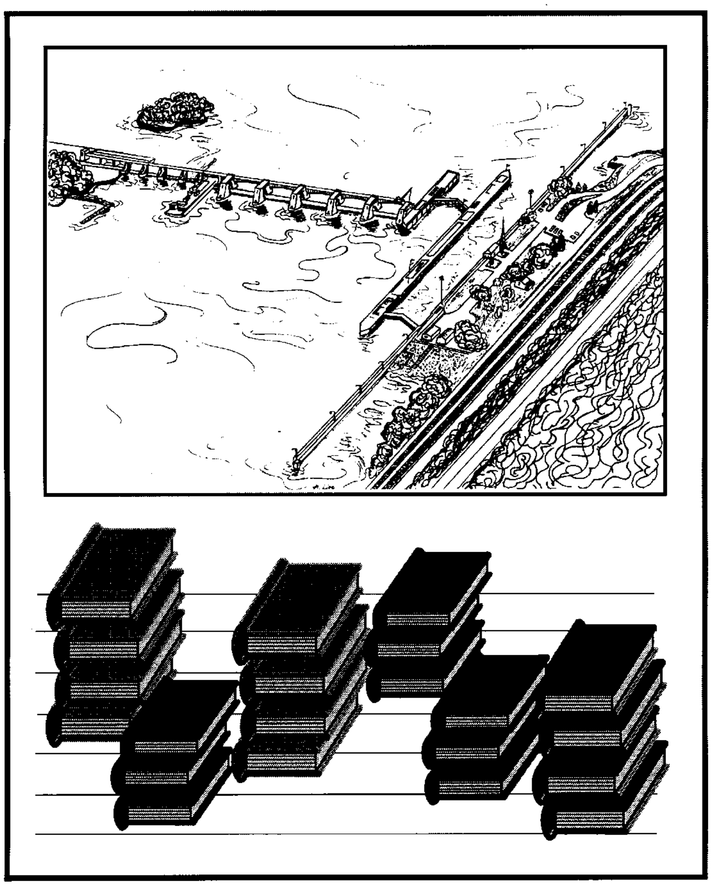
Long Term Resource Monitoring Program

Technical Report

96-T007

Effects of Water Levels on Ecosystems:

An Annotated Bibliography



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Effects of Water Levels on Ecosystems: An Annotated Bibliography

by

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December 1996

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Contents

Preface

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

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

This report was developed with funding provided by the Long Term Resource Monitoring Program under Strategy 1.2.3, *Determine Effects of Water Levels and Discharges on the Upper Mississippi River Ecosystem,* as specified in the Operating Plan of the LTRMP for the Upper Mississippi River System (USFWS 1993).

Effects of Water Levels on Ecosystems: An Annotated Bibliography

By Joseph H. Wlosinski and Eden R. Koljord

Abstract

This report contains annotations from more than 800 papers and reports describing the effects of water levels on ecosystem components, primarily in fresh waters. An index containing key words is included to facilitate the location of references on certain subjects. Key words are also grouped into general categories. The work was performed as part of the Upper Mississippi River System Long Term Resource Monitoring Program.

Introduction

Twenty-seven dams allow for the management of water levels on the Upper Mississippi River System (UMRS). Most of these dams were authorized by Congress in 1930 to maintain a 9-ft navigation channel (Rivers and Harbors Act, July 3, 1930, H.R. 11781). As noted in Wilcox and Willis (1993), Engineering Manual 1110-2-3600, November 30, 1987, provides guidance on the management of water control projects. According to the guidance, even for single-purpose projects, operations "must be tuned to produce the benefits for environmental and social goals. . . ."

In the General Plan for the UMRS Environmental Management Program (U.S. Army Corps of Engineers, North Central Division 1986), major goals for the Long Term Resource Monitoring Program (LTRMP) were to predict the effects of natural and human-induced actions on various ecosystem components, and recommend management actions to ameliorate undesirable natural and human-induced effects on the ecosystem. These goals have been carried forward with a strategy in the Operating Plan (USFWS 1993) for the LTRMP of determining the effects of water levels and discharges on the UMRS. This annotated bibliography was written to help meet the above goals and strategy.

We searched Current Contents (Agriculture, Biology, and Environmental Sciences), DIALOG (Compendex; Aquatic Science and Fisheries Abstracts, Enviroline, and Life Sciences), TYMNET (Scisearch), Water Resources Abstracts, Ecological Abstracts, the Aquatic Plant Information Retrieval System at the University of Florida, and various other sources at the Environmental Management Technical Center and the Upper Mississippi Science Center at La Crosse, Wisconsin. Many of the abstracts in this report were taken directly, or with some changes, from annotated bibliographies authored by Ploskey (1982) or Triplett, Culver, and Waterfield (1980). Other abstracts were taken directly, or with some changes, from original papers. Some abstracts were copied from Selected Water Resources Abstracts. We generated annotations in instances where no abstracts were available after copying sections from the report verbatim, and as such take responsibility for errors and misstatements. This report is not a complete bibliography on the effects of water levels on ecosystems. We arbitrarily excluded most of the literature from tidal, brackish, and salt waters, and made no attempt to translate foreign works. The units of measure used in all abstracts are consistent with those from the original paper or abstract.

An index, with key words, is provided to assist readers in finding abstracts concerning certain subjects. The majority of key words were obtained from the Upper Mississippi River Conservation Committee Library Database (Janecek 1989). Key words, grouped into general categories, are presented in the Table. The index was constructed electronically by scanning each abstract, including its citation.

The numbers used in the index refer to the abstract number, not the page.

Acknowledgments

We are indebted to Gene Ploskey, James Triplett, David Culver, and Gerald Waterfield for allowing us to use their annotated bibliographies. We also thank Jean Schmidt, Kristi Jackson, and Amanda Helbing for their assistance in performing literature searches and Debbie Harris and Georginia Ardinger for editorial assistance.

References

Janecek, J. A. 1989. UMRCC Library Database User's Manual. U.S. Fish and Wildlife Service, Rock Island, Illinois.

Ploskey, G. R. 1982. Fluctuating water levels in reservoirs; an annotated bibliography on environmental effects and management for fisheries. Prepared by the U.S. Department of the Interior, Fish and Wildlife Service, for the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi, Technical Report E-82-5.

Triplett, J. R., D. A. Culver, and G. B. Waterfield. 1980. An annotated bibliography on the effects of water level manipulation on lakes and reservoirs. Ohio Department of Natural Resources, Federal Aid Project F-57-R, Study 8. 50 pp.

U.S. Army Corps of Engineers, North Central Division. 1986. General plan, Upper Mississippi River System Environmental Management Program, January. 31 pp.

U.S. Fish and Wildlife Service. 1993. Operating Plan for the Upper Mississippi River System Long Term Resource Monitoring Program. Environmental Management Technical Center, Onalaska, Wisconsin, Revised September 1993. EMTC 91-P002R. 179 pp. (NTIS #PB94-160199)

Wilcox, D. B., and K. W. Willis. 1993. Identification of constraints on river regulation. Lock and Dam 9 near Lynxville, Wisconsin, Upper Mississippi River Nine-Foot Channel Project. Report by the U.S. Army Corps of Engineers, St. Paul District-Minnesota, for the U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin, August 1993. EMTC 93-S012. 91 pp. (NTIS # PB94-103603)

Table. Key word list by major topic (after Janecek 1989)

Vegetative Descriptors
- Algae
- *Alisma*
- Aquatic
- *Ceratophyllum*
- Chlorophyll
- *Echinochloa*
- *Eleocharis*
- *Elodea*
- Emergent
- Floating-leaved
- Forb
- Forest
- Grass
- Macrophyte
- Moist-soil
- *Najas*
- *Nelumbo*
- *Nuphar*
- *Phragmites*
- Phytoplankton
- Plant
- *Polygonum*
- *Pontederia*
- *Potamogeton*
- Purple loosestrife
- Root
- *Sagittaria*
- *Scirpus*
- Shrub
- Submergent
- Submersed
- Terrestrial
- Tree
- *Typha*
- *Vallisneria*
- Vegetation
- *Zizania*

Microorganisms
- Algae
- Chlorophyll
- Phytoplankton
- Plankton
- Zooplankton

Invertebrate Descriptors
- Annelids
- Arthropod
- Aufwuchs
- Benthos
- Clam
- Crustacean
- Insect
- Macroinvertebrate
- Mollusc
- Mussel
- Zooplankton

Fish Descriptors
- Bass
- Bluegill
- Buffalo
- Bullhead
- Carp
- Catfish
- Commercial fishing
- Crappie
- Drum
- Fish
- Fish kill
- Fisheries
- Fishing
- Paddlefish
- Perch
- Pike
- Sauger
- Shad
- Sturgeon
- Sucker
- Sunfish
- Walleye

Wildlife Descriptors
- Amphibians
- Beaver
- Birds
- Duck
- Furbearers
- Geese
- Mallard
- Mammal
- Muskrat
- Otter
- Shorebird
- Teal
- Waterbird
- Waterfowl
- Wildlife
- Wood duck

Life History Descriptors
- Abundance
- Den
- Disease
- Distribution
- Diversity
- Fecundity
- Forage
- Fry
- Growth
- Larval
- Length–frequency
- Life history
- Migration
- Mortality
- Movement
- Nest
- Nesting
- Niche
- Nursery
- Physiology
- Population
- Population dynamics
- Predation
- Predator
- Range
- Reproduction
- Spawn
- Territory
- Young-of-year

Habitat Descriptors
- Agriculture
- Aquatic
- Backwaters

Bay
Channel border
Cover
Developed
Dikes
Ecosystem
Edge
Estuary
Floodplain
Forest
Habitat
Illinois River
Island
Lacustrine
Lake
Levees
Littoral
Main channel
Mississippi River
Moist-soil
Mudflat
Physical
Pond
Pool
Prairie
Refuge
Reservoir
Riparian
River
Riverbank
Riverine
Sandbars
Shore
Spring
Stream
Substrate
Tailwaters
Terrestrial
Upper Mississippi River
Urban
Wetland
Woodland

General Study Descriptors

Analysis
Bathymetry
Ecology
Geology
Geomorphology
History
Hydraulic
Hydrology
Limnology
Monitoring
Physiology
Research
Sampling
Soils
Studies
Study
Survey
Taxonomy
Water level

Specific Study Descriptors

Aerial survey
Assayed
Creel census
Database
Efficiency
Electrofishing
Gear
Harvest
Identification
Instream flow
Inventory
Methods
Model
Modeling
Procedure
Tagging
Technique
Telemetry
Trawling

Management Descriptors

Aeration
Conservation
Control
Culture
Dewater
Drawdown
Fluctuation
Management
Manipulation
Mapping
Rehabilitation
Stocking

Administrative Descriptors

Criteria
Nongame
Planning
Policy
Procedure
Program
Rare
Regulation
Standard
Status
Threatened
Water quality

Perturbing Elements

Anoxia
Anoxic
Channelization
Clearing
Contaminants
Dams
Development
Dikes
Diversion
Drawdown
Dredging
Drought
Effluent
Erosion
Eutrophication
Fish kill
Flooding
Fluctuation
Hydropower
Impoundment
Levees
Navigation
Runoff
Sedimentation
Sediments
Turbidity
Waves
Winter

Public Use Descriptors

Access
Boating
Hunting
Recreation

- Sport-fishing
- Trapping
- Water use

General Reference

- Bibliography
- Proceedings
- Reference
- Review

Qualifying Descriptors

- Aquatic
- Control
- Developed
- Drift
- Ecosystem
- Floodplain
- Illinois River
- Lacustrine
- Littoral
- Management
- Mississippi River
- Nursery
- Physical
- Riparian
- Riverine
- Terrestrial
- Upper Mississippi River
- Winter

Effects of Water Levels on Ecosystems: An Annotated Bibliography

1. AASS, P. 1960. The effects of impoundment on inland fisheries. Seventh Technical Meeting, 1958. International Union for Conservation of Nature and Natural Resources 4:69–76.

Factors that significantly affect the aquatic biota of Norwegian impoundments are discussed. The extent of water-level fluctuation is the only factor that affects changes in the fish-food fauna. The abundance of species with poor ability to follow receding waters is greatly reduced, or eliminated. Aquatic plants and benthos without a diapause or resting mechanism die from overwinter exposure and freezing. Gastropods and *Gammarus* are usually severely reduced by fluctuating water levels, and destruction of aquatic vegetation reduces populations of benthos by eliminating refuge and food. Initially, high water levels flood terrestrial areas and temporarily increase the food supply of fish by making terrestrial animals and nutrients available. Erosion induced by water-level fluctuations and wave action creates rocky shorelines that support a poor benthic fish-food fauna. Fish growth usually declines, because many species must supplement their diet with plankton. Although rapidly receding water seemingly does not affect tipulids, oligochaetes, or plecopterans; ephemeropterans and trichopterans are eliminated. Occasionally, growth and yields of fish increase for several years after filling, but ultimately production declines even below the original level. Flooding may enhance the reproduction of fishes, such as perches and pikes, which spawn over flooded areas in spring. Fry of these species prosper with increased cover and food. Reduced water levels may cause atresia or increase mortality of fry by stranding or predation. Because of water-level fluctuations and resulting variations in year-class strength, a single year class is apt to dominate the harvest for a number of years. Although trout catches invariably decline in fluctuating impoundments, probably because of low benthos populations, the harvest of chars frequently increases as a result of improved zooplankton production. The overall decline in harvest may be due to physical problems encountered in fishing areas in flooded timber or drifting vegetation.

2. AGER, L. A., AND K. E. KERCE. 1970. Vegetational changes associated with water level stabilization in Lake Okeechobee, Florida. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 24:338–351.

The purpose of this study was to compare the long-range effects of water-level fluctuation on the marsh vegetation of Lake Okeechobee. Factors thought to be important are soil moisture and the inundation tolerance of the various species. In 1956, the Florida Game and Fresh Water Fish Commission conducted a vegetational analysis of the lake marsh to predict the probable results on vegetation from construction of a levee to contain the lake waters. A subsequent analysis of the area was conducted in 1969 to determine what vegetational changes had occurred. Comparison of the data from the two studies revealed that stabilization of the water level had occurred resulting in perennials replacing annual plants, an increased frequency of submergent species, and a decrease in the total number of species present. The change in time at which inundation occurs coupled with a more stable water level were identified as the primary factors responsible for the reduction of important waterfowl plants and the greater frequency of submergent vegetation. A total of 42 species of plants were identified in 1969, compared with 46 species in the 1956 study.

3. AGGUS, L. R. 1971. Summer benthos in newly flooded areas of Beaver Reservoir during the second and third years of filling, 1965–1966. Pages 139–152 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

Multiple-plate samplers showed that areas of recently flooded herbaceous vegetation contained greater numbers and biomass of benthos than did cleared areas or those with woody vegetation. Recently inundated herbaceous plants presumably provided space for attachment, food, and refuge from predators. Cleared areas were less productive than areas with vegetation and were subjected to greater and more rapid erosion. The typical summer decline in the number of organisms was more rapid after the breakup or decomposition of herbaceous vegetation, and decreases in chironomid abundance coincided with a conspicuous increase in the rate of shoreline erosion and sediment redeposition.

4. AGGUS, L. R. 1979. Effects of weather on freshwater fish predator–prey dynamics. Pages 47–56 *in* H. Clepper, editor. Predator–prey systems in fisheries management. Sport Fishing Institute, Washington, D.C.

The effects of environmental changes are difficult to understand because of the heterogeneous nature of reservoir habitats that modify the effects of meteorological events and because of difficulties in assigning cause–effect relations. In reservoirs, flow-related factors that result from changes in precipitation or water release may affect fish more than temperature, which exerts its greatest effect in physically stable environments such as natural lakes. Seasonal and annual variations in rainfall affect the fish community by altering water levels, rates of nutrient input, and runoff volumes. Literature on water levels indicates that spawning success of many species is influenced by the timing and duration of flooding and the type of substrate covered. Some studies suggest that high water levels have little positive effect on reproduction when terrestrial plants are not inundated. Changes in water levels alter the ratio of prey to predatory fish and the carrying capacity of the environment. Data suggest that populations of closely related species (e.g., largemouth, spotted, and smallmouth bass) may respond differently to changes in water level. As a result of receding waters, prey availability may increase rapidly for existing predators, thereby improving predator growth and use of prey.

5. AGGUS, L. R., AND G. V. ELLIOT. 1975. Effects of cover and food on year-class strength of largemouth bass. Pages 317–322 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Strong year classes of largemouth bass occurred only in years of high inflow and high water. The number of bass surviving their first summer was significantly correlated with the amount and duration of flooding of shoreline vegetation. Predation probably was a major cause of mortality in young-of-year bass. Growth of young largemouth bass accelerated when high inflows resulted in extensive flooding of terrestrial vegetation or when bass converted from a diet of invertebrates to one of fish. Overwinter survival was higher for large individuals.

6. AGGUS, L. R., AND S. A. LEWIS. 1976. Environmental conditions and standing crops of fishes in predator-stocking evaluation reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:131–140.

Of 11 environmental variables tested (from 23 reservoirs) by multiple regression analysis, only storage ratio (i.e., reservoir volume divided by the annual outflow volume), outflow volume, growing season, and total dissolved solids were consistently related to the standing crop of fish. Total standing crops and crops of sunfishes, clupeids, and small fishes were larger in impoundments with rapid rates of water exchange (a storage ratio less than 0.165, as in mainstream reservoirs) than in storage reservoirs with slow rates of water exchange. During periods of high inflow, storage reservoirs may become similar to mainstream reservoirs in hydrology, fish standing crops, and fish community structure. Standing crops of all fishes increased more in storage reservoirs than in mainstream reservoirs after the high inflows of 1973. During 1973, flooded shoreline vegetation in the 23 fluctuating reservoirs added a new source of detritus, but the effects of water-level fluctuation (in vertical feet) were not significant, although relations were generally positive. Combinations of environmental variables explained 41%–67% of the variation in the standing crops of selected taxa.

7. AHLGREN, C. E., AND H. L. HANSEN. 1957. Some effects of temporary flooding on coniferous trees. Journal of Forestry 55:647–650.

Flooded areas in northern Minnesota were studied between 1950 and 1952. Balsam fir and black spruce seemed to be the most flood-resistant species. The relative survival of coniferious species for submergence periods as long as 48 days was balsam fir, black spruce, white spruce, white pine, and red pine, in decreasing order. However, all of these species and jack pine were killed by flood periods of greater duration. No observations were made on jack pine for shorter flood periods. Observations on several other areas indicated that balsam fir was less tolerant of flooding than most of the associated hardwoods, such as aspen, American elm, rock elm, black ash, red maple, basswood, red oak, bur oak, and balsam poplar. Of the hardwoods, paper birch suffered most heavily.

8. AL RAWI, T. R. 1971. Investigating the validity of the scale method in determining the growth of two species of fish in Oklahoma and its relation to temperature and water level. Ph.D. Thesis, Oklahoma State University, Stillwater. 152 pp.

Studies of gizzard shad and white crappie in Keystone Reservoir indicated that growth was independent of water-level fluctuation. However, fluctuations in water level were small during most of the sampling period except for 1 month, mid-June through mid-July. Growth seemed to be more closely related to temperature than to water level.

9. ALHONEN, P. 1970. On the significance of the planktonic/littoral ratio in the cladoceran stratigraphy of lake sediments. Commentationes Biological 35:1–9.

Evidence is presented that relates water-level oscillations (as caused by rainfall) to variations in the abundance of major cladoceran taxa in pelagic and littoral zones. Water-level oscillations were associated with the index ILL = Bosminidae + Daphnidae / Chydoridae.

10. ALLAN, R. C., AND J. ROMERO. 1975. Underwater observations of largemouth bass spawning and survival in Lake Mead. Pages 104–112 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington D.C.

Major factors affecting the reproduction and survival of largemouth bass in Lake Mead are evaluated (i.e., water-level fluctuation, wind and wave action, water quality, cover, temperature, predation, and human activities). Before impoundment of Lake Powell upstream, occasional floods in Lake Mead pushed water levels to new heights during the spawning season and resulted in good recruitment and several years of good fishing. After 1964, while Lake Powell was filling, water levels in Lake Mead declined. In the spawning season of 1974, receding water levels and strong winds caused excessive erosion, which buried or suffocated some nests. Nesting success was not positively correlated with the availability and quality of cover. The species and amount of zooplankton produced in coves and available for fry may be related to the inundation of green cover by rising waters. Poor survival of fry and fingerling bass may be related to a limited food supply.

11. ALLEN, G. W. 1969. Pool fluctuations in Corps impoundments in relation to fish spawning. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 23:553–558.

The efforts of conservation agencies and the U.S. Army Corps of Engineers to provide suitable water levels during the spawning season of sport fishes is discussed. In spite of coordinated efforts, manipulation of water levels in reservoirs has never been proven to benefit or harm fisheries resources consistently, but because of the complex nature of the relation between fish populations and fluctuating water levels, coordinated manipulations will be continued until it is proved that they have no beneficial effect. Biologists apparently do not know enough about fish dynamics in reservoirs to predict future conditions in fisheries or to pinpoint exactly what is right or wrong with existing conditions.

12. ALLEN, H. H., AND L. R. AGGUS, EDITORS. 1983. Effects of fluctuating reservoir water levels on fisheries, wildlife, and vegetation; summary of a workshop, February 24–26, 1981. U.S. Army Waterways Experiment Station, CE, Vicksburg, Mississippi, Miscellaneous Paper E-83-2. n.p.

For many years, large reservoirs have been constructed throughout the United States to provide flood control, power sources, and recreation areas. Design and operational characteristics of these reservoirs determine the types of habitat available to fish and wildlife species. Periodic fluctuations in water level on reservoirs are of particular concern to natural resource managers. The seasonal fluctuations that occur on many lakes and flood-control reservoirs and the daily fluctuations that are necessary on some hydroelectric projects often result in the elimination of shoreline vegetation, which causes erosion, diminished water quality, and habitat loss or degradation. This report presents abstracts of papers presented at a workshop organized to identify the problems resource managers face and to present research results that might be applied to alleviate or moderate the adverse effects of reservoir fluctuation. Sessions were organized under the general topics of vegetation, wildlife, and fisheries. Discussions of the results of the workshop sessions and possible means of resolving conflicts between the requirements of the reservoir biota and the principal operational goals of the reservoir projects are also presented. Addresses of the principal authors are provided to allow readers to seek further information regarding particular studies.

13. ANDERSON, D. R., AND F. A. GLOVER. 1967. Effects of water manipulation on waterfowl production and habitat. Transactions of the North American Wildlife and Natural Resources Conference 32:292–300.

From 1965 to 1966, a study was performed at the Monte Vista National Wildlife Refuge in Colorado. The main thrust of the experiment was the amount of time that water was available on the study areas and its effect on waterfowl production, ecology, and habitat. The results showed that waterfowl production and use may be increased on managed areas by the application of water before spring migration.

14. ANDERSON, E. A., AND A. WOOLF. 1984. River otter (*Lutra canadensis*) habitat utilization in northwestern Illinois. Page 12 *in* Proceedings of the Mississippi River Research Consortium, Volume 16, La Crosse, Wisconsin, April 18–20, 1984.

A study was conducted from August 1982 through December 1983 to identify and characterize critical areas of river otter habitat along and near the Mississippi River in northwestern Illinois, to determine seasonal use of an example of such habitat, and to assess potential effects of the various resource uses on the otter population in these areas. Two male otters were livetrapped, and each was surgically implanted with a radio transmitter and released. The monitoring of habitat and den selection by these otters through radiotelemetry and the monitoring of other otters, including a small family group, through field observations identified the type of areas used by otters and seasonal use of those areas. Characteristics of suitable habitat were (1) isolation from the main channel, (2) riparian habitats of extensive woodlands, (3) good water quality, (4) areas of open water in winter, and (5) the presence of suitable den sites. The evaluation of habitats along that portion of the Mississippi River bordering Illinois resulted in identification of 13 areas of critical river otter habitat. In spring and fall, food and Mississippi River stage seemed to exert the greatest influence on habitat selection. In winter, the presence of areas of open water determined habitat use. Of all the resource uses, barge traffic and furbearer trapping seemed to have the greatest potential adverse effect on the otter population. In addition, high water levels during March and April may adversely affect otter reproduction and therefore be a potential limiting factor to the population. Analysis of 765 otters scats indicated fish were the principal otter prey, with Centrarchidae, Cyprinidae, and Clupeidae occurring in 49%, 41%, and 36% of the scats, respectively. (Abstract only)

15. ANDERSON, R. V., AND M. C. ANDERSON. 1994. Revegetation in flooded habitats, the potential importance of seed banks. Page 23 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

During the 1993 flood on the Upper Mississippi River, deep layers of sediment were deposited over much of the floodplain. The duration of the flooding and burial by the deposited sediments killed most of the nonwoody floodplain vegetation. This, in effect, leaves a new habitat available for colonization by plants, a necessary precursor to reestablishing animal communities. Plant development in these newly deposited sediments is likely to be predominantly by seeds. Seeds that were transported and deposited with the flood-delivered sediments become part of the reproductive potential "seed bank" of the sediments and may account for much of the new herbaceous layer that develops. To determine how much the seed bank may contribute, sediments deposited in the floodplain of Western Illinois University's Kibbe Field Station during the 1993 flood were collected. Particle size, organic content, and soil nutrients were determined. All seeds were wet-sieved from sediment samples, counted, and identified. Collected sediment was also spread in greenhouse flats to the depth (5.5 cm) that the sediments had been deposited in the floodplain. Germination tests, germination distribution, and growth success were examined in a greenhouse study. Twenty-one species of plant seeds were found with grasses and moist-soil plants predominating the seed community. Of these, only seven species of plants developed. Approximately 19% of the seeds present germinated, but only 8% of those germinating survived more than 1 month. Seed distribution and germination was random and no competition between plants was apparent in the first 6 months of growth. (Abstract only)

16. ANDERSON, R. V., AND D. M. DAY. 1986. Predictive quality of macroinvertebrate–habitat associations in lower navigation pools of the Mississippi River. Hydrobiologia 136:101–112.

Macroinvertebrate community structure was compared between habitat types within a navigation pool and between navigation pools of the Upper Mississippi River. Bottom samples were taken by using a grab or Wilding sampler from 40 stations on Pool 19 and 14 on Pool 26. The major factor in determining macroinvertebrate community structure in both pools was substrate rather than the more artificial habitats defined by river morphometry.

17. ANTIPOVA, O. P. 1961. Some basic information about reservoirs of the U.S.S.R. which are already built, or are planned. Izvestiya Gosudarstvennogo Nauchno-Issledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozvaistva 50:261–269. (In Russian)

Information on 119 reservoirs is presented. Data include the river or lake source, year filled, area, volume, maximum and mean depths, maximum length, average long-term water turnover, decrease in water level for an average year, and anticipated catch of fish. (Abstract adapted from Referativmyi Zhurnal. Biologiya 1963, 5158; Biological Abstract 45:2718)

18. APPLEGATE, R. L., AND J. W. MULLAN. 1967. Food of the black bullhead (*Ictalurus melas*) in a new reservoir. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 20:288–292.

Diets of black bullheads collected during periods of relatively stable water level differed significantly from those of fish sampled during periods of rapidly rising water. When water levels were stable, young-of-year bullheads fed mainly on entomostracans (72% of the stomach volume), and diets of bullheads 4.0 to 11.3 inches long consisted mostly of filamentous algae and detritus (94% by volume). By contrast, when water levels rose rapidly during winter and spring and flooded terrestrial soils for the first time, terrestrial animals such as earthworms and insects were eaten preferentially (56% by volume).

19. APPLEGATE, R. L., AND J. W. MULLAN. 1967. Food of young largemouth bass (*Micropterus salmoides*) in a new and an old reservoir. Transactions of the American Fisheries Society 96:74–77.

Foods of young largemouth bass during the early development of a new reservoir and in a 14-year-old reservoir are described. Growth of fish was substantially faster in the new than in the old reservoir. Average daily growth during early summer was 0.52 mm in Bull Shoals Lake and l.17 mm in Beaver Lake. Large food items such as chironomid larvae, which "bridged the gap" from an entomostracan diet to a diet of fish in Beaver Lake, were almost completely lacking in the older reservoir. In Beaver Lake, chironomids were the dominant food (superseding entomostraca) for bass about 36 mm long. At 40 mm, bass preferentially selected gizzard shad over chironomid larvae. In Bull Shoals Lake, 40-mm-long bass switched from a diet dominated by entomostraca to one dominated by fish.

20. APPLEGATE, R. L., AND J. W. MULLAN. 1967. Zooplankton standing crops in a new and an old Ozark reservoir. Limnology and Oceanography 12:592–601.

The zooplankton populations (April 1964 through June 1966) of Beaver Reservoir before full impoundment are compared with those of 14-year-old Bull Shoals Reservoir, both on the White River in the Arkansas–Missouri Ozarks. Seasonal standing crop estimates show a unimodal curve in the old reservoir and a bimodal curve in the new reservoir. Significant seasonal differences between the reservoirs occurred in densities, species composition of cladoceran communities, and horizontal distribution. An increase in the standing crop in the new reservoir in spring 1966 was associated with species changes within the genus daphnia. Mean annual standing crops of entomostracans and rotifers were similar in the two impoundments. The bimodal curve of zooplankton abundance might contribute more to fish production.

21. APPLEGATE, R. L., J. W. MULLAN, AND D. I. MORAIS. 1966. Food and growth of six centrarchids from shoreline areas of Bull Shoals Reservoir. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 20:469–482.

