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Minimum flows and levels criteria development

Evaluation of the importance of water depth and frequency of water levels/flows on fish population dynamics

Literature review and summary

Annotated bibliography for water level effects on fish populations

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Introduction

Water level, instream flows, and water fluctuations have a number of significant effects in aquatic systems. The response of fish to water levels can have important implications for reproduction, survival, growth, and recruitment of fishes, as well as the fisheries they support. Stream flow has effects not only within the stream itself, but also in associated estuary and coastal marine habitats.

This document is an annotated bibliography of the effects of water levels on fish populations, with special reference to Florida fishes, habitats, and systems. This annotated bibliography provides 290 references to primary and gray literature. This bibliography is by no means exhaustive, but it directs users to relevant literature and the extensive citations therein. The coverage is primarily 1980 to 2000.

This information will be used by the St. John's River Water Management District (SJRWMD) Water Supply Management Division for the development of ecological criteria for its Minimum Flow and Levels (MF&Ls) Program. Ecological research concerning the required hydrologic regimes of aquatic and wetland fauna is needed to set meaningful MF&Ls. These MF&Ls will protect water resources from significant ecological harm caused by water withdrawal or diversion and, at the same time, assure water for non-consumptive uses.

Methods

Citations included in this annotated bibliography were found in several ways. Most citations were revealed through key-word computer searches of on-line bibliographic databases. A list of relevant key words was produced from a meeting of interested state agency and university personnel (Appendix A). These key words and various key word combinations were searched in the following databases: Cambridge Aquatic Science and Fisheries Abstracts, the Aquatic, Wetland, and Invasive Plants database, Biological Abstracts, Biological and Agricultural Index, and Zoological Record. Over 10,000 potential citations were produced by this method. The minimum flows and levels database of the SJRWMD Library was also searched. Sources of gray literature were indexed in some bibliographic databases, most notably in the Cambridge database selection and the SJRWMD database. Additional references were obtained from state and federal agency personnel and the authors' personal libraries.

Citations were examined for potential inclusion in the annotated bibliography and then imported or typed into EndNote Plus bibliographic database software. These potential citations were obtained and further examined for relevance. Documents to be included were then annotated for pertinent information.

Inclusion criteria involved geographic location, species of interest, and relevance to Florida habitats. Representative papers from other regions, with species of less interest, habitats rare or not found in Florida, or testing methodology were included, but no effort was made for an exhaustive search of these references. Several papers were included that describe the effects of freshwater inflow on estuaries and estuarine fishes, but this was not a focus of the search. Similarly, a few papers discussing the effects of water levels on plant communities and invertebrates were included, but no effort was made to access this vast literature. Additionally, some bibliographies with pertinent information were found and included.

Some of the computer databases included abstracts in their downloadable output. Abstracts, however, were not included in the annotated bibliography due to copyright law. Instead, annotations were produced. Annotations were limited to information relevant to the effects of water level on fish populations, with special reference to Florida fishes or habitats. English units were reported if these were exclusively used in the original paper.

Annotated bibliography

Aadland, L. P. 1993. Stream habitat types: Their fish assemblages and relationship to flow. North American Journal of Fisheries Management 13: 790-806.

This study determined habitat preferences for 114 fish species-life stage combinations (e.g., age and reproductive state) in Minnesota. Most age-0 fishes preferred shallow pools. Ictalurids and centrarchids preferred deep pools. Flow affected the relative abundance and characteristics of several habitat types. Shallow pools were less abundant during high flows. Medium and deep pool habitat area changed relatively little with changes in flow, whereas slow riffle, fast riffle, and raceway habitat became scarce or absent during low flows. Species that depend on riffle habitats may be considered sensitive to low flows. Life stage is an important consideration in any minimum flow determination and using pool-oriented game fish as sole targets for instream flow regimes is not adequate to protect fish assemblages.

Adebisi, A. A. 1988. Changes in the structural and functional components of the fish community of a seasonal river. Archiv fur Hydrobiologie 113: 457-463.

Adicks, V. K. and C. E. Cichra. 1997. Bibliography of aquatic research for the Florida Big Bend coastal region. University of Florida, Gainesville, Florida.

This bibliography covers all aspects of aquatic research for the Big Bend coastal region, Gulf of Mexico, Florida. This coastal region is heavily influenced by the freshwater discharge of the Suwannee River and other coastal streams. There are potential references of interest regarding salinity and freshwater inputs as well as species-specific information.

Adicks, V. K. 1998. Relationships of juvenile and small fish populations to season and salinity in Alligator Pass, Suwannee River, Florida. Masters Thesis. University of Florida. Gainesville, Florida.

This thesis reports on sampling conducted in 1996. Salinity was generally below 5 ppt, but significantly more fishes were collected in samples above this value. Otherwise, significant relationships between fish and salinity were not found. Fish were dominated numerically and in species richness by euryhaline and marine species.

Aho, J. M., C. S. Anderson, et al. 1986. Habitat suitability index models and instream flow suitability curves: Redbreast sunfish. FWS/OBS-82/10.119. U. S. Fish and Wildlife Service. Washington, D. C.

This report provides a Habitat Suitability Index model and instream flow suitability

curves for redbreast sunfish *Lepomis auritus* based on a literature review. Summarizes the bulk of the literature on the species and applies this to instream flow requirements.

Albanese, B. 2000. Reproductive behavior and spawning microhabitat of the flagfin shiner *Pteronotropis signipinnis*. American Midland Naturalist 143: 84-93.

The author reports on aquarium observations, instream observations, and microhabitat sampling to describe spawning in the flagfin shiner *Pteronotropis signipinnis* from a Mississippi stream. Although actual egg release was not observed in the field, based on behavior and spawning condition of fish within the microhabitat, the author concluded that vegetated riffle habitat is the microhabitat used in spawning. These areas were shallow (mean = 16 cm deep) with a moderate current (mean = 7 cm/s). Macrophytes present in the vegetated riffles were *Sparganium americanum*, *Orontium aquaticum*, and cattail *Typha* spp. Feeding behavior was most frequently observed in vegetated runs. Runs were moderate in depth (mean = 42 cm), had moderate to swift current (mean = 5 cm/s) and had a substrate of sand and *S. americanum*.

Ali, A. B. and M. S. Kathergany. 1987. Preliminary investigation on standing stocks, habitat preference and effects of water level on riverine fish population in a tropical river. Tropical Ecology 28: 264-273.

This paper reports on fish sampling in relation to water levels on the Peral River, Malaysia. Fish abundance, biomass, and catch rate were positively correlated with high water level.

Annear, T. C. and A. L. Conder. 1984. Relative bias of several fisheries instream flow methods. North American Journal of Fisheries Management 4: 531-539.

This paper evaluated instream flow methods to determine relative bias using 13 Wyoming streams. Two habitat retention methods, both associated with riffle maintenance, and the Tennant method were unbiased. Wetted perimeter and Physical Habitat Simulation Model (PHABSIM) methods were biased.

Araujo-Lima, C. A. and E. C. Oliveira. 1998. Transport of larval fish in the Amazon. Journal of Fish Biology 53 (Supplement A): 297-306.

This study notes two drift strategies used by larval fishes in the Amazon River near Manaus, Brazil. Some larvae drifted mostly during the rising waters and were more abundant near the banks. Their strategy seemed to be a passive dispersion towards the floodplain with the flood pulse. The groups that drifted during the lowering waters showed an alternative strategy. They were flushed from the floodplain lakes and may have stayed in the main river channel for a few months before returning to the floodplain. This shows that some fishes spawn in the main channels but their larvae use the floodplain. Alternately, some species spawn in the floodplain and their larvae may use the main channel.

Armour, C. L., R. J. Fisher, et al. 1984. Comparison of the use of the Habitat Evaluation Procedures (HEP) and the Instream Flow Incremental Methodology (IFIM) in aquatic analyses. FWS/OBS-84/11. U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report compares use of Habitat Evaluation Procedures (HEP) and the Instream Flow Incremental Methodology (IFIM) and aids in choosing the appropriate method for aquatic habitat

analyses. It also provides information on the development and use of Suitability Index (SI) curves. These methods are widely applied to instream flow needs of fishes.

Armour, C. L. and J. G. Taylor. 1991. Evaluation of the instream flow incremental methodology by US Fish and Wildlife Service field users. Fisheries 16: 36-43.

This paper reports on a survey of 57 U. S. Fish and Wildlife Service offices concerning experiences applying Instream Flow Incremental Methodology (IFIM) and recommendations to improve its use and performance. Main complaints about IFIM were that it is too simplistic in concept and that it is too complex to implement. Recommendations for future research and refinement include improving the suitability index (SI) curves and computer models and evaluating the relationship of weighted useable area (WUA) to fish responses.

Aumen, N. G. and S. Gray. 1995. Research synthesis and management recommendations from a five-year, ecosystem-level study of Lake Okeechobee, Florida (USA). Archiv fur Hydrobiologie Ergebnisse der Limnologie 45: 343-356.

This paper discusses the deleterious effects of sustained high water levels on Lake Okeechobee, Florida. Adverse effects have included declines in submerged aquatic vegetation, dominance by inundation tolerant emergent vegetation (e.g., cattails *Typha* spp.), decreased macroinvertebrate diversity, and lower sport fish abundance. A review of the literature showed that fish distribution in the lake was influenced by water depth and lake stage, although the relationships were weak. Although fish assemblage composition had changed little over time, abundance, species richness, and standing crop had declined within vegetated habitats. The authors recommended implementation of a water level regime that allows a more natural hydrologic variability.

Bain, M. B., J. T. Finn, et al. 1988. Streamflow regulation and fish community structure. Ecology 69: 382-392.

Since changes in streamflow directly modify physical habitat, the authors compared fish assemblages in two streams, one with a natural flow regime, the other regulated. They developed habitat models for 15 species and life stages in the stream with natural flow. They found that the most abundant and diverse microhabitat group in the natural river used areas of shallow depth, low velocity, and were concentrated in stream margins. In the regulated stream, this microhabitat group was greatly reduced or absent. Flow regulation is a disturbance that effects fishes depending on how they use stream habitat and acts to reduce assemblage complexity.

Baker, J. A. and K. J. Kilgore. 1994. Use of a flooded bottomland hardwood wetland by fishes in the Cache River system, Arkansas. Wetlands Research Program Technical Report WRP-CP-3. U. S. Army Corps of Engineers. Washington, D. C.

This report investigated use of channel, flooded tupelo forest, and flooded oak forest by adult, juvenile, and larval fishes. The authors documented extensive utilization of the floodplain by a large number of taxa. A total of 56 species were collected in the study area. Larval fish abundance was greater in the year with more extensive and prolonged flooding relative to the year with less flooding. Most species collected are considered to normally use flooded areas, but larvae of fluvial species (e.g., river darter *Percina shumardi*) were found in the floodplain as well. Because of a lack of permanent backwater habitats (e.g., oxbows and ponds) in the study

area and the collection of relatively few species in the channels after flood waters had receded, the authors were unable to determine if permanent backwaters or streams represent the source populations for many floodplain-associated species. The fish assemblage is typical (but rich) of coastal plain systems and Florida has many of the species collected in this study.

Bart, H. L., Jr., J. Martinat Peter, et al. 1998. Influence of taxonomy, ecology, and seasonality in river stage on fish contamination risks in floodplain swamps of the lower Mississippi river. Ecotoxicology 7: 325-334.

Bartels, A. D. 1997. Growth of selected fishes in Navigation Pool 8 of the upper Mississippi River: A test of the flood-pulse concept. LTRMP97-R001. U. S. Geological Survey. Onalaska, Wisconsin.

Bass, D. G. J. 1990. Stability and persistence of fish assemblages in the Escambia River, Florida. Rivers 1: 296-306.

This paper reports on electrofishing sampling of the Escambia River, Florida. The author found fish assemblages to be stable and persistent over the 6-year study despite the occurrence of large natural fluctuations of stream flows, and to a lesser degree, salinity intrusions.

Bayley, P. B. 1988. Factors affecting growth rates of young tropical floodplain fishes: Seasonality and density-dependence. Environmental Biology of Fishes 21: 127-142.

The author investigated water level fluctuations and density-dependence as factors influencing growth of fishes of Amazon River floodplains. With minor exceptions, density-dependence was not a significant factor. On the other hand, water level fluctuations were important, especially for omnivores. Omnivores exhibited faster growth during the rising water season, possibly associated with increased availability of food. Detritivores did not experience significant seasonal growth effects.

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

Beam, J. H. 1983. The effect of annual water level management on population trends of white crappie in Elk City Reservoir, Kansas. North American Journal of Fisheries Management 3: 34-40.

This paper reports on the results of a management plan to manipulate water level in Elk City Reservoir, Kansas, to improve white crappie *Pomoxis annularis* populations. The main action was to raise water levels in order to inundate terrestrial vegetation during the spawning season. Relative year-class strengths of white crappie during a 5-year period after implementation of the management plan was higher compared to year-class indices measured 5 years previously. Hectare-days of flooded vegetation were not related to increased white crappie recruitment, but the authors explain that environmental conditions that limited recruitment likely overshadowed the positive trend. Fluctuations in water level during the spawning season were negatively correlated with white crappie year-class strength.

Becker, C. D., D. H. Fickeisen, et al. 1981. Assessment of impacts from water level fluctuations on fish in the Hanford Reach, Columbia River. NL-3813. U. S. Department of Energy. Washington, D. C.

Beecher, H. A., T. H. Johnson, et al. 1993. Predicting microdistributions of steelhead (*Oncorhynchus mykiss*) parr from depth and velocity preference criteria: Test of an assumption of the Instream Flow Incremental Methodology. Canadian Journal of Fisheries and Aquatic Sciences 50: 2380-2387.

The authors tested the assumption that fish select microhabitats based on the quality of hydraulic conditions. This is a basic assumption of the Physical Habitat Simulation Model (PHABSIM) of the Instream Flow Incremental Methodology (IFIM). The test used rainbow trout (steelhead) *Oncorhynchus mykiss* in Washington. The results showed a significant rank correlation between steelhead density and preferences with velocity and depth x velocity, but not for depth alone. The authors interpreted this as support for the PHABSIM assumption.

Beecher, H. A., J. P. Carleton, et al. 1995. Utility of depth and velocity preferences for predicting steelhead parr distribution at different flows. Transactions of the American Fisheries Society 124: 935-938.

This paper tested the Physical Habitat Simulation Model (PHABSIM) assumption that depth and velocity preferences of fish are independent of stream flow. This was tested with rainbow trout (steelhead) *Oncorhynchus mykiss* in Washington. The authors found that steelhead depth and velocity preferences were independent of stream flow, supporting Instream Flow Incremental Methodology (IFIM).

Belanger, T. V., C. G. Annis, Jr., et al. 1990. Growth rates of the Asiatic clam, *Corbicula fluminea*, in the upper and middle St. Johns River, Florida. Nautilus 104: 4-9.

The authors described distribution and growth of Asiatic clam *Corbicula fluminea* in the St. Johns River, Florida, in relation to environmental variables. The distribution of Asiatic clams was correlated with sediment type and flow rate, with highest densities found in areas of sand substrate and fast, but not scouring, flow. Sediment type was more important, however, as Asiatic clams were not found at sites with favorable flow but unsuitable sediment substrates. In at least one case, high densities of Asiatic clam were found in a sand substrate with little or no flow. Fast growth was associated with sandy substrate, high flow, and high dissolved oxygen concentrations.

Benke, A. C., I. Chaubey, et al. 2000. Flood pulse dynamics of an unregulated river floodplain in the southeastern U.S. coastal plain. Ecology 81: 2730-2741.

This paper presents a floodplain inundation model for the Ogeechee River, Georgia and relates this system into the context of flood pulse dynamics (i.e., land-water subsidy). Models such as this are useful for developing management plans for other coastal plain streams.

Bennett, W. A., D. J. Ostrach, et al. 1995. Larval striped bass condition in a drought-stricken estuary: Evaluating pelagic food-web limitation. Ecological Applications 5: 680-692.

The authors investigated poor year class success of striped bass *Morone saxatilis* in the San Francisco Bay estuary, California, during drought conditions. They tested two hypotheses: (1) larval starvation due to food limitation and (2) toxic exposure due to undiluted runoff.

During drought conditions, productivity of plankton declined markedly. Nevertheless, sampled larvae had been feeding and lacked histopathological indications of starvation. On the other hand, up to 30% of larvae showed signs of toxic exposure. The levels of toxic exposure were not consistent, however, and did not correlate with larval survival. The authors concluded that the data suggest a synergy of food limitation, predation, and toxic exposure and illustrate the futility of pursuing single-factor explanations for recruitment failure.

Blindow, I., G. Andersson, et al. 1993. Long-term pattern of alternative stable states in two shallow eutrophic lakes. Freshwater Biology 30: 159-167.

The authors report on the conditions of two shallow eutrophic lakes in Sweden over a several decade long period. The lakes have shifted between two stable equilibrium states - a macrophyte-dominated and a phytoplankton-dominated state. Piscivorous fishes were most abundant during times of macrophyte-dominated equilibria. Water level fluctuations were the most common factors causing the shifts. Macrophyte-dominated state was produced during periods of lowering water level whereas increases in lake level led to the phytoplankton-dominated state.

Bohnsack, B. L. and A. V. Zale. 1992. Spatial and temporal distributions of striped bass eggs in the Arkansas River, Oklahoma, 1987 and 1988. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 46: 458-468.

This paper reports on striped bass *Morone saxatilis* eggs in the Arkansas River, Oklahoma. Eggs were found at water velocities of 0.2 - 1.8 m/s. Striped bass spawned farther upstream during periods of high discharge. Spawning activity was heavy near the confluence of the Salt Fork and Arkansas rivers, a zone where temperatures and discharge increased abruptly. Spawning was also influenced by photoperiod and temperature.

Boujard, T. 1992. Space-time organization of riverine fish communities in French Guiana. Environmental Biology of Fishes 34: 235-246.

This paper summarizes research conducted in French Guiana and reviews the literature concerning space-time organization in South American, and to a lesser extent, African river fish assemblages. The author presents a conceptual model describing the relationship between water level and fish breeding, feeding, growth, fat storage, and lateral migration into flooded forest. Citations are provided for extensive floodplain use by neotropical fishes.

Bowen, S. H. and B. R. Allanson. 1982. Behavioral and trophic plasticity of juvenile *Tilapia mossambica* in utilization of the unstable littoral habitat. Environmental Biology of Fishes 7: 357-362.

This paper reports on habitat and feeding plasticity of Mozambique tilapia *Oreochromis mossambicus* related to changes in water level in Lake Sibaya, South Africa. A low lake levels, the littoral zone was relatively free of structural complexity and juvenile Mozambique tilapia refuged in deep water during the day and entered littoral areas during the day to feed. At high lake levels, sparse terrestrial vegetation and debris were inundated. The diel movement of Mozambique tilapia was reversed - day light hours were spent in deeper water and the flooded areas were used at night for feeding. This behavioral change was apparently in response to predation threat by the labyrinth catfish *Clarias gariepinus*, which was found in deeper water during the day at low lake levels but invaded shallow areas during all times at high lake levels.

This paper shows the behavioral plasticity of Mozambique tilapia and an indirect way that water level fluctuations can alter predation regimes.

Bowen, Z. H., M. C. Freeman, et al. 1996. Index of biotic integrity applied to a flow-regulated river system. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 50: 26-37.

This paper presents a modified Index of Biotic Integrity (IBI) using small-bodied fishes in the Tallapoosa River, Alabama. Values for IBI were lower at flow-regulated sites, implying that severe flow fluctuations are detrimental to stream fish assemblages.

Braschler, D. W., M. G. White, et al. 1988. Movements and habitat selection of striped bass in the Santee-Cooper reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 42: 27-34.

This study noted the use of thermal refugia (e.g., springs, wells, sinkholes, inundated creek beds) by radio-tagged striped bass *Morone saxatilis* in the Santee-Cooper reservoirs, South Carolina. Use of the Congaree River was presumed as spawning activity. The authors explained the greater use of the Congaree River relative to the Wateree River as being due to the former's much higher discharge.

Browder, J. A. 1985. Relationship between pink shrimp production on the Tortugas grounds and water flow patterns in the Florida Everglades. Bulletin of Marine Science 37: 839-856.

This paper reports on the results of regression modeling of the relationship between freshwater levels in the Everglades National Park and landings of pink shrimp *Penaeus duorarum* on the Tortugas grounds. Freshwater inputs to the Florida Bay estuary, as indexed by park water levels, had a significant positive relationship to pink shrimp landings for three quarters during the year. The relationship had a lag time of one quarter. However, an inverse relationship between landings and water levels from April through June was suggested. This study suggests the importance of freshwater inputs in maintaining estuarine fisheries.

Brown, D. J. and T. G. Coon. 1994. Abundance and assemblage structure of fish larvae in the lower Missouri River and its tributaries. Transactions of the American Fisheries Society 123: 718-732.

