon spathula* were sampled by boat-mounted electrofishing and gill netting in the Tallapoosa and Cahaba rivers and in oxbow lakes of the Alabama River floodplain, Alabama, during January-June of 1992 and 1993. Tagging studies, characterization of spawning migrations, and comparative analyses of catches suggested that paddlefish in the Tallapoosa and Cahaba rivers represented functionally discrete populations that reside in the adjacent reservoirs. Variation in population characteristics appeared to be related to differences in the hydrologic and thermal regimes of the two study rivers and to differences in historical exploitation of populations in the two resident reservoirs. Growth (calculated via back-calculated body length at age) differed between populations in the upper and lower Alabama River, probably reflecting the relatively lentic (upper) and lotic (lower) nature of habitats in these two reaches. Life history characteristics of paddlefish in the Alabama River drainage differed from fish in the Mississippi River drainage. Growth, fecundity, spawning frequency, and age at maturity all were advanced for Alabama River fish relative to Mississippi River fish, whereas maximum age and size of Alabama River fish were less than had been previously reported for populations in the Mississippi River drainage. Differences between populations in the two drainages may reflect geographic variation in biotic and abiotic variables as well as long-term geographic and reproductive isolation.

247. Lelek, A. (1987). Threatened fishes of Europe. Aula-Verlag, Wiesbaden (Germany).

The primary aim of this volume is to provide a general review of the freshwater fish fauna of Europe. Attention is directed to the status of the survival of each species. Wherever possible, suggestions have been made of immediate protection of individual species. However, the actual, modern conservation has to be based on the protection of

species communities and their environments. It is hoped this publication will stimulate the effort to overcome the existing gaps in the knowledge of the fish communities in rivers, and particularly of their dynamics in artificially modified environments. Past experience has proved that exaggerated attention to a few "useful" species influences the remaining fish community negatively. A separation of the "utilitarian" and "conservation" usages of the aquatic environment and its fish fauna is thus called for.

248. Lelek, A. and G. Buhse (1992). [Fishes of the Rhein river -- former times and today]. Springer-Verlag, Berlin (Germany).

This book presents a historical overview of fish fauna in the Rhein River. Information about geological, hydrological, hydrographical aspects are given. The ramifications of man-induced changes to the river environment are discussed. Commercial use with respect to the river fisheries are considered with emphasis on future potential.

249. Leonard, J. (1997). The Energetics of Swimming and Upstream Migration in Adult American Shad *Alosa sapidissima* in the Connecticut River. PhD Dissertation. University of Michigan272 pp.

This study was designed to assess the energetic cost of upstream migration in American shad *Alosa sapidissima* and to examine physiological changes during migration that relate to swimming performance or energetic efficiency. Overall total stored energy expenditure ranged from 35-60% during upstream migration. Migrating American shad preferentially use energy stores (lipid and protein) in some tissues, such as the skin and its sub-dermal fat layer (depleted by 63%), while sparing other tissue stores such as red muscle protein. American shad generally increased the activity of aerobic and energy mobilization enzymes as much as 60%, while decreasing the activity of anaerobic enzymes as much as 80% during upstream migration. There was a generalized reversal of these enzyme changes seen during migration at the most upriver site sampled. It is suggested that American shad may be able to metabolically prepare for migration prior to its onset and cessation. The data demonstrate that fish migrating in the middle of the migratory period possessed higher (5-42%) total stored energy content than fish migrating early or late in the season, primarily due to elevated lipid in the white muscle and the sub-dermal fat layer. American shad demonstrate a spleen- controlled increase in available blood hemoglobin (22%) and hematocrit likely resulting in increased oxygen carrying capacity during upstream migration. Active and standard metabolic rates of American shad, determined by respirometry, were intermediate between salmonids and fast-swimming perciforms. Active metabolic rate was logarithmically related to swimming speed ($r^2 = 0.26$; slope = 0.2) and tailbeat frequency ($r^2 = 0.36$; slope = 0.002). Directly determined standard metabolic rate was 71-198 $mgO^2kg^{-1}h^{-1}$. The energetically optimal swimming speed was 1.45 plus or minus 0.51 body lengths per second. Using the data from the swimming respirometer, an empirical model of the Cabot Station fish ladder in Turners Falls, MA was constructed which suggests that the impact of the fish ladder on migration is highly dependent on passage time. This study demonstrates that American shad are equipped with a variety of mechanisms for increasing energetic efficiency during upstream migration and highlights the importance of short-term physiological adaption to migration and the ultimate success of an iteroparous, anadromous fish.

250. Libby, D. A. (1981). Difference in sex ratios of the anadromous alewife, *Alosa pseudoharengus*, between the top and bottom of a fishway at Damariscotta Lake, Maine. Fishery Bulletin. **79**:207-211.

The Damariscotta River alewife, *Alosa pseudoharengus* , fishery has been monitored every year since 1971 for abundance of fish, length and weight frequencies, age distribution, and sex ratios. From 1977 through 1979, sampling plans were also devised to estimate numbers, size, and sex composition of ripe alewives escaping the fishery and entering the lake to spawn. While sampling the 1977 escapement run it became evident that a greater number of males than females were entering the lake to spawn. This male dominance was not unusual as it was reported in other alewife runs as well. What prompted this investigation was the fact that while the escapement runs had significantly more males than females, the samples from the commercial catch revealed a consistent sex ratio of 1:1. The explanation for the change in the sex ratio from the tidal area to the lake appears to be an effect of the fishway. The greatest disproportionate ratio of male to female alewives occurred at the first part of the escapement run when the largest fish were in the fishway. It seemed that the construction of the fishway was selective against the largest or heaviest fish which were the females at that time. As the size of females tended to decrease, the male to female ratio became more equal.

251. Liew, P. K. L. (1982). Impact of the eel ladder on the upstream migrating eel *Anguilla rostrata* population in the St. Lawrence River at Cornwall: 1974-1978. Pages 17-21 *in* K. H. Loftus, ed. The 1980 North American Eel Conference, Toronto, Ontario (Canada), Ontario Fisheries Technical Report Series.

An eel ladder was constructed in 1974 at the Moses-Saunders Dam, situated in the St. Lawrence river at Cornwall, Ontario, to facilitate the upstream migration of the American eel *Anguilla rostrata*. Several million eels passed through this fishway between 1974 and 1979. Age, length and growth characteristics of the eels using the ladder were examined annually between 1974 and 1978. Trends in the reduction of mean weight and mean length at corresponding ages suggest that the eel ladder has reduced the effect of the dam as an obstacle to eel migration. The results suggest that during the first year of operation the majority of the eels moved were those whose migration had been blocked by the dam for several years. In subsequent years, the ladder appears to have moved eels into the upper St. Lawrence River almost as fast as they reached the dam.

252. Loch, J. J. and S. A. Bonar (1999). Occurrence of grass carp in the Lower Columbia and Snake Rivers. Transactions of the American Fisheries Society. **128**:374-379.

Forty-nine adult grass carp *Ctenopharyngodon idella* were observed migrating upriver past Lower Columbia and Snake river hydroelectric dams between August 1, 1996, and September 30, 1997, representing the first recorded sightings of this fish species in this system. From videotape records and visual counts, grass carp were estimated to range between 55 and 77 cm in total length (TL). One 7.7-kg, 86-cm individual captured in a gill net was identified as a sterile triploid. Although the source of these fish is unknown, their appearance in the Columbia and Snake rivers might have been related to extensive flooding that occurred in western Washington and Oregon in February 1996. The unintentional escape of grass carp into this large river system reemphasizes the need for the current requirement that all grass carp stocked in Pacific Northwest lakes be sterile triploids. It also suggests that increased attention to effective

barrier construction and maintenance is important to prevent grass carp impacts in nontarget areas.

253. Lubinski, K., R. Gaugush, S. Gutreuter, T. Owens and S. Rogers (1993). Current ecological conditions. Long term resource monitoring program. USGS Environmental Management Technical Center, Report EMTC93R021.

Describing the status of the Upper Mississippi River is a continuing function of the Long Term Resource Monitoring Program. Some ecologically important characteristics that serve as indices of overall system status include depositional habitats, vegetation, invertebrates, fish biodiversity, and our capability to apply information to achieve ecological goals. The filling of depositional aquatic habitats has been measured sufficiently to identify this as the major long term resource problem in navigation pools. Many depositional habitats currently are at high risk of entering a successional phase that will be characterized by poor water quality and reduced aquatic vegetation. One of the first steps in the strategy will be the establishment of ecological objectives and action levels appropriate for a large flood plain river.

254. Lubinski, K. S. (1995). Bridging the gap between theory and practice on the Upper Mississippi River. Regulated Rivers: Research & Management. **11**:137-138.

In July 1994, the Upper Mississippi River (UMR) served as a nexus for coalescing scientific information and management issues related to worldwide floodplain river ecosystems. The objective of the conference 'Sustaining the Ecological Integrity of Large Floodplain Rivers: Application of Ecological Knowledge to River Management', was to provide presentations of current ideas from the scientific community. To translate the many lessons learned on other river systems to operational decisions on the UMR, a companion workshop for managers and the general public was held immediately after the conference. Regardless of authority or responsibility, management agencies supported the conference and workshop for the purpose of providing state-of-the-science ecological guidance. Data and interpretations were presented through 150 platform and poster papers on the definition of river ecological integrity, the ways by which rivers have been impacted by human activity, the future of rivers, and river rehabilitation. This issue of Regulated Rivers: Research and Management is intended to group papers on the UMR or closely related topics.

255. Lubinski, K. S., G. Carmody, D. Wilcox and B. Drazkowski (1991). Development of water level regulation strategies for fish and wildlife, Upper Mississippi River System. Regulated Rivers: Research & Management. **6**:117-124.

Water level regulation has been proposed as a tool for maintaining or enhancing fish and wildlife resources in navigation pools and associated flood plains of the Upper Mississippi River System. Research related to the development of water level management plans is being conducted under the Long Term Resource Monitoring Program. Research strategies include investigations of cause and effect relationships, spatial and temporal patterns of resource components, and alternative problem solutions. The principal hypothesis being tested states that water level fluctuations resulting from navigation dam operation create less than optimal conditions for the reproduction and growth of target aquatic macrophyte and fish species. Representative navigation pools have been selected to describe hydrologic, engineering, and legal constraints within

which fish and wildlife objectives can be established. Spatial analyses are underway to predict the magnitude and location of habitat changes that will result from controlled changes in water elevation.

256. Lubinski, K. S., G. Carmody, D. Wilcox and B. Drazkowski (1993). Development of water level regulation strategies for fish and wildlife, Upper Mississippi River system. Long Term Resource Monitoring Program. USGS Environmental Management Technical Center, Report EMTC93R005.

Water level regulation has been proposed as a tool for maintaining or enhancing fish and wildlife resources in navigation pools and associated flood plains of the Upper Mississippi River System. Research related to the development of water level management plans is being conducted under the Long Term Resource Monitoring Program. Research strategies include investigations of cause-and-effect relationships, spatial and temporal patterns of resource components, and alternative problem solutions. The principal hypothesis being tested states that water level fluctuations resulting from navigation dam operation create less than optimal conditions for the reproduction and growth of target aquatic macrophyte and fish species. Representative navigation pools have been selected to describe hydrologic, engineering, and legal constraints within which fish and wildlife objectives can be established. Spatial analyses are under way to predict the magnitude and location of habitat changes that will result from controlled changes in water elevation.

257. Lucas, M. C. and E. Batley (1996). Seasonal movements and behaviour of adult barbel *Barbus barbus*, a riverine cyprinid fish: Implications for river management. Journal of Applied Ecology. **33**:1345-1358.

To provide information on the movements and localized activity of barbel *Barbus barbus* (Cyprinidae) in a river containing potentially obstructing weirs, 31 adult barbel were radio-tracked in the River Nidd, a tributary of the Yorkshire Ouse, North East England between June 1993 and September 1994. Barbel exhibited substantial movements, ranging from 2 to nearly 20 km. Four fish are known to have moved between the Nidd and the Ouse, demonstrating that at least a part of the barbel population utilize the Nidd and Ouse at different times of the year. Range of upstream movement was restricted by the presence and nature of several weirs, including Skip Bridge flow-gauging weir. Low levels of spawning downstream of Skip Bridge weir appear to have been due to a lack of suitable spawning habitat. Movements followed a seasonal pattern, with males and females migrating upstream in spring to spawn on gravel beds. Females moved downstream more quickly than males over the summer months. Both sexes moved downstream in autumn and winter. Day length and water temperature were the best predictors in relation to distance moved up the River Nidd. Descriptive models, relating movement to water temperature and day length, are provided. For both sexes, localized activity varied greatly on both diel and seasonal scales, and was mainly associated with foraging. During summer there was typically a bimodal pattern of diel activity with peaks usually in early morning and late evening. In winter, mean daily activity was less than 20% of peak summer levels and fish were relatively dormant. In winter, diel activity patterns exhibited a single peak towards dusk. Mean daily activity levels for each month were linearly correlated with mean monthly water temperatures, even during the months where movement to and on the spawning sites occurred. The importance of natural migrations and seasonal activity patterns for barbel, and likewise many other riverine cyprinids, has probably been underestimated for a wide variety of river systems. As

major components of riverine fish communities, the importance of seasonal movements of mobile cyprinid species should be considered when constructing weirs and other obstructions. Greater consideration should be given to ways of mitigating effects of existing barriers to movement of non-salmonid species.

258. Lucas, M. C. and P. A. Frear (1997). Effects of a flow-gauging weir on the migratory behaviour of adult barbel, a riverine cyprinid. Journal of Fish Biology. **50**:382-396.

Barbel *Barbus barbus* exhibited substantial movements in the River Nidd between March and July 1994, with some individuals moving nearly 20 km upstream, although there was considerable individual variation. Most upstream movement occurred during May. Fifteen of the 23 fish tracked attempted to pass the weir, and of these six were successful. Barbel tended to approach the weir around dusk and dawn, reflecting observed patterns of localized activity, or at night, but crossed the weir only at night. Those fish which crossed the weir moved substantial distances upstream to spawn, while those that were unsuccessful moved downstream. The weir delayed the net upstream progress of all adult barbel. Successful traversal was not closely related to flow or water temperature conditions. The study emphasizes the impact of relatively minor obstructions on the natural migrations of barbel.

259. Lucas, M. C., T. Mercer, J. D. Armstrong, S. McGinty and P. Rycroft (1999). Use of a flat-bed passive integrated transponder antenna array to study the migration and behaviour of lowland river fishes at a fish pass. Fisheries Research (Amsterdam). **44**:183-191.

The suitability of fish pass designs currently installed in rivers for non-salmonid species is poorly known, particularly in terms of their efficiency. The use of an automated flat-bed passive integrated transponder (PIT) antenna array to study the behaviour of fish at a Denil pass on the Yorkshire Derwent, North East England, is described. The array comprised four flat PIT antennae, each connected to a detector unit. Two antennae were positioned at the downstream end of the fish pass, and two at the upstream end. Each detector unit sent interrogation signals, received transponded signals from tags, and stored the data in a memory chip. Efficiency of the upstream detectors was validated as near 100% using tagged brown trout *Salmo trutta* introduced below the detectors and observed to swim past them. Between 22 May 1998 and 23 June 1998 a total of 284 fish, comprising 11 species with a combined length range of 9-95 cm, were PIT tagged and released downstream of the fish pass. Continuous recording between 23 May 1998 and 31 August 1998 demonstrated the effectiveness of the PIT array at this site, for recording entry to, and successful exit from the pass. A total of 160 separate entires from 36 different fish were recorded at the downstream detectors, and six fish successfully exited from the top of the pass, giving a pass efficiency of 16.7%, based on the proportion of different fish which passed. Overall 12.7% of tagged fish entered the pass, comprising chub *Leuciscus cephalus*, dace *Leuciscus leuciscus*, roach *Rutilus rutilus*, perch *Perca fluviatilis*, bleak *Alburnus alburnus* and brown trout.

260. Lupton, C. J., M. J. Heidenreich and P. Byrne (1995). An assessment of fisheries resources and fishway modification on the Ben Anderson tidal barrage in the Burnett River, Queensland 1994. Department of Primary Industries, Brisbane, Queensland (Australia).

Due to community concern about the perceived decline in fish stocks above and below the tidal barrage in the Burnett River, a project was undertaken to: document species diversity, abundance, reproductive condition and the migratory timing of the species in the upper estuarine limits of the river; assess and compare modified vertical slots and the existing pool-weir configuration; identify design and operational deficiencies whilst offering feasible modifications and preliminary costings that would enhance the fishway's performance. Results and recommendations are reported.

261. Mader, H., G. Unfer and S. Schmutz (1998). The effectiveness of nature-like bypass channels in a lowland river, the Marchfeldkanal. Pages 384-402 *in* M. Jungwirth, S. Schmultz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

We investigated the effectiveness of two nature-like bypass channels in a lowland river, the Marchfeldkanal (MFK), a man-made side channel of the Danube river. The flow of the MFK is controlled by several weirs, each circumvented by a fish pass consisting of a sequence of nature-like pools connected by flumes. Physical conditions were measured in the bypasses and at the entrances across varying discharges. Fish passage was recorded using traps during spring and early summer from 1993 to 1995. Electrofishing samples in the pools below the weirs, and in a stretch of the canal below the lowermost weir, were compared with the species composition found in the traps. Flow experiments showed that the most efficient bypass channel discharge is about 0.25 m^2u^3/s, which provides both large cross-sectional areas with low flow velocities and high water depths within the flumes. There was no significant correlation between attraction flow (412% of the MFK mean flow) and fish passage. From 1993 to 1995 more than 150000 individuals of 40 species passed the bypass channels. Species composition was dominated by so-called 'non-migratory' small-sized species; juvenile fish comprised 14% of the catch. Comparing species composition below the weirs with passage provided a useful tool to assess species-specific efficiency of the bypass. This study proved the effectiveness of two nature-like bypass channels in a lowland river for almost all occurring species and lifehistory stages.

262. Mallen-Cooper, M. and J. H. Harris (1992). Fish migration in the Murray Darling system and the decline of the silver perch. Newsletter of the Australian Society of Fish Biologists. **22**:41.

Upstream movements of fish were studies in the River Murray at Torrumbarry Weir (near Echuca), which is the site of a new vertical-slot fishway that has been operating since February 1991. Sites were established 35 km above the weir and less than 1km and 6km below the weir. These sites were sampled monthly with gill-nets and fyke-nets from January 1990 to June 1992. Upstream fish movement was inferred from differences in relative fish density between the three sites. Potentially migrating fish which entered the base of the fishway were also trapped each month, and the numbers and species of fish reaching the top of the fishway were monitored daily at other times. Large accumulations of fish were recorded below the weir, particularly of golden perch and silver perch. In these two species the dominant migrating group was immature sub-adults, which appeared to move upstream in response to a wider range of environmental cues than adults. Over 4500 fish used the new fishway in the first ten weeks of operation and most size-classes and species of fish moving upstream appeared able to ascend the fishway. Reproductively mature silver perch moved upstream during small increases in flow in summer. These flow events are severely affected by river regulation, which may

explain the decline in silver perch indicated by commercial catches in the river and also supported by historical data of fish movements through weirs.

263. Mallen-Cooper, M., J. H. Harris and G. A. Thorncraft (1992). Enhancing upstream passage of fish through a navigation lock on the River Murray. Pages 41-42 *in* Annual Conference and Workshop: Australian Society for Fish Biology, Victor Harbour, S.A. (Australia), Newsletter of the Australian Society of Fish Biologists.

The potential for using the navigation locks of the River Murray to enhance the passage of migratory fish was examined. The upstream movement of fish through Lock 15 at Euston Weir was monitored during simulated standard operations of the lock and during modified operations. The latter operation used the gates of the lock partially open with a one metre gap and water flowing through this gap at 0.5 m/s. Fish movement was measured during three replicates of each type of operation. The modified operation of the lock led to a marked increase in fish passage. Thirteen fish moved upstream through the lock during three standard operations, and 601 fish moved through the lock during the three modified operations. Native fish constituted 90% of the catch. Using the navigation locks to pass migratory fish is valuable for enhancing fish passage in the River Murray but not a substitute for new fishways. Because the entrances of the locks are downstream of the face of the weir they can never act as highly efficient fishways. Nevertheless, the simple modifications to standard lock-operating procedures can provide a worthwhile adjunct to fishways in meeting the migration requirements of the River Murray native fish fauna. This study was funded by the Murray-Darling Basin Commission, which has since agreed to modify the operating procedures of the locks under its control.

264. Mann, R. H. K. (1988). Fish and fisheries of regulated rivers in the UK. Regulated Rivers: Research & Management. **2**:411-424.

This paper examines the historical and recent influences of river regulation on fish populations and fisheries in Britain. The construction of a series of canals and interconnecting waters during the 18th and 19th centuries facilitated the spread of some species between catchments. These slow-flowing habitats allowed many lowland species to thrive and this is reflected today in the fish community structure in some rivers. The problems to barriers to the movement of migratory species imposed by dams and weirs and the efficacy of compensation measures are discussed. The latter embrace fish passes, adult fish and smolt transport, and stocking. Potential problems for the future include the disruption of the homing of salmon to their natal rivers caused by transfers of water between catchments.

265. Mann, R. H. K. (1996). Environmental requirements of European non-salmonid fish in rivers. Hydrobiologia. **323**:223-235.

There is much evidence to show that the bottlenecks to recruitment in many non-salmonid fish populations relate principally to spawning success and to the growth and survival rates of newly-hatched larvae (Mills & Mann, 1985). This review deals with these parts of the life-cycle, together with the habitat requirements of adult fishes and the wider aspects of fish community structure. The review concentrates on the most common European species, especially those that are of commercial or angling importance (Table 1). However, data on habitat requirements are available for only some of these 32 species.

266. Maracek, S. and J. Wlosinski (1996). Fish movement through dams on the Upper Mississippi River. Pages 13 *in* J. T. Dukerschein, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

We analyzed the results from 89, mark-recapture and telemetry studies which were performed by others on the Upper Mississippi River as part of an investigation on fish passage opportunities. Fish were marked in Pools 4 through 18 and 26. Studies included information for 15 species of fish; black crappie, white crappie, bluegill northern pike, common carp, channel catfish, freshwater drum, flathead catfish, largemouth bass, paddlefish, sauger, shovelnose sturgeon, smallmouth bass, walleye, and white bass. The total number of fish marked in 59 of the studies was 62,618. Totals were not available for the remaining 30 studies. Less than ten percent of the marked fish were recaptured. No black crappie, white crappie, bluegill, northern pike, or common carp were found to move across a single lock and dam, either in an up or down direction. Of the total number of fish recaptured in all studies 4,594 (79.7%) were in the pool where the fish was initially marked, 712 (12.4%) moved upriver and 458 (7.9%) moved downriver. We also investigated the head differential between headwaters and tailwaters for each day the fish was at large. Unfortunately, most fish were at large for fairly long periods, so we could not pinpoint the head differential when the fish actually crossed a dam. The minimum head differential during the period when fish were at large was used to conservatively estimate fish passage opportunities. Of the fish moving upriver through dams 88.0% crossed with a head differential less than 2.0 feet. Of the fish moving downriver through dams 72% crossed with a head differential less than 2.0 feet. Only 3.9% of the fish that moved upriver did so when the head differential was at least 4.0 feet and 19.4% of the fish that moved downriver did so at that head differential. Of the walleyes, which made up 53% of the total number of fish that moved, 78% moved upriver through at least one dam. Of the walleyes that moved upriver, the majority crossed 1 to 5 dams. Ninety-one percent of the sauger, which made up 15% of the observations, also moved upriver through at least one dam. In contrast, 94% of the channel catfish, which made up 20% of the observations, moved downriver through at least one dam. Of the channel catfish that moved downriver, the majority crossed 4 to 9 dams.

267. Martin, R., A. Miller and N. Hahn (1994). Protecting Wisconsin waters from exotic invaders. Wisconsin Department of Natural Resources, Madison, Wisconsin (USA).

On April 29, 1992, Governor Thompson signed the budget adjustment bill (Act 269) into law. Section 9142 requires the Wisconsin Department of Natural Resources, in consultation with the Aquatic Nuisance Control Council, to prepare a report to the Legislature on zebra mussels by June 30, 1994. The Governor directed WDNR and the Council to examine additional staffing needs for zebra mussel activities and to develop recommendations on an appropriate funding level and potential non-general purpose revenue funding sources for consideration in the 1995-97 budget bill. Specifically the report was to identify the following key issues related to zebra mussels: The current and potential economic and environmental impacts; The potential control strategies; The geographical areas, public facilities or activities which need technical or financial assistance to reduce the environmental, public health or safety risk caused by this species; and The adequacy of existing state resources and staffing to address the problems posed by zebra mussels. This report was compiled to meet those requirements.

268. Matheney, M. I. and C. F. Rabeni (1995). Patterns of movement and habitat use by northern hog suckers in an Ozark stream. Transactions of the American Fisheries Society. **124**:886-897.

Although the northern hog sucker *Hypentelium nigricans* is widely distributed throughout the Mississippi and Ohio river basins and is both ecologically and recreationally important, much of its basic ecology is not known. We determined movement and habitat use for 25 fish in the Current River, Missouri, for 1 year using radio telemetry. Seasonal movements were recorded two or three times each week during daylight hours from January to November 1988. Diel movement and habitat use were recorded once each hour for 17 d in winter and 12 d in summer. Mean daily distance traveled was greater in summer (425 m) than in winter (276 m). Home range was greater in winter and spring (812 m) than in summer and fall (426 m). Habitat use changed seasonally from slower, deeper water and smaller substrates during winter to increasing use of faster, shallower water and larger substrates through warmer-water periods. In both seasons, fish had a consistent daily pattern, moving more during the day than at night. Diel patterns of use were distinct. In winter, fish used pool habitat with moderate flow during the day and riffle or edge habitat at night. In summer, fish used run habitat during the day and riffle or edge habitat at night. Patterns of habitat use indicated fish used one area of the river during the day to feed and another at night to rest. Fish remained in their home area during high-flow events but used flooded riparian areas where current velocities were lower. Fish moved up- or downstream short distances (mean = 497 m, N = 7) into spawning areas during late February and early March. This study emphasizes the importance of habitat diversity to accommodate this species' diel and seasonal preferences and the necessity of a connected floodplain for the fish to survive catastrophic events.

269. McCutcheon, C. S., E. F. Prentice and D. L. Park (1994). Passive monitoring of migrating adult steelhead with PIT tags. North American Journal of Fisheries Management. **14**:220-223.

In 1985, two independent passive integrated transponder (PIT) tag monitoring systems were installed at the exit area of weir leading into a fish trap on the north-shore fish ladder at Bonneville Dam, Columbia River. One hundred PIT-tagged adult steelhead *Oncorhynchus mykiss* were released in groups of 10 into an enclosed area of the ladder downstream from the detectors. The tagged fish were detected after they volitionally swam through the weir and slid through the detection system at velocities of 0.6 m/s or greater. Overall PIT tag reading efficiency was 98% and no tag-reading errors were recorded. Individual tag code, date, and time of the passage of each tagged fish were automatically recorded into a computer file and simultaneously printed onto a paper copy. These results suggest that PIT tag monitors of this design could be deployed at select adult passage facilities presently operating in the Columbia River Basin to interrogate returning PIT-tagged adult salmonids.

270. McIninch, S. P. and C. H. Hocutt (1987). Effects of turbidity on estuarine fish response to strobe lights. Journal of Applied Ichthyology. **3**:97-105.

The efficacy of a strobe light and a combined strobe light/bubble curtain system was evaluated under turbid water conditions as a fish avoidance scheme. Three estuarine

species commonly impinged at electric generating facilities along the Atlantic coast of the United States were tested: Atlantic menhaden *Brevoortia tyrannus*, spot *Leiostomus xanthurus*, and white perch *Morone americana*. The strobe light/bubble curtain combination was the most effective system studied in all cases. An interesting phenomenon was that fish avoidance to strobe light systems increased with turbidity over the range tested (clear, 39-45 and 102-138 NTU).

271. Mesiar, D. C., D. M. Eggers and D. M. Gaudet (1991). Development of techniques for the application of hydroacoustics to counting migratory fish in large rivers. Pages 223-232 *in* W. A. Karp, ed. Developments in Fisheries Acoustics: A Symposium, Seattle, Washington (USA), Rapports et Process-Verbaux des Reunions Conseil International pour l'Exploration de la Mer.

Management of commercial fisheries for Pacific salmon *Oncorhynchus* stocks returning to many of Alaska's (USA) large rivers has been hindered by the lack of timely information on stock strength and migratory timing. These rivers share characteristics (e.g., extensive multi-channel river mouths, turbid water, debris, large physical river dimensions, and presence of several fish species with overlapping spatial and temporal distributions) which make collection of such information difficult. Sonar was identified as a potential solution to the problem, and techniques of application and analysis were developed in the Yukon River between 1982 and 1985. Four primary components of the application are: identifying an appropriate site for equipment installation; identifying and ensonifying all areas of fish passage; expanding fish passage rates to temporal and spatial strata; and apportioning fish-passage estimates to species.

272. Miller, A. C. (1988). Mussel fauna associated with wing dams in Pool 7 of the Mississippi River. Journal of Freshwater Ecology. **4**:299-302.