Stomach contents of longear sunfish, green sunfish, bluegills, largemouth bass, smallmouth bass, and spotted bass from Bull Shoals Lake were analyzed and compared. Fish were collected from nearshore areas of the fluctuating reservoir throughout the growing season of 1964, and seasonal changes in diets were documented. Data refute the hypothesis that fluctuations of water level (averaging 16 ft yearly) limit benthos production in littoral areas and thereby decrease the value of these areas as nurseries for young fish. The littoral benthos of Bull Shoals Reservoir contributed substantially to the diets of all centrarchids less than 4 inches long.

22. ARMITAGE, P. D. 1984. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities. Pages 139–165 *in* A. Lillehammer and S. J. Saltveit, editors. Regulated Rivers. Engers Boktrykkeri, Norway.

Information on invertebrate responses to modified flow and temperature regimes obtained from recent reviews and other published work is summarized. In addition, various changes in water quality arising from impoundment are described with particular reference to their effect on stream biota. Special emphasis is given to the quality of suspended particulate material downstream of reservoirs and original data are presented on the nutritional "value" of seston in a regulated and in an unregulated stream in northern England. Nitrogen levels in coarse particulate seston from the regulated stream were higher and carbon:nitrogen ratios lower than in the unregulated stream.

23. ARNER, D. H., W. J. LORIO, B. M. TEELS, AND E. D. NORWOOD. 1971. The effects of age and water fluctuations on the limnological factors of impounded waters. Mississippi Water Resources Research Institute, Mississippi State University, Completion Report A-047-Miss. 49 pp.

The effects of reservoir age and drawdown were studied by comparing the plankton, chlorophyll levels, benthos, fish, and water chemistry of Bluff Lake, Mississippi (an old lake subjected to drawdown), to that of Oktibbeha County Lake, Mississippi (a new lake with stable water levels). Drawdown had no obvious effect on the populations of phytoplankton and zooplankton, which reached peak abundance in fall in both lakes. Bluff Lake exhibited a strong spring algal bloom that was lacking in the new nonfluctuating lake. Chlorophyll concentrations were significantly higher in Bluff Lake than in Oktibbeha County Lake during the fall drawdown. Indications are that Bluff Lake is more productive than the other lake. Because no significant difference was noted in the numbers or weights of benthic taxa in the two lakes, the authors concluded that the 5- to 6-ft drawdown of Bluff Lake had no effect on benthos. However, all of the sampling stations in Bluff Lake were below the drawdown limit. Largemouth bass and bluegills collected from Bluff Lake had better condition factors than those from Oktibbeha County Lake. Rotenone sampling indicated that the sport fish populations were low in both lakes but that there were more harvestable-sized fish in the drawdown lake. Drawdown apparently increased the amount of prey fish available to piscivores.

24. ARONIN, E. S., AND P. V. MIKHEEV. 1963. Rehabilitation of the fishery in the shallows of large reservoirs. First Scientific–Technical Conference for the Study of the Kuibyshev Reservoir 3:3–12. (In Russian)

The fluctuation of water levels in reservoir shallows destroyed conditions for the reproduction of fish and reduced the area of their summer feeding grounds. In winter, power generation at the hydroelectric station caused shallows to dry, resulting in mass mortality of young fish, particularly common carp (*Cyprinus carpio*). Construction of large fish hatcheries in the shallows would ensure an increase in the reservoir's fish production. (Abstract adapted from Referativmyi Zhurnal. Biologiya 1964, 5158; Biological Abstract 46:14374)

25. ASCH, R. L., AND P. J. KINGSBURY. 1972. Copepoda and cladocera population of Red Rock Reservoir, Iowa, from April to November 1970. Proceedings of the Iowa Academy of Science 78:73–75.

The effects of nutrient renewal, water level, and average weekly discharge of water on the species composition, relative abundance, and population fluctuations of the Copepoda and Cladocera in Red Rock Reservoir are examined. Three distinct seasonal peaks in populations were correlated with temperature, transparency, discharge rate, and nutrient levels. Abundance was not related to water level.

26. ASHTON, F. M., AND S. R. BISSELL. 1987. Influence of water regime on growth of dwarf spikerush and slender spikerush. Journal of Aquatic Plant Management 25:51–54.

Pregerminated two- to three-leaf seedlings of dwarf spikerush (*Eleocharis coloradoensis* [Britt.] Gilly) and slender spikerush (*Eleocharis acicularis* [L.] R. & S.) were transplanted into a soil mix and subjected to four water regimes for 56 weeks starting in June. These regimes were (1) continuously submerged, (2) continuously emerged, (3) submerged–winter emerged–submerged, and (4) submerged winter drained–submerged under otherwise normal environmental conditions. Fresh weight and dry weight biomass were determined at approximately 4-week intervals. Both species increased in biomass with time, except in winter when growth of dwarf spikerush decreased but remained relatively constant with slender spikerush. Slender spikerush grew more rapidly than dwarf spikerush as the temperatures increased in spring. Slender spikerush produced the most biomass at 56 weeks in treatment 4, about twice as much as in treatment 1 and about 1.4 times as much as in treatments 2 and 3. In contrast, there was little difference in the biomass of dwarf spikerush among the four treatments at 56 weeks. Slender spikerush produced about three times more biomass than dwarf spikerush in their respective best water regimes. These results, along with other data, indicate that slender spikerush would be better than dwarf spikerush for the competitive inhibition of undesirable aquatic species under our environmental conditions, and the growth of the former species can be optimized by manipulation of the water regime, whereas this does not seem to be the case for the latter species.

27. AUBLE, G. T. 1989. Modeling wetland and riparian vegetation change. Pages 399–403 *in* The Association of Wetland Managers, Inc., Wetlands and river corridor management. Proceedings of the International Wetland Symposium, Charleston, South Carolina, July 5–9, 1989. Omnipress, Madison, Wisconsin.

A review is made of several modeling approaches for predicting the composition of wetland and riparian vegetation at a site.

28. AXELSON, J. 1961. Zooplankton and impoundment of two lakes in northern Sweden (Ransaren and Kultsjoen). Institute of Freshwater Research Drottningholm Report 42:84–168.

Water regulation and resulting water-level fluctuations affect zooplankton abundance. Data from Kultsjoen Lake was used as a control to account for natural variation in zooplankton abundance. Regulation of Ransaren Lake created environmental conditions favorable to zooplankters, and densities increased greatly when water levels reached the upper limit. Increased abundance of zooplankton was attributed to reduced losses in summers when water discharge was low. Apparently large releases of water during the growing season impoverish the plankton and may result in deteriorated food conditions for fish.

29. BABIŃSKI, Z. 1992. Hydromorphological consequences of regulating the lower Vistula, Poland. Regulated Rivers: Research & Management 7:337–348.

Quantitative and qualitative data on channel changes along the lower Vistula arising from regulation works carried out in the nineteenth and twentieth centuries are presented. The construction of groynes narrowed the bed by 50% and straightened its thalweg. Regulation led to the deepening of the main channel into sediment deposition in the inner growing areas. After more than 100 years of regulation, the channel bed lowered, on average, by 1.3 m, whereas the inner growing zone rose, on average, by 1.8 m, forming a strip of floodplain about 375 m wide. River islands and central bars were replaced by alternate bars. The bed load was reduced from 1.9 to 1.3 $\times$ $10^6 m^3$ per year.

30. BAEKKEN, T., A. FJELLHEIM, AND R. LARSEN. 1981. Seasonal fluctuations of physical and chemical parameters of a weir basin in a regulated west Norwegian river. Nordic Hydrology 12:31–42.

Both before (1967–69) and after (1976–78) the regulation of the river Ekso in western Norway, physical and chemical analyses were made of the river water. After the regulation, water samples for chemical analyses were taken at the inlet and outlet of a weir basin 375 m long that had recently been built to maintain the previous water level. The reduced water discharges and the increased water temperatures that followed the regulation presumably increased the amount and the quality of food available to detritus-feeding animals. The O_2 content of the water was slightly reduced after the regulation. The pH was in the same range. Specific conductance and the concentrations of major ions before and after the regulation were also in the same range, but a distinct seasonal variation appeared after the regulation. These variations were thought to have three main reasons: (1) water discharge, (2) biological production, and (3) nonspecified physicochemical relations. Regression analyses based on the concentrations of major ions and water discharge after the regulation were made separately for the summer and the winter seasons. Specific conductance and SO_4^{-2} concentrations were not correlated to water discharge, Cl^- concentrations were positively correlated, and Ca^{2+} showed a negative correlation. Mg^{2+} and NO_3^--N were not correlated to water discharge during the summer season, but showed a significant negative correlation during winter.

31. BAILEY, R. M., AND H. M. HARRISON, JR. 1945. The fishes of Clear Lake, Iowa. Iowa State Journal of Science 20(1):57–77.

A description of Clear Lake, its history, and fish community is presented and compared with Spirit Lake, Iowa. The authors mention that small fishes were abundant in shallow areas a year after water levels rose rapidly in Spirit Lake in 1943. Additional sampling indicated improved sport-fish populations. Poor angling was attributed to an abundance of minnows, which presumably increased food availability and thereby decreased the susceptibility of sport fish to harvest by fishermen.

32. BAKER, L. A., AND E. B. SWAIN. 1989. Review of lake management in Minnesota. Lake and Reservoir Management 5(2):1–10.

Drawdown, as a management option, was only used in Highland Lake, Minnesota, as part of the clean lakes project. The drawdown was intended to remove phosphorous-rich hypolimnetic water from the lake, reduce future release of phosphorous from the sediments, and consolidate the sediments. Because other management techniques were applied at the same time, it is unclear which management technique had the greatest effect on water quality.

33. BALL, J., C. WELDON, AND B. CROCKER. 1975. Effects of original vegetation on reservoir water quality. Water Resource Institute, Texas A&M University, Technical Report 64. 54 pp.

A series of leaching studies was conducted on grasses, herbaceous plants, and trees representative of those in basins of new reservoirs to determine the relative rates of nutrient release (nitrogen and phosphorus) and the effects of released nutrients on overlying waters. The quantity and rate of nutrient release varies greatly with the type of vegetation flooded. Nutrients from grasses and herbaceous plants were released at a greater rate and quantity per unit of vegetation weight than were nutrients from trees. Also, nutrients from herbaceous plants were more available in greater quantities per unit of area than were nutrients from trees. The rate at which nutrients are released and the amounts released are functions of the surface area to biomass ratio for vegetation. Productive or eutrophic waters leach nitrogen faster than less productive waters. Leaching apparently is rapid on the first day, but after the initial period (which may last 2 weeks) the rate slows. Herbaceous terrestrial plants usually are completely degraded and assimilated within l year.

34. BARANOV, I. V. 1961. Biohydrochemical classification of the reservoirs in the European USSR. Pages 139–183 *in* P. V. Tyurin, editor. The Storage Lakes of the USSR and their importance for fishery. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian)

An elaborate scheme for classifying reservoirs is presented. It is based primarily on the nature of humus in the water, anion concentrations, and the trophic phase of the reservoir. The "evolution" of most reservoirs can be divided into three arbitrary phases based on productivity. The initial phase (trophic upsurge), which lasts 2 to 3 years is characterized by high productivity of bacteria, which release nutrients to algae and thereby heighten algal production. Secondary production by all trophic levels is increased. In shallow reservoirs, slight increases in water level inundate vast areas of terrestrial vegetation, and the trophic upsurge is usually prolonged and intense. Trophic upsurges seldom occur in deep reservoirs, which usually pass into a second phase or "trophic depression." In this phase, the rate of decay of submerged terrestrial vegetation decreases, and nonproductive silts eroded from shorelines cover organic materials. Zooplankton and benthos biomasses decrease gradually during this 25- to 30-year period. The third phase is identified by a gradual increase in productivity because of the deposition of planktogenic detritus. The three stages vary in duration and detail, and not all reservoirs exhibit all three phases.

35. BAREN, C. F. 1971. Limnological effects of simulated pump-storage operation at Yards Creek. Pages 1–158 *in* Delaware River Basin Committee.

Four 2-acre ponds were used to simulate the effects of water-level fluctuations on the biology of selected species of fishes. Centrarchid fishes successfully spawned when exposed to water-level fluctuations of about 1 m during the spawning season. Fluctuations of about 1.7 m exposed some

nests, although the production of juvenile centrarchids in ponds subjected to water-level fluctuations was similar to production in a control pond. Smallmouth bass eggs may be tolerant of short exposures to air. Nest-building and guarding of the nest by smallmouth bass may be interrupted, but not necessarily terminated, by large drawdowns if water level is subsequently restored. Effects on water chemistry, macroinvertebrates, plankton, and aquatic plants are also discussed.

36. BARKO, J. W., M. S. ADAMS, AND N. L. CLESCERI. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management 24:1–10.

A variety of environmental factors interact in affecting the productivity, distribution, and species composition of submersed macrophyte communities. Light and temperature are important in determining morphology and distribution (with latitude, season, and depth), thereby influencing productivity and species composition as well.

37. BARMAN, E. H., JR., AND D. G. BAARDA. 1978. An evaluation of the effect of drawdown on the trophic status of a small reservoir. Environmental Resource Center, Georgia Technical University, ERC 01-78. 73 pp.

Water levels of 5.4-ha Lake Laurel, Georgia, were drawn down to the original creek bed for 178 days (October 1975–April 1976). Pre- and post-drawdown estimates of dissolved oxygen, biological oxygen demand, turbidity, sulfide, nitrogen, phosphorus, and iron were compared. The distribution and abundance of benthos, phytoplankton biomass, and periphyton accrual were quantified before and after drawdown. Total phosphorus, total soluble phosphorus, and orthophosphate were significantly lower after drawdown. Phytoplankton biomass and periphyton production were reduced during summer 1976 after drawdown, but the effect lasted less than 1 year. Organic compounds and iron concentrations near the sediments increased after drawdown. No changes were apparent in dissolved oxygen, biological oxygen demand, turbidity, sulfides, or nitrogen, nor in the qualitative composition of the benthos. The abundance of benthic organisms was reduced. The lake pH was low (5.0–6.4).

38. BARNES, W. J. 1978. The distribution of floodplain herbs as influenced by annual flood elevation. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 66:254–266.

Herbaceous plants were sampled in a Chippewa River bottomland forest at Eau Claire, Wisconsin. Spatial dispersion patterns of the herbs were examined in relation to elevation, soil characteristics, and flood recurrence intervals. Frequency and magnitude of spring floods seem to be the major influence on the distribution of herbaceous species in this river bottom site.

39. BATAILLE, K. J., AND G. A. BALDASSARRE. 1993. Distribution and abundance of aquatic macroinvertebrates following drought in three prairie pothole wetlands. Wetlands 13:260–269.

The authors collected aquatic macroinvertebrates in seasonal, semipermanent, and permanent potholes in southwestern Manitoba, Canada. Cladocera, Copepoda, Ostracoda, Culicidae, Dytiscidae, and Gastropoda composed more than 98% of the total number of individuals. Chironomids were the most abundant in the permanent pothole. After drought, it seemed that macroinvertebrates were abundant and widely distributed in all three potholes.

40. BATEMA, D. L., G. S. HENDERSON, AND L. H. FREDRICKSON. 1985. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. Pages 196–202 *in* J. O. Dawson and K. A. Majerus, editors. Proceedings of the Fifth Central Hardwood Forest Conference, University of Illinois, Urbana, April 15, 1985.

Wetland invertebrates in bottomland hardwoods were studied to examine the linkage among forest type, flooding regime, and invertebrate populations. Sixteen plots were established, representing two forest types: pin oak–sweetgum (*Quercus palustris* Muenchh.–*Liquidamber styraciflua* L.) and overcup oak-red maple (*Q. lyrata* Walt.–*Acer rubrum* L.) and two flooding regimes: natural flooding and greentree reservoirs (impounded bottomland forests managed for waterfowl). Invertebrates responded rapidly to flooding and within 4 weeks peak numbers occurred on pin oak sites (6,275 individuals/m^2). Chironomid larvae, isopods (*Asellus* sp.), fingernail clams (*Pisidium* sp.), amphipods (*Crangonyx* sp.) and oligochaetes were the dominant taxa identified. For both flooding regimes, pin oak sites had greater invertebrate densities in fall (October–November) than overcup oak sites, but in spring (March–May), overcup oak sites had greater densities. Functional feeding groups of invertebrates were dominated by shredders and collectors.

41. BATES, J. M. 1962. The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River. American Midland Naturalist 68:232–236.

Collections made in Kentucky Reservoir during 1958 indicate that the preimpoundment assemblage of species, characterized by a preponderance of species belonging to the Unioninae, is doomed; only *Quadrula quadrula* has adapted to the altered ecological conditions. This species, along with two species of *Leptodea*, one species of *Carunculina*, and three species of *Anodonta* compose the dominant species assemblage in postimpoundment habitats. The author notes that a substrate maturation process may be one of the main limiting factors in mussel invasion of new impoundments.

42. BATZER, D. P., M. MCGEE, V. H. RESH, AND R. R. SMITH. 1993. Characteristics of invertebrates consumed by mallards and prey response to wetland flooding schedules. Wetlands 13:41–49.

We examined characteristics of the invertebrates consumed by mallards *(Anas platyrhynchos)* and green-winged teals *(Anas crecca)* and responses of these invertebrates to manipulations of flooding date in Suisun Marsh, Solano County, California. Numbers of *Chironomus stigmaterus* midge larvae (Chironomidae) and *Eogammarus confervicolus* amphipods (Gammaridae) in mallard esophageal samples were positively correlated with abundance of these invertebrates in wetlands. Mallards primarily consumed large midge larvae (fourth instars) and amphipods (> 5 mm long). Smaller green-winged teals consumed smaller midges. Mallards consumed few *Trichocorixa verticalis* water boatmen (Corixidae) or *Cricotopus sylvestris* midge larvae, despite their being abundant. Wetlands first flooded in early September had higher winter populations of amphipods and *Berosus ingeminatus* beetle larvae (Hydrophilidae) than wetlands first flooded in late October. Late-winter abundance of benthic *C. stigmaterus* midge larvae was highest at 40-cm water depths in the former habitats and at 20-cm depths in the latter habitats.

43. BATZER, D. P., AND V. H. RESH. 1992. Macroinvertebrates of a California seasonal wetland and responses to experimental habitat manipulation. Wetlands 12:1–7.

Responses of macroinvertebrate populations to temporal change and to management of plant cover and water depth were examined in 12 experimental ponds designed to mimic seasonally flooded

(early fall to early spring) wetlands in Suisun Marsh, California. Ponds were flooded in September 1988. Initially, rat-tailed maggots (*Eristalis tenax*), brine fly larvae *(Ephydra millbrae)*, and mosquito larvae *(Culex tarsalis)* were numerically dominant components of the fauna in the ponds, but these populations did not persist beyond December. Water boatmen *(Trichocorixa verticalis)*, midge larvae *(Cricotopus sylvestris* and *Chironomus stigmaterus)*, and hydrophilid beetle larvae *(Berosus ingeminatus)* were numerically dominant components of the fauna in both autumn and winter, but water boatmen and midge densities declined by March. Amphipods *(Eogammarus confervicolus)* and three-spined stickleback (*Gasterosteus aculeatus*) were introduced during initial floodings in September, and they subsequently increased to become numerically dominant components of the pond fauna by February and March 1989.

44. BATZER, D. P., AND V. H. RESH. 1992. Wetland management strategies that enhance waterfowl habitats can also control mosquitoes. Journal of the American Mosquito Control Association 8(2):117–125.

A study in nine experimental ponds in Suisun Marsh, California, demonstrated that raised water levels could enhance populations of the macroinvertebrates important in waterfowl diets: general macroinvertebrate densities were higher at 60 cm depths than at 20 or 40 cm depths. In contrast, *Culiseta inornata* densities were lowest at 60 cm depths and highest at 20 cm depths. A study conducted in a perennial-water cattail wetland in Minneapolis–St Paul, Minnesota, demonstrated that a temporary water-level drawdown, designed to enhance waterfowl habitat quality of perennial-water wetlands, also reduced densities of *Coquillettidia perturbans* mosquito larvae. These mosquitoes disappeared immediately after the drawdown, but even after water depths were restored to predrawdown levels, significant numbers did not reappear until 4 years postdrawdown. Studies in 202 other Minnesota wetlands also demonstrated the susceptibility of *C. perturbans* populations to drawdown, but the effect of drawdown was greater in stands of emergent cattail than in floating cattail.

45. BAXTER, R. M., AND P. GLAUDE. 1980. Environmental effects of dams and impoundments in Canada: Experience and prospects. Canadian Bulletin of Fisheries and Aquatic Sciences 205:1–34.

The authors present an extensive review of the literature on the environmental effects of dams and impoundments in Canada, including information on water-level fluctuations and drawdown zones.

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

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

47. BAYLEY, S. E., J. ZOLTEK, JR., A. J. HERMANN, T. J. DOLAN, AND L. TORTORA. 1985. Experimental manipulation of nutrients and water in a freshwater marsh: Effects on biomass, decomposition, and nutrient accumulation. Limnology and Oceanography 30:500–512.

Experimental freshwater marsh plots (2,000 m^2) received 9.6, 3.7, and 1.5 cm $week^{-1}$ of treated sewage effluent, and the control plot received 4.4 cm $week^{-1}$ potable water during a 2-year study. Surface water elevation above the peat substrate averaged 0.2 m in the second year. During the first year, the marsh surface remained dry. Application of treated effluent increased net primary production only during the dry year. During the wet year, there was no significant difference between the highest effluent plot and the control plot in aboveground biomass, or in phosphorus (P) content in the aboveground live or dead vegetation and in the belowground vegetation. A natural increase in water level above the marsh surface had the same effect on the marsh production and nutrient accumulation as did application of 42 g P m^{-2} $year^{-1}$ in treated effluent. This was presumably due to the release of P from the peat substrate under flooded conditions.

48. BEARD, T. D. 1971. Impact of an overwinter drawdown on feeding activities of northern pike. Wisconsin Department of Natural Resources, Bureau of Research Report 4. 6 pp.

Murphy Flowage, located in Rusk County, Wisconsin, was a 180-acre flowage with a maximum depth of 14 ft. Between mid-October and mid-November of 1967–1969, the water level was lowered 5 ft to reduce a standing crop of slow-growing panfish. As a result of the overwinter drawdown in Murphy Flowage, feeding activities of approximately 2,028 northern pike over 12 inches long increased, with consumption of bluegills ranked the highest. The lower number of fish found with empty stomachs and the increased number of food items found in pike stomachs indicated that when water levels were drawn down, northern pike consumed more panfish than they did when water levels were normal. However, small panfish outnumbered northern pike by about 417 to 1, and because of the high reproductive capacity of panfish and the continuous growth of these fish into sizes less subject to predation, it is doubtful that northern pike in Murphy Flowage could have reduced the panfish population.

49. BEARD, T. D. 1973. Overwinter drawdown-impact on the aquatic vegetation in Murphy Flowage, Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 61. 14 pp.

A study of the effects of an overwinter drawdown on aquatic vegetation in Murphy Flowage, located in Rusk County, Wisconsin, found that the drawdown released approximately 60 acres from thick vegetative cover. *Potamogeton robbinsii*, *Potamogeton amplifolius*, *Ceratophyllum demersum*, *Myriophyllum* spp., and *Nuphar* spp. showed the greatest decrease in abundance after the drawdown. The primary factors responsible for the reductions observed appeared to be related to the effect of lowered water levels on reproduction. The main mode of reproduction for the major plant species in the flowage is by vegetative means. When these species were subjected to low water levels, the plants may not have had time to develop mature fruit and most of the vegetative parts were destroyed. Also, lower water levels may modify various other factors such as temperature, light intensity, rate of photosynthesis and growth, any of which could cause a change in the vegetation. Type of vegetation in a flowage, invasion of resistant species after drawdown, phytoplankton bloom, landowners' wells, timing and number of drawdowns, winterkill, fishing pressure, and other uses of the flowage are factors that management personnel should consider before an overwinter drawdown is used to control aquatic vegetation.

50. BEARD, T. D., AND H. E. SNOW. 1970. Impact of winter drawdown on a slow-growing panfish population and associated species. Wisconsin Department of Natural Resources, Bureau of Research, Madison. 18 pp.

Two consecutive winter drawdowns of Murphy Flowage to improve the growth of panfish populations reduced the abundance of all species except yellow perch and white suckers. Numbers of bluegills less than 5 inches long were greatly reduced. Feeding activity of northern pike increased after drawdowns, and largemouth bass ate more fish and fewer crayfish.

51. BEAUFAIT, W. R. 1955. Soil profile observations relating to drought damage in black willow stands. Journal of Forestry 53:517.

In summer 1954, drought damage was noted in a 300-acre willow stand along the Mississippi River. The stand was 27 years old, and the trees averaged 100 ft in height. A sharp line of demarcation was observed between healthy and drought-stricken portions. A single 16-acre area was a complete loss. What had been an excellent site under normal weather conditions became incapable of supporting tree growth during protracted drought. Neighboring sites with different subsurface conditions did not suffer as much mortality.

52. BECKER, C. D., D. H. FICKEISEN, AND J. C. MONTGOMERY. 1981. Assessment of impacts from water level fluctuations on fish in the Hanford Reach, Columbia River. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830, Pacific Northwest Laboratory, Richland, Washington. n.p.

Observations on the effects of water-level fluctuations in the Hanford Reach of the Columbia River, Washington, were made in 1976 and 1977. The 2 years provided contrasting flow regimes: high water and fluctuations of greater magnitude prevailed in 1976; low water and higher temperatures prevailed in 1977. Situations where fish and other aquatic organisms were destroyed by changing water levels were observed and evaluated each year in three study areas: Hanford, F-Area, and White Bluffs sloughs. Losses were primarily due to stranding, entrapment (with or without complete dewatering), and predation. Juvenile fish were more susceptible to entrapment and stranding than were adult fish. Estimates of actual losses were biased and conservative because relatively few fish could be found after each decline of water level and dewatering. Smallmouth bass nests were susceptible to exposure and temperature changes resulting from repeated water-level fluctuations; thus, flow manipulations are crucial to their survival. The extent to which other species of riverine fish were affected by water-level fluctuations depended on their use of shoreline zones for spawning and rearing young. Few of these relations are completely known or understood. Most fish fry found stranded or entrapped in 1976 and 1977 consisted of "coarse fish" species, which are abundant and of limited economic value. Loss of young coarse fish from water-level fluctuations might not be reflected at the adult population level. While some invertebrates lost in shoreline zones may be replaced by survivors from deeper water, those removed are no longer available to higher trophic level consumers. The magnitude of fish and invertebrate losses in shoreline zones may be of little importance to overall ecosystem dynamics.

53. BECKETT, D. C., B. W. GREEN, A. C. MILLER, AND R. F. GAUGUSH. 1994. *Hexagenia* in backwater lakes of the Upper Mississippi River: The 1993 great flood bonanza. Page 22 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

From a sociological and economic perspective, the great Mississippi River flood in summer 1993 was extremely detrimental. However, for the burrowing mayflies of the genus *Hexagenia* (family Ephemeridae) in the backwater lakes of the Upper Mississippi River, the flood provided a unique opportunity. Evidence for this supposition is based on sampling over 3 years (July 1991, July 1992, and September 1993) from three dissimilar lakes in Pools 8 and 10 of the Upper Mississippi River. Thumb Lake, a small, shallow lake, supported *Hexagenia* nymphs on each sampling occasion. Sampling of McGregor Lake, a large, fairly deep lake, produced a few nymphs in a few of the samples taken in 1991, and no nymphs among the 20 samples taken in 1992. In contrast, sampling in 1993 showed large numbers of nymphs present in the bottom of the lake. Mean density of nymphs equaled 904 *Hexagenia*/m^2 at the nearshore sampling sites, with mayfly nymphs present in all the samples. Similarly, our sampling of Lawrence Lake, a large, shallow, heavily vegetated lake in Pool 8 did not yield any *Hexagenia* in 1992, yet the nymphs were abundant in the 1993 samples. We hypothesize that the flood of 1993 precluded the establishment of anoxic conditions that normally occur in summer in the bottoms of McGregor Lake and Lawrence Lake (and other Mississippi River backwater lakes as well). Consequently, the massive elimination of nymphs by anoxia that normally occurs did not take place, and unprecedented numbers of *Hexagenia* continued to develop. (Abstract only)

54. BECKMAM, L. G., AND J. H. ELROD. 1971. Apparent abundance and distribution of young-of-year fishes in Lake Oahe, 1965–69. Pages 333–347 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

A 100- by 8-ft seine and an otter trawl were used to estimate the abundance and distribution of young-of-year fishes in Lake Oahe, North Dakota and South Dakota, during the last 5 years of filling. Young-of-year fishes were most abundant in waters at the upper ends of embayments. Large year classes of northern pike, common carp, smallmouth buffalo, and bigmouth buffalo were associated with rising water levels that covered terrestrial grasses and remained stable throughout the spawning period. Small year classes occurred in years when no vegetation was flooded. Inasmuch as future water levels will normally fluctuate over mud bottoms, prospects for strong year classes are poor unless terrestrial vegetation recovers and is flooded in spring, or some aquatic plants become established. Yellow perch used inundated brush for egg deposition, and year classes were good when more brushy areas were flooded. After 1967, much of the brush had deteriorated and was sparse at higher elevations. As a result, the abundance of perch began to decline thereafter.

55. BEDINGER, M. S. 1971. Forest species as indicators of flooding in the lower White River Valley, Arkansas. Pages 248–253 *in* U.S. Geological Survey, Professional Paper 750-C.