This paper reports larval fish sampling in four tributaries and the main channel of the lower Missouri River. The purpose was to determine the importance of lower sections of tributary streams as larval fish habitat and their contribution to fish productivity and assemblage maintenance. The authors found that the lower tributary sections had higher densities of most larval fishes than did the main channel and concluded that these habitats are critical in this system because of the loss of other backwater nursery areas.

Burkardt, N. 1990. Opportunities to protect instream flows and wetland uses of water in Florida. Biological Report 90(7). U S Fish And Wildlife Service.

This report summarizes the existing laws in the State of Florida relating to protection of instream flow. It does not directly address fishes.

Burt, D. W. and J. H. Mundie. 1986. Case histories of regulated stream flow and its effects on salmonid populations. Canadian Technical Report of Fisheries and Aquatic Sciences 1477: 1-98.

Buynak, G. L. and H. W. Mohr, Jr. 1978. Larval development of the redbreast sunfish (*Lepomis auritus*) from the Susquehanna River. Transactions of the American Fisheries Society 107: 600-604.

This paper reports on a nest site and larval development of redbreast sunfish *Lepomis auritus* in the Susquehanna River, Pennsylvania. The nest was in swift current downstream of several large rocks, 2 m from shore, and 40 cm deep.

Buynak, G. L., W. N. McLemore, et al. 1991. Changes in largemouth bass populations at Kentucky and Barkley Lakes: Environmental or regulatory responses? North American Journal of Fisheries Management 11: 285-292.

This study attempted to evaluate the effectiveness of a new recreational fishery regulation for largemouth bass *Micropterus salmoides* on Kentucky (Tennessee River) and Barkley (Cumberland River) lakes. A severe drought, however, led to low flows and confounded the analysis, making it impossible to separate drought-induced changes from regulatory effects. Most largemouth bass population characteristics improved during the drought. Standing crop of other fishes also increased. The authors attribute this to a combination of regulations and increases in productivity. Productivity increased in both reservoirs due to release of phytoplankton from light limitation and longer reservoir retention times (i.e., lower flushing rate). The authors pointed out three positive factors for largemouth bass - (1) increased standing crop of forage species, (2) increased incidence of catch-and-release by anglers, and (3) productivity-related increases in young largemouth bass growth rates.

Buynak, G. L., B. Mitchell, et al. 1999. Management of largemouth bass at Kentucky and Barkley lakes, Kentucky. North American Journal of Fisheries Management 19: 59-66.

The paper examined the relationship between a number of environmental and population variables and recruitment of age-0, age-1, and age-5 and older largemouth bass *Micropterus salmoides* in Kentucky Lake, Tennessee River, and Barkley Lake, Cumberland River, Kentucky. Recruitment of age-1 largemouth bass was negatively correlated with annual rainfall. For Kentucky Lake, age-5 and older recruitment was negatively related to reservoir discharge. Recruitment to age-5 and older fish at Barkley Lake was positively related to rainfall and negatively related to reservoir discharge. The authors present regression models to assist in prediction of changes in recruitment and suggest implementation of management actions based on these predictions prior to the occurrence of undesirable changes in the fish population.

Cardwell, H., H. I. Jager, et al. 1996. Designing instream flows to satisfy fish and human water needs. Journal of Water Resources Planning and Management 1996: 356-363.

The authors present a flexible, multiobjective optimization model to address water supply and fishery resource needs. This model takes into account size and frequency of water supply shortages and life stage-specific habitat available for fish. When applied to a west-slope Sierra Nevada stream, the model output included a range of alternatives involving trade-offs between water shortage and fish population capacity.

Carmichael, J. T., S. L. Haeseker, et al. 1998. Spawning migration of telemetered striped bass in the Roanoke River, North Carolina. Transactions of the American Fisheries Society 127: 286-297.

The authors studied the effect of temperature and flow on movements and spawning site residency of striped bass *Morone saxatilis* in the Roanoke River, North Carolina. The results showed little change in fish distribution on the spawning grounds due to drops in temperature or increases in flow. Spawning activity, however, slowed or ceased for a period of time after flow increases. The authors attributed this to decreases in temperature associated with the increased flows.

Carr, S. H., F. Tatman, et al. 1996. Observations on the natural history of the Gulf of Mexico sturgeon (*Acipenser oxyrinchus de sotoi* Vladykov 1955) in the Suwannee River, southeastern United States. Ecology of Freshwater Fish 5: 169-174.

The authors describe migratory patterns for Gulf of Mexico sturgeon *Acipenser oxyrinchus desotoi* in the Suwannee River, Florida. The fish entered the Suwannee River from mid-February to early May and exited the river in October and November. Some movement of Gulf of Mexico sturgeon between the Suwannee River and Apalachicola River was observed. The authors discuss the hypothesis that the Suwannee River represents a thermal refuge for the species in warm months and stress the need to protect the river and its associated springs.

Chapman, L. J. and D. L. Kramer. 1991. The consequences of flooding for the dispersal and fate of poeciliid fish in an intermittent tropical stream. Oecologia 87: 299-306.

The authors report on the effects of flooding on individual *Poecilia gillii* (Poeciliidae), a small livebearer, in streams in Costa Rica. Fates of marked fish were followed through two floods, one severe, the other of equal duration but lesser magnitude. In the severe flood, high percentages of fish were lost, many becoming trapped in desiccating pools. In the less severe flood, few fish were lost. Population loss was positively related to magnitude of the flood, streambed slope, and pre-flood population size and negatively related to pool volume. Therefore, severe floods can have large effects on fish populations, especially in small, high gradient streams.

Chapman, L. J. 1995. Seasonal dynamics of habitat use by an airbreathing catfish (*Clarias liocephalus*) in a papyrus swamp. Ecology of Freshwater Fish 4: 113-123.

The author studied distribution of *Clarias liocephalus* in a Uganda papyrus wetland in relation to environmental factors. These catfish breathe air and dissolved oxygen did not limit their distribution. This catfish was more widely distributed during wet periods (i.e., high water) and its distribution was positively correlated with water depth during the dry season, reflecting use of pools as refuge during periods of receding waters. *Clarias liocephalus* is similar to the walking catfish *Clarias batrachus*, an exotic species found in Florida.

Chapman, F. A. and S. H. Carr. 1995. Implications of early life stages in the natural history of the Gulf of Mexico sturgeon, *Acipenser oxyrhynchus desotoi*. Environmental Biology of Fishes 43: 407-413.

This paper reports on collections and ultrasonic tracking of Gulf of Mexico sturgeon *Acipenser oxyrhychus desotoi* in the Suwannee River, Florida. Peak numbers of fish moved into the river in March and April, corresponding to high river flows and temperatures of 14.8-17.2 C. Gulf of Mexico sturgeon remained in the river in very localized areas until water temperatures dropped to 20 C in the fall. The authors concluded that the cool springs and groundwater

intrusion associated with the surficial and Floridan aquifers represent a thermal refuge for Gulf of Mexico sturgeon in the Suwannee River.

Cheslak, E. F. and A. S. Jacobson. 1990. Integrating the instream flow incremental methodology with a population response model. Rivers 1: 264-288.

The authors constructed a mechanistic simulation model from Instream Flow Incremental Methodology (IFIM) Physical Habitat Simulation Model (PHABSIM), a network hydrological model (NETWORK), an IFIM stream temperature model (SNTEMP), and field fishery studies to evaluate temporal changes in stream carrying capacities for rainbow trout *Oncorhynchus mykiss*. The model predicted substantial improvements in fish populations given instream flows proposed for the system. These were later confirmed by monitoring. Sensitivity analysis indicated that the model was valid over a wide range of possible parameter values.

Christensen, J. D., M. E. Monaco, et al. 1997. An index to assess the sensitivity of Gulf of Mexico species to changes in estuarine salinity regimes. Gulf Research Reports 9: 219-229.

This paper presents the BioSalinity Index (BSI) to quantify estuarine-specific sensitivity of organisms to changes in estuarine salinity regimes. Estuarine salinity is related to freshwater inputs of coastal streams. Values of BSI for 44 species of fishes and macroinvertebrates, including life stages, from 22 Gulf of Mexico estuaries are developed. Findings indicate that there are significant differences between juvenile and adult stage sensitivity, with adults typically less sensitive, and there is disparity in species-specific sensitivities among estuaries.

Cloe, W. W., III and G. C. Garman. 1996. The energetic importance of terrestrial arthropod inputs to three warm-water streams. Freshwater Biology 36: 105-114.

This paper describes the importance of allochthonous arthropod inputs as an energetic linkage and subsidy of terrestrial systems to streams. The study site was in the James River system, Virginia. Bluegill *Lepomis macrochirus* and redbreast sunfish *L. auritus* were studied and found to heavily utilize terrestrial arthropods as food. This paper did not address flooding but is of interest as one of the few papers documenting and estimating contributions of terrestrial arthropods to stream food webs.

Coastal, E. 1997. An analysis of the effects of freshwater inflows on salinity distributions, dissolved oxygen concentrations, and habitat characteristics of the Hillsborough River and Palm River/Tampa Bypass Canal. Tampa Bay National Estuary Program. Tampa, Florida.

This report details effects of freshwater inflows from the Hillsborough River Reservoir on downstream salinity, oxygen, and habitat characteristics. This report was conducted due to concern about aquatic biota in the downstream estuarine zone, including important commercial and recreational fishes (e.g., spotted seatrout *Cynoscion nebulosus*, red drum *Sciaenops ocellatus*, tarpon *Megalops atlanticus*, and common snook *Centropomus undecimalis*) and forage species (e.g., bay anchovy *Anchoa mitchilli*). Graphs and tables are provided estimating salinity, dissolved oxygen, shoreline miles, surface volume, and existing habitat for the Hillsborough River and the Palm River/Tampa Bypass Canal under a variety of flow regimes. No executive summary.

Cone, R. S., K. Barbour, et al. 1986. The effects of flooding on the growth rates of fishes in Lake Texoma. Proceedings of the Oklahoma Academy of Science 66: 21-25.

This paper reports on growth of fishes in Lake Texoma, Oklahoma and Texas in a flood year compared to previous, non-flood, years. Growth was significantly greater during the flood year for blacktail shiner *Cyprinella venustus*, smallmouth buffalo *Ictiobus bubalus*, and inland silverside *Menidia beryllina*. Striped bass *Morone saxatilis* did not exhibit increased growth during the flood year, possibly due to lack of prey caused by a winterkill of threadfin shad *Dorosoma petenense*. The authors postulated that increased growth was due to large increases in reservoir area and allochthonous inputs to the reservoir due to the floods. Some fishes also were flushed or left the reservoir when the floodgates were opened. A combination of increased area and loss of fishes may also have released fish growth from density-dependent limitations.

Conklin, D. J., Jr., S. P. Canton, et al. 1995. Habitat suitability curves for selected fish species in the central Platte River, Nebraska. Rivers 5: 250-266.

This study developed habitat suitability curves for select fishes in the central Platte River, Nebraska for use in Instream Flow Incremental Methodology (IFIM) modeling. This study includes channel catfish *Ictalurus punctatus* and common carp *Cyprinus carpio*. The authors also compared the habitat suitability curves they developed with others developed for the lower Platte River and in Minnesota. The comparisons between curve sets indicate that fish species probably select different habitats in different streams. The transferability is enhanced by constructing curves with broad ranges of suitable and optimal conditions. However, these broad curves are probably less accurate in representing conditions in any particular stream than are stream-specific curves.

Coomer, C. E., Jr., D. R. Holder, et al. 1977. A comparison of the diets of redbreast sunfish and spotted sucker in a coastal plain stream. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 31: 587-596.

The authors compared diets of redbreast sunfish *Lepomis auritus* and spotted sucker *Minytrema melanops* in the Satilla River, Georgia. Lower coastal plain streams often support an abundance of both species and have fluctuating flows. The authors hypothesized that low flow periods would be potential times of competition between these species. No relationship was found between invertebrate prey density and flow and the authors therefore concluded that there is more prey available to both species during high flow than low flow (i.e., more area covered in water means more prey organisms at a given density).

Copp, G. H. and M. Penaz. 1988. Ecology of fish spawning and nursery zones in the flood plain, using a new sampling approach. Hydrobiologia 169: 209-224.

This paper reports on the use of random point-abundance sampling and modified electrofishing to investigate early life ecology of fishes. The authors report that the method is mobile, effective for larvae and juveniles of most species, quantitative, applicable to various habitats, and comparable both spatially and temporally. They applied this approach to floodplain spawning and nursery areas in the upper Rhone River, France. The main findings were similar standing crops in both lentic and lotic portions of the river, but differences in reproductive and trophic guild structure of the assemblages.

Copp, G. H. 1992. Comparative microhabitat use of cyprinid larvae and juveniles in a lotic floodplain channel. Environmental Biology of Fishes 33: 181-193.

This study concerns microhabitat use of cyprinid larvae and juveniles in the upper Rhone

River, France. Overlap in microhabitat was least at highest water levels and greatest during periods of reduced discharge. Reduced discharge limited the amount of floodplain habitat for fish use and increased the threat of predation due to reduced amounts of structure.

Corti, D., S. L. Kohler, et al. 1997. Effects of hydroperiod and predation on a Mississippi River floodplain invertebrate community. Oecologia 109: 154-165.

This paper reports on invertebrate sampling in Mississippi River floodplain ponds with differing hydroperiods. It provides estimates of species richness, abundance, and biomass. Generally, invertebrate populations were highest in ponds with low access by fishes and intermediate hydroperiods. Long hydroperiods promote fishes or predatory invertebrates.

Crance, J. H. 1984. Habitat suitability index models and instream flow suitability curves: Inland stocks of striped bass. FWS/OBS-82/10.85. United States Fish and Wildlife Service. Ft. Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for inland stocks of striped bass *Morone saxatilis*. Relevant biological data and citations are presented.

Crance, J. H. 1986. Habitat suitability index models and instream flow suitability curves: Shortnose sturgeon. Biological Report 82(10.129). U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for shortnose sturgeon *Acipenser brevirostrum*. Relevant biological data and citations are presented.

Crance, J. H. 1988. Relationships between palustrine wetlands of forested riparian floodplains and fishery resources: A review. Biological Report 88(32). U. S. Fish and Wildlife Service. Washington D. C.

This report provides a brief literature review on the use of floodplains by fish and floodplain structure, function, and productivity. A point made by the author is that general concepts of floodplain use and ecology are generally known, but documentation is often lacking. In particular, quantification of nutrient inputs, productivity, and trophic relationships is needed.

Cushman, R. M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. North American Journal of Fisheries Management 5: 330-339.

This paper reviews the effects of rapidly variable flows in streams due to peaking operations of hydroelectric facilities. Some of these effects include daily exposure of substrate, scouring flow, induced invertebrate drift, alternate torrent and ponding, and water quality fluctuations (e.g., dissolved oxygen and temperature). No examples are from Florida, but some information is applicable. Most information, however, deals with specific extremely modified and disturbed systems that are generally lacking in Florida.

Dahm, C. N., K. W. Cummins, et al. 1995. An ecosystem view of the restoration of the Kissimmee River. Restoration Ecology 3: 225-238.

This paper discusses the restoration of the Kissimmee River, Florida, and its associated floodplain in an ecosystem context. It reviews information on the past and present system

function and makes predictions as to functional attributes of the restored river and floodplain that should be measured to evaluate the restoration effort. Predictions include increased primary productivity of the system and expanded fish communities that will use the reopened channel and the inundated floodplain.

Davis, J. R. 1971. The spawning behavior, fecundity rates, and food habits of the redbreast sunfish in southeastern North Carolina. Proceedings of the Annual Conference, Southeastern Association of Game and Fish Commissioners 25: 556-560.

This study reported on reproduction and feeding of redbreast sunfish *Lepomis auritus* in the Lumber, South, and Waccamaw Rivers in North Carolina. Redbreast sunfish nested from about late May to early July, a period of relatively constant stream flow. The mean stream velocity for the South River during this period was 0.59 ft/s and ranged from 0.11 to 1.84 ft/s. Nests were found on sand or fine gravel substrates and sheltered by woody debris. All nests were found in 14-15 inch depths.

Day, J. W., Jr., W. H. Connor, et al. 1981. The relationship of estuarine productivity to wooded swamps and bottomland forests in the southeastern U.S. FWS/OBS-80/59. U. S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States, U. S. Fish and Wildlife Service, Big Pine Key, Florida.

This review paper describes the link between swamps and floodplain forests and productivity of estuaries in the southeastern USA. Information is summarized on productivity, composition, chemistry, and hydrology of these wooded systems. Direct and indirect couplings between wetlands and estuaries are also discussed in terms of fish habitat, nutrient inputs, hydrological effects, and anthropogenic alterations. In general, these wetlands provide habitat for juvenile and adult fishes and macroinvertebrates, including many commercially and recreationally important species. The wetlands export nutrients to the estuary and heavily influence estuarine productivity. Additionally, wetlands and floodplains help stabilize the important fresh-brackish-salt water gradient against rapid fluctuations caused by erratic freshwater pulses. The paper discusses the many changes wetlands have experienced due to drainage, channelization, control structure construction, and other human modifications. These modifications have reduced the ability of many wetlands to perform vital ecosystem functions that relate to fisheries and productivity in estuaries.

Day, D. M., R. D. Sallee, et al. 1996. Changes in goldfish abundance in the upper Mississippi River: Effects of a drought. Journal of Freshwater Ecology 11: 351-361.

This study documents the increase of an exotic fish, the goldfish *Carassius auratus*, in the upper Mississippi River during a drought. The authors explain this increase as an indirect effect of low flow conditions. Water temperatures, water clarity, and submerged macrophyte abundance increased during the drought period, promoting goldfish reproduction and growth.

DeAngelis, D. L., W. F. Loftus, et al. 1997. Modeling fish dynamics and effects of stress in a hydrologically pulsed ecosystem. Journal of Aquatic Ecosystem Stress and Recovery 6: 1-13.

This paper provides a model of seasonal fish production in freshwater marshes with fluctuating water level under various hydroperiod regimes. This model is especially applicable to the Everglades/Big Cypress region of Florida. High densities of fish are produced by the end of the high water period. Ponds and depressions are critical as fish refugia and additionally act

as sinks during low water periods. The model predicts a threshold effect in the length of hydroperiod necessary to produce high densities of small, marsh-associated fishes. It also predicts that recovery of small-fish populations following a major drought may take up to a year.

Deegan, L. A. and B. A. Thompson. 1985. The ecology of fish communities in the Mississippi River deltaic plain. pp. 1-653. *in* A. Yanez Arancibia. Fish community ecology in estuaries and coastal lagoons. Universidad Nacional Autonoma de Mexico, Mexico City.

Dudgeon, D. 1983. The utilization of terrestrial plants as food source by the fish stock of a gently sloping marginal zone in Plover Cove Reservoir, Hong Kong. Environmental Biology of Fishes 8: 73-77.

This paper reports that five fish species, including Mozambique tilapia *Oreochromis mossambicus*, heavily utilized inundated terrestrial vegetation as a food source. The fish represent an important pathway of transmission and conversion for inputs of allochthonous carbon into the aquatic system.

Dudgeon, D. and G. Bretschko. 1995. Land-water interactions and stream ecology: Comparison of tropical Asia and temperate Europe. Tropical Limnology 1: 69-108.

Dunson, W. A., C. J. Paradise, et al. 1997. Patterns of water chemistry and fish occurrence in wetlands of hydric pine flatwoods. Journal of Freshwater Ecology 12: 553-565.

This paper reports on fish and water sampling in wetlands associated with the Myakka River, Florida. These wetlands were mostly hydric flatwoods that connected with other wetlands during periods of high rainfall. Differences in ion concentration among wetlands are probably due to differing degrees of isolation from surface water flow. The most isolated wetlands, and those with the smallest drainage areas, had the lowest specific conductance, the shortest hydroperiods, and the greatest proportion of volume derived from rainwater. Patterns of fish distribution are discussed.

EA Engineering, S., and Technology, Inc. 1986. Instream flow methodologies. EPRI EA-4819 Project 2194-2. Electric Power Research Institute. Palo Alto, California.

This report summarizes and reviews 70 methods to determine instream flow requirements. Although many of these models have been widely applied, none have been linked adequately to biological responses.

Elder, J. F. 1987. Indicator bacteria concentrations as affected by hydrologic variables in the Apalachicola River, Florida, (USA). Water Air and Soil Pollution 32: 407-416.

Ellis, J. M., G. B. Farabee, et al. 1979. Fish communities in three successional stages of side channels in the upper Mississippi River. Transactions of the Missouri Academy of Science 13: 5-20.