Twenty-three species of freshwater mussels (Mollusca: Unionidae) were collected by divers in May, 1987, at 32 sites on and between wing dams in Pool 7 of the upper Mississippi River. Five species (*Amblema plicata*, *Obliquaria reflexa*, *Obovaria olivaria*, *Lampsilis ventricosa* and *Quadrula pustulosa*) comprised 90% of the fauna and were found at 88 - 100% of the sites. Specimens of *Actinoaias ligamentina*, *Plethobasus cyphyus*, and *Strophitus undulatus*, last reported in 1930, and the endangered *Lampsilis higginsi*, last reported in 1966, were collected alive.

273. Miller, A. C. and B. S. Payne (1991). Investigation of freshwater mussels (Unionidae) at selected sites in the lower Ohio and Cumberland rivers, September 1990. U.S. Army Corps of Engineers Waterways Experimental Station, Technical Report WES/TR/EL-91-9.

A survey to assess community characteristics, density, population demography of dominant species, and the likelihood of finding endangered species of freshwater mussels (Unionidae) was conducted in the lower Ohio River (river miles (RM) 954.0-964.0), the lower two miles of the Cumberland River, and a reach of the Ohio River (RM 920.0-920.5) near Smithland Dam in September 1990. Data will be used to analyze impacts of construction and operation of a new lock and dam at RM 964.4 on the Ohio River and modification of Smithland Lock and Dam near the confluence of the Cumberland River. Twenty-three species of unionids were collected using qualitative methods in the lower Ohio River; the fauna was dominated by *Fusconaia ebena* (40.9 percent), *Quadrula*

pustulosa pustulosa (10.76 percent), *Quadrula quadrula* (10.6 percent), and *Amblema plicata plicata* (9.0 percent). Total unionid density ranged from 37.6 to 68.0 individuals/sq m, and *Corbicula fluminea* density ranged from 11.2 to 26.8 individuals/sq m. Four specimens of the orange-footed pimpleback *Plethobasus cooperianus*, listed as endangered by the US Fish and Wildlife Service (1987), were collected (two using qualitative methods; two using quantitative methods).

274. Miller, A. C. and B. S. Payne (1991). Investigation of freshwater mussels (Unionidae) in the Tennessee River below Kentucky lock and dam. WES/TR/EL-91-8.

A survey to assess community characteristics, density, population demography of dominant species, and the likelihood of finding endangered species of freshwater mussels (Unionidae) was conducted in the lower Tennessee River. Data were collected to analyze environmental impact of construction and operation of a second lock at Kentucky Lock and Dam, RM 22.4. Twenty-three species and 4,768 freshwater mussels were obtained in 287 qualitative collections. The bivalve fauna was dominated by two thick-shelled species, *Amblema plicata* (39.43 percent) and *Fusconaia ebena* (39.41 percent). Six species comprised 1 to 10% of the collection, and 15 species made up less than 1% of the collection. No Federally listed endangered species were found. Species diversity was moderate, and evenness was low Unionid density at six sites in the area to be dredged ranged from 9.2 to 128.0 individuals per square meter. *Corbicula fluminea* density ranged from 6.0 to 26.4 individuals per square meter, which was considerably less than values reported in this river reach in 1969. The total commercial value of four species (*A. plicata, Megalonaias nervosa, F. ebena*, and *Quadrula quadrula*) within the area the will be dredged was estimated at $101,707. Total density of snails ranged from 8.0 to 86.8 individuals per square meter; the fauna was dominated by *Pleurocera canaliculatum* , with lesser numbers of *Lithasia armigera* and *L. verrucosa* . Impacts due to construction and operation of the second lock can be partially offset by creating submerged habitats with dredged materials along an eroding bank downriver of the lock and dam.

275. Miller, A. C. and B. S. Payne (1998). Effects of disturbances on large-river mussel assemblages. Regulated Rivers: Research and Management. **14**:179-190.

Data from more than 10 years of quantitative sampling from stable gravel shoals in large rivers of the central US were used to test the effects of specific disturbances (passage of commercial navigation vessels, the flood of 1993, and introduction of *Corbicula fluminea*) on native freshwater mussels (Family: Unionidae). Although many lotic species of Unionidae have been eliminated from large rivers because of degraded water quality, poor land use practices, and large-scale navigation projects, the resulting fauna appears to tolerate many disturbances. For example, high density populations of *C. fluminea* had no effect on unionid density at two shoals in the lower Ohio River. The record flood of 1993 in the Upper Mississippi River had no measurable effect on mussels at three locations; species richness (22-25), density (45.3-60.3), and percentage of juveniles (11-26%) varied among years but showed no temporal trend. In a barge turning basin that was dredged in 1976, density of recently recruited *Amblena plicata plicata* was not significantly different from density at a reference site for six of nine study years indicating that recruitment is proceeding at a similar rate regardless of current traffic levels. The mussel fauna now inhabiting large rivers, dominated by thick-shelled species tolerant of reduced water velocity and increased sedimentation, appears to be quite resilient to many natural and man-induced disturbances.

276. Miller, R. R., J. D. Williams and J. E. Williams (1989). Extinctions of North American fishes during the past century. Fisheries. **14**:22-38.

Extinctions of 3 genera, 27 species, and 13 subspecies of fishes from North America are documented during the past 100 years. Extinctions are recorded from all areas except northern Canada and Alaska. Regions suffering the greatest loss are the Great Lakes, Great Basin, Rio Grande, Valley of Mexico, and Parras Valley in Mexico. More than one factor contributed to the decline and extinction of 82% of the fishes. Physical habitat alteration was the most frequently cited causal factor (73%). Detrimental effects of introduced species also were cited in 68% of the extinctions. Chemical habitat alteration (including pollution) and hybridization each were cited in 38% of the extinctions, and overharvesting adversely affected 15% of the fishes. This unfortunate and unprecedented rate of loss of the fishery resource is expected to increase as more of the native fauna of North America becomes endangered or threatened.

277. Millette, A. J. (1987). Wilder fish ladder with a hydroturbine as a fish-attracting water system. Pages 551 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Cooper, eds. Common Strategies of Anadromous and Catadromous Fishes, American Fisheries Society Symposium Serial, Boston, Massachusetts (USA).

Fish ladders and hydroelectric power generation have historically competed for water from available streamflow. For a fish ladder to be effective, migrating fish must be attracted to the fishway entrance. To attract fish, a large volume of "attraction" flow is added to the relatively small fishway flow just inside the fishway entrance, and the combined flow discharges to the tailrace as a plume, which attracts upstream-migration fish such as Atlantic salmon *Salmo salar* and American Shad *Alosa sapidissima* . The common methods of providing attraction flow are pumped flow lifted to the fishway from the tailrace and gravity flow dropping from the forebay pond. Both options are net users of power, since pumps consume electric power and gravity flow uses water which has the potential to generate electricity. At Wilder Dam, a 17-m head had to be dissipated. Two options were studied: energy-dissipating valves and chambers; and a small hydroturbine. Both did the job; however, the energy-dissipating valve is an energy waster, whereas the hydroturbine drives a 3,200-kW hydroelectric generator, producing economic benefits that offset its cost. The fishway turbine-generator has the additional benefits of providing year-round low-flow augmentation at peak generating efficiency and increased base-load generation during high-flow periods.

278. Mims, S. D. (1998). Paddlefish in Kentucky. Aquaculture Magazine. **24**:20-22.

Paddlefish, spoonfish, spoonbill cat and *Polydon spathula* are among several names given to this unique prehistoric fish. Paddlefish are the largest freshwater fish in the United States at 6 feet in length and weighing over 200 pounds. They are found in 22 states that have large streams, rivers and impoundments within the Mississippi River basin and adjacent Gulf Coastal drainages. Unlike most fish, a paddlefish is a filter feeder able to remove zooplankton (minute free-floating animals) from the water as their main food source.

279. Minshall, G. W., K. W. Cummins, R. C. Petersen, C. E. Cushing, D. A. Bruns, J. R. Sedell and R. L. Vannote (1985). Developments in stream ecosystem theory. Canadian Journal of Fisheries and Aquatic Sciences. **42**:1045-1055.

Four significant areas of thought, (1) the holistic approach, (2) the linkage between streams and their terrestrial setting, (3) material cycling in open systems, and (4) biotic interactions and integration of community ecology principles, have provided a basis for the further development of stream ecosystem theory. The River Continuum Concept (RCC) represents a synthesis of these ideas. Suggestions are made for clarifying, expanding, and refining the RCC to encompass broader spatial and temporal scales. Factors important in this regard include climate and geology, tributaries, location-specific lithology and geomorphology, and long-term changes imposed by man. It appears that most riverine ecosystems can be accommodated within this expanded conceptual framework and that the RCC continues to represent a useful paradigm for understanding and comparing the ecology of streams and rivers.

280. Mitchell, C. P. (1986). Effects of introduced grass carp on populations of two species of small native fishes in a small lake. New Zealand Journal of Marine and Freshwater Research. **20**:219-230.

Stocking *Ctenopharyngodon idella* (grass carp) for aquatic weed control into a 1.92 ha lake (Parkinsons Lake, 37 degree 19'S, 174 degree 41'E) altered the size and abundance of two species of small native fish, *Retropinna retropinna* (smelt) and *Gobiomorphus cotidianus* (bully). The response of the two species differed. *R. retropinna* recruitment apparently failed during the "high impact" phase of *C. idella* stocking (44 fish ha super(-1)), when all aquatic weeds were removed. Immature fish disappeared and samples comprised 100% large females. *G. cotidianus* also increased in size, however, condition improved and the sex ratio did not alter markedly. Following reduction in *C. idella* stocking density, some return of population meristics toward prestocking values occurred. Loss of the weed bed habitat, water quality deterioration, and increased predation were considered the major environmental impact factors during the period when these changes occurred.

281. Mitchell, C. P. (1989). Swimming performances of some native freshwater fishes. New Zealand Journal of Marine and Freshwater Research. **23**:181-187.

Observations were made of the response to water velocity for upstream migrating juveniles of 5 diadromous native fishes (*Anguilla australis*, *Galaxias maculatus*, *G. fasciatus* , *Retropinna retropinna*, *Gobiomorphus cotidianus*). Swimming performance within a hydraulic flume was measured and observations made of the behavioural adaptions of some species to swim through high water velocities. Timed swimming at known water velocities allowed estimation of critical velocities for fish passage. For juvenile fishes (30-80 mm total length), velocities below 0.3 m/s should allow unrestricted passage over obstacles less than 15 m in length. Water velocities below 0.25 m/s may be necessary for obstacles over 15 m.

282. Mitchell, C. P., P. Dinamani and R. W. Hickman (1980). Culture and uses of grass carp in New Zealand. Pages 75-76 *in* Aquaculture Conference, Wellington (New Zealand), Occasional Publications of Fisheries Research, Division of the Ministry of Agriculture (New Zealand).

Grass carp *Ctenopharyngodon idella* were firstly imported into New Zealand in the late 1960's for aquatic weed control. However, it is believed that further possible uses may be realised as the potential of the species becomes apparent. Grass carp could be cultured as a food fish, having the advantages of being palatable rapid growing, cheap to feed and tolerant to handling and adverse environment conditions. As they are difficult to spawn in warmer climates, a demand exists for fingerlings throughout the tropics. They may also be used in New Zealand for protein reclamation systems. Grass carp may have potential roles in New Zealand for environmental protection, food production, and possibly as export earners.

283. Mitzner, L. (1978). Evaluation of biological control of nuisance aquatic vegetation by grass carp. Transactions of the American Fisheries Society. **107**:135-145.

Grass carp *Ctenopharyngodon idella* introductions at Red Haw Lake, Iowa resulted in a decrease of aquatic macrophytes from 2438 g/m^{-2} in 1973 to 211 g/m^{-2} in 1976, with species of *Potamogeton*, *Elodea*, *Ceratophyllum* and *Najas* all controlled effectively. During 1974-1976 mean nitrites, nitrates, biological oxygen demand, and turbidity showed significant decreases, while alkalinity increased significantly from a mean of 115 mg/l in 1974 to 132 mg/l in 1976. Mean concentrations of organic and inorganic phosphates gradually increased during the investigation, but were not statistically different. Average primary production was nearly identical in 1974-1975 at about 2 g carbon/m^{-2} /day, but decreased significantly to 1.35 g carbon/mm^{-2} /day in 1976. Growth of stocked grass carp was rapidly increasing from a mean weight of 380 g in July, 1973 to 6847 g by October, 1976. Body condition ranged from 1.05-2.02 with average condition over 1.37 in October and 1.25-1.30 in January-February. Greatest population biomass was estimated in 1975 at 61 kg/hectare. Grass carp consumed all major plant groups at the lake with greatest selection for Najas and Potamogeton . Movement, behaviour and activity as determined by ultrasonic telemetry showed grass carp inhabited all areas of the lake, but overall there was a preference for shallow areas of the main lake with lesser selection for embayments. Most of the time grass carp were sedentary near weed beds with more rapid and extended movement in midwater. Normal swimming speed in midwater was 0.12-0.35 m/s with maximum speed of 1.46 m/s. Homing tendency was shown in 2 of 9 tagged fish. There was similarity in nocturnal and diurnal activity

284. Mitzner, L. (1994). Management of aquatic vegetation with grass carp in Iowa, 1973-1993. Lake and Reservoir Management. **9**:99-100.

Diploid grass carp have been used in Iowa to control aquatic macrophytes for over two decades. Initial introduction occurred at Red Haw Lake in 1973 as part of a research investigation to study the feasibility of macrophyte control. Routine use of grass carp as a fisheries management technique in state-owned lakes commenced in 1975, and by 1979, the general public was permitted to buy and stock grass carp into public waters. Over 700 permits were issued to the private sector the first year the permitting system went into effect. Since 1973, grass carp have been stocked in over 40 state-owned lakes, and since 1979 approximately 2,000 private waters have been stocked. Stocking rate was initially 10 per acre (total lake surface), but more recently the recommended stocking rate was reduced to 5 or less per lake surface acre. Length of grass carp at stocking is recommended at >8 inches in waters containing largemouth bass. Partial control of vegetation by grass carp is rarely attained; normally there is an all-or-none response. At

lakes with 100% control of vegetation, there are only minor changes in sport fish populations. For example, fisheries managers reported diminished bluegill recruitment at some lakes with 100% vegetation control. The most common complaint comes from bass anglers who perceive the "weedline" as being greatly reduced. Thus, according to anglers, bass are not nearly as vulnerable to hook and line at lakes with extensive macrophyte control. Overall, sportfishing has not been adversely impacted by grass carp introductions and in most cases catch has increased because of more available access to shore anglers fishing for bluegill and crappie. Grass carp reproduction has not been documented in Iowa waters; however, adults have been caught incidentally (60 lbs per pool) in commercial fishing gear in the Mississippi River bordering Iowa.

285. Moen, C. T., D. L. Scarnecchia and J. S. Ramsey (1992). Paddlefish movements and habitat use in Pool 13 of the Upper Mississippi River during abnormally low river stages and discharges. North American Journal of Fisheries Management. **12**:744-751.

The authors determined the movements and habitat use by adult paddlefish *Polyodon spathula* during unusually low water levels in Pool 13 of the Upper Mississippi River. Thirty-two large fish (6.3-25.4-kg) implanted with radio transmitters were located an aggregate of 812 times during March-August 1988, and spring 1989. No relation could be discovered between changes in river stage or discharge and direction of movement. No tagged paddlefish moved upstream from Pool 13, but during 1988 six fish moved downstream into Pool 14. Rates of movement were not significantly different between sexes, but the linear range for females was twice that of males. The greatest linear distance a paddlefish moved was 92 km downstream, and the greatest cumulative movement--entirely within Pool 13--was 435 km; both records were set by females. Nearly three-fourths of all contacts with paddlefish occurred in about 5% of available habitat in Pool 13. Paddlefish were located most frequently at the head of Pool 13 in the tailwaters below Lock and Dam 12. Even though the gates of Lock and Dam 12 were fully open in 1989, fish did not move upstream into Pool 12. The fish also commonly used main-channel borders with wing dams but rarely used backwaters or side channels. Water depth and velocity in areas used by paddlefish were generally within the optima suggested by current habitat suitability models, but water temperatures were usually greater than optimum.

286. Moffitt, C. M., B. Kynard and S. G. Rideout (1982). Fish passage facilities and anadromous fish restoration in the Connecticut River basin. Fisheries. **7**:2-11.

Fish passage facilities now exist at three dams on the mainstem of the Connecticut River and at two dams on tributaries in the State of Connecticut: the Farmington and Salmon Rivers. Facilities on the tributary rivers were not included in the Federal Power Commission settlement agreements. Efforts by state and federal agencies to mitigate fish losses have been in progress since the mid-1800's in the form of fishing regulations, stocking programs, and construction of fish passage facilities. The purpose of this paper is to review the decline of anadromous fish following the construction of dams, and the subsequent fish restoration efforts. The latter focuses primarily on the results achieved after the construction of fish passage facilities.

287. Monk, B., D. Weaver, C. Thompson and F. Ossiander (1989). Effects of flow and weir design on the passage behavior of American shad and salmonids in an experimental fish ladder. North American Journal of Fisheries Management. **9**:60-67.

During the 1960s, as more dams went into full operation on the Columbia River, it was discovered that the passage of American shad *Alosa sapidissima* was restricted or completely blocked through the regulating sections of some of the fish ladders. To study the problem, a full-scale laboratory model of six pools of the regulating section of the fish ladders at John Day Dam was built. American shad, chinook salmon *Oncorhynchus tshawytscha* , sockeye salmon *O. nerka* and steelhead *O. mykiss* (formerly *Salmo gairdneri*) were counted and timed through various weir designs at different heads. American shad oriented toward surface flows, tending to reject submerged orifices as shallow as 2 m. The amount of time spent in the ladder by American shad depended on the head between pools. The species of salmonids tested were not significantly impeded by any of the weir designs or head differentials.

288. Moring, J. R. (1993). Anadromous stocks. Pages 553-580 *in* C. C. Kohler and W. A. Hubert, eds. Inland Fisheries Management in North America, American Fisheries Society, Bethesda, Maryland (USA).

Management of anadromous species can be highly complex, involving the input of many agencies, municipalities, and groups, as well as biological and political concerns. Fortunately, fisheries managers have numerous tools at their disposal. Fish culture has been an important component of management plans since the mid-1800s, but refinements in diet, disease control, growth, and survival are still needed. A critical concern for anadromous species is fish passage: maximizing survival for upstream and downstream-migrating fish. Computerized modelling exercises suggest that new techniques for diverting downstream fry, smolts, and spent adults may have a significant effect on survival, overall run numbers, and production. Genetic selection and improvements in stream habitat are also options available to fisheries managers to improve survival of wild and hatchery-produced fish. Further management options include some of the more innovative techniques, such as delayed release programs to promote localized sport fisheries. Fisheries managers must then decide how resources should be allocated. Along with this comes questions such as What is the optimal size of fish and time at release? How can the public become involved in habitat improvement and other restoration and enhancement programs? How can fisheries be improved through interagency and other types of cooperative management? These are the challenges in anadromous fish management.

289. Morrow, J. V., Jr., J. P. Kirk, K. J. Killgore and S. G. George (1998). Age, growth, and mortality of shovelnose sturgeon in the Lower Mississippi River. North American Journal of Fisheries Management. **18**:725-730.

Two hundred of 295 shovelnose sturgeon *Scaphirhynchus platorynchus* captured in the Mississippi River near Rosedale and Vicksburg, Mississippi, were aged by examining sectioned pectoral fin rays. Ages ranged from 2 to 16 years, and the annual mortality was 20% for ages 7 and greater. The weight (W, g), to fork length (FL, mm) relation was $W = 0.000001257\ FL^{3.174}$ ($R^2 = 0.87$). The von Bertalanffy growth equation for fork length was $FL = 730(1 - e^{-0.213(t+0.972)})$; the equation for weight was $W = 1{,}604(1 - e^{-0.148(t-1.841)})$. Mortality and mean length at age were less than has been reported for Upper Mississippi River populations of shovelnose sturgeon. Knowledge of causes of mortality of shovelnose sturgeon may have applications in management of the sympatric pallid sturgeon *Scaphirhynchus albus*.

290. Morrow, J. V., Jr., J. P. Kirk, K. J. Killgore, H. Rogillio and C. Knight (1998). Status and recovery potential of gulf sturgeon in the Pearl River System, Louisiana-Mississippi. North American Journal of Fisheries Management. **18**:798-808.

From 1992 through 1996, 257 Gulf sturgeon *Acipenser oxyrinchus* desotoi were captured in the Pearl River system of Louisiana and Mississippi, but adults (>130 cm fork length) constituted less than 2% of the catch. The summer population size in 1996, estimated by mark-recapture methods, was 292 individuals that were age 2 or older. Instantaneous total mortality rate (Z), estimated with a catch curve, was 0.41, for an annual mortality rate of 34%. Modeling the population with Z = 0.41 resulted in declining populations under two different recruitment scenarios. Mortality rates will have to be reduced to Z = 0.16-0.24 for the population to be self-sustaining by 2023, the target year in the Gulf Sturgeon Recovery Plan. Mean fork length of Gulf sturgeon in the Pearl River system was significantly larger in 1970 than in 1985 and 1992-1996, indicating that the population may not have improved since 1985. An increase in population size should be detectable within 6 years of achieving acceptable levels of mortality. Efforts to reduce mortality should focus on commercial bycatch and improving winter habitat in the Lake Pontchartrain estuary and summer habitat in the Pearl River system. Weirs in the Pearl and Bogue Chitto rivers need further study to determine if improved fish passage would improve recruitment and survival of Gulf sturgeon.

291. Moser, M. L., A. M. Darazdi and H. J.R. (2000). Improving passage efficiency of adult American shad at low-elevation dams with navigation locks. North American Journal of Fisheries Management. **20**:376-385.

Use of navigation locks represents a low-cost alternative to the construction of fishways or lifts at low elevation (<5 m) dams. We used sonic tracking to assess the passage efficiency of adult American shad *Alosa sapidissima* in 1996-1998 through the navigation locks at Lock and Dam 1 on the Cape Fear River, North Carolina. We also tested the passage efficiency at a steeppass fishway installed in 1997. Eighty-six tagged American shad were released below the dam over the 3-year study; passage efficiency ranged from 18% in 1997 (a year of high discharge during the tracking period) to 61% in 1998. During low flows, we were able to improve passage efficiency by (1) operating the lock to pass fish through until mid-June, (2) increasing attraction flows emanating from the lock entrance, (3) conducting as many lockages (i.e., use of locks to pass fish upstream) as possible in a day, and (4) closing one of the lower lock gates to better retain fish in the lock chamber after they had enterred. The steeppass fishway was not as effective as the navigation locks for passage of American shad. Only three tagged fish (8%) used the fishway in 1998, probably because of design deficiencies and the lack of attraction flow at the fishway entrance.

292. Mourad, M. H. (1991). Influence of body size on swimming performance of carp (Cyprinus carpio). Acta Ichthyologica et Piscatoria. **21**:87-91.

The influence of body size on fish swimming performance was investigated. There was a positive correlation between body size and swimming speed. On the contrary, the relations between body size and time of fatigue, fish travel, physical effort were reverse. The reasons for the differences and the assumptions involved are discussed. (DBO)

293. Mueller, U. K., E. J. Stamhuis and J. J. Videler (2000). Hydrodynamics of unsteady fish swimming and the effects of body size: comparing the flow fields of fish larvae and adults. Journal of Experimental Biology. **203**:193-206.

Zebra danios (*Brachydanio rerio*) swim in a burst-and-coast mode. Most swimming bouts consist of a single tail flick and a coasting phase, during which the fish keeps its body straight. When visualising the flow in a horizontal section through the wake, the effects of the flow regime become apparent in the structure of the wake. In a two-dimensional, medio-frontal view of the flow, larvae and adults shed two vortices at the tail during the burst phase. These vortices resemble a cross section through a large-core vortex ring: two vortex cores packed close together with the central flow directed away from the fish. This flow pattern can be observed in larvae (body length approximately 4 mm) at Reynolds numbers below 100 as well as in adult fish (body length approximately 35 mm) at Reynolds numbers above 1000. Larval vortices differ from those of adult zebra danios mainly in their relatively wider vortex cores (higher ratio of core radius to ring radius) and their lower vortex circulation. Both effects result from the increased importance of viscosity on larval flows. During the coasting phase, larval and adult flows again differ because of the changing importance of viscosity. The high viscosity of the water causes large vortical flows adjacent to the larva's body. These regions of high vorticity represent the huge body of water dragged along by the larva, and they cause the larva to stop almost immediately after thrust generation ceases. No such areas of high vorticity are visible adjacent to adult zebra danios performing a comparable swimming manoeuvre. The rapid decrease in vortex circulation and the severe reduction in the coasting distance due to viscous drag contribute to the high cost that larvae - unlike adult fish - face when using a burst-and-coast swimming style.

294. Mukherjee, A. B. (1987). Preliminary observations on the efficacy of fish locks in the Farakka Barrage. Pages 25 *in* Symposium on the Impact of Current Land Use Pattern and Water Resources Development on Riverine Fisheries, Barrackpore (India).

Various types of hydraulic structures and headworks such as dams, barrages, weirs, etc. constructed on many of rivers, have posed a threat to the migration of riverine fishes. This resulted in considerable fall in fish productivity in the river system. In most of the hydraulic structures, although different types of facilities (fish ladders, fishways, fish locks) have been provided to enable the fish to migrate upstream past the obstacles, it is reported that majority of the devices are hardly usable for the migrating fish. This is because of empirical design of most of the devices where due consideration has not been given to the performance and behaviour of the fish species that would utilise the pass for ascending upstream. Some preliminary observations made on the utility and effectiveness of the fish locks provided in the Farakka Barrage and their role to pass fish upstream over the barrage, having a rather wide range of heads, are presented.

295. Mulvey, M., H. P. Liu and K. L. Kandl (1998). Application of molecular genetic markers to conservation of freshwater bivalves. Journal of Shellfish Research. **17**:1395-1405.

Freshwater bivalves (Unionacea) are among the most endangered faunal elements in North America. Molecular genetic studies have much to offer conservation efforts directed to this declining fauna. Molecular genetic data can provide information needed to identify evolutionarily significant units, resolve taxonomic ambiguities, describe population structure, evaluate impacts of habitat fragmentation and reduced gene

flow among populations, reconstruct phylogenetic relationships, clarify fish host-glochidia relationships, and provide evidence in legal actions. Molecular genetic techniques and their application to freshwater bivalves are reviewed.

296. Mundie, J. H. (1991). Perspectives: Overview of effects of Pacific Coast river regulation on salmonids and the opportunities for mitigation. Pages 1-11 *in* J. Colt and R. J. White, eds. Fisheries Bioengineering Symposium, Bethesda, Maryland (USA), American Fisheries Society.

Current awareness of the seriousness of losses of salmonid fishes associated with hydroelectric developments and with water abstraction from river systems has stimulated renewed commitments on the part of fishery agencies to mitigation of damage, restoration of degraded habitat, protection and promotion of wild stocks, and increased artificial production of salmonids. To achieve these aims the fish system, the fluvial system, and the system of human values and intentions must be integrated; in addition today's knowledge must be equal to the challenge. Examination of the present status of six aspects of the task shows that (1) facilitation of fish passage at dams is a very high priority but requires greater commitment, (2) hatchery production has generated unreasonable expectations and may be laying the basis for the demise of wild populations, (3) the practice of stocking fry has run ahead of its evaluation, (4) determination of instream flow requirements is bedeviled by spurious quantification, (5) drawdown requirements of impoundments seem incompatible with fishery objectives, and (6) stream habitat improvements give mixed results and may be of restricted application in terms of scale. Yet another limitation of fisheries' aspirations lies in political support. It is concluded that this is a time for stock-taking, improvement of current practices, and assessment of trends.

297. Mutsin'sh, A. N. (1979). Current velocities and the behavior of young fish. Journal of Ichthyology. **19**:171-173.

The paper is a brief account of experiments carried out to study the behavior (swimming speed, swimming duration, orientation) of young roach and rainbow trout in relation to flow velocities in the zone influenced by water intake structures.

298. Nakamura, S. (1997). Fishways for upstream diadromous migrants. Pages 34-38 *in* International Symposium on Fish Migration: Physiology and Ecology of Fish Migration, Hokkaido (Japan), Memoirs of the Faculty of Fisheries, Hokkaido University.

This paper presents a short review of some recent advances in fishway technology such as new types of fishways and new data on velocities in fishways and on fish swimming ability. It also includes new concepts such as maintaining a fishway's effectiveness in high water stages and the need to offer equal opportunity for successful migration to all diadromous migrants.

299. National Technical Information Service (1991). Fishways: design and operation 1970 - February 1986. NTIS, Bibliography PB86-857299/GAR.

An annotated bibliography from the open literature on the design and operation of fishways, covering the period 1970 to 1986, is presented.

300. Nemenyi, P. (1941). An annotated bibliography of fishways. University of Iowa Studies in Engineering Bulletin24.

An effort has been made to give to this bibliography a fairly comprehensive scope in the sense that it includes abstracts and titles of papers covering an entire group of interrelated subjects; and to make it as far as possible representative of all significant trends of recent progress in these fields attained mainly in western and northwestern Europe, as well as in this country.