The dominant environmental factor of forest habitats within the lower valley of the White River, Arkansas, is flooding. The floodplain consists of a series of terraces. Distribution of forest species on the terrace levels is related to flooding. The relation is sufficiently distinct to permit determination of flood characteristics at a given site by evaluation of forest-species composition. The vegetation of the lower White River valley can be divided into four groups. Each group occurs on sites having distinctly different flooding characteristics. On sites flooded 29%–40% of the time, the dominant species are water hickory and overcup oak. On sites flooded 10%–21% of the time, a more varied flora exists—including Nuttall oak, willow oak, sweetgum, southern hackberry, and American elm. The third group of sites is subject to flooding at intervals of 2 to 8 years. This group is marked by the presence of southern red oak, shagbark oak, and black gum. The presence of blackjack oak marks the fourth group (not flooded historically).

56. BEDINGER, M. S. 1979. Forests and flooding with special reference to the White River and Ouachita River basins, Arkansas. U.S. Geological Survey, Water Resource Investigations 79-68. 24 pp.

The observed response of trees to hydrologic stress and distribution of trees in relation to habitat indicate that flooding, groundwater level, soil moisture, soil factors, and drainage characteristics exert a strong influence on bottomland forest species distribution. The dominant hydrologic factor influencing the distribution of bottomland tree species is flooding. Individual tree species are distributed as a function of frequency and duration of flooding. In the lower White and Ouachita River basins, the floodplains consist of a series of terraces; progressively higher terraces have less frequent flooding and less duration of flooding, and a significantly different composition of forest tree species. The sites studied can be divided into four basic groups and several subgroups on the basis of flood characteristics. On Group I (water hickory–overcup oak) sites, flooded near annually 32%–40% of the time, the dominant species are water hickory and overcup oak. On Group II (Nuttall oak) sites, flooded near annually 10%–21% of the time, a more varied flora exists, including Nuttall oak, willow oak, sweetgum, southern hackberry, and American elm. Group III (shagbark hickory–southern red oak) sites are flooded at intervals of 2 to 12 years. This group includes southern red oak, shagbark hickory, and black gum. The presence of blackjack oak in addition to Group III species marks Group IV (not flooded historically).

57. BEDISH, J. W. 1967. Cattail moisture requirements and their significance to marsh management. American Midland Naturalist 78:288–300.

A hybrid cattail resulting from a natural cross of *Typha latifolia* and *T. angustifolia* was studied under greenhouse and field conditions in an attempt to determine optimum soil moisture, water depth determination, growth, and vegetative reproduction. No differences in percent germination were detected between water depths of 1 and 6 inches. No germination of artificially established seeds occurred in the field. The fastest rate and amount of growth were reported for plants in 1 inch of water. Plants in saturated soil and 6 inches of water grew nearly as well as plants in 1 inch of water. Vegetative reproduction was similar in saturated soil and soil flooded with depths of 1–6 inches of water.

58. BELANGER, T. V., AND R. A. KIRKNER. 1994. Groundwater/surface water interaction in a Florida augmentation lake. Lake and Reservoir Management 8(2):165–174.

Mountain Lake, Florida, is augmented with water pumped from the underlying Floridan aquifer to maintain the water level; a detailed 1990 water budget was developed for this lake to determine how the lake interacts with the surrounding groundwater system. Groundwater interaction with the lake was calculated from flow-net analysis of surficial well data, seepage meter data, and the residual of the water budget equation. Strong leakage through the lake bottom was observed, primarily controlled by the head difference between the lake and the Floridan aquifer and the sediment hydraulic leakance (sediment hydraulic conductivity/thickness). Areas of seepage into the lake (15% of the lake area) were observed at possible sinkhole features in the central portion of the lake. Areas of strong leakage occurred in shore areas where steep outflow gradients and sandy sediments existed. Results from this study indicate that the lake recycles groundwater, as the equivalent of over 90% of augmentation water returns to the groundwater system. Water budget data from this lake dispute the public perception in Florida that lake augmentation is a wasteful practice.

59. BELL, D. T. 1974. Tree stratum composition and distribution in the streamside forest. American Midland Naturalist 92:35–46.

The woody vegetation of the streamside forest in Robert Allerton Park, Piatt County, Illinois, is described in relation to the distribution of river-level frequencies of the Sangamon River. The habitats most frequently flooded are dominated by *Acer saccharinum*. With decreasing flooding frequency, dominance is transferred to *Celtis occidentalis* and *Quercus imbricaria*. The areas experiencing no flooding are dominated by *Q. alba*. Changes in the vegetational structure of elevational increments of 0.304 m (1 ft) are discussed. The principle that communities change gradually along environmental gradients is illustrated in a vertical elevation of less than 4 m.

60. BELL, D. T. 1980. Gradient trends in the streamside forest of central Illinois. Bulletin of the Torrey Botanic Club 107(2):172–180.

The streamside forest vegetation in the Sangamon River basin of east-central Illinois was studied by direct gradient analysis. A gradient of river flood frequencies was used to combine data from three vegetational gradients and to study gradient trends in species richness, diversity, evenness, dominance, and the Gaussian curve model of species distribution. Species richness, diversity, and evenness increased from minima at the streambank to maxima in midcoenocline areas and then regressed slightly in the unflooded portion of the flood-frequency gradient. Dominance was strongest at the extremes of the gradient. Tolerance to flood and moisture conditions are suggested as the primary sorting factors controlling the distribution of species in the streamside forest. Historical disturbances, however, are also important and represent an alternative hypothesis. The Gaussian curve model was determined to statistically fit 20 of the 27 species for which there were sufficient data for analysis. Species distribution modes were distributed on the gradient apparently at random. Minor species were distributed independent of the dominants.

61. BELL, D. T., AND F. L. JOHNSON. 1974. Flood-caused tree mortality around Illinois reservoirs. Transactions of the Illinois State Academy of Sciences 67(1):28–37.

The effects of high reservoir levels on species of streamside forests are described in southern Illinois. Intolerant species (severe effects with < 50 days flooding) include *Quercus velutina* (black oak), *Prunus serotina* (black cherry), and *Sassafras albidum* (sassafras). Slightly tolerant species (most individuals survive > 50 days but < 100 days of flooding) were *Quercus rubra* (red oak), *Q. alba* (white oak), and *Carya tomentosa* (mockernut hickory). Somewhat tolerant species (some individuals killed by < 90 days flood and some individuals survived > 150 days inundation) were *Cercis canadensis* (eastern red bud), *Juglans nigra* (black walnut), *Quercus imbricaria* (shingle oak), *Carya ovata* (shagbark hickory), *Celtis occidentalis* (hackberry), *Ulmus americana* (American elm), and *Fraxinus pennsylvanica* (green ash). Tolerant species (most individuals survived > 150 days inundation) were *Acer saccharinum* (silver maple), *Populus deltoides* (eastern cottonwood), *Platanus occidentalis* (sycamore), *Salix nigra* (black willow), *Quercus macrocarpa* (bur oak), *Gleditsia triacanthos* (honeylocust), *Acer negundo* (boxelder), *Crataegus mollis* (red haw), *Quercus bicolor* (swamp white oak), *Diospyros virginiana* (persimmon), and *Quercus palustris* (pin oak).

62. BELL, J. G. 1953. Horicon Marsh—a decade of management. Wisconsin Conservation Bulletin 17:7–10.

The authors review water-level management at Horicon Marsh dating back to 1935. The policy at Horicon was to draw down the level of the marsh in summer so as to promote the revegetation of open areas, which have been created as a result of wave action, carp, and muskrats.

63. BELLROSE, F. C. 1950. The relationship of muskrat populations to various marsh and aquatic plants. Journal of Wildlife Management 14:299–315.

Muskrat populations were studied in the bottomland lakes of the Illinois River Valley in fall and winter seasons of 1940–41 and 1943–44, and on glacial lakes of Lake County in northeastern Illinois in 1943–44. One of the objectives of the study was to evaluate the influence of the depth of water and fluctuating water levels on the density of dwelling houses and the relation between dwelling and feeding houses. Water depth was a factor affecting muskrat house density in different marsh plant types. Optimum depths varied with the type of vegetation and the exposure to wave action and probably with the bottom soil type. Fluctuating water levels adversely affected muskrat populations there by lowering the value of river bulrush and marsh smartweed. These plants are so abundant as to characterize Illinois River bottomland marshes.

64. BELLROSE, F. C., AND L. G. BROWN. 1941. The effect of fluctuating water levels on the muskrat population of the Illinois River Valley. Journal of Wildlife Management 5:206–212.

From 1939 to 1940, studies made along the Illinois River showed that fluctuating water levels have a marked bearing on muskrat populations. Areas with stable water levels had 3.5 muskrat houses per acre of emergent vegetation. Areas with semistable water levels had 0.6 houses per acre, and areas with fluctuating water levels had only 0.3 houses per acre of emergent vegetation. The optimum depth of water for muskrat lodge construction ranged between 12 and 18 inches with 6 inches about the minimum and 24 inches approaching the maximum. The authors concluded that muskrat populations are affected more by changing water levels than by types of marsh vegetation in the Illinois River Valley.

65. BELLROSE, F. C., S. P. HAVERA, F. L. PAVEGLIO, JR., AND D. W. STEFFECK. 1983. The fate of lakes in the Illinois River Valley. Illinois Natural History Survey, Biological Notes 119:3–27.

The authors present information concerning receding water levels and sedimentation rates in the Illinois River Valley. Deposition of sediments in the bottom of the lakes is dynamic because the annual rate lessens as the lakes become shallower. To approximate when selected lakes may lose half of their current average depth, the half-life equation was used to adjust to constantly lessening water depths. Estimates of half-life for water depth in different lakes in the Illinois River ranged from 24 to 127 years.

66. BELLROSE, F. C., F. L. PAVEGLIO, JR., AND D. W. STEFFECK. 1979. Waterfowl populations and the changing environment of the Illinois River Valley. Illinois Natural History Survey, Bulletin 32(1):1–54.

The authors review the changing waterfowl populations and the environment of the Illinois River Valley. Aquatic and terrestrial habitats of the Illinois River Valley suffered a series of cataclysmic events since 1900, including a permanent rise in water levels from water diverted from Lake Michigan, the draining of more than half of the 161,878-ha floodplain through construction of levees and pumping stations, and the creation of a 2.7-m channel and its intended navigation dams in the 1930s. Fluctuating river levels adversely affect the development of aquatic and marsh vegetation

on those bottomland lakes connected with the river at all stages. In the early years of the study, the more the lakes were separated from the river, the more extensive were their aquatic and marsh plant beds. During the earlier years of the study, aquatic and marsh plants disappeared from those lakes connected with the river at all water stages. During the later years of the study, aquatic plants disappeared and the area of marsh plants greatly declined in all lakes, even in those enjoying a degree of separation from the river and minimal water-level fluctuations. Increases in water turbidity and bottom softness, stemming from sedimentation, seem to be responsible. However, low levees and pumps have increasingly been used to dewater all or part of the lake basins. This procedure controls small summer fluctuations and exposes mudflats for the development of moist-soil plants between July 15 and October 15. Moist-soil plants—millets, smartweeds, nutgrasses, rice cutgrass, water hemp, and teal grass—produce an abundance of seed palatable to many species of ducks. Low summer water levels permit or expedite dewatering. Summer rises that overtop low levees usually destroy moist-soil plant beds. Fall river levels determine the depths in bottomland lakes and thus the availability of moist-soil plant foods. If the river is low and mudflats are exposed, moist-soil plant seeds will be unavailable to waterfowl. If, on the other hand, the river is high and mudflats are too deeply submerged, the result is the same. The higher the fall rise in water, the greater the reduction in numbers of green-winged teal, with the same influence to a lesser degree on Northern pintails, American wigeons, and mallards. Private duck clubs control 23,198 ha (57,320 acres) of land and water in the Illinois River Valley and have 6,723 ha (16,612 acres) under varying degrees of low water-level control. State and Federal agencies control 15,644 ha (38,656 acres) and have 4,688 ha (11,585 acres) under similar water-level management.

67. BELLROSE, F. C., R. E. SPARKS, F. L. PAVEGLIO, JR., D. W. STEFFECK, R. C. THOMAS, AND R A. WEAVER. 1977. Fish and wildlife habitat changes resulting from the construction of a nine-foot navigation channel in the Illinois Waterway from La Grange Lock and Dam upstream to Lockport Lock and Dam. U.S. Department of the Army, Corps of Engineers, Chicago District. 148 pp.

The authors provide qualitative information on the changes of the effects of fluctuating water levels on stable water-bottom lakes, semistable backwater lakes, and plant communities.

68. BENNETT, D. H. 1975. Effects of pumped storage project operations on the spawning success of centrarchid fishes in Leesville Lake, Virginia. Ph.D. Thesis, Virginia Polytechnical Institute, Blacksburg. 141 pp.

Bluegills, redbreast sunfish, and largemouth bass spawned successfully during pumped storage, where maximum weekly fluctuations in water levels were 4 m during the spawning season. Some individuals seemed to increase their spawning depth in response to regular, widely fluctuating water levels. Fluctuating water levels and low water temperatures combine to cause about 81% mortality of eggs and fry of bluegills in the upper lake. Eggs and fry develop slowly at low temperatures and therefore are vulnerable to dewatering and desiccation for a longer time than eggs and fry in warmer water. Because the lower lake was warmer than the upper lake, eggs and fry developed more rapidly and their survival was about double that of fry in the upper lake. Spawning success of bluegills was about 31%. Exposure to air for 24 hours or more caused 100% mortality of eggs.

69. BENNETT, G. W. 1954. Largemouth bass in Ridge Lake, Coles County, Illinois. Illinois Natural History Survey, Bulletin 26(2):217–276.

A management technique for culling small fishes to improve populations of largemouth bass for anglers from 1941 to 1951 is evaluated. There was no relation between the number of bass fry produced and the number of bass of spawning age, but the production of fry was greater in years following draining when the number of small fish (particularly bluegills) was low. The largest catches (number and weight) of bass were made in the year after draining and culling. From 40% to 69% of the bass standing crop was harvested in these years, compared with 27% to 34% in years when the lake was not drained before the fishing season.

70. BENNETT, G. W. 1954. The effects of a late summer drawdown on the fish population of Ridge Lake, Coles County, Illinois. Transactions of the North American Wildlife Conference 19:259–270.

At 2-year intervals for 10 years, Ridge Lake was drained in March to facilitate the counting of fish populations. In 1951 and 1952, the area of the lake was reduced by drawdown from 17 acres in early September to 5 acres in December, when runoff began to refill it. Fishery data collected during and after the drawdown were compared with data collected in the preceding 10 years (primarily 1947, 1949, and 1951), when water levels were relatively stable. From the standpoint of individual fish, no loss of bass resulted from drawdown. In years when the lake was drained in March and small fish were culled, production of bass fry was relatively heavy—suggesting that survival of young bass was largely controlled by predation. Drawdowns probably greatly reduced the benthos of Ridge Lake, because some invertebrates were trapped in macrophytes or depressions as waters receded. The concentration of aquatic animals in a reduced volume of water exposed them to predators, which probably accounted for the greatly reduced number of fish-food animals. Numbers of bluegills, especially the smaller ones, were severely reduced by drawdown. The extent of drawdown probably was too severe (especially with respect to its effect on bluegills).

71. BENNETT, G. W. 1962. Theories and techniques of management. Chapter 6 *in* G. W. Bennett, editor. Management of artificial lakes and ponds. Reinhold Publishing Company, New York. n.p.

Techniques for fish sampling, removal (draining and poisoning), and population adjustment, as well as lake fertilization, vegetation controls, and water-level manipulation are discussed. Drawdown is viewed as a means of changing the relative abundance of fishes to favor the species important to man. Receding waters crowd fish, and over a period of months or years of low water, the smaller populations best equipped to deal with severe competition dominate previously abundant species. Upon reflooding, habitat is expanded and food becomes abundant. Predators frequently can take advantage of the large broods produced by nearly all fish during the first year of inundation. Exposure of sediments to the atmosphere during drawdown increases decomposition and soil pH. Under these conditions, greater quantities of potassium and phosphorus are available. Exposure of bottom sediments to the air is considered more important to fish production than is the growth of terrestrial vegetation after drawdown. Drawdown does not greatly affect most macrophytes and is not considered to be an effective method of control. In fact, *Potamogeton crispus* expanded its habitat lakeward as drawdown occurred. On reflooding, it was established at greater depths. Drawdown strands and kills invertebrates or exposes them to new environmental conditions that decrease their chances for survival. Many small fishes also become stranded and perish. Those that migrate must leave the protection of vegetation and are exposed to increased predation. The net result is a selective culling action, which reduces the number of small sunfishes and thereby improves the chances for a successful bass spawn in the spring after the basin is reflooded. Drawdown to cull fish must reduce the surface area by 50% and force small fish from beds of aquatic plants. Predation will be significant only as long as prey is concentrated and temperatures are above 55 °F. Annual cycles of water-level fluctuation have a great effect on fish populations, but even droughts that cause water levels to slowly recede can have an effect. Timing of annual drawdowns to benefit fish and waterfowl often conflict.

72. BENNETT, G. W. 1974. Ecology and management of largemouth bass, *Micropterus salmoides*. Pages 10–17 *in* J. L. Funk, editor. Symposium on overharvest and management of largemouth bass in small impoundments. American Fisheries Society, Special Publication 3.

On the basis of 30 years of data from Ridge Lake, Illinois, and the experience of many researchers, a discussion is presented on how bass production and harvest can be improved. Largemouth bass in a pond demonstrated their ability to replace their numbers and weights by producing a single successful year class, after surviving 1,400 and 1,600 man-hours of fishing pressure over two consecutive seasons. A fall drawdown is one of the simplest ways to reduce populations of sunfishes (predators of eggs and fry) and thereby produce a strong year class of bass the next spring. A fall drawdown every second or third year, or once in 3 years, should help bass maintain their numbers. During drawdown, fish are supposedly crowded, and excessive populations of crappies, sunfishes, and rough fishes are reduced. As the lake slowly refills in winter, most fish assemblages are composed of larger individuals and contain fewer egg and fry predators than before drawdown.

73. BENNETT, G. W., H. W. ADKINS, AND W. F. CHILDERS. 1969. Largemouth bass and other fish in Ridge Lake, Illinois, 1941–1963. Illinois Natural History Survey, Bulletin 30(1):1–67.

Fish populations of Ridge Lake were studied intensively by creel survey and biennial draining. Expansion of bluegills was directly related to time and inversely related to drawdowns and to the abundance of bass. The bass population controlled the numbers of bluegills only when drawdown was employed.

74. BENNETT, G. W., H. W. ADKINS, AND W. F. CHILDERS. 1973. The effects of supplemental feeding and fall drawdowns on the largemouth bass and bluegills at Ridge Lake, Illinois. Illinois Natural History Survey, Bulletin 31(1):1–30.

In summers 1965 to 1969, fish in Ridge Lake were fed supplementally with a commercial pelleted food. In September, lake levels were reduced until temperatures reached 55 °F in October, and then the lake was refilled. This management program was successful in improving the bluegill fishery; twice as many large bluegills (>152 mm) were caught during 1965–1969 than in earlier years. Without a fall drawdown, supplemental feeding probably would be wasteful, inasmuch as the bluegill population would increase in numbers rather than in mean weight per fish.

75. BENNETT, L. A. 1990. Density, distribution, and habitat of American and least bitterns on Agassiz National Wildlife Refuge. Final Report for Contract 32510-0-0174 submitted to Agassiz National Wildlife Refuge, Middle River, Minnesota. 15 pp.

From May to July 1990, on Agassiz National Wildlife Refuge, Marshall County, Minnesota, American and least bitterns were distributed unevenly among pools and distribution was directly related to water levels. American bitterns were most consistently sighted in pools where all or a portion of the pool had received some form of vegetation or water-level manipulation during the past 3 years.

76. BENSON, D., AND D. FOLEY. 1956. Waterfowl use of small, man-made wildlife marshes in New York State. New York Fish and Game Journal 3:217–224.

From 1953 to 1955, studies were conducted on 559 small marshes created under Federal Aid and Fish and Wildlife restoration projects. Studies included observations on the pairs of breeding ducks attracted to these areas, food production, and fall use by waterfowl. Productivity of these marshes and the species composition on them vary with regional differences in habitat through the state. After the third season of flooding, their attractiveness and productivity tend to decline.

77. BENSON, N. G. 1968. Review of fishery studies on Missouri River main stem impoundments. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries, Wildlife Research Report 71. 61 pp.

Six mainstem Missouri River reservoirs are described, and information on plankton, water chemistry, fish populations, and watershed management is discussed. A number of findings were related to changes in water levels. Rising water levels in Garrison and Oahe Reservoirs probably were responsible for an increased abundance of phytoplankton and rotifers from 1953 to 1961. Reproduction of bottom-spawning fishes (e.g., northern pike, white crappie, black crappie, largemouth bass, sauger, walleye, and yellow perch) was limited by wind action, suitability of substrate, and fluctuating water levels. Lowering water levels to reduce the spawning success of common carp was of questionable value, as their success was largely independent of fluctuation patterns. Raising water levels in Lake Oahe to flood terrestrial vegetation was successful in improving the spawning success of northern pike, but this technique was not evaluated in an old reservoir where vegetation was sparse or absent.

78. BENSON, N. G. 1968. Some effects of water management on biological production in Missouri River mainstem reservoirs. Presented at the American Society of Civil Engineers Specialty Conference, Portland, Oregon, January 1968. 17 pp. (Mimeo)

The author reviews information gathered in a study of the relations between reservoir environments and fish growth, mortality, abundance, and reproduction in Missouri River main stem impoundments. The water management practices considered to be factors affecting reservoir biota are water-level fluctuation, water exchange rate, and depth and timing of discharges from powerhouses. The reservoir system has the capacity (76 million acre-ft) to store three times the average annual runoff. Fort Peck, Garrison, and Oahe Reservoirs are large and are used for long-term storage. Lake Sharpe, Lake Francis Case, and Lewis and Clark Lake have relatively small storage capacities and water management programs are similar each year. The data discussed were collected on Oahe Reservoir, Lake Francis Case, and Lewis and Clark Lake. The normal water level in Oahe rises in spring, reaches a maximum in June, decreases in summer and early fall, and then increases gradually in late fall and winter. Lake Francis Case has a normal annual fluctuation of 35 ft with a minimum about December 1 and a maximum in April. The water level of Lewis and Clark Lake is quite constant except for a drawdown of 2–3 ft in late May and June.

79. BENSON, N. G. 1973. Evaluating the effects of discharge rates, water levels, and peaking on fish populations in Missouri River mainstem impoundments. Pages 683–689 *in* W. C. Ackermann, G. F. White, and E. B. Worthington, editors. Man-made lakes: Their problems and environmental effects. American Geophysical Union, Geophysical Monograph 17, William Byrd Press, Richmond, Virginia.

Biological changes that can be attributed to water management are discussed. Effects of water-level fluctuation, discharge rates, and peaking (diurnal variation in water level below dams) on reservoir biota are described. Reproduction of fishes that spawn during high water in spring in rivers was successful during filling and during early years of impoundment but was irregular under normal operations. The reproduction of common carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo is keyed to rising or stable water levels over suitable substrates. Northern pike depend on the inundation of herbaceous vegetation for spawning; however, rising water levels (which are usually beneficial) have no value if the proper substrate is lacking. Northern pike reproduction can also be disrupted by rapidly receding water levels before the spawning season. A succession of spawning periods exists for fish that deposit adhesive eggs on the bottom or on submerged material at depths less than 1.5 m. Although the exact time varies among years and reservoirs, any decline in water level between April l and July l reduces the spawning success of some species. Species like walleye, freshwater drum, and goldeyes are less affected by changes in water levels. Freshwater drum and goldeyes have buoyant or semibuoyant eggs, and walleyes usually spawn at a depth below the limits of most drawdowns. Benthos biomass on submerged trees and on the bottom is reduced by late summer or fall drawdowns. Many littoral forms that are important as fish foods are rare in lakes with widely fluctuating water levels. Submerged trees in some Missouri River reservoirs support enormous growths of periphyton, which in turn support large populations of benthos. Drawdowns kill the periphyton and thereby severely limit the production of benthos. A tentative model is presented that graphically describes interactions between abiotic and biotic components of Missouri River reservoirs.

80. BENSON, N. G. 1976. Water management and fish production in Missouri River main stem reservoirs. Pages 141-147 *in* J. F. Osborn and C. H. Alman, editors. Instream flow needs, Volume 2. American Fisheries Society, Bethesda, Maryland.

Although most reservoirs on the Missouri River are managed primarily for flood control, power generation, and navigation, conditions in some years permit changes in water levels or peaking schedules to benefit fish. Because growth and survival reflect the net reproductive success after predation and because knowledge of habitat requirements for spawning and nurseries are important (as is information about the time of spawning), most recommendations are directed toward altering water levels to enhance fish reproduction. Spawning and nursery requirements of 16 species of fish are presented. Time of spawning may vary annually but is directly related to water temperature, and each fish species initiates spawning activity when temperatures reach some species-specific level (+2–5 °C). Water-level management is the most promising technique for increasing fish production. Most fishes in the reservoirs evolved in rivers or glacial lakes and developed reproductive cycles keyed to spring floods that inundated suitable substrates. High and constant water levels from April 1 to July 1 benefit the reproduction of northern pike, yellow perch, walleye, white crappie, common carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo. Water levels that are lowered after July 1 permit terrestrial vegetation to develop on the exposed bottoms and thereby provide good spawning habitat the following year. Growth of terrestrial vegetation also is important for aesthetic purposes and erosion control.

81. BENSON, N. G. 1980. Effects of post-impoundment shore modifications on fish populations in Missouri River Reservoirs. U.S. Fish and Wildlife Service, Research Report 80. 32 pp.

The configuration and lengths of shorelines in mainstem Missouri River reservoirs have changed as a result of hydrodynamic processes (i.e., erosion and redeposition caused by wave action and water-level fluctuations) during the first 20–25 years of impoundment. Physical changes probably most influenced fish abundance and species composition by altering the quality and quantity of spawning and nursery habitats. As a result, the fish community sampled before reservoir shorelines reached some degree of stability was not indicative of the ultimate species composition. Water-level fluctuations retarded the development of relatively stable shores. Species of fish that spawned in tributaries or along rocky shores (sauger, channel catfish, white bass, goldeye, and river carpsucker) were seemingly unaffected by shoreline changes. Other species requiring vegetation or suitable substrates for spawning (white crappie, black crappie, yellow perch, northern pike, bigmouth buffalo, smallmouth buffalo, and common carp) were adversely affected. Walleyes benefited from shoreline changes.

82. Benson, N. G., and B. C. Cowell. 1967. The environment and plankton density in Missouri River reservoirs. Pages 358–373 *in* C. E. Lane, Jr., editor. Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

A limnological description of six mainstem reservoirs on the Missouri River is presented. Elements of the environment such as morphometry, chemistry, water exchange rate, temperature, and turbidity form the background for an evaluation of changes in phytoplankton and zooplankton abundance and biomass. Submerged trees are important substrates for periphyton development in Missouri River reservoirs; dense growths developed on submerged trees in Lewis and Clark Lake (6 × 106 cells cm^{-2}) in May. The maximum standing crop of periphyton on trees in Lake Francis Case was only 6.6 × 103 cells cm^{-2}, about 0.11% of that in Lewis and Clark Lake, because Lake Francis Case fluctuated 9–11 m each year and its periphyton communities died from exposure.

83. Benson, N. G., and P. L. Hudson. 1975. Effects of a reduced fall drawdown on benthos abundance in Lake Francis Case. Transactions of the American Fisheries Society 104:526–528.

Water levels of Lake Francis Case, which are normally drawn down 10–12 m in fall to make room for inflowing water in winter, were lowered only 6–7 m in 1971–73. Benthos samples collected in May from 1966 to 1973 showed more than a threefold increase in the density of bottom organisms during the period of reduced drawdown. Increased abundance was most evident in five burrowing taxa: chironomids, *Hexagenia*, *Caenis*, oligochaetes, and ceratopogonids. The abundance of benthos in September was similar under both drawdown regimes, except that *Hexagenia* was extremely abundant in September 1973. Reduced drawdown in fall seemingly allowed silt deposits to form at higher elevations and increased the amount of habitat for organisms requiring soft substrates.

84. Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Wisconsin Department of Natural Resources, Technical Bulletin 112. 38 pp.

Water manipulation is generally the most important management tool for the control of cattails in southeastern Wisconsin. A marsh must have a dependable, all-season water supply and be situated so the drainage is easily and quickly accomplished through an outlet structure. Management guidelines are presented for three different types of water depths: deep water, intermediate water, and shallow water.

85. Bhowmik, N. G., and J. R. Adams. 1986. The hydrologic environment of Pool 19 of the Mississippi River. Hydrobiologia 136:21–29.

Pool 19 on the Mississippi River and Peoria Lake on the Illinois River are used as examples of pools that are formed by navigation dams that have nearly reached a new equilibrium condition for scour and deposition of sediment. Both pools have had more than 50% of their original volume filled with sediment.

86. BHOWMIK, N. G., AND J. R. ADAMS. 1989. Successional changes in habitat caused by sedimentation in navigation pools. Hydrobiologia 176–177:17–27.

Upstream of St. Louis, Missouri, navigation on the Upper Mississippi River is made possible by a series of lock and dam structures. Many of the pools formed by these navigation dams have nearly reached a new equilibrium condition for scour and deposition of sediment. Several pools with extensive backwater or channel border areas are still accumulating sediment at rates similar to those for man-made lakes. The original open-water habitats in these pools are changing to aquatic macrophyte beds and then to marsh or terrestrial floodplain conditions because of sediment deposition.