This paper reports on fish assemblages of three successional stages of side channels along the Mississippi River in Missouri. The three channel types were riverine, lacustrine, and intermediate. These categories were based on flow, substrate, and degree of thermal stratification. The intermediate channels are in the process of successional change to lacustrine. Relative abundance of sport fish and panfish was highest in the lacustrine channel and lowest in the riverine channel. The reverse was true for catfish. The riverine and lacustrine channels each contained species that were not collected in the other. Lacustrine channels represent a successional stage that will eventually become floodplain forest.

Estevez, E. D. 2000. A review and application of literature concerning freshwater flow management in riverine estuaries. Mote Marine Laboratory Technical Report Number 680. South Florida Water Management District. West Palm Beach, Florida.

This review outlines research and trends in freshwater flow management for estuaries. The author points out that there has been a relative lack of attention given to the effect of altered instream flows on estuaries and that estuary scientists have a smaller tool box than do riverine scientists. It presents insight from river science and instream flow determinations, basic and applied estuarine ecology, Texas estuaries studies, and Florida minimum flows and levels work. Includes a fairly extensive bibliography.

Everard, M. 1996. The importance of periodic droughts for maintaining diversity in the freshwater environment. Freshwater Forum 7: 33-50.

Fausch, K. D. and R. G. Bramblett. 1991. Disturbance and fish communities in intermittent tributaries of a western Great Plains river. Copeia 1991: 659-674.

This paper reports on fish populations of isolated pools in the Purgatorie River, Colorado, an intermittent stream with permanent pools and unpredictable flooding regimes. Large, structurally complex permanent pools had relatively consistent and stable fish assemblages whereas small, shallow, simple pools had highly variable fish assemblages, both in abundance and species composition. The larger pools provided refuge from flooding effects and served as reservoirs for recolonization and recruitment.

Fisher, W. L. and A. V. Zale. 1991. Effect of water level fluctuations on abundance of young-of-year largemouth bass in a hydropower reservoir. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 45: 422-431.

This paper examined the relationship between water level fluctuation and young-of-year (YOY) largemouth bass *Micropterus salmoides* abundance in Grand Lake, Oklahoma. The authors found substantial evidence that water level fluctuations influence recruitment. There were significantly positive relationships between YOY largemouth bass abundance and both days of littoral flooding during spawning and nursery seasons and drawdown during revegetation season in the previous calendar year.

Fisher, S. J. and D. W. Willis. 2000. Seasonal dynamics of aquatic fauna and habitat parameters in a perched upper Missouri River wetland. Wetlands 20: 470-478.

This paper documents aquatic fauna and habitat characteristics of small floodplain wetlands before, during, and after connection with the Missouri River in North Dakota. Several fish species were found in the wetlands and zooplankton density exceeded regional means by up to 900%. In summer, low dissolved oxygen levels were associated with decay of inundated terrestrial vegetation and woody debris, high temperatures, and flushing out of algal biomass. The authors concluded that although the wetland habitat may be harsh at times, the presence of juvenile fishes and dense zooplankton populations suggest the importance of small floodplain wetlands to the Missouri River ecosystem.

Flotemersch, J. E., D. C. Jackson, et al. 1997. Channel catfish movements in relation to river channel-floodplain connections. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 51: 106-112.

This paper reports on movements of channel catfish *Ictalurus punctatus* relative to river channel-floodplain connections in the Yockanookany River, Mississippi. The study area included sections of river isolated from its floodplain by levees and sections that maintained floodplain connection. During elevated flows, radio-tagged fish remained within or moved to sections of river that retained floodplain connection. Some channel catfish entered an oxbow that was connected to the river during high water and some individuals entered the floodplain at least once.

Fontenot, Q. C., D. A. Rutherford, et al. 2001. Effects of environmental hypoxia associated with the annual flood pulse on the distribution of larval sunfish and shad in the Atchafalaya River basin, Louisiana. Transactions of the American Fisheries Society 130: 107-116.

This paper discusses larval fish distributions, especially sunfish *Lepomis* spp. and shad *Dorosoma* spp., in relation to hypoxic conditions in the Atchafalaya River floodplain, Louisiana. There was a strong positive relationship between dissolved oxygen (DO) level and larval fish abundance and distribution. Large areas of the inundated floodplain become hypoxic due to the decomposition of organic matter. Larval fish were found in previously hypoxic areas almost immediately after water became normoxic (DO > 2.0 mg/L), suggesting use of nearby vegetated littoral areas as refuges by larval fish. The authors recommended implementation of water plans that increase exchange between channels (normoxic) and backwater areas to increase nursery benefits of the floodplain.

Foster, A. M. and J. P. Clugston. 1997. Seasonal migration of Gulf Sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 126: 302-308.

This study documents movements of Gulf sturgeon *Acipenser oxyrinchus desotoi* in the Suwannee River, Florida. Transmitters were attached to 67 individuals and monitored from 1989-1992. Gulf sturgeon entered the river from February to April and returned to the Gulf of Mexico from September to December. Gulf sturgeon spawn in the Suwannee River and use the system as a thermal refuge. The movements were correlated with water temperature but not river discharge.

Fraser, T. H. 1997. Abundance, seasonality, community indices, trends and relationships with physicochemical factors of trawled fish in upper Charlotte Harbor, Florida. Bulletin of Marine Science 60: 739-763.

This paper relates juvenile fish abundance, community indices, and species richness to physicochemical factors, including freshwater inflow, in Charlotte Harbor, Florida. The author found that decreased freshwater inflow from the Peace River correlated with a more diverse assemblage of fishes using the upper Charlotte Harbor.

Freeman, M. C. 1995. Movements by two small fishes in a large stream. Copeia 1995: 361-367.

The author reports on movements of adult blackbanded darters *Percina nigrofasciata* and juvenile redbreast sunfish *Lepomis auritus* in a fifth order Coastal Plain stream, Ichawaynochaway Creek, Flint River (Apalachicola River) system, Georgia. Both species performed relatively long movements (200-400 m) and at least 40% of movements were not associated with periods of extreme high flow.

Funicelli, N. A. and H. M. Rogers. 1981. Reduced freshwater inflow impacts on estuaries. FWS/OBS-80/59. U. S. Fish and Wildlife Service Workshop on Coastal Ecosystems of the Southeastern United States, U. S. Fish and Wildlife Service, Big Pine Key, Florida.

This review paper discusses the importance of freshwater inflows in maintaining habitat and salinity regimes suitable for fish and shellfish. Reductions in freshwater inflow lead to higher salinities that generally have the most negative effect on various shellfish life stages and larval/juvenile fish stages.

Furse, J. B., L. J. Davis, et al. 1996. Habitat use and movements of largemouth bass associated with changes in dissolved oxygen and hydrology in Kissimmee River, Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 50: 12-25.

This paper reports on movement by largemouth bass *Micropterus salmoides* in relation to water level changes in the Kissimmee River, Florida. During periods of high flow and high water levels, fish moved in vegetated areas along channel margins and into floodplain with inundated terrestrial vegetation. In these areas, flow averaged < 6 cm/s. Largemouth bass returned to channels and canals in response to low dissolved oxygen concentrations or receding water levels.

Gaff, H., D. L. DeAngelis, et al. 2000. A dynamic landscape model for fish in the Everglades and its application to restoration. Ecological Modelling 127: 33-52.

The authors present a model (ALFISH) as applied to assess spatial fish density patterns through time in the greater Everglades area of southern Florida. It is a size-structured model using hydrology as a major component. It is being used to compare alternative management options in the Everglades restoration.

Galat, D. L., L. H. Fredrickson, et al. 1998. Flooding to restore connectivity of regulated, large-river wetlands. BioScience 48: 721-733.

This paper summarizes information on connectivity of floodplain wetlands and large rivers of the Mississippi-Missouri system. The response of fishes to flooding is largely temperature-dependent. If temperatures are appropriate, flooding benefits reproduction of many fish species. Access (i.e., connectivity) to wetlands is critical for their use by riverine fishes. Pools that are isolated for long periods tend to have a riverine fauna (e.g., minnows, suckers, and drum) for a period after isolation and then a succession toward a lake fish assemblage (e.g., sunfish). There is little evidence of riverine fish reproduction in isolated pools.

Garutti, V. and M. L. Figueiredo-Garutti. 2000. Lateral migration of *Liposarcus anisitsi* (Siluriformes, Loricariidae) in the Preto river, Alto Parana Basin, Brazil. Iheringia Serie Zoologia 88: 25-32.

Portuguese with an English abstract. This paper describes lateral migrations (i.e., river channel to floodplain) of snowking sailfin catfish (gray catfish) *Pterygoplichthys* (*Liposarcus*) *anisitsi* in Brazil. This species uses main river channel, river banks, temporary lagoons, and permanent lagoons depending on water levels. Lateral migrations are apparently associated with feeding.

Gatz, A. J., Jr. and S. M. Adams. 1994. Patterns of movement of centrarchids in two warmwater streams in eastern Tennessee. Ecology of Freshwater Fish 3: 35-48.

The authors studied movements of redbreast sunfish *Lepomis auritus* bluegill *Lepomis macrochirus*, rock bass *Ambloplites rupestris*, largemouth bass *Micropterus salmoides*, and warmouth *Chaenobryttus gulosus* in two eastern Tennessee streams. A fair amount of information is presented on movements of these species but no relation to flow or water level is mentioned. Seasonal movement patterns, however, may be influenced by seasonal differences in flow. The presented data would have to be matched to flow patterns to be of relevance.

Glova, G. J. and M. J. Duncan. 1985. Potential effects of reduced flows on fish habitats in a large braided river, New Zealand. Transactions of the American Fisheries Society 114: 165-181.

This paper investigated the effect of reduced flow on weighted usable area (WUA) curves for fishes in a braided river in New Zealand. As flow decreased, WUA also decreased for most species. The authors used water depth, velocity, and substrate to construct WUA curves and commented that inclusion of substrate reduced the curve area for most species. Most losses in WUA were associated with side channels. Braided rivers, unlike single-thread rivers, show relatively little overall change in WUA with decreasing flows over a wide range of flow conditions, mainly because losses in side changes are largely made up by gains in larger channels. Therefore, some species (i.e., those that depend on side channels) are more affected than others (i.e., those that use larger channels) by decreases in flow.

Grant, G. C. and J. E. Olney. 1991. Distribution of striped bass *Morone saxatilis* (Walbaum) eggs and larvae in major Virginia rivers. Fishery Bulletin 89: 187-193.

This paper reports on sampling striped bass *Morone saxatilis* eggs and larvae in five Virginia rivers. The authors noted that spawning location, as indicated by egg collections, was displaced upstream in the James River in response to drought (i.e., low flow conditions). Other streams in the study were not significantly affected by the drought and interannual variation in spawning location was low.

Grimes, C. B. 2001. Fishery production and the Mississippi River discharge. Fisheries 26: 17-26.

This paper discusses the importance of Mississippi River freshwater discharge to the Gulf of Mexico fishery. The author provides evidence for this importance to fish populations (biological, chemical, and fishery data) and proposes that the mechanism is enhancement of recruitment. Recruitment is enhanced by both physical and biological processes affecting recruitment - larval production, feeding, growth, and survival.

Grossman, G. D., R. E. Ratajczak, Jr., et al. 1998. Assemblage organization in stream fishes: Effects of environmental variation and interspecific interactions. Ecological Monographs 68: 395-420.

The authors examined the effects of environmental variation, space competition, and predator abundance on fish assemblage structure and microhabitat use in a North Carolina stream. The study covered a 10-year period and included 50-year highs and lows. Hydrology (i.e., pre-, during, or post drought period) explained more variability in habitat availability than did either season or year.

Guillory, V. 1979. Utilization of an inundated floodplain by Mississippi River fishes. Florida Scientist 42: 222-228.

This paper reports on use of inundated floodplain by fishes in the lower Mississippi River, Louisiana. Lateral movement onto the inundated floodplain was observed and the presence of juveniles and spawning adults indicated that these areas are used for reproduction and nursery habitats. Of 62 species collected, 15 species were found in channels and floodplains equally and a total of 32 species used the inundated floodplain.

Gutreuter, S., A. D. Bartels, et al. 1999. Evaluation of the flood-pulse concept based on statistical models of growth of selected fishes of the Upper Mississippi River system. Canadian Journal of Fisheries and Aquatic Sciences 56: 2282-2291.

This study investigated growth in bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, and white bass *Morone chrysops* in the upper Mississippi River and Illinois River in relation to the flood pulse concept. Bluegill and largemouth bass are littoral, white bass are limnetic, and black crappie are intermediate in habitat use. The authors predicted that the species would exhibit different responses to flooding related to their habitat affinities. A statistical modeling approach was used to detect stage-structured growth responses. The authors found that bluegill and largemouth bass showed increased growth, white bass no effect, and black crappie ambiguous results coincident with floods and relative to low-flow years, supporting the flood pulse concept.

Hale, M. M. and D. R. Bayne. 1982. Effects of water level fluctuations on the littoral macroinvertebrates of West Point Reservoir. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 34: 175-180.

This study compared benthic invertebrate communities that experience exposure during annual drawdowns with adjacent communities that are not exposed in West Point Reservoir, Chattahoochee River. The authors found fewer organisms in the contour exposed during drawdown soon after inundation and 2 months later, but no differences by 4 months inundation. They also found a higher percentage of sand and a lower percentage of silt and clay in the annually exposed zone. Continued annual fluctuation of the water level is expected to cause deterioration in soil composition of the exposed littoral areas, leading to lower production of benthic fish-food organisms.

Halyk, L. C. and E. K. Balon. 1983. Structure and ecological production of the fish taxocene of a small floodplain system. Canadian Journal of Zoology 61: 2446-2464.

The authors investigated fish species richness, production, and ecological function of floodplain pools in an Ontario, Canada stream. Species richness in the pools is a function of spring invasion from the stream (i.e., during connection caused by spring floods) and species extirpation during the summer (i.e., after stream connection is lost). Number of days of connection to the stream did not correlate with species richness in the pool but did positively correlate with pool productivity. Species richness was positively correlated with pool size. The authors concluded that floodplain pools are beneficial as nursery areas, for producing fish biomass which can contribute to the stream during periods of connection, and as refugia against catastrophic stream mortality.

Hamilton, K. and P. C. Nelson. 1984. Habitat suitability index models and instream flow suitability index curves: White bass. FWS/OBS-82/10.89. U. S. Fish and Wildlife Service. Fort Collins, Colorado.

Hamilton, H., J. B. Box, et al. 1997. Effects of habitat suitability on the survival of relocated freshwater mussels. Regulated Rivers: Research & Management 13: 537-541.

This study tested for differences in survival and recovery of four freshwater mussels (*Elliptoideus sloatianus*, *Elliptio crassidens*, *Megalonaias boykiniana*, and *Lampsilis teres*) relocated into different substrate types in the Apalachicola River, Florida. Survival ranged from 0-100% . *Elliptio crassidens* was a habitat generalist, with similar survival in all three substrates - stable sand, limestone/sand, and cobble. *Elliptoideus sloatianus* (cobble and limestone/sand) and *Megalonaias boykiniana* (limestone/sand and stable sand) were habitat specialists. Although the authors consider both species to differ in habitat specificity, *M. boykiniana* (habitat specialist) actually had equal or higher survival than *E. crassidens* (habitat generalist) in all habitat types. *Lampsilis teres* recovery was too low to determine habitat specificity. Although no flow requirements are given, this is one of the few studies that provides empirical data concerning substrate requirements that may be related to river flow.

Harvey, B. C. 1987. Susceptibility of young-of-the-year fishes to downstream displacement by flooding. Transactions of the American Fisheries Society 116: 851-855.

This study documents the susceptibility of small (< 25 mm TL) fishes (mostly cyprinids and centrarchids) , including longear sunfish *Lepomis megalotis* and largemouth bass *Micropterus salmoides*, to displacement by flooding. Results were obtained by sampling in Brier Creek, Oklahoma and conducting experiments in an artificial stream. Smaller fishes (< 10 mm TL) were highly susceptible to drift whereas larger fishes (10-25 mm TL) were substantially less vulnerable to flood-induced drift. There were also indications of taxon-specific differences. The author concluded that timing, duration, and intensity of flooding can have large effects on fish communities and recruitment in small streams.

Hatfield, T. and J. Bruce. 2000. Predicting salmonid habitat-flow relationships for streams from western North America. North American Journal of Fisheries Management 20: 1005-1015.

This paper presents a review of 1500 habitat-flow curves from 127 studies that used the physical habitat simulation (PHABSIM) of the instream flow incremental methodology (IFIM) for salmonids in northwestern North America. The authors present regression models predicting PHABSIM optima using mean annual discharge for a number of salmonid species and life stages. These models explained 36-82% of the variation in optimum flow. The use of mean annual discharge is not surprising as habitat and flow increase with increasing stream size.

Heggenes, J., S. J. Saltveit, et al. 1996. Predicting fish habitat use to changes in water flow: Modelling critical minimum flows for Atlantic salmon, *Salmo salar*, and brown trout, *S. trutta*. Regulated Rivers Research and Management 12: 331-344.

This study examined minimum flows, habitat availability, and habitat selection by young Atlantic salmon *Salmo salar* and brown trout *S. trutta* in a Norwegian river. The species involved are not found in Florida and the methodology is only partially applicable to most Florida systems. In particular, this study relied heavily on direct observation of fish by observers to gather data to input into the RIMOS (RIver MOdelling System) model. The authors noted that pool habitats were more stable and connected than were riffle habitats. Also, the authors concluded that short-term habitat preference studies may give too narrow results due to indicating limited optimal conditions and ignoring hydro-physical and temporal variability. They also found that critical fish habitat decreased dramatically below certain minimum flow values.

Heidinger, R. C. 1974. An indexed bibliography of the largemouth bass, *Micropterus salmoides* (Lacepede). Bass Research Foundation, Montgomery, Alabama.

This work provides an extensive bibliography for largemouth bass *Micropterus salmoides*, including a time period not covered in the computer database search that provides the basis for the present annotated bibliography on water levels and fishes. Relevant topics incorporated include depth distribution, draw down or water fluctuation, migration or movement, morphometric consideration of lake (size, depth, shoreline, location, etc.), nursery area, spawning behavior, tailwaters, and year-class strength or spawning success.

Heidinger, R. C. 1975. Life history and biology of the largemouth bass. pp. 11-20. *in* R. H. Stroud and H. Clepper. Black bass biology and management. Sport Fishing Institute, Washington, D. C.

This book chapter gives life history information on largemouth bass *Micropterus salmoides*, including nest depths (15 cm to 5.5 m; usually 0.33 - 1.33 m).

Helfrich, L. A., K. W. Nutt, et al. 1991. Habitat selection by spawning redbreast sunfish in Virginia streams. Rivers 2: 138-147.

This study reports on habitat values for spawning redbreast sunfish *Lepomis auritus* in 10 Virginia streams. Nests were found in low velocity, relatively shallow water with abundant cover. The authors report that water depths and nest site cover closely corresponded to published habitat suitability index (HSI) values for the species. However, selected current velocity was slower and substrate size range narrower than published HSI values. High current velocities (> 3 cm/s) during spawning (June-August) could substantially limit spawning microhabitat availability for redbreast sunfish in these streams.

Henderson, P. A. and I. Walker. 1990. Spatial organization and population density of the fish community of the litter banks within a central Amazonian blackwater stream. Journal of Fish Biology 37: 401-411.

The authors surveyed leaf litter banks in the Taruma-Mirim, Rio Negro system, near Manaus, Brazil. They found a fairly rich (20 species) and dense (100 individuals/m2) fish fauna using this allochthonous resource as habitat. Nearly all species were microcarnivores, feeding on abundant invertebrates in the leaf litter rather than the litter itself. Water level fluctuations change the spatial distribution and size of leaf litter banks, with low water periods being the time of least available habitat. Leaf litter is extremely abundant during periods of high water levels.

Henley, D. E. and D. G. Rauschuber. 1981. Freshwater needs of fish and wildlife resources in the Nueces-Corpus Christi Bay area, Texas: A literature synthesis. FWS/OBS-80/10. U. S. Fish and Wildlife Service. Washington, D. C.

This review report provides extensive information and literature citations concerning coastal hydrology, freshwater inflow, and their biological effects for a Gulf of Mexico bay

system. There is a large section covering important fisheries species that is relevant to estuarine and marine fisheries in Florida.

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

This paper links broad interactions of fluvial-geomorphic processes, riverine-riparian habitat, and the geographic setting to develop multiple flow recommendations. The authors identify four types of stream flow regimes: instream flows, channel maintenance flows, riparian maintenance flows, and valley maintenance flows. Five steps are used for developing these multiple recommendations: average annual hydrograph, physical habitat simulation model (PHABSIM) flow analysis, a hydraulic simulation model (HEC-2) analysis, frequency of occurrence curve, and flow duration curve. Instream flow management is not enough to protect fisheries and ecological systems dependent on streams and multiple flow regimes are generally necessary.

Hill, M. J., E. A. Long, et al. 1994. Effects of dam removal on Dead Lake, Chipola River, Florida. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 48: 512-523.