301. Neves, R. J., J. R. Weaver and A. V. Zale (1985). An evaluation of host fish suitability for glochidia of *Villosa vanuxemi* and *V. nebulosa* (Pelecypoda: Unionidae). American Midland Naturalist. **113**:13-19.

Fish species congeneric with previously identified hosts, as well as exotic fishes (*Xiphophorus variatus* and *Tilapia aurea*) and the mosquitofish *Gambusia affinis*, were exposed to glochidia of *Villosa vanuxemi* or *V. nebulosa* to determine whether phytogenetically similar fishes can serve as hosts. Glochidia of *V. vanuxemi* metamorphosed on black *Cottus baileyi*, mottled *C. bairdi* and slimy *C. cognatus* sculpins, and glochidia of *V. nebulosa* metamosphosed on spotted *Micropterus punctulatus*, largemouth *M. samoides* and Suwannee *M. notius* basses and the mosquitofish. Exotic fishes were unsuitable hosts. A review of previous *in vivo* and *in vitro* studies suggests that chemical components of the blood serum in fishes, as yet unidentified, dictate host suitability to specific glochidia.

302. Neves, R. J. and J. D. Williams (1994). Status of the freshwater mussel fauna in the United States. Journal of Shellfish Research. **13**:345-346.

A comprehensive review of the conservation status of the 297 species and subspecies of native freshwater mussels in the U.S. was completed to assess present and future trends for the fauna. Distributional data, historic and recent collection records of biologists, and literature reviews provided sufficient information to categorize the status of each species. Twenty-one taxa (7%) are listed as endangered but presumed extinct; 77 (21%) are endangered but extant; 43 (14%) are threatened; 72 (24%) are of special concern, 14 (5%) are of undetermined status; and only 70 (24%) are considered stable at this time. The primary reasons for the decline of freshwater mussels are habitat destruction from dams, channel modification, siltation, contaminants, and the introduction of exotic mollusks. Construction of dams within the Tennessee River system by the Tennessee Valley Authority, and dams and navigation projects in large rivers by the U.S. Army Corps of Engineers created impoundments and tailwaters that were unsuitable for many indigenous species. Nonpoint source pollution from agriculture and urban runoff, and point source discharges have contributed pollutants and contaminants to degrade water quality. Competition from non-native mollusks such as the Asian clam (*Corbicula fluminea*) has seemingly affected some mussel populations in streams, and the zebra mussel (*Dreissena polymorpha*) appears poised to decimate commercially important mussel populations occurring in large rivers. The high numbers of imperiled freshwater mussels in the U.S., which harbors the most diverse mussel faunal globally, indicate an impending extinction crisis that will severely reduce an important component of aquatic biodiversity. The harvest and export of mussel shells for the cultured pearl industry in Asia will be affected by the decline in mussel populations in the U.S.

303. Nicola, G. G., B. Elvira and A. Almodovar (1996). Dams and fish passage facilities in the large rivers of Spain: effects on migratory species. Archiv fuer Hydrobiologie Supplement. **113**:375-379.

The construction of dams in Spain has steadily increased during this century, with a peak between 1960 and 1990. Today, there are more than 1100 operating large dams. The presence of dams without fish passes in large rivers appears to be a major contributing factor in the decline of native fish, especially of migratory species. In fact, all anadromous and catadromous fish are presently threatened and included in the Spanish Red Data Book. Species such as lamprey *Petromyzon marinus*, sturgeon *Acipenser sturio*, shads *Alosa* and eel *Anguilla anguilla* are now extinct in wide areas of central Spain, due to the blockage of fish movements caused by dams built in large rivers. As part of an ongoing national project started in 1993, we researched the existence and effectiveness of fish passage facilities at Spanish dams. The main preliminary finding is that fishways are frequently absent in large dams, while fish ladders are the most common type of fish pass used in weirs. Additional mitigating measures to reduce the negative effect of dams on fish populations are also suggested.

304. Nilsson, C. and J. E. Brittain (1996). Remedial strategies in regulated rivers: Introductory remarks. Pages 347-351 *in* J. E. Brittain, I. Brinkman and C. Nilsson, eds. Remedial Strategies in Regulated Rivers, Lycksele (Sweden), Regulated Rivers: Research & Management.

This paper summarizes recent examples of measures to remediate the ecology of regulated and fragmented rivers in boreal and temperate regions. The catchment area is suggested as the most appropriate scale and framework for such measures. Suitable measures may include reinstatement of flooding and productivity levels, management of nuisance growth of aquatic macrophytes, rehabilitation of depauperate riparian zones, increased habitat diversity, stocking of fish and construction of bypass channels for fish migration. Finally, an overall approach to remedial measures is proposed in which they form part of an integrated catchment management for regulated rivers.

305. North, J. A., R. C. Beamesderfer and T. A. Rien (1993). Distribution and movements of white sturgeon in three lower Columbia River reservoirs. Northwest Science. **67**:105-111.

The authors determined the distribution and movement of white sturgeon *Acipenser transmontanus* in Bonneville, The Dalles, and John Day reservoirs on the Columbia River from April through August, 1987-1991. The study also evaluated effects of hydroelectric dams on white sturgeon populations. Differences in catch per setline-day indicated that white sturgeon densities were greatest in Bonneville Reservoir and least in John Day Reservoir. White sturgeon concentrated in tailraces of dams and density generally declined downstream through each reservoir. Distribution within each reservoir varied with sampling month and were related, in part, to temperature. Most fish were caught at depths from 10 to 30 m. Tagged fish were often recaptured in locations other than those where originally marked. Some fish were recaptured as far as 152 km from where released. Individual fish frequently traveled the length of a reservoir, but were seldom recaptured in another reservoir. Dams restrict white sturgeon movements, may limit populations in some reservoirs, and concentrate fish immediately downstream,

potentially increasing their vulnerability to exploitation. To optimize these fisheries, resource managers must recognize differences among reservoirs and employ regulatory schemes specific to each.

306. Northcote, T. G. (1978). Migratory strategies and production in freshwater fishes. Pages 326-359 *in* S. D. Gerking, ed. Ecology of Freshwater Fish Production, Blackwell Science, Oxford (England).

There are many mechanisms for increasing survival, growth, abundance and hence production of freshwater fish which can result from their migratory behaviour. The importance of migrations seems assured as an adaptive feature of major significance in production of freshwater fish, especially in environments subject to sharp temporal fluctuations or to marked spatial patches in habitat fertility. Studies to determine more precisely the degree to which these phases of migration regulate production are badly needed together with the extent to which they can purposefully be used to better exploit the phenomenon in production of species useful to man.

307. Northcote, T. G. (1998). Migratory behaviour of fish and its significance to movement through riverine fish passage facilities. Pages 3-18 *in* M. Jungwirth, S. Schmultz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

Migration - movements involving regular cyclic alternation between different habitats used for spawning, feeding, or survival is a common behavioural phenomenon in the Old and New World as well as antipodal freshwater fish faunas. Usually it involves, at some stage in the life cycle, both upstream and downstream movements to reach the appropriate habitats. Upstream phases of migration are active with high energy demands and are directed by a variety of cues, whereas downstream phases often but not always occur by passive drift. Cyclic patterns of movement in such migrations are generally linked to seasonal environmental changes, in concert with the hormonal stage of the individuals involved, but they may be overlaid by did fluctuations. These features of migration are discussed in detail, with specific examples of the migratory capabilities and requirements of various species. Also discussed is the relevance of life-history stages to problems of fish passage over dams, weirs and other man-made obstructions in river channels. Of nearly 200 European fleshwater fish species, 67 are now considered to be threatened by a variety of human activities and major causes have been identified for 48 of these. Over half of these causes are associated with obstructions to migration pathways at dams and weirs, or other alterations in river channel features. There can be little doubt that migratory passageway problems are threatening a high proportion of European fleshwater fishes. Similar conditions are shown to affect many North and South American species, as well as those in the antipodes. If a major loss of freshwater fish biodiversity is to be avoided, more information must be gained rapidly on the migratory behaviour of freshwater fishes, and on effective means to facilitate the passage of young and adults in both upstream and downstream directions. Furthermore, attention must also be given to ensuring that appropriate habitat conditions for spawning, feeding and survival are available at either end of the migratory passageways used.

308. O'Connell, M. T. and R. J. Neves (1999). Evidence of immunological reponses by a host fish *Ambloplites rupestris* and two non-host fishes *Cyprinus carpio* and *Carassius auratus* to glochidia of a freshwater mussel *Villosa iris*. Journal of Freshwater Ecology. **14**:71-78.

Immunological responses of fishes to glochidia were evaluated using glochidia of the rainbow mussel *Villosa iris* to infest a host species, rock bass *Ambloplites rupestris*, and two nonhost species, common carp *Cyprinus carpio* and goldfish *Carassius auratus*. Ouchterlony double-diffusion tests showed that host and non-host species expressed a humoral defense factor specific to glochidial antigens after induced infestation with glochidia. Precipitin bands were observed in tests on infested fishes but not in tests on uninfested fishes. Microagglutination tests showed that host and non-host species that were uninfested, infested, or reinfested with glochidia all expressed some agglutination response to glochidial antigens. Experimental fishes had specific humoral defense factors that reacted immunologically to glochidia tissue.

309. Odeh, M. and C. Orvis (1998). Downstream fish passage design considerations and developments at hydroelectric projects in the north-east USA. Pages 267-280 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

As water wheels at mills in the north-eastern United States have been replaced with more modern turbine generators, the need to protect downstream migrating fishes has increased. To protect and guide fish from entrainment, devices such as closely spaced bar racks (angled or straight), louvres, curtain walls and netting have been used. Breaches, weirs, notches, chutes, pipes, multiple entrances and plunge pools are other features considered in the design development of downstream fish passage facilities. Critical elements of the design process include flow approach, attraction flow, behavioural guidance devices, bypass location, conveyance mechanism and plunge pool conditions. This chapter discusses the developments in design criteria for downstream fish passage facilities at hydroelectric sites in the north-east part of the USA. Targeted anadromous species include Atlantic salmon *Salmo salar*, American shad *Alosa sapidissima*, blueback herring *Alosa aestivalis*, and alewife *Alosa pseudoharengus*. Bioengineering perspectives on the design criteria, type of fish protection used and examples of existing facilities are offered.

310. Ogden, S. E. (1974). Fish escalator. Official Gazette of the United States Patent Office. January 8, 1974. Patent Number 3,783,623. **918:** 577-581.

A fish elevator or escalator is designed to provide a means whereby fish may be passed through, over or around a dam. The elevator has a pair of parallel tubular passageways having one set of identical corresponding transverse dimensions and a second set of different corresponding dimensions. Endless chains are arranged in parallel reaches with one reach extending along the mid-point of the adjacent side of one of the passageways and the other reach of the chain extending midway along the adjacent side of the other passageway. Corresponding reaches of the chains have partitions secured between them. The partitions are mounted so as to be slightly oscillatable and held in tight sliding engagement with the associated passageways. The elevator works somewhat in the manner of an undershot waterwheel with means provided to admit fish to be elevated to the higher level or lowered to the lower level into the compartments between adjacent partitions.

311. Oldani, N. O. (1996). [Environmental impact assessment of the Yacyreta Dam on the fish community. The transference system]. Doctoral Dissertation. Facultad de Formacion Docente en Ciencias66 pp.

The increasing interest and need for taking advantage of the Parana River (South America) resources, together with the building of hydroelectric dams, produces a high impact on the fish community due to the interruption of the migratory processes and to the loss of reproductive areas. The construction of the Yacyreta Dam (Argentina-Paraguay) started in December, 1983, level with km 1460 of the Parana River, in one of the richest regions of Argentina as regards to the size of fish populations, the number of species and the specimens length. The aims of the present thesis are: 1) to establish the variations in the fish community structure downstream Yacyreta Dam; and 2) to establish the structure of fish community in the left and right elevators. To propose handling rules in order to improve the fishway efficiency. Fieldworks were carried out monthly, from October 3, 1994, until July 17, 1996, and consisted in: 1) acoustic evaluation of fish abundance and control captures downstream the dam; and 2) fish elevatoris census. The studies allowed to establish that, the total number of fish tranferred in 1995 reached 1,766,924, with a monthly average of 176,692 fish (n=10). The total biomass transferred in 1995 reached 982 metric tons (mt), with a monthly average of 98.6 mt. The right elevator was the most efficient, as regards to the number and weight of fish transferred, due to its nearness to the bank and because the right turbines were not in operation. During the whole period studied, this fish elevator transferred 29% more fish and 42% more biomass. A seasonal variation in the abundance of fish was noticed in the elevators, showing maxima in spring and summer which coincided with the results of fishing control. *Pimelodus clarias* was the most abundant species in the fish elevator, reaching 76.6% followed by *Pterodoras granulosus* with 11.8%. *P. clarias* was the only species having almost constant presence in the fish elevator during the whole year; *Megalancistrus gigas* was also present but to a lesser degree. The species considered as migratory are predominant in the system from October until January, and they are the following ones: *Pseudoplatystoma coruscans, P.fasciatum, Paulicea lutkeni, Pseudopimelodus zungaro, Oxydoras kneri, Ptedoras granulosus, Rhinodoras d'orbignyi, Prochilodus lineatus, Salminus maxillosus, Leporinus obtusidens* and *Raphiodon vulpinus*. Fish elevators were highly selective for small and very big sizes, favouring the transfer of fish whose length vary between 35 and 55 mm. Fish elevators allowed the passing of 5 cohorts for *L.obtusidens, O.kneri, P.clarias*; of 4 for *P.granulosus, P.lineatus*; of 3 for *M.gigas, R.d'orbingyi, S.maxillosus, P.labrosus*, of 2 for *Sorubim lima* and of 1 for *Schizodon borelli*. The size and average of transferred fish increases in spring and summer, associated to migratory species. The average annual weight (in 1995) reached 0.66 kg. The highest specific abundance was noticed in the early morning hours and in the late afternoon hours. Considering the daily cycles of system use, 3 groups of species were identified: diurnal species (*M.gigas, L.obtusidens, R.d'orbignyi*); nocturnal species (*P.clarias, P.coruscans, P.granulosus*) and diurnal-nocturnal species (*S.borelli, O.kneri, S.lima, S.maxillosus, P.lineatus*). The highest estimates of the total number of fish obtained by means of acoustic evaluations in the area under consideration took place between March and April. As an average, they represent 1,014 and 1,207 f/ha with 107 and 214 FPEU (Fish Per Effort Unit) values. The highest abundance of fish and species takes place between October and November (in spring), while the lowest, in both cases, happens mainly in autumn. In the periods of highest abundance, the total number of fish would reach 2,000,000.

312. Olson, D. E., D. H. Schupp, V. Macins and R. L. Kendall (1978). An hypothesis of homing behavior of walleyes as related to observed patterns of passive and active

movement. Pages 52-57 *in* R. Kendall and J. Stewart, eds. Selected Coolwater Fishes of North America, American Fisheries Society Special Publication, St. Paul, Minnesota (USA).

An hypothesis that walleye, *Stizostedion vitreum*, homing is an adult-learned behavior rather than a natal-imprinted response is presented. Marked adult walleyes tend to home to spawning areas. Individual walleyes tend to return to the same open-water feeding areas in successive years. Movement of immature walleyes often differs from that of adults in the same waters. Intensity of walleye homing varies in separate waters and appears to be influenced by physical characteristics of the environment and strengthened by repeated migrations. River and wind currents commonly move walleye eggs and fry great distances from the site of egg deposition before fry are sufficiently developed to commence feeding. This makes natal conditioning to spawning areas unlikely.

313. Orsborn, J. F. (1987). Fishways -- historical assessment of design practices. Pages 122-130 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Cooper, eds. Common Strategies of Anadromous and Catadromous Fishes, American Fisheries Society Symposium Serial, Boston, Massachusetts (USA).

Fishway design has evolved in a conservative fashion. Initial costs or practicality have limited the development of some innovative structures. Conservative design stems from (1) a lack of hard data on fish swimming and leaping capabilities, (2) a lack of integration of fluid mechanics with fish capabilities, and (3) designs based on fish responses rather than on stimuli. This paper summarizes the state of the art in fishway design and the development of several more efficient fishway designs. The efficiencies are derived from a combination of more expeditious fish passage, maximization of the instream flow operating range, and less costly construction. When competing or conflicting water uses are present, such as in the development of small hydropower, the minimization of water use in the fishway can become a fourth consideration.

314. Orsborn, J. F. and P. D. Powers (1986). Fishways: An assessment of their development and design. Part 3 of 4. Final project report. U.S. Department of Energy, Final project report DOE/BP-300.

The historical developments of certain design features, criteria and research activities are traced. Current design practices are summarized based on the results of an international survey and interviews with agency personnel and consultants. The fluid mechanics and hydraulics of fishway systems are discussed. Fishways (or fishpasses) can be classified in two ways: (1) on the basis of the method of water control (chutes, steps (ladders), or slots); and (2) on the basis of the degree and type of water control. This degree of control ranges from a natural waterfall to a totally artificial environment at a hatchery. Systematic procedures for analyzing fishways based on their configuration, species, and hydraulics are presented. Discussions of fish capabilities, energy expenditure, attraction flow, stress and other factors are included.

315. Parasiewicz, P., J. Eberstaller, S. Weiss and S. Schmutz (1998). Conceptual guidelines for nature-like bypass channels. Pages 348-362 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

A wide range of technologies exist, and are being further developed, to pass fish both upstream and downstream around various obstacles primarily involving hydropower or irrigation projects. Most of these technologies are highly engineered and follow design criteria that have been developed with the aid of both hydraulic modelling and empirical data. Concurrent with these developments is an increasing interest in more nature-like bypass designs, especially at small-scale or low-head river barriers. This interest is not accompanied by specific or even general design criteria, and thus there may be some hesitance to apply such designs more broadly. This chapter presents conceptual guidelines for both defining and planning nature-like bypass channels, primarily based on experiences gained in Austria but also considering their potential application elsewhere. A basic planning strategy is presented based on river size and general channel morphology in consideration of the fish assemblage present, the goal being to mimic natural systems in which the species of interest are found, rather than engineering channels that accommodate set hydraulic criteria. Emphasis is placed on the site-specific nature of such constructions, their inherent heterogeneity, and necessity for post-construction monitoring and adaptation. The role that nature-like bypasses can play in providing critically needed flowing water habitat in heavily engineered rivers is also articulated.

316. Pasch, R. W. (1986). Assessment of fish passage technology applicable to John Sevier Detention Dam. Tennessee Valley Authority, Division of Air and Water Resources, Report TVA/ONRED/WRF-87/5.

This report provides an assessment of existing technologies and developments in fish passage technology applicable to moving sauger and paddlefish upstream and downstream of the John Sevier Detention Dam.

317. Pasch, R. W., P. A. Hackney and J. A. Holbrook, II (1980). Ecology of paddlefish in Old Hickory Reservoir, Tennessee, with emphasis on first-year life history. Transactions of the American Fisheries Society. **109**:157-167.

Paddlefish, *Polyodon spathula* , moved to the upper reaches of Old Hickory Reservoir (a mainstem reservoir on the Cumberland River in north-central Tennessee) during the March-May spawning period and concentrated in the tailwaters of Cordell Hull Dam (Cumberland River) and Center Hill Dam (Caney Fork River). Paddlefish eggs were collected 5.6 km downstream from Cordell Hull Dam beginning 13 April, and larvae were found beginning 21 April 1977. No paddlefish eggs or larvae were collected in the Caney Fork River, presumably because the low temperature (11-11.5 C) of the Center Hill Dam discharge prevented spawning there. No paddlefish greater than 18 mm total length were taken by larvae sampling gear, and gill nets were ineffective in capturing young of year and yearlings. Paddlefish from 50 mm to 400 mm total length, however, were impinged on the intake screens at the Gallatin Steam Electric Plant on Old Hickory Reservoir in large numbers (approximately 9000 from August 1975 to May 1976). Comparisons of lengths on capture dates with similar data reported in the literature demonstrated that the impinged paddlefish were young of year which attained approximately 300 mm total length by age I.

318. Paukert, C. P. and W. L. Fisher (2000). Abiotic factors affecting summer distribution and movement of male paddlefish, *Polyodon spathula*, in a prairie reservoir. Southwestern Naturalist. **45**:133-140.

Six male paddlefish, *Polyodon spathula*, were implanted with ultrasonic temperature-sensing transmitters and tracked during June through August 1997 to quantify effects of physicochemical conditions on their distribution and movement in Keystone Reservoir, Oklahoma. Paddlefish moved about twice as much during night than day. Movement rate of paddlefish was related to reservoir water level, inflow, and discharge from the reservoir at night; however, none of these variables was significant during the day. Location in the reservoir (distance from the dam) was negatively related to water level and positively related to inflow during day and night periods. Location in the reservoir was negatively related to discharge during the day. Paddlefish avoided the highest available water temperatures, but did not always avoid low dissolved oxygen concentrations. Paddlefish avoided the Cimarron River arm of the reservoir in summer, possibly because of high salinity. Our study demonstrates that distribution of paddlefish during summer and movement in Keystone Reservoir was influenced by physicochemical and hydrologic conditions in the system. However, biotic factors (e.g., food availability) not measured in this study may have been influenced by abiotic conditions in the reservoir.

319. Paukert, C. P. and W. L. Fisher (2001). Spring movements of paddlefish in a prairie reservoir system. Journal of Freshwater Ecology. **16**:113-124.

Paddlefish (Polyodon spathula) movements and habitat use were monitored in the Keystone Reservoir System, Oklahoma during 1996-1998 to determine reproductive activity patterns. Paddlefish spring spawning migrations were more dependent on water flows than water temperature or photoperiod. Paddlefish moved up the Cimarron River and Arkansas River in 1997 and 1998 when spring flows increased. However, they did not migrate up the rivers in 1996, a year with extremely low flows. Suitable spawning substrata were found in the Salt Fork River, a major tributary of the Arkansas River, and the tailwaters of Kaw Dam on the Arkansas River. Paddlefish were located over suitable spawning substrata in the Salt Fork River; however, no larvae were collected. Although paddlefish migrate up the Cimarron River in spring, minimal spawning habitat may limit successful spawning in that river. In 1998, paddlefish moved into the Salt Fork River rather than the Kaw Dam tailwaters, presumably because there was limited flow from Kaw Dam that spring. Paddlefish in the Keystone Reservoir system appear to have adapted to the high spring water temperatures and fluctuating flows enabling successful reproduction.

320. Pavlov, D. S., A. S. Barekyan, M. A. Skorobogatov and L. G. Shtaf (1983). Hydraulic characteristics of the current that produces routes for fish movement. Doklady Biological Sciences. **270**:230-233.

A model hydrosystem with a fish passing structure arranged along the axis of the spillway front was set up in a hydraulic tank of 6.5 m length and 1.2 m width. Various hydraulic regimes were created in the lower water race of the model with the help of the gates of the model itself. The current depth in the lower water race of the hydrosystem comprised 0.08 m. Current hydraulic characteristics seen to be involved in the production of routes of fish movement in a current included the longitudinal velocity component, the turbulence intensity, and the transverse gradient. The data obtained was used to develop a method for predicting the entrance of fish into the fish-passing structures.

321. Pavlov, D. S., A. M. Pakhorukov, G. N. Kuragina, V. K. Nezdoliy, N. P. Nekrasova, D. A. Brodskiy and A. L. Ersler (1977). Some features of the downstream migrations of juvenile fishes in the Volga and Kuban Rivers. Journal of Ichthyology. **17**:363-374.

The pattern of downstream migration of juveniles of various fish species in the Volga and Kuban rivers was studied. With the exception of clupeids 6-10 mm long, a daily migratory rhythm was found in all the fish species investigated. The migration is associated with the loss of visual orientation by the fish and is observed only during the hours of darkness. The downstream migration continues round the clock in the Kuban River owing to the low transparency of the water. A dynamic pattern has been established in the vertical distribution of downstream migrating cyprinid, clupeid and gobiid juveniles throughout the 24 hours. Some features of the horizontal distribution of juveniles are noted. The distribution of juvenile fishes in the river is regarded as an active process controlled by definite behavioral reactions.

322. Pavlov, D. S., M. A. Skorobogatov and L. G. Shtaf (1982). Effect of turbulence on current velocity critical for fish. Doklady Biological Sciences. **267**:1019-1021.

Results of experiments with 21-29 mm long roach *Rutilus rutilus* demonstrated that the rate of turbulence had a pronounced effect on current velocity critical for single fish as well as for groups of 5 fish. Increasing the turbulence by 40% decreased the critical velocity by 40-50%. Experiments with longer (31-39 mm) fish showed that the critical current velocity was higher for groups of fish than for single individuals.

323. Pavlov, D. S., M. A. Skorobogatov and L. G. Shtaf (1982). Influence of degree of stream turbulence on the magnitude of the critical current velocity for fish. Doklady Biological Sciences. **267**:560-562.

One of the most important characteristics of a stream is the degree of its turbulence. In fish motion the critical current velocity equals the minimum current velocity that exhausts a fish. In order to increase the range of change in the turbulence intensity in the stream, a system of races was created above the upper net with the help of a submerged hydraulic spring, acting as a generator of elevated turbulence. Young roach were used in the study. A stream with a higher degree of turbulence possesses a greater kinetic energy for fish. Therefore, the energy expenditures of fish will be higher in such currents, leading to a decline in the critical current velocity. The findings should be taken into account in the control of fish behavior. An increase in the degree of turbulence in active fishing equipment, such as a trawler, will promote the most rapid exhaustion of the fish and an increase in the catch. At the same time an increased stream turbulence in the fish tanks of fish-passing structures is undesirable as it will result in the loss of fish to the current.

324. Payne, B. S. and A. C. Miller (1992). Mussel surveys at potential mooring sites for barge tows near Upper Mississippi River Locks and Dams 9 and 10. U.S. Army Corps of Engineers, Miscellaneous Papers of the U.S. Army Corps of Engineers Waterways Experimental Station WES/MP/EL-92-11.

In September 1990, a survey was conducted of 10 potential mooring sites for barges along the edge of the navigation channel just above below Locks and Dams 9 and

10. In general, conditions were too erosional just below and too depositional just above the locks and dams to support substantial populations of mussels. The only substantial community found was at a site designated as A3, at river mile 649.2 to 649.5 above Lock and Dam 9. Nineteen species of unionids were represented among 629 individuals collected at this location. A low-density assemblage (2 to 11 individuals/m^2) occurred at the upper and lower ends of Site A3. The endangered species *Lampsilis higginsii* comprised approximately 0.3 percent of the mussel community at Site A3. The estimated density of *L. higginsii* equaled 0.02 individual/m^2. This density value was slightly less than the range of densities (0.04 to 0.23 individual/m^2) that have been estimated for the least dense populations of species that have persisted in several other large-river mussel beds. Thus, the density of the *L. higginsii* population at Site A3 may be slightly less than the minimum required for a reproductively viable population.

325. Payne, B. S. and A. C. Miller (1998). Evaluation of freshwater mussels in the Lower Ohio River in relation to the Olmstead Locks and Dam Project: 1995, 1996, and 1997 Studies. U.S. Army Corps of Engineers, Miscellaneous Papers of the U.S. Army Corps of Engineers Waterways Experimental Station WES-TR-EL-98-12.

Surveys were conducted in 1995, 1996, and 1997 to assess community characteristics, population demography of dominant species, status of endangered species, and characteristics of nonindigenous populations of freshwater bivalves in the Lower Ohio River. Data will be used to analyze impacts of construction and operation of a new lock and dam at River Mile (RM) 964.4. The greatest focus has been on a mussel bed just downstream of the project. Density categories of <20, 20 to 50, and >50 individuals per square meter are reasonable for delineating low-, moderate-, and high-density assemblages within this bed. Density >200 individuals per square meter is occasionally measured, but always describes a location heavily dominated by recent recruits. The native mussel community of the Lower Ohio River is dominated by *Fusconaia ebena*. Dominance of this species was high at RM 967 (near Olmsted, IL), typically exceeding 80 percent of the community. At RM 957 (near Post Creek, IL), *F. ebena* is much less dominant (33 percent). Species richness is similar at both locations. The *F. ebena* population in the Lower Ohio River is heavily dominated by a single-year class (probably 1990) of recent recruits. Prior to the exceptional recruitment in 1990, this population was dominated by a very abundant 1981 cohort.

326. Peake, S., F. W. H. Beamish, R. S. McKinley, D. A. Scruton and C. Katopodis (1997). Relating swimming performance of lake sturgeon, *Acipenser fulvescens*, to fishway design. Canadian Journal of Fisheries and Aquatic Sciences. **54**:1361-1366.

Fishways have traditionally been designed to provide safe passage for jumping fish and only recently have nonjumping species been considered. Concern over dwindling populations of lake sturgeon, *Acipenser fulvescens,* has focused attention of fishway designs that accommodate its swimming abilities. The objective of this study was to derive a model that relates endurance of lake sturgeon to length and flow characteristics of fishways. Endurance at sustained and prolonged swimming speeds increased with water temperature but was independent of temperature at higher burst speeds. Endurance increased with total length at all swimming velocities. Swimming performance of lake sturgeon, relative to body length, is inferior to that of most salmonids, particularly at burst speeds. Fishway designers need to consider swimming ability, space requirements, and behavior of lake sturgeon to ensure that they can ascend potential migratory obstacles safely.