87. BIRCH, H. F. 1960. Soil drying and soil fertility. Tropical Agriculture (Trinidad) 37:3–10.

A brief review of the literature illustrates the beneficial effect of soil drying on soil fertility. Drying increases the availability of several elements, among which soil nitrogen seems to be affected most consistently. Improved physical conditions after drying may also be involved, but this is less well established. Recent work on the effect of drying on humus decomposition and nitrification is discussed. The effect of soil drying on the amount of mineral nitrogen produced by moistening is largely a function of the humus content of the soil and the logarithm of the time the soil is in an air-dry state before it is moistened. Amounts of mineral nitrogen produced in this way are sufficiently large, even with soils poor in humus, to exert a considerable influence on soil fertility. A possible explanation for the drying effect is presented, along with recorded observations.

88. BLINDOW, I., G. ANDERSSON, A. HARGEBY, AND S. JOHANSSON. 1993. Long-term pattern of alternative stable states in two shallow eutrophic lakes. Freshwater Biology 30(1):159–167.

Lake Taakern and Lake Krankesjoen, two moderately eutrophic, shallow lakes in southern Sweden, have during the past few decades shifted several times between a clearwater state with abundant submerged vegetation and a turbid state with high phytoplankton densities. Between 1985 and 1991, Lake Taakern was in a clear state, whereas Lake Krankesjoen shifted from a turbid to a clear state. During this shift, the area covered by submerged macrophytes expanded, followed by an increase in water transparency, plant-associated macroinvertebrates, and piscivorous fish. Nutrient concentrations, phytoplankton biomass, and abundance of planktonic cladocerans decreased. In both lakes, water-level fluctuations were the most common factor causing shifts, affecting submerged macrophytes either through changes in light availability or through catastrophic events such as dry-out or mechanical damage by ice movement. Our data give further support for the existence of two alternative stable states in shallow lakes maintained by self-stabilizing feedback mechanisms.

89. BODENSTEINER, L., AND R. SHEEHAN. 1988. Implications of backwater habitat management strategies to fish populations. Pages 60–65 *in* Proceedings of the Forty-Fourth Annual Meeting of the Upper Mississippi River Conservation Committee, Peoria, Illinois, March 8–10, 1988.

In winter, backwaters function as refuges because of their relative isolation from flow. In spring, inundation can occur through the upper end, exposing fish to flow from the main channel. Water temperature during inundation determines the fate of the fish inhabiting the refuge, and exposure to lethal temperatures during inundation may account for the large portion of the fish found in river drift. The use of increased river flow and stage during spring by diversion into backwaters to reduce sedimentation could also incapacitate overwintering fish populations.

90. BONDURANT, D. C., AND R. H. LIVESEY. 1967. Operational problems associated with a basin reservoir system. Pages 47–55 *in* C. E. Lane, Jr., editor. Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

The operation of the Missouri River reservoir system is described, as well as problems encountered in fulfilling primary needs (flood control, hydroelectric power, navigation, and irrigation) and supplemental benefits to fish and wildlife or other concerns such as public health. When operational modifications required to benefit fish and wildlife are reasonable and well defined, primary operations frequently can be changed to provide supplemental benefits. Three essential elements are required for support and success in accomplishing fishery programs that require modification of reservoir operations: (1) an understanding and appreciation of the operational requirements of the overall system, (2) an effort to educate project management about needs, and (3) cooperative planning to most benefit all concerned groups.

91. BONNER, F. C. 1978. Mechanical control of aquatic vegetation. Pages 1–9 *in* Delaware Division of Fish and Wildlife, Project F-27-R-4, Job I-1.

Winter drawdown was evaluated as a mechanical method for control of aquatic vegetation. Ponds were drawn down to where an estimated 60% of the pond bottom was exposed to freezing temperatures and subsequent desiccation of the aquatic plants. Five ponds were drawn down in winter 1975–76. Three ponds were drawn down in winter 1976–77. In winter 1977–78, only one pond was drawn down. The overwinter drawdown was found to be an effective method of controlling certain types of aquatic vegetation. At two of the ponds, the water control structures were inadequate to handle excess runoff and the water levels fluctuated between near empty and normal high water levels. This prevented adequate freezing of the ponds' bottom soils. To kill the target aquatic plants, it is necessary to completely freeze all parts of the plant. For the ponds and lakes that had adequate water control structures, the rooted aquatic plants were controlled. The filamentous blue-green alga *Lyngbya* was not controlled by drawdown.

92. BORN, S. M. 1972. Chippewa Flowage investigations Part 1: Summary report. University of Wisconsin and Wisconsin Department of Natural Resources, Inland Lakes Demonstration Project. n.p.

The Chippewa Flowage in Wisconsin, a 15,300-acre reservoir at normal water levels, was first filled in 1923. The project is operated by Northern States Power Company under license from the Federal Power Commission (FPC). For the past several decades, the Chippewa Flowage region has been highly regarded for its spectacular undeveloped lands and recreational opportunities—particularly fishing. Several conservationist groups have alleged that present management of the flowage threatens its existence as a recreational asset, and that ecological and environmental values are being impaired. In 1972, the FPC considered applying for a new license. This study, designed to provide a better basis for decision making, is composed of two parts: (1) basic scientific investigations of the limnology, hydrology, and ecology of the flowage and Chippewa River system, and (2) an analysis of the policy questions posed by conflict over relicensing. Relicensing may have an effect on control of water levels in the Chippewa Reservoir and discharges below the dam, and on the uses that are made of the lands around the flowage. Parameters affected by water-level fluctuations include discharge rate, water chemistry, temperature, dissolved oxygen, fish population, fish harvest, benthic invertebrates, plankton, aquatic macrophytes, and shoreland erosion. No parameters involving fish abundance or growth could be correlated with degree of overwinter drawdown.

93. BORN, S., AND D. STEPHENSON. 1972. Shoreland erosion: Chippewa Flowage. Appendix U. University of Wisconsin and Wisconsin Department of Natural Resources, Chippewa Flowage Investigations, Part 3B. n.p.

A study was conducted to define the existing physical conditions and causes of erosion and to predict the erosional consequences of alternative water-level management schemes at Chippewa Flowage. Erosion is widely distributed around the shoreline of the Chippewa Flowage and takes place wherever waves impact on steep slopes of unconsolidated sandy materials. Water-level fluctuations simply change the elevation of wave attack; they do not terminate the inexorable attack of the water on the land, although they can sometimes lessen the effects. On the other hand, several feet of winter drawdown will reduce the amount of shoreline affected by ice-related shoreline erosion. The present operating rule for the flowage accomplishes this. However, a counteracting factor is the increased erosion of the littoral zone by runoff and direct rainfall. A practical winter drawdown therefore is one that limits the exposure of the littoral to these forces. Erosion is not a direct result of fluctuating water levels but, rather, a result of impoundment of a waterway with substantial topographic relief. However, shoreline erosion can be minimized by holding lake levels lower than normal during storms. This causes wave energy to be dissipated lakeward from unstable shorelands.

94. BOULDIN, D. R., D. J. LATHWELL, E. A. GOYETTE, AND D. A. LAUER. 1973. Changes in water chemistry in marshes over a 12-year period following establishment. New York Fish and Game Journal 20:129–146.

Twenty artificial marshes, varying in depth from 1 to 3 ft, were measured between 1961 and 1971. Aquatic depth had a major influence on emergent versus submergent vegetation, with emergent vegetation being much more important in the shallower marshes. These studies show that water chemistry will be primarily dependent on the ratio of surface area with depths of 2 ft or less to surface area with depths of 2 ft or more, providing a reasonable amount of emergents occur in the shallows. Marshes with predominantly shallow water should contain large amounts of inorganic carbon. Predominantly deep marshes should have relatively little emergent vegetation, and the accumulation of inorganic carbon in water should be limited.

95. BRASCH, J. G. 1953. Drawdowns: Fish management tool. Wisconsin Conservation Bulletin 23(12):25–28.

Possible benefits of reservoir drawdowns as observed in impoundments of the Tennessee Valley and the States of Wisconsin and Illinois are outlined. After winter drawdown of water levels in Castle Rock Flowage, Pentenwell Flowage, and Lake Eau Claire, populations of common carp were reduced and sport-fish populations seemed to increase. The reduction of water levels by 20 inches in Lake Eau Galle in spring exposed common carp eggs and limited the production of young carp, but the reproduction of bass and crappies was successful. Severe winter drawdown to induce winterkill of undesirable fishes is discussed.

96. BRINK, V. C. 1954. Survival of plants under flood in the lower Fraser River Valley, B.C. Ecology 35:94–95.

The author noted the effect of floodwaters on the Fraser, Nooksack, Skagit, Columbia, and other river systems of the Pacific Northwest. The lethality of waters was associated with their temperature, depth, duration, and movement.

97. BRITTAIN, J. E., AND T. J. EIKELAND. 1988. Invertebrate drift—A review. Hydrobiologia 166:77–93.

A review of the literature for papers published 10 or 15 years before 1988 revealed that the abiotic factors that usually influence drift are current discharge, substrate disturbance, dislodgement, water chemistry and pollution, temperature, and photoperiod.

98. BROADFOOT, W. M., AND H. L. WILLISTON. 1973. Flooding effects on southern forests. Journal of Forestry 71:584–587.

Spring floods in the lower Mississippi Valley can improve growth of dominant, vigorous hardwoods primarily by supplying additional water later in the growing season. Flood-resistant hardwoods are damaged where silt and sand are deposited to depths of 3 inches or more where soil conditions are adverse, and in depressions where water does not leave promptly. In these areas, mortality may occur over the next 4 years. Young seedlings of resistant species die back if inundated after they leaf out, but many still sprout from surviving rootstocks. The pines and many hardwoods in uplands behind flood control dams are not tolerant of flooding. There, high water for just a few weeks during the growing season may cause severe mortality.

99. BROCKMAN-HAWORTH, M. J., H. R. MURKIN, AND R. T. CLAY. 1993. Effects of shallow flooding on newly established purple loosestrife seedlings. Wetlands 13:224–227.

Purple loosestrife (*Lythrum salicaria*) is a nuisance exotic species that displaces native plants and has little value as food or habitat for wildlife. Attempts to control adult plants have had limited success. We investigated the effects of shallow flooding (< 30 cm) on the growth and survival of purple loosestrife seedlings. Pots containing purple loosestrife seedlings were assigned to each of 12 treatment combinations: 3 seedling height categories and 4 flooding depths. Mean stem densities were not affected by the treatments $P > 0.05$). The flooding treatments significantly affected mean stem heights, but there were no identifiable trends within size classifications. All seedlings continued to grow during the experiment. The survival of any purple loosestrife plants can have serious implications in wetlands. The results from this study indicate that shallow flooding is not an effective approach to limiting or preventing the establishment of purple loosestrife seedlings.

100. BROCKMAN-HAWORTH, M. J., H. R. MURKIN, R. T. CLAY, AND E. ARMSON. 1991. Effects of underwater clipping of purple loosestrife in a southern Ontario wetland. Journal of Aquatic Plant Management 29:117–118.

Greenhouse experiments in which uncut purple loosestrife seedlings were flooded to various depths showed that seedlings would continue to grow through the water column. Once a stem broke through the water surface, the overall growth accelerated.

101. BROOKER, M. P., AND R. J. HEMSWORTH. 1978. The effect of the release of an artificial discharge of water on invertebrate drift in the R. Wye, Wales. Hydrobiologia 59:155–163.

An artificial discharge of water (3.0 m^3/s), over 48 hours, from an impoundment into the R. Wye did not substantially affect water temperature or concentrations of dissolved oxygen and suspended solids at a site 16 km below the impoundment. However, the load of suspended material on the second day of the release was about 10 times greater than the prerelease load. The total number of drifting macroinvertebrates on the first and second days of the release was about 7 and 3 times greater than the number on the day preceding the release. The initial increase in flow at 1500 hours resulted in an immediate increase in the number of drifting larvae of *Rheotanytarsus*, a tubicolous chironomid. Subsequently, an enhanced nighttime increase occurred in the total number of drifting invertebrates, particularly the mayfly, *Ephemerella ignita* (Poda); this also occurred on the second night of the release. Increases in the number of drifting *Rheotanytarsus* and *Ephemerella*, the most abundant invertebrates, resulted in increases in drift density. Results from this and other studies indicate that rapid changes in flow resulting from natural or artificial causes substantially modify the drift of invertebrates in rivers.

102. BROSS, M. G. 1969. Fish samples and year-class strength (1965–1967) from Canton Reservoir, Oklahoma. Proceedings of the Oklahoma Academy of Science 48:194–199.

August abundance of young-of-year fishes based on rotenone samples forms the basis for evaluating the effects of a number of physicochemical variables on year-class strength in Canton Reservoir, Oklahoma. Except for temperature and water levels, measured variables (dissolved oxygen concentration, pH, alkalinity, conductivity, and turbidity) remained relatively constant over the 3-year period, whereas the number of young-of-year fishes was much higher in 1965 and 1967 than in 1966. Water temperatures rose earlier in 1966 than in 1965 or 1967, but the rise was not smooth; frequent cool periods kept temperatures below 60 °F most of April. In 1965 and 1967, temperatures probably favored spawning and egg survival more than in 1966, as they exceeded 60 °F through most of April. Water levels were high but stable during spawning and early growth periods in 1966, but rose 15 ft in 1965 and 6 ft in 1967. Rising water levels presumably stimulated spawning, provided spawning sites, and enhanced the food base and survival by inundating vegetation and increasing the biomass of plankton and benthos. Wind was not considered a primary factor affecting year-class strength because both pelagic-spawning and vulnerable nest-building species produced strong year classes in the same years.

103. BROUHA, P., AND C. E. VON GELDERN, JR. 1979. Habitat manipulation for centrarchid production in western reservoirs. Pages 11–17 *in* D. L. Johnson and R. A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Special Publication 6.

Water-fluctuation regimes and a general lack of cover for fish in western reservoirs pose severe problems for management of cover-dependent centrarchids. Floating artificial reefs, midwater reefs, artificial seaweed, and revegetation of drawdown zones have all proved effective in providing habitat for centrarchids. Living vegetation, established in much of the drawdown zone, coupled with the addition of structure below the normal low-water zone, can provide cover for centrarchids at all water levels. Reefs increase cover and firm substrate, thus improving primary and invertebrate productivity and, ultimately, the condition, growth, and survival of fish. Plants such as *Salix alba tristis*, *Taxodium distichum*, and *Eucalyptus camaldulensis* have shown considerable tolerance to flooding, and test plots of these and other plant species have been successfully established in fluctuation zones. Guidelines to implement revegetation programs are described.

104. BROWN, A. G. 1943. Vegetation and lake level correlations at Catahoula Lake, Louisiana. Geographical Review 33:435–445.

Catahoula Lake has an extreme variation of water level of more than 40 ft and a normal seasonal variation of more than 25 ft. The vegetation zones can be directly correlated with lake levels and elevations of the land surface. The following stages are distinguished: dry, low levels, normal low water, normal high water, flood, and extreme flood levels. There are a number of dry low levels in the grass zone. The dwarf-shrub zone is an area subject to frequent inundation, which seems to be the reason for the dwarfism of plants, since they grow better on drier sites. The water elm–swamp privet forest varies in width, according to the slope of the soil. This forest occupies the level between normal low and high water levels. The occasional cypress in the water elm–swamp privet forest has much higher knees than those in the cypress fringe. As cypress seeds will not germinate and grow when submerged, the cypress zone must have developed at high water level; hence it indicates mean high water level for Catahoula Lake.

105. BROWN, S. 1985. Response of tree growth to changes in flooding regime in a mixed hardwood bottomland forest in southern Illinois. Pages 203–208 *in* J. O. Dawson and K. A. Majerus, editors. Proceedings of the Fifth Central Hardwood Forest Conference, University of Illinois, Urbana, April 15, 1985.

The objectives of this study are to investigate if the altered hydrology of Horseshoe Lake in southern Illinois is having an effect on the growth of the most important species in a mixed hardwood bottomland forest that is flooded by the lake and, if tree growth is affected, to determine during what part of the growing season the most important species are affected. Evidence suggests that Horseshoe Lake has undergone several changes in recent years due to an increase in sediment input from the surrounding watershed. As a result, the lake hydrology has an altered depth and duration of flooding in the bottomland forest so that flooding tends to extend longer into the growing season. In general, these studies showed that an increase in the depth and duration of flooding, particularly into the growing season, resulted in decreased growth rates of trees and increased tree mortality. If, however, flooding is restricted to the dormant season, tree growth in the subsequent growing season may increase because of improved soil moisture. The major effect of flooding is the creation of anaerobic conditions in the soil, especially when the floodwaters are stagnant or slowly moving as when flooding regimes are altered. Anaerobic soils generally result in death of roots produced under aerobic conditions. Species tolerant to flooding will produce new, secondary roots in a short time, whereas intolerant species are incapable of producing new roots. However, even for tolerant species few water roots are produced if flooding is seasonal; more or less continuously saturated soils are needed for abundant production of these secondary roots. Altered flooding regimes that result in the presence of standing water well into the growing season will affect the growth of bottomland trees over the long term through reduced root activity and the resulting reduction in photosynthesis and thus stem growth.

106. BROWNLOW, M. D., A. D. SPARROW, AND G. G. GANF. 1994. Classification of water regimes in systems of fluctuating water level. Australian Journal of Marine and Freshwater Research 45:1375–1385.

Aquatic macrophyte communities have been shown to form sequences along water depth gradients, and water depth has been related to various types of environmental stresses. However, in semipermanent wetlands, water depth is rarely constant through time; there are large fluctuations in water level between seasons and years, and the relative lengths of wet and dry periods may be as significant a stressor as the average (or maximum) depth of water. A method is presented of quantifying water regimes on the basis of infrequently sampled water-level data and of comparing and defining regime-types within and between semipermanent swamps. Time periods per depth class are calculated from water depth data for each gradient position from the bottom of the swamp to the high-water mark. These data can be represented as a histogram that describes the wet–dry pattern of each gradient position. A multivariate clustering is used to compare gradient positions in different swamps on the basis of depth and period of inundation. Water regime types are then defined on the basis of the groups derived in the clustering. The method is illustrated for the Bool Lagoon system in southeastern South Australia.

107. BRUSVEN, M. A., AND E. F. TRIHEY. 1978. Interacting effects of minimum flow and fluctuating shorelines on benthic stream insects. Idaho Water Resources Research Institute, University of Idaho, Moscow. 78 pp.

A 50-mile (80-km) reach of the Clearwater River, Idaho, was studied from its confluence with the Snake River upstream to Orofino, Idaho. The study examined two important changes in the River: (1) effects of hydropower releases from Dworshak Dam on the aquatic insect community in the free-flowing reach of the Clearwater River, and (2) backwater effects of Lower Granite Dam on benthos in the lower 5 miles (8 km) of the Clearwater River. As a result of the operational mode of Dworshak Dam, late summer and fall flows are greater than during the preproject era. Although hydropower releases cause frequent and marked fluctuations in discharge, there is a stable postproject low flow. This higher, late summer flow guarantees the submergence of additional substrate, thereby increasing macrobenthic habitat. More than 120 species of aquatic insects, exclusive of Chironomidae, have been collected from the Clearwater River. While small to moderate shifts in seasonal densities of principal species have occurred between intensive study sites above and below the influence of Dworshak Dam, present evidence does not indicate these shifts are attributable to hydropower releases. Approximately 1 month was required for sterile rocks to support a standing crop similar to that of continually watered rocks. In most instances, numbers of species and densities increased with increasing depths of 15, 30, and 45 cm. Numbers of drifting insects were greatest at night. Drift rates and standing crop relations above and below the influence of Dworshak Dam suggest insects drifted more in response to daily fluctuations than because of bottom density. Within the lower 5 miles of the Clearwater River, variable backwater effects of Lower Granite Reservoir have a far more pronounced effect on the amount of potential benthic habitat available than do releases from Dworshak Dam. Formation of Lower Granite Reservoir has resulted in insect community shifts from a riverine to a lentic community as a result of physical changes in water depth, velocity, and substrate; dipteran midges are the dominant insect group.

108. BRYANT, H. E., AND A. HOUSER. 1971. Population estimates and growth of largemouth bass in Beaver and Bull Shoals Reservoirs. Pages 349–357 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

Shoreline estimates of largemouth bass populations were made in large coves on Beaver and Bull Shoals Reservoirs, Arkansas, in April 1969 and 1970. Scale readings and length–weight relations were used to estimate growth of bass. There were 55 more bass ≥250 mm long and 195 fewer bass < 250 mm long (per kilometer of shoreline) in 1970 than in 1969. Differences were due to the strong year class of 1968, which was associated with rising water levels, inundated terrestrial vegetation, and large populations of young-of-year gizzard and threadfin shad.

109. BUCK, H., AND F. CROSS. 1952. Early limnological and fish population conditions of Canton Reservoir, Oklahoma, and fishery management recommendations. Report to the Oklahoma Fish and Game Council Research Foundation, Oklahoma A&M College. 174 pp.

Limnological features and characteristics of the fish populations of Canton Reservoir were studied during the first 2.5 years of impoundment (1948–50), and standard physicochemical variables were recorded. The largest year classes and the greatest annual growth by each age group of most fishes occurred in 1948, during the first year of impoundment. Growth of carpsuckers was most rapid in 1949. High rates of survival and growth presumably resulted from the inundation of over 4,000 acres of heavily vegetated bottomland. Reproduction and growth of most fishes were poor in 1949 due to receding water levels during the spawning and growing seasons. Angling was best when water levels were rising or high.

110. BUECH, R. R. 1985. Beaver in water impoundments: Understanding a problem of water level management. Pages 95–105 *in* M. D. Knighton, editor. Proceedings, water impoundments for wildlife: A habitat management workshop. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota. General Technical Report NC-100.

Information is provided on water as a habitat requirement, on impoundment problems, on the design of water control structures, and on controlling the water levels in beaver ponds.

111. BUKATA, R. P., J. E. BRUTON, J. H. JEROME, AND W. S. HARAS. 1988. An evaluation of the impact of persistent water level changes on the areal extent of Georgian Bay/North Channel Marshlands. Environmental Management 12:359–368.

A conceptual mathematical model has recently been devised to assist environmental managers in predicting the effect on coastal marsh areas of long-term changes in water levels. The model considers such effects solely according to the geometry of the confining basin, the change in ambient water level, and the maximum depth for which bottom-rooted emergent vegetation is present. This model is applied to 17 shoreline marshes of various shapes in the Georgian Bay/North Channel region of the Great Lakes. Model outputs of predicted maximum and minimum marsh area after changes in long-term levels are compared with marsh areas measured from available historical air photos from 1935 to 1985. The results of such comparisons indicate that such a geometric model, despite its neglect of the biological complexities of marsh ecology, can serve as a valuable tool for assessing the range of effects of both natural and man-made changes in long-term ambient water levels on shoreline marshes.

112. BULKLEY, R. V. 1975. Chemical and physical effects on the centrarchid basses. Pages 286–294 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

The effects of several physicochemical factors (turbidity, water-level fluctuations, oxygen concentration, acidity, salinity, and pesticides) on the biology of black basses are discussed. Water-level changes or manipulation affect growth, food supply, reproduction, and movement. High water levels at appropriate times are associated with improved growth and reproduction. Drawdowns in midsummer or fall may also improve growth the following year. Fluctuations in water depth in the form of wave action may hinder spawning success.

113. BURGESS, H. H. 1969. Habitat management on a mid-continent waterfowl refuge. Journal of Wildlife Management 33:843–847.

Plant- and waterfowl-use studies were used to formulate a basic water management program. The program consisted of: (1) winter drawdowns to aerate the soil and to eradicate carp and other turbidity agents, (2) spring flooding to provide accessible food for migrant waterfowl and to help control weed plants, (3) summer drawdowns to produce annuals and other food plants, (4) fall flooding to make marsh foods accessible to waterfowl, and (5) December drawdowns to discourage wintering by waterfowl. During the 10-year study, waterfowl-use days increased from a low of 13 million in 1961 to 43 million in 1965. Summer drawdowns produced abundant vegetation which, when flooded a second summer, produced an abundant crop of small invertebrates. These in turn produced an optimum crop of larger invertebrates and vertebrates for herons the third year. Large numbers of many shorebird species were attracted to the extensive mudflats and shallow waters accompanying midsummer drawdowns. During 1958 and 1967, water management practices were studied at Squaw Creek National Wildlife Refuge in Missouri. Waterfowl use varied from 6 million to 27 million duck-use days and from 7 million to 19 million goose-use days annually at Squaw Creek National Wildlife Refuge during 1958–1967. Changes in waterfowl use were related to changes in habitat management and the resulting ecological succession. In general, annual use by ducks increased when the largest expanses of renewed marshes were flooded. Annual use by geese increased when the largest acreages of renewed marshes and succulent green browse were available.

114. BURRIS, W. E. 1954. The bottom fauna development of a newly constructed pond in central Oklahoma. Proceedings of the Oklahoma Academy of Science 33:129–136.

Bottom samples were collected with a Peterson dredge from a 1/3-acre pond being filled for the first time. Quantitative and qualitative development of benthos was documented for 1 year. A rapid rise in water level may have caused the apparent decline in the volume of benthos in July. It seems unlikely that bottom organisms migrate into newly inundated areas, as no organisms were found along the 1- and 2-ft bottom contours after water had covered these areas for 2 weeks.

115. BUSCH, W. D. N., AND L. M. LEWIS. 1984. Wetlands and lake interrelationships; responses of wetland vegetation to water level variations in Lake Ontario. Pages 519–524 *in* Proceedings of the Third Annual Conference, Lake and Reservoir Management, Knoxville, Tennessee, October 18–20, 1983. U.S. Environmental Protection Agency, Washington, D.C., EPA 440/5/84-001.

Water-level fluctuations, naturally occurring phenomena in the Great Lakes, cause a continuing rejuvenation of lake-influenced wetlands. Two Lake Ontario wetlands (Campbell and Sage Creek Marshes) were mapped for 1-ft contour intervals and habitat–vegetation type. Historical habitat–vegetation conditions were evaluated through interpretation of aerial photography. The photography was selected to represent water levels different from the present. Habitat types defined at Campbell Marsh and their most important herbaceous species include (1) narrow-leaved persistent emergents, *Typha glauca*; (2) aquatic bed, *Ceratophyllum demersum*; (3) grass sedge, *Calamagrostis canadensis*; (4) scrub/shrub, *Cornus* spp; and (5) flooded deciduous forest, *Fraxinus* spp. Habitat types defined at Sage Creek Marsh and their most important herbaceous species include (1) narrow-leaved nonpersistent emergent, *Sparganium eurycarpum*; (2) broad-leaved nonpersistent emergent, *Pontederia cordata*; (3) aquatic bed, *Elodea canadensis;* and (4) grass sedge, *Calamagrostis canadensis*. Computerized data analysis showed that vegetation types occurred within rather distinctive elevational ranges. As water levels changed, the area of the various habitat types changed, adjusting to both the new water depth and to the size of the area at that depth. In Sage Creek Marsh, a large area of narrow-leaved nonpersistent emergents was lost as water levels increased. The greatest loss in Campbell Marsh occurred to persistent emergents; however, this loss did not have a linear relation to annual mean water depth.

116. BUSCH, W. D. N., R. L. SCHOLL, AND W. L. HARTMAN. 1975. Environmental factors affecting the strength of walleye (*Stizostedion vitreum vitreum*) year-classes in western Lake Erie, 1960–1970. Journal of the Fisheries Research Board of Canada 32:1733–1793.

Under present conditions, success of year classes of walleyes in western Lake Erie depends largely on favorable spawning conditions, especially rapidly warming water and a lack of strong winds. Year-class strength was not correlated with the size of the brood stock or with fluctuations of water level, but water levels fluctuated only 0.7 m in spring each year (1960–1970).

117. BUTLER, L. 1962. Periodicities in the annual muskrat population figures for the Province of Saskatchewan. Canadian Journal of Zoology 40:1277–1286.

A major factor in summer production of muskrat populations seems to be the quality, rather than the quantity, of food. An influx of silt-laiden water, or the drying up of an area and then reflooding, will greatly increase muskrat production. The silt-laiden water brings in plant nutrients and drying up encourages decomposition of plant material, thus furnishing nutrient minerals.

118. BUTLER, R. L. 1965. Freshwater drum, *Aplodinotus grunniens*, in the navigational impoundments of the Upper Mississippi River. Transactions of the American Fisheries Society 94:339–349.

The freshwater drum fishery was evaluated on the basis of a study of scale samples and estimates of total and fishing mortality. Year-class strength was related to air and water temperatures but not to water levels during the spawning season.

119. BUTLER, R. L., AND L. L. SMITH, JR. 1950. The age and growth of the sheepshead, *Aplodinotus grunniens* Rafinesque, in the Upper Mississippi River navigational pools. Transactions of the American Fisheries Society 79:43–54.

Nine hundred two sheepshead were taken from navigation Pools 4A, 8, 10, and 17 in summer months 1946–1948. No relation existed between growth rates and average annual water levels.

120. CAHOON, W. G. 1953. Commercial carp removal at Lake Mattamuskeet, North Carolina. Journal of Wildlife Management 17:312–317.