A coffer dam was constructed on the Chipola River at Dead Lake in 1960. This structure reduced the natural variation in water level fluctuation of Dead Lake and the dam was removed in 1987. This paper reports the results of fish and water sampling before and after dam removal. After dam removal, Dead Lake experienced increased water level fluctuation, improved water quality, and strong year classes of largemouth bass *Micropterus salmoides*. Percent composition of sport fish changed little but total fish species richness increased from 34 to 61 species.

Holcomb, D. and W. Wegener. 1971. Hydrophytic changes related to lake fluctuations as measured by point transects. Proceedings of the Annual Conference, Southeastern Association of Game and Fish Commissioners 25: 570-583.

This study reports on changes in plant communities of Lake Tohopekaliga, Florida, after a 7 ft drawdown conducted to restore fish habitat. After lake level stabilization, a number of deleterious effects were observed in the lake. There was an accumulation of organic detritus and unconsolidated mud, loss of rooted aquatic vegetation, and blue-green algae blooms. After the drawdown, littoral plant communities increased 16%, with many species valuable for fish habitat increasing. For example, bulrush *Scirpus* sp., an important plant for centrarchid spawning habitat, increased. The authors felt that the artificial fluctuation had improved fish habitat and food resources.

Horwitz, R. J. 1978. Temporal variability patterns and the distributional patterns of stream fishes. Ecological Monographs 48: 307-321.

This paper reports on the relationship of variability in flow with fish species richness and distribution in 15 river systems from the northern and central USA. The author found that species richness increased with stream order (i.e., upstream to downstream). Stability in hydrology also correlated with increased species richness.

Hostache, G., M. Pascal, et al. 1993. Reproductive seasonality through the evolution of the gonado-somatic index in *Hoplosternum littorale* (Siluriformes, Teleostei) from French Guiana. Aquatic living resources/Ressources vivantes aquatiques 6: 155-162.

Hostache, G. and J. H. Mol. 1998. Reproductive biology of the neotropical armoured catfish *Hoplosternum littorale* (Siluformes, Callichthyidae): A synthesis stressing the role of the floating bubble nest. Aquatic living resources/Ressources vivantes aquatiques 11: 173-185.

Humphries, P., A. J. King, et al. 1999. Fish, flows and flood plains: Links between freshwater fishes and their environment in the Murray-Darling River system, Australia. Environmental Biology of Fishes 56: 129-151.

The authors review information concerning the importance of flooding for fishes in the Murray-Darling River system, Australia. Although the flood-pulse concept has been the primary paradigm for Murray-Darling fishes, the authors found relatively little evidence that most species are heavily dependent on flooding and floodplains for spawning, nursery areas, or feeding. They present an alternative low-flow recruitment hypothesis that explains spawning by several fish species during low flow periods. The hypothesis stresses temperature, instead of flow, as the main factor inducing spawning. There is some anecdotal evidence and a logical argument for concentrations of appropriate food organisms for larval fishes during low flow. The authors argue that life history patterns largely dictate when fishes reproduce and therefore the role of floodplains in the ecology of a given species. Importantly, since high (or rising) temperatures and high flows do not coincide, and floodplain inundation may be unpredictable in timing and duration, Murray-Darling fishes may have life history strategies such as spawning during a predictable season (i.e., low flow periods), having flexibility in spawning times, having protracted spawning seasons, or having long lifespans. The main theme of this paper is challenging an unquestioning application of the flood-pulse concept to every river with a floodplain.

Huntingford, F. A., D. Aird, et al. 1999. How juvenile Atlantic salmon, *Salmo salar* L., respond to falling water levels: Experiments in an artificial stream. Fisheries Management and Ecology 6: 357-364.

This paper reports that juvenile Atlantic salmon *Salmo salar* leave riffles in response to falling water levels in an artificial stream. These fish moved upstream more often than downstream and entered pools shortly after water levels began falling.

Il'ina, L. K. and N. A. Gordeev. 1980. Importance of the water-level regime for a reservoir fishery. Water Resources 7: 153-164.

Jackson, D. C., R. V. Kilambi, et al. 1982. The impact of drought on Lake Elmdale largemouth bass. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 36: 272-279.

This study reports the effects of drought on largemouth bass *Micropterus salmoides* in Lake Elmdale, Arkansas. Low water levels, sustained high temperatures, and potential increases in predatory pressure adversely affected the largemouth bass population. Spawning activity and parental care were probably disrupted due to decreasing water levels. Physiological stress due to

high temperature and low oxygen also likely increased mortality. Lastly, reduced water levels led to less shelter for age-0 largemouth bass and increased vulnerability to predation.

Jackson, J. R. and R. L. Noble. 2000. Relationships between annual variations in reservoir conditions and age-0 largemouth bass year-class strength. Transactions of the American Fisheries Society 129: 699-715.

This study investigates the relationship between largemouth bass *Micropterus salmoides* year class strength and adult stock characteristics, dynamics of larval and juvenile shad *Dorosoma* spp., lake elevation dynamics, and seasonal air temperatures in Jordan Lake, North Carolina. No significant relationships were observed between largemouth bass year-class size and spawning stock size, shad dynamics, or variations in lake levels. However, late-winter and early spring air temperatures explained a significant amount of the observed variation in catch rates of age-0 largemouth bass. Abundance of age-0 largemouth bass in early spring was significantly correlated with differences in age-0 abundance at 50 mm TL the previous year, suggesting that differences in abundance established early in the life history play a significant role in recruitment variation of largemouth bass.

Jensen, A. J. and B. O. Johnsen. 1999. The functional relationship between peak spring floods and survival and growth of juvenile Atlantic salmon (*Salmo salar*) and Brown trout (*Salmo trutta*). Functional Ecology 13: 778-785.

This paper reports on mortality and growth of juvenile Atlantic salmon *Salmo salar* and brown trout *Salmo trutta* in Norway in relation to spring flooding. Flooding during the alevin stage increased mortality for both species. For older fish, spring flooding had little effect except that growth of Atlantic salmon parr was decreased.

Johnson, M. R. and F. F. Snelson, Jr. 1996. Reproductive life history of the Atlantic stingray, *Dasyatis sabina* (Pisces, Dasyatidae), in the freshwater St. Johns River, Florida. Bulletin of Marine Science 59: 74-88.

This paper reports on reproduction of a freshwater population of Atlantic stingrays *Dasyatis sabina* in Lake Monroe, St. Johns River, Florida. This species is a marine fish that can complete its life cycle in freshwaters of high conductivity (mineral content). Conductivity is reduced in years of high rainfall and river discharge, causing osmotic stress to the Atlantic stingray, resulting in total reproductive failure.

Johnson, B. L., B. C. Knights, et al. 1998. Estimating flow rates to optimize winter habitat for centrarchid fish in Mississippi River (USA) backwaters. Regulated Rivers Research and Management 14: 499-510.

This study is of limited utility to Florida. It mostly concerns the importance of backwater areas along rivers as overwintering habitat for centrarchids. In the northern USA, combinations of cold temperatures and low oxygen can limit the use of these areas. The study recommends introducing some flow into these oxbow systems to increase oxygen levels while not greatly increasing water velocity or decreasing temperature. The main importance to Florida are the values for minimum oxygen and maximum velocity for high quality centrarchid backwater habitat and the recommendation of maintaining some flow into backwater habitats.

Johnston, C. E. and C. L. Knight. 1999. Life-history traits of the bluenose shiner, *Pteronotropis welaka* (Cypriniformes: Cyprinidae). Copeia 1999: 200-205.

This paper reports on life history of bluenose shiner *Pteronotropis welaka* in the Pearl River, Mississippi. No actual spawning was observed, but aggregations of ripe individuals expressing behavior associated with spawning were observed over longear sunfish *Lepomis megalotis* nests, suggesting this species is a nest associate. Based on gonadosomatic index, spawning season is protracted and lasts from May to August. When not breeding, bluenose shiners were found in schools in vegetated areas with sluggish currents.

Jordan, F., K. J. Babbitt, et al. 1998. Seasonal variation in habitat use by marsh fishes. Ecology of Freshwater Fish 7: 159-166.

This paper reports on fish sampling in a wet prairie-slough mosaic in Blue Cypress Marsh Conservation Area in the St. Johns River system. Small fishes were quantitatively sampled with 1-m^2 throw traps in both habitats. The dominant taxa collected were eastern mosquitofish *Gambusia holbrooki*, least killifish *Heterandria formosa*, bluefin killifish *Lucania goodei*, golden topminnow *Fundulus chrysotus*, and Everglades pygmy sunfish *Elassoma evergladei.* The authors describe species-specific patterns of abundance that varied with water level. There was a negative correlation between water level and fish density due to fish being concentrated in sloughs at lower water levels. Total fish density was positively correlated with plant biomass in both wet prairies and sloughs. Eastern mosquitofish and flagfish *Jordanella floridae* quickly invaded newly flooded areas during rising water levels. Extended periods of inundation of wet prairies provided extended opportunities for dispersal, reproduction, and growth. This pattern was shown in increasing densities over time at high, stable water levels. The authors recommend the use of small fish communities in the implementation and evaluation of management and restoration activities.

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.

Jude, D. J. and J. Pappas. 1992. Fish utilization of Great Lakes coastal wetlands. Journal of Great Lakes Research 18: 651-672.

This paper reviews the use and importance of wetlands to Great Lakes fish assemblages. Fishes were divided into habitat groups that used open water, that used nearshore areas and wetlands, and those that used wetlands. Species using wetlands were divided into species that were permanent residents, those that spawned in wetlands and left, those that used wetlands as nursery areas, and those that used wetlands for other purposes (e.g., feeding and shelter). Wetlands functioned as an important habitat by exporting large quantities of fish, first to avian, piscine, and mammalian food chains through predation, and second to the Great Lakes as sport and forage fish. The research implies that a wetland must maintain a connection with a Great Lake to promote and enhance fish utilization of the high productivity of the marshes and that fluctuating water levels are important in sustaining habitat diversity and productivity.

Junk, W. J. 1983. Amazonian floodplains (Brazil): Their ecology, present and potential use. Revue d'Hydrobiologie Tropicale 15: 285-302.

Junk, W. J. 1985. Temporary fat storage, an adaptation of some fish species to the water level fluctuations and related environmental changes of the Amazon River. Amazoniana 9: 315-352.

The author analyzed seasonal changes in proximate composition of fishes in the Amazon River, Brazil. Migratory species that spawn once during the high water period accumulate large amounts of lipids. Lipid content is highest during the highest flood period and lowest at low water levels. Species which spawn batches over an extended period showed little or no seasonality in lipid content. The author attributes these patterns of proximate composition to the interplay of fish life history characteristics and seasonal water level fluctuations in the Amazon River basin.

Junk, W. J., P. B. Bayley, et al. 1989. The flood pulse concept in river-floodplain system. *in* D. P. Dodge (ed.). Proceedings of the International Large River Symposium 106:89-109 .

Junk, W. J. 1999. The flood pulse concept of large rivers: Learning from the tropics. River ecosystem concepts., Schweizerbart'sche Verlagsbuchhandlung, Stuttgart 115: 261-280.

Jurajda, P. 1995. Effect of channelization and regulation on fish recruitment in a flood plain river. Regulated Rivers Research and Management 10: 207-215.

The author sampled fishes in the Morava River, Czech Republic, to determine effects of channelization and flow regulation on species richness and recruitment. Species richness was unchanged, but proportions of fish species present had changed dramatically. Fishes that require vegetation or gravel for reproduction or as nursery areas were heavily affected. Also, some species with more generalized reproduction were also lower in abundance.

Karenge, L. and J. Kolding. 1995. On the relationship between hydrology and fisheries in man-made Lake Kariba, central Africa. Fisheries Research 22: 205-226.

This paper reports on inshore and pelagic catch-per-unit-effort (CPUE) in relation to water level in Lake Kariba, Africa. Values for CPUE correlated with time-lagged water level changes. Water level rises were particularly related to high CPUE. Absolute water levels did not correlate with CPUE.

Keith, W. E. 1975. Management by water level manipulation. pp. 489-497. *in* R. H. Stroud and H. Clepper. Black bass biology and management. Sport Fishing Institute, Washington, D. C.

This book chapter describes water level manipulation as a management tool for largemouth bass *Micropterus salmoides*. Increasing water level has the following benefits- detritus and decomposition add nutrients to the system to stimulate productivity, terrestrial food organisms are available, excellent cover is created, new areas are opened, lowering overall fish density. This situation is best exemplified by new reservoirs and inundation of floodplains. Decreasing water levels have an opposite effect. Decreasing water levels can increase fish growth, however, by concentrating prey fish and increasing their vulnerability to sport fish predators. The author recommends use of drawdowns and subsequent refill prior to largemouth bass spawning as a management tool.

Keller, A. E. and D. S. Ruessler. 1997. Determination or verification of host fish for nine species of unionid mussels. American Midland Naturalist 138: 402-407.

This paper reports on host fishes for the glochidia stage of nine unionid mussels, mostly

from Florida. Fish host identification is important in mussel conservation because habitat requirements of the fish host (e.g., instream flow requirements) must be provided in addition to the habitat requirements of the mussel itself. The authors identified previously unknown hosts for *Elliptio buckleyi*, *E. icterina*, *Lampsilis straminea claibornensis*, *Villosa lienosa,* and *V. villosa.* Successful transformations of host were achieved for *Lampsilis siliquoidea*, *L. teres*, *Megalonaias nervosa* and *Utterbackia imbecillis.* Fish hosts included, among others, minnows, catfish, and sunfish.

Kelsch, S. W. 1994. Lotic fish-community structure following transition from severe drought to high discharge. Journal of Freshwater Ecology 9: 331-341.

The author reports on fish sampling in the Little Missouri River, North Dakota, during a nine day flood period following a six year drought. During sampling, water velocities were high, but water discharge, levels, and temperatures fluctuated in response to rainfall. The author collected only about one half of the number of species known to occur in the study area. Only three species, all known to be well-adapted to high flow, were common. Other fishes were apparently relegated to refugia or were swept from this portion of the river.

Killgore, K. J. and A. C. Miller. 1985. Effects of water level changes on fishes of the Yazoo River basin, Mississippi. 85-10. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Killgore, K. J. and P. M. Hathorn. 1987. Environmental impact research program: Application of the habitat evaluation procedures in Cypress Bayou basin, Texas. 87-4. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Kissick, L. A., M. H. Paller, et al. 1988. Seasonal and diel patterns of larval fish drift in a western South Carolina swamp. 880775-1. U. S. Department of Energy. Washington, D. C.

Knight, J. G., M. B. Bain, et al. 1991. A habitat framework for assessing the effects of streamflow regulation on fish. Alabama Cooperative Fish and Wildlife Research Unit.

This report presents a habitat-based method for describing how fish assemblages use microhabitat and a framework for assessing instream flow needs. This method was developed using fish and habitat data from seven Alabama River basin streams. Using multivariate analysis of variance and principle components analysis, the authors identified five habitat-use assemblages- shallow-fast habitat, slow-cover habitat, deep-fast habitat, shallow-slow habitat, and shallow-coarse habitat. Instream flow recommendations should include the shallow-slow habitat and the shallow-coarse habitat because these contain the highest species richness and fish densities, and these types of habitats are most sensitive to reductions in flow.

Kohler, C. C., R. J. Sheehan, et al. 1993. Largemouth bass hatching success and first-winter survival in two Illinois reservoirs. North American Journal of Fisheries Management 13: 125-133.

This paper explored the relationship between water level and recruitment of largemouth bass *Micropterus salmoides* in Illinois reservoirs. Hatching success was disrupted during rapid fluctuations in water level and hatching success was best under stable water level conditions. There was no relationship, however, between water level fluctuations during the spawning season and year-class strength. The authors do caution that hatching disruptions may greatly influence cohort strength if water level fluctuations occur throughout the spawning period. Largemouth bass recruitment was considerably higher in high-water years than in low-water years.

Kondolf, G. M., E. W. Larsen, et al. 2000. Measuring and modeling the hydraulic environment for assessing instream flows. North American Journal of Fisheries Management 20: 1016-1028.

This paper describes some problems with physical habitat simulation model (PHABSIM) and the use of two-dimensional models to better define depth and velocity fields. The authors question the applicability and utility of PHABSIM models and review the assumptions, accuracy, and precision of hydraulic modeling for instream flow requirements. Information on depth, velocity, and substrate is important for assessing instream flows, but information from hydraulic models should be treated with great caution and is not a substitute for biological understanding.

Krieger, D. A., J. W. Terrell, et al. 1983. Habitat suitability information: Yellow perch. FWS/OBS-82/10.55. U. S. Fish and Wildlife Service. Ft. Collins, Colorado.

This report presents Habitat Suitability Indices (HSI) and Suitability Index (SI) curves for riverine and lacustrine populations of yellow perch *Perca flavescens*. Relevant biological data and citations are presented.

Kushlan, J. A. 1973. Differential responses to drought in two species of *Fundulus*. Copeia 1973: 808-809.

The author noted differences in behavior of golden topminnow *Fundulus chrysotus* and marsh killifish *F. confluentus* in relation to lowering water levels in the Big Cypress Swamp, Florida. Golden topminnow retreated to remaining pools whereas marsh killifish massed in shallow areas that were frequently isolated from permanent water. These differences may relate to different reproductive strategies. Marsh killifish may spawn during this time as their eggs can survive periods out of water in humid microclimates. Golden topminnows spawn on submerged vegetation.

Kwak, T. J. 1988. Lateral movement and use of floodplain habitat by fishes of the Kankakee River, Illinois. American Midland Naturalist 120: 241-249.

The author trapped fishes moving between channel and two floodplain habitats: an ephemeral ditch and a permanent pool in the Kankakee River, Illinois. Number of fish trapped was positively correlated with river discharge. The high numbers of juveniles trapped indicated the value of floodplains as nursery habitat. The author concluded that floodplain-associated species, including grass pickerel *Esox americanus* and pirate perch *Aphredoderus sayannus*, seek similar backwater habitats when flood water recede from the floodplain.

Kwak, T. J., M. J. Wiley, et al. 1992. Application of diel feeding chronology to habitat suitability analysis of warmwater stream fishes. Canadian Journal of Fisheries and Aquatic Sciences 49: 1417-1430.

This paper reports on diel feeding chronology for common carp *Cyprinus carpio*, golden redhorse *Moxostoma erythrurum*, channel catfish *Ictalurus punctatus*, smallmouth bass *Micropterus dolomieu*, and longear sunfish *Lepomis megalotis* in the Vermillion River, Illinois. Current habitat suitability analyses (e.g., instream flow incremental methodology, IFIM) do not take into account food availability or temporal habitat use based on feeding chronology, ignoring potentially important information needed to implement biologically meaningful instream flow recommendations. The authors found significant differences in microhabitat use during high feeding periods relative to low feeding periods for each species. The authors report microhabitat utilization in terms of depth, mean velocity, bottom velocity, and substrate for high and low feeding periods. The results imply that realism could be improved in instream flow assessments if habitat suitability criteria were stratified according to feeding chronology and microhabitat use.

Lamouroux, N., E. Doutriaux, et al. 1999. Modelling impacts of minimum flow management on fish communities of the Rhone river, France. Bulletin francais de la peche et de la pisciculture 352: 45-61.

Lamprecht, S. D. and W. L. Shelton. 1986. Spatial and temporal movements of striped bass in the upper Alabama River. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 40: 266-274.

This paper documents movements of radio-tagged striped bass *Morone saxatilis* in the Alabama River, Alabama. Fish showed differences in movement and holding site based on water releases from Thurlow Dam. The authors stated that interpretation of fish movements was complicated by co-occurrence of daylight and flow and that both factors were likely important in influencing daily behavior.

Layzer, J. B. and L. M. Madison. 1995. Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs. Regulated Rivers: Research & Management 10: 329-345.

This study investigated the use of instream flow incremental methodology (IFIM) for determining instream flow needs for freshwater mussels in Horse Lick Creek, Cumberland River system, Kentucky. The authors found that IFIM curves are of limited utility for mussel conservation because the hydraulic measures are too simple and the curves are flow-specific. Mussels have limited mobility and their distribution was linked to shear stress over a range of flows. Nevertheless, simple measures of water depth and velocity were important at low flows. At high flows, the relationship between shear stress and mussel abundance was not significant due to variable relationships between shear stress and discharge as modified by channel morphology. The authors stated that shear stress was a major factor limiting mussel recruitment and that floods during critical periods of juvenile settlement may destroy potential recruits. Host-fish habitat was not significantly related to mussel abundance, perhaps due to unacceptably high shear stress values found in much of the host-fish habitat. The authors still stressed that host-fish habitat be considered in any determination of instream flow needs for mussels with parasitic glochidia. The general conclusion was that determining instream flow needs for mussel conservation is complex and data-intensive, that IFIM is not adequate for mussels, minimum depths are necessary for mussels during low flow, that shear stress be minimized over existing mussel beds.