327. Peake, S., F. W. S. Beamish, R. S. McKinley, C. Katopodis and D. A. Scruton (1995). Swimming performance of lake sturgeon *Acipenser fulvescens*. Canada Department of Fisheries and Oceans, Canadian Technical Report of Fisheries and Aquatic Sciences No. 2063.

Fishways have traditionally been designed to provide safe passage for jumping fish and only recently have non-jumping species been considered. Concern over dwindling populations of lake sturgeon *Acipenser fulvesens* has focused attention on fishway designs that accommodate its swimming abilities. The objective of this study was to derive models that describe swimming endurance and critical speed for lake sturgeon. Critical speed increased with temperature and with total length. Endurance at sustained and prolonged swimming speeds increased with temperature but was independent of temperature at higher burst speeds. Endurance increased with total length at all speeds. Swimming performance of lake sturgeon, relative to body length, is inferior to that of salmonids. Fishway designers need to consider swimming ability, space requirements and behavior of lake sturgeon to ensure them safe passage of migratory obstructions.

328. Peake, S., R. S. McKinley and D. A. Scruton (2000). Swimming performance of walleye (*Stizostedion vitreum*). Canadian Journal of Zoology. **78**:1686-1690.

Swimming performance of walleye (*Stizostedion vitreum*) from a wild population was measured relative to fork length (0.18-0.67 m) and water temperature (5.8-20.5 ^{o}C), to provide models for setting water velocities in fishways and culverts. $Ucrit_{60}$ (the highest speed maintainable for 60 min) values ranged from 0.30 to 0.73 m/s and increased significantly with length and temperature. $Ucrit_{10}$ (the highest speed maintainable for 10 min) values ranged from 0.43 to 1.14 m/s and also increased significantly with fish length and water temperature. When startled, walleye were able to attain higher speeds (1.60-2.60 m/s) during short (temperature-independent) bursts of swimming activity. The relatively low $Ucrit_{60}$ values suggest that walleye possess a narrow scope for aerobic activity compared with other species, which may account for their poor performance in fishways. However, the small differences between $Ucrit_{60}$ and $Ucrit_{10}$ values and the large differences between $Ucrit_{10}$and fast-start performance suggest that low passage efficiency may be caused by a behavioural disinclination to switch from low to high intensity activity.

329. Pearson, W. D. and K. L.A. (1984). Distribution and status of Ohio River fishes. Oak Ridge National Laboratory, Final Subcontract Report ORNL/Sub/79-7831/1.

This substantial report presents information on the distribution and status of Ohio River fishes. Data is provided on species composition, diversity, biomass, relative abundance, density, and changes in community composition associated with the navigation system on the Ohio River. Of particular interest is data pertaining to lock rotenoning that may provide some inference into lock use by migrating fishes.

330. Pearson, W. D. and B. J. Pearson (1989). Fishes of the Ohio River. Ohio Journal of Science. **89**:181-187.

To date, 159 species of fishes (14 of them introduced by humans) have been reported from the Ohio River. Three native fishes (*Acipenser fulvescens*, *Alosa alabamae*, and *Ammocrypta asprella*) have apparently been eliminated from the river. The Ohio River fish community was severely affected by the siltation of clean gravel substrates, and the inundation of those substrates by the canalization of the river before 1927. In the past 20-30 years, populations of many species have increased, particularly in the upper third of the river. Some pollution-intolerant species which had disappeared from the upper reaches of the river between 1900 and 1950 have been returning since 1970 (e.g. *Polyodon spathula*, *Hiodon tergisus*, and *Carpiodes velifer*). A few pollution-tolerant species have declined in abundance since 1970 (e.g. bullheads and *Ictalurus catus*). The most abundant fishes in the lock chamber samples of 1957-87 were *Notropis atherinoides*, *Dorosoma cepedianum*, *Aplodinotus grunniens*, *Notropis volucellus*, and *Ictalurus punctatus*. The ongoing recovery of the Ohio River fish community should encourage us to take additional steps to protect the river from catastrophic spills of toxic materials and to reintroduce eliminated native fishes.

331. Pegg, M. A., P. W. Bettoli and J. B. Layzer (1997). Movement of saugers in the lower Tennessee River determined by radio telemetry, and implications for management. North American Journal of Fisheries Management. **17**:763-768.

Since 1979, abundances of sauger *Stizostedion canadense* have declined in the Tennessee River system. Reasons for this decline may include overharvest, loss of spawning habitat, and low recruitment due to extreme flows. The purpose of this study was to investigate the movements of saugers following winter concentration below Pickwick Dam, Tennessee. Thirty-seven saugers were implanted with radio transmitters directly below Pickwick Dam and were tracked between December 1992 and June 1993. Four saugers moved upstream through the locks at Pickwick Dam; the remaining fish stayed within the first 30 km of the tailwater throughout the spawning season. Three areas below Pickwick Dam were identified as possible March prespawn staging sites. After April 1, saugers in the tailwater area began a rapid downstream migration to the main basin of Kentucky Lake. Some fish moved downstream more than 200 km in less than 10 d in this semiclosed system. Movements encompassed four states (Kentucky, Tennessee, Mississippi, and Alabama) along the Tennessee River system, underscoring the need for interjurisdictional management.

332. Pellett, T. D., G. J. Van Dyck and J. V. Adams (1998). Seasonal migration and homing of channel catfish in the Lower Wisconsin River, Wisconsin. North American Journal of Fisheries Management. **18**:85-95.

A multiyear tag and recapture study was conducted to determine whether channel catfish *Ictalurus punctatus* were migratory and if they had strong homing tendencies. Over 10,000 channel catfish were tagged from the lower Wisconsin River and adjacent waters of the Upper Mississippi River during the 3-year sampling period. Data on movements were obtained from study recaptures and through tag returns and harvest information provided by sport anglers and commercial fishers. Channel catfish occupied relatively small home ranges during summer, migrated downstream to the upper Mississippi River in autumn, then migrated back up the Wisconsin River in spring to spawn and to occupy the same summer home sites they had used in previous summers. Fish size was a factor in the degree of fidelity to summer home sites, with larger fish showing greater fidelity.

333. Penczak, T., R. Mahon and E. K. Balon (1984). The effect of an impoundment on the upstream and downstream fish taxocenes (Speed River, Ontario, Canada). Archiv fur Hydrobiologie. **99**:200-207.

After damming of the Speed River substantial qualitative and quantitative changes were observed in the fish taxocenes at two localities, one upstream and the other downstream. Upstream the species composition changed only slightly, but the total populations biomass increased growth rates. Downstream new species were found and four previously dominant species were absent, probably as a result of the cold hypolimnial water released from the reservoir. Disturbances or declines in reproduction of several species were observed. In spite of this the production increased 3.2 times.

334. Penczak, T. and R. H. K. Mann (1993). A preliminary evaluation of the effect of human activity on the fish populations of the Pilica River, central Poland. Pages 101-115 *in* R. J. Wootton, ed. International Symposium on the Ecology of Fluvial Fishes: Environmental Variation of Riverine Fishes: Management Implications, Lodz (Poland), Polish Archives of Hydrobiology.

The impact of human activity in the Pilica River drainage basin (9245 km^2) was assessed by an electrofishing survey of 140 sites of the main river and tributaries. The sites, which included all stream orders from I-VI, were divided into three categories: natural, modified and moderately polluted. In lower order streams, river channel modifications had a negative influence on fish species diversity and the population density and the standing crop of lithophilous species. In modified, higher order streams these indices of fish population dynamics increased probably because of an increase in fish refuges along the banks, where the latter were reinforced with large stones and tree branches.

335. Peter, A. (1998). Interruption of the river continuum by barriers and the consequences for migratory fish. Pages 99-112 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

The following contribution summarises the results of several small studies, and uses a short literature review to emphasise the importance of barrier-free streams in maintaining populations of both salmonid and non-salmonid fish species. The effect of a high (6.5 m) and a very low obstacle (40 cm) on the fish fauna in two Swiss rivers was documented. A considerable loss of fish species was observed in stream reaches above the barriers. Surveys of small artificial barriers in several Swiss river systems demonstrate the density of these potential migration obstacles. Movements of brown trout *Salmo trutta* and rainbow trout *Onchorhynchus mykiss* were shown over diel, seasonal and an annual time scale using radio-telemetry. Non-salmonid fish species, typically thought of as resident, also undergo extensive movements and therefore depend on barrier-free streams to maintain their distribution. Like salmonids, cyprinids and small-sized fish species depend on an intact river corridor that allows migration, habitat shifts and survival of the population. In order to maintain and restore biodiversity, there is an urgent need to restore the longitudinal integrity of running waters.

336. Pethebridge, R., A. Lugg and J. Harris (1998). Obstructions to fish passage in New South Wales south coast streams. NSW Fisheries, Cronulla, N.S.W. (Australia).

All Australian freshwater fish have a need to move between habitat areas in streams and most freshwater species of southeastern Australia are known to migrate at some stage of their life cycle. In the southern coastal areas of New South Wales, a survey was undertaken to identify and document fish passage obstructions. The 254 obstructions documented included high dams, farm dams, fixed crest weirs, rock weirs, culverts, causeways, bridges and tidal floodgates, with causeways and culverts being the most common structures to obstruct fish passages. A fishway priority scheme was developed to provide a quantitative, objective basis to rank the priority of a fish passage restoration project for any obstruction, either by building a fishway or removing the obstruction. The evaluative criteria used include the size of the river system, location of the obstruction, presence of threatened species and the severity of the obstruction.

337. Petrere, M., Jr. (1985). [Migration of freshwater fishes in Latin America: Some comments]. FAO, Rome (Italy).

Numerous fish species of the inland waters of Latin America carry out migrations for feeding purposes, reproduction or as a means of escape from adverse environmental conditions. These migrations are studied by tagging or direct observation. Information is presented showing that the types of migrations observed differ. The importance of continuing investigations on fish migration is stressed, considering its relevance in fishery management, and environmental impact effects.

338. Petrere, M., Jr. (1989). River fisheries in Brazil: A review. Regulated Rivers: Research and Management. **4**:1-16.

Riverine fisheries in Brazil are reviewed. There is a broad description of the environment and the fish, and arguments for the high diversity of fish fauna diversity are examined. The country is divided into five large river basins and the fisheries are described in relation to the main fish species caught, the main gear employed, and the fishing strategies. Exotic species introduction is discussed along with strategies for fish stock management. Effects of dams on resident fish stocks and consequences for the small scale fisheries are discussed and compared with the effects of pollution.

339. Petts, G. E. (1989). Perspectives for ecological management of regulated rivers. Pages 3-24 *in* J. A. Gore and G. E. Petts, eds. Alternatives in Regulated River Management, CRC Press, Inc., Boca Raton, Florida (USA).

Since about 3000 B.C., efforts have been made to regulate rivers for the benefit of agriculture. Now many other purposes are cited, including flood control, industrial uses, navigation, fisheries, and recreation and leisure. The ecological impact of river regulation schemes is considered, including a conceptual framework for the evaluation of that impact, tools available for mitigation of effects and even enhancement of river ecosystems, and problems of implementing policies for the ecological management of regulated rivers. Regulation of the Zambezi River is emphasized as an example. Assessment of the environmental impact of river regulation requires consideration of spatial dimensions (global and catchment scales) and the temporal dimension. Three approaches to potentially harmful river regulation schemes have been recognized: (1) preserving a portion of wild river; (2) secondary regulation, in which additional structural measures and special operation rules are employed; or (3) compensation schemes (e.g.,

fish ponds to compensate for lost fish). Of these, secondary regulation should be considered first. Measures available include flow modifications, water quality control, channel design and maintenance, fish passage, biological alternatives (e.g., stocking), and controls on human activities. It has been argued that in developing nations the pressures for agricultural development should take precedence over concerns about environmental impacts from river regulation. This view does not recognize that sustainable development requires environmentally sound management. As illustrated by the approach taken in Zambia , development activities and environmental management can be integrated.

340. Pigg, J., R. Gibbs and H. Weeks (1991). Recent increases in number of skipjack herring, *Alosa chrysochloris* (Rafinesque), in the Arkansas River, Oklahoma. Proceedings of the Oklahoma Academy of Science. **71**:49-50.

The skipjack herring *Alosa chrysochloris* is a highly migratory freshwater species common to the Mississippi River and its larger tributaries north to Minnesota and South Dakota. In 1946 small numbers of young skipjacks were collected from five sites on the Illinois River between Flint Creek and the mouth of the Illinois River near Gore. The skipjack herring also has been collected in the tailwaters of the Red River below Lake Texoma. The species was not found in the pre-impoundment surveys conducted by the Oklahoma Department of Wildlife Conservation (ODWC) of the Arkansas and Cimarron rivers in the area of the proposed Lake Keystone in 1961. Annual fish collections by ODWC using gill netting, electrofishing, and seining have produced the following numbers of skipjack from mainstream reservoirs of the Arkansas River: from Robert S. Kerr Lake, 1 in 1979, 28 in 1980, none in 1981, 9 in 1982, 12 in 1983, 31 in 1984, 3 in 1985 , 8 in 1986, 45 in 1988, and 18 in 1990. From Webbers Falls Lake , ODWC obtained 15 in 1981, 2 in 1982, 7 in 1983, 1 in 1985, and 27 in 1988, and from W. D. Mayo Lake, 29 in 1987 and 7 in 1988. The skipjack herring appears to be more abundant today then before impoundment of the Arkansas River in the 1970s. The upstream distribution is now limited to the Arkansas River below the Keystone Dam. The lakes of the Arkansas navigational system have provided a desirable habitat and may account for the recent increases in the skipjack. (Brunone-PTT)

341. Pitlo, J., Jr. (1989). Walleye spawning habitat in Pool 13 of the Upper Mississippi River. North American Journal of Fisheries Management. **9**:303-308.

Continued development in the Upper Mississippi River may pose a threat to critical fish habitats. The purpose of this study was to identify spawning habitat for walleyes *Stizostedion vitreum* so those areas could be afforded protection from future alterations. Radiotelemetry, egg collections, and the presence of sexually mature fish were used to identify walleye spawning sites in Pool 13 of the upper Mississippi River. Over 2,000 walleye eggs were collected in drift nets at two sites from 1983 through 1986. Substrates at spawning sites comprised sand, gravel, and cobble and included a freshwater mussel bed at one location. Water depths at spawning sites ranged from 0.6 to 6.1 m, and the current velocity ranged from 42.7 to 115.8 cm/s during 1986. Most walleye eggs were collected in April within 2 weeks of peak discharges when water temperatures were 8.3-12.2 degree C. Both spawning sites were adjacent to the navigation channel.

342. Pitlo, J., A. VanVooren and J. Rasmussen (1995). Distribution and relative abundance of Upper Mississippi River fishes. Upper Mississippi River Conservation Committee Fish Technical Section, Rock Island, Illinois (USA).

A total of 156 species of fish have been collected and identified from the Upper Mississippi River since record keeping began late in the 19th century. Records of occurrence appearing in this document have been obtained from a variety of sources, including personal notations by field biologists, annual reports from various agencies, published reports in the scientific literature on the distribution of fishes in various regions, and the more recent habitat and community fish sampling initiated by the Long Term Resource Monitoring Program (LTRMP). This document is meant to provide a consolidated listing of species that presently occur, have occurred, or have been collected in the UMR. Rankings were assigned concerning distribution and relative abundance of those species throughout the river. This is the most up-to-date listing presently available for the UMR and appends earlier works by Nord (1976), Rasmussen (1979), and Van Vooren (1983).

343. Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks and J. C. Stromberg (1997). The natural flow regime. A paradigm for river conservation and restoration. Bioscience. **47**:769-784.

The ecological integrity of river ecosystems depends on their natural dynamic character.

344. Pollard, D. A., B. A. Ingram, J. H. Harris and L. F. Reynolds (1990). Threatened fishes in Australia--An overview. Journal of Fish Biology. **37**:67-78.

Considering the size of the continent, the Australian freshwater fish fauna is a relatively depauperate one, comprising only about 192 species (belonging to 34 families) which spend significant portions of their life cycles in freshwater habitats. Of these freshwater species, the latest (1989) analysis indicates that six can be classified as endangered, five as vulnerable, four as potentially threatened, two as indeterminate, 32 as restricted, and 16+ as of unknown status, totalling 65+ species. Thus approximately 34% of the entire Australian freshwater fish fauna falls within the above six conservation status categories. Conservation problems of these fishes, and particularly man-made changes to their habitats, are discussed, and some possible management solutions outlined. Brief mention is also made of several marine species which may also fall into one or more of the above conservation categories, although not enough information is yet available to classify them accurately.

345. Power, G. (1989). One rung at a time. Atlantic Salmon Journal. **38**:30-32.

The author describes the four basic categories of fishways; the pool and step (or weir), the Denil, the vertical slot and the fish elevator.

346. Power, M. E., W. E. Dietrich and J. C. Finlay (1996). Dams and downstream aquatic biodiversity: Potential food web consequences of hydrologic and geomorphic change. Environmental Management. **20**:887-895.

Responses of rivers and river ecosystems to dams are complex and varied, as they depend on local sediment supplies, geomorphic constraints, climate, dam structure and operation, and key attributes of the biota. Therefore, "one-size-fits-all" prescriptions cannot substitute for local knowledge in developing prescriptions for dam structure and operation to protect local biodiversity. One general principle is self-evident: that biodiversity is best protected in rivers where physical regimes are the most natural. A sufficiently natural regime of flow variation is particularly crucial for river biota and food webs. We review our research and that of others to illustrate the ecological importance of alternating periods of low and high flow, of periodic bed scour, and of floodplain inundation and dewatering. These fluctuations regulate both the life cycles of river biota and species interactions in the food webs that sustain them. Even if the focus of biodiversity conservation efforts is on a target species rather than whole ecosystems, a food web perspective is necessary, because populations of any species depend critically on how their resources, prey, and potential predators also respond to environmental change. In regulated rivers, managers must determine how the frequency, magnitude, and timing of hydrologic events interact to constrain or support species and food webs. Simple ecological modeling, tailored to local systems, may provide a framework and some insight into explaining ecosystem response to dams and should give direction to mitigation efforts.

347. Powers, P. D. and J. F. Orsborn (1986). Analysis of barriers to upstream fish migration. An investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. U.S. Department of Energy, Final Report Part 4 DOE/BP-297.

This paper presents a detailed analysis of waterfalls and culverts as physical barriers to upstream migration by salmon and trout. Analysis techniques are based on combining barrier geometry and stream hydrology to define the existing hydraulic conditions within the barrier. These conditions then can be compared to known fish capabilities to determine fish passage success. A systematic classification system is developed which defines the geometric and hydraulic parameters for a given stream discharge. This classification system is organized in a format can be used to catalog barriers in fisheries enhancement programs. The analysis compares hydraulic conditions and fish capabilities in detail, as the fish enters the barrier, attempts passage and exists the barrier.

348. Prignon, C., J. C. Micha and A. Gillet (1998). Biological and environmental characteristics of fish passage at the Tailfer Dam on the Meuse River, Belgium. Pages 69-84 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

From 1989 to 1994, we continuously monitored upstream fish passage using a trap at the Tailfer Dam on the Meuse River in Belgium. A total of 157 897 individuals of 23 species (bleak *Alburnus alburnus* not included) were captured in the fish ladder. The dominant species captured, in order of abundance, were bleak (not counted), roach *Rutilus rutilus* (87.7%), silver bream *Abramis bjoerkna* (4.3%) and European chub *Leuciscus cephalus* (2.0%). Non-rheophilic species accounted for around 93.4% of the total. Most seasonal movements of cyprinid fishes are observed in spring and are reproductive migrations. Roach, Eurasian dace *Leuciscus leuciscus*, silver bream, nase *Chondrostoma nasus*, and European chub of indeterminate sex begin migrating in mid-March and continue as long as the water temperature is between 10 and 15 degree C. Movements of mature European chub, bream *Abramis brama*, and barbel *Barbus barbus*

begin in mid-May, when water temperature reaches 13-15 degree C. Salmonids migrate in May-June and autumn. While seasonal periodicity of migration is clearly associated with water temperature, circadian variations are dependent on luminosity.

349. Purkett, C. A. (1961). Reproduction and early development of the paddlefish. Transactions of the American Fisheries Society. **90**:125-129.

Paddlefish, *Polyodon spathula* (Walbaum), were observed spawning over gravel bars in the Osage River, Missouri. Eggs and prolarvae were collected. Eggs were hatched and young paddlefish were reared. The external features of the egg and prolarvae, hatching, and early behavior of the larvae are described. The effect of impoundment of rivers on the paddlefish population is discussed.

350. Quiros, R. (1988). [Structures to aid non-salmon fish species during migrations: Latin America]. FAO, Technical Report 92-5-302683-9.

The document reviews existing information in Latin America regarding structures built to aid fish during local movements and migrations to overcome various obstacles caused by dams and their construction. An examination is also made of current legislation regarding the obligation of building fish passages in the dams and aquaculture possibilities.

351. Raibley, P. T., D. Blodgett and R. E. Sparks (1995). Evidence of grass carp *Ctenopharyngodon idella* reproduction in the Illinois and Upper Mississippi Rivers. Journal of Freshwater Ecology. **10**:65-74.

Grass carp *Ctenopharyngodon idella* is an exotic species which was imported into the United States in 1963 to control aquatic vegetation. Individuals escaped from ponds and subsequently spread into streams in the Mississippi River basin. The authors have been collecting grass carp in the Illinois River since 1990, and some of their associates have also collected grass carp in other portions of the upper Mississippi River system. The presence of juveniles and adults in the collections makes it appear that grass carp are reproducing in the Illinois River, and their larvae are finding suitable nursery areas in backwaters. Naturalized, reproducing grass carp populations probably exist as far north as 209 km into the Illinois River.

352. Raistakka, J. E. (1973). Conduit structure for migrating fish. Official Gazette of the United States Patent Office. November 20, 1973. Patent Number 3,772,891. **916:** 857-858.

Migrating fish may circumvent a dam by use of a conduit enabling their passage upstream and downstream. The conduit terminates in segments projecting in a submerged manner outward into the river; the segments are flexible to a degree to permit vertical positioning of the conduit ends for optimum fish ingress and egress. It is closed from the atmosphere to prevent the addition of nitrogen to the water passing through the conduit. A constant gradient and constant flow facilitate fish passage. Spaced along the conduit are series of flow disrupting projections which cause the water to form areas of eddying water currents providing resting areas for the fish. Fish attracting substances are fed into

the conduit water to help overcome the natural tendency of fish to shy away from the entry of the conduit.

353. Rajaratnam, N. and C. Katopodis (1984). Hydraulics of Denil fishways. Journal of Hydraulic Engineering. **110**:1219-1233.

This paper presents the results of an experimental study on the hydraulics of simple Denil fishways. For the standard Denil, the characteristic velocity profile that exists in the fully developed flow region is found. A rating, curve is developed for the standard Denil, which would be very useful in the design of Denils over a range of slopes and discharges. A number of other interesting and practical features of the Denil fishways are found. Some results are also obtained for some "nonstandard" Denil designs.

354. Rajaratnam, N. and C. Katopodis (1990). Hydraulics of culvert fishways 3: Weir baffle culvert fishways. Canadian Journal of Civil Engineering. **17**:558-568.

This paper presents the results of a laboratory study of culvert fishways with weir-type baffles. Baffles with heights equal to 0.15 and 0.1 times the diameter (D) of the culvert were studied with longitudinal spacings of 0.6D and 1.2D. Equations have been developed to describe the relation between the discharge, slope, diameter, and the depth of flow. It has been possible to predict the barrier velocity that would exist at the baffles. The performance of the weir baffles has been found to be as good as that of the slotted-weir baffles.

355. Rajaratnam, N. and C. Katopodis (1991). Hydraulics of steeppass fishways. Canadian Journal of Civil Engineering. **18**:1024-1032.

This paper presents the results of an experimental study on the hydraulics of steeppass fishways. Using theoretical considerations and experimental observations, an expression has been developed that relates the flow rate, slope of the fishway, and depth of flow. It was also found that the characteristic (similarity) velocity profile found earlier, for smaller values of depth to width ratio, y sub(0)/b, with the maximum velocity near the bottom, changes to a rather symmetrical profile with the maximum velocity occurring somewhere near the mid-depth for larger values of y sub(0)/b. A correlation has also been found for the maximum velocity. This paper also includes some observations on the M-type backwater curves that would appear in the fishway when the tailwater depths exceed uniform flow depths.

356. Rajaratnam, N., C. Katopodis and M. A. Fairbairn (1990). Hydraulics of culvert fishways 5: Alberta fish weirs and baffles. Canadian Journal of Civil Engineering. **17**:1015-1021.

This paper presents the results of a laboratory study of the hydraulic performance of fish weirs and fish baffles used by Alberta Transportation for improving the fish-passing capacity of culverts. It was found that if the longitudinal spacing of the weirs is limited to 0.6 and 1.2 times the diameter of the culvert, their performance is comparable to that of the corresponding weir and slotted-weir baffle systems, with regard to the depth of pool between the baffles as well as the barrier velocity. On the other hand, the fish baffles did not perform as well as the fish weirs under the conditions tested.

357. Rajaratnam, N., C. Katopodis and L. Flint-Petersen (1987). Hydraulics of two-level Denil fishway. Journal of Hydraulic Engineering. **113**:670-676.

The design of the simple Denil, along with some minor variations, has been studied by the first two writers for use in inland waterways in western Canada.

358. Rajaratnam, N., C. Katopodis and S. Lodewyk (1988). Hydraulics of offset baffle culvert fishways. Canadian Journal of Civil Engineering. **15**:1043-1051.

The results of an experimental study are presented for the hydraulics of culverts with offset baffles to pass fish. Using analytical considerations and experimental observations, a flow equation has been developed between the discharge, diameter, depth, and slope for a culvert fishway with the standard offset baffle system. The velocity field at the slot has also been evaluated. Some further experiments were performed to assess the effect of baffle spacing and height on the hydraulics of the culvert fishway. Based on preliminary experimental observations and theoretical considerations, a functional relation has been developed between the dimensionless discharge (Q) and the relative depth (yo/D) for culvert fishways with the offset baffle system. This relation has been evaluated using experimental results on two smooth pipes and one rough pipe. These relations are of the form (Q = C(yo/D) to the n power), where the average dimensionless coefficient (C) and the exponent (n) have been experimentally found to be equal to 12.0 and 2.6, respectively. The velocity profiles at the slot offset system are similar and follow a power law with U and the height of the baffles as the scales. The velocity scale (U) in terms of the square root of (gDSo) has been found to be equal to 12.8(yo/D). The effect of doubling the height and keeping the same spacing of the baffles increases the flow resistance appreciably. Keeping the standard height but reducing the spacing to one-half of the standard spacing also improves upon the performance of the standard baffle system.

359. Rajaratnam, N., C. Katopodis and A. Mainali (1988). Plunging and streaming flows in pool and weir fishways. Journal of Hydraulic Engineering. **114**:939-944.

A pool-and-weir fishway consists of a number of pools formed by a series of weirs. It is known that the flow over the weirs can be either in the plunging or streaming mode. When the flow is in the plunging mode, the water level in the pool immediately below the weir is generally below the crest of the weir. In the streaming flow mode, a surface stream appears to flow over the crest of the weirs, skimming over the water surface in the pools in between. For pool-weir fishways in the plunging flow regime, a simple weir analysis has been found to be adequate with the dimensionless discharge Q sub + = 0.61. For the surface streaming state, the dimensionless discharge Q sub was found to be equal to 1.5 x the square root of (L/d), where L is the length of the pool and d is the depth of the surface stream. A criterion has been established to predict the transition from plunging to surface streaming state.

360. Rajaratnam, N., C. Katopodis and A. Mainali (1989). Pool-orifice and pool-orifice-weir fishways. Canadian Journal of Civil Engineering. **16**:774-777.

This technical note presents a method of analyzing the flow in pool-orifice fishways by dividing it into vertical slot and submerged orifice flow regimes. For a pool-orifice-weir fishway, with flow through the orifice as well as over the weir, a method has been suggested for predicting the total flow rate in the fishway. Experimental observations are presented in support of these methods.

361. Rajaratnam, N., C. Katopodis and N. McQuitty (1989). Hydraulics of culvert fishways. 2: Slotted-weir culvert fishways. Canadian Journal of Civil Engineering. **16**:375-383.

This paper presents the results of an experimental study on the hydraulics of culvert fishways with a slotted-weir baffle system. Six designs with two baffle heights and three spacings were tested. A flow equation has been developed to predict the flow depth for any given discharge, diameter, and slope. The barrier velocity that would exist at the slot in the baffles has also been predicted in a general manner. This relatively simple slotted-weir baffle system has been found to match the performance of the more complicated but frequently used offset baffle system of similar dimensions.

362. Rajaratnam, N., C. Katopodis and N. McQuitty (1990). Hydraulics of culvert fishways 2: Slotted-weir culvert fishways: Reply. Canadian Journal of Civil Engineering. **17**:671-672.

We appreciate Hansen's interest in our paper and thank him for his comments and for subjecting some of our data to a rigorous statistical analysis. Hansen's analysis has successfully reproduced our equations for designs 1 and 5. We would like to point out that for turbulent free surface flows over roughness elements of the type encountered in culvert fishways (discussed in the paper), the depth measurements are necessarily approximate and subjecting these approximate depths to a very refined analysis is perhaps not warranted. We established the flow parameters Q sub(*) and y sub(0)/D not from purely data correlation but from sound fluid mechanics. Having established a functional relationship between these (compound) parameters, we wanted to evaluate this function for the different designs. The simple power law relations were developed primarily by plotting the data on double-log sheets and fitting a line by judgement, giving more weight to regions of more importance. Hence we see no problem with inverting these equations.