Feeding action by carp in Lake Mattamuskeet, North Carolina, was believed to be a major cause of the high turbidity in the lake proper, which prevented the existence of desired submerged waterfowl food plants. Carp feeding was observed to be the cause of widespread destruction to marginal marsh plants. To improve waterfowl habitat, a program of carp removal was started. The removal of more than 1,600,000 lb of carp from the lake has resulted in the Secchi disk visibility gradually increasing from 6 inches (1948) to 3–4 ft (1953). Desirable submerged waterfowl food plants have invaded 15,000 acres of the formerly barren lake bottom, and the spread continues. Carp-destruction of shoreline emergents has been reduced; Lake Mattamuskeet has its water levels lowered during the growing season to expose shorelines as early as possible in spring for proper growth of native, emergent, waterfowl food plants. The number of waterfowl utilizing the area has increased substantially as a result of this drawdown; therefore, this new and large supply of waterfowl food will undoubtedly influence future populations and movements of waterfowl in eastern North Carolina.

121. CAMARGO, A. F. M., AND F. A. ESTEVES. 1995. Influence of water level variation on fertilization of an oxbow lake of Rio Mogi-Guaçu, state of São Paulo, Brazil. Hydrobiologia 299:185–193.

Variation in water level in Lagoa do Mato, an oxbow lake of the Rio Mogi-Guaçu, fertilized the water column with phosphorus, nitrogen and silicates during periods when the waters of the Rio Mogi-Guaçu overflowed to the lake. An increase in electrical conductivity and a reduction in transparency was also observed. After fertilization, the nutrients declined rapidly, remaining low until the next floods. Principal component analysis revealed three distinct periods relative to the concentration of nutrients: a fertilization period, an assimilation period, and a period of stocking in biomass. These results are discussed in relation to other oxbow lakes in an attempt to identify ecological factors responsible for the fertilization of these ecosystems.

122. CANTRELL, M. A., AND A. J. MCLACHLAN. 1977. Competition and chironomid distribution patterns in a newly flooded lake. Oikos 29:429–433.

In the early colonization of a new lake, interaction (competition) between colonizing midges is important in determining their distribution in new areas. *Chironomus plumosis* is frequently the first species to successfully colonize new habitats made available by rising waters. Its large size and tolerance of low oxygen tensions enables it to outcompete most other species—including *Tanytarsus gregarius*, which moves toward lake margins where encounters with *C. plumosis* are less frequent.

123. CARPENTER, J. R., AND C. A. MITCHELL. 1977. Root respiration characteristics of flood tolerant red maple (*Acer rubrum* L.) and flood intolerant sugar maple (*Acer saccharum* Marsh) trees. Journal of the American Society for Horticultural Science 105:684–687.

Red maple (*Acer rubrum* L.) and baldcypress (*Taxodium distichum* [L.] Rich.) seedlings were very tolerant of extended flooding, whereas shoots of sugar maple (*Acer saccharum* Marsh) seedlings experienced desiccation after 8 days of flooding, and leaf death after 14 days. Shoot desiccation occurred after 14 days of flooding. Roots of all three species utilized O_2 with similar efficiency before flood stress. However, the respiratory capacity of sugar maple roots declined substantially during the first 8 days of flooding, and more gradually from 8 to 22 days, at 21%, 5%, or 0.5% O_2. Red maple roots declined gradually in respiratory capacity over the entire flooding period at 21% and 5%, but not at 0.5%, O_2. After an initial sharp decline, baldcypress roots gradually regained their capability to utilize O_2 from 8 to 22 days of flooding at all three levels of O_2. When tested at 21% O_2, both red maple and baldcypress roots had two- to threefold higher respiratory capacities than did sugar maple roots after 22 days of flooding. Presoaking root sections from flooded red and sugar maples in a sucrose solution mildly stimulated respiration rates measured at 21% O_2, but did not fully restore respiratory capacity lost by flooding either species.

124. CARROLL, B. B. 1964. Growth of catfishes in Norris Reservoir, Tennessee. Journal of the Tennessee Academy of Science 39(3):86–91.

Growth rates of 87 channel and 254 flathead catfishes in Norris Reservoir were determined by examining annuli of pectoral spines. Growth of 3- to 5-year-old flathead catfish accelerated after an extreme drawdown of water levels in 1955–56. Growth acceleration did not occur in younger flatheads and was not evident in channel catfish, although the channel catfish of the 1956 year class were longer at all ages than those of the 1954 and 1955 year classes. A strong year class of channel catfish was produced in 1957, 1 year after drawdown.

125. CARROLL, B. B., G. E. HALL, AND R. D. BISHOP. 1963. Three seasons of rough fish removal at Norris Reservoir, Tennessee. Transactions of the American Fisheries Society 92:356–364.

The composition and value of the commercial catch, the effectiveness of different types of commercial gear in fishing, the effects of these gears on game fish, and the possibility for a sustainable commercial fishery in Norris Reservoir were examined. The harvest of rough fishes, which progressively declined over 3 years, seemingly was more closely related to annual variations in abundance and the size composition of individuals than to the effects of water-level fluctuations. Although commercial fishermen blamed high water levels for reduced catches in the second season, the catch continued to decline in the third season, when water levels were comparable to those in the first season. The fishermen preferred declining water levels because fish movement apparently increased.

126. CARTER, J. P. 1963. Experimental crappie removal. Kentucky Department Fish and Wildlife Resources, Federal Aid Project F-21-R, Job I-13. 18 pp.

Crappies and rough fishes were removed from Dewey Lake, Kentucky, during the planned winter drawdown of 1962–63. Effects of their removal on fish populations of Dewey Lake were obscured by the effects of drawdown. Increased predation through crowding and loss of fish through the dam probably reduced the population of gizzard shad. Exposure and weathering of large areas of lake bottom probably are important in increasing lake fertility.

127. CARTER, V. 1986. An overview of the hydrologic concerns related to wetlands in the United States. Canadian Journal of Botany 64:364–374.

There is a tremendous diversity in wetland types and wetland vegetation in the United States, caused primarily by regional, geologic, topographic, and climatic differences. Wetland hydrology, a primary driving force influencing wetland ecology, development, and persistence, is still poorly understood. The interaction between groundwater and surface water and the discharge–recharge relations in wetlands affect water quality and nutrient budgets as well as vegetative composition. Hydrologic considerations necessary for an improved understanding of wetland ecology include detailed water budgets, water chemistry, water regime, and boundary conditions. Wetland values are often based on perceived wetland functions. These hydrologic functions include flood storage and flood-peak desynchronization, recharge and discharge, base flow and estuarine water balance, and water quality regulation. Expanded research and basic data collection focused on wetland hydrology and its relation to wetland ecology are needed to identify and quantify the hydrologic functions of wetlands.

128. CASANOVA, M. T. 1994. Vegetative and reproductive responses of charophytes to water-level fluctuations in permanent and temporary wetlands in Australia. Australian Journal of Marine and Freshwater Research 45:1409–1419.

Chara australis responded to changes in water levels by altering its morphology and allocation of resources. In a field harvest experiment, vegetative vigour of *C. australis* was greatest after water-level rises, and the overall morphology of the plants varied depending upon season and site of collection. Allocation of dry weight varied over time, but allocation to sexual reproduction was always less than 10% of the total in this dioecious perennial species. *C. australis* reproduced sexually through the spring, summer, and fall, and where water levels were continually decreasing more female than male shoots were present. Field growth rates increased when depth was increased, and sexual reproduction was stimulated when water levels fell. An annual charophyte species (*Nitella sonderi*) did not display significant vegetative or sexual responses to water-level changes. The results of these experiments show that charophyte species can display morphological and reproductive plasticity in response to water-level changes; however, because charophytes are not uniform in their adaptations to fluctuations, results from one species cannot be extrapolated to another species. Life history could be a more important determinant of vegetative and reproductive characteristics than is phylogenetic affinity.

129. CHAMBERLAIN, E. B., JR. 1948. Ecological factors influencing the growth and management of certain waterfowl food plants on Back Bay National Wildlife Refuge. Transactions of the North American Wildlife and Natural Resources Conference 13:347–356.

Water-level fluctuations, which are due primarily to shifts in wind direction and velocity, seemed unimportant in the growth of waterfowl food plants on Back Bay National Wildlife Refuge in Virginia.

130. CHANGNON, S. A. 1993. Changes in climate and levels of Lake Michigan: Shoreline impacts at Chicago. Climatic Change 23:213–230.

This study concerns effects along the Illinois shoreline resulting from the record low levels of Lake Michigan during 1964 to 1965, and the potential effects of future low water levels at Chicago resulting from potential climate changes. The study was confined to the physical and economic effects and the potential responses along the Illinois shoreline. It did not address the effects of low lake levels on Lake Michigan water quality or other effects beyond those identified along the Illinois shore.

131. CHARLES, J. R. 1967. The Buckhorn Reservoir fishery during the fourth, fifth, and sixth years of impoundment. Pages 1–40 *in* Kentucky Fisheries Bulletin 46.

The standing crop and harvest of fishes from Buckhorn Reservoir were evaluated by rotenone sampling and a nonuniform probability creel census, respectively. Although a tremendous spawn of threadfin shad occurred in 1964, threadfin shad were absent from the reservoir by 1965. Presumably they migrated from the reservoir during the winter drawdown, and were not killed by cold water. The maximum carrying capacity (89 lb/acre) of the reservoir was apparently reached in 1962, the second year after the lake was filled. Fish standing crops declined after 1962, but harvest increased slightly from 18 to 23 lb/acre from 1964 to 1966.

132. CHEVALIER, J. R. 1977. Changes in walleye (*Stizostedion vitreum vitreum*) population in Rainy Lake and factors in abundance, 1924–1975. Journal of the Fisheries Research Board of Canada 34:1696–1702.

Yearly commercial harvests of walleyes steadily decreased from 150,000 kg in the 1920s to 19,000 kg in the early 1970s. Observed increases in growth probably were a compensatory mechanism in response to decreased abundance of walleyes and related decreases in intraspecific competition for prey. Abundance of brood stock and spring water levels were positively related to abundance 5 years later. Coefficients for correlations (r) of commercial catch per unit effort and water levels 4, 5, and 6 years earlier were 0.48, 0.71, and 0.47, respectively. The regression equation for the 5 years combined was $Y = -93.26 + 16.81\ X$, where Y is the annual commercial catch per unit effort, and X is the average spring water level 5 years earlier. The coefficient of determination (r^2) was 0.50. Low water levels force walleyes to spawn in less desirable habitat than the clean shoal areas that are normally available.

133. CHRISTENSEN, M. S. 1993. The artisanal fishery of the Mahakam River floodplain in east Kalimantan, Indonesia. 3. Actual and estimated yields, their relationship to water levels and management options. Journal of Applied Ichthyology 9:202–209.

Annual catches were most significantly related to the number of days when water levels were greater than 9.2 m above mean sea level in a 12-month period beginning in May of the year preceding the catch.

134. CHRISTENSON, L. M., AND L. L. SMITH. 1965. Characteristics of fish populations in Upper Mississippi River backwater areas. U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Washington, D.C., Circular 212. 49 pp.

Standing crops of fish and their fluctuations from year to year, age- and size-class structure of the populations, and growth rates of the common species present in three backwater areas of the Upper Mississippi River were determined for the period 1947 to 1952. Differences in standing crop and species composition cannot be related to changes in water levels.

135. CLAFLIN, T. O. 1968. Reservoir aufwuchs on inundated trees. Transactions of the American Microscopical Society 87(1):97–104.

Periphyton and associated benthic invertebrates on inundated trees were studied from April 1964 to January 1966 in Lewis and Clark Lake and in Lake Francis Case. Because fluctuating water levels in Lake Francis Case exposed most of the suitable tree substrates for 4 or 5 months of the year, the standing crop of periphyton was much lower there than in Lewis and Clark Lake. Periphyton growth was slower in deep than in shallow water; the heaviest standing crop occurred between 3 and 7 m. There was a significant positive correlation between the density of midge larvae and the standing crop of periphyton. In 1964, abundance of midges in Lewis and Clark Lake increased from a seasonal low on April 15 to about 10,500 m^{-2} by May 24; density of pupae increased from 0 to 4,800 m^{-2}. Peak densities of midges in Lake Francis Case were in June and August but never exceeded 300 m^{-2}. Periphyton and benthos populations inhabiting shallow-water areas of Lake Francis Case are severely reduced annually by fluctuating water levels.

136. CLARK, W. R. 1985. Variation in harvest rates of muskrats on the Mississippi River. Page 17 *in* Proceedings of the Mississippi River Research Consortium, Volume 17, La Crosse, Wisconsin, April 17–19, 1985.

Muskrats (*Ondatra zibethicus*) were ear- and leg-tagged from 1980 to 1984 in Pool 9, Upper Mississippi River, to determine survival and harvest rates with tag recovery methods. Direct recovery rates varied widely among habitats within the pool and were less in Wisconsin (18 ± 5%), where trapping seasons opened approximately 3 weeks later than in Iowa (30 ± 3%). Low temperatures and deeper pool levels during the early weeks of trapping depressed recovery rate in Wisconsin. The tag reporting rate, estimated from trapper interviews, averaged 82 ± 1% and was constant among years due to rewards for tags and public meetings. Recoveries to date best fit a model assuming constant survival but year-specific recovery rates. Recovery rate averaged 38 ± 2% and was significantly greater in 1981, a year of higher pelt values and good trapping conditions. Harvest rates ranged from 21% in backwaters in 1982 to 85% in open-water habitat in 1981, and averaged 46 ± 18% for all years and habitats combined. In spite of variable harvest rate, annual survival rate was constant, averaging 14.9 ± 2.5%. Experimentation is continuing to establish the relative importance of regulations, pelt values, and weather influencing harvest and survival of muskrats on Pool 9. (Abstract only)

137. CLAY, R. T., AND W. R. CLARK. 1982. A preliminary report on muskrat habitat and population parameters in Pool 9. Page 26 *in* Proceedings of the Mississippi River Research Consortium, Volume 15, La Crosse, Wisconsin, April 14–16, 1982.

Channel side and backwater habitats were studied to determine whether the habitats differed and if water-level changes due to navigation events affect arrowhead (*Sagittaria latifolia*), the most common muskrat habitat. Water depths were greatest in channel side habitats and water temperatures were highest in backwater habitats. Above- and belowground standing crops, stem density, and area covered by arrowhead were greater in channel side areas, whereas individual plant height and weight were greater in backwater areas. Water-level fluctuations due to barge passage had no measurable effect on arrowhead abundance. Natality of muskrat populations was greater in backwater areas (16.3 versus 13.2 young per female); however, live trapping catch per effort throughout summer was consistently greater in channel side areas. Muskrat body condition of individuals, the ratio of weight to length, did not differ between habitats. Exploitation and survival rates will be estimated using tags recovered from muskrats marked during summer and harvested by trappers in fall. A sample of carcasses will be used to determine the age and sex composition of the harvested animals. (Abstract only)

138. COHEN, Y., AND P. RADOMSKI. 1993. Water level regulations and fisheries in Rainy Lake and the Namakan Reservoir. Canadian Journal of Fisheries and Aquatic Sciences 50:1934–1945.

The difference between the yearly maximum and minimum water levels (YMXR) is an index of lake dynamics: shoals are exposed and inundated, nutrients are oxidized and reduced, and the diversity and density of the aquatic plant community are affected. Shoals and emergent macrophytes provide spawning habitat for fish. The 5-year moving variance of YMXR fluctuates regularly with periods of about 11.2 years (periodicity of sunspot cycles). This reflects the effects of within-year consecutive periods of storms and dry spells. Water-level regulations resulted in changes in both amplitudes and frequencies of YMXR compared with natural fluctuations. We established links between fluctuations in YMXR and fluctuations in fish populations. Water-level regulations, through their effects on YMXR, corresponded to changes in interspecific interactions on Rainy Lake and the Namakan Reservoir. In both, walleye (*Stizostedion vitreum*) fluctuations were synchronized with those of lake whitefish (*Coregonus clupeaformis*) and northern pike (*Esox lucius*) more than those of either species with the other two. On the Namakan Reservoir, YMXR fluctuations were accentuated by water-level regulation; on Rainy Lake, they were dampened. Regulations should consider frequencies and amplitudes of changes in water level and their effect on fish populations.

139. COLE, R. A., F. A. WARD, T. J. WARD, AND R. M. WILSON. 1990. Development of an interdisciplinary planning model for water and fishery management. Water Resources Bulletin 26:597–609.

The development of an interdisciplinary model that analyzes the effects of resource management decisions on New Mexico fishery production, yield, sportfishing effort, and economic benefit to anglers is described. The model re-creates river flows and materials transported through reservoirs and their tailwaters from 1974 through 1987. Solar radiation, water temperature, phosphorus, nitrogen, suspended solids, and water exchange rates determine primary production. Organic loads from watershed sources, added to primary production, form a trophic base for sport fish forage. Fish production is partitioned into biomass and growth of each age class in sport fish and forage fish groups by differential responses to food type, light, water-level fluctuation, and predation. Fish biomass, with angler population distribution and site condition, contributes to determining angler effort and economic benefits. Model users can vary and analyze water level and quality, stocking, fishing regulations, site access, site facilities, and site entry fees. The model (on floppy disks with a user manual) is available for operation on MS-DOS-compatible computers with a hard disk. (Contact R. M. Wilson, New Mexico Game and Fish Department, State Capitol, Santa Fe, New Mexico 87503)

140. COOK, A. H., AND C. F. POWERS. 1958. Early biochemical changes in the soils and water of artificially created marshes in New York. New York Fish and Game Journal 5:9–65.

Shallow-water environments were studied over a 2-year period in six artificially created marshes in New York between 1953 and 1954. In general, much of the vegetation that was present prior to flooding died during the following 2 years. Of the woody species present, part of the red maple (*Acer rubrum*), American and slippery elms (*Ulmus americana* and *U. fulva*), alder (*Alnus* sp.), black ash (*Fraxinus nigra*), winterberry (*Ilex verticillata*), red osier dogwood (*Cornus stolonifera*), and meadowsweet (*Spiraea alba*) survived. Of these, only meadowsweet seemed to be prospering. None of the herbaceous species withstood the change in water level. At another site, red and white oaks (*Quercus rubrum* and *Q. alba*), water beech (*Carpinus caroliniana*), and thornapple (*Crataegus* sp.) died the first year of flooding. Willows (*Salix* sp.), winterberry, and a few alders survived into the second year. Of the herbaceous species present prior to flooding, only cattail survived. A discussion of fluctuation, water levels, and marsh management is given.

141. COOKE, C. R., JR. 1970. Fisheries investigations. Region 5-C. Stabilization study of Falcon Reservoir. Texas Parks and Wildlife Department, Federal Aid Project F20-R-4. n.p.

In the 10 years prior to the study, the water level of Falcon Reservoir had fluctuated from a low of 266.5-ft elevation to a high of 306.8-ft elevation. It was believed that the construction of Amistad Reservoir on the Rio Grande would stabilize the water level of Falcon Reservoir to a degree. Consequently, this study was designed to measure the effects of stabilization on stratification, food forms, fish populations, sport fishing, and water quality. However, stabilization has not occurred. The water level fluctuated over 35 ft in 1971, the last year of the study. Fishermen were fairly successful in 1971 compared with 1970, when water levels were relatively stable (7-ft variation). In 1971, 1.0 lb of bass per man-hour and 1.2 lb of crappies per man-hour were harvested. Of other species, 1.4 lb per man-hour were harvested. These were significant increases over 1970.

142. COOKE, C. R., JR. 1971. Stabilization study of Falcon Reservoir. Texas Parks and Wildlife Department, Federal Aid Project F-20-R-3. 18 pp.

Gill netting, seining, and trawling data showed no significant change in the percent of rough or game fish in the reservoir fish community after 1 year of stabilized water levels. Water chemistry changed little, and no thermocline was established. Fishing quality decreased; the catch rate decreased at two locations.

143. COOKE, D. 1988. Chapter 6: Lake and reservoir restoration and management techniques. Pages 6.1–6.38 *in* L. Moore and K. Thornton, editors. Lake and Reservoir Restoration Guidance Manual. U.S. Environmental Protection Agency, Washington, D.C., EPA 440/5 88 002.

Information is given on water-level drawdown as a management technique for lakes and reservoirs. The responses of common aquatic plants to drawdown are discussed.

144. COOKE, G. D. 1980. Lake level drawdown as a macrophyte control technique. Water Resources Bulletin 16:317–322.

Lake drawdown as a management or restoration technique for controlling macrophytes in eutrophic lakes is reviewed for effectiveness, longevity, and positive and negative effects. Drawdown can be effective but is species–specific, and some nuisance plants are resistant or stimulated. The responses of 63 nuisance plants are reviewed. Advantages of the technique include low cost, absence of toxic chemicals, enhancement of fisheries, and the opportunity to carry out other lake improvements. Drawbacks include nutrient release, algal blooms, low dissolved oxygen, lake user dissatisfaction during the process, and failure to refill. The technique is recommended for situations where susceptible species are the major nuisance and where prolonged (1–2 months) dewatering of sediments under rigorous conditions of heat or cold is possible.

145. COOKE, G. D., E. B. WELSH, S. A. PETERSON, AND P. R. NEWROTH. 1986. Lake and reservoir restoration. Butterworth Publishers, Boston. n.p.

Water-level management is discussed in relation to lake renewal, eutrophication, and water quality.

146. COOPER, B. D. 1957. A study of the game fish species in Sheldon Reservoir. Texas Parks and Wildlife Department, Federal Air Project F-012-R-02/WKPL, B/Job 04. 11 pp.

Diets of young largemouth bass stocked in Sheldon Reservoir, Texas, in 1956 were studied from April to December, and weight gain or loss of tagged bass was monitored after July. As bass grew and water levels were reduced 1.5 ft in fall, food apparently became limiting, though it had initially been abundant when terrestrial vegetation was first flooded. Many bass lost weight, and others grew at slower rates. The reservoir was filled to only one-fifth its total capacity during the study.

147. COOPER, C. M. 1980. Effects of abnormal thermal stratification on a reservoir benthic macroinvertebrate community. American Midland Naturalist 103:149–154.

Increased water levels in Grenada Reservoir, Mississippi, during 1973–76, prolonged hypolimnial stagnation because the reservoir was not drawn down sufficiently to disrupt thermal stratification. Massive kills of immature *Hexagenia bilineata* and *Oecetis inconspicua* occurred in 1973. Recurring stagnation in 1974 prevented recolonization, and during 1973–76 period the benthic community was altered from one dominated by *Hexagenia, Oecetis, Chaoborus*, and chironomids to one dominated by *Limnodrilus*, *Chaoborus*, and chironomids—forms that are more tolerant of low oxygen than are *Hexagenia* and *Oecetis*. Standing crops initially decreased but later recovered.

148. COOPER, G. P. 1966. Fish production in impoundments. Pages 1–21 *in* Michigan Department of Conservation, Research and Development Report 104.

The production of sport fishes in U.S. impoundments is reviewed, with emphasis on fisheries in the northeast. Nutrients that precipitate or are bound to sediments after organisms die may be released if basins are drained and left fallow for several months. Retention of nutrients by sediments probably is a major reason for the decline in productivity as impoundments age. Some large impoundments remain highly productive for 10 to 30 years; smaller ponds may be productive for only 5 to 10 years. The concept of declining productivity is most often associated with sport fish, and two hypotheses have been developed to explain decreasing production. One hypothesis is related to losses of nutrients and the other to a change in the species composition of fishes. Evidence supporting both hypotheses has been published.

149. CORDELL, H. K., AND J. C. BERGSTROM. 1993. Comparison of recreation use values among alternative reservoir water level management scenarios. Water Resources Research 29:247–258.

Water-level drawdowns for hydropower, stream flow regulation, and flood control often reduce the suitability of reservoirs for water-based recreation. The gain in aggregate economic use value of outdoor recreation under three alternative water-level management scenarios was measured for four reservoirs in western North Carolina as part of an interagency policy analysis. Use values were estimated using a contingent valuation survey and expert panel data. Maintaining high water levels for longer periods in summer and fall was found to result in considerable gains in estimated recreational benefits.

150. CORRARINO, C. A., AND M. A. BRUSVEN. 1983. The effects of reduced stream discharge on insect drift and stranding of near-shore insects. Freshwater Invertebrate Biology 2:88–98.

The effects of seasonally reduced stream discharge on insect drift and stranding were studied in two experimental channels on the Grande Ronde River, Oregon. Five experiments were conducted (spring, summer, and fall 1980, and spring and fall 1981) at three test flows (0.57, 0.28, and 0.03 m^3/s). Insect samples were taken with a modified Hess sampler and standard drift nets. Reduced stream discharge caused catastrophic drift in the test channel with drift peaking at night. *Simulium* sp. and *Baetis tricaudatus* were the principal drift components. Evidence of stranded insects in the dewatered zone was greatest in fall and least in spring.

151. COWELL, B. C., AND P. L. HUDSON. 1967. Some environmental factors influencing benthic invertebrates in two Missouri River Reservoirs. Pages 541–555 *in* C. E. Lane, Jr., editor.

Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

Variations in water levels and water discharge interact with environmental factors (e.g., temperature, bottom type, depth, dissolved oxygen concentration, wave action, and the presence or absence of inundated vegetation) to strongly influence the abundance, distribution, migration, and survival of benthic invertebrates. Water-level fluctuations of 13.7 m annually (often 0.3 m/day) and wave action probably were responsible for the relative scarcity of *Hexagenia* in Lake Francis Case. Despite exposure of the littoral area in Lake Francis Case, chironomids are three times more abundant there than in Lewis and Clark Lake, which fluctuated little. Although *Hexagenia* migrates in response to temperature and population density, chironomid larvae migrate with water levels. Water discharge can result in significant losses (44 metric tons in Lewis and Clark Lake in 1964) of invertebrates through the turbines. The distribution of invertebrates is strongly influenced by substrate type, and in Lake Francis Case, wave action at different water levels has mechanically sorted populations into horizontal bands of different size groups. Stranding of invertebrates by rapidly receding waters was observed on all sampling dates, and survival of stranded individuals was negligible. In one instance, 6,146 chironomids m^{-2} were stranded 4 m above the shoreline in Lake Francis Case. Inundated trees serve as substrates for periphyton communities, which are eventually colonized by benthos. Densities of most invertebrates were higher—11 times greater in Lewis and Clark Lake—on the tree-based periphyton than on adjacent bottom substrates. In Lake Francis Case, the density of benthos on the periphyton-tree substrate was only four times greater than on adjacent bottom areas. Winter drawdown apparently destroyed the full development of periphyton communities in Lake Francis Case. Invertebrates were two times more abundant in smartweed than in barren areas.

152. CRAWFORD, B. 1957a. Report on fall and winter drawdown on Blue Mountain Lake, 1956–57. Pages 1–7 *in* Arkansas Game and Fish Commission.

A fall and winter drawdown was carried out on Blue Mountain Lake, Arkansas, in 1956–57 to improve a fishery that had been deteriorating since 1952. The lake had become very muddy, and drum, buffalo, shad, and minnows had tripled from 1953 to 1956. The objectives of the drawdown were to: (1) aerate the bottom soil, (2) remove as many rough and commercial fish as possible, (3) concentrate the forage species, thus allowing them to be utilized by the predator population, (4) plant rye grass to aid in stabilizing the bottom muck, and (5) allow fishermen and boat dock operators to build suitable locations and depths. Predation by channel catfish on shad appeared to be high, as indicated by stomach analysis. Commercial fishermen were much more successful in the nearby Arkansas River and therefore quit fishing the lake, even after the drawdown. Blue Mountain Lake was reduced to approximately 600 acres from a surface area of 2,900 acres at a conservation pool level. No further results were reported.

153. CRAWFORD, B. 1957b. Report on the second fall and winter drawdown on Nimrod Lake, 1956–57. Arkansas Game and Fish Commission, Little Rock. 8 pp.

Nimrod Lake was drawn down to aerate bottom soils, to facilitate removal of commercial and rough fishes, to improve the availability of prey fish for predators by concentrating them, to permit the construction of fish attractors, and to permit seeding of rye grass in the drained zone. After the first drawdown, Secchi disk readings increased 2 to 3 ft, and boat dock owners reported improved fishing in spring. Also, sport fishes caught commercially increased 28% by number and 15% by weight in 1 year.

154. CRAWFORD, R. M. 1978. Physiological responses to flooding. Pages 453–477 *in* O. L. Lange, P. S. Nobel, C. B. Osmond, and H. Ziegler, editors. Physiological ecology. 2. Water relations and carbon assimilation. Springer Verlag, New York.

An extensive literature review is made by the author concerning the physiological responses to the flooding of trees. Major topics discussed are flooding injury and survival mechanisms.

155. CRISTOFOR, S., A. VADINEANU, AND G. IGNAT. 1993. Importance of flood zones for nitrogen and phosphorus dynamics in the Danube Delta. Hydrobiologia 251:143–148.

The change of concentration of total reactive phosphorus (TRP) and dissolved inorganic nitrogen (DIN) was studied in the lower Danube River and in selected lakes situated in the wetland area of the Danube Delta. The highest retention was found in periods of moderate and low water level when the surface-to-volume ratio of the lakes was high. In these periods, the in-lake concentration of TRP and DIN could be as low as 11 and 23% of the values found in the inflowing river.

156. CRITES, R. W., AND J. E. EBINGER. 1969. Vegetation survey of flood plain forests in east-central Illinois. Transactions of the Illinois State Academy of Science 62:316–330.