Lee, L. A. and J. W. Terrell. 1987. Habitat suitability index models: Flathead catfish. Biological Report 82(10.152). U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability

Index (SI) curves for flathead catfish *Pylodictis olivaris*. Relevant biological data and citations are presented.

Leitman, H. M., M. R. Darst, et al. 1991. Fishes in the forested flood plain of the Ochlockonee River, Florida, during flood and drought conditions. Water Resources Investigations Report 90-4202. United States Geological Survey and Florida Game and Fresh Water Fish Commission. Tallahassee, Florida.

This report provides extensive data on use by fishes of inundated floodplain and isolated floodplain pools of the Ochlockonee River, Florida. A total of 48 species were collected during the study and three-quarters of the species used inundated floodplains. Species commonly collected from inundated floodplain were gizzard shad *Dorosoma cepedianum*, weed shiner *Notropis texanus*, brown bullhead *Ameiurus nebulosus*, eastern mosquitofish *Gambusia holbrooki*, bluegill *Lepomis macrochirus*, redbreast sunfish *Lepomis auritus*, and redear sunfish *Lepomis microlophus*. Common species (of 13 collected) sampled from isolated floodplain pools during a 10-14 month drought included eastern mosquitofish, pirate perch *Aphredoderus sayannus*, flier *Centrarchus macropterus*, and warmouth *Chaenobryttus gulosus*. Seven common floodplain species were rare or absent in main channel collections, redfin pickerel *Esox americanus*, taillight shiner *Notropis maculatus*, brown bullhead, least killifish *Heterandria formosa*, banded pygmy sunfish *Elassoma zonatum*, flier, and bluespotted sunfish *Enneacanthus gloriosus*, implying reliance on floodplains for their persistence. Information is presented on the hydrology and vegetation associated with this floodplain. The authors present some circumstantial evidence of reproduction by fishes on the floodplain, including 16 species collected as young-of-year or as adults in spawning condition. Seven species were collected in spawning condition in isolated pools during low water, but only eastern mosquitofish was confirmed as successfully producing offspring. Young-of-year of nine species were collected on the floodplain during or shortly after the flood. The report provides a discussion, with citations, of the importance of floodplain hydrology and vegetation to fishes.

Leonard, P. M. and D. J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. North American Journal of Fisheries Management 8: 399-409.

This paper grouped eight warmwater fishes, including redbreast sunfish *Lepomis auritus*, into four habitat-use guilds based on a cluster analysis of depth, velocity, substrate, and cover use. The guilds were largely separated by water velocity. Habitat-suitability criteria were developed for each species and life stage combination, and these criteria were used in physical habitat simulations to determine relations between weighted usable area (WUA) and discharge for three streams in the upper James River basin, Virginia. The relationship between WUA and discharge was relatively stable for habitat generalists and a few habitat specialists over a wide range of flows. The authors recommend including species or life stages from different habitat-use guilds to ensure that instream flow management actions address the needs of the entire fish assemblage.

Light, H. M., M. R. Darst, et al. 1993. Biology, vegetation, and soils of four north Florida river floodplains with an evaluation of state and federal wetland determinations. Water Resources Investigations Report 93-4033. United States Geological Survey and Florida Department of Environmental Regulation. Tallahassee, Florida.

This report discusses hydrology, vegetation, and soils for the Ochlockonee River, Aucilla

River, Telogia Creek, and St. Marks River floodplains in the eastern Florida Panhandle. There is no information presented on fish populations. This report was included due to the extensive descriptions and other relevant information presented on these Florida floodplain river systems.

Light, H. M., M. R. Darst, et al. 1995. Hydrologic conditions, habitat characteristics, and occurrence of fishes in the Apalachicola River floodplain, Florida: Second annual report of progress, October 1993-September 1994. Open-File Report 95-167. U. S. Geological Survey and Northwest Florida Water Management District. Tallahassee, Florida.

This is a progress report for a study of Apalachicola River, Florida, hydrology and habitats. It contains an appendix of relative abundance of Apalachicola River fish species in floodplains of eastern rivers, with citations.

Light, H. M., M. R. Darst, et al. 1998. Aquatic habitats in relation to river flow in the Apalachicola River floodplain, Florida. U. S. G. S. Professional Paper 1594. U. S. Geological Survey and Northwest Florida Water Management District. Tallahassee, Florida.

This report provides a great deal of hydrological and habitat information of relevance to fishes for the Apalachicola River, Florida. It contains a brief review of fishes in river floodplains in the southeastern USA, including a table of floodplain use by species found in the Apalachicola River. At least 80% of fish species in the Apalachicola River have been collected on floodplains in the southeastern USA during various hydrological stages. The system has several floodplain-associated fish species.

Lindberg, W. J., (ed.). 1997. Florida Big Bend Coastal Research Workshop: Toward a scientific basis for ecosystem management. Technical Paper 88. Florida Sea Grant and University of Florida. Steinhatchee, Florida.

Proceedings of a conference held to define the state of knowledge relating to the Florida Big Bend region and to foster coordination of research activities among researchers interested in the region. There are a few papers of potential interest in terms of instream flow effects on fishes, but generally as these relate to coastal and estuarine areas.

Liston, C. R. and S. Chubb. 1985. Relationships of water level fluctuations and fish. pp. 121-140. *in* H. H. Prince and F. D. D'Itri. Coastal wetlands. Lewis Publishers, Chelsea, Michigan.

This book chapter reviews the effects of water level fluctuations on fish. High water in spring can have the benefits of increasing productivity by releasing nutrients from inundated terrestrial vegetation, flushing in terrestrial food items (e.g., insects and oligochaetes), adding structure and cover by flooding vegetation and snags, and increasing area of habitat available for fish to exploit. Largemouth bass *Micropterus salmoides* reproduction is enhanced when water level increases occur immediately before, during, and for a short time following the spawning and nursery period. Not only high water levels, but high and stable water levels are important for fish recruitment. Fluctuations can adversely affect spawning activities and nursery function. Water level changes may also affect reproduction through water temperature changes. Moreover, unstable water levels may alter substrate composition (e.g., accelerate silt accumulation) and benthic invertebrate communities.

Livingston, R. J. 1997. Trophic response of estuarine fishes to long-term changes of river runoff. Bulletin of Marine Science 60: 984-1004.

This paper reports on the results of a 13 year study that explored the response of estuarine fishes to seasonal and annual variations of outflow from the Apalachicola River and the associated habitat changes in East Bay, Apalachicola Bay system, Florida. Changes in freshwater flow were major influences on fish numbers and biomass. Complex productivity and trophic patterns within the estuary were altered by changes in river discharge. Estuarine fish assemblages were indirectly responsive to changes of river flow through prey responses to habitat and productivity variables associated with river flows. This suggests that the fish associations were strongly dependent on interannual patterns of Apalachicola River flow, but that such relationships were primarily caused by biological interactions as defined by specific predator/prey relationships. A prolonged drought led to reduced fish species richness and trophic diversity. Drought-associated habitat stress was related to enhanced instability of the biological components of the estuary as a function of changes in nutrient cycling. The food web was simplified while overall fish biomass and individual species populations were numerically reduced. This paper focuses on the trophic mechanisms resulting in changes in fish populations due to fluctuations in freshwater inputs.

Livingston, R. J., X. Niu, et al. 1997. Freshwater input to a gulf estuary: Long-term control of trophic organization. Ecological Applications 7: 277-299.

This paper examined the relationship between freshwater inflows of the Apalachicola River and trophic organization of the Apalachicola Bay, Florida. Loss of freshwater inflow resulted in a major loss of productivity in this river-dominated estuary. The long-term data indicated that, with reduction of freshwater flow below a level specific for the receiving system, the physically controlled, highly productive river-estuarine system would become a species-rich, biologically controlled bay with substantially reduced productivity.

Livingstone, R., Jr. 1965. A preliminary bibliography with KWIC Index on the ecology of estuaries and coastal areas of the eastern United States. Special Scientific Report-Fisheries no. 507. U. S. Fish and Wildlife Service. Washington, D. C.

This bibliography includes nearly 5,500 citations concerning estuaries of the eastern USA, mainly covering the period 1900-1960.

Loftus, W. F., J. D. Chapman, et al. 1986. Hydroperiod effects on Everglades marsh food webs, with relation to marsh restoration efforts. 6: Fisheries and Coastal Wetlands Research. The Fourth Conference on Research in the National Parks and Equivalent Reserves: Conference on Science in the National Parks, U. S. National Park Service and The George Wright Society, Ft. Collins, Colorado.

The authors hypothesized that marsh hydroperiod determines the development of aquatic animal communities. Short hydroperiods limit fish populations through desiccation, food web effects, and predation. Conversely, long hydroperiod marshes should have higher fish abundance, partly due to increased availability of detritus to support food webs. Preliminary fish data from the Everglades, Florida, support this hypothesis. The authors predict that efforts to restore historic water inputs will result in increased aquatic animal abundance.

Loftus, W. F., R. A. Johnson, et al. 1992. Ecological impacts of the reduction of groundwater levels in short-hydroperiod marshes of the Everglades. Proceedings of the First International Conference on Ground Water Ecology, U. S. Environmental Protection Agency and American

Water Resources Association, Tampa, Florida.

Higher elevation and short hydroperiod marshes in the Everglades, Florida, have suffered reduced surface-water and groundwater levels due to water management practices since the 1930s. Fishes and other aquatic organisms survive seasonal dry-downs by moving into surface depressions and subsurface solution cavities. These karst features serve as refugia until seasonal rains refill marshes. Higher numbers of fishes presumably survived dry-downs historically due to greater availability and persistence of refugia. Reduced water resources limit surface refugia, force earlier entry into subsurface refugia, and reduce food resources available to wading birds.

Loftus, W. F. and A. Eklund. 1994. Long-term dynamics of an Everglades small-fish assemblage. pp. 461-483. *in* S. Davis and J. Ogden. Everglades: The Ecosystem and its Restoration. St. Lucie Press, Delray Beach, Florida.

This study re-evaluates data from a long-term pull-trap study in the Everglades, Florida, and provides new information from long-term throw-trap sampling. The pull-trap study orignally led to the conclusion that long hydroperiods benefitted large-bodied, predatory fishes at the expense of small fishes. The new data and the re-interpretation of old data suggest that both large and small fishes benefit from longer hydroperiods and that predation does not limit small fishes during these times. Therefore, the authors conclude that restoration efforts that emphasize a return to historic hydrology with more water inputs will increase fish production in the Everglades.

Loneragan, N. R. and S. E. Bunn. 1999. River flows and estuarine ecosystems: Implications for coastal fisheries from a review and case study of the Logan River, southeast Queensland. Australian Journal of Ecology 24: 431-440.

This paper discusses the importance of freshwater inputs to estuarine productivity and fisheries. River inputs likely do not directly enter food webs but exported nutrients stimulate estuarine productivity, thereby increasing survival and growth of fish and macroinvertebrates. Salinity fluctuations caused by river inputs determine available habitat and fish distributions. High river discharges are important for fisheries. However, the seasonal pattern of flow may be more important than the magnitude of annual flow.

Lorenz, J. J. 1999. The response of fishes to physicochemical changes in the mangroves of northeast Florida Bay. Estuaries 22: 500-517.

This paper reports on the influence of freshwater inflow on fishes in a Florida Bay mangrove habitat. Fish density was significantly related to short-term and long-term changes in water level. Temperature was also a factor. Sites with a longer hydroperiod had higher densities of fish than sites with a shorter hydroperiod. Increased water level and decreased variability in depth were correlated with higher fish biomass. Salinity, influenced by freshwater inputs, also affected biomass. Sites with longer freshwater periods had more fish biomass and larger-bodied fish than sites with shorter freshwater periods. The author concluded that salinity was a primary determinant of community structure and that altered freshwater delivery to the mangrove zone has lowered prey availability for higher trophic levels.

Lowe-McConnell, R. H. 1987. Ecological studies in tropical fish communities. Cambridge University Press, Cambridge, England.

This book contains general discussions concerning relationships of fishes and fish assemblages to environmental factors in Africa, South America, and southeast Asia. Many aspects of these relationships are dominated by seasonal flooding and the use of inundated floodplain by fishes for food, spawning, and nursery areas.

Lukas, J. A. and D. J. Orth. 1993. Reproductive ecology of redbreast sunfish *Lepomis auritus* in a Virginia stream. Journal of Freshwater Ecology 8: 235-244.

This report examines reproduction in redbreast sunfish *Lepomis auritus* in North Anna River, Virginia. Nests were constructed in pools with low velocities and in water deeper than 0.5 m. A high flow event destroyed all redbreast sunfish nests in early summer. Low, stable flow during summer enhanced reproduction.

Maceina, M. J. 1993. Summer fluctuations in planktonic chlorophyll a concentrations in Lake Okeechobee, Florida: The influence of lake levels. Lake and Reservoir Management 8: 1-11.

This study documented a positive relationship between water levels and chlorophyll a concentrations in littoral areas in summer in Lake Okeechobee, Florida. The author concluded that the large size of the lake, its shallow depth, and bottom configuration contributed to horizontal mixing and circulation, thus leading to increased phosphorus levels in littoral areas.

Maceina, M. J. and P. W. Bettoli. 1998. Variation in largemouth bass recruitment in four mainstream impoundments of the Tennessee River. North American Journal of Fisheries Management 18: 998-1003.

The authors used catch-curves, hydrologic data, and aquatic plant abundance to explore their relationships with year class strength in largemouth bass *Micropterus salmoides*. Poor year classes correlated with high June-July reservoir discharge and short retention times. These occurrences resulted from wet early summer conditions. Water level fluctuations during spawning (April-May) and late-summer aquatic plant abundance were not related to year class strength. The authors speculated that higher discharges and faster flushing rates were associated with reduced production at lower trophic levels and poorer survival of young largemouth bass that ultimately affected recruitment to adult size.

Martin, D. B., L. J. Mengel, et al. 1981. Spring and summer water levels in a Missouri River reservoir: Effects on age-0 fish and zooplankton. Transactions of the American Fisheries Society 110: 370-381.

The authors examined abundance, growth, and diet of age-0 fishes, and zooplankton abundance and composition for a low water and a high water year in Lake Francis Case, Missouri River, South Dakota. Yellow perch *Perca flavescens*, white bass *Morone chrysops*, buffaloes *Ictiobus* spp., and centrarchids were significantly more abundant in the high water year than the low water year. The authors attribute this to enhanced spawning success and larval survival due to areas of flooded vegetation. Zooplankton standing crops for larger species were lower, but smaller species had higher standing crops in the high water year. The authors attribute this to increased predation by increased numbers of larval fishes. Even with increased abundance of age-0 fishes and decreased overall zooplankton standing crop, there was no significant difference in first summer growth of the four most abundant species.

Martin, M. H. 1995. The effects of temperature, river flow, and tidal cycles on the onset of glass eel and elver migration into fresh water in the American eel. Journal of Fish Biology 46: 891-

902.

This paper reports the effects of environmental variables on migration of American eel *Anguilla rostrata* glass eels and elvers into freshwater in Rhode Island. Early in the migration period, low river flow enhanced entry into freshwater whereas higher flows enhanced freshwater entry later in the period. Near the end of the migration period, tidal stage (i.e., incoming tide) was most influential.

Mathews, R. C., Jr. and Y. Bao. 1991. The Texas Method of preliminary instream flow assessment. Rivers 2: 295-310.

This paper presents the Texas Method for preliminary instream flow assessment. This method considers riverine fishes as primary target species, flow needs during the critical periods in the life stage of the fishery, and maintenance of the natural streamflow pattern. It also incorporates biological characteristics and regional hydrological characteristics. The paper also compares this new method with the five other commonly used preliminary planning methods.

Matthews, W. J., B. C. Harvey, et al. 1994. Spatial and temporal patterns in the fish assemblages of individual pools in a midwestern stream (USA). Environmental Biology of Fishes 39: 381-397.

This paper discusses results of 19 months of snorkeling surveys in 14 pools of Brier Creek, Oklahoma. The pool fish fauna of the total 1 km reach (i.e., including all 14 pools) was highly consistent throughout the study, despite two major floods. Some variation was evident at the finer scale of individual pool. Overall, floods had relatively little effect on pool fish assemblages.

McAdam, D. S. O., N. R. Liley, et al. 1999. Comparison of reproductive indicators and analysis of the reproductive seasonality of the tinfoil barb, *Puntius schwanenfeldii*, in the Perak River, Malaysia. Environmental Biology of Fishes 55: 369-380.

This paper outlines reproductive seasonality of the tinfoil barb *Puntius schwanenfeldii* in Malaysia. Tinfoil barbs typically spawn in close association with seasonal floods. In the regulated Perak River, however, tinfoil barbs show aseasonal reproduction, indicating some flexibility in reproductive strategy of a floodplain-dependent species in accommodating variable flow regimes.

McKinney, T., D. W. Speas, et al. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21: 216-222.

This paper reports on changes in rainbow trout *Oncorhynchus mykiss* in the tailwater below Glen Canyon Dam, Colorado River, Arizona, after implementation of a new minimum flow regime. Under the new flow schedule, flow variability was reduced. Under the new regime, rainbow trout were more abundant. However, condition of larger rainbow trout (> 350 mm TL) declined. The data were interpreted by the authors as suggesting that small rainbow trout were more influenced by physical factors (e.g., flow variation, mean discharge, water temperature) than were larger rainbow trout.

McMahon, T. E. and J. W. Terrell. 1982. Habitat suitability index models: Channel catfish. FWS/OBS-82/10.2. U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for channel catfish *Ictalurus punctatus*. Relevant biological data and citations are presented.

McMahon, T. E., G. Gebhart, et al. 1984. Habitat suitability index models and instream flow suitability curves: Spotted bass. FWS/OBS-82/10.72. U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for spotted bass *Micropterus punctulatus*. Relevant biological data and citations are presented.

McMahon, T. E., G. Gebhart, et al. 1984. Habitat suitability index models and instream flow suitability curves: Warmouth. FWS/OBS-82/10.67. U. S. Fish and Wildlife Service. Ft. Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for warmouth *Chaenobryttus* (*Lepomis*) *gulosus*. Relevant biological data and citations are presented.

Meals, K. O. and L. E. Miranda. 1991. Variability in abundance of age-0 centrarchids among littoral habitats of flood control reservoirs in Mississippi. North American Journal of Fisheries Management 11: 298-304.

Abundance of age-0 sunfishes *Lepomis* spp., largemouth bass *Micropterus salmoides*, and crappies *Pomoxis* spp. was determined in five types of habitats in four flood control reservoirs in years of high and low water. Although the rankings of abundance among habitat types remained similar during the years of high and low water, relative increases in abundance during high water were disproportional, and habitat types with low fish abundance generally benefited more from increases in water level. Nesting success and survival of nest-building gamefish were enhanced by high water flooding terrestrial vegetation.

Mesing, C. L. and A. M. Wicker. 1986. Home range, spawning migrations, and homing of radio-tagged Florida largemouth bass (*Micropterus salmoides*) in two central Florida lakes. Transactions of the American Fisheries Society 115: 286-295.

The authors found that Florida largemouth bass *Micropterus salmoides floridanus* in Lake Yale and Lake Eustis moved to littoral areas, often near structure, during the spawning season (i.e., late winter through early spring). Many fish moved to areas protected from wind and waves.

Michaletz, P. H. 1997. Factors affecting abundance, growth, and survival of age-0 gizzard shad. Transactions of the American Fisheries Society 126: 84-100.

This study examined abundance, growth, and survival of age-0 gizzard shad *Dorosoma cepedianum* in Missouri as influenced by temperature and reservoir level. Rising water levels coincided with intense spawning activity, high larval abundance, and the formation of large peaks of weekly cohort abundance. Low water levels coincided with lower, more even, abundance of larval gizzard shad. Larval gizzard shad showed density-dependent mortality. Growth and mortality of juvenile gizzard shad was not significantly associated with water level.

Miranda, L. E., W. L. Shelton, et al. 1984. Effects of water level manipulation on abundance, mortality and growth of young-of-year largemouth bass in West Point Reservoir, Alabama and Georgia (USA). North American Journal of Fisheries Management 4: 314-320.

The authors explored the relationship between water level and abundance, growth, and survival of age-0 largemouth bass *Micropterus salmoides* in West Point Reservoir, Alabama and Georgia. They felt that inundation of terrestrial vegetation was a major factor in enhancing cohort strength. A positive relationship was observed between early survival of age-0 largemouth bass and water level during the spawning period. In the post-spawning period, survival rate, and abundance of age-0 were related directly to water level, but growth was inversely affected. The results indicated that increased abundance and survival of age-0 largemouth bass can lead to slower growth due to limitations on system carrying capacity.

Mitchell, D. F. 1982. Effects of water level fluctuation on reproduction of largemouth bass, *Micropterus salmoides*, at Millerton Lake, California, in 1973. California Fish and Game 68: 68-77.