363. Rajaratnam, N., C. Katopodis and R. Paccagnan (1992). Field studies of fishways in Alberta. Canadian Journal of Civil Engineering. **19**:627-638.

Field studies were performed on one pool-weir, four Denil, and four vertical slot fishways in Alberta, Canada, over a period of several years. Velocity measurements were made with a 10-mm impeller minicurrent meter, and velocity profiles were calculated. The velocity profiles obtained in the field studies have confirmed the measurements made in the laboratory on scale models and have enhanced the general picture, particularly for the vertical slot fishways. A routine inspection and maintenance program would be helpful in ensuring that the fishways in Alberta operate at maximum efficiency. The design of the fish entrance is very important in determining the success of a fishway. Where the flow at the water outlet is not strong enough, the use of auxiliary attraction water should be considered. The standard Denil fishway provides a strong flow at the water outlet and therefore effectively supplies attraction water. One exception to this is a high tailwater condition, where the velocity of flow can be significantly reduced. All

fishways should be equipped with trash racks at the water inlet to prevent fishway blockage by debris. The field measurements on standard Denil fishways in Alberta were found to agree reasonably well with the laboratory results. The field measurements on vertical slot fishways, in addition to supporting laboratory measurements, have also provided more information on the circulation in the pools and should be useful in building a better understanding of the hydraulics of the vertical slot fishway.

364. Rajaratnam, N., C. Katopodis and S. Solanki (1992). New designs for vertical slot fishways. Canadian Journal of Civil Engineering. **19**:402-414.

An experiment was performed to study 18 designs of vertical slot fishways. Seven designs previously studied in 1986 were further examined (designs 1-7) and 11 more designs (numbered 8-18) were tested. The vertical slope fishway models were installed in a plexiglass flume having nine pools, at a scale of 1:8. Slopes of 0.05, 0.10, and 0.15 were used, and the flow rate was measured by means of a magnetic flow meter installed in the supply line. Designs 8-13 were tested mainly to determine how sensitive the standard length of ten times the width of the slot and the standard width of eight times the width of the slot are for satisfactory performance of the vertical slot fishway. Designs 14-18 were simplified versions of the standard design (design 1). For all 18 designs, the dimensionless discharge was found to vary linearly with the relative depth of flow, with the straight line passing approximately through the origin on most of the designs. The results showed that a width of eight times the width of the slot and a length of ten times the width of the slot for the pools are satisfactory, and minor variations can be made to these dimensions without affecting their satisfactory performance. The performance rating curves were essentially the same for one group including designs 3, 5, 6, and 7 and for another group including designs 1,2, 14, 16, 17, and 18. Design 6 in the first group and designs 16 and 18 in the second group are recommended for practical use because of their ease of construction.

365. Rajaratnam, N., C. Katopodis, S. Wu and M. A. Sabur (1997). Hydraulics of resting pools for Denil fishways. Journal of Hydraulic Engineering. **123**:632-638.

This paper presents the results of an exploratory laboratory study on the hydraulics of fish resting pools that are built between two Denil fishways, making a full turn or arranged in a folded-back pattern. These experiments show that the flow from the Denil entering the pool diffuses as a surface jet, with an increased growth rate, possibly because of the circulation and turbulence in the pool. This diffusing jet impinges on the backwall and dives into the pool. The flow formation in the vicinity of the outflowing Denil appears to occur in a relatively small region. The energy dissipation in the pool is significant. To provide some resting areas for fish ascending the multiple Denils, it is necessary to provide some depth below the common invert of the two Denils. Some suggestions have been made for determining the size of these resting pools.

366. Rajaratnam, N., G. van der Vinne and C. Katopodis (1986). Hydraulics of vertical slot fishways. Journal of Hydraulic Engineering. **112**:909-927.

This paper presents the results of an experimental study on the hydraulics of vertical slot fishways. Seven designs, including some conventional designs, were tested. A conceptual uniform flow state has been defined for which a linear relation has been found between the dimensionless flow rate and relative flow depth. Non-uniform flow of

the M1 and M2 types has been analyzed using the Bakhmeteff-Chow method. Some observations have also been made on the velocity profiles at the slot and circulation patterns in the pools.

367. Ransom, B. H., S. V. Johnston and T. W. Steig (1998). Review on monitoring adult salmonid *Oncorhynchus and Salmo spp.* escapement using fixed-location split-beam hydroacoustics. Fisheries Research (Amsterdam). **35**:33-42.

Since 1992, split-beam hydroacoustic techniques have been used to monitor adult salmonid escapement (*Oncorhynchus and Salmo spp.*) in 14 rivers in North America and Europe. Monitoring in rivers is one of the more challenging applications for fisheries acoustics. Rivers typically have a high reverberation level, uneven bottom bathymetry, and nonlaminar hydraulics, requiring sophisticated equipment and careful deployment, calibration, and testing. The major issues that were addressed in order to obtain estimates of adult salmon escapement included hydroacoustic equipment and techniques, site selection, transducer deployment, and fish behavior. Fixed-location hydroacoustic techniques were employed, utilizing narrow-beam transducers aimed horizontally, monitoring migrating fish in side-aspect. Fish were tracked in three dimensions as they passed through the acoustic beam. A bottom substrate of low acoustic reflectivity enabled the acoustic beam to be aimed close to the bottom. Sites were selected where fish were actively migrating, not holding or milling. In most cases, migrating salmonids were strongly shore- and bottom-oriented, where water velocities were slowest. Diel distributions of fish passage were weighted toward nighttime. Other results included fish size and velocity. Potential improvements in riverine monitoring capabilities include quadrature demodulation and FM Slide/Chirp signals.

368. Ransom, B. H. and T. W. Steig (1994). Using hydroacoustics to monitor fish at hydropower dams. Pages 163-169 *in* International Symposium of the North American Lake Management Society, Seattle, WA (USA), Lake and Reservoir Management.

In the USA hundreds of existing hydropower sites have federal operating licenses that expire by the year 2000, and many licenses are being considered for new sites. The mortality to fish passing through hydropower dams has been variously estimated at 2-30%. Many of the power producers applying for licenses in the USA and elsewhere have been required to evaluate the impact their facilities have on fish. Entrainment studies are potentially expensive, labor intensive, and can effect project operations. Estimates of fish entrainment may be required 24 hour/day for up to 12 months, with periodic evaluations of fish survivability through turbine units. Underwater acoustics (sonar) provides one method of obtaining these data that has been accepted by many government fisheries agencies (Federal Energy Regulatory Commission 1987). Fixed-location hydroacoustic techniques have proved effective at documenting and quantify the abundance and behavior of fish passing through hydropower dams, and in reservoirs. In the last 15 years, hundreds of hydroacoustic evaluations of entrainment at hydropower dams have been conducted in the USA.

369. Ransom, B. H., T. W. Steig and P. A. Nealson (1996). Comparison of hydroacoustic and net catch estimates of Pacific salmon smolt *Oncorhynchus spp.* passage at hydropower dams in the Columbia River Basin, USA. Pages 477-481 *in* E. J. Simmonds and D. N. Maclennan, eds. Fisheries and Plankton Acoustics. Proceedings of an ICES International

Symposium held in Aberdeen, Scotland, 12-16 June 1995, Academic Press, London (UK).

In the last 16 years, fisheries agencies and power producers in the Columbia River Basin (Washington, USA) have increasingly relied on hydroacoustic assessments of downstream migrating, anadromous Pacific salmon smolts *Oncorhynchus spp.* when evaluating bypass system designs at hydroelectric dams. Accompanying this reliance has been an interest in comparing hydroacoustic estimates of smolt passage with net catch estimates of fish passage, single-beam hydroacoustic techniques were used. The correlation between hydroacoustic and net catch estimates of smolt passage into the sluiceway at Ice Harbor Dam was statistically significant. Rocky Reach Dam hydroacoustic and fyke net catch vertical distributions were very similar. At Lower Granite Dam, the correlation between net catch estimates and hydroacoustic estimates of smolt passage was statistically significant. At Wanapum Dam in 1994, there was significant correlation between net catch and hydroacoustic estimates of smolt passage, and there was no statistically significant difference between the paired estimates. From 1991 to 1994, there was a significant correlation between mean hydroacoustic and net catch estimates of in-turbine diversion screen fish guidance efficiency, with no significant difference between the paired estimates.

370. Rasmussen, J. L. (1979). A compendium of fishery information on the Upper Mississippi River. Upper Mississippi River Conservation Commission, Rock Island, Illinois (USA).

The distribution, life histories and harvests of important sport and commercial species (including mussels) of the Upper Mississippi River from Minnesota to Missouri.

371. Rasmussen, J. L. and J. H. Wlosinski (1988). Operating plan of the Long Term Resource Monitoring Program for the Upper Mississippi River System. USGS Environmental Management Technical Center, Report EMTC-88/01.

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System (UMRS) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662). The UMRS is composed of the navigable reaches of the Upper Mississippi, Illinois, Kaskaskia, Black, St. Croix and Minnesota rivers. Program objectives are: to analyze significant resource problems such as sedimentation, water level management, and navigation impacts; to monitor selected habitats and species; and to develop data management systems and techniques which will assist resource personnel to better manage the rivers' ecosystems.

372. Reed, B. C., W. E. Kelso and D. A. Rutherford (1992). Growth, fecundity, and mortality of paddlefish in Louisiana. Transactions of the American Fisheries Society. **121**:378-384.

Growth, mortality, fecundity, egg diameter, and age at maturity were determined from samples of 270 paddlefish *Polyodon spathula* collected from the Atchafalaya River basin and Lake Pontchartrain, Louisiana, during a commercial harvest moratorium from 1987 to 1989. Early growth of paddlefish determined from back-calculation of annular measurements on dentary cross sections was high relative to paddlefish populations in the Upper Mississippi River drainage; lengths of age-1 fish ranged from 411 to 455 mm in eye-fork length. Natural mortality of Louisiana paddlefish was high (26-48%), and data

suggested a reduction in age at maturity (100% females mature at age 10), lower fecundity (average fecundity, 9,500 eggs/kg body weight), and larger eggs (average diameter, 2.67 mm) relative to other paddlefish populations. Changes in reproductive life history characteristics may reflect rapid growth and high natural mortality rates. As the postmoratorium commercial fishery for Louisiana paddlefish develops, conservative harvest regulations should be promulgated until the effects of harvest on paddlefish stock dynamics can be determined.

373. Regier, H. A., R. L. Welcomme, R. J. Steedman and H. F. Henderson (1989). Rehabilitation of degraded river ecosystems. Pages 86-97 *in* International Large River Symposium, Honey Harbour, Ont. (Canada), Canadian Special Publications of Fisheries and Aquatic Sciences.

Ecodevelopment of pristine rivers and sustainable redevelopment of degraded rivers is intended to result in more harmonious and productive human/nature ecosystems. Conventional environmental and resource sciences in their present states are poorly suited for this challenge. A more appropriate scientific approach to river rehabilitation may emerge from a synthesis of recent work on historical ecology, ecosystem development and empirical generalizations from comparative studies of river ecosystems. Here we take an ecosystem approach with a focus on self-organizing ecosystem properties that lead to the production of highly valued products and features.

374. Richmond, A. M. and B. Kynard (1995). Ontogenetic behavior of shortnose sturgeon, *Acipenser brevirostrum*. Copeia. 172-182.

Ontogenetic behavioral changes of young shortnose sturgeon *Acipenser brevirostrum* of Connecticut River stock are described for three morphological stages (embryo-larva-juvenile). Hatchlings (<1-day embryos) were positively rheotactic, photonegative, benthic, and vigorously sought cover. If denied cover, they exhibited vertical swim-up and drift behavior until cover was found. Older 1-8 day embryos exhibited the same behaviors as hatchlings; except when denied cover, they searched along the bottom until cover was found. The photonegative and cover seeking behaviors are adaptations that enable embryos to complete development while concealed under structure at a spawning site. Larvae 9-16 days old left cover and were positively rheotactic and photopositive. An estimated 75% of 9-14 day larvae left bottom cover and swam in the water column, suggesting that larvae, not embryos, initiate the downstream migration from a spawning site. Larvae were most active at night and preferred deep water and silt substrate. Most 43-66 day juveniles were benthic swimmers and, like larvae, positively rheotactic, photopositive, and nocturnally active. Behavior of embryos and larvae suggests shortnose sturgeon should be classified in the lithophil reproductive guild, not the litho-pelagophil guild.

375. Roe, K. J., A. M. Simons and P. Hartfield (1997). Identification of a fish host of the inflated heelsplitter *Potamilus inflatus* (Bivalvia: Unionidae) with a description of its glochidium. American Midland Naturalist. **138**:48-54.

A survey of the fishes of the Black Warrior River was undertaken to determine fish host(s) of the federally threatened inflated heelsplitter, *Potamilus inflatus*. Seven hundred-twenty individual fishes representing 30 species were examined; mussel glochidia were found on 10 individual fishes representing nine species. *Potamilus inflatus*

glochidia were only found infesting one freshwater drum *Aplodinotus grunniens*, which is concordant with previous findings for the genus *Potamilus*. The morphology of *P. inflatus* glochidia is described and compared to *P. purpuratus*.

376. Romano, M. A., D. B. Markillie and R. V. Anderson (1991). Electrophoretic analysis of the host-parasite relationship between flathead catfish *Pylodictus olivaris* and the mapleleaf mussel *Quadrula quadrula*. Pages 66 *in* K. Johnson, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

The only reported fish host for the glochidial stage of the mapleleaf mussel is the flathead catfish; therefore, patterns of genetic structure within these two species should be correlated. To test this hypothesis, sample sites of similar mussel density and diversity were chosen from Pools 15, 16, 18, 19, 26 of the Mississippi River, and one site from the Illinois River. Electrophoretic analysis indicated gene flow among the mapleleaf populations tended to be higher within pools and lower between pools separated by lock and dam systems. Catfish populations exhibited relatively low levels of genetic variability, particularly in Pool 19, where episodes of pollutant stress may have been a factor. *P. olivaris* appears to have a direct effect on the genetic structure of *Q. quadrula*. Analyses of systematic relationships among populations of both species showed some parallelism of population structure between the two species. A previous study on *Amblena plicata* did not produce a similarity in that species population structure with *P. olivaris*. Therefore, the data suggest that the flathead catfish is the predominant host fish with mapleleaf mussel's glochidia.

377. Ryckman, J. R. (1986). Effectiveness of fish ladders in the Grand River. Michigan Department of Natural Resources, Fisheries Research Report 1937.

Fish ladders were built on the Grand River to allow anadromous salmonids to migrate from Lake Michigan to the Lansing area. The study was started in the fall of 1982 to evaluate the fishing pressure and catch of anadromous fish. Visual counts were made at each fish ladder in spring and fall on a random around-the-clock basis to measure the number of salmonids moving upstream. Spring floods appeared to aid steelhead migration but hindered fishing. Returns of stocked salmonids to the Grand River fishery were roughly estimated by comparing average number stocked to average number harvested. Returns were about 2.8% for coho, 3.4% for chinook, and 2.2% for steelhead.

378. Saila, S. B., T. T. Polgar, D. J. Sheehy and J. M. Flowers (1972). Correlations between alewife activity and environmental variables at a fishway. Transactions of the American Fisheries Society. **101**:583-594.

An automatic recording system for fish counting and for the monitoring of water temperature, dissolved O_2, pH, and solar radiation was employed on a newly constructed fishway on the Annaquatucket River, North Kingstown, Rhode Island. Records of fishway utilization by the alewife, *Alosa pseudoharengus* and of the environmental variables were critically examined by time series autocorrelation and cross-correlation techniques. It was demonstrated that migratory activity was hormonic with a diurnal periodicity and was closely associated with incident solar radiation. Suggestions for an improved monitoring system and further analysis were made.

379. Sandell, G., L. Pettersson and I. Abrahamsson (1994). [Fishways -- a literature survey]. Informationen Soetvattenslab, Drottningholm (Sweden).

The construction of fishways ensures free passage around natural or man-made barriers. Construction and maintenance of fish passes represents one of the most important ways of preserving wild fish populations. The survey contains 183 references and deals with all the basic types of fishways described in the literature. The information has been selected in the light of its potential relevance in the Nordic countries. Eight basic types of fishways may be identified and are descibed in the document: weir fishways, Denil fishways, vertical slot fishways, fish locks and elevators, culvert fishways, channels, fishways for juveniles migrating upstream, bypasses.

380. Sanguine, W. L. (1985). Channel modification for fish passage on Umatilla River. Final report. U.S. Department of Energy, Report DOE/BP/15807-T1.

This report describes the construction of modifications to the bed of the Umatilla River and to the Threemile Dam fish ladder to improve fish passage during periods of low flow. The report also provides a preliminary assessment of the effectiveness of the modified channel in improving fish passage.

381. Schmutz, S., C. Giefing and C. Wiesner (1998). The efficiency of a nature-like bypass channel for pike-perch *Stizostedion lucioperca* in the Marchfeldkanalsystem. Hydrobiologia. **371-372**:355-360.

This radio telemetry study is part of a large interdisciplinary research program on the colonisation and development of the Marchfeldkanal(MFK)-system, a man made channel. The immigration of fishes into the MFK is dependent on the effectiveness of fish bypass channels at several weirs. To investigate the efficiency of the lower most fishway we estimated the population densities along the MFK-system and below the weirs using electrofishing. In addition, the movements of 15 radio-tagged pike-perch at the fishway were observed. Although more than 57 000 fishes of 35 species passed the bypass channel, pike-perch *Stizostedion lucioperca* were under-represented in the fishway traps compared to their occurrence in the channel. The average daily movement of radio-tagged pike-perch was 108 m (range 6-333 m) and the maximum observed daily movement was 1050 m. The entrance to the bypass channel (280 m below the weir, and 100 m above the release site) was approached a number of times by 6 tagged fish, though none of them entered the bypass channel during the period of tracking. We conclude that although pike-perch migrate actively they do not utilise the bypass channel as much as most fish species of the MFK. Therefore the weir still represents a bottleneck for the immigration of pike-perch into the MFK.

382. Schwalme, K., W. C. Mackay and D. Lindner (1985). Suitability of vertical slot and Denil fishways for passing north-temperate, nonsalmonid fish. Canadian Journal of Fisheries and Aquatic Sciences. **42**:1815-1822.

A vertical slot fishway and two Denil fishways (of 10 and 20% slope) built into a weir on the Lesser Slave River (55^{o} 18'N, 115^{o} 45'W) were studied from May 12 to June 25, 1984, to determine how effectively these designs pass north-temperate, nonsalmonid fishes. Thousands of spottail shiner *Notropis hudsonius*, substantial numbers (> 100) of

northern pike *Esox lucius*, longnose sucker *Catostomus catostomus*, white sucker *Catostomus commersoni*, immature yellow perch *Perca flavescens*, and lesser numbers of burbot *Lota lota*, adult yellow perch, lake whitefish *Coregonus clupeaformis*, and trout-perch *Percopsis omiscomaycus* ascended the fishways. Walleye *Stizostedion vitreum* and goldeye *Hiodon alosoides*, although probably moving extensively through the river, did not use the fishways.

383. Scott, W. B. and E. J. Crossman (1973). Freshwater fishes of Canada. Fisheries Research Board of Canada, Ottawa, Ontario (Canada).

This book is a classical monograph on the freshwater fishes of Canada. It contains a key to family taxonomy and species-by-species accounts that contain extensive information on description, colour, systematics, distribution (with maps), biology, and relation to man. Each species-specific section contains abundant information with cited references throughout so that readers can go to the original sources used to compile the species-specific accounts.

384. Seeb, J. E., L. W. Seeb, D. W. Oates and F. M. Utter (1987). Genetic variation and postglacial dispersal of populations of northern pike *Esox lucius* in North America. Canadian Journal of Fisheries and Aquatic Sciences. **44**:556-561.

The authors studied the genetic relationships and postglacial dispersal of northern pike *Esox lucius* populations in North America using allozyme data. Allelic products of up to 65 protein coding loci were examined in eight populations: five from drainages in western Canada; two from the Missouri River drainage, and one from the upper Mississippi River drainage. Only two polymorphic loci were identified, Est-1 and Ck-1, and the average observed heterozygosity was only 0.001. All of the populations from the drainages in western Canada and the Missouri River were genetically identical. The Mississippi River population was unique, expressing Ck-1(140), an allele nearly absent in all other populations, at a frequency of 0.99.

385. Senanan, W. and A. R. Kapuscinski (2000). Genetic relationships among populations of northern pike *Esox lucius*. Canadian Journal of Fisheries and Aquatic Sciences. **57**:391-404.

Genetic variation was assessed, using microsatellite markers, in 14 populations of northern pike *Esox lucius* in the North Central United States and in six populations from Quebec, Alaska, Siberia, and Finland. Eight of 13 loci examined were polymorphic in at least one population with an average heterozygosity at all loci and across all populations of 0.14. The R sub(st) and F sub(st) values indicated differentiation among populations (R sub(st) = 0.61, F sub(st)). Although microsatellite variation found in northern pike was much lower than that found in sympatric and other fish species, the allozymes and mitochondrial DNA. UPGMA-clustering phenograms were generated based on five genetic distance measures with 2000 bootstrap replicates per measure. All measures yielded highly repeatable population structure between continents (supporting values = 92.4-100%) and within Finland (42.3-98%). Four measures differentiated the Alaskan population and Young Lake (Great Lakes drainage) from other North American populations (56.6-87.7%). Relationships among other North Central United States populations were unclear, as indicated by low supporting values. Results support the

hypotheses of one refugium in the North Central United States and more than one refugium in Europe during the last glaciation.

386. Shtaf, L. G., D. S. Pavlov, M. A. Skorobogatov and A. Barekyan (1983). The influence of flow turbulence on fish behavior. Journal of Ichthyology. **23**:129-140.

The influence of degrees of flow turbulence on the behavior of the roach, *Rutilus rutilus* , and the minnow, *Phoxinus phoxinus* are presented. Data are given on the manner of selection by fish of zones with a heightened degree of turbulence, on places of concentration, swimming capacity, compactness of schools of fish in currents with varying turbulence characteristics, and degree of orientation of fish at speeds close to threshold, depending on the flow movement regime.

387. Simonson, T. D. and W. A. Swenson (1990). Critical stream velocities for young-of-year smallmouth bass in relation to habitat use. Transactions of the American Fisheries Society. **119**:902-909.

The authors defined relationships between current velocity and displacement of young smallmouth bass *Micropterus dolomieui* from nests, and between velocity and the distribution, swimming, respiration, feeding, and growth of larger young. Young that had recently risen from the nest gravel (7-9 mm standard length, SL) were displaced from field nest sites and from laboratory flumes at low velocities (8 mm/s). Nests in areas of higher velocities (15 mm/s) failed to produce young. Comparison of respiration and foraging rates of young fish (16-71 mm SL) in laboratory flumes suggested that the ratio of feeding reward to energy expenditure reached a maximum at current velocities between 80 and 130 mm/s. This velocity range produced maximum growth in the flumes and was also the range most frequented by young (43-116 mm SL) in the Mississippi River.

388. Skalski, J. R., A. Hoffmann, B. H. Ransom and T. W. Steig (1993). Fixed-location hydroacoustic monitoring designs for estimating fish passage using stratified random and systematic sampling. Canadian Journal of Fisheries and Aquatic Sciences. **50**:1208-1221.

Five alternative finite sampling designs are compared using 15 d of 24-h continuous hydroacoustic data to identify the most favorable approach to fixed-location hydroacoustic monitoring of salmonid outmigrants. Four alternative approaches are compared among themselves and with stratified random sampling (STRS). Stratifying systematic sampling (STSYS) on a daily basis is found to reduce sampling error in multiday monitoring studies. Although sampling precision was predictable with varying levels of effort in STRS, neither magnitude nor direction of change in precision was predictable when effort was varied in systematic sampling (SYS). Modifying systematic sampling to include replicated (e.g., nested) sampling (RSYS) is shown to provide unbiased point and variance estimates as does STRS. Numerous short sampling intervals (e.g., 12 samples of 1-min duration per hour) must be monitored hourly using RSYS to provide efficient, unbiased point and interval estimates. For equal levels of effort, STRS outperformed all variations of SYS examined.

389. Skorobogatov, M. A., D. S. Pavlov, A. Barekyan and L. G. Shtaf (1983). Selecting sites of projected fish passes. Doklady Biological Sciences. **272**:508-510.

One of the most important problems arising in the planning of areas for fish to pass through a dam is choosing the sites of the passes in the system at the hydroelectric center. A procedure for this choice is presented based on a comparison of the probable working efficiency of a fish pass at each possible location site. Hydraulic-biological studies carried out a few years ago make it possible to ascertain the factors influencing the formation of the paths of motion of fish, as well as the reactions of fish to various flow characteristics. The behavioral features of each school of fish are taken into account by finding the deviations of the transverse and longitudinal fish velocities from the average values. In order to determine the efficiency of a fish pass for a known flow structure in the tailwater of a hydroelectric system, all possible paths of fish motion from the initial point to the entry of the fish collecting chute are calculated. As an example , the efficiency was calculated for one operating regime of a model hydroelectric center with a fish pass located in the middle of the spillway, for passage through the system of schools of roach with an average length of 25.4 mm. This approach provides an objective evaluation of the likelihood that fish will enter a fish pass and indicates the optimum location of the pass in the hydroelectric system, as well as the optimum operating regime. In order to apply this approach to specific planning operations, it is advisable to carry out studies in two possible directions: to seek small experimental fish with behavior similar to that of spawning migrants and to study the reactions of fish likely to pass through hydroeletric centers.

390. Slatick, E. and L. R. Basham (1985). The effect of Denil fishway length on passage of some nonsalmonid fishes. Marine Fisheries Review. **47**:83-85.

This paper documents the success of passage of some non-salmonid fishes through Denil-type steep-pass fishways of varying length and slope. Length ranged from 7.9 m (26 feet) to 20.1 m (66 feet), and slope ranged between 23.3 and 28.7 percent. American shad, *Alosa sapidissima*; common carp, *Cyprinus carpio*; chiselmouth, *Acrocheilus alutaceus*; northern squawfish, *Ptychocheilus oregonensis*; Pacific lamprey, *Lampetra tridentata*; and suckers, *Catostomus sp*., were observed at Bonneville and McNary dams on the Columbia River and Little Goose Dam on the Snake River from 1971 to 1979. Observations indicate that Denil ladders of selected length could be used, if desired, to pass salmonid fishes over small barriers while denying upstream access to certain unwanted nonsalmonids.

391. Smiley, P. C., Jr. and G. R. Parsons (1997). Effects of photoperiod and temperature on swimming performance of white crappie. Transactions of the American Fisheries Society. **126**:495-499.

Photoperiod and temperature are two environmental factors that have significant effects on fish physiology and behavior but few studies have investigated the effect of photoperiod on swimming performance. We studied the effects of five photoperiods, designated 24L:0D (24 h light:0 h dark), 16L:8D, 12L:12D, 8L:16D, 0L:24D, and three temperatures (5, 15, and 25 ^{o}C) on the swimming performance of white crappie *Pomoxis annularis* (5-11 cm in standard length) in a swim tunnel with propeller-driven flow. Two-factor analysis of variance (alpha = 0.05) indicated that both photoperiod and temperature significantly affected fish swimming performance but the interaction of photoperiod and temperature did not. At all temperatures, the 8L:16D photoperiod resulted in the highest

mean swimming speeds. In addition, the temperature effect was consistent at all photoperiods. The mean swimming speed at 5 ^{O}C was significantly slower than at 15 ^{O}C or 25 ^{O}C; however there was no significant difference between swimming speeds at 15 ^{O}C and 25 ^{O}C. Our documentation of a photoperiod effect on fish provide further confirmation of the importance of this environmental variable on swimming performance.

392. Smith, D. G. (1985). Recent range expansion of the freshwater mussel *Anodonta implicata* and its relationship to clupeid fish restoration in the Connecticut River system. Freshwater Invertebrate Biology. **4**:105-108.

The range of *Anodonta implicata* in the Connecticut River prior to 1970 was known not to extend upstream from Hartford, Connecticut. Since 1970 *A. implicata* has increased its range upstream in the Connecticut River to Bellows Falls, Vermont. This rapid range expansion appears to be correlated with chronological episodes of clupeid fish restoration above successive dams in the Connecticut River. *Anodonta implicata*, therefore, can be used as an indicator of success of clupeid fish restoration.

393. Soloman, R. C., D. R. Parsons, D. A. Wright, B. K. Colbert and C. Ferris (1975). Environmental inventory and assessment of Navigation Pools 24, 25, and 26, Upper Mississippi and Lower Illinois Rivers. Army Engineer Waterways Experiment Station, Technical Report Y-75-1.