Woody and herbaceous vegetation surveys were made of six areas (13.75 acres) in the Embarrass River floodplain in east-central Illinois. A total of 12 species were found, with *Acer saccharinum, Populus deltoides, Acer negundo,* and *Salix nigra* being the most important. Reproduction in the areas indicate that *Acer negundo* and *Acer saccharinum* will continue to be of major importance. However, there was little *Populus deltoides* reproduction, and *Salix nigra* was able to reproduce only in wet areas near the river's edge.

157. CRIVELLI, A. J., P. GRILLAS, AND B. LACAZE. 1995. Responses of vegetation to a rise in water level at Kerkini Reservoir (1982–1991), a Ramsar site in northern Greece. Environmental Management 19(3):417–430.

The floodplain of the river Strymon at Kerkini (northern Greece) was transformed into an irrigation reservoir by the construction of a dam in 1932 and was subsequently enlarged in 1982. The aims of this study were to quantify the changes occurring in the various habitat types after raising of the water level and to assess the stability of the plant communities present at this Ramsar site. The current hydrological regime, which has been stable since 1986, is typified by an increase in mean annual reservoir level of 2.2 m and by an increase in the annual range in level of 1.3 m. Landsat (1980, 1981, 1984, 1986, and 1988) and SPOT (1990) satellite images show a decrease in the area of grassland and shallow water areas, the rapid disappearance of reedbeds, the appearance of beds of *Nymphaea*, and the disappearance of half the forest area. The flooded forest, dominated by *Salix alba*, is a key habitat contributing to the biological richness of this wetland of international importance. The decrease in the forested area will continue because of the death of standing trees, the absence of regeneration under the new regime, the felling of trees, and grazing. Management could be undertaken to ensure the survival of forested habitat and reedbeds at Kerkini, but this would require that the authorities take into account nature conservation and the protected status of the site and not raise the water level again.

158. CROLEY, T. E., II, K. N. RAJA RAO, AND F. KARIM. 1978. Reservoir sedimentation model with continuing distribution, compaction, and sediment slump. Iowa Institute of Hydraulic Research 198:1–136.

A comprehensive reservoir simulation scheme has been developed to estimate changes in the reservoir profile due to sedimentation over any length of reservoir operation. The model includes several input submodels, e.g., time series models for generating sequences of water inflow, sediment inflow, and evaporation, and an operating submodel to supply necessary input data to the sedimentation submodel, which forms the heart of the simulation scheme. The sedimentation submodel estimates the total volume of sediment trapped in the reservoir in a selected time interval, and then distributes this over the height of the reservoir. The simulation model, at the end of each time interval, outputs the water outflow, the reservoir pool elevation, the volume of deposited sediment with its distribution over the reservoir height, the resulting new zero elevation, and the adjusted elevation–area–volume relation. The validity of the model was checked by application to the Coralville Reservoir on the Iowa River near Iowa City, Iowa.

159. CROSS, D. H., AND K. L. FLEMING. 1989. Control of *Phragmites* or common reed. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.12. U.S. Fish and Wildlife Service, Washington, D.C. 5 pp.

Established stands of *Phragmities* will not be altered by flooding, but water levels greater than 12 inches will keep stands from expanding. Seedlings can be killed by raising water levels.

160. CROWDER, L. B., AND W. E. COOPER. 1979. Structural complexity and fish–prey interactions in ponds: A point of view. Pages 2–10 *in* D. L. Johnson and R. A. Stein, editors. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Special Publication 6.

A conceptual model of fish–prey interactions as influenced by structure was developed from a review of current literature. The model predicts that the feeding efficiency and growth of fish peaks at intermediate levels of structural complexity. As a test of this hypothesis, macrophytes (primarily *Ceratophyllum demersum*) were manipulated by hand in three 0.l-ha experimental ponds at the Kellogg Biological Station, Michigan, to form ponds with high, medium, and low densities. Bluegills (8.6 cm long) grew fastest at intermediate macrophyte densities. Alterations of structural complexity, whether by addition of artificial structures or removal of macrophytes, may alter feeding efficiency and production of fishes in the littoral zone.

161. CULVER, D. A., J. R. TRIPLETT, AND G. B. WATERFIELD. 1980. The evaluation of reservoir water-level manipulation as a fisheries management tool in Ohio. Ohio Department of Natural Resources, Division of Wildlife, Federal Aid in Fish Restoration Project, F-57-R, Study 8. 67 pp.

Dual problems of high fishing pressure and declining fishing success associated with reservoir aging confront fishery managers in Ohio. Water-level fluctuation (drawdowns and reflooding) can do much to restore high productivity to fisheries of older lakes. In the application of this management technique, an attempt is made to revert older lakes to an earlier sere of succession, when fish populations were expanding into new habitat. This study attempts to delineate potential applications of existing techniques of water-level management to enhance sport fisheries of Ohio impoundments. To identify existing techniques, the authors conducted an exhaustive literature survey and interviewed fishery administrators throughout the northeastern United States to ascertain present use of water-level manipulation in the region. Potential reservoir sites were selected for field studies. Available data on Ohio reservoirs were surveyed, and a list of studies that might be performed in

Ohio to assess the utility of water-level manipulation was developed. (Abstract adapted from Triplett et al. 1980)

162. CURLEY, A., AND R. URICH. 1993. The flood of '93, an ecological perspective. Journal of Forestry 91(9):28–30.

By late July, short-term effects of the flood of 1993 on the Mississippi River were obvious. Along shorelines, some trees with waterlogged roots lost their foothold in the saturated soils and fell victim to windthrow and stronger currents. In a review of the literature, the authors found that in studies in the 1930s, the U.S. Fish and Wildlife Service determined the effects of flooding to be insignificant for the first year of impoundment. However, many trees showed signs of stress in the second year and were dead after 2 to 3 years of permanent flooding.

163. CURRIER, J. P. 1954. The history of Lake Minnewonka with reference to the reaction of lake trout to artificial changes in environment. Canadian Fish Culturist 15:1–9.

The population of lake trout was dominated by small fish less than 15 inches long after successive increases in lake level for development of hydroelectric power. Mortality of eggs and fry decreased after construction of a dam in 1941, but mortality seemed to be high when fish reached a length of 12 or 13 inches. After impoundment, newly flooded areas that had been dewatered for the previous 5 months were not productive. Food studies showed that fish shorter than 15 inches were not piscivorous. Young lake trout were seemingly inhabiting much deeper water than their prey (ciscoes and mountain whitefish). The two prey fishes were still present in moderate numbers after impoundment but were not well adapted to the environment that was inhabited by young lake trout and created by increased water levels. Many young lake trout could not survive the critical transition from a diet of plankton and benthos to one of fish.

164. CURTIS, G. L., J. S. RAMSEY, AND D. L. SCARNECCHIA. 1989. Habitat use by shovelnose sturgeon in Pool 13, Upper Mississippi River, during extreme low flow. Page 13 *in* Proceedings of the Mississippi River Research Consortium, Volume 21, La Crosse, Wisconsin, April 27–28, 1989.

The movements of 28 radio-tagged shovelnose sturgeon (*Scaphirhynchus platorynchus*) were monitored in Pool 13, Upper Mississippi River at Bellevue, Iowa, between April 15 and August 25, 1988. General habitat types frequented were recorded for 217 telemetry fixes. Specific habitat (depth, water temperature, substrate, and current at surface, midwater, and bottom) was performed for sightings. Most sturgeon position fixes (48.8%) were in main channel habitat during the extreme low flow observed in 1988, in sharp contrast to the results of a 1982 study conducted during normal flow. Other low-flow sightings were in main-channel border wingdam fields (30.0%) and upper tailwater (15.2%). Fewer were in open main-channel border (4.6%) and side-channel habitat (1.0%). The fish tended to scatter widely in the upper part of Pool 13 but were unable to move above Lock and Dam 12. We detected neither specific movement patterns nor strong tendencies for sturgeon to congregate. Data analysis on habitat selection or avoidance continues. (Abstract only)

165. DAHL, K. 1932. Influence of water storage on food conditions of trout in Lake Paalsbufjord. Skrifter av det Norske Videnskaps-Akademi i Oslo. Pages 5–53 *in* Mathematisk Naturvidenskapelig Klasse, 1931, N.4.

Growth of trout in certain Norwegian storage reservoirs occurred after impoundment. Certain crustaceans were extremely abundant as a result of winter drawdown. The conclusion was made that the winter eggs of these crustaceans were dried and frozen in the exposed shore zone during winter—a condition of great benefit to the propagation of these species. Originally minor elements of the population, these crustaceans constituted important sources of trout food and contributed to the improved growth of trout.

166. DAHL, K. 1933. The influence of river regulations on fisheries in lakes. J. W. Cappelens Forlag, Oslo, Norway. 120 pp. (In Norwegian)

A thorough discussion is presented on the influence of water storage on fisheries, fish, and fish-food animals in Norwegian hydroelectric reservoirs. In 1932, the standing crop of the cladoceran *Eurycercus lamellatus* increased greatly after water storage. The reduction or disappearance of such important fish-food animals as *Gammarus lacustris*, snails, and insect larvae was more than compensated for by the increased density of Cladocera after regulation. (Abstract from K. W. Jensen, Vollebekk, Norway, as adapted from Fraser 1972)

167. DALE, E. E., JR., AND J. R. SULLIVAN, JR. 1978. The composition and abundance of vegetation inhabiting the water fluctuation zones of Beaver and Bull Shoals Lakes. Final Report to the U.S. Fish and Wildlife Service, Arkansas Water Resources Center, Fayetteville. 78 pp.

Relations between microenvironmental factors and the composition and abundance of plants and organic mulch in the fluctuation zone of two Arkansas reservoirs are discussed. Information was collected from the literature and the field to determine which species of plants would be suitable for planting in fluctuation zones and which would provide increased cover and food for fish. In general, woody plants provide more cover than herbaceous plants, but herbaceous plants provide more food (directly or indirectly). Black willow and button bush are woody plants highly tolerant of flooding. Smartweed, bermuda grass, rushes, and sedges are herbaceous plants that survived up to 90 days of flooding. Assemblages of plants after 1, 2, 3, and 4 years of flooding are described.

168. DANE, C. W. 1959. Succession of aquatic plants in small artificial marshes in New York State. New York Fish and Game Journal 6:57–76.

A study of 22 marshes in New York State in 1956 showed that the water level during the growing season was the single most important factor recognized in the succession of aquatic plants in small, artificial marshes.

169. DANELL, K. 1978a. Intra- and interannual changes in habitat selection by the muskrat. Journal of Wildlife Management 42:540–549.

Habitat selection by the muskrat (*Ondatra zibethica*), as reflected by house location, was studied over a 7-year period (1970–1976) in a shallow lake, rich in emergent aquatic plants (belts of sedges, water horsetail [*Equisetum fluviatile*], and bulrush [*Choenoplectus lacustris*]), in northern Sweden. Houses built in horsetail during August 1–September 1 were situated in a mean water depth of 0.15 m, whereas the mean water depth for houses constructed during October 2–10 was 0.30 m. A similar tendency was found in the bulrush belt the same year. During September 12–October 1 and October 2–10, mean water depths near the houses were 0.64 and 0.80 m, respectively.

170. DANELL, K. 1978b. Use by muskrats of an area in Sweden containing highly differentiated habitats. Journal of Wildlife Management 42:908–913.

The light utilization of habitats is probably related to the fluctuating water levels and the scarcity of emergent vegetation.

171. DAVENPORT, L. A. 1959. Dams, dikes, and ducks. Michigan Conservation 28:6–11.

Mud Lake and Molasses River Marshes in Gladwin County, Michigan, were completed in 1934. Stable water levels change the plant life of the area of Mud Lake. After an early wildlife boom, the area tapered off in production of both fish and waterfowl. In 1958, the dam was open and the water removed to dry out bottom soils, which encouraged a lush stand of plants. The Molasses River Marshes had varying water levels and accomplished the same effect at Mud Lake without the need of a drawdown.

172. DAVIES, W. D., W. L. SHELTON, D. R. BAYNE, AND L. M. LAWRENCE. 1980. Fisheries and limnological studies on West Point Reservoir, Alabama, Georgia. U.S. Corps of Engineers District, Mobile, Alabama. Contract DACW 01-78-C-0082. 238 pp.

Changes in the fisheries and limnology of West Point Reservoir (impounded in 1974) are described, with emphasis on identifying the factors contributing to an expected decline in sportfishing quality. Postspawning abundance of largemouth bass fingerlings in 1978 was twice that in 1977. Improved production of fry was associated with high water levels that were maintained throughout the growing season in 1978. Unfortunately, mortality in summer 1978 was also high and, by fall, the density of young-of-year bass was essentially the same as it was in 1977. A bimodal length–frequency distribution in the 1975 year class was attributed to food availability and not to disrupted spawning. A water management plan was proposed that would encourage terrestrial plant development in the fluctuation zone. Flooding these areas should improve the chances of producing a strong year class of bass by providing cover during their first year of life.

173. DAVIS, J. T. 1967. Water fluctuation. Louisiana Conservationist (January–February 1967):5–7.

Manipulation of water level for fish management is not a new procedure but one that has occurred in nature for many years and results in balanced fish populations, weed control, and nutrient addition. However, water-level fluctuations are not always popular for a variety of reasons: mudflats and decaying vegetation are not aesthetically appealing; access for boaters is difficult; boating and water skiing become hazardous due to exposed stumps, logs, or treetops; some aquatic weeds proliferate; and drought may prolong the drawdown for one or more years. Nevertheless, the benefits of properly planned and implemented water-level programs usually outweigh the bad features. Drawdowns effectively control aquatic weeds; whereas, chemical control is prohibitively expensive or harmful to fish. High spring water levels improve spawning of sport fishes, and low winter levels reduce numbers of bluegills and shad by crowding them and exposing them to increased predation. The fishery improves because sport fish grow rapidly and nutrient levels of lakes are increased.

174. DAVIS, J. T., AND J. S. HUGHES. 1965. Effects of impoundment on the benthic population of Bayou D'Arbonne, Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 19:364–374.

An investigation was conducted to determine the effects of impoundment on stream benthos and the effects of water-level fluctuations on benthic invertebrates in reservoirs. Many species rapidly colonized newly inundated areas, whereas others remained in the old creek channel. Impoundment greatly reduced the number of benthic families, and except for chironomids, reduced the density of individuals. The benthos was established within 1 year. The abundance of all benthic families increased during drawdown. If we assume a high degree of mobility of organisms and a lack of significant predation, the crowding of individuals as waters receded may explain increases in abundance. Organisms either rapidly recolonized newly flooded areas or managed to survive desiccation during the 3-month drawdown, because densities were high even in recently inundated areas. Drawdown did not depress benthos populations and may have enhanced them.

175. DAVIS, J. T., AND J. S. HUGHS. 1970. Investigations of fish management practices in Bussey Lake. Louisiana Wildlife and Fisheries Commission, Dingell-Johnson Final Report F-7-R8. n.p.

An 8-ft drawdown was begun in October 1962 to control vegetation. Refilling of the lake started in 1963. The lake was drawn down again in late October 1965 to manipulate the fish community. Water-level fluctuations effectively controlled aquatic vegetation and forage fishes. The densities of benthic invertebrates increased sharply during and immediately after drawdown, as did populations of game fish. Fishing pressure and harvest on the lake also increased after the drawdown, because fishing improved and interest in the lake project increased.

176. DAY, F. P., JR. 1987. Effects of flooding and nutrient enrichment on biomass allocation in *Acer rubrum* seedlings. American Journal of Botany 74:1541–1554.

A greenhouse experiment was conducted on *Acer rubrum* seedlings to evaluate the effects of flood frequency on production and allocation of biomass and to test the effects of N and P fertilization on production and allocation. Seedlings from the Dismal Swamp were subjected to three flood treatments (no flooding, intermittent flooding, and continuous flooding) and four enrichment treatments (no enrichment, N additions, P additions, and N + P additions). More continuous flooding resulted in less biomass production. Biomass increased during the study in all treatments except for root mass in the continuously flooded treatment. However, production of abundant adventitious roots compensated for the lack of normal root growth. Root:shoot ratios exhibited the greatest decreases in the continuously flooded plants. Plants with N + P added had significantly more leaf, stem, and total mass than the nonenriched plants 4 months after the study began. The N + P additions had seemingly compensated for the effects of flood stress in the continuously flooded plants by the end of the study. The fertilized seedlings accumulated higher concentrations of N and P, but their nutrient use efficiency (biomass production per unit nutrient absorbed) was lower than in the nonenriched plants. *Acer rubrum* seedlings survive flooded conditions through several adaptations; however, their growth is slowed by continuous flooding.

177. DE GRUCHY, J. H. B. 1956. Water fluctuations as a factor in the life of six higher plants of central Oklahoma. Proceedings of the Oklahoma Academy of Science 37:45–46.

The ability of six species of higher plants to withstand inundation was examined. The major portion of this study was carried out at Lake Carl Blackwell, Oklahoma. The green ash withstood water depths of about 30 inches for a 17-month period, May 1951 through August 1952 and an earlier shallow-water inundation period of about 3 months in summer 1950. American elms (*Ulmus americana*) can withstand a shallow-water inundation period of about 3 months for the rapid growing season, a period of 4 months or more for the late summer season, and possibly longer for the dormant season. At Canton Reservoir, elms withstood water coverage of 8 ft for 3 months during the spring and summer growing season of 1951. Button bush (*Cephalanthus occidentalis*) withstood inundation to a depth of 36 inches for 3 months and again to a depth of 44 inches for 15 months. False indigo (*Amorpha fruticosa)* and French tamerisk (*Tamarix gallica*) can withstand inundation for about 3 months, but will be completely killed if inundated for longer periods. Bermuda grass (*Cynodon dactylon*) covered to a depth of 6 inches lived about 15 months.

178. DELLINGER, G. P., E. L. BRUNK, AND A. D. ALLMON. 1976. Tree mortality caused by flooding at two midwestern reservoirs. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 30:645–648.

Tree species vary greatly in their tolerance to flooding. Trees that normally grow on wet sites are less likely to be damaged by flooding than those that normally grow on dry sites. Upland species will die the same year flooded if inundated long enough, whereas bottomland species may not die until the following year. The season of flooding is extremely important. Dormant season inundation affects few trees, but nearly all species are killed if flooded for a long period during the growing season. The growing season was not defined specifically in most studies. Trees entirely submerged are often killed or seriously injured. Thus, seedlings and low growing trees are more prone to damage than tall ones. Natural reproduction is made difficult or impossible under conditions of recurrent flooding. Periodic flooding may be tolerated in varying degrees, depending upon the length of time the roots are continuously submerged. Repeated flooding may eventually cause decline and mortality of trees that survive occasional flooding. Vigorous trees withstand flooding better than unthrifty trees. Growth of trees may be reduced after flooding but may later return to normal or even be stimulated. In general, cold water is less injurious than warm water, clear water is less harmful than muddy water, and flowing water is less harmful than standing water.

179. DENDY, J. S. 1946. Food of several species of fish, Norris Reservoir, Tennessee. Journal of the Tennessee Academy of Science 21(1):105–127.

Stomach contents of nine species of fish from Norris Reservoir were examined: largemouth bass, spotted bass, smallmouth bass, walleye, sauger, freshwater drum, black crappie, channel catfish, and gizzard shad. Aquatic insects and crayfish were scarce in Norris Reservoir, presumably because of large water-level fluctuations (60–80 ft). Small shad and black crappies provided most of the food for game fish; consequently the most important food chain was plankton–shad–piscivores.

180. DENISOVA, A. I. 1977. Factors governing the biological productivity, regime, and content of biogenic and organic substances in the sequence of Dnepr reservoirs. Vodnye Resury 6:106–119. (Translated from Russian, 1978, Plenum Publishing Corporation)

Two decades of study of Dnepr River reservoirs revealed the primary factors and processes that determine the content, dynamics, and transformation of biogenic (P, N, Si, Fe) and organic elements in reservoirs and how these elements affect productivity. A number of nutrient sources are discussed, such as runoff and inflow from drainage basins, leaching from newly flooded areas, wastewater (industrial, municipal, or agricultural), precipitation, shoreline erosion, bottom deposits, and in situ production. The amount of nutrients and organic matter from newly flooded areas in the first year of impoundment was one to two times the amount inflowing from the drainage basin in several reservoirs and greatly enhanced productivity. Organic materials in newly flooded areas are derived from soils, higher aquatic plants, and herbaceous and woody terrestrial vegetation, especially during the first years of impoundment. The quantity and rate of nutrient leaching during decomposition of vegetation depends on the type, age, and amount of flooded material. The quantity of nutrients, per unit of plant material, is greatest in higher aquatic plants, followed by meadow vegetation, and then woody vegetation. Decomposition of different plants is important in forming bottom deposits. Most biogenic substances enter the reservoirs in spring (50%–60%) and winter (22%–30%). In spring, inflows carry most of the annual load of organic nitrogen (47%–72%) and organic phosphorus (56%–61%).

181. DERKSEN, A. J. 1967. Variations in abundance of walleyes, *Stizostedion vitreum vitreum* (Mitchell), in Cedar and Moose Lakes, Manitoba. M.S. Thesis, University of Manitoba, Winnipeg, Manitoba, Canada. 98 pp.

By gill netting walleyes and examining the age composition of walleyes in catches of commercial fishermen, year-class strength was estimated in two ways. Estimates of year-class strength based on catches in 9.5- and 10-cm mesh gill nets were significantly correlated with estimates based on commercial catches and with discharge of water from the Saskatchewan River during the year in which a year class was produced. Water levels affected spawning success by determining the amount of spawning area available. Water levels may affect the sustained production of zooplankton, the principal food of young-of-year walleyes and thereby influence the survival of young walleyes, by increasing or decreasing competition for food.

182. DICKSON, R. E., J. F. HOSNER, AND N. W. HOSLEY. 1965. The effects of four water regimes upon the growth of four bottomland tree species. Forest Science 11:299–305.

Seedlings of four wet-site species, tupelo gum (*Nyssa aquatica* L.), pin oak (*Quercus palustris* Muench.), green ash (*Fraxinus pennsylvanica* Marsh.), and sycamore (*Platanus occidentalis* L.), were grown under four moisture regimes: continuously water saturated soil, soil watered to moisture equivalent daily, soil watered to moisture equivalent when 50% or more of the available water was removed, and soil watered to the moisture equivalent when the wilting point was reached. On the basis of height growth and total dry weight, tupelo and green ash seedlings grew best under the continuously saturated conditions. Sycamore and pin oak grew best under the moisture equivalent regime. With few exceptions, seedlings of all species grown under the wilting point regime were the smallest. The significance of the results to the segregation of species along soil moisture gradients in bottomland areas is discussed.

183. DILLON, F. 1988. Habitat use and movement of channel catfish in the Illinois River and effects of barge traffic. Pages 17–29 *in* Proceedings of the Forty-Fourth Annual Meeting of the Upper Mississippi River Conservation Committee, Peoria, Illinois, March 8–10, 1988.

The channel catfish (*Ictalurus punctatus*) is an important sport and commercial species in the Illinois River. Commercial navigation has the potential to disrupt habitat use and movements of channel-dwelling species. From July to September 1987, locks at Peoria and La Grange, Illinois, were closed for rehabilitation, allowing a unique opportunity to monitor the habitat use and movements of channel catfish in the absence of barge traffic and their response to resumption of traffic. Thirty-four channel catfish were collected from various habitats (main channel, channel border, and tributary) and implanted with radio transmitters to determine movement patterns and habitat use. Water temperature, dissolved oxygen, water depth, and stream flow were measured at the places that radio-tagged fish were located. Preliminary results indicate that movement was most influenced by water-level fluctuations. Fish moved upstream into side channels, backwaters, and flooded areas during rises in water levels. Radio-tagged fish selected main channel border and side channel habitats. Tagged fish were found at sites with water depths ranging from 0.5 to 6.9 m and flow velocities ranging from 0 to 0.488 m/s. Two catfish in main channel border sites showed no change in location when barges passed. However, one fish was protected from the hydraulic effects by a sunken barge. Six other radio-tagged fish had moved out of the main channel and main channel border areas during a flood that occurred just before the locks were reopened and were not exposed to barge traffic. (Abstract only)

184. DISTER, E., D. GOMER, P. OBRDLIK, P. PETERMANN, AND E. SCHNEIDER. 1990. Water management and ecological perspectives of the upper Rhine's floodplains. Regulated Rivers: Research & Management 5:1–15.

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

185. DOAN, K. H. 1945. Catch of *Stizostedion vitreum* in relation to changes in lake level in western Lake Erie during the winter of 1943. American Midland Naturalist 33:455–459.

The winter catch of walleyes (y), in pounds per man-hour, was significantly correlated ($P < 0.01$) with the total change in water level (x) between 0800 and 2000 hours as follows: $y = 0.15 + 2.08 \log x$, where x is expressed in hundredths of feet. Currents under the ice are closely related to water levels in Lake Erie, and currents probably affect movements of walleyes and hence their chance of being caught by anglers.

186. DOMERMUTH, R., AND L. DOWLIN. 1975. Fisheries management report for Tuttle Creek Reservoir, status 1975. Fisheries Division, Kansas Forestry, Fish and Game Commission, Pratt. 59 pp.

Water-level manipulation is the only management technique readily applicable to entire reservoirs. Weak year classes of largemouth bass in 1969 and 1970 were associated with high turbidity caused by peak inflows in early February to mid-April and high rates of water discharge from mid-April through June. Crappie year classes did not seem to depend on water-level patterns but more on some intrinsic control such as intraspecific predation. The strong 1974 year class of walleyes resulted from stable to slowly rising water levels from March to April and outflows less than 1,000 cfs. In other years, walleye year classes were poor due to unfavorable water-level patterns. The purposes of water-level management are twofold in this turbid reservoir: Water-level fluctuations must be favorable for spawning and survival, and discharge must be controlled to lessen turbidity. In 1974, a multiple spawn of gizzard shad ensured the presence of shad of a forage size throughout the growing season. Because gizzard shad often exceed forage size by the end of their first season, reservoir operations that result in slightly increased water levels in late June are desirable because they may produce multiple spawns of gizzard shad. Decreased abundance of river carpsuckers in 1975 may have resulted from a midsummer drawdown that increased predation.

187. Donnermeyer, G. N., and M. M. Smart. 1984. The influence of water depth on the biomass of the submergent macrophyte *Vallisneria americana*. Page 11 *in* Proceedings of the Mississippi River Research Consortium, Volume 16, La Crosse, Wisconsin, April 18–20, 1984.

Vallisneria americana Michx. (wild celery) was studied in Navigation Pool No. 9 of the Upper Mississippi River in summer and fall 1980 and spring 1981. One objective of this study was to examine the relation between water depth and rosette number, biomass and shoot:root ratios. Mean shoot:root (S:R ratios) increased from 1:3 in late May to the maximum of 8:7 in mid-July. Shoot:root ratios were positively correlated with water depth at the end of July (r = .080, $P < 0.05$). At this time, mean shoot biomass (leaves, peduncles, pistillate flowers, and fruit) were similar in deep ($>$ 1 m) and shallow ($\leq$1 m) areas of the study area. Mean root biomass (stolons, root-stocks, winter buds) was higher (25.6 g/m^2) in shallow areas when compared with deep regions (14.5 g/m^2). Conversely, by September 1, shoot biomass was greater in deep water (206.8 g/m^2) than in to shallow water (149.3 g/m^2), and root biomass was similar in both. Rosette density increased from 80 rosettes/m^2 on May 28, 1980, to 214/m^2 on September 1. The maximum correlation between rosette density and depth was observed on September 1 ($r = -0.74$, $P < 0.05$). (Abstract only)

188. Donohoe, R. W. 1966. Muskrat reproduction in areas of controlled and uncontrolled water-level units. Journal of Wildlife Management 30:320–326.

Basic aspects of muskrat (*Ondatra zibethicus*) productivity in Lake Erie marshes were investigated to determine if differences in reproduction could be detected between animals living in areas of controlled (managed) and uncontrolled (unmanaged) water-level habitats. From the regular trapping seasons of 1954–55 through 1957–58 and in summer 1955, 9,091 muskrats were examined. The results suggest that diked units will increase population densities through a reduction of mortality, but these enclosures seemingly have little influence on reproductive physiology.

189. Dorris, T. C., and B. J. Copeland. 1962. Limnology of the middle Mississippi River. 3. Mayfly populations in relation to navigation water-level control. Limnology and Oceanography 7:240–247.

Naiads of *Hexagenia rigida* in Navigation Pool 21 of the Mississippi River were most abundant at the upstream end of the channel in summer. Densities of naiads were reduced at all stations, especially at near-shore sites, after a 6-week drawdown of about 4 ft.

190. Driver, E. A. 1977. Chironomid communities in small prairie ponds: Some characteristics and controls. Freshwater Biology 7:121–134.

In small prairie ponds in central Saskatchewan, chironomid diversity depends on the stage of development of the plant community within a moisture gradient. Rapid or complete water-level reduction in a pond maintains a very simple chironomid community of 3 to 10 species and a simple plant community of two to three species. Increased water levels eliminate emergent and submergent plants and associated chironomids.

191. DUDGEON, D. 1992. Effects of water transfer on aquatic insects in a stream in Hong Kong. Regulated Rivers: Research & Management 7:369–377.