The author found that largemouth bass *Micropterus salmoides* reproduction was adversely effected by rising and falling water levels during the nesting period. Nests were lost to rising water levels due to reduced temperatures that were unfavorable to egg development and apparently led to reduced nest defense and tending by the guarding male. Nests were exposed during water level drops. Successful nesting only occurred during periods of water level stability. The water level changes were rapid and the author suggested staged water level changes to prevent loss of largemouth bass reproduction.

Mol, J. H. 1994. Effects of salinity on distribution, growth and survival of three neotropical armoured catfishes (Siluriformes: Callichthyidae). Journal of Fish Biology 45: 763-776.

The author found that juvenile brown hoplo *Hoplosternum littorale* growth was optimal at salinities ranging from 1000 to 4000 mg Cl/L. The species was not capable of surviving in electrolyte-poor water.

Mol, J. H. 1996. Reproductive seasonality and nest-site differentiation in three closely related armoured catfishes (Siluriformes: Callichthyidae). Environmental Biology of Fishes 45: 363-381.

This study describes the reproductive biology of brown hoplo *Hoplosternum littorale* in coastal plain swamps and marshes in Suriname. This species builds an elaborate bubble nest incorporating plant material for the eggs. The male builds and defends the nest. Males may build up to 14 nests per season and the females may lay eggs up to 14 times per season. The species spawns in small batches. Nests are usually built in flooded areas, near floating vegetation or in open stands of emergent vegetation, and at depths > 30 cm. A few nests were found along canal banks, but not in flooded areas with forest canopy or extremely dense stands of floating or emergent vegetation. Reproduction is closely tied to rising water levels and success correlates with rainfall amounts. In Suriname, the species has two reproductive peaks coincident with bimodal flood peaks. The author reviewed much of the published work on brown hoplo reproduction.

Mosley, M. P. 1982. Critical depths for passage in braided rivers, Canterbury, New Zealand. New Zealand Journal of Marine and Freshwater Research 16: 351-357.

The author measured minimum depths in shallow sections of New Zealand rivers and related these depths to river flow. These data can then be used to predict discharges required to maintain critical minimum depths for fish passage and recreational boating. He then found literature on minimum depths required for passage of salmonids and used these data for developing flow recommendations. The author mentioned that he felt the minimum depths in the literature were conservative, being based on fish morphology and not behavior and that minimum depth requirements must be more accurately determined before instream flow needs can be properly assessed.

Moyer, E. J., M. W. Hulon, et al. 1995. Fishery responses to habitat restoration in Lake Tohopekaliga, Florida. North American Journal of Fisheries Management 15: 591-595.

This paper reports on the effects of an extreme draw-down and muck removal on fishes in Lake Tohopekaliga, Florida. The authors found an immediate positive response in fish populations. Electrofishing catch-per-effort of largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, redear sunfish *L. microlophus*, and forage species was higher in restored sites than in control (unrestored) sites. Also, Wegener ring sampling revealed more abundant age-0 largemouth bass and other sport fish in restored compared to control sites. The authors commented that although immediate benefits were evident, long-term benefits were less certain. Dense vegetation returned to restored sites within three years, limiting the benefits to sport fish. Nevertheless, the study documented water level fluctuation as a tool for sport fish enhancement.

Moyle, P. B. and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: Developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114: 695-704.

The authors investigated microhabitat use by a California stream fish assemblage. They found that each species and life stage studied had a specific microhabitat preference based on depth, velocity, and substrate, although there was much similarity among species and life stages in their preferences. The amount of available preferred microhabitat differed among species but did not explain local assemblage structure. The authors recommend using site-specific microhabitat use and availability data for instream flow needs but caution that abiotic factors and biotic interactions may cause unexpected shifts in microhabitat use.

Moyle, P. B. and T. Light. 1996. Fish invasions in California: Do abiotic factors determine success? Ecology 77: 1666-1670.

The authors discuss abiotic resistance of California habitats to invasion by nonindigenous fishes. Several predictions regarding fish invasions were made, including that the most successful invaders will be those adapted to the local hydrologic regime.

Moyle, P. B., M. P. Marchetti, et al. 1998. Fish health and diversity: Justifying flows for a California stream. Fisheries 23: 6-15.

Nelson, C. M. and W. Loftus. 1996. Fish communities of alligator ponds in the high water periods of 1983-1985 and 1994-1996. Ecological Assessment of the 1994-1995 High Water Conditions in the Southern Everglades, Miami, Florida.

Alligator ponds are important refuges for fishes during dry periods in the Everglades, Florida. This study describes seasonal and inter-annual changes in fish community characteristics of alligator ponds for 1983-1996 relative to water level changes.

Noltie, D. B. and M. H. A. Keenleyside. 1987. Breeding ecology, nest characteristics, and nest-site selection of stream- and lake-dwelling rock bass, *Ambloplites rupestris* (Rafinesque). Canadian Journal of Zoology 65: 379-390.

The authors reported on breeding ecology, including relationships to stream flow, of the rock bass *Ambloplites rupestris* in Ontario, Canada. Variable flooding was a major factor in rock bass reproductive success. Stream-dwelling populations bred earlier, at lower temperatures, and over a longer time period than did lake-dwelling rock bass. This was interpreted as a response to the variable and rigorous stream environment.

O'Brien, W. J. 1990. Perspectives on fish in reservoir ecosystems. pp. 209-225. *in* K. W. Thornton, B. L. Kimmel and F. E. Payne. Reservoir limnology: Ecological perspectives. John Wiley & Sons, New York.

This book chapter discusses fish ecology in reservoirs. It notes that fluctuating water level is a major factor in spawning success or failure. In general, high or rising water benefits fish reproduction. Inundated terrestrial vegetation is often used as a spawning substrate. Initial fish productivity is high following impoundment due especially to benthic invertebrate production. Inundated terrestrial vegetation is an important source of invertebrate food and nutrient input for new reservoirs.

O'Brien, C. A. and J. B. Box. 1999. Reproductive biology and juvenile recruitment of the shinyrayed pocketbook *Lampsilis subangulata* (Bivalvia: Unionidae) in the Gulf coastal plain. American Midland Naturalist 142: 129-140.

This paper reports on reporductive biology, especially fish hosts, for the shinyrayed pocketbook *Lampsilis subangulata*, a federally endangered mussel, from the Apalachicola and Ochlockonee river systems. Water temperatures and dates of glochidia release, but no flow data, were given for a Flint River tributary in Georgia. Primary fish hosts identified were largemouth bass *Micropterus salmoides* and spotted bass *M. punctulatus*.

Orth, D. J. and O. E. Maughan. 1981. Estimated stream flow requirements for fishes of the Washita River below Foss Reservoir, western Oklahoma. Water Resources Bulletin 17: 831-843.

This paper is an example of developing a new model and applying an existing model for Instream Flow Incremental Methodology (IFIM) for red shiner *Cyprinella lutrensis* (new) and channel catfish *Ictalurus punctatus* (existing) for the Washita River, Oklahoma.

Orth, D. J. and O. E. Maughan. 1982. Evaluation of the incremental methodology for recommending instream flows for fishes. Transactions of the American Fisheries Society 111: 413-445.

The authors tested the Instream Flow Incremental Methodology (IFIM) assumption that depth, velocity, and substrate are perceived independently by fishes using four species in an Oklahoma stream. This assumption was violated at least once for all species, especially so with the interaction between depth and velocity. The only large predator and sport fish tested, smallmouth bass *Micropterus dolomieu*, had no correlation between density and weighted usable area (WUA). Three other relatively small fishes did show correlations of density with WUA.

The authors concluded that low levels of usable habitat are certainly limiting and may be produced by extremely low or high flows, however, above a threshold WUA, other factors may override habitat limitation. In particular, for black bass *Micropterus* spp., recruitment processes are more complex than modeled by the construction of WUA curves.

Orth, D. J. and P. M. Leonard. 1990. Comparison of discharge methods and habitat optimization for recommending instream flows to protect fish habitat. Regulated Rivers Research & Management 5: 129-138.

Orth, D. J. 1995. Food web influences on fish population responses to instream flow. Bulletin Francais de la Peche et de la Pisciculture 339: 317-328.

Osborne, L. L., M. J. Wiley, et al. 1988. Assessment of the water surface profile model: Accuracy of predicted instream fish habitat conditions in low-gradient, warmwater streams. Regulated Rivers Research & Management 2: 619-631.

Osborne, L. L., P. B. Bayley, et al. 1993. Restoration of lowland streams: An introduction. Freshwater Biology 29: 187-194.

This paper discusses the recommendations derived from the Lowland Streams Restoration Workshop in Lund Sweden in 1991. It includes hydraulics and species ecologies as criteria. This reference also provides an avenue to access other papers from the workshop.

Paller, M. H. 1987. Distribution of larval fish between macrophyte beds and open channels in a southeastern floodplain swamp. Journal of freshwater ecology 4: 191-200.

Paller, M. H., S. F. Modica, et al. 1992. Short-term changes in a southeastern coastal plain fish assemblage following artificial increases in streamflow. Rivers 3: 243-259.

This paper reports on the effects of two artificial flooding events on the fish assemblages of two North Carolina streams. The fish assemblages were in the process of recovering and recolonizing the streams after a cessation in the discharge of heated cooling water. Both high flow events used non-heated water. Samples taken before and after the first flood event revealed major changes in the fish assemblages whereas the changes following the second event were less dramatic. After the first event, species number and fish abundance were reduced. After the second event, only minnows *Notropis* sp., spotted sucker *Minytrema melanops*, and largemouth bass *Micropterus salmoides* were reduced in number. Species number, total fish abundance, and condition (k) were little affected. The authors attribute the greater effects of the first flood event to the fact that only a few, transient fish of flow-sensitive species were initially present.

Paller, M. H. 1997. Recovery of a reservoir fish community from drawdown related impacts. North American Journal of Fisheries Management 17: 726-733.

This paper reports on the effect of an extended drawdown on a reservoir fish community in South Carolina. The drawdown lasted 3.5 years, reduced the reservoir surface area and volume by 50%, and completely exposed the littoral zone. The drawdown resulted in significant reductions in fish abundance and number of fish species, changes in the relative abundance of fishes, and changes in the size structure of individual species of fish. The reservoir fish community responded quickly to refilling. Fish numbers, species richness, and species

composition returned to pre-drawdown levels, but size structures of several species, including largemouth bass *Micropterus salmoides*, were dominated by smaller individuals. The authors stated that inundated terrestrial vegetation and rapid regrowth of aquatic macrophytes contributed to the quick rebound in fish populations. Small, vegetation-dependent species probably persisted during the drawdown in refugia provided by the inflowing stream and rapid macrophyte growth in shallow coves. No widespread fish kills were observed. This study provides evidence that reservoir fish communities may be resilient to large scale disturbances and quickly return to near pre-disturbance conditions provided that major fish kills do not occur and refugia are available for small, vegetation-dependent species.

Pearsons, T. N., H. W. Li, et al. 1992. Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. Transactions of the American Fisheries Society 121: 427-436.

The structure of fish assemblages in high desert streams of John Day Basin in Oregon was compared before and after a summer flash flood and two spring floods. Hydraulically complex stream reaches lost fewer fish and had higher fish diversities than hydraulically simple stream reaches. Timing of flooding affecting recruitment, with floods during or soon after reproduction being most detrimental.

Peebles, E. B. and M. S. Flannery. 1992. Fish nursery use of the Little Manatee River estuary (Florida): Relationships with freshwater discharge. Final report. Southwest Florida Water Management District.

Peterson, M. S. and M. R. Meador. 1994. Effects of salinity on freshwater fishes in coastal plain drainages in the southeastern U. S. Reviews in Fisheries Science 2: 95-121.

This paper presents a review of the effects of salinity on freshwater fish distribution, behavior, physiology, growth, reproduction, food habits, and fish communities. The review found that many freshwater fish can withstand extended exposure to salinities < 9 ppt, brief exposure to salinities < 15 ppt, but cannot survive chronic salinities of > 9 ppt. Salinity cannot be viewed as a solitary factor influencing freshwater fish distributions. Many other habitat and physiological factors also influence their distributions. The effects of salinity on growth of freshwater fish is mixed, but generally growth is slower at salinities near where the blood is isotonic. Most freshwater fishes cannot reproduce at salinities greater than 3-4 ppt. Freshwater fishes feed on functionally equivalent foods (but generally different species) in estuarine environments as they do in freshwater. The structure and function of freshwater fish communities in brackish habitats are largely determined by environmental stability.

Petr, T. 2000. Interactions between fish and aquatic macrophytes in inland waters. A review. FAO, Rome, Italy.

This work discusses the importance of flooded forest to fish and fisheries, submergence of forests in reservoirs, and the effects of drawdowns on macrophytes and fish. Most examples, particularly of fish use of floodplains, are for tropical regions (e.g., Africa, South America, southeast Asia). This work provides a brief general discussion and a limited introduction to the literature.

Pezold, F. 1998. Fish diversity in an isolated artificial wetland. Journal of Freshwater Ecology 13: 171-179.

This paper reports on sampling of adult, juvenile, and larval fishes in the Red Chute Bayou floodplain, Louisiana, from winter 1994 to mid-summer 1995. The sampled site is an isolated wetland and is not directly connected to the river. The authors found a fish assemblage resembling assemblages described from isolated, irregularly inundated, floodplain ponds in the lower Mississippi River basin. This assemblage is also qualitatively similar to that found in certain Florida habitats. Juvenile and larval fish densities were low and dominated by the flier *Centrarchus macropterus*. Fishes found in the system were characterized by the ability to reproduce in lotic conditions. The authors attributed the paucity of larval fishes and the absence of several species of fishes common in lower Mississippi River oxbows and sloughs to the lack of any connection to a river.

Pine, R. T., L. W. J. Anderson, et al. 1989. Effects of static versus flowing water on aquatic plant preferences of triploid grass carp. Transactions of the American Fisheries Society 118: 336-344.

The authors tested aquatic macrophyte preferences of triploid grass carp *Ctenopharyngodon idella* in static and flowing systems and in summer and winter. They found slight differences in winter food preferences between static and flowing water systems.

Pitman, V. M. 1993. Relationship between power plant recharge waters and young-of-year largemouth bass abundance. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 47: 605-610.

The author assumed that failures in largemouth bass *Micropterus salmoides* reproduction in a Texas cooling reservoir were associated with a repressive factor (e.g., poor water quality, pesticides, heavy metals, crowded conditions, or the presence of competitive species). Previous work on the reservoir failed to identify a repressive factor. In this study, the reservoir was diluted with recharge water from the San Antonio River and with rainfall. These two inputs plus the discharge water volume were used to make an index of dilution. Density of age-0 largemouth bass was related to each of the variables independently and in combination. The combination (i.e., total dilution) during the pre-spawn (i.e., January-February) period was significantly related to age-0 abundance. The author concluded that a repressive factor must be involved and that diluting the reservoir immediately prior to the spawning period released the largemouth bass from this constraint. On the other hand, the author did not examine water level or other possible contributors to reproductive success.

Ploskey, G. R. 1982. Effects of water-level changes on reservoir ecosystems, fish, and fishing, with guidance on reservoir operations to enhance fisheries. Technical Report E-81. U. S. Fish and Wildlife Service and U. S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

This report reviews information on the effects of water level fluctuations on fish and reservoir ecosystems. The author found that most effects on fish were indirect, mediated by physicochemical changes that alter habitat or trophic conditions. This report contains a large amount of material of direct and indirect relevance to Florida. Included are sections on physicochemical systems, food organisms, trophic relations, reproduction, and productivity. The author also provides recommendations on reservoir operations that will enhance fisheries.

Ploskey, G. R. 1982. Fluctuating water levels in reservoirs: An annotated bibliography on environmental effects and management for fisheries. Technical Report E. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Ploskey, G. R., L. R. Aggus, et al. 1985. Effects of reservoir water levels on year-class development and the abundance of harvestable fish. 85-5. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

Poff, N. L. and J. V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: A regional analysis for streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46: 1805-1818.

This paper presents the results of a cluster analysis based on long-term discharge and biological characteristics of 78 streams in the United States. No streams were from Florida and only a half dozen were Gulf of Mexico or lower Atlantic coastal plain streams. The authors placed each in one of nine categories based on flow variability, flood regime, and extent of intermittency. The paper then discusses biological attributes of fish and invertebrate populations and communities based on a continuum of hydrologic factors.

Poff, N. L. and J. D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. Ecology 76: 606-627.

This paper used canonical discriminant analysis and regression analysis to test the hypothesis that functional organization of fish communities is related to hydrological variability. Data from 34 sites in Wisconsin and Minnesota were used for the analysis. Hydrological data could clearly separate the two ecologically defined groups of assemblages, which were associated with either hydrologically variable streams (high coefficient of variation of daily flows, moderate frequency of floods) or hydrologically stable streams (high predictability of daily flows, stable baseflow conditions). Findings were in general agreement with theoretical predictions that variable habitats should support resource generalists whereas stable habitats should be characterized by a higher proportion of specialist species. The strong hydrological-assemblage relationships suggest that hydrological factors are significant environmental variables influencing fish assemblage structure, and that hydrological alterations could modify stream fish assemblage structure.

Poizat, G. and A. J. Crivelli. 1997. Use of seasonally flooded marshes by fish in a Mediterranean wetland: Timing and demographic consequences. Journal of Fish Biology 51: 106-119.

The authors report on continuous monitoring of fish movements between a canal and two seasonally flooded marshes in southern France. Fish traps were used to capture fish moving into or out of the marshes for 2 or 3 years. The authors categorized the fish assemblage according to usage of the marsh as 1) small species that entered the marsh in large numbers to breed (e.g., mosquitofish *Gambusia affinis*), 2) larger species that entered the marsh in smaller numbers to breed (e.g., pumpkinseed *Lepomis gibbosus*, common carp *Cyprinus carpio*, and black bullhead *Ameiurus melas*), 3) species that seldom entered the marsh, and 4) migratory species that entered the marsh in small numbers but did not breed there (e.g., striped mullet *Mugil cephalus*). A demographic balance was estimated as the difference between the number of fish leaving and the number of fish entering the marsh. Most species showed a net negative demographic balance, the sole exception being the three-spined stickleback *Gasterosteus aculeatus*. Mosquitofish occasionally showed a positive demographic balance. Species that entered the marshes soon after flooding, reproduced rapidly, and left the marsh early had less risk of stranding, desiccation, and predation. The variability and short duration of flooding exposed most species to high risks. The authors concluded that hydrology may influence fish community structure through interspecific differences in survival and recruitment, as a result of temporal variations in the use of seasonally flooded marshes.

Power, G., R. S. Brown, et al. 1999. Groundwater and fish -- insights from northern North America. Hydrological Processes 13: 401-422.

This paper reports on the role and importance of ground water to stream fishes in northern North America. Ground water is critical to the ecology of several fish species and the authors point out the necessity of protecting its quality and quantity. Although the paper focuses on cool temperate regions, Florida, with its numerous spring systems, also has several examples of the importance of groundwater to fishes (e.g., Gulf of Mexico sturgeon *Acipenser oxyrinchus desotoi* and striped bass *Morone saxatilis*).

Puckridge, J. T., F. Sheldon, et al. 1998. Flow variability and the ecology of large rivers. Marine & Freshwater Research 49: 55-72.

This paper focuses on categorizing rivers based on flow variability and expanding the flood pulse concept to include hydrological variability and climatic differences. Representative rivers from around the world are included, but no southeastern USA systems are included except the Mississippi River.

Putnam, J. H., C. L. Pierce, et al. 1995. Relationships between environmental variables and size-specific growth rates of Illinois stream fishes. Transactions of the American Fisheries Society 124: 252-261.

The authors measured 12 biological, 22 physical, and 8 chemical variables and used simple and multiple regression techniques to investigate environmental influence on growth rate for several fishes in Illinois streams. The fishes included channel catfish *Ictalurus punctatus*, bluegill *Lepomis macrochirus*, and largemouth bass *Micropterus salmoides*. The variables measured included mean depth, mean velocity, discharge, and substrate characteristics. Several regression models are presented to predict fish growth. Small channel catfish had no significant regression and large largemouth bass had insufficient data. Of the 32 regression models presented, only one (i.e., large channel catfish) had velocity as a significant variable. Substrate variables were significant in 12 models.

Quinn, T. P. and D. J. Adams. 1996. Environmental changes affecting the migratory timing of American shad and sockeye salmon. Ecology 77: 1151-1162.

The authors examined temperature and flow as cues for migration in American shad *Alosa sapidissima* in an introduced population in the Columbia River. They found that, although flow correlated with temperature, temperature was the dominant factor influencing American shad spawning migrations into freshwater.