The River and Harbor Act of 3 July 1930 authorized the construction and maintenance of a 9-ft-deep by 300-ft-wide channel for commercial navigation of the Upper Mississippi and Lower Illinois Rivers. Construction of locks and dams supplemented by dredging and bank stabilization was required to maintain the 9-ft depth, particularly during periods of low flow. An investigation was performed by Colorado State University to evaluate the river reaches before and after man-made changes and overall changes in geomorphology. Additionally, trends of future geomorphic changes that could result from existing and potential future developements were addressed with the aid of a mathematical simulation model. Vegetation and vegetative successional patterns of the floodplain were characterized by the Missouri Botanical Gardens. Vegetation maps were produced delineating vegetational communities adjacent to the rivers and on islands. An inventory of the animals and their habitats was conducted by Southern Illinois University. Seven habitats were distinguished in the unprotected floodplain. Based on literature, 49 species of mammals, 286 species of birds, and 81 species and subspecies of amphibians and reptiles were expected to occur in the study area. Members of the Waterways Experiment Sttion study team collected water and sediment samples for chemical and physical analysis and biological samples from four habitat types. The data were subjected to various statistical analyses to determine if there were differences between habitats and sampling dates. Fish samples were collected from the Illinois River by the Illinois Natural History Survey and results were compared with literature to determine temporal and spatial changes in distribution. The overall impacts of operation and maintainance of the 9-ft channel were discussed relative to the effects on the biological, chemical, and physical system in the study area. Recommendations were made for further studies that are needed to define impact more adequately.

394. Southall, P. D. (1982). Paddlefish movement and habitat use in the Upper Mississippi River. Pages 35 *in* J. G. Weiner, R. V. Anderson and D. R. McConville, eds.

Contaminants in the Upper Mississippi River: Proceedings of the 15th Annual Meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

The paddlefish is an important sport and commercial fish species in the Upper Mississippi River. Paddlefish movement and habitat use were investigated by radio-telemetry. Fish were surgically implanted with 49 MHz radio transmitters and released at capture site in Pool 13. Radio-tagged fish measured 68 to 96 cm, eye to fork length, and weighed 4 to 18 kg. Seven paddlefish were monitored during the summer of 1980, and 10 fish were tracked through the spring and into the summer of 1981. Tracking was conducted primarily by boat, with a single search by aircraft for lost fish 1981. Physical characteristics of the habitat measured at telemetry location sites were: water depth, current velocity, water temperature, bottom contour, and proximity to navigation improvement structures. Paddlefish exhibited great mobility, especially during the spring months. Individual linear range varied from 12.5 to 104.6 km during the study period. Interpool movement through navigation dams was observed. Group movement upstream through Lock and Dam 12 occurred when dam gates were raised during a high water period in the spring, 1981. Movement downstream through Lock and Dam 12 was accomplished when dam gates were partially closed. Movement from and subsequent return to specific areas suggested recognition of particular habitats. Main channel border and tailwater habitats were utilized most frequently, although telemetry locations were also made in backwater, main channel, and side channel habitats. Association with wing dams was observed.

395. Southall, P. D. and W. A. Hubert (1984). Habitat use by adult paddlefish in the Upper Mississippi River. Transactions of the American Fisheries Society. **13**:123-131.

Information on paddlefish habitat associations in the Upper Mississippi River is useful because of continuing adverse effects on habitat by navigation, siltation, and industrial siting, as well as potential hydroelectric power development. Seventeen paddlefish were tracked in two pools (12 and 13) of the Upper Mississippi River during the summer of 1980 and spring and summer of 1981. Interpool movement occurred during spring high water periods when dam gates were lifted to create a free-flowing river. Habitat use varied by season. Selection was greatest for tailwater and channel habitats, although strong association with one backwater slough was evident. Even when backwaters are not directly utilized, invertebrate drift from these areas may be important. Paddlefish often congregated near man-made structures that created eddies and reduced current velocities.

396. Sparks, R. E. (1995). Need for ecosystem management of large rivers and their floodplains. BioScience. **45**:168-182.

The author outlines what ecosystem management is as well as what it is not. The importance of large river floodplain ecosystems in providing diverse and rich habitats for aquatic and terrestrial species is discussed. Anthropogenic impacts on large floodplain rivers are reported to be extensive and to have profound consequences in system function. Most salient are issues of connectivity. The goals of ecosystem management are defined to be the maintenance or recovery of biological integrity of the ecosystem. Biological integrity is argued to comprise not just the full range of species present prior to anthropogenic impacts, but more importantly, all of the variability and processes that comprise the system. To define a reference point from which to manage from, the author

suggests that the predisturbed ecosystem should be the appropriate benchmark. Restoration of the floodplain, the annual flood pulse, and the long-term variability in the system are forwarded as management policies to restore large river floodplain ecosystems.

397. Stamhuis, E. J. and J. J. Videler (1995). Quantitative flow analysis around aquatic animals using laser sheet particle image velocimetry. Journal of Experimental Biology. **198**:283-294.

Two alternative particle image velocimetry (PIV) methods have been developed, applying laser light sheet illumination of particle-seeded flows around marine organisms. Successive video images, recorded perpendicular to a light sheet parallel to the main stream, were digitized and processed to map the flow velocity in two-dimensional planes. In particle tracking velocimetry (PTV), displacements of single particles in two subsequent images were determined semi-automatically, resulting in flow diagrams consisting of non-uniformly distributed velocity vectors. Application of grid-cell averaging resulted in flow field diagrams with uniform vector distribution. In sub-image correlation PIV (SCPIV), repetitive convolution filtering of small sub-areas of two subsequent images resulted in automatic determination of cross-correlation peaks, yielding flow field diagrams with regularly spaced velocity vectors. In both PTV and SCPIV, missing values, caused by incomplete particle displacement information in some areas of the images or due to rejection of some erroneous vectors by the vector validation procedure, were interpolated using a two-dimensional spline interpolation technique. The resultant vector flow fields were used to study the spatial distribution of velocity, spatial acceleration, vorticity, strain and shear. These flow fields could also be used to test for flow in the third dimension by studying the divergence, and to detect the presence and location of vortices. The results offer detailed quantitative descriptions of the flow morphology and can be used to assess dissipated energy. The versatile character of the technique makes it applicable to a wide range of fluid mechanical subjects within biological research. So far it has been successfully applied to map the flow around swimming copepods, fish larvae and juvenile fish and the ventilation current of a tube-living shrimp.

398. Stanford, J. A., F. R. Hauer and J. V. Ward (1988). Serial discontinuity in a large river system. Pages 1114-1118 *in* V. Sladecek, ed. Congress in New Zealand, Hamilton (New Zealand), International Association of Theoretical and Applied Limnology.

In this paper, abiotic and biotic discontinuities were studied which exist serially within the Flathead River system (Canada and USA). These discontinuities occur as a result of natural (lakes and springs) and anthropogenic (epilimnial and hypolimnial release dams) stream regulation.

399. Steiner, H. A. (1991). Investigations at the fish ladder from the River Drau into the Kellerberg Loop. Osterreichs Fischerei. **44**:87-100.

The measurings showed, that the installation of a fish ladder for the preservation of the flowing water continuum for the old branch of the River Drau is absolutely feasible, taking the ecological conditions and the fishery biological outline conditions into consideration. Beside variable outlets on account of the natural catchment area, the fish ladder at the Kellerberg Loop took the performance of the fish, disposition of the fish

path and sufficient decoy current into consideration. The fish ladder was well accepted and serves as permanent living space for at least 10 different species of fish. The fish ladder also serves a good purpose with regard to ascents during the spawning time.

400. Steingraeber, M. T., A. L. Runstrom and P. A. Thiel (1997). Round Goby (*Neogobius melanostromus*) distribution in the Illinois waterway system of metropolitan Chicago. Pages 45 *in* M. Olekszyn and M. Steingraeber, eds. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

There is concern that the range of the round goby *Neogobius melanostromus*, a nonindigenous fish recently introduced to the Great Lakes drainage basin from Eurasia, may expand to other drainage basins with adverse ecological consequences. The Illinois Waterway System (IWS) connects the Great Lakes and Mississippi River basins and facilitated the spread of another exotic nuisance species, the zebra mussel *Dreissena polymorpha*, to other environmentally sensitive drainages of interior North America earlier this decade. We surveyed the distribution of round goby in a portion of the IWS near metropolitan Chicago in autumn 1996 with traps, seines, trawls, set lines, and by angling. A total of 61 round goby were captured in the Little Calumet River in south Chicago at locations upstream of river mile 321.4 (12 miles inland from Lake Michigan). No round goby were captured at sites in connecting channels downstream (i.e., further inland) of this point as far away as Joliet (river mile 283). Bottom trawling, particularly over rocky substrates, was the most successful means of capturing round goby and accounted for 87% of the total catch. Goby captured by trawling were significantly smaller than those captured by other gears and significantly smaller goby were captured at the sampling site furthest upstream. The length frequency distribution of the round goby we captured suggested the presence of fish from the three most recent year classes (1994-1996). The rocky substrate preferred by round goby may be less common in a short reach of the Little Calumet River downstream of river mile 321. Despite this potential habitat deficiency, population growth and human interventions are soon likely to expand the range of the round goby in the IWS.

401. Stier, D. J. and B. Kynard (1986). Use of radio telemetry to determine the mortality of Atlantic salmon smolts passed through a 17-MW Kaplan turbine at a low-head hydroelectric dam. Transactions of the American Fisheries Society. **115**:771-775.

Mortality among 108 radio-tagged 2-year-old smolts of Atlantic salmon *Salmo salar* passed through a 17-MW Kaplan turbine was estimated at Holyoke Dam on the Connecticut River. The survival of test and control fish in 1981 was determined by comparing their rate of downstream movement with that of 28 prekilled fish. The survival of test fish in 1982 was determined as in 1981 by using nine prekilled fish. At full power generation, the mean percent turbine-induced mortality at 2 h (95% confidence interval in parentheses) was 11.8 (3.8-18.0) in 1981 ad 13.7 (1.9-22.5) in 1982.

402. Stuart, I. G. and M. Mallen-Cooper (1999). An assessment of the effectiveness of a vertical-slot fishway for non-salmonid fish at a tidal barrier on a large tropical/subtropical river. Regulated Rivers: Research and Management. **15**:575-590.

Fishways for salmon in temperate rivers have often been successful, but salmonid-type fishways for non-salmonid species in tropical and subtropical rivers have

frequently failed. This study assessed the effectiveness of modifying a salmonid-type pool-and-weir fishway into a vertical-slot design on a tidal barrage on the subtropical Fitzroy River, in Queensland, north-eastern Australia. In 38 paired samples of the top and bottom of the fishway, over 16 months, 29 fish species and over 23 000 fish were collected at a maximum rate of 3400 per day. This study shows much greater potential for success with a vertical-slot fishway as relatively few fish negotiated the original pool-and-weir design. Common species using the vertical-slot fishway included blue-catfish (*Arius graeffei* [Ariidae]), bony herring (*Nematalosa erebi* [Clupeidae]), striped mullet (*Mugil cephalus* [Mugilidae]), barramundi (*Lates calcarifer* [Centropomidae]), and long-finned eels (*Anguilla reinhardtii* [Anguillidae]). Freshwater shrimp (*Macrobrachium australiense* [Palaemonidae]), juvenile crabs (*Varuna litterata* [Grapsidae]) and long-finned elvers did not ascend the full length of the fishway and specific fishways for these species are recommended. Fish between 25 and 640 mm in length ascended the fishway, although the passage of smaller size classes of immature fish was restricted and this may be important for the sustainability of these migratory populations. The barramundi (200-640 mm) which ascended the fishway were all immature fish. However, during a period of low river flows enlarging the width of the vertical-slot from 0.15 to 0.45 m only encouraged a small number of larger fish (890 mm maximum length) to enter. The strong diel movement patterns of many species will need to be considered in future fishway design. Blue-catfish could ascend the fishway in 2 h, but many fish remained in the fishway and this behaviour may cause crowding and a reduction in fishway capacity. Further work is needed to assess the proportion of fish finding the fishway entrance. However, the findings suggest that vertical-slot fishways with lower water velocities and turbulence than salmonid fishways have great potential to pass the diverse migratory fish fauna of subtropical and tropical rivers.

403. Sylvester, J. R. and J. D. Broughton (1983). Distribution and relative abundance of fish in Pool 7 of the Upper Mississippi River. North American Journal of Fisheries Management. **3**:67-71.

The distribution and relative abundance of fish species in Pool 7 of the Upper Mississippi River near Dresbach and Dakota, Minnesota were compared in three habitat types on the basis of catches in hoop nets and gill nets. Habitat types included the main channel, side channels, and backwater areas. A total of 36 species was collected. Twenty-four species and 14% of the total number of individual fish caught were collected in the main channel. Thirty species and 33% of the total number caught were captured in the side channel, and 28 species and 53% of the total number caught were collected in the backwater areas. The species caught most frequently were not limited to a particular habitat, but were perhpas relatively more accessible to gill nets and hoop nets in backwater habitats. The low relative abundance of species and individual fish in the main channel suggested a lower habitat diversity there than in the side channel and backwater areas.

404. Taylor, E. W., S. Egginton, S. E. Taylor and P. J. Butler (1997). Factors which may limit swimming performance at different temperatures. Cambridge University Press, Cambridge (Uk).

As thermal diffusion is an order of magnitude more rapid than molecular diffusion, it is clear that the same design features that make the gills of fish well suited for respiratory gas exchange from water (large surface area, active convection of water and blood at appropriate ventilation/perfusion ratios across a functional counter-current)

also provide for very effective branchial heat exchange. This is reinforced by the relatively high heat capacity of water which is more than 3000 times that of air, so that for most fishes, and indeed all other water-breathing ectotherms, body temperature equilibrates rapidly to any change in environmental temperature. Consequently, in the absence of specific anatomical specialization to maintain thermal gradients, temperature throughout the body of fishes is in equilibrium with the environment to within a fraction of a degree. Thus, large changes in body temperature may be experienced: diurnally, by coastal fish subjected to tidal variations; or by vertically migrating pelagic species, particularly if they cross a thermocline; or seasonally by eurythermal temperate zone fish. Over evolutionary time, speciation of tropical and polar fishes has resulted in species with widely different thermal ranges within the accepted biological temperature range (between the freezing point of water and the temperature for protein denaturation), which do not overlap.

405. Taylor, R. E. and B. Kynard (1985). Mortality of juvenile American shad and blueback herring passed through a low-head Kaplan hydroelectric turbine. Transactions of the American Fisheries Society. **114**:430-435.

Immediate mortality of juvenile alosids, American shad *Alosa sapidissiam* and blueback herring *A. aestivalis* , passed through the 17-MW Kaplan turbine at Holyoke Dam on the Connecticut River was estimated with mark-capture methods. Turbine-induced mortality was 62% at 16.5-MW generation, 82% at 12 MW, and 82% at 5.5 MW. The significantly lower mortality of fish at full power output is thought to be related to greater turbine efficiency.

406. Theler, J. L. (1987). Prehistoric freshwater mussel assemblages of the Mississippi River in southwestern Wisconsin. Nautilus. **101**:143-150.

Archaeological excavations at aboriginal sites adjacent to the Upper Mississippi River (UMR) in southwestern Wisconsin produced a series of freshwater mussel (naiad) assemblages. These subfossil mussel valves are the remains of mollusks harvested as a food source by prehistoric peoples between circa A.D. 1 and A.D. 1000. The aboriginal assemblages provide an approximation of the regions' main stem UMR naiad communities during the latter part of the prehistoric era. A quantitative comparison of the subfossil collection with modern mussel survey data documents dramatic changes in the species composition of molluscan communities following habitat degradation of the UMR associated with EuroAmerican settlement.

407. Traebing, K., D. Hering, T. Kilian and E. Korte (1997). Water management and the river continuum. Wasser und Boden. **49**:46-50.

Migration along streams or rivers is often interrupted by hydraulic structures which form barriers. In stream restoration projects, high priority is usually attached to establishing migration facilities for aquatic organisms. However, aquatic migration may also be limited under natural conditions. The example of beaver dams is considered. When determining restoration goals it is necessary to take into account morphological, hydrological and biological conditions for the river continuum.

408. Travade, F., M. Larinier, S. Boyer-Bernard and J. Dartiguelongue (1998). Performance of four fish pass installations recently built on two rivers in south-west France. Pages 146-170 *in* M. Jungwirth, S. Schmutz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

During the 1970s, a number of projects were initiated in France directed towards the conservation and rehabilitation of migratory fish stocks. Stemming from these efforts, four relatively large fish passes were built between 1984 and 1989 on the Garonne and Dordogne rivers in south-west France. Two are pool-type fish passes (one with a double vertical slot at Bergerac on the Dordogne River, and the other with a single vertical slot at Le Bazacle on the Garonne River); the other two are fish elevators (Golfech on the Garonne River and Tuilieres on the Dordogne River). This chapter describes the characteristics and operating constraints of each installation. Since construction, operations have been monitored on a more or less (dependent on site) constant basis using a semi-automated video counting device which provides precise data on the quantity and timing of fish passage. The four installations have enabled passage of some 30 fish species, including migratory diadromous populations of Atlantic salmon *Salmo salar*, sea-run brown trout *Salmo trutta*, allice shad *Alosa alosa*, European eel *Anguilla anguilla*, sea lamprey *Petromyzon marinus*, and a number of so-called 'sedentary' species such as roach *Rutilus rutilus*, bream *Abramis brama*, and barbel *Barbus barbus* for which very clear migration rhythms have been nonetheless observed. Passage of allice shad, which has often been difficult to achieve over traditional fish passes, has been found satisfactory in both the pool and elevator installations, with annual passage of several tens of thousands of individuals (80 000 to 86 000 shad at the Tuilieres and Golfech fish elevators in 1995). The relative effectiveness of each type of pass is discussed in relation to the various migratory species. Finally, the main results concerning the seasonal and daily migratory rhythms of various diadromous and resident species are presented.

409. Trivellato, D. and M. Larinier (1987). [The use of hydraulic models to study fish facilities on large rivers]. Pages 149-157 *in* M. Thibault and R. Billard, eds. Restoration of salmon rivers, Bergerac (France), Collections de la Hydrobiogica et Aquaculture.

Fish facilities at the Belleville weir on the Loire River, the Bergerac dam on the Dordogne River, and the Golfech powerhouse on the Garonne River were optimized by the use of hydraulic model studies at the "Institut de Mecanique des Fluides" at Toulouse. In the first two fishways, flow conditions, i.e. flow velocity, drop between pools and rate of energy dissipation per unit of volume, were studied in relation to tailwater and headwater fluctuations. The main purpose of these studies was to optimize the position of entrances and determine the discharge needed to provide adequate attraction at these sites. The modeling resulted in design changes that should improve fish passage.

410. Truebe, J. and M. Drooker (1980). Modular innovations in upstream fish passage. U.S. Department of Energy, Report DOE/ID/12207-T2.

This project examined design alternatives for the construction, equipping and operation of upstream fish passage facilities suitable for installation at small hydropower sites being developed or re-developed. These alternatives were examined for technical feasibility and economic viability with the object of providing alternative means of meeting the biological requirements of an upstream fish passage in a more cost-effective manner than strictly traditional methods. An overview is presented of the fish passage design process in a project formation flowchart and design data checklist. The design

features, materials and equipment specifically considered in this study are described with information on the characteristics, advantages, and applicability of each item.

411. Trump, C. L. and W. C. Leggett (1986). Optimum swimming speeds in fish: the problem of currents. Canadian Journal of Fisheries and Aquatic Sciences. **37**:1086-1092.

A model is presented describing the energetic consequences of various behavioral responses to currents. To minimize the energy cost of migration, when confronted with currents, fish must optimize both the mean swimming speed and the degree to which swimming speed is altered in response to changes in current velocity. The optimum swimming speed in a current is $U_0 + 1/b$ where U_0 = mean current speed and b is a constant in the equation $E(t) = a e^{-bW(t)}$ describing the relationship between specific energy expenditure per unit time (E(t) and swimming speed W(t). In a variable current, such as might occur in estuaries and coastal areas, energy expenditure is minimized when these variations are ignored and a constant speed through the water is maintained. This is true even in conditions where occasional retrograde motion over the botton may occur. The added energy costs of swimming at mean speeds or of varying swimming speeds in response to changes in current velocity are rigorously defined. Predictions of the model are in general agreement with empirical data on fish swimming behavior.

412. Tsuyuki, H. and S. N. Williscroft (1977). Swimming stamina differences between genotypically distinct forms of rainbow *Salmo gairdneri* and steel-head trout. Journal of the Fisheries Research Board of Canada. **34**:996-1003.

Rainbow trout *Salmo gairdneri* homozygous for liver lactate dehydrogenase alleles *ldh*$H\alpha^A$ and *ldh*$H\alpha^B$ were artificially propagated and their swimming stamina compared. The time required to fatique 50% of the $H\alpha^AH\alpha^A$ phenotypes in fixed water velocity tests was 2.3 times greater on the average than that of $H\alpha^BH\alpha^B$ phenotypes. Likewise, LDH phenotypes $H\alpha^AH\alpha^A$, $H\alpha^AH\alpha^B$, and $H\alpha^BH\alpha^B$of steelhead trout from the Thompson River were artificially propagated and their swimming stamina compared. In contrast to the rainbow trout, significant differences in stamina among the three phenotypes of steelhead were not evident in the stocks from this river not between phenotypes $H\alpha^AH\alpha^A$ and $H\alpha^AH\alpha^A$ from another stream, the Vedder River, which has a very low frequency of the *ldh*$H\alpha^A$ allele. The stamina of young steelhead from the Thompson River was, however, 3.8 times greater than that of those from the Vedder River.

413. Tucker, J. K. (1998). Union mussels associated with the construction of the Melvin Price Lock and Dam on the Upper Mississippi River. Journal of Freshwater Ecology. **13**:249-252.

Eighteen species of native unionid mussels (Unionidae) were recovered from sediments dredged from behind a coffer dam built during the construction of the Melvin Price Lock and Dam on the Upper Mississippi River. For three species (*Amblema plicata*, *Anodonta grandis*, and *Obliquaria reflexa*), shells in the dredged material were significantly smaller than those of the same species collected at about the same time from other sites in Pool 26 of the Illinois and Mississippi rivers. The concentration of juvenile specimens in the dredged material is thought to represent a *de novo* development associated with silt accumulation behind the coffer dam.

414. Tucker, J. K., F. A. Cronin, R. A. Hrabik, M. D. Petersen and D. P. Herzog (1996). The bighead carp *Hypophthalmichthys nobilis* in the Mississippi River. Journal of Freshwater Ecology. **11**:241-243.

The authors report collections of the bighead carp, *Hypophthalmichthys nobilis* in the Mississippi River in Missouri and Illinois between 1991 and 1994. In all, 48 specimens were collected ranging from 18 to 790 mm total length. Young-of-the-year fish were caught in 1992 and 1994, which suggested that the species is able to reproduce in the Mississippi River and may become established. Because *H. nobilis* is a low-level filter feeder, its presence may affect other filter feeding fishes such as the paddlefish *Polyodon spathula*, bigmouth buffalo *Ictiobus cyprinellus*, and gizzard shad *Dorosoma cepedianum*.

415. Tucker, J. K., F. A. Cronin, R. A. Hrabik, M. D. Petersen and D. P. Herzog (1997). Bighead carp *Hypophthalmichthys nobilis* in the Mississippi River. Unites States Geological Survey Long Term Resource Monitoring Program, Report LTRMP97-R014.

The authors report collections of the bighead carp, *Hypophthalmichthys nobilis* (Richardson, 1845), in the Mississippi River in Missouri and Illinois between 1991 and 1994. In all, the authors collected 48 specimens ranging from 18 to 790 mm total length. Young-of-the-year fish were caught in 1992 and 1994, which suggests that the species is able to reproduce in the Mississippi River and may become established. Because *H. nobilis* is a low level filter feeder, its presence may affect other filter feeding fishes such as the paddlefish *Polyodon spathula*, bigmouth buffalo *Ictiobus cyrinellus*, and gizzard shad *Dorosoma cepedianum*. Further research is needed to confirm that the species is established and what its biological impact will be.

416. Tyus, H. M. (1990). Effects of altered stream flows on fishery resources. Fisheries. **15**:18-20.

Alteration of the quantity and timing of river or stream flow can significantly affect fisheries resources. The American Fisheries Society (AFS) is alarmed at the loss of natural streams in North America, and greatly concerned with management of fisheries in streams that have been altered. The AFS believes that public trust rights need more recognition and stronger consideration in the management of stream resources. This policy statement revises the 1981 version by J.C. Peters entitled "Effects of River and Streamflow Alteration on Fishery Resources".

417. Underhill, J. C. (1989). Distribution of Minnesota fishes and Late Pleistocene glaciation. Journal of the Minnesota Academy of Science. **55**:32-37.

The fishes of Minnesota have been the focus of research for almost a century. At present the ichthyofauna totals 153 species belonging to 19 families, including 13 species which have been introduced. Because Minnesota was covered by glacial ice until at least late Wisconsinan time, species that migrated into the state from the periglacial region could have been derived from three refugia: unglaciated Alaska, the Atlantic refugium, and the lower Mississippi River refugium. The routes followed in their dispersal were dependent upon the drainage connections that existed during late Pleistocene and early

Holocene time. Fish migration paths were largely determined by the formation of large glacial lakes such as Lake Agassiz, Lake Koochiching, Lake Duluth, and Lake Ontonagon. Advances and retreats of various glacial lobes controlled the size and drainage directions of the glacial lakes, allowing migration of fishes from different refugia at different times. The geologic evidence for Holocene drainage is more conjectural, and the present distribution of species can be used to infer changes in drainage during this period of time.

418. Vallazza, J., B. Knights, M. Dewey, S. Zigler, R. Kennedy, P. Rust and D. Betz (1998). Seasonal habitat use and movements of lake sturgeon in the Upper Mississippi River. Pages 47 *in* M. Knutson, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

In the early 1900's, lake sturgeon *Acipenser fulvescens* populations precipitously declined in the Upper Mississippi River resulting in a 96% decline in harvest. Despite harvest restrictions, lake sturgeon are still considered uncommon or rare in the Upper Mississippi River and are listed as endangered or a species of concern by four of five states bordering the Upper Mississippi River. Recovery of lake sturgeon populations in the Upper Mississippi River may be hindered due to system modifications, including the construction of low-head dams in the 1930's to accommodate commercial navigation. Moreover, recent proposals to further modify the Upper Mississippi River to accommodate increased commercial navigation has raised concern for remaining lake sturgeon populations. We are conducting a biotelemetry study to identify and describe inportant seasonal habitats of lake sturgeon in the Upper Mississippi River and to determine the effects of commercial navigation on lake sturgeon movements and habitat use. We tagged 23 lake sturgeon in the Upper Mississippi River with radio and ultrasonic transmitters during summer and fall, 1997. Twelve fish were tagged in the East Channel in Navigation Pool 10 near Prairie du Chien, WI and 11 fish were tagged in Polander Lake, an off-channel area in Navigation Pool 5A near Winona, MN. We attempted to obtain weekly locations and habitat use data on all fish, recording a total of 376 locations. Many lake sturgeon have moved considerable distances in 1997. Five fish tagged in Pool 10 moved up the Wisconsin River about 120 km to Prairie du Sac, five fish remained in Pool 10, and one fish moved 40 km upstream into Pool 9. One tagged lake sturgeon was harvested in the Wisconsin River by an angler in early September. Six fish tagged in Pool 5A remained in that pool and five fish moved up to 62 km to downstream pools. Preliminary analyses of data indicated that habitat use by lake sturgeon was similar between summer and fall. For fish tagged in Pool 10, 97% of the locations in the Mississippi River occurred in channel habitats, and 3 percent in off-channel habitats. In contrast, 57% of the locations of fish tagged in Pool 5A occurred in off-channel habitats. Mean depth and current velocity at fish locations in the Upper Mississippi River were 5.0 m and 22 cm/s, respectively. About 60% of fish locations occurred over sand, and 25% occurred over silt. We plan to continue tracking these tagged lake sturgeon until November 1998.

419. Vallazza, J. M., J. W. Deller, W. E. Lynch and D. L. Johnson (1994). Seasonal behavior, movements, and habitat preferences of hybrid striped bass and sauger in the Ohio River. Ohio Department of Natural Resources, Final Report Federal Aid in Sport Fish Restoration Project F-69-P.

Hybrid striped bass *Morone saxatilis x M. chrysops* and sauger *Stizostedion canadense* are important components of the Ohio River sport fishery. Little is known

about the behavior of either taxa in large river systems. Hence, to increase angler awareness of harvest opportunities and to identify critical habitats, radio telemetry was used to collect data on the seasonal movements and habitat preferences of hybrid striped bass and sauger in the Ohio River. Adult hybrid striped bass (N=59) and adult sauger (N=42) were surgically implanted with radio transmitters. No interpool movements were observed for either taxa. Median monthly movement rates were 0 - 498 mh^{-1} with fish-day medians up to 1,567 mh^{-1} for hybrid striped bass. Sauger moved considerably less; monthly medians were 15-40 mh^{-1} with fish-day medians up to 90 mh^{-1}. Monthly depth-at-location ranged 3.1 - 5.8 m and 2.1 - 5.3 m for hybrid striped bass and sauger, respectively. Hybrid striped bass were located over deeper water in winter, whereas post-spawn sauger were over deeper water in May and June. Both taxa made extensive use of habitats associated with dams. Hybrid striped bass usually were located in the tailwaters spring and summer, whereas sauger increased their use of dam habitats in fall and remained there during winter. Neither taxa used tailwaters during high flows; hybrid striped bass moved downstream and sauger moved behind the lock wall. Island habitats were rarely used by either taxa. Hybrid striped bass and sauger both used confluence habitat during winter, especially during high flow. Sauger were more often associated with drop-offs than hybrid striped bass, which exhibited little preference for bottom contour type. Sauger often used woody structure along shore during high flows; hybrid striped bass did not. Hybrid striped bass were more likely to move out into the main channel during high flow. Habitats associated with dams seasonally provide some of the best angling opportunities for both taxa. However, during winter for hybrid striped bass and summer for sauger, angling opportunities also exist in a variety of downstream habitats. The lack of interpool exchange, particularly for hybrid striped bass, suggests the potential for pool-by-pool management for these two taxa. Future research needs include timing of pool fidelity development by juvenile hybrid striped bass, detailing specific spawning requirements of sauger in the Ohio River, and describing habitat overlap by congeneric *Morone* and *Stizostedion* fishes.

420. Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell and C. E. Cushing (1980). The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences. **37**:130-137.

From headwaters to mouth, the physical variables within a river system present a continuous gradient of physical conditions. This gradient should elicit a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river. Based on the energy equilibrium theory of fluvial geomorphologists, we hypothesize that the structural and functional characteristics of stream communities are adapted to conform to the most probable position of mean state of the physical system. We reason that producer and consumer communities characteristic of a given river reach become established in harmony with the dynamic physical conditions of the channel. In natural stream systems, biological communities can be characterized as forming a temporal continuum of synchronized species replacements. This continuous replacement functions to distribute the utilization of energy inputs over time. Thus, the biological system moves towards a balance between a tendency for efficient use of energy inputs through resource partitioning (food, substrate, etc.) and an opposing tendency for a uniform rate of energy processing through the year. We theorize that biological communities developed in natural streams assume processing strategies involving minimum loss of energy. Downstream communities are fashioned to capitalize on upstream processing inefficiencies. Both the upstream inefficiency (leakage) and the downstream adjustments seem predictable. We propose that this River

Continuum Concept provides a framework for integrating predictible and observable biological features of lotic systems. Implications of the concept in the areas of structure, function, and stability of riverine ecosystems are discussed.

421. Vaughn, C. C. and C. M. Taylor (1999). Impoundments and the decline of freshwater mussels: A case study of an extinction gradient. Conservation Biology. **13**:912-920.

One major factor leading to the imperilment of freshwater mussels (Bivalvia, Unionidae) has been the large-scale impoundment of rivers. We examined the distribution and abundance of mussels at 37 sites along a 240-km length of the Little River in southeastern Oklahoma, U.S.A., which is affected by both mainstem and tributary reservoirs. We observed a mussel extinction gradient downstream from impoundments in this river: with increasing distance from the mainstem reservoir there was a gradual, linear increase in mussel species richness and abundance. Mussel species distributions were significantly nested, with only sites furthest from the impoundment containing relatively rare species. Below the confluence with the inflow from the second reservoir these same trends were apparent but much weaker, and overall mussel abundance was greatly reduced. Our results suggest that considerable stream lengths are necessary to overcome the effects of impoundment on mussel populations, and such information should be considered in conservation and management plans.

422. Vehanen, T., P. Hyvaerinen and A. Maeki-Petaeys (1998). Downstream fish migration from two regulated lakes monitored by hydroacoustics. Fisheries Management and Ecology. **5**:107-121.

The migration of fish from two large northern Finnish lakes to their outflowing rivers was studied by echosounding and exploratory fishing. Both lakes are regulated for hydroelectric purposes. In both rivers, two sonar stations with stationary up- and down-looking transducers were used to collect data for one year. The fish migration rate in the River Oulujoki was greater than in the River Paatsjoki. In the River Oulujoki, the fish migrated mainly downstream and in the River Paatsjoki both down- and upstream. In the River Paatsjoki, larger fish showed active migration in the spring and autumn, whereas in the River Oulujoki the increase in the migration occurred simultaneously in all size groups. The different species composition and the different nature of the lakes, together with the different regulation practices, were considered to be responsible for the varying migration patterns. It was concluded that no barriers to fish migration should be built on these rivers.

423. Videler, J. (1993). Fish swimming. Chapman & Hall, London (United Kingdom).

The fascinating subject of fish swimming is thoroughly covered in this readable and well illustrated book. Included are details of morphology, hydrodynamics, physiology and evolution.

424. Videler, J. J., U. K. Mueller and E. J. Stamhuis (1999). Aquatic vertebrate locomotion: wakes from body waves. Journal of Experimental Biology. **202**:3423-3430.

Vertebrates swimming with undulations of the body and tail have inflection points where the curvature of the body changes from concave to convex or vice versa.

These inflection points travel down the body at the speed of the running wave of bending. In movements with increasing amplitudes, the body rotates around the inflection points, inducing semicircular flows in the adjacent water on both sides of the body that together form proto-vortices. Like the inflection points, the proto-vortices travel towards the end of the tail. In the experiments described here, the phase relationship between the tailbeat cycle and the inflection point cycle can be used as a first approximation of the phase between the proto-vortex and the tailbeat cycle. Proto-vortices are shed at the tail as body vortices at roughly the same time as the inflection points reach the tail tip. Thus, the phase between proto-vortex shedding and tailbeat cycle determines the interaction between body and tail vortices, which are shed when the tail changes direction. The shape of the body wave is under the control of the fish and determines the position of vortex shedding relative to the mean path of motion. This, in turn, determines whether and how the body vortex interacts with the tail vortex. The shape of the wake and the contribution of the body to thrust depend on this interaction between body vortex and tail vortex. So far, we have been able to describe two types of wake. One has two vortices per tailbeat where each vortex consists of a tail vortex enhanced by a body vortex. A second, more variable, type of wake has four vortices per tailbeat: two tail vortices and two body vortices shed from the tail tip while it is moving from one extreme position to the next. The function of the second type is still enigmatic.

425. Videler, J. J. and B. A. Nolet (1990). Costs of swimming measured at optimum speed: Scale effects, differences between swimming styles, taxonomic groups and submerged and surface swimming. Comparative Biochemistry and Physiology, A. **97A**:91-99.

Data on swimming energy expenditure of 30 submerged and nine surface swimmers, covering different swimming styles and taxonomic groups, are selected from the literature. The costs of transport at the optimum speed are compared and related to body mass and Re numbers. Fish and turtles use relatively less and most surface swimmers slightly more energy than the other submerged swimmers; man and mink are poorly adapted to swimming. The metabolic rate in W at optimum is approximately equal to the body mass in kg for fish and turtles and three times the mass figure for the other submerged swimmers.

426. Videler, J. J. and D. Weihs (1982). Energetic advantages of burst-and-coast swimming of fish at high speeds. Journal of Experimental Biology. **97**:169-178.

A theoretical model describes how an intermittent swimming style can be energetically advantageous over continuous swimming at high average velocities. Kinematic data are collected from high-speed cine pictures of free swimming cod and saithe at high velocities in a burst-and-coast style. These data suggest that fish make use of the advantages shown by choosing initial and final burst velocities close to predicted optimal values. The limiting role of rapid glycogen depletion in fast white anaerobic muscle fibres is discussed.

427. Von Oettingen, S. and D. Mignogno (1997). National strategy for the conservation of native freshwater mussels. Journal of Shellfish Research. **16**:327.

The continental United States contains the world's greatest diversity of freshwater pearly mussels, nearly 300 species. This faunal group has been characterized as 6 percent extinct, 19 percent threatened or endangered, and 23 percent as potentially

warranting federal protection. No other widespread group of animals in North America approaches this level of faunal collapse. At an April 1995 meeting of representatives from several federal and state natural resources agencies and the commercial mussel industry, the magnitude and the immediacy of threats, nationwide, to our native freshwater mussel fauna was recognized. The group agreed that a coordinated effort of national scope was needed to prevent further mussel extinctions and population losses. To address these needs, the group decided to: 1) draft a national strategy for the conservation of native freshwater mussels; and 2) establish a national ad hoc committee with broad based representation from state, tribal and federal agencies, the mussel industry, private conservation groups, and the academic community to help implement mussel conservation at the national level. A draft national strategy was presented in October 1995 at a national mussel symposium in St. Louis, Missouri. I will discuss the strategy and the results of the first ad hoc committee meeting scheduled for February 1997.

428. Waidbacher, H. G. and G. Haidvogl (1998). Fish migration and fish passage facilities in the Danube: past and present. Pages 85-98 *in* M. Jungwirth, S. Schmultz and S. Weiss, eds. Fish Migration and Fish Bypasses, Fishing News Books, Vienna (Austria).

The Danube River flows 2850 km from its source in Germany to the Black Sea and historically contained no barriers to fish migration. Three species of diadromous sturgeon (*Huso huso, Acipenser gueldenstaedtii, Acipenser stellatus*) historically migrated from the Black Sea to the upper reaches of the Danube in Austria and Germany to spawn. However, beginning in the Middle Ages, fishing weirs were used to harvest sturgeon, sometimes blocking the entire river channel. Populations of upriver sturgeon were thus decimated long before permanent barriers to migration were constructed. Since the early 1970s, a hydropower facility at the Iron Gate in Romania (river km 931) has limited sturgeon to the lower river. Diadromous shad species (Pontic shad *Alosa pontica* and Caspian shad *Alosa caspia spp*.) also underwent historic migrations up into Hungary but were most abundant below the Iron Gate and thus still exist in some abundance. The middle and upper reaches of the main Danube channel were free of permanent migration barriers until 1927 when the Kachlet power plant was constructed; a fish ladder there demonstrated substantial movements of nase *Chondrostoma nasus* and barbel *Barbus barbus* as well as other species. This fishway, however, was the last built in the main channel for over 60 years, although within this time 29 power plants were constructed between Ulm, Germany and Vienna, Austria. Recently, two bypass systems have been built on the main channel of the Danube (Freudenau in Austria and Vohburg in Germany). The conservation of the rich Danubian ichthyofauna will largely depend on efforts to open up both the longitudinal and lateral connectivity of this alluvial river system.

429. Waldman, J. R. (1995). Sturgeons and paddlefishes: A convergence of biology, politics, and greed. Fisheries. **20**:20-21.

The International Conference on Sturgeon Biodiversity and Conservation, held July 1994 in New York City at the American Museum of Natural History, brought together almost 200 of the world's experts on these fishes. This two-day immersion in the status of Acipenseriformes left participants feeling cautiously hopeful about the future of North American sturgeons and paddlefish but also deeply pessimistic about the prospects for most of the Eurasian species. In the United States, interest appears high in conserving sturgeons and paddlefish, and each species is receiving federal protection or intensified

state management. Most worrisome is the status of the extremely rare Alabama sturgeon *Scaphirhynchus suttkusi*, which only occurs in the Mobile River system. Also of concern is the scarce pallid sturgeon, which shows strong morphological indication of introgression with the shovelnose sturgeon *Scaphirhynchus platorynchus*, possibly due to habitat modifications in their native Mississippi River system. The situation in Europe and Asia is far more grim. European sea sturgeon *Acipenser sturio* once ranged widely along coastal Europe and Scandinavia; today, only marginal populations exist in the Gironde River, France, and possibly the Black Sea. Beluga *Huso huso*, which occurred in many of the major rivers and seas of eastern Europe and Russia, now has limited natural reproduction. Only a few adults of the Chinese paddlefish *Psephurus gladius* have been seen annually in the Yangtze River in recent years. Dabry's sturgeon *Acipenser dabryanus*, also limited to the Yangtze River; the Adriatic sturgeon *Acipenser naccarii*; and the Amu-Dar shovelnose sturgeon *Psuedoscaphirhynchus kaufmanni* of the Amu-Darya River are all in sharp decline or near extinction.

430. Waller, D. L. and L. E. Holland-Bartels (1988). Fish hosts for glochidia of the endangered freshwater mussel *Lampsilis higginsi* Lea (Bivalvia: Unionidae). Malacological Review. **21**:119-122.

Laboratory tests of nine species of fish as hosts for glochidia of *Lampsilis higginsi* Lea indicated that four species were fully suitable: largemouth bass *Micropterus salmoides* Lacepede, smallmouth bass *M. dolomieui* Lacepede, walleye *Stizostedion vitreum vitreum* Mitchill, and yellow perch *Perca flavescens* Mitchill. Juvenile *L. higginsi* also developed on green sunfish *Lepomis cyanellus* Rafinesque but some fish sloughed their infections prematurely.

431. Waller, D. R. (1988). Studies on *Lampsilis* mussels of the Upper Mississippi River. Ph.D. Dissertation. Iowa State University210 pp.

The glochidial stage of the endangered freshwater mussel, *Lampsilis higginsi*, and several related species was studied to provide information on their early life histories. The glochidia of *L. higginsi* and the three species, *L. radiata siliquoidea*, *L. ventricosa*, and *Ligumia recta*, were compared using morphometrics and scanning electron microscopy (SEM). The glochidia of *L. higginsi* were morphometrically similar to those of the related species; however, they could be distinguished using SEM by the position of the hinge ligament and the dorsal ridge width. Fifteen species of fishes were tested for their suitability as hosts for the glochidia of *L. higginsi*. The following were found to produce at least one juvenile mussel: northern pike *Esox lucius*, brook stickleback *Culea inconstans*, bluegill *Lepomis macrochirus*, green sunfish *L. cyanellus*, largemouth bass *Micropterus salmoides*, smallmouth bass *M. dolomieui*, yellow perch *Perca flavescens*, and walleye *Sitzostedion vitreum vitreum*. A test of host quality using three members of the Family Centrarchidae ranked smallmouth bass highest with a transformation of 7.68%, followed by green sunfish (2.43%) and bluegill (0.00038%). Two propagation methods for juvenile Lampsilis mussels were tested. *In vitro* culture averaged 1.28 juveniles/plate, with a transformation of 1.05%. Transformation averaged 15-24 juveniles/fish on infected host fish. The pathogenesis associated with *L. radiata siliquoidea* on a suitable (walleye) and an unsuitable host (common carp) was compared using light and transmission electron microscopy. Encapsulation of glochidia on walleye gills was completed by 4-6 hr at 21 ^{O}C. At 24-48 hr, the capsule was thin and compact. Fibrous tissue appeared in the capsule at 48 hr and increased in quantity to the end of the infection. Excystment occurred by thinning of the capsule aided by movement of the

juvenile. Most of the glochidia attached to the common carp gills did not encapsulate. Partial capsular growth was evident in some, but the portions of the capsule distal to the bite consisted of necrotic cells and debris. A few complete capsules were found at 12-48 hr; however, all glochidia were sloughed by 60 hr. There was no evidence of leucocytosis; however, the number of heterophil type cells was greater in the capsular tissue of the common carp than in walleye.

432. Ward, J. V. (1989). The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society. **8**:2-8.

The dynamic and hierarchical nature of lotic ecosystems may be conceptualized in a four-dimensional framework. Upstream-downstream interactions constitute the longitudinal dimension. The lateral dimension includes interactions between the channel and riparian/floodplain systems. Significant interactions also occur between the channel and contiguous groundwater, the vertical dimension. The fourth dimension, time, provides the temporal scale. Lotic ecosystems have developed in response to dynamic patterns and processes occurring along these four dimensions. An holistic approach that employs a spatio-temporal framework, and that perceives disturbances as forces disrupting major interactive pathways, should lead to a more complete understanding of the dynamic and hierarchical structure of natural and altered lotic ecosystems.

433. Ward, J. V. and J. A. Stanford (1995). The serial discontinuity concept: Extending the model to floodplain rivers. Regulated Rivers: Research and Management. **10**:159-168.

The serial discontinuity concept (SDC) was developed as a theoretical construct that views impoundments as major disruptions of longitudinal resource gradients along river courses. According to the SDC, dams result in upstream-downstream shifts in biotic and abiotic patterns and processes; the direction and extent of the displacement depend on the variable of interest and are a function of dam position along the river continuum. As originally formulated, the SDC did not consider interactions between the river and its floodplain. The new perspective presented herein is an initial attempt to encompass the dynamics of alluvial flood plain rivers into the model using a three reach characterization: constrained headwater reach, braided reach and meandering reach. The constrained headwater reach has conditions similar to those described in the original SDC, but the braided and meandering reaches provide a perspective that was not addressed in the model. Lateral interactions between the channel and the flood are critical to a holistic understanding of natural river ecosystems and the alterations induced by regulation. The fringing floodplain, with its diverse water bodies and alluvial forest mosaic, is considered an integral part of the river system.

434. Wardle, C. S., J. J. Videler and J. D. Altringham (1995). Tuning in to fish swimming waves: Body form, swimming mode and muscle function. Journal of Experimental Biology. **198**:1629-1636.

Most fish species swim with lateral body undulations running from head to tail. These waves run more slowly than the waves of muscle activation causing them, reflecting the effect of the interaction between the fish's body and the reactive forces from the water. The coupling between both waves depends on the lateral body shape and on the mechanical properties of the tail. During steady swimming, the length of each myotomal muscle fibre varies cyclically. The phase relationship between the strain

(muscle length change) cycle and the active period (when force is generated) determines the work output of the muscle. The muscle power is converted to thrust either directly by the bending body or almost exclusively by the tail, depending upon the body shape of the species and the swimming kinematics. We have compared the kinematics and muscle activity patterns from seven species of fish with different body forms and swimming modes and propose a model which yields a consistent pattern, with at least three extremes. Subtle tuning of the phase relationship between muscle strain and activation cycles can lead to major changes in the way muscles function in different swimming modes.

435. Warren, M. L. and M. B. Brooks (1994). Status of freshwater fishes of the United States. Fisheries. **19**:6-18.

Conservation biologists have begun a concerted effort to educate the public, resource administrators, and politicains about the decline of temperate ecosystems, including their fishes. The United States harbors the most diverse temperate fish fauna in the world with about 790 species represented, about 90% of which are nongame fishes. From a state-by-state perspective, diversity of fishes in the United States is concentrated in the South, primarily in Alabama, Kentucky, Georgia, Mississippi, Tennessee, and Virginia, each of which supports at least 200 native fish species. Endemicity of fishes is high in both the South and West; in the latter region, up to 70% of the fishes in some drainages (e.g., Colorado River) are endemic. Imperilment apparently is not confined to particular taxonomic groups. Of the five most diverse fish families in the United States, total imperilment ranges from 7% in the Centrarchidae to 50% in nonanadromous salmonids and indicates widespread and pervasive degradation of aquatic habitats. Imperilment is most accute in areas of high diversity and / or endemicity (i.e., the southern and western states). States with 20 or more imperiled fishes include Alabama, Arizona, California, Georgia, Nevada, New Mexico, North Carolina, Oregon, Virginia, Tennessee, and Texas. Backlogs in listing species as federally threatened or endangered are most egregious (10 or more backlogged taxa) in Alabama, Georgia, Nevada, and Tennessee.

436. Watters, G. T. (1992). Unionids, fishes, and the species-area curve. Journal of Biogeography. **19**:481-490.

The number of fish species in thirty-seven systems of the Ohio River may be predicted by the area of the drainage basin. On a large river system scale, the number of unionid species is directly related to the number of fish species present and, to a lesser extent, the drainage area. In small systems, such as headwater tributaries, the number of unionid species is related to the drainage basin area. Unionid diversity in systems intermediate in size may be related to both. This may be the result of transient fishes in small streams depositing glochidia. The overall distribution and diversity of unionids within the study area is dependent upon the distribution and diversity of their fish hosts.

437. Watters, G. T. (1994). An annotated bibliography of the reproduction and propogation of the Unionidea (primarily of North America). Ohio Biological Survey, Miscellaneous Contribution 1.

Citations for the published literature on unionoidean reproduction and propogation are presented in chronological order, beginning with 1695 and continuing

through December 1993. Each citation is briefly annotated, and cross-indexed according to its relevance to freshwater mussel culture, transplantation, ecology, development, parasites, and host relationships. Recorded hosts for unionoideans are cross indexed by mussel species and fish species. Appendix A gives literature records of suspected or proven hosts for unionoideans. Appendix B lists unionoidean parasites for each host, as well as unspecified glochidia found on hosts. The chronological bibliography of the main text is ordered alphabetically by author in Appendix C, and categorized by topic. Topics emphasized include culturing and transplanting unionoideans, identifying unionoidean hosts and parasites, unionoidean development, and unionoidean ecology.

438. Watters, G. T. (1996). Small dams as barriers to freshwater mussels (Bivalvia, Unionoida) and their hosts. Biological Conservation. **75**:79-85.

The distributions of two unionoids (fragile papershell *Leptodea fragilis* and pink heelsplitter *Potamilus alatus*) were examined in five North American Midwest river systems in relation to the location of dams on the rivers. These dams were non-navigational (without locks), lacked fish ladders, and varied in height from 1 to 17.7 m. Both species were restricted in their distribution to the river downstream of the dams. This suggests that the host fish(es) of these species was unable to move upstream of these obstacles. Both unionoids are believed to parasitize the freshwater drum *Aplodinotus grunniens*. Several endangered unionoid species also may use this fish, or other dam-limited fishes, as hosts. Dams, even lowhead structures, may contribute to the overall depletion of unionoids by artificially restricting their distributions and isolating populations from each other. Management practices for endangered fishes and mussels must take into account these physical obstacles.

439. Watters, G. T. and S. H. O'Dee (1999). Glochidia of the freshwater mussel *Lampsilis* overwintering on fish hosts. Journal of Molluscan Studies. **65**:453-459.

Largemouth bass were infected with glochidia of the freshwater mussel *Lampsilis cardium*. Three fishes each were held at 4.5, 10, and 15.5 ^{o}C; five fish were held at 21 ^{o}C. By 64 days, metamorphosed juveniles were found in the 15.5 and 21 ^{o}C trials but not in the 5.5 and 10 ^{o}C trials, indicating that the lower threshold temperature for metamorphosis was between 10 and 15.5 ^{o}C for the duration. In a second experiment, largemouth bass were infected with glochidia of *L. cardium* and held at 10 ^{o}C. A sample of fishes was removed monthly and brought to 21 ^{o}C. Numbers of glochidia that metamorphosed after being warmed were compared to the number that metamorphosed without warming. The percentage that metamorphosed after warming decreased linearly with time. At one month, 100% of the glochidia metamorphosed after warming. This decreased to 80% by two months, to 30% by four months and 3% by six months. Although this post-warming percentage decreased with time, the total percentage of metamorphosed juveniles (at all temperatures) was not correlated with time. Controls kept at 21 ^{o}C required three weeks to reach peak metamorphosis, but test subjects subjected to 10 ^{o}C required less than nine days to metamorphose once warmed. Many overwintering glochidia therefore complete a portion of their development on the host at winter temperatures, but stop short of excystment. Some glochidia metamorphosed without being warmed, but this phenomenon is not understood. This study confirms that glochidia may overwinter on hosts, with some glochidia persisting for more than six months before metamorphosing when warmer conditions return.

440. Webb, P. W. (1983). Speed, acceleration and manoeuvrability of two teleost fishes. Journal of Experimental Biology. **102**:115-122.

Speed, acceleration rate and turning radius were measured for rainbow trout (*Salmo gairdneri*; length 25 multiplied by 7 cm) and smallmouth bass (*Micropterus dolomieu* ; length 23 multiplied by 6 cm) attacking live minnows. The observations sampled a range of values for each kinematic variable up to the limits of maximum performance. Minimum turning radius was independent of speed and acceleration rate. Expressed as a ratio of total length, L, minimum radii were 0 multiplied by 18 plus or minus 0 multiplied by 2 L for trout and 0 multiplied by 11 plus or minus 0 multiplied by 02 L for bass ($\bar{X}$) plus or minus 2 S.E.). Differences in minimum turning radius, R, between trout and bass were attributed to differences in the volume of the body and entrained water, V, and projected lateral surface area of the body and median fins, A. For subcarangiform swimmers, the dimensionless minimum specific turning radius R/L = 2V/AL.

441. Webb, P. W. (1986). Kinematics of lake sturgeon, *Acipenser fulvescens*, at cruising speeds. Cannadian Journal of Zoology. **64**:2137-2141.

Lake sturgeon *Acipenser fulvescens*, 15.7 cm in total length, have a 2-min critical swimming speed of 38.6 plus or minus 4.2 cm multiplied by s^{-1} (2.45 body lengths multiplied by s^{-1}) at 15 ^{o}C. Tail beat frequency (f, Hz), amplitude (a, cm), and propulsive wavelength (lambda , cm) increased linearly with swimming speed (U, cm multiplied by s^{-1}), according to the following equations: f = 1.67 + 0.07U, a = 3.2 + 0.020U, and lambda = 11.0 + 0.039U. Tail depth and the cosine of the angle of the tail with the axis of motion were independent of swimming speed with mean values of 1.98 plus or minus 0.08 cm and 0.7 plus or minus 0.08, respectively. Swimming kinematics were generally similar to those of teleosts and anuran implying that body and caudal fin propulsive movements are conservative among actinopterygians and tetrapods.

442. Webb, P. W. (1993). Swimming. Pages 47-74 *in* D. H. Evans, ed. The Physiology of Fishes, CRC Press, Boca Raton, Florida (USA).

By definition, fish swim, but "swimming" is a loose term for a wide and complex set of adaptive movements whereby fish perform the numerous activities necessary to survive in diverse habitats. As a result, physiological studies pertinent to swimming are legion, necessitating discussion of only a few selected topics in this chapter, which focuses on the nature and properties of the propulsion system. This is comprised of a propulsor that transfers momentum from the fish to the water, thereby generating thrust, and the muscles that drive those propulsors. Neural control systems are not discussed. Swimming energetics are discussed because driving the propulsors is a major expense affecting design criteria for many other physiological systems as well as the impact of fish on their ecological resource base. In addition, the amount of energy available for swimming is often constrained by environmental factors. Scale effects are omitted.

443. Webb, P. W. and V. De Buffrenil (1990). Locomotion in the biology of large aquatic vertebrates. Transactions of the American Fisheries Society. **119**:629-641.

As aquatic vertebrates increase in size, hydrofoils, which use lift to generate thrust, are increasingly used as propulsors. One factor affecting the magnitude of the lift

force is the area of the propulsor. Resistance to cruising and sprints is mainly due to drag, but inertia is important during maneuvers when animals accelerate or turn. The inertia of the body and entrained water, which is proportional to body volume, resists acceleration. Because a thrust that is proportional to surface area is used to maneuver a resistance that is proportional to volume, acceleration performance and maneuverability are expected to decline with increasing size. This trend is ameliorated to some extent by the high swimming speeds attainable by warm-bodied vertebrates and the reduced resistance to acceleration characteristic of the skeletons of dolphins and ichthyosaurs. Maneuvers are essential for capture of elusive prey and avoidance of predators. As they increase in size, aquatic vertebrates use various means to ensure that their prey are less maneuverable than they.

444. Webb, P. W., D. H. Hardy and V. L. Mehl (1992). The effect of armored skin on the swimming of longnose gar, *Lepisosteus osseus*. Canadian Journal of Zoology. **70**:1173-1179.

Fast-starts and steady swimming were compared for two piscivorous fishes, the longnose gar *Lepisosteus osseus*, which has an integument armored with ganoid scales, and the unarmored tiger musky *Esox sp*.. The body was similarly flexed by both species during fast-starts and steady swimming. Therefore, the heavy integument of the gar did not affect flexibility during swimming. Distance traveled in a given elapsed time during fast-starts was lower for the gar, which averaged 65% of the work done by the musky. On the basis of differences in muscle mass, gars would be expected to perform 72% of the work of muskies during a fast-start. The heavier integument of the gar was estimated to contribute about 90% to the reduced fast-start performance. In steady swimming, mechanical power requirements at a given speed were similar for both gar and musky. Therefore, steady swimming costs do not appear to be affected by armor. The critical swimming speed of gars was 1.9 body lengths/s compared with 3.4 body lengths/s for muskies, but the difference could not be attributed to differences in armoring. The slip speed at which gars first began to swim was 1.21 body lengths/s compared with 0.75 body lengths/s for muskies. Higher station-holding performance is probably not important to modern gars and esocids, but may have been advantageous during the early radiation of fishes.

445. Webb, P. W., G. D. LaLiberte and A. J. Schrank (1996). Does body and fin form affect the maneuverability of fish traversing vertical and horizontal slits. Environmental Biology of Fishes. **46**:7-14.

The purpose of this study was to determine if body and fin form affected the maneuverability of teleostean fishes as measured buy their ability to negotiate simple obstacles. Obstacles were vertical and horizontal rectangular slits of different widths, for which width was defined as the minimum dimension of a slit irrespective of slit orientation. Performance was measured as the smallest slit width traversed. Three species with different body and fin patterns were induced to swim through slits. Species tested were: goldfish Carassius auratus with a fusiform body, anterio-ventral pectoral fins and posterio-ventral pelvic fins; silver dollars Metynnis hypsauchen with the same fin configurations but a gibbose body; angelfish Pterophyllum scalare with a gibbose body and anterio-lateral pectoral fins. Minimum slit widths negotiated were normalized with the length of various body dimensions: total length, maximum width, span at the pectoral fins, and volume super(1/3) (numerically equal to mass super(1 /3)). Goldfish had the poorest performance, requiring the largest slit widths relative to these body dimensions.