Hong Kong streams serve as indirect catchments for storage reservoirs to which they are connected by a network of underground tunnels. Water transfer to reservoirs reduces stream flow downstream of the extraction point, and surface flows may disappear in affected reaches during the dry season. The ecological effects of periodic dewatering on aquatic insects were investigated in Tai Po Kau Forest Stream, Hong Kong, where water extraction at a weir gives rise to intermittent flow immediately downstream of a well-studied perennial stream section. Benthic samples were taken from the intermittent reach on 48 occasions over 2 years encompassing two dry seasons. Trends in total population densities were unclear, with considerable fluctuations over the study period. In contrast, species richness declined markedly after surface flow disappeared, reaching the lowest values at the end of both dry seasons. A rapid increase accompanied flow resumption on the onset of the summer monsoon, and maximum wet season values were up to five times greater than species richness during the dry season. Dry season declines in Ephemeroptera and Trichoptera were accompanied by a dramatic increase in Coleoptera (Elmidae and especially Helodidae). The situation was reversed during the set season when Trichoptera (especially *Cheumatopsyche* and *Chimarra*) and Ephemeroptera (Leptophlebildae, Baetidae, and Heptageniidae) were numerous. Community structure in the intermittent reach recovered quickly from the dewatering disturbance, due largely to recolonization by drifting animals.

192. DUMONT, P., AND R. FORTIN. 1977. Effects of spring water levels on the reproduction of upper Richelieu and Missisquoi Bay: northern pike (*Esox lucius*). International Joint Commission, International Champlain–Richelieu Board, University of Massachusetts. 105 pp.

Upper Richelieu and Missisquoi Bay floodplain and wetland areas are classified according to their potential for northern pike spawning and early development. Four potential spawning areas begin to be inundated at a lake level of 98.5 ft and are productive at a level of 100 ft. Good fry production also seems to be related to relatively stable water levels for 30–40 days after the lake reaches elevation 98.5, and to a gradual drawdown from peak elevations. If regulation is implemented, a predictive model based on air temperature profiles, precipitation, and other criteria should be developed from historical data on Lake Champlain. Also, measures should be taken to protect all high-potential spawning areas from drainage and land fill. (From Selected Water Resources Abstract 12[16]:W79-07742)

193. DUNST, R., AND T. WIRTH. 1972. The Chippewa Flowage fish population. Appendix O. University of Wisconsin and Wisconsin Department of Natural Resources, Chippewa Flowage Investigations, Part 3A. n.p.

The Chippewa Flowage investigation had two basic directives as related to the fish population: (1) determine its present condition in terms of reproduction, growth, and abundance; and (2) where possible, determine the effect of various water management schemes. During summer 1971, electrofishing was conducted in all major segments of the flowage. A population estimate was made for walleye. The best estimate of the standing crop (13 inches or greater in length) in spring 1971 was 16.1–38.4 lb/acre for the entire flowage. Age–growth analysis were limited to the muskellunge and walleye. Some evidence for successful natural reproduction in 1971 was found for many of the fish species. The age population of the structure suggested successful reproduction for the last several years. Historical records indicate that winterkill occurs occasionally in some parts of the flowage. Some evidence suggests that winterkills are an undesirable occurrence. Reference is made

to other studies aimed at determining whether a water level regime with a reduced winter drawdown could provide some protection against winterkill. A number of fish population parameters were tested for correlation with the depth of potential drawdown for an area. However, the influence could not be definitely established.

194. DUNST, R. C., S. M. BORN, P. D. UTTORMARK, S. A. SMITH, S. A. NICHOLS, J. O. PETERSON, D. R. KNAUER, S. L. SERNS, D. R. WINTER, AND T. L. WIRTH. 1974. Survey of lake rehabilitation techniques and experiences. Wisconsin Department of Natural Resources, Madison, Technical Bulletin 75. 179 pp.

A comprehensive survey of techniques for limiting fertility, controlling sedimentation, and managing eutrophication is presented. Results obtained in almost 600 accounts of management programs provide the basis for evaluating various techniques. Drawdown to consolidate sediments was successfully employed in a number of waters. In Beaver Lake, Wisconsin, for example, drawdown increased the lake depth by 11% after refilling and improved the fishery. Consolidation of flocculent sediments is largely irreversible and may increase nutrients in the lake when it is refilled. Many accounts of successful control of macrophytes by drawdown are cited. Aquatic macrophytes are reduced primarily as a result of desiccation, freezing, mechanical removal, or soil compaction. Drawdown can be effective in controlling populations of fish by exposing eggs, by stranding small individuals, or by concentrating fish and thereby increasing harvest and predation. When drawdown is implemented in a nonspawning period, timing is less critical, perhaps because predation is the main factor affecting the fish community. Although drawdown can be successful, cause–effect relations are not always clear.

195. DUTHIE, H. C. 1968. Ecology of phytoplankton in Lake Belwood, a storage reservoir in southern Ontario. Journal of the Fisheries Research Board of Canada 25:1229–1245.

A 16-month investigation, conducted to determine what factors control the seasonal development of phytoplankton in an Ontario reservoir, revealed that populations of blue-green algae and flagellates were reduced in the upper end of the reservoir when water levels of the impoundment were lowered. Densities of phytoplankton below the dam increased at the same time.

196. DUTHIE, H. C., AND M. L. OSTROFSKY. 1975. Environmental impact of the Churchill Falls (Labrador) hydroelectric project: A preliminary assessment. Journal of the Fisheries Research Board of Canada 32:117–125.

Construction of the Churchill Falls hydroelectric project created two reservoirs totaling 6,650 km^2. Inundation began in 1971 and full pool was expected in 1974. Researchers concentrated on cataloging fish and wildlife, determining the effects of impoundment on plants in the spray zone of the falls, and evaluating the effect of flooding on water quality and aquatic biota. Preliminary findings showed little humification or oxygen deficiency in newly flooded areas (perhaps as a result of the rapid rate of water exchange and the polymictic nature of these reservoirs). Conductivity and dissolved ion concentrations increased. The immediate effect of impoundment was a decrease in primary production per unit of surface area due to increased turbidity and diluted standing crops. The long-term effect was a severalfold increase in primary production, increased nutrients, and increased standing crops of phytoplankton. Both phytoplankton and zooplankton populations generally increased and changed qualitatively with impoundment, especially in shallow water.

197. DUVAL, M. C., AND L. E. HOLLAND. 1986. Early life history of channel catfish in Navigation Pool 7 of the Upper Mississippi River. Page 13 *in* Proceedings of the Mississippi River Research Consortium, Volume 18, La Crosse, Wisconsin, May 1–2, 1986.

Channel catfish (*Ictalurus punctatus*) is a major commercial species in the Upper Mississippi River. However, concern exists over its status in many areas of the river. Poor recruitment and/or over-exploitation may be occurring. Few data exist to evaluate recruitment of this species in the system. A study was designed to examine spatial and temporal distribution patterns, daily age and growth relations, and food habits of young-of-year (YOY) in Navigation Pool 7. Fish (15–83 mm SL) were collected by otter trawl at night during summers 1984 and 1985. There was no significant difference in catch by station. Also, size of fish varied little between stations. However, in 1984, significantly smaller fish were collected from the main channel area associated with a large backwater-tributary input. In 1985, significantly smaller fish were collected approximately 1.6 km downstream of this backwater area at a constriction of the main channel. This backwater area may be an important spawning habitat or at least an important early nursery habitat from which YOY are recruited to the main channel. Two peaks in the 1984 length–frequency distribution data suggest two separate spawning events in the pool or rather a disruption in spawning correlated with a rapid doubling of river discharge in late June. Analyses of age distributions as determined by examination of sagittae and verified in laboratory studies have supported this hypothesis. Growth of YOY was relatively uniform throughout the pool, with fish growing at an approximate rate of 1.0 mm/day. However, growth became more variable with age, particularly after 50 days posthatch. Food items varied little among fish or between sampling stations (Trichoptera > Cladocera > Diptera). Smaller individuals consumed food types that were common in the drift, whereas larger individuals switched to a benthic feeding pattern as evidenced by sand grains in stomachs. This behavioral change dramatically affected the catchability of YOY. All regions of the main channel seem to be of equal value as channel catfish nursery habitat. In addition, discharge seems to be a major factor influencing spawning of channel catfish and distribution patterns of YOY. (Abstract only)

198. ECKBLAD, J. W. 1973. Population studies of three aquatic gastropods in an intermittent backwater. Hydrobiologia 41:199–219.

Populations of three species of snails in an intermittent backwater were studied for 20 months. Population dynamics, mean biomass, net production, and survival were estimated. Although one snail (*Lymnaea palustris*) could reduce desiccation structurally, drought caused high mortality in the other two species.

199. EGGLER, W. A., AND W. G. MOORE. 1961. The vegetation of Lake Chicot, Louisiana, after 18 years impoundment. Southwestern Naturalist 6:175–183.

The vegetation of the basin of Lake Chicot was originally cypress–tupelo gum swamp bordered by upland hardwood forest. After 18 years of flooding, cypress has decreased in density in the channel but has increased in the shallow peripheral zone. Radial growth of cypress trees has not decreased, even in the deepest water. Upland forest trees have all died; a few bottomland hardwoods survive in shallow water. The lake is presently dominated by submerged weedy aquatics. In an attempt to reduce the excessive growth of submerged and floating leaved aquatic plants, the lake level has been lowered every year since 1945, except in 1952 and 1956. For a few years, recessions of 5 to 7 ft were practiced, resulting in good control in the peripheral and backwater areas of the basin. In

recent years, the level has been drawn down only about 4 ft below the spillway. The aquatic weed problem has not been solved.

200. ELDER, H. Y. 1964. Biological effects of water utilization by hydro-electric schemes in relation to fisheries, with special reference to Scotland. Proceedings of the Royal Society of Edinburgh, Section B. Biology 69:246–271.

The creation of reservoirs and the effects of increased reservoir water levels on agriculture, rare plants or animals, benthos, production of plankton and fish, and reproduction of fish are discussed. Initially, biological production increases because of (1) nutrient leaching from soils and terrestrial vegetation, (2) increased production of Cladocera, (3) increased food sources for fish (terrestrial invertebrates), and (4) increased foraging area. Ultimately, however, fluctuating water levels result in the loss of valuable benthic fish-food organisms and in the increased survival of species that are less available to fish or of lower caloric values than other forms. Fish feeding may eventually be reduced.

201. ELDRIDGE, J. 1990. Aquatic invertebrates important for waterfowl production. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.3.3. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Habitat information is presented for annelids, arthropods, and molluscs, which are important food sources for waterfowl species.

202. ELDRIDGE, J. 1990. Ecology of northern prairie wetlands. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.3.5. U.S. Fish and Wildlife Service, Washington, D.C. 8 pp.

Guidelines for improving wetland management include increasing water levels slowly in fall and establishing submergents by allowing several years of stable water levels.

203. ELDRIDGE, J. 1992. Management of habitat for breeding and migrating shorebirds in the Midwest. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.2.14. U.S. Fish and Wildlife Service, Washington, D.C. n.p.

Many shorebird species look for a wetland in partial drawdown and a combination of open mudflat and 1 to 2 inches of water in a wetland basin with gradually sloping sides.

204. ELLIS, M. M. 1937. Some fisheries problems in impounded waters. Transactions of the American Fisheries Society 66:63–75.

Major fishery problems in reservoirs are associated with basin configuration (and the creation of large areas of slack water), reservoir age, water inflow, and water removal. One of the most difficult problems is the decline of fish production as reservoirs age and favorable biological conditions (produced by the solution of nutrients from organic debris and vegetation) are lost. The problem seemingly is one of nutrient loss, and fish restocking programs are not entirely successful in restoring productivity. Some nutrients may be provided from plants that develop in areas dewatered during drawdowns, but effective operations for such drawdowns are difficult to schedule when other needs are considered first. Of all factors adversely affecting fisheries, drawdown is the easiest to recognize. Nesting areas are exposed in the spawning season, beds of submerged vegetation are left dry, and fish are often forced into waters that are unsuitable or lethal (anoxic).

Some ways to ease the harmful effects of drawdown include the establishment of marginal pools with shallow stable water levels and the construction of floating nest areas that ride at anchor and maintain a constant spawning depth.

205. ELLIS, M. M. 1942. Fresh-water impoundments. Transactions of the American Fisheries Society 71:80–93.

A number of conditions can limit the productivity of reservoirs: stagnation, flushing of nutrients and materials, limited littoral area, extensive fluctuation of water levels, and heavy siltation. Production can be increased to some extent by maintaining fairly constant water levels in spring when desirable fishes are spawning. Other measures include stocking, enhancement of spawning and nursery habitat by building lateral pools with constant levels, construction of artificial structures or shelters, and chemical enrichment.

206. ELROD, J. H., AND T. J. HASSLER. 1971. Vital statistics of seven fish species in Lake Sharpe, South Dakota, 1964–69. Pages 27–40 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

The abundance of seven species of fish (goldeye, common carp, river carpsucker, blue sucker, smallmouth buffalo, bigmouth buffalo, and shorthead redhorse) declined after impoundment. Data on the age composition, year-class strength, growth, and survival are presented for each species. Rapid growth of most species in 1964 may have resulted from an abundance of food in the newly flooded lake. When large areas of terrestrial vegetation were first flooded, strong year classes of common carp, bigmouth buffalo, and smallmouth buffalo were produced. Since 1964, no new areas were flooded and little aquatic vegetation developed. As a result, only weak year classes were produced.

207. ELSTAD, C. A. 1986. Macrobenthic distribution and community structure in the upper navigation pools of the Upper Mississippi River. Hydrobiologia 136:85–100.

Benthic assemblages were inventoried twice in summer 1975 in Pool 8 to provide quantitative and qualitative baseline data for measuring future changes in the quality of the aquatic environment. Samples were taken from 41 study areas with depths of 0.51 to 6.71 m. Depth significance for various groups is presented.

208. EMERSON, F. B., JR. 1961. Experimental establishment of food and cover plants in marshes created for wildlife in New York State. New York Fish and Game Journal 8:130–144.

Some depth and water fluctuation information is given in experiments concerning 125 introductions of 10 species of aquatic plants in the 32 wildlife marshes in south-central New York during 1955–1960.

209. ENGELHARDT, W. 1958. Limnological investigations in Lake Walchensee in the years 1950–58: 2. Investigations of the littoral fauna of the Walchensee in upper Bavaria and the influence of regulation. Archiv fuer Fischereiwissenschaft 9(3):203–222.

Since 1924, the Walchensee has been used for generation of electricity and, as a result, its water level has fluctuated up to 6.6 m. Although the total density of benthos is similar to that of benthos in natural lakes, certain turbellarians, plecopterans, and trichopterans are noticeably scarce. Many

littoral organisms descend with the receding waters and densities often increase markedly in sublittoral and secondary littoral areas. Other species dig into the substrate to survive desiccation or freezing for over 3 months. Ample amounts of fish-food organisms are present for existing fish populations.

210. ENVIRONMENTAL WORK TEAM. 1981. Comprehensive master plan for the management of the Upper Mississippi River System. W. Boyd, and J. G. Harber, editors. Effects of fluctuating pool levels caused by normal operation of the Upper Mississippi River System nine-foot channel on wetland plants, waterfowl, muskrats, invertebrates, and fish. Prepared for the Upper Mississippi River Basin Commission. 223 pp.

The Expert Panel entitled "Effects of Upper Mississippi River System Pool Level Fluctuating caused by Normal Operation and Maintenance of the Nine-Foot Channel on Wetland Plants, Waterfowl, Muskrats, Invertebrates and Fish" was held in La Crosse, Wisconsin, on June 9, 10, and 11, 1981. The panel was charged with discussing the effects of pool level fluctuations on the biological resources of the UMRS. Findings of the panel were incorporated into the Upper Mississippi River Basin Commission's Master Plan.

211. ERICKSON, J., AND F. STEVENSON. 1972. Evaluation of environmental factors of Ohio reservoirs in relation to the success of walleye stocking. Ohio Department of Natural Resources, Division of Fisheries Research, Dingell-Johnson Final Report F-29-R-11, 6-B. n.p.

Physical, chemical, and biological data are related to the success of walleye introductions in Ohio reservoirs. Fluctuations in water levels are important to walleye populations, especially if water levels fluctuate slowly and permit waves to clean gravel bars in river reservoirs or the rip-rap in man-made basins (up-ground reservoirs). Clean, rocky areas are necessary for successful spawning and for improving the survival of stocked fish. Stocking is most successful in larger impoundments where water levels recede slowly, as in water supply and navigation reservoirs.

212. ERRINGTON, P. L. 1937. Drowning as a cause of mortality in muskrats. Journal of Mammalogy 18:497–500.

The author describes a number of drowning incidents in the muskrat (*Ondatra zibethica*) in two marshes of about 400 and 450 acres near Ruthven, Iowa. Many of the incidences were in areas having rather stable water levels.

213. ERRINGTON, P. L. 1939. Reactions of muskrat populations to drought. Ecology 20:168–186.

Recent drought seasons have provided exceptional opportunities for the study of muskrat populations living under emergency conditions. Although the animals may show considerable tolerance to habitat changes and may modify their living routines accordingly, their behavior remains basically rather stereotyped. A large proportion of the muskrats resident in habitats that are drying out tend to stay in familiar home ranges, and, while they may suffer heavy or even annihilative mortality, they are usually more fortunate than the animals that attempt to go elsewhere. As vicissitudes become intensified, there is a conspicuous increase of intraspecific strife, vulnerability to predation (notably by mink), random and often lethal wandering, and, in winter, losses from hunger and cold.

214. ESCHMEYER, R. W. 1947. The fisheries picture on TVA impoundments. Pages 1–7 *in* Ninth Midwest Wildlife Conference.

Fishing remained good on the 26 TVA reservoirs which had been completed by 1947 for many years following impoundment despite predictions that these reservoirs would become biological deserts. It was thought that reservoirs with fluctuating water levels would not support angling. This prediction proved to be false to the extent that permanent-level pools constructed on arms of the reservoirs have provided only mediocre fishing-inferior to that furnished by the reservoirs themselves. All aspects of fishing on TVA impoundments are touched upon including regulations, fishing pressure, harvest, the food chain, spawning, growth, distribution, stocking, and commercial fishing. The winter drawdown for flood control apparently limits the abundance of rough fish by limiting their food supply. Most carp are in poor condition and most female carp apparently fail to spawn. Gamefish, however, are not adversely affected, as they rely on a diet of fish, notably shad.

215. ESCHMEYER, R. W. 1949. The fisheries picture with special reference to the TVA impoundments. Progressive Fish-Culturist 11:267–271.

Three significant components of the picture of fish conservation are (1) the importance of fishing for relaxation in a stressful world, (2) the decline in satisfactory angling due to increased fishing pressure, and (3) the realization that more large impoundments will have to support increasing angling pressure. In addition to a discussion of the many different conditions that exist in mainstream and storage impoundments and of general trends in fishing on TVA reservoirs, topics related to water-level changes, such as spawning success, winter drawdown, food-chain interactions, and vegetation are discussed. Slowly declining waters seemingly do not decrease spawning success, and under normal operations water levels are usually constant (mainstream reservoirs) or rising slowly (storage reservoirs) at spawning time. Winter drawdown does not seem to hinder the reproduction of game fishes, although rough fishes (bottom feeders such as common carp, buffalo, and adult shad) may be hindered by food shortages. Rough fishes are much more abundant in mainstream reservoirs (where drawdowns are limited) than in storage reservoirs. Although drawdown helps control rough fishes, it may interfere with boating and degrade aesthetic qualities of shorelines. Aquatic macrophytes seldom become established in storage reservoirs where drawdown is common, but they are present in mainstream impoundments where drawdown is limited to a few feet.

216. ESCHMEYER, R. W., R. H. STROUD, AND A. M. JONES. 1944. Studies of the fish population on the shoal area of a TVA main-stream reservoir. Journal of the Tennessee Academy of Science 19(1):70–122.

The distribution and abundance of fish on the shoals of Chickamauga Reservoir, Tennessee, are described. Drawdown seems to be the best means of controlling the large, rough-fish populations so typical of mainstream reservoirs. Commercial fishing may be useful, except that the average size of rough fishes is too small. Limited drawdowns can control spawning of buffaloes and common carp without affecting the reproduction of shad and some rough fishes.

217. ESTES, R. D. 1971. The effects of the Smith Mountain Pump Storage Project on the fishery of the lower reservoir, Leesville, Virginia. Ph.D. Thesis, Virginia Polytechnic Institute and State University, Blacksburg. 151 pp.

The effects of water-level fluctuation and temperature on the spawning, growth, and standing crop of fishes in a mainstream pump–storage reservoir were examined. Water levels frequently fluctuated 6 to 8 ft weekly and 1 to 4 ft daily in response to operations of the Smith Mountain power plant. Neither water-level fluctuation nor temperature reduced the numbers of young fish produced. Water-level fluctuation did not affect spawning or growth of bass or bluegills directly, but its effect on the reproduction of gizzard shad may have influenced bass growth, since the growth of bass was correlated with shad reproduction. Low water temperatures apparently delayed the normal spawning of bass, which spawned in mid-July instead of in May and June. Because there was no indication that bass or bluegill reproduction was more successful in 1 of the 3 years than in the others, there was no basis for correlating the degree of fluctuation with spawning success during the 3 years of the study. Fluctuations may sometimes have caused nest abandonment and fry mortality, but not the loss of an entire year class, although fluctuations may have been one factor influencing relative year-class strength. Evidently, largemouth bass and bluegills are more flexible in their spawning requirements than once thought, as they successfully spawned when water levels fluctuated widely. Perhaps water levels can be manipulated to control reproduction of forage and undesirable fishes without adversely affecting centrarchid spawning.

218. ESTES, R. D. 1972. Ecological impact of fluctuating water levels in reservoirs. Pages 7–9 *in* Ecological impact of water resource development. Bureau of Reclamation Report Rec-Erc-72-17.

This article is a summary of some of the literature concerning fluctuating water levels in reservoirs. The importance of the littoral zone for spawning, protection, and food for young fish, higher aquatic plants as substrate for other plants and animals, and as a site for nutrient exchange between land and water, is stressed.

219. EXTENCE, C. A. 1981. The effect of drought on benthic invertebrate communities in a lowland river. Hydrobiologia 83:217–224.

Benthic macroinvertebrates were sampled at regular intervals from rural and urban sections of the River Roding, Essex, England, in 1975 and 1976. During the latter year, a severe drought led to a marked decline in flows and to desiccation of parts of the river bed. In general, drought conditions resulted in an increase in invertebrate populations; possible reasons for this are presented. Many individuals of certain groups such as cased caddisfly larvae and prosobranch molluscs were, however, eliminated from the river at this time, mainly as a result of stranding and chemical changes in the environment. The effect of reduced flows on river faunas is briefly discussed.

220. FERGUSON, V. M., AND R. C. FOX. 1978. A comparison of aquatic insects in natural inlets with those in the heated effluent from the Oconee Nuclear Station-littoral zone. Journal of the Georgia Entomological Society 13:202–213.

Aquatic insects were sampled weekly from May 1975 to May 1976 at the discharge cove and in three natural inlets on Lake Keowee, South Carolina. Abundance was influenced by the type of substrate, the amount of organic matter present, and water levels.

221. FILLION, D. B. 1967. The abundance and distribution of benthic fauna of three mountain reservoirs on the Kananaskis River in Alberta. Journal of Applied Ecology 4:1–11.

Three oligotrophic reservoirs (Barrier Reservoir and Upper and Lower Kananaskis Lakes) do not support high standing crops or diversity of benthos. Maximum abundance occurs in the vicinity of the drawdown limits rather than in the littoral zone. In Barrier Reservoir, the regions with the greatest standing crops of benthos are those not directly influenced by water-level fluctuations, and which receive input of allochthonous materials from the river. The fluctuation zone contains various benthic organisms, but is dominated by chironomids, which survived in areas dewatered up to 85 days. Although chironomids in Barrier Reservoir were most diverse in the 0- to 10-m zone, greater numbers occurred below the drawdown limit.

222. FINGER, T. R., AND E. M. STEWART. 1987. Response of fishes to flooding regime in lowland hardwood wetlands. Pages 86–92 *in* W. Mathews and D. Hines, editors. Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Larval, juvenile, and small adult fishes were sampled with activity traps in seasonally flooded lowland hardwood habitats in southeastern Missouri. In habitats with natural flooding regimes, fish-assemblage structure in a year with a wet spring (1981) was markedly different from the structure observed in the following dry year (1982). A shift from numerical dominance of early spring spawners (*Elassoma zonatum*, *Centrarchus macropterus*) in 1981 to dominance by late spring and summer spawners (*Fundulus dispar*, *Gambusia affinis*) in 1982 accompanied reduced spring flooding in 1982. Comparison of these naturally flooded habitats with nearby sites where water levels are manipulated by man suggests, however, that there are limits to the amount of fluctuation in fish-assemblage structure related to natural variations in flooding. Manipulated sites were characterized by a very different assemblage structure dominated by juvenile *Micropterus salmoides* and *Ictalurus nebulosus* and essentially lacking several of the most abundant fishes of the natural areas.

223. FINNELL, J. C. 1954. Comparison of growth-rates of fishes in Stringtown Sub-Prison Lake prior to, and three years after draining and restocking. Proceedings of the Oklahoma Academy of Science 35:30–33.

Population removal and restocking after the Stringtown Sub-Prison Lake was filled converted the fish population from an overpopulated, stunted condition to one of accelerated growth commonly associated with new impoundments. It is not known to what extent drawdown, which occurred during rotenone treatment, may have influenced this process. Fishing success has not increased in proportion to the improvement of fish growth because high turbidity curtailed angling.

224. FISHER, S. G., AND A. LAVOY. 1972. Differences in littoral fauna due to fluctuating water levels below a hydroelectric dam. Journal of the Fisheries Research Board of Canada 29:1472–1476.

Water-level fluctuations below a hydroelectric dam on the Connecticut River produce a freshwater "intertidal" zone. Along a transect in this zone from high to low water mark, benthic invertebrates increased markedly in density and taxonomic diversity. Community composition shifted from chironomid–oligochaete predominance on the most exposed sites to mollusc predominance on the least exposed sites. The data clearly show that water-level fluctuations resulting from conventional hydroelectric power generation may prevent the establishment of normal benthic invertebrate communities on periodically exposed areas.

225. FOURT, R. A. 1978. The effects of a two year water-level management plan on the production of sport fish in Beaver Reservoir. Arkansas Game and Fish Commission, Little Rock. 15 pp.

In 1977, water levels of Beaver Lake were reduced to permit the growth of terrestrial vegetation around the barren shoreline. In spring 1978, abundant rainfall enabled an inundation of terrestrial vegetation on about 6,880 acres of the fluctuation zone without severely reducing the generation of electric power. Favorable environmental conditions during spawning produced the highest density of young bass since the reservoir was impounded. Cove sampling with rotenone indicated a density of 733 young black bass per acre; the average number in August for the preceding 10 years was 281 per acre, and the highest density previously recorded was 491 per acre. Young-of-year crappies also were abundant (78 per acre). The abundance of prey fishes (sunfishes, minnows, and shad) was low—an unfortunate occurrence, since the overwinter survival of young-of-year bass depends greatly on high sunfish production, especially when other forage is scarce. Although low survival may result from cannibalism by larger young-of-year and yearling bass, improved growth of surviving young-of-year bass should benefit the fishery.

226. Fowler, D. K., and D. A. Hammer. 1976. Techniques for establishing vegetation on reservoir inundation zones. Journal of Soil and Water Conservation 31:116–118.

The authors evaluated the seeding of inundation zones with all-terrain vehicles, hovercraft, air cushion vehicles, and helicopters. Vegetation was successfully established on inundation zones by all techniques evaluated. Simple, per acre cost comparisons indicate that helicopter or air cushion vehicle seeding is better than that of the aquaseeder, and seeding rate comparisons indicate the helicopter to be the most efficient method for large acreages.

227. Fowler, D. K., and J. B. Maddox. 1974. Habitat improvement along reservoir inundation zones by barge hydroseeding. Journal of Soil and Water Conservation 29:263–265.

Reservoir drawdown zones have long been recognized by resource managers as potential food-producing lands for waterfowl and upland wildlife. However, a lack of suitable plant establishment techniques and materials has impeded achievement of this potential. During 1971, three species of plants were successfully established on inundation zone test plots by hydroseeding from a barge. Fertilizer was necessary for acceptable plant growth along steeper shoreline areas, but wood fiber mulch was not. This seeding technique has promise as a wildlife management tool. With equipment modifications, large portions of shoreline could feasibly be treated by barge hydroseeding.

228. Fox, J. L., P. L. Brezonik, and M. A. Keirn. 1977. Lake drawdown as a method of improving water quality. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon, EPA-600/3-77-005. 94 pp.

The feasibility of using rapid drawdown to improve water quality of Lake Apopka, Florida (a hypereutrophic lake with continual algae blooms, abundant macrophytes, and nutrient-rich sediments), was examined. Laboratory studies indicated that dewatering compacts sediments but produces only minor changes in their chemistry. Two algae colonized the sediments, and respiration by algae and bacteria created anoxic conditions that caused a large fish kill. The standing crop of fish decreased from 146.2 lb/acre in 1954 to 19.1 lb/acre after drawdown in 1958.

229. Franklin, D. R., and L. L. Smith, Jr. 1963. Early life history of the northern pike, *Esox lucius* L., with special reference to the factors influencing the numerical strength of year classes. Transactions of the American Fisheries Society 92:91–110.

The abundance of adults and year-class strength of northern pike were not directly related. Growth and concentrations of oxygen, ammonia, and sulfide did not seem to affect young-of-year survival. Mortality was increased by rapid changes in temperature and toxic concentrations of iron compounds during two critical periods. Survival of fingerlings was greatest when water levels in nursery areas were stable for 3 months after the spawning season.

230. FRASER, J. C. 1972. Water levels, fluctuation, and minimum pools in reservoirs for fish and other aquatic resources—an annotated bibliography. FAO Fisheries Technical Paper 113. 42 pp.