Raibley, P. T., T. M. O'Hara, et al. 1997. Largemouth bass size distributions under varying annual hydrological regimes in the Illinois River. Transactions of the American Fisheries Society 126: 850-856.

This study links flooding and floodplain use with increased cohort strength of largemouth bass *Micropterus salmoides* in the Illinois River, Illinois from 1990-1995. Flood years had strong year classes and years with low or fluctuating water levels had weak year classes. Exceptionally strong cohorts were produced in two years with long-term floodplain inundation. The pattern was also consistent for other centrarchids (e.g., bluegill *Lepomis macrochirus* and black crappie *Pomoxis nigromaculatus*) and gizzard shad *Dorosoma cepedianum*. The authors explain these results as a combination of improved spawning and nursery habitat as well as increased prey availability.

Ramnarine, I. W. 1995. Induction of nest building and spawning in *Hoplosternum littorale*. Journal of Fish Biology 47: 555-557.

This paper reports that captive brown hoplo *Hoplosternum littorale* were induced to build bubble nests and spawn by reducing the conductivity of the water, but not by simulating rain or increasing water level without reducing conductivity. It was generally believed that an increase in water level stimulated this species to spawn.

Reimer, G. 1991. The ecological importance of floodplains for fish at the river March (Austria). Archiv Fuer Hydrobiologie 121: 355-364.

This study documents 11 fish species feeding in floodplain forests and several species spawning there.

Reinert, T. R., G. R. Ploskey, et al. 1995. Effects of hydrology on black bass reproductive success in four southeastern reservoirs. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 49: 47-57.

Risotto, S. P. and R. E. Turner. 1985. Annual fluctuation in abundance of the commercial fisheries of the Mississippi River and tributaries (USA). North American Journal of Fisheries Management 5: 557-574.

This paper reports on National Marine Fisheries Service catch-effort data and relates them to seasonal flooding, temperature, and floodplain development for the Mississippi River basin for 1954-1976. No evidence of the influence of seasonal flooding on fish abundance was found, but some evidence for the influence of bottomland hardwood acreage (maximum flooded area) was found. Water temperatures during spring and winter were inversely related to the catch of several species. The paper also gives a review of factors affecting floodplain fishes.

Robinson, A. T., R. W. Clarkson, et al. 1998. Dispersal of larval fishes in a regulated river tributary. Transactions of the American Fisheries Society 127: 772-86.

The authors investigated larval fish distributions in the Little Colorado River, Arizona and determined that spawning peaked during the period of decline of high water. Decreasing flows may cue spawning in some of the fishes, although temperature and photoperiod are also probably important in the Little Colorado River. Larvae actively moved to nearshore areas and were of lower density in midchannel. Egg drift densities were not different between the two areas.

Rodriguez, M. A. and W. M. Lewis, Jr. 1997. Structure of fish assemblages along environmental gradients in floodplain lakes of the Orinoco River. Ecological Monographs 67: 109-128.

The authors investigated the influence of environmental variables in structuring fish assemblages in floodplain lakes of the Orinoco River system. Analyzed variables included depth, distance from river channel, and distance from floodplain edge. Only four variables were predictably related to fish assemblage structure- transparency, conductance, depth, and surface area.

Rogers, S. G., T. E. Targett, et al. 1984. Fish-nursery use in Georgia salt-marsh estuaries: The influence of springtime freshwater conditions. Transactions of the American Fisheries Society 113: 595-606.

The study investigated juvenile fish distributions in the Ogeechee River-Ossabaw Sound estuary of Georgia in relation to freshwater discharges. Upper estuary nursery areas were important for several fish species and their use was regulated by the magnitude of freshwater inputs. Recruitment of estuarine fishes was likely inhibited during periods of high freshwater discharge. Nevertheless, most estuarine fishes utilized freshwater areas and nursery function remained essentially intact throughout seasonal freshwater encroachment.

Ross, R. M., R. M. Bennett, et al. 1997. Habitat use and feeding ecology of riverine juvenile American shad. North American Journal of Fisheries Management 17: 964-974.

The authors examined habitat use by juvenile American shad *Alosa sapidissima* in the Delaware River. They found that juveniles used most riverine habitats (i.e., were habitat generalists). They determined habitat suitability indices for this life stage, including depth and velocity variables.

Rutherford, D. A., W. E. Kelso, et al. 1995. Influence of physicochemical characteristics on annual growth increments of four fishes from the lower Mississippi River. Transactions of the American Fisheries Society 124: 687-697.

This study examined growth of young (≤ age-2) blue catfish *Ictalurus furcatus*, channel catfish *I. punctatus*, freshwater drum *Aplodinotus grunniens*, and gizzard shad *Dorosoma cepedianum* in the lower Mississippi River in relation to physical and chemical parameters of the river for 1987-1990. Growth of age-0 blue catfish, channel catfish, and gizzard shad were related only to length of the growing season. Moreover, positive relationships between growth and total organic carbon levels (age-1 blue catfish), and negative relationships between growth and total hectares flooded (age-1 gizzard shad) and discharge (age-0 and age-1 freshwater drum) indicated that these fishes exhibited highest growth during years of limited floodplain inundation. These results suggest that for some fishes in large rivers with reduced floodplains, mainstem primary and secondary production may influence growth rates more than allochthonous inputs from seasonal flooding.

Sabo, M. J., C. F. Bryan, et al. 1999. Hydrology and aquatic habitat characteristics of a riverine swamp: I. Influence of flow on water temperature and chemistry. Regulated Rivers: Research & Management 15: 505-523.

This study gives temperature and water chemistry values for high and low energy channels and lakes in the Atchafalaya Basin, Louisiana. The authors found that water temperature and chemistry values varied among the three habitats and that flow and air temperature affected these values. Variability was found within the habitats spatially and as

stratification. The study emphasizes maintenance of habitat (channel and lake) diversity largely through sediment control and manipulation of flow.

Sabo, M. J., C. F. Bryan, et al. 1999. Hydrology and aquatic habitat characteristics of a riverine swamp: II. Hydrology and the occurrence of chronic hypoxia. Regulated Rivers: Research & Management 15: 525-542.

This study investigated links between hydrology and hypoxia in the Atchafalaya Basin, Louisiana. The authors note that floods in the basin produce productive shallow water habitats and flush nutrients into the system. On the other hand, flood pulses also induce hypoxic conditions that may be widespread. Acute hypoxia has been associated with hurricanes. Chronic hypoxia is associated with flood pulses, limits use of swamp areas by many species of fishes, and causes fish kills. The authors found that hypoxia is normally associated with low-energy channels. Although flood pulses often increase dissolved oxygen (DO) initially, as waters recede, organic materials are concentrated, temperatures increase, and DO falls. Water flow patterns significantly affected when and if hypoxia occurred. Stagnation or low flow rate of flood waters associated with high temperatures produced hypoxic events.

Scheidegger, K. J. and M. B. Bain. 1995. Larval fish distribution and microhabitat use in free-flowing and regulated rivers. Copeia 1995: 125-135.

The authors report larval fish distributions and habitat use in the unregulated Cahaba River and the regulated Tallapoosa River in Alabama. The authors sampled main channel and presumed shoreline nursery habitats (i.e., shallow areas with low flow). Larvae were significantly more abundant in the unregulated river, especially in nursery areas. Altered flow appeared to have reduced larval fish abundance, changed taxonomic composition, and disrupted microhabitat associations.

Schiemer, F. 1995. Restoration of floodplains -- possibilities and constraints. Archiv fur Hydrobiologie 101: 3-4.

Schiffer, D. M. 1998. Hydrology of central Florida lakes - a primer. USGS Circular 1137. United States Geological Survey in cooperation with the St. Johns River Water Management District. Denver, Colorado.

This report discusses numerous aspects of hydrology associated with central Florida lakes. Little biological information is provided, but there are sections on lake water-level fluctuations and water quality that are of some relevance to water level effects on fishes.

Schlosser, I. J. 1985. Flow regime, juvenile abundance, and the assemblage structure of stream fishes. Ecology 66: 1484-1490.

The paper reports on fish sampling in a second-order stream in Illinois during periods of differing stream flow. Species richness and density of adult fish differed little in relation to flow. Juvenile fish were more influenced by stream flow. High stream discharge had little effect on juvenile suckers and darters, species that spawn early in the year. Some minnows and all sunfish species had higher juvenile densities during low, stable flow conditions. These species typically spawned later and over an extended period of time. The author concluded that ontogenetic stage and life history modify the role that stochastic environmental variables play in population regulation.

Schlosser, I. J. and P. L. Angermeier. 1990. The influence of environmental variability, resource abundance, and predation on juvenile cyprinid and centrarchid fishes. Polskie Archiwum Hydrobiologii 37: 265-284.

The authors summarized several years of data on the influence of abiotic and biotic factors on juvenile cyprinid and centrarchid fishes in an Illinois stream. They found that spring floods were associated with large reductions in the abundance of macroinvertebrates and density of juvenile fishes.

Schmutz, S. and M. Jungwirth. 1999. Fish as indicators of large river connectivity: The Danube and its tributaries. River Ecosystem Concepts 115: 329-348.

Schramm, H. L., Jr., M. A. Eggleton, et al. 2000. Habitat conservation and creation: Invoking the flood-pulse concept to enhance fisheries in the lower Mississippi River. Polskie Archiwum Hydrobiologii 47: 45-62.

This paper explores the relationship between temperature and hydrologic variables with growth of catfish in the lower Mississippi River. No single temperature or hydrologic variable consistently accounted for variation in annual growth of catfishes (blue catfish *Ictalurus furcatus*, channel catfish *I. punctatus*, and flathead catfish *Pylodictis olivaris*). However, a composite variable of duration of floodplain inundation when water temperature exceeded the minima for active feeding explained a significant proportion of the variation in catfish growth. These results indicate the importance of floodplain inundation varies on a temporal scale.

Setzler, E. M., W. R. Boynton, et al. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). NOAA/NMFS.

Simpkins, D. G., W. A. Hubert, et al. 2000. Effects of spring flushing flow on the distribution of radio-tagged juvenile rainbow trout in a Wyoming tailwater. North American Journal of Fisheries Management 20: 546-551.

This study documents the lack of displacement of juvenile rainbow trout *Oncorhynchus mykiss* during high flows released to flush sediments from a streambed. Periodic high flows are necessary to improve salmonid spawning habitat, but displacement or loss of juvenile fish is a concern during high flow events.

Smith, T. I. J. and J. P. Clugston. 1997. Status and management of Atlantic sturgeon, *Acipenser oxyrinchus*, in North America. Environmental Biology of Fishes 48: 335-346.

This paper reviews general information on both subspecies of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus* and *A. o. desotoi*). It does not mention affects of flows on sturgeon migration or spawning. Good source of literature for Atlantic sturgeon.

Snedden, G. A., W. E. Kelso, et al. 1999. Diel and seasonal patterns of spotted gar movement and habitat use in the lower Atchafalaya River basin, Louisiana. Transactions of the American Fisheries Society 128: 144-154.

This study reported on movements and habitat use of 37 spotted gar *Lepisosteus oculatus* determined by radiotelemetry. Spotted gar moved more with increased river stage and used floodplain areas as spawning and nursery habitat.

Snodgrass, J. W., C. H. Jagoe, et al. 2000. Effects of trophic status and wetland morphology, hydroperiod, and water chemistry on mercury concentrations in fish. Canadian Journal of Fisheries and Aquatic Sciences 57: 171-180.

This study investigated mercury (Hg) levels in lake chubsucker *Erimyzon sucetta*, mud sunfish *Acantharcus pomotis*, and redfin pickerel *Esox americanus* in depression wetlands in coastal South Carolina. Trophic level of the fish was less important than wetland location (site) in terms of Hg accumulation. The authors found that hydroperiod was a significant factor in Hg levels in the fishes. Levels of Hg were generally higher in wetlands that experienced water level fluctuations (i.e., drying and re-flooding). They hypothesized that aerobic conditions during a dry-down promote bioavailability of Hg and that Hg enters the food web when the wetland is flooded. Long periods of inundation lead to anaerobic conditions at the substrate-water interface, reducing bioavailability of Hg.

Sommer, T., B. Harrell, et al. 2001. California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26: 6-16.

This paper describes the Yolo Bypass, a flood control system on the Sacramento River, California, that allows inundation of a broad floodplain in order to maintain system function. The authors discuss the use of the bypass for fish spawning and as a nursery area. The system is also important to the San Francisco estuary as a source for nutrients and detrital material for enhanced system productivity. Floodplain function and processes are important management considerations.

Staggs, M. D. and K. J. Otis. 1996. Factors affecting first-year growth of fishes in Lake Winnebago, Wisconsin. North American Journal of Fisheries Management 16: 608-618.

This paper reports on first-year growth of several fish species between 1962 and 1984 in Lake Winnebago, Wisconsin. The authors found a positive relationship between water levels in spring as an indicator of spawning date (along with temperature), and fish growth for all species. Two water level factors in a factor analysis explained 75.5% of the variance in six monthly mean growth values. Overall, water level influenced age-0 growth in all species, but explained only 3-10% of observed variance. The results of high water levels were mixed for overall age-0 growth. Spring levels positively influenced one species but negatively influenced two others. High summer water levels positively influenced a fourth species. The authors state that water levels only fluctuate modestly and this may explain the small influence that water level has on Lake Winnebago fishes.

Stalnaker, C. B. and J. L. Arnette. 1976. Methodologies for the determination of stream resource flow requirements: An assessment. FWS/OBS-76/03. U. S. Fish and Wildlife Service.

This report summarizes and critiques methods for assessing instream flow needs for fishes. This report pre-dates many methods now in use. The examples include mostly salmonids.

Stalnaker, C. B. 1980. Effects on fisheries of abstractions and perturbations in streamflow. pp. 366-383. *in* Allocation of Fishery Resources. Proceedings of the Technical Consultation on Allocation of Fishery Resources, Vichy, France.

This paper reviews know effects of streamflow modification on stream environments,

methods for evaluating instream flow requirements for fisheries, and microhabitat as niche space. The author also discusses hydrologic processes as probability processes and stochastic processes, both of which have important influences on fish populations.

Stalnaker, C. B., K. D. Bovee, et al. 1996. Importance of the temporal aspects of habitat hydraulics to fish population studies. Regulated Rivers: Research & Management 12: 145-153.

The major point of this paper is that, although current instream flow modeling efforts take into account spatial aspects of habitat quality and quantity, they generally ignore temporal effects. The authors used time-series simulations to demonstrate that usable space and its stability during early life history is directly related to year-class strength in rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta*, and smallmouth bass *Micropterus dolomieu*. Due to the stochastic nature of precipitation, temporal dynamics in instream flow must be considered in water management.

Starnes, L. B., P. A. Hackney, et al. 1983. Larval fish transport: A case study of white bass. Transactions of the American Fisheries Society 112: 390-397.

The authors studied downstream transport of larval white bass *Morone chrysops* in the Holston River, Tennessee. They found that distributions did not reflect passive drift, but active entrainment. Experiments showed that larvae used currents and areas of low velocity to reduce downstream transport. Therefore, at least this riverine species has mechanisms for reducing loss of larvae to displacement.

Steele, R. J. and K. E. Smokorowski. 2000. Review of literature related to the downstream ecological effects of hydroelectric power generation. Canadian Technical Report of Fisheries and Aquatic Sciences 2000: 1-55.

Stevens, D. E. 1977. Striped bass (*Morone saxatilis*) year class strength in relation to river flow in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 106: 34-42.

Striped bass *Morone saxatilis* young-of-year abundance was known to correlate with river discharge during April-July. This paper determined if subsequent striped bass recruitment to the fishery is also correlated with river flow. The authors constructed abundance indices from recreational party boat anglers for two periods (1938-1954 and 1958-1972) and regressed these values with log-transformed river flow. The data indicated that the number of striped bass available to the fishery was dependent on early survival and that high early survival coincided with moderately high flows.

Stewart, E. M. and T. R. Finger. 1985. Diel activity pattern of fishes in lowland hardwood wetlands. Transactions of the Missouri Academy of Science 19: 5-10.

This paper reports on activity patterns and occurrence of larval, juvenile, and small adult fishes in seasonally flooded and semipermanently flooded bottomland wooded wetlands in Missouri (Mississippi River system). One species, banded pygmy sunfish *Elassoma zonatum*, had different activity patterns by reproductive season and by habitat.

Stier, D. J. and J. H. Crance. 1985. Habitat suitability index models and instream flow suitability curves: American shad. FWS/OBS-10.88. National Coastal Ecosystems Team for U. S. Fish and Wildlife Service. Slidell, Louisiana.

Streever, W. J. 1992. Report of a cave fauna kill at Peacock Springs cave system, Suwannee County, Florida. Florida Scientist 55: 125-128.

This paper reports on a cave fauna kill in the Peacock Springs cave system, Florida, following inundation by flood waters of the Suwannee River. Asiatic clam *Corbicula fluminea*, pallid cave crayfish *Procambarus pallidus*, American eel *Anguilla rostrata*, and yellow bullhead *Ameiurus natalis* were affected. The mechanism of the kill is unknown (e.g., hypoxia, toxins). Other flood events are known without an associated kill, and kills have occurred without an associated flood.

Stuber, R. J., G. Glebhart, et al. 1982. Habitat suitability index models: Bluegill. FWS/OBS-82/10.8. U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for bluegill *Lepomis macrochirus*. Relevant biological data and citations are presented.

Sulak, K. J. and J. P. Clugston. 1998. Early life history stages of gulf sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 127: 758-771.

This study reports on aspects of reproduction and early life history of Gulf sturgeon *Acipenser oxyrinchus desotoi* in the Suwannee River, Florida. Reproduction was timed with temperature and lunar cycle. The authors speculated that a strong, consistent current is necessary for suitable spawning habitat. They also described the spawning habitat as clean gravel-cobble on clean sand over a horizontal bedrock platform. The spawning site identified is at river km 215 near the mouth of the Alapaha River. The authors also speculated that other river mouths may provide the necessary elements of current and substrate for Gulf sturgeon spawning.

Summerfelt, R. C. and K. E. Shirley. 1978. Environmental correlates to year-class strength of largemouth bass (*Micropterus salmoides*) in Lake Carl Blackwell. Proceedings of the Oklahoma Academy of Science 58: 54-63.

This paper reports the results of 11 years of monitoring age-0 largemouth bass *Micropterus salmoides* density in Lake Carl Blackwell, a reservoir in Oklahoma. Significant positive correlations were found between estimates of age-0 largemouth bass density and both water level and water level change. Strong year classes developed in years of high water level. The authors felt that inundated terrestrial vegetation was the key to strong year classes by several mechanisms- food in the form of terrestrial invertebrates, cover for nesting, reduction in wave action, structure as refuge against predation for young largemouth bass, and as nutrient input to increase productivity. Falling water levels have the opposite effect, as well as increasing the effects of temperature fluctuations and stranding nests, young largemouth bass, and food organisms.

Sutton, R. J., W. J. Miller, et al. 1997. Application of the instream flow incremental methodology to a tropical river in Puerto Rico. Rivers 6: 1-9.

This study used Instream Flow Incremental Methodology (IFIM) to determine minimum

flow needs for the Icacos River, Puerto Rico. The primary aquatic species assessed were mountain mullet *Agonostomus monticola* and river shrimp *Macrobrachium carcinus*.

Theiling, C. H. and J. K. Tucker. 1999. Nektonic invertebrate dynamics and prolonged summer flooding on the lower Illinois River. Journal of Freshwater Ecology 14: 499-510.

This study examined nektonic invertebrate dynamics in the Illinois River floodplains and backwater lakes during flood events in 1993. Invertebrate densities were much greater during rising stages than during falling stages of the flood. Density estimates taken along the shoreline during rising water also greatly exceeded nektonic invertebrate estimates from open waters. Invertebrate densities by habitat during rising water, in order of highest to lowest, were inundated grasses, flooded trees, floating macrophytes, and open water. These findings exemplify the flood pulse hypothesis in that productivity, as measured by invertebrate density, increased dramatically on the rising flood but then fell just as dramatically on the falling flood.

Thorp, J. H., M. D. Delong, et al. 1998. Isotopic analysis of three food web theories in constricted and floodplain regions of a large river. Oecologia 117: 551-563.

The authors used stable isotope analysis of fishes in a floodplain and a constricted-channel portion of the Ohio River to test three alternative floodplain river food web hypotheses. The riverine productivity model was chosen as the best model relative to the flood pulse concept and the river continuum concept. For this system, flooding occurs in winter and spring, a time of low temperatures and minimal terrestrial invertebrate production. Terrestrial plants contributed little to the food webs and most other allochthonous-derived organic material was too depleted to support a food web. Most productivity was associated with the river itself.

Tibbs, J. E. and D. L. Galat. 1998. The influence of river stage on endangered least terns and their fish prey in the Mississippi River (USA). Regulated Rivers: Research and Management 14: 257-266.