No consistent patterns in performance were found for silver dollars vs. angelfish. There were no differences among species in the ratio of minimum vertical slit width negotiated to that for horizontal slits, indicating fish were equally able to control posture while swimming on their sides. There were also no consistent patterns in the times taken to transit slits. Although the deep-bodied fish were able to maneuver through smaller slits, the most striking result is the similarity of minimum slit widths traversed in spite of the large variation in body form. Body form and fin plan may be more important for maneuvering and posture control during sub-maximum routine activities.

446. Weihs, D. (1987). Hydromechanics of fish migration in variable environments. Pages 254-261 *in* M. J. Dadswell, R. J. Klauda, C. M. Moffitt, R. L. Saunders, R. A. Rulifson and J. E. Cooper, eds. International Symposium on Common Strategies of Anadromous and Catadromous Fishes, Boston, Massachusetts (USA), American Fisheries Society Symposium Serial.

Migrations of fish species are often very long (in both time and space) and costly in terms of energy. Thus, efficient use of available energy is of great importance and various adaptations of morphology and behavior have resulted. These are especially significant for diadromous species, which encounter large variations in buoyancy, salinity, temperature, and flow conditions during their life cycles, which include large-scale migrations. A mathematical approach to fish migratory adaptations is utilized to analyze observed behavioral patterns and to predict effects of changing environmental pressures. The study is based on the hydrodynamical and mechanical principles of fish locomotion, feeding, and predator-prey interactions. Existing work is reviewed with the goal of identifying areas of future observational and theoretical research applicable to the understanding of the behavioral strategies of these species, many of which are commercially important.

447. Weiss, J. L. and J. B. Layzer (1995). Infestations of glochidia on fishes in the Barren River, Kentucky. American Malacological Bulletin. **11**:153-159.

We collected fish monthly from the Barren River, Kentucky, to assess glochidial infestations. Glochidia were encysted on 4.1% of the 2,510 fish of 43 species examined. Twenty-five fish species in 11 families were infested; 14 of these species are not known to be hosts of any of the 27 mussel species (Unionidae) occurring in the Barren River. Amblemine glochidia occurred on 19 species of fish. Eight species of fish were infested with anodontine glochidia, while lampsiline glochidia occurred on only five species. Differences in the degree of host specificity were striking among the Ambleminae. Glochidia of *Amblema plicata* (Say, 1817) occurred on 12 species of fish, whereas those of *Quadrula pustulosa* (I. Lea, 1831) were found only on channel catfish [*Ictalurus punctatus* (Rafinesque, 1818)]. Overlap in host fishes occurred between the Ambleminae and the other subfamilies, but not between the Anodontinae and Lampsilinae. Potential new hosts are identified for *Lasmigona complanata* (Barnes, 1823), *Lasmigona costata* (Rafinesque, 1820), *Megalonaias nervosa* (Rafinesque, 1820), *A. plicata*, and *Pleurobema spp*.

448. Welcomme, R. L. (1979). Fisheries ecology of floodplain rivers. Longman, London (United Kingdom).

This book assembles information on the general ecology of those rivers that undergo seasonal flooding, and applies it to the special case of fisheries. The author shows how the various activities occurring in river basins can influence the fish communities inhabiting them. The book is divided into six parts, the first of which is a general introduction outlining previous work done in the field. This is followed by a substantial section on the environment, dealing with the physical and chemical composition of rivers and their floodplains. It also summarises data on the living elements of the system other than fish. A section on fish discusses the adaptations they show for life in a fluctuating environment, and examines the effects of seasonal alternations of flood and dry phases on feeding, growth, reproduction, mortality and the general dynamics of the community. The fishery is treated in a fourth section, which considers the specialisation of fishermen and their gear to the river environment. It also reviews the state of exploitation of some of the main rivers of the world, and examines how catch is related to such variables as water regime and fisherman density. The fifth section explores the relationships of the fish community to other activities in the river basin. The concluding chapter discusses the stages through which fish communities and fisheries pass as the environment is altered by basin development.

449. Welcomme, R. L. (1985). River fisheries. FAO, Fisheries Technical Paper 92-5-102299-2.

A summary is presented of the present state of knowledge of the fish and fisheries of river systems, emphasizing the role of a river as a food producer. The following topics are discussed: 1) morphology of river systems: 2) physical and chemical processes; 3) primary production in rivers; 4) secondary production in rivers; 5) river fish and the riverine system; 6) production biology of river fish; 7) the fishery; and 8) management of the river fishery.

450. Welcomme, R. L. (1992). A history of international introductions of inland aquatic species. Pages 3-14 *in* C. Sindermann, B. Steinmetz and W. Hershberger, eds. Introductions and Transfers of Aquatic Species, Halifax, Nova Scotia (Canada), ICES Marine Science Symposia.

A register of 1,673,000 records of introductions of 291 species into 148 countries has been analysed for trends and motives for introductions. Some introductions occurred in historical times, but the rate of movement of species between countries has accelerated since 1900. The majority of introductions have been carried out in support of aquaculture, although sport and improvement of wild fish stocks have also been significant motives. A large number of introductions have occurred through accidental escape or transmission between countries. Most introductions have proved benign in that they have had no detectable influence on native fish communities or have contributed significantly to aquaculture or capture fishery yield. A small proportion of introductions have proved ecologically undesirable, and these have arisen mainly either from species capable of producing stunted populations or from predatory species which have damaged indigenous species.

451. Welcomme, R. L. (1992). [River fisheries]. FAO Fisheries Technical Report, Rome (Italy).

A review is presented on the current state of knowledge on the fish and fisheries of river systems. The following 8 chapters are included: morphology of river system; physical and chemical processes; primary production in rivers; secondary production in rivers; freshwater fish and the river system; productive biology in freshwater fish; the fishery industry; and management of river fisheries.

452. White, D. K. and B. J. Pennino (1980). Connecticut River fishways: model studies. Journal of the Hydraulics Division, American Society of Civil Engineers. **106**:1219-1233.

The fishways at the Vernon and Turners Falls Dams were optimized by use of hydraulic model studies. In both cases, slotted weirs were modified so that a better head loss distribution was obtained. In addition, the diffusers were modified to produce acceptable exit face velocity distributions. At Turners Falls, the fish entrance was modified to produce velocity conditions known to be acceptable to the two migrating species of fish, Atlantic salmon and shad. At Vernon Dam, flow conditions were optimized at the fish exit and attraction water intake. Modeling of these fishways has resulted in design changes that should improve fish passage and minimize water consumption.

453. White, M. M. and S. Schell (1995). An evaluation of the genetic integrity of Ohio River walleye and sauger stocks. Pages 52-60 *in* H. L. Schramm, Jr. and R. G. Piper, eds. International Symposium and Workshop on Uses and Effects of Cultured Fishes in Aquatic Ecosystems, Albuquerque, New Mexico (USA), American Fisheries Society.

An electrophoretic survey of populations of walleye *Stizostedion vitreum* and sauger *S. canadense* from the Ohio River was conducted to determine the patterns of genetic variation, population structuring, and the degree of hybridization between these two species and their stocked F_1 hybrid, the saugeye (female walleye x male sauger). Thirty-six presumptive structural loci were surveyed from the eye, liver, and muscle tissue of 500 sauger from nine locations and 222 walleyes from seven locations. Levels of variation in sauger were low and suggested limited population differentiation along the river. Levels of variation among walleye populations suggested a significant degree of population differentiation; however, no clear pattern of differentiation was observed. Two polymorphisms, not previously observed in walleye populations, are shared with sauger, suggesting past hybridization events or geographically unique alleles. Recombinant genotypes were detected in samples from three Ohio River pools, confirming that hybrid reproduction has occurred. These three pools are consecutively affected by one major river and four smaller watersheds that have received large numbers of stocked saugeyes. If maintaining the genetic integrity of the parental species is a concern, our data strongly suggest that saugeye should not be stocked where self-sustaining parental populations occur.

454. Whitfield, R. E. and D. P. Kolenosky (1978). Prototype eel ladder in the St. Lawrence River. Progressive Fish Culturist. **40**:152-154.

A fishway to accommodate the American eel *Anguilla rostrata* has been constructed at the Moses-Saunders Hydro-Electric Power Dam in the St. Lawrence River at Cornwall, Ontario, Canada. The fishway is 29.3 m high and 156.4 m long, rising at a

12 slope from tailwater level below the dam to headwater level. More than 3 million eels have been passed over the dam during 4 years of operation.

455. Wilcox, D. B. (1986). Fish passage through dams on the Upper Mississippi River. Pages 12 *in* C. E. Korschgen and K. L. Curtis, eds. 18th Annual meeting of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium, Inc.

Adult fish of nine species are known to undergo movements through dams on the Upper Mississippi River (UMR). Design characteristics of UMR navigation dams allow both upstream and downstream fish passage. Upstream fish passage is dependent upon hydraulic conditions at the dam, fish behavior, and swimming performance. Physical hydraulic modeling of current patterns through UMR dam gates and analysis of swimming performance of several UMR fish species indicate that opportunity for upstream fish passage occurs at lock and dam 8 during most water years. Operation of hydropower units at UMR dams may decrease opportunity for upstream fish passage.

456. Wilcox, D. B. and K. W. Willis (1993). Identification of constraints on river regulation. Lock and Dam 9 near Lynxville, Wisconsin, Upper Mississippi River 9-foot channel project. U.S. Army Corps of Engineers, St. Paul District, Special Report EMTC93S012.

The timing, amplitude, frequency, and duration of water level fluctuations and changes in current velocity greatly affect river life. On regulated rivers such as the Mississippi, water level and velocity fluctuations are caused by natural hydrologic events that change river discharge and by operation of water control structures. The Upper Mississippi River System (UMRS) includes the Mississippi River upstream of the mouth of the Ohio River at Cairo, Illinois, to Minneapolis, Minnesota; the Illinois River; and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. River regulation greatly influences habitat conditions in the river. Changes to the present system of river regulation could improve habitat conditions and ecological productivity of the UMRS. Any modifications to the existing regulation plans must be compatible with constraints on operation. The purpose of the report is to identify the constraints on regulation of Lock and Dam 9 in the Upper Mississippi River 9-foot channel navigation system.

457. Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris and R. J. Neves (1993). Conservation status of freshwater mussels of the United States and Canada. Fisheries. **18**:6-22.

The American Fisheries Society (AFS) herein provides a list of all native freshwater mussels (families Margaritiferidae and Unionidae) in the United States and Canada. This report also provides state and provincial distributions; a comprehensive review of the conservation status of all taxa; and references on biology, conservation, and distribution of freshwater mussels. The list includes 297 native freshwater mussels, of which 213 taxa (71.7%) are considered endangered, threatened, or of special concern. Twenty-one taxa (7.1%) are listed as endangered but possibly extinct, 77 (20.6%) as endangered but extant, 43 (14.5%) as threatened, 72 (24.2%) as of special concern, 14 (4.7%) as undetermined, and only 70 (23.6%) as currently stable. The primary reasons for the decline of freshwater mussels are habitat destruction from dams, channel modification, siltation, and the introduction of nonindigenous mollusks. The high

numbers of imperiled freshwater mussels in the United States and Canada, which harbor the most diverse fauna in the world, portend a trajectory toward an extinction crisis that, if unchecked, will severely impoverish one of our richest components of aquatic biodiversity.

458. Williams, J. E. and R. R. Miller (1990). Conservation status of the North American fish fauna in freshwater. Journal of Fish Biology. **37**:79-85.

The status of the North American fish fauna includes 292 species of fishes in the categories of endangered, vulnerable, rare, indeterminate, and extinct. This constitutes 28% of the known fauna. The status of fishes and their habitats continues to decline, especially in the arid regions of western U.S.A. and northern Mexico. The Endangered Species Act is the most powerful tool currently available to protect rare fishes. While many fishes probably have been saved from extinction by this act, surprisingly few have improved enough to be removed from under its protection.

459. Willson, M. F., S. M. Gende and B. H. Marston (1998). Fishes and the forest. Bioscience. **48**:455-462.

In this article, we argue that anadromous and inshore-spawning marine fish provide a rich, seasonal food resource that directly affects the biology of both aquatic and terrestrial consumers and indirectly affects the entire food web that knits the water and land together. In addition, we suggest that the presence of a seasonally abundant food resource has helped to shape the evolution of aquatic and terrestrial consumers and that predators have probably exerted reciprocal evolutionary pressures on their prey, potentially influencing the life history and morphology of these fishes. Finally, we suggest that anadromous and inshore-spawning fishes constitute such an important prey base for terrestrial wildlife that conventional ecological and management dogmas need to be revised. Interactions between anadromous fishes and wildlife have been recognized as having some general ecological importance, but only recently have the ramifications of these interactions and their potential magnitude begun to be explored. Because many of the nuts and bolts of the ecological links still need to be described and quantified, we concentrate on sketching an outline of the interactions, documenting the effects where possible but also noting effects that seem probable, subject to future research.

460. Winemiller, K. O. and K. A. Rose (1992). Patterns of life-history diversification in North American fishes: Implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences. **49**:2196-2218.

Interspecific patterns of fish life histories were evaluated in relation to several theoretical models of life-history evolution. Data were gathered for 216 North American fish species (57 families) to explore relationships among variables and to ordinate species. Multivariate tests, performed on freshwater, marine, and combined data matrices, repeatedly identified a gradient associating later-maturing fishes with higher fecundity, small eggs, and few bouts of reproduction during a short spawning season and the opposite suite of traits with small fishes. A second strong gradient indicated positive associations between parental care, egg size, and extended breeding seasons. Phylogeny affected each variable, and some higher taxonomic groupings were associated with particular life-history strategies.

461. Winston, M. R., C. M. Taylor and J. Pigg (1991). Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society. **120**:98-105.

A spatially intensive survey in 1989 of 52 sites in the Red River drainage in southwest Oklahoma and surveys in all years from 1978 to 1987 on four sites in the drainage provided evidence that construction of Altus Dam on the North Fork of the Red River caused changes in fish community structure in the river above the dam. Twenty-five species were collected in the North Fork above Altus Dam, compared to 33 in the Salt Fork and 34 in the North Fork below the dam. The speckled chub *Macrhybopsis* (formerly *Hybopsis*) *aestivalis* and the chub shiner *Notropis potteri* were absent in the North Fork above Altus Dam but fairly common in similar streams elsewhere in the area. The plains minnow *Hybognathus placitus* and the Red River shiner *Notropis bairdi* were among the most common fish species found in southwest Oklahoma, but were not collected above Altus Dam in the 1989 survey and were collected only intermittently and in small numbers in the long-term survey.

462. Wirgin, II, J. E. Stabile and J. R. Waldman (1997). Molecular analysis in the conservation of sturgeons and paddlefish. Environmental Biology of Fishes. **48**:385-398.

Sturgeon and paddlefish populations worldwide have declined because of anthropogenic influences. The structure and magnitude of genetic diversity of natural populations serves to buffer these fishes against environmental variation and should be maintained. Modern molecular biological techniques provide the ability to sensitively characterize and quantify the extent of genetic variation in natural populations. We provide a summary of those problems in sturgeon population biology that are amenable to investigation with DNA approaches, and their applications to date. These have included genetic identification and discrimination of taxa, identification of hybrids, stock identification, mixed-stock analysis, and estimation of gene flow and homing fidelity. To date, almost all studies have been restricted to North America fauna. Improvements to these technologies, including nondestructive sampling, should permit more widespread application of molecular approaches to problems of acipenserform conservation. We suggest that the use of more sensitive molecular tools such as analyses of hypervariable repetitive and non-coding single copy nuclear DNA may assist management even in those taxa which exhibit overall low levels of genetic diversity.

463. Witherell, D. B. and B. Kynard (1990). Vertical distribution of adult American shad in the Connecticut River. Transactions of the American Fisheries Society. **119**:151-155.

Adult American shad *Alosa sapidissima* were sampled with vertical gill nets during the 1986 and 1987 spawning and postspawning migrations in the Connecticut River. Most (83%) were caught in the lower half of the water column, but not on the river bottom. The vertical distributions of gravid and spent fish were similar for both males and females. American shad showed no diel, seasonal, or yearly changes in depth distributions. Larger gravid fish swam deeper in the water column than did smaller gravid fish.

464. Wlosinski, J. H. and L. Hill (1995). Analysis of water level management on the Upper Mississippi River (1980-1990). Regulated Rivers: Research and Management. **11**:239-248.

Management at 27 low-head dams affects water surface elevations for a 1050 km stretch of the Upper Mississippi River (UMR) between St Louis, Missouri and Minneapolis, Minnesota. A systemic overview is given of current operating plans at dams on the UMR and historical data are analysed to determine how well the operating plans are being met. Water level elevations at all 27 dams are regulated as a function of discharge, although plans are specific for each dam. The management objective is to maintain a target water level at specific locations (control point) in each impoundment over specific ranges of discharge. The target water level and control point may change as discharge changes in each impoundment. In some of the impoundments water regulation causes drawdowns below the elevation for which the dams were planned, and at other dams no drawdown occurs. During the navigation seasons of 1980 to 1990, water levels were within their target window for an average of 72.5% of the time for 25 dams analysed. Difficulties in meeting targets are caused by winds, local rainfall events, ice dams and rapidly fluctuating discharges from tributaries with upstream reservoirs used for peaking hydropower.

465. Woody, C. A. and L. E. Holland-Bartels (1993). Reproductive characteristics of a population of the washboard mussel *Megalonaias nervosa* (Rafinesque 1820) in the Upper Mississippi River. Journal of Freshwater Ecology. **8**:57-66.

We examined monthly and age-specific gametogenic development of the washboard mussel, *Megalonaias nervosa*, from April 1986 to March 1987 in navigation Pool 10 of the Upper Mississippi River. We found *M. nervosa* to be a late tachytictic breeder. Female marsupia contained eggs or glochidia primarily from August (17 ^{o}C) through October (9 ^{o}C). Males were mature from July through October. Most females released their glochidia in October. Only one female was gravid in November (3 ^{o}C). Most mussels were mature at 8 years of age and then had an estimated average size of 68mm (shell height). Only 8% of the individuals <= 4 years of age showed any degree of reproductive development, while > 90% of age 5 and older individuals had recognizable reproductive material present. In host specificity studies, we verified three species of fish as hosts for the glochidia stage. Green sunfish *Lepomis cyanellus*, black bullhead *Ictalurus melas*, and channel catfish *Ictalurus punctatus* produced juveniles after 26-28 days at 17 ^{o}C. White suckers *Catostomus commersoni* and yellow perch *Perca flavescens* retained glochidia from 23 up to 26 days, but no juveniles were produced. Glochidia remained attached to common carp Cyprinus carpio and fathead minnows Pimephales promelas <= 3 days. Channel catfish were retested at 12 ^{o}C and produced juveniles after 56 days.

466. Wu, S. and N. Rajaratnam (1995). Effect of baffles on submerged flows. Journal of Hydraulic Engineering. **121**:644-652.

This paper introduces the concept of a submerged hydraulic jump being used for energy dissipation. A baffle wall is used to produce a stable deflected surface jet, thereby deflecting the high-velocity supercritical stream away from the bed to the surface. Based on a series of experiments, a diagram was developed that predicts the conditions under which such a surface jet would be produced. A second series of experiments were performed to study the characteristics of the deflected jet, as it travels upward first as a

curved turbulent jet to eventually become a turbulent surface jet. The decay of the maximum velocity in the deflected as well as the surface jet was studied and compared with that of a plane turbulent wall jet that is a model for deeply submerged jumps.

467. Wu, S., N. Rajaratnam and C. Katopodis (1999). Structure of flow in vertical slot fishway. Journal of Hydraulic Engineering. **125**:351-360.

This paper presents the results of an experimental study on the structure of flow in a vertical slot fishway of an effective and simple design. The flow at the slot could be treated as a plane jet, but there are a number of differences from the plane jet. It was found that for a slope of 5%, the main flow travels from one slot to the next through the pool as a 2D curved jet with two recirculation regions - one on each side. For slopes of 10 and 20%, the main flow is 3D. Water flows toward the side wall between the long baffles near the bed and piles up along the sidewall; part of the flow rises to the surface and then travels to the outlet. The decay of longitudinal velocity in the pool is much larger than that of the plane jet. The volume averaged velocity head of the water in the pool was found to be similar to 12% of Delta h, the head drop per pool. The volume of the recirculation region between the short baffles was similar to 28% of the volume of the pool for all three slopes and all discharges whereas the corresponding volume of the horizontal eddy just downstream of the long baffles for the two larger slopes was similar to 10%. The relative volume of the two recirculation regions was similar to 73% for the 5% slope and similar to 38% for the 10 and 20% slopes.

468. Ylinaerae, T. (1991). Measuring the velocity of water at fish ladders. Vesitalous. **32**:31-34.

A more versatile apparatus than the propeller current meter has been tested for measuring water velocity in the course of research into the swimming behaviour of migratory fish. A multidimensional rather than a unidimensional device was needed for continuous recordings. The new apparatus is a two-channel electromagnetic Marsh-McBirney M511 water velocity meter. The recorded analog signal is processed with a personal computer and Data Translation's DT 2801-A data acquisition board. The software is Asystant+, which is a menu-run scientific program for data acquisition, analysis and graphics.

469. Zerrath, H. (1996). Burst-swimming performance of native small and young fish species in slope-models -- dates for valueing fishways. Fischokologie. 27-48.

In a variant of a slope model with an inclination of 1:20 which had inserted lines of stakes the swimming behaviour of the following fish species (all between 3,3 and 10,5 cm in length) was investigated: three-spined-stickleback (*Gasterosteus aculeatus*), pearch (*Perca fluviatilis*), carp (*Cyprinus carpio*), roach (*Rutilus rutilus*), chub (*Leuciscus cephalus*) and gudgeon (*Gobio gobio*). The swimming behaviour of tree-spined-stickleback and chub was additionally investigated in two more variants with other hydraulic conditions. By putting high numbers into the testing arrangement it was succeded, expect with the pearch, to cause the burst swimming of the test animals and to analyse it by videotape records. The average burst speed is for all investigated species near 15 BL/s, the average burst time is about 5 seconds. Maximum values of more than 30 BL/s were noticed for nearly all species. The swimming achievement of sticklebacks was almost equal in each of the three investigated variants. Chubs showed a swimming

achievement adapted to the hydraulic conditions, depending on their body length. The aspects for water constructing and fishways are discussed: For the critical area of fishways streaming velocities of 80 cm/s should not be gone beyond, and should be restricted to distances under 50 cm. In other areas the critical streaming velocity of local small fish species of 40 cm/s should not gone beyond.

470. Zhao, X. and Z. Han (1980). Experiments on the current overcoming ability of some freshwater fishes. Journal of the Fishes of China. **4**:31-37.

The ability of fish to overcome currents should be the first consideration in designing the inlet of a fishway according to the authors. A series of experiments were conducted in the flume of a hydraulic laboratory. Various kinds of fishes were selected for the experiments, such as common carp *Cyprinus carpio*; Crucian carp *Carassius auratus*; silver carp *Hypophthalmichthys molitrix*; grass carp *Ctenopharyngodon idellus*; mullet *Liza soiuy*; whitefish *Erythroculter erythropterus*; snake head *Ophiocephalus argus*; catfish *Parasilurus asotus*; blunt-headed bream *Megalobrama amblycephala*, etc. At a water temperature of 10-27^{O}C, and a water depth of 25-50 cm, the starting velocity of the various kinds of fishes is about 0.2 m/sec. The optimum velocity ranges from a lower limit of 0.3-0.4 m/sec to an upper limit of 0.5-0.8 m/sec. The limiting velocity for the different kinds of fish varies greatly. The upper limit of optimum velocity is generally considered as the preferable velocity for a fishway inlet. The value is about 15-30% less than the limiting velocity. The experiments denote that the current overcoming ability of fish is mainly related to their body shape, body length and the variation of the water temperature. By analyzing the results of the experiments and date from some existing fishways, it was seen that the current overcoming ability of a fish is closely related to its body length. An empirical formula is proposed for estimation purposes.

471. Zholdasova, I. (1997). Sturgeons and the Aral Sea ecological catastrophe. Environmental Biology of Fishes. **48**:373-380.

A short description of the catastrophic changes in the ecology of the Aral Sea basin during the three last decades is presented. These changes have influenced the status of two acipenserid endemics to the area, the large Amu-Dar shovelnose, *Pseudoscaphirhynchus kaufmanni*, and the ship sturgeon, *Acipenser nudiventris*. The main biological characteristics of both species in the new environmental conditions are given. Previous unsuccessful attempts to introduce other acipenserid species into the area are also described. International cooperation is needed for saving the last surviving species representing the genus *Pseudoscaphirhynchus*. The only two other species of the same genus, *P. fedtschenkoi*, and *P. hermanni*, have already become victims of the Aral Sea catastrophe and are apparently extinct.

472. Zigler, S., M. Dewey, B. Knights, M. Steingraeber and A. Runstron (1996). Habitat use and movement of paddlefish in the Upper Mississippi River. Pages 24 *in* J. T. Dukerschein, ed. Proceedings of the Mississippi River Research Consortium, La Crosse, Wisconsin (USA), Mississippi River Research Consortium.

Restoration of depleted paddlefish *Polyodon spathula* populations is a goal of several state and federal natural resource agencies. Knowledge of movements is important for defining the spatial scales for effectively managing paddlefish stocks and for evaluating the effects of habitat alterations, such as dams, on paddlefish. In 1994 and

1995, we evaluated movement and habitat use of paddlefish with radiotelemetry in Pools 5A and 8 of the Upper Mississippi River, and in the Wisconsin and Chippewa Rivers. Paddlefish were tagged in the lower Black River (Pool 8, upper Mississippi River), in Pool 5A of the upper Mississippi River, near Caryville in the Chippewa River, and in the Wisconsin River below Prairie du Sac dam. Many remained at these locations throughout the year. In spring, 1995 about half of the radiotagged paddlefish moved downstream up to 90 km in the Wisconsin and Chippewa Rivers, presumably for spawning activities. Paddlefish in Pool 8 remained in the upper portion of the pool throughout spring. Paddlefish that moved downstream during spring returned in early summer. Diel studies conducted in Pool 8 during spring 1995 indicated greater movement at night (mean = 525 m/h) as compared to day (mean = 212 m/h), but use of habitat types did not differ among day, night, or crepuscular periods. While most paddlefish did not move great distances during summer, a few fish moved between 150 and 250 km from tributaries into the upper Mississippi River. In the lower portion of the tributaries rivers, which do not contain dams, paddlefish moved large distances upstream and downstream. In the upper Mississippi River, dams appear to be effective barriers to upstream paddlefish movement. Research studies are continuing to monitor seasonal patterns of habitat use and movement.

473. Zigler, S. J., M. R. Dewey and B. C. Knights (1999). Diel movement and habitat use by paddlefish in Navigation Pool 8 of the Upper Mississippi River. North American Journal of Fisheries Management. **19**:180-187.

We studied diel movement and habitat use by paddlefish *Polyodon spathula* implanted with radio transmitters in Navigation Pool 8 of the Upper Mississippi River. We radio-tracked five paddlefish during three randomly chosen 24-h periods each month in May, August, and October 1995. Paddlefish were located by boat one to three times every 3 h during each 24-h period. At each location, geographic coordinates were determined with a global positioning system receiver using the Precise Positioning Service, and depth was measured with a depth sounder. Location coordinates were plotted with ARC/INFO software on a Geographic Information System land-water coverage. Movement distances were calculated as the linear distance between sequential locations. Radio-tagged paddlefish usually remained in a secondary channel that had low current velocity during all seasons, whereas main channel, main channel border, tailwater, and backwater habitats were seldom used. Paddlefish strongly selected areas that were deep; about 62% of paddlefish locations were in areas with more than 6 m of depth, although this habitat constituted only 14.5% of the total study area. However, paddlefish used significantly shallower areas during the night than during the day. Paddlefish moved significantly larger distances at night than during the day in spring and fall, but differences in movement among diel periods during summer were not significant. Our research suggests that radiotelemetry studies that need to determine depth use or movement of paddlefish during small time scales may need to incorporate a diel component. However, study objectives to determine use of general habitat types by radio-marked paddlefish can be adequately met by tracking during the day.

474. Zimpfer, S. P., C. F. Bryan and C. H. Pennington (1987). Factors associated with the dynamics of grass carp larvae in the Lower Mississippi River Valley. Pages 102-108 *in* R. D. Hoyt, ed. Proceedings of the 10th Annual Larval Fish Conference, American Fisheries Society Symposium Serial, Miami, Florida (USA).

Larvae of grass carp *Ctenopharyngodon idella* were captured in 4 major rivers of the lower Mississippi River valley. Catches were greatest in the lower Red River; peaks were associated with increasing river stage, current speeds of 1.2-2.2 m/s, water temperatures of 23.5-28.2 ^{o}C, pH values of 7.2-7.7, dissolved oxygen concentrations of 4.0-7.6 mg/L, and secci disc readings of 1-9 cm. Catches were least near navigation locks and dams on the Ouachita River, where flows were 0.6 cm/s or less when water temperatures were optimum. Intermediate catches of larvae were taken from the Atchafalaya River and the Mississippi River Diversion Channel. Major spawning areas in the Mississippi and Red rivers were located in or near Arkansas, where grass carp were first released. The occurrences of juveniles and adults in commercial catches from the Black, Mississippi, and Red rivers, and of newly hatched larvae in the backwaters of the Atchafalaya River basin, suggest that grass carp are successfully recruited to fish stocks of the lower Mississippi Valley.