The authors sampled small fishes ($\leq$ 100 mm TL) in six habitats in the Mississippi River, Missouri. Highest catches of fish occurred between 56 and 64 days after peak spring floods. About 80% of total fish catch consisted of species known to spawn in floodplain habitats. The authors provide a conceptual model linking river stage and fish reproduction/recruitment. They also stressed the necessity of connectivity of rivers and floodplains.

Toth, L. A. 1991. Environmental responses to the Kissimmee River Demonstration Project. Technical Publication 91-02. South Florida Water Management District. West Palm Beach, Florida.

This publication is the report for the Kissimmee River Demonstration Project, a pilot project designed to provide information necessary for the dechannelization of the Kissimmee River. A major effect of dechannelization is a reconnection of the river channel with its floodplain. The author presents data on hydrology, habitats, vegetation, invertebrates, and fish. Use of broadleaf marsh by fish was influenced by water level. Peak fish densities were found at highest water level and much lower densities were found during rising or falling stages. Therefore, fish density was positively correlated with water depth. Fishes were mostly small, floodplain-associated species such as cyprinodontids, fundulids, poeciliids, pirate perch *Aphredoderus sayannus*, small centrarchids, and small ictalurids. Invertebrate densities were influenced by length of inundation and season.

Toth, L. A. 1993. The ecological basis of the Kissimmee River restoration plan. Florida Scientist 56: 25-51.

This paper reviews ecological literature of relevance to the Kissimmee River dechannelization project and summarizes data from the Kissimmee River Demonstration Project. Dechannelization reconnected the river channel with its floodplain in order to restore ecosystem function. Fish populations in an oxbow greatly increased after a prolonged period of high water over the winter and spring of 1987-1988. Resident marsh fish numbers also increased, but water levels never reached a point allowing marsh access by sport fish. With high water levels, remnants of river connections were reestablished and these were heavily used by sport fish, including largemouth bass *Micropterus salmoides*. In fall, these areas experience low flow and low dissolved oxygen concentrations and are then abandoned by sport fish. These adverse environmental factors may have limited the success of the pilot restoration project. For example, although largemouth bass numbers increased, standing crop did not, indicating that the population was made of smaller individuals. Gar *Lepisosteus* spp. and bowfin *Amia calva* numbers also significantly increased.

Toth, L. A., J. T. B. Obeysekera, et al. 1993. Flow regulation and restoration of Florida's Kissimmee River. Regulated Rivers: Research & Management 8: 155-166.

Travnichek, V. H. and M. J. Maceina. 1994. Comparison of flow regulation effects on fish assemblages in shallow and deep water habitats in the Tallapoosa River, Alabama. Journal of Freshwater Ecology 9: 207-216.

The authors compared shallow and deep water fish assemblages in regulated and unregulated portions of the Tallapoosa River, Alabama. They found that flow regulation had a greater effect on shallow rather than deep water fishes. Shallow water fish assemblage species diversity, species richness, and fish density were reduced in regulated portions of the river. This was mainly due to reductions in species adapted to fluvial conditions. In the deep water fish assemblages, only catostomids had higher densities in unregulated portions than in modified portions of the river.

Travnichek, V. H., M. B. Bain, et al. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam. Transactions of the American Fisheries Society 124: 836-844.

This study compares fish assemblages in the Tallapoosa River, Alabama, 3 km and 37 km downstream of Thurlow Hydroelectric Dam before and after implementation of an enhanced water release regime. The authors sampled shoreline areas because these habitats are important nursery habitat and refugia for fishes and are also sensitive to fluctuating streamflow effects. Prior to implementing enhanced water releases, the fish fauna 3 km below the dam was restricted to a few macrohabitat generalist species. After the new release schedule, species richness and fish abundance increased, including the addition of several fluvial specialists. The changes in the site 37 km downstream was less dramatic, but more fluvial species were collected under the enhanced regime. Fluvial specialists are particularly sensitive to altered stream flow whereas macrohabitat generalists, especially those species capable of sustaining populations under lentic conditions, may be relatively unaffected.

Trexler, J. C. 1995. Restoration of the Kissimmee River: A conceptual model of past and present fish communities and its consequences for evaluating restoration success. Restoration Ecology 3: 195-210.

The author presents a conceptual model for evaluating the restoration of the Kissimmee River, Florida, and its associated floodplain. He argues that simple measures of fish abundance or diversity are not sufficient measures of restoration because little historic information exists on the system prior to channelization. The alternative is evaluation of ecosystem function relative to similar systems elsewhere. The model emphasizes the flux of floodplain-channel nutrients and movement of larvae, juvenile, and adult fish and macroinvertebrates. A specific prediction is an increase in centrarchid populations, partly due to restored access to the floodplain and resultant release from spawning site limitation.

Trexler, J., W. Loftus, et al. 1996. High water assessment: The consequences of hydroperiod on marsh fish communities. Ecological Assessment of the 1994-1995 High Water Conditions in the Southern Everglades, Miami, Florida.

Rainfall patterns and water control structure operation schedules influence water depth and hydroperiod of Everglades marshes in Florida. The authors concluded that fish and macroinvertebrate population responses depend more on the length and severity of dry-downs than on absolute water levels. Small fishes varied in response to hydroperiod, with marsh killifish *Fundulus confluentus* and flagfish *Joranella floridae* characteristic of short hydroperiod marshes whereas bluefin killifish *Lucania goodei* and least killifish *Heterandria formosa* were more common in long hydroperiod marshes. Eastern mosquitofish *Gambusia holbrooki* recovered rapidly from dry-downs but some species may require one to two years to recover from drought. Total fish density moderately correlated with water depth. Receding waters often had higher fish densities than rising water of the same depth. High water levels during 1994-1995 may have benefited exotic Mayan cichlid *Cichlasoma urophthalmus*. Species richness was highest for longer hydroperiods but peak densities were found at intermediate hydroperiods.

Turner, T. F., J. C. Trexler, et al. 1994. Temporal and spatial dynamics of larval and juvenile fish abundance in a temperate floodplain river. Copeia 1994: 174-183.

The authors studied larval fish assemblages of main channel and floodplain in the Tallahatchie River, Yazoo River system, Mississippi. They found a progression of larval fish assemblages throughout the year based on species composition. Early assemblages (spring) were composed of shad *Dorosoma* spp., crappie *Pomoxis* spp., and darters *Etheostoma* and *Percina* spp. Later assemblages (summer) were dominated by sunfishes *Lepomis* spp., western mosquitofish *Gambusia affinis*, and minnows *Cyprinella* and *Notropis* spp. Spring assemblages did not differ in habitat use whereas in summer, sunfish were more prevalent in areas of low flow and minnows in areas of moderate to high flow. The authors concluded that high larval fish abundance in floodplain areas results from inclusion of species that inhabit both channel and floodplain as adults.

Twomey, K. A., G. Gebhart, et al. 1984. Habitat suitability index models and instream flow suitability curves: Redear sunfish. FWS/OBS-82/10.79. U. S. Fish and Wildlife Service. Washington, D. C.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability

Index (SI) curves for redear sunfish *Lepomis microlophus*. Relevant biological data and citations are presented.

Tyus, H. M. 1990. Effects of altered stream flows on fishery resources. Fisheries 15: 18-20.
This paper is a policy statement of the American Fisheries Society concerning the effects that altered stream flows may have on fishery resources. There is a definition of the issue, a section on impacts of altered flow, and recommendations for needed actions.

Van Den Avyle, M. J. and M. A. Maynard. 1994. Effects of saltwater intrusion and flow diversion on reproductive success of striped bass in the Savannah River estuary. Transactions of the American Fisheries Society 123: 886-903.
This study documents reduced reproductive success of striped bass *Morone saxatilis* in the Savannah River following river modifications, including construction of a tide gate and diversion canal. The data indicated that striped bass still spawned in the historic areas, but that changes in flow and salinity in the downstream areas greatly increased egg and larval mortality. Striped bass spawn buoyant eggs and require specific conditions of flow and salinity for reproductive success. These are long-lived fish and are capable of sustaining populations over occasional poor recruitment years. The reduced flow in the river, however, led to the intrusion of salt water each season, causing a complete lack of recruitment.

Van Winkle, W., H. I. Jager, et al. 1998. Individual-based model of sympatric populations of brown and rainbow trout for instream flow assessment: Model description and calibration. Ecological Modelling 110: 175-207.
This paper presents an individual-based model for sympatric stream populations of brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss*. The approach predicts effects of flow and temperature on trout populations by linking Instream Flow Incremental Methodology/Physical Habitat Simulation Model (IFIM/PHABSIM) hydraulic habitat modeling with an individual-based population model. The authors present seven advantages for such models: (1) links between changes in habitat and fish populations are explicit, (2) there are limiting factors besides weighted usable area (WUA) that are not modeled in IFIM/PHABSIM, (3) these models predict measurable and relevant endpoints, (4) daily time steps allows a more realistic treatment of temperature and flow, (5) time series allows simulation of population-limiting events over multiple years, (6) density-dependence is included, and (7) model predictions help identify management options that minimize adverse effects on fish populations. This approach is data-intensive.

VanGenechten, D. T. 1999. Effects of habitat and season on fish communities of the Wekiva River system, Florida. Masters Thesis. University of Florida. Gainesville, Florida.
This thesis provides quantitative information on fish assemblages and habitat characteristics for the Wekiva River, a spring-fed system in the St. Johns River drainage, Florida. Sampling was conducted in both historic high flow and low flow periods, but actual flows did not significantly differ during the study. Measures of fish habitat included vegetation, water physicochemical variables, and hydraulic variables (i.e., depth and velocity). There were significant differences among fish assemblages for the vegetation-defined habitats sampled. The author developed several simple and multiple regression models to describe the relationship between fish density, biomass, and species richness and various environmental variables by river

segment and habitat. Depth, bottom velocity, or surface velocity were significant factors in many of the predictive equations.

Vogele, L. E. 1975. The spotted bass. pp. 34-45. *in* R. H. Stroud and H. Clepper. Black bass biology and managment. Sport Fishing Institute, Washington, D. C.

This book chapter gives life history information on spotted bass *Micropterus punctulatus*, including nest depths. Nest depth varies widely in different habitats. In lakes, nest depths ranged from about 3 to 22 ft. In a Missouri stream, depths were 13 to 29 inches.

Waite, I. R. and R. A. Barnhart. 1992. Habitat criteria for rearing steelhead: A comparison of site-specific and standard curves for use in the instream flow incremental methodology. North American Journal of Fisheries Management 12: 40-46.

This paper compared three standard habitat utilization curves used in Instream Flow Incremental Methodology (IFIM) for rainbow trout (steelhead) *Oncorhynchus mykiss*. They found that different curves gave different results and concluded that stream width, depth, flow, gradient, substrate, pool:riffle ratio, seasonal hydrography, and other habitat variables should be compared before habitat utilization curves developed on one stream are applied to other streams.

Ward, G. H., Jr. and N. E. Armstrong. 1980. Matagorda Bay, Texas: Its hydrography, ecology and fisheries resources. FWS/OBS-81/52. U. S. Fish and Wildlife Service. Washington, D. C.

This report reviews information on hydrography, including freshwater inflows, and fishery resources of Matagorda Bay, Texas. The document contains information on many important fish and shellfish species that support estuarine and marine fisheries in Florida.

Weeks, G. N. and M. J. Van Den Avyle. 1996. Selection of thermal refuges by striped bass in a Gulf of Mexico coastal river. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 50: 51-61.

This paper describes striped bass *Morone saxatilis* use of springs as thermal refuges in the Flint River, Apalachicola River system, Georgia. Groundwater from springs within river systems are important thermal refuges in summer for striped bass near the southern end of their range.

Weisberg, S. B. and W. H. Burton. 1993. Enhancement of fish feeding and growth after an increase in minimum flow below the Conowingo Dam. North American Journal of Fisheries Management 13: 103-109.

This paper reports on food consumption and growth of white perch *Morone americana*, yellow perch *Perca flavescens*, and channel catfish *Ictalurus punctatus* before and after implementation of a summer minimum flow release regime below Conowingo Hydroelectric Dam, Susquehanna River, Maryland. Fish condition (weight at length) was significantly greater for all species in years when the minimum flow was maintained. Similarly, growth rate (length at age) was significantly higher after the minimum flow requirement was instituted. Changes in food consumption appear to explain the differences in growth, as fewer empty stomachs and greater food consumption occurred after the minimum flow was instituted. Increases in benthic invertebrate abundance coincided with the increase in consumption by fishes.

Welcomme, R. L. 1979. Fisheries ecology of floodplain rivers. Longman Group Limited, London.

This book provides a broad overview of ecology, hydrology, fishes, and fisheries of tropical floodplain river systems. Sections on fish include a description of the faunas, habitats, adaptations to extreme environments (e.g., hypoxia), migrations, feeding, growth, reproduction, mortality, and production. A central theme of the book is the importance of floodplain to maintenance of riverine fisheries.

Welcomme, R. L. 1989. Floodplain fisheries management. pp. 209-233. *in* Alternatives in regulated river management. CRC Press, Inc., Boca Raton, Florida.

Wilber, D. H. 1992. Associations between freshwater inflows and oyster productivity in Apalachicola Bay, Florida. Estuarine Coastal and Shelf Science 35: 179-190.

This paper reports on the analysis of catch per unit effort (CPUE) data for the Apalachicola Bay oyster fishery in relation to Apalachicola River flows from 1960-1984, including various lag times. Low flows were correlated with low oyster CPUE two years later. Oysters take two years to mature in the bay. Low flow leads to higher salinities which may allow marine species to prey on newly settled oyster spat. High flows of short duration (i.e., $\leq$ 30 d) were not significantly related to oyster CPUE. However, longer duration high flows ($\geq$ 100 d) were associated with low oyster CPUE that same year.

Wilber, D. H. 1994. The influence of Apalachicola River flows on blue crab, *Callinectes sapidus*, in north Florida. U. S. National Marine Fisheries Service Fishery Bulletin 92: 180-188.

Williamson, K. L. and P. C. Nelson. 1985. Habitat suitability index models and instream flow suitability curves: Gizzard shad. Biological Report 82(10.112). U. S. Fish and Wildlife Service. Fort Collins, Colorado.

This report presents Habitat Suitability Index (HSI) models and instream flow Suitability Index (SI) curves for gizzard shad *Dorosoma cepedianum*. Relevant biological data and citations are presented.

Winemiller, K. O. 1987. Feeding and reproductive biology of the currito, *Hoplosternum littorale*, in the Venezuelan llanos with comments on the possible function of the enlarged male pectoral spines. Environmental Biology of Fishes 20: 219-227.

The author describes the reproductive seasonality and diet of brown hoplo *Hoplosternum littorale* in Venezuela. Reproduction begins at the onset of the rainy season. The cues for initiation of reproduction are unknown, but the author provides several possible parameters (e.g., temperature, dissolved oxygen, pH, dissolved solids, transparency, and depth).

Wlosinski, J. H. and E. R. Koljord. 1996. Effects of water levels on ecosystems: An annotated bibliography. Long Term Resource Monitoring Program Technical Report 96-T007. United States Geological Survey. Onalaska, Wisconsin.

This report provides an annotated bibliography to over 800 citations on the effects of water levels on ecosystem components, primarily in freshwater systems. An index with keywords is included.

Woodward, K. O. and R. L. Noble. 1997. Over-winter movements of adult largemouth bass in a North Carolina reservoir. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51: 113-122.

This paper reports on radio-telemetry results of largemouth bass *Micropterus salmoides* movements over the fall to spring period in a North Carolina reservoir. During high water levels some fish moved inshore to use inundated terrestrial habitat, even at water temperatures as low as 6 C. Less movement was associated with low temperatures and movement of fish into newly flooded areas was greater in November and after late January than in the December-early January period. Largemouth bass used inundated vegetation during the day and night. Use of inundated terrestrial vegetation as cover in this reservoir may be related to a general lack of structure when waters are at normal pool levels.

Wooley, C. M. and E. J. Crateau. 1983. Biology, population estimates, and movement of native and introduced striped bass, Apalachicola River, Florida. North American Journal of Fisheries Management 3: 383-394.

This paper discusses native (Gulf strain) and introduced (Atlantic strain) populations of striped bass *Morone saxatilis* in the Apalachicola River, Florida. Springs represent thermal refugia for striped bass, especially Atlantic strain individuals.

Wooley, C. M. and E. J. Crateau. 1985. Movement, microhabitat, exploitation, and management of Gulf of Mexico sturgeon, Apalachicola River, Florida (USA). North American Journal of Fisheries Management 5: 590-605.

The authors report movement and habitat use of tagged and radio-tagged Gulf sturgeon *Acipenser oxyrhynchus desotoi* in the Apalachicola River, Florida from 1982-1984. Fish congregated below Jim Woodruff Lock and Dam during the summer, briefly staged at the mouth of Brothers River in November, and left the river for Apalachicola Bay or the Gulf of Mexico in November. Gulf sturgeon returned to the river in April. Depth and velocity data are presented and the authors feel that these factors greatly influence river microhabitat selection in the summer and fall.

Wylie, G. D. and J. R. Jones. 1986. Limnology of a wetland complex in the Mississippi alluvial valley of southeast Missouri (USA). Archiv Fuer Hydrobiologie 74: 288-314.

Yeager, D. M. 1982. Ultrasonic telemetry of striped bass x white bass hybrids in the Escambia River, Florida. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 36: 62-73.

This study reports on movements of 13 ultrasonic tagged hybrid striped bass (striped bass *Morone saxatilis* x white bass *M. chrysops*) in the Escambia River, Florida in 1980-1982. Movements were influenced by river discharge. Fish were found in the lower, tidal portions of the river during low or normal flows. During periods of rising water, the tagged hybrid striped bass moved into Escambia Bay and adjacent river systems (i.e., Blackwater and Perdido River systems). There was no indication of spawning runs up the river, however, hybrid striped bass were caught by anglers in the upper Escambia River in Alabama.

Yu, S. and E. J. Peters. 1997. Use of Froude number to determine habitat selection by fish. Rivers 6: 10-18.

The authors electrofished grids in the Platte River, Nebraska, and determined the Froude number for each grid. The Froude number is a composite of water depth and velocity and may be used to describe fish habitat (e.g., pool, run, and riffle habitats). They determined selected distributions of 24 species and life stages. They also concluded that Froude number can provide an objective criterion for classifying habitat types and habitat suitability for instream flow analyses.

Zalewski, M., B. Brewinska-Zaras, et al. 1990. Potential for biomanipulation using fry communities in a lowland reservoir: Concordance between water quality and optimal recruitment. Hydrobiologia 200/201: 549-556.

This paper presents the results of 7 years of monitoring the larvae fish assemblage of Slejow Reservoir, Poland. Reproductive success of fishes was correlated with water level fluctuations but not temperature.

Zalumi, S. G. 1976. On the causes of variable fish productivity in the lower reaches of the Dnieper. Journal of Ichthyology 16: 659-663.

The magnitude of floods in the Dnieper River, Russia, are thought to determine the strength of fish recruitment. The author found that not only is magnitude of flooding important (i.e., height and size of flooded area), but temperature during flooding and pre-flood condition of parental stocks also influence recruitment.

Zincone, L. H. J. and R. A. Rulifson. 1991. Instream flow and striped bass recruitment in the lower Roanoke River, North Carolina (USA). Rivers 2: 125-137.

Zorn, T. G. and P. W. Seelbach. 1995. The relation between habitat availability and the short-term carrying capacity of a stream reach for smallmouth bass. North American Journal of Fisheries Management 15: 773-783.

The authors present the results of a behavioral carrying capacity (BCC) experiment using smallmouth bass *Micropterus dolomieu* to test the instream flow incremental methodology (IFIM) assumption of a positive linear relationship between available fish habitat (weighted usable area, WUA) and fish biomass. There was not a positive relation between WUA and BCC, and moreover, there was a negative relation between stream discharge and BCC. The authors argue that IFIM works for salmonids in high velocity streams but cannot be recommended for lower velocity, warm water streams. The IFIM assumption that habitat availability is the most important factor in determining fish populations in streams may not hold for warm water species. Other factors, including competition, predation, and previous events reducing recruitment, may maintain populations of warm water stream fishes below carrying capacity.

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APPENDIX A

Keywords and taxa searched

Keywords

allochthonous
cohort
dispersal
drought
duration
essential fish habitat
feeding
fish
flood
Florida
habitat
high
hydraulic regime
hydrobiology
hydroperiod
instream flow
inundation
level
MFL
minimum flow
minimum depth
periodicity
pulse
recruitment
reproduction
spate
spawning
stage
timing
use/utilization
water
year class

Taxa

brown hoplo *Hoplosternum littorale*
redbreast sunfish *Lepomis auritus*
spotted sunfish *Lepomis punctatus*
largemouth bass *Micropterus salmoides*
striped bass *Morone saxatilis*
bluenose shiner *Pteronotropis welaka*
Unionidae