A collection of references, abstracts, and notes is presented of much of the literature concerning the effects of water-level fluctuations and minimum pools on fish and other aquatic resources.

231. FREDRICKSON, L. H. 1991. Strategies for water level manipulations in moist-soil systems. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.6. U.S. Fish and Wildlife Service, Washington, D.C. 8 pp.

The effects of the timing of drawdowns and the effects of drawdown rate are discussed.

232. FREDRICKSON, L. H., AND M. E. HEITMEYER. 1988. Waterfowl use of forested wetlands in the southern United States: An overview. Pages 307–323 *in* M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis.

Forested wetlands of the southern United States tend to occur along a flooding gradient rather than as distinct basins. The timing, duration, and depth of flooding determine the structure and composition of vegetation. A complex of habitat types provides a rich source of plant and animal foods for the eight species of waterfowl commonly using southern forested wetlands in winter. The species include a carnivore (hooded merganser, *Mergus cucullatus)*, two grazing herbivores (Canada goose, *Branta canadensis;* gadwall, *Anas strepera)*, three seedeating herbivores (northern pintail, *Anas acuta;* green-winged teal, *Anas crecca;* ring-necked duck, *Aythya collaris)*, and two omnivores (mallard, *Anas platyrhynchos;* wood duck, *Aix sponsa)*. Annual and long-term fluctuations in flooding create a resource base that provides for the constantly changing needs of birds with different age, sex, pair, and social status. Management to ensure the survival and reproduction of waterfowl requires careful decisions on size, location, and type of acquisitions that enhance or simulate historical hydrologic regimes, and that maintain rich plant communities. Additional research must elucidate the relations among short- and long-term flooding and food production as well as the distribution of southern wetlands. Integration of these results with information on waterfowl energetics, behavior, and habitat use will provide a framework for new management directions.

233. FREDRICKSON, L. H., AND F. A. REID. 1986. Wetland and riparian habitats: A nongame management overview. Pages 59–96 *in* J. B. Hale, L. B. Best, and R. L. Clawson, editors. Management of nongame wildlife in the Midwest: A developing art. Proceedings of the Symposium of the Forty-Seventh Midwest Fish and Wildlife Conference, Chelsea, Michigan.

Wetland and riparian habitats have been severely disrupted by man's activities, especially agriculture. Over half of these lands, transitional between terrestrial and aquatic systems, have been destroyed, and few of the remaining habitats in the 48 coterminous states have not been adversely affected. Birds are obvious members of wetland and riparian communities and are the focus of this paper. Effective management for wildlife requires an understanding of biotic and abiotic factors influencing these habitats. Hydrology, a key element among these factors, determines the composition and productivity of plants and corresponding animal associations. Wetland complexes are required to meet the broad needs of diverse bird faunas and the constantly changing requirements of organisms in the annual cycle. Wetlands with naturally occurring hydrological regimes should be protected, and managed habitats should be manipulated as complexes with dynamic water regimes. Drawdown management is a common procedure in wetland and riparian habitats that promotes high productivity and, in turn, attracts a diverse bird fauna. Discing, fire, and reflooding are techniques commonly used to enhance the effectiveness of drawdowns to meet the needs of a variety of species. A holistic management approach can meet the needs of game and nongame alike while providing plant structure and food requirements for wetland wildlife.

234. FREDRICKSON, L. H., AND F. A. REID. 1988. Control of willow and cottonwood seedlings in herbaceous wetlands. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.10. U.S. Fish and Wildlife Service, Washington, D.C. 3 pp.

Flooding all aboveground growth can eliminate young seedlings. Dewatering during the hottest days of summer prevents the development of root systems in newly established seedlings.

235. FREDRICKSON, L. H., AND F. A. REID. 1988. Invertebrate response to wetland management. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.3.1. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

The potential for invertebrate consumption by waterfowl can be enhanced if peak periods of waterfowl use coincide with reduced water levels.

236. FREDRICKSON, L. H., AND F. A. REID. 1988. Preliminary considerations for manipulating vegetation. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.9. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Constant water regimes can cause wetlands to quickly shift to a monoculture of robust plants. A record of water-level changes is needed when assessing the effects of dewatering on vegetation.

237. FREDRICKSON, L. H., AND F. A. REID. 1988. Waterfowl use of wetland complexes. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.2.1. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

A 3-year water regime is suggested for seasonally flooded wetlands in the Midwest: a gradual drawdown in late spring followed by gradual flooding in year 1; a gradual drawdown in year 2 lasting into midsummer with gradual reflooding in fall; spring flooding in year 3 followed by late spring drawdown and gradual reflooding in fall.

238. FREDRICKSON, L. H., AND T. S. TAYLOR. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service, Washington, D.C. Resource Publication 148. 29 pp.

The concepts and practices that make up moist-soil management were developed at Mingo National Wildlife Refuge in southeastern Missouri from 1968 to 1982. Moist-soil management offers opportunities to attract and hold a wide variety of wildlife on man-made impoundments. Plant and

animal species differ with latitude, and some specific management techniques that work well at southern latitudes may have little or no value at northern latitudes, or vice versa. Nevertheless, there are may ecological and management principles that are important in moist-soil management, regardless of location. Low sites where row crops are often lost to flooding are particularly well suited for moist-soil management. Optimum success requires good levees, control structures for precise water manipulations, and a pumping system to remove or add water. On some southern sites where annual rainfall is 100 cm or more, this management has been successful despite the lack of pumping potential. Precise water manipulations not only provide food and cover for many kinds of wildlife, but costs and energy consumption are less than for row cropping, and native foods are more nutritionally complete. The growth of woody and undesirable herbaceous plants are expected problems that require regular inspections and corrective measures if food production and wildlife use are to remain high. A group of small impoundments provides more management flexibility than a single large one because control of vegetation or flooding to attract one group does not preclude options to attract other wildlife on adjacent areas.

239. FREY, D. G. 1967. Reservoir research—objectives and practices with an example from the Soviet Union. Pages 26–36 *in* C. E. Lane, Jr., editor. Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

Differences in approach and goals of reservoir research in the Soviet Union and the United States are examined, and some limnological perspectives are presented on how reservoirs differ from natural lakes. A distinct difference between lakes and reservoirs is water-level fluctuation, a common phenomenon in many Soviet and U.S. impoundments. Some Soviet reservoirs are very large and shallow; consequently even a relatively small drop in water level exposes large areas of the bottom (as much as 75% in the Rybinsk Reservoir) and severely stresses benthos and fishes. As a result, Soviet biologists have extensively studied the drained zone of reservoirs. Invertebrates associated with gravel or well-drained soils are killed by drawdown, but many organisms on silt or clay soils often are able to burrow into the substrate and survive. In reservoirs where the drained substrate retains water and where bottom animals can burrow, productivity of the drained zone may not be appreciably less than that on continually flooded bottoms. In reservoirs where drawdown lasts long enough for a dense growth of terrestrial vegetation to develop, reflooding usually increases the production of algae and benthos.

240. FRIEND, M., G. E. CUMMINGS, AND J. S. MORSE. 1964. Effect of changes in winter water levels on muskrat weights and harvest at the Montezuma National Wildlife Refuge. New York Fish and Game Journal 11:125–131.

During winter 1961–62, data on muskrat weights, water levels, and air temperature were recorded at the Montezuma National Wildlife Refuge. On areas where the water level had been lowered by drainage, subfreezing temperatures resulted in ice formation reaching the bottom as well as the feed beds, and heavy weight losses occurred. Lesser weight losses occurred on an area where normal water levels were maintained. Reflooding of the drained areas resulted in most of the lost weight being regained. Evidence of disease and parasitic infection was heaviest in muskrats from areas of low water. The possible control of muskrat populations in northern marsh areas through winter drainage is suggested.

241. FROST, W. E. 1956. The growth of brown trout (*Salmo trutta* L.) in Haweswater before and after the raising of the level of the lake. Salmon Trout Magazine 148:266–275.

Growth of trout in the lake increased after the lake water level was raised 38 ft. Growth was fastest during the first year of flooding and was accounted for by the many terrestrial organisms that were consumed (53% of stomach contents). The decrease in size and growth several years after impoundment indicated that the increased fish production was only temporary.

242. FUERST, M. 1970. Experiments on the transplantation of new fish-food organisms into Swedish impounded lakes. Fauna Flora 3:94–105. (In Swedish)

The abundance of bottom-dwelling fish-food organisms decreases greatly as a result of artificial water-level fluctuations in impounded lakes. Plankton does not provide enough food to maintain sufficient growth and quality of char, brown trout, or whitefish. Three species of Crustacea (*Mysis relicta*, *Pallasea quadrispinosa*, and *Gammaracanthus lacustris*) are being introduced to replace the original bottom-fauna. They live near the bottom and are not influenced by water-level fluctuations because of their mobility. Char, brown trout, burbot, and grayling fed heavily on dense *Mysis* populations. The quality of the fish flesh improved greatly, and the flesh coloration of char and trout became more reddish than before the introductions. The effect of the new diet on fish growth and density is not yet evident. (Abstract adapted from Fraser 1972)

243. GABEL, J. A. 1974. Species and age composition of trap net catches in Lake Oahe, South Dakota, 1963–67. U.S. Fish and Wildlife Service, Technical Paper 75. 21 pp.

Twenty-seven species of fish were sampled with trap nets in Lake Oahe. Because catch per unit effort did not accurately reflect the abundance of some species (due to variations in water level and other environmental conditions), the ability of species to adapt to reservoir conditions was based on the frequency and strength of postimpoundment year classes. As the reservoir filled and waters inundated terrestrial vegetation for the first time, strong year classes of bigmouth buffalo, common carp, smallmouth buffalo, and northern pike were produced. Due to the strong 1962 year class, freshwater drum, common carp, and bigmouth and smallmouth buffaloes remained abundant through 1967. After 1962, year classes of some species that do not require flooded vegetation for spawning were more consistent than those of species that require vegetation. The exceptional year classes of 1962 can be attributed to a marked rise in water level that continued during and after the spawning season of most species. Rising water levels in spring may be required for successful reproduction of the bigmouth buffalo. Because the growth of aquatic vegetation was hindered by water-level fluctuations in Lake Oahe and the inundation of vegetation was not timely, reproduction of common carp was poor. Because freshwater drum are pelagic spawners, their reproductive success was relatively independent of water-level fluctuations.

244. GABOR, T. S., AND H. R. MURKIN. 1990. Effects of clipping purple loosestrife seedlings during a simulated wetland drawdown. Journal of Aquatic Plant Management 28:98–100.

A purple loosestrife study was conducted in a greenhouse at the Delta Waterfowl and Wetlands Research Station in south-central Manitoba. Clipping seedlings may compound infestation problems by increasing the number of aboveground first-year stems that are capable of producing seed.

245. GALATOWITSCH, S. M., T. V. MCADAMS, AND E. E. KLAAS. 1994. Biological information on distribution and requirements of plants used by migratory birds on the Upper Mississippi River. Iowa Cooperative Fish and Wildlife Research Unit, Ames, Unit Cooperative Agreement 14-16-0009-1560, Work Order 36. 176 pp. (Draft report)

A major focus of river monitoring within the past 25 years has been to document patterns of vegetative cover within the Upper Mississippi River. Yet, little attempt has been made to link environmental factors to vegetation distribution, a key element for any environmental impact assessment. A way to begin developing a predictive basis for environmental assessment of habitat is to review the past studies of the vegetation of the Upper Mississippi River, gleaning pertinent information that suggest vegetation distribution results from specific environmental conditions. This literature review is meant to be this first step towards predicting habitat changes and developing habitat management strategies on the Upper Mississippi River. The bibliography is designed to be comprehensive for the vegetation below the historical high water elevations for the Upper Mississippi River. Information is given on water levels, depths, and water-level fluctuations and how the plant community responds to each.

246. GALINATO, M. I., AND A. G. VAN DER VALK. 1986. Seed germination traits of annuals and emergents recruited during drawdowns in the Delta Marsh, Manitoba, Canada. Aquatic Botany 26:89–102.

Seed germination traits of the most abundant mudflat annuals and perennial emergents that become established during drawdowns (periods when all or part of a wetland is free of standing water) in the Delta Marsh, Manitoba, Canada, were examined. The seeds of both annuals *(Aster laurentianus* Fern., *Atriplex patula* L., and *Chenopodium rubrum* L.) and emergent perennials *(Hordeum jubatum* L., *Scolochloa festucacea* [Wild.] Link, *Phragmites australis* [Cav.] Trin. ex Steud., and *Typha glauca* Godr.) from this prairie, lacustrine marsh germinated best in the light. Stratification also improved the seed germination percentages of all species except for *Scolochloa*. Germination percentages were highest in alternating 15–25 °C and 20–30 °C temperature regimes and lowest in a 5–15 °C regime. Because the germination of seeds of each species is affected differently by temperature, salinity, light conditions, and depth of burial, microenvironmental variations from site to site during a drawdown could result in different species becoming established at sites with identical seed banks.

247. GARCIA-NOVO, F., AND R. M. M. CRAWFORD. 1973. Soil aeration, nitrate reduction, and flooding tolerance in higher plants. New Phytologist 72:1031–1039.

Flood-tolerant species from natural habitats differ from flood-intolerant species by being able to make more effective use of nitrate as an alternative electron acceptor to oxygen during periods of partial anaerobiosis. When flooded, tolerant species show marked increases in nitrate-reductase acidity in roots and leaves. A greater ability to synthesize aminoacids under anoxia was also found in the tolerant species than in the intolerant. It is suggested that these properties enable the flood-tolerant species to facilitate the reoxidation of $NADH_2$ under conditions of anoxia and that this is associated with the greater ability of the species to withstand a reduction in the partial pressure of oxygen.

248. GASAWAY, C. R. 1970. Changes in the fish population in Lake Francis case, South Dakota, during the first 16 years of impoundment. U.S. Department of the Interior, Fish and Wildlife, Bureau of Sport Fisheries and Wildlife, Washington, D.C. Technical Paper 56. 30 pp.

The abundance of adult fish in Lake Francis Case declined after impoundment in 1952 and the catch by fishermen decreased from 1.37 to 0.27 fish per hour after 1954. Growth of 13 species increased after impoundment but later declined. The species composition in the lake and in the harvest changed somewhat since impoundment; some species became rare and others abundant. Reproduction was unusually high for many species in 1967, a year of high water levels. Strong year classes of northern pike were produced in 1954, 1964, and probably 1965. The 1964 year class of northern pike and common carp may have come from Lake Sharpe (upstream), as water levels in Francis Case were not conducive to good spawning that year (i.e., they were drawn down 3 ft to control common carp spawning). Attempts to destroy the spawn of common carp in 1956 were unsuccessful. Scarcity of submerged terrestrial vegetation probably was as important as water-level drawdown in limiting carp reproduction. Because common carp spawn over an extended period, short-term manipulation of water levels may be of only limited value as a control measure.

249. GATES, F. C., AND E. C. WOOLETT. 1926. The effects of inundation above a beaver dam upon upland vegetation. Torreya 26:45–50.

The effect of inundation upon upland vegetation (beech-maple forest and lowland forest) was studied above a beaver dam in Carp Creek (an area of approximately 9,700 m^2), in the vicinity of Douglas Lake, Michigan, during the second summer of its construction. The original vegetation was affected seriously. All herbaceous vegetation with two exceptions was eliminated following the flooding; no shrubs except seedlings or very small saplings, on large logs at or in the water, were to be found, and 77% of all the trees in the impounded area were dead or dying.

250. GAUDET, J. J. 1977. Natural drawdown on Lake Naivasha, Kenya, and the formation of papyrus swamps. Aquatic Botany 3:1–47.

The flora of Lake Naivasha (108 species) is presented along with an account of primary succession on wet mud at the lake edge. During the course of succession, three zones developed: S*paeranthus* Zone (closest to the lake water); Sedge Zone (dominated by *Cyprus papyrus* L., *C. digitatus* Roxb., and *C. immensus* C.B.Cl.); Composite Zone (dominated by *Conyza* spp., closest to dry land). This primary succession occurred during a recent drop in lake level (natural drawdown). Succession continued after reflooding and resulted in a papyrus fringe swamp, a most common sub-climax community along the edges of this lake. An analysis of lake-edge soils and germination and growth studies were carried out to determine some of the factors affecting lake-edge succession. It is concluded that of all species present, *C. papyrus* is the most adaptable, starting from seed on bare mud in competition with hygrophilous annuals and later growing up in water as a perennial emergent macrophyte. Annual drawdown and reflooding are discussed in relation to the general productivity of inshore regions of tropical water bodies. Primary succession of papyrus during a drawdown is recorded for the first time and the production of bands of papyrus swamp along the lake edge is shown to be correlated with the larger cycles of drying and flooding that occur on this lake.

251. GEAGAN, D. W. 1961. A report of a fish kill in Chicot Lake, Louisiana, during a water level drawdown. Proceedings of the Louisiana Academy of Science 23:39–44.

After water levels were reduced in Lake Chicot to control aquatic plants (especially *Elodea*, which covered 50% of the lake), large numbers of fish died due to near-anoxic conditions (oxygen concentrations were less than 0.1 mg L^{-1} near the main boat landing). This kill reduced the fish standing crop from 146.2 to 19.1 lb/acre. This kill might have been avoided if the lake had been drawn down annually to control plants (it was not drawn down in 1956–57; consequently plants became overabundant).

252. GEHRT, S. D., L. B. FOX, AND D. L. SPENCER. 1993. Locations of raccoons during flooding in eastern Kansas. Southwestern Naturalist 38:404–406.

Extensive flooding caused by a man-made reservoir in eastern Kansas did not, in general, force raccoons out of the floodplain, even though this area remained under water for weeks. In addition, fall flooding of this type did not contribute to raccoon mortality.

253. GEIGER, N. S. 1983. Winter drawdown for the control of Eurasian watermilfoil in an Oregon oxbow lake (Blue Lake, Multnomah County). Pages 193–197 *in* Lake restoration, protection, and management. U.S. Environmental Protection Agency, Washington, D.C., EPA 440/5-83-001.

Watermilfoil (*Myriophyllum spicatum* L.), chemically similar to the nuisance milfoil species in British Columbia, was first reported in Blue Lake in 1973. Dense stands of the plant have since interfered with recreational use of the lake. Funding from the U.S. EPA Clean Lake Phase I was used to examine the feasibility of lake drawdown as a control technique during winter 1981–82. Drawdown reduced standing crop biomass by 44% to 57%. Aerial photography also showed a reduction in area occupied by milfoil. The effects of drawdown on rootcrown viability were forecast by laboratory aquaria tests. Results were mixed because of less than desirable drawdown and meteorological conditions. However, new growth was exclusively at the sediment surface from surviving rootcrowns, providing an opportunity for an effective lakewide application of granular 2,4-D.

254. GEIGER, W., H. J. MENG, AND C. RUHLE. 1975. Effects of simulated pumped storage operation on northern pike fry. Schweizerische Zeitschrift fuer Hydrologie 37:225–232. (In German)

Effects of periodic simulated water-level fluctuations on northern pike fry, as produced by pumped-storage operations, were examined. Daily fluctuations of 10 cm caused a significant increase in mortality of fry. Waves reduced the detrimental effect of water-level fluctuations, at least during the adhesive phase of development.

255. GENTRY, A. H., AND J. LOPEZ-PARODI. 1980. Deforestation and increased flooding of the upper Amazon. Science 210:1354–1356.

The height of the annual flood crest of the Amazon at Iquitos, Peru, has increased markedly in the 1970s. During this period, there was greatly increased deforestation in the upper parts of the Amazon watershed in Peru and Ecuador, but no significant changes in regional patterns of precipitation. The change in Amazonian water balance during this decade seems to be the result of increased runoff due to deforestation. If so, the long-predicted regional climatic and hydrological changes that would be the expected result of Amazonian deforestation may have already begun.

256. GIBBS, J. P., F. A. REID, AND S. M. MELVIN. 1992. Least bittern. *In* A. Poole, P. Stettenheim, and F. Gill, editors. The American Ornithologists' Union, Birds of North America 17. The Academy of Natural Sciences, Washington, D.C. n.p.

In a review of other papers, the authors note that the least bittern is most abundant in freshwater marshes during years when ratios of emergent vegetation cover to open water were equal. The birds were found restricted to deep- and shallow-water cattails in a Wisconsin marsh, apparently avoiding areas of dried cattail, river bulrush, and sedge. In Maine, the birds have been found associated with

stable water regimes at managed impoundments and coves on lakes. On moist-soil impoundments in Missouri, the birds were associated with waters up to 50 cm deep where rank, dense vegetation borders open water. Least bitterns are not associated with open, sparse, or short vegetation cover or muddy openings.

257. GILL, C. J. 1970. The flooding tolerance of woody species—a review. Forest Abstracts 31:671–688.

The effects of flooding on woody species and the adaptations of plants to conditions of excess soil moisture were reviewed. The study was undertaken as part of an attempt to mask the barren margins of reservoirs in Britain by the establishment of groups of flood- and wave-tolerant trees in the upper drawdown zone. The resistance of various woody plants to flooding varies. Some species show increased growth when flooded. Various factors determining the survival of trees are discussed as well as mechanisms of tolerance. A comprehensive listing of resistant woody vegetation is given.

258. GINZBURG, YA. I. 1958. Biology and abundance of young fish in the Tsimlyansk Reservoir (according to observations of 1953–1955). Izvestiya Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Ozernogo I Rechnogo Rybnogo Khozyaistva 45:111–141. (In Russian)

Variations in the reproduction of fish in different years resulted from the following factors: (1) changes in the water regime, (2) the absence of permanent spawning grounds and the sharp fluctuations in their dimensions and condition, (3) the number of spawners, and (4) biological conditions in the reservoir. Spawning of phytophilic fish was successful in 1952, the first year the reservoir was filled; 1953 and 1954 were poor years for most species, but 1955 was better. The decrease in common carp reproduction in 1953 and 1954 was due to the sparse distribution of spawners in the reservoir, together with a sharp reduction in the size of the spawning area (due to reduced water levels, common carp spawned in a narrow coastal strip of meadow and aquatic vegetation). Replenishment of pike-perch (*Stizostedion* sp.) reserves after they shift to a fish diet depends on prey availability and production. The reproduction of bream (*Abramis ballerus*) was more successful than pike-perch, and common carp and its stocks were more abundant. Favorable spawning conditions in 1955 improved the reproduction of bream, common carp, pike-perch, and predatory fishes. (From Referativmyi Zhurnal. Biologiya 1959, 88778; Biological Abstract 48:79056)

259. GISLASON, J. C. 1985. Aquatic insect abundance in a regulated stream under fluctuating and stable diel flow patterns. North American Journal of Fisheries Management 5:39–46.

Aquatic insect abundance at water depths of 15–45 cm was examined in a fifth-order reach of the Skagit River, Washington, from May 1976 to November 1977. The study site was subject to diel flow fluctuation in 1976 from hydroelectric power-peaking, and to a relatively stable flow pattern in 1977 while peaking was curtailed. Under fluctuating flow conditions, insect density increased from shallow to deep water and was negatively correlated (r = -0.76, P < 0.001) with hours of dewatering during the 2 weeks prior to sampling. Current fluctuation seemed to limit insect density at the 45-cm deep sampling locations that were not extensively dewatered during the daily peaking cycle. The highest density observed in 1976 was 1,788 insects/m^2 at 25 cm in July. Under stable flow conditions, the abundance of benthic insects was greatly enhanced and the densities at corresponding depths and months were 1.8–59 times higher in 1977 than in 1976. Insect densities increased steadily from May 1977 through September 1977 when they reached a maximum level of

16,763 insects/m^2 at 15 cm. Reduction in the amplitude and duration of power-peaking flow fluctuation can be a highly effective management strategy for enhancing aquatic insect standing crop, with a potential for increasing the survival and growth of fish dependent on insects for food.

260. GIVENS, L. S., AND T. Z. ATKESON. 1957. The use of dewatered land in southeastern waterfowl management. Journal of Wildlife Management 21:465–467.

Farming, though expensive, remains the most reliable method of producing large quantities of preferred food. This is better accomplished by row cropping the higher elevations to corn, grain sorghums, and soybeans than by broadcast planting the lower elevations to the grain sorghums, soybeans, millets, and buckwheat.

261. GLADDEN, J. E., AND L. A. SMOCK. 1990. Macroinvertebrate distribution and production on the floodplains of two lowland headwater streams. Freshwater Biology 24:533–545.

Two first-order, blackwater streams in Surry County, Virginia, were studied. Spatial and temporal distribution patterns of invertebrates were affected by inundation patterns. Numbers, biomass, and production were greater in low floodplain areas continuously inundated over 9 months. Here, annual invertebrate production, was 6.1 g m^{-2}. Production on the periodically inundated floodplain was 1.7 g m^{-2}.

262. GODDARD, J. A., AND L. C. REDMOND. 1978. Northern pike, tiger muskellunge, and walleye populations in Stockton Lake, Missouri: A management evaluation. Pages 313–319 *in* R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11.

In addition to describing the fishery of Stockton Lake and the effects of stage filling, the authors evaluated the effectiveness of length limits and stocking. Survival and growth of walleye and northern pike fry were excellent during the first year of impoundment and continued to be good for several years thereafter. High survival and rapid growth were attributed to the abundance of flooded terrestrial vegetation in three successive springs of stage filling. Filling in three stages provided a fertile environment as flooded plants decayed, and zooplankton and small forage fishes were abundant. The continual rise of water into terrestrial vegetation also provided protection and an important feeding area for young fishes.

263. GOOD, B. J., AND W. H. PATRICK, JR. 1987. Gas composition and respiration of water oak (*Quercus nigra* L.) and green ash (*Fraxinus pennsylvanica* Marsh.) roots after prolonged flooding. Plant and Soil 97:419–427.

We compared the effects of 9.5 months of a continuous flooding treatment with a drained control treatment on 1-year-old seedlings of green ash *(Fraxinus pennsylvanica* Marsh.) and water oak (*Quercus nigra* L.), two tree species common to the bottomland-hardwood forests of eastern North America. The internal root gas composition of the more flood tolerant species, green ash, maintained higher oxygen and lower carbon dioxide concentrations under the flooding treatment than water oak. This apparently resulted in differences in rhizosphere oxidation. The amounts of Fe and Mn and the Fe:Mn ratio of the root coating extracted from trees in reduced soil conditions were much higher for the green ash than the water oak.

264. GOODSON, L. F., JR. 1965. Diets of four warmwater game fishes in a fluctuating, steepsided, California reservoir. California Fish and Game 51:259–269.

Food studies of largemouth bass, black crappies, white catfish, and bluegills collected from Pine Flat Lake in 1963 and 1964 revealed that stomachs contained a seasonal abundance of cladocerans, terrestrial arthropods, and threadfin shad. White catfish ate terrestrial plants when water levels were rising in winter. Terrestrial insects were the main food of bluegills from July to October. Chironomids apparently are well adapted to the lake's changing environment and may prove to be the most important invertebrate fish food in fluctuating steep-sided reservoirs.

265. GOPHEN, M. 1979. Population density, migration and food composition of *Echinogammarus veneris* in Lake Kinneret, Israel. Hydrobiologia 66:99-104.

Migrations of *Echinogammarus veneris* (a small amphipod) were controlled by water levels and littoral currents.

266. GORE, J. A. 1977. Reservoir manipulations and benthic macroinvertebrates in a prairie river. Hydrobiologia 55(2):113–123.

Samples were taken on the Tongue River, Montana, between 1974 and 1975 to determine the distributions and abundances of the benthic fauna after various reservoir manipulations. The upper, cold water section, influenced by hypolimnial discharge from the Tongue River Reservoir, was impoverished in insect fauna and dominated by the molluscs *Physa* and *Sphaerium*. The lower, warm water sections of the river contained two communities determined primarily by turbidity and periphyton cover. The upper, warm water area was dominated by *Strophopteryx* and hydropsychid caddis larvae. The lower river was dominated by *Cheumatopsyche*. The summer fauna, in the warm water area, was dominated by short-lived mayfly species. In summer 1975, the cold water section was invaded by many insects due to warming of the area when no hypolimnion was formed in the reservoir. Invasion was apparently due to increased thermal fluctuations, which caused diapause eggs to hatch and influenced the upstream migration of older nymphs and larvae. The results of drift and distributional samples after closure of the Tongue River Reservoir Dam for repairs showed that massive drift of all invertebrates began at a discharge of 130 cfs (3.68 m^3/s), a drop from 190 cfs (3.38 m^3/s) over 3 days. Community composition was radically altered by reduced discharge.

267. GORYAINOVA, L. I., O. V. KARPICHOVA, L. N. KOPYTEVA, L. P. KOSTYUCHENKO, L.. D. LYSIN, N. Y. MILOVIDOVA, AND A. N. PANGINA. 1969. The Neberdzhai Reservoir during its first eight years. Hydrobiological Journal 5(6):45–50.

Information is presented on the qualitative and quantitative composition of plankton, benthos, and fish in Neberdzhai Reservoir during the first and eighth years of impoundment. Declining water levels expose large portions of the reservoir bottom by late summer. The number of species of benthos decreased from 21 to 11, as species living in thick plant growths disappeared after the vegetation was eliminated. The average biomass of benthos was highest in the first year (3.3 g m^{-2}), declined to 0.2 g m^{-2} in the second year, and gradually increased to 2.2 g m^{-2} by the eighth year. In 1959–60, the benthos was very diverse, but by 1967 only oligochaetes and chironomids remained.

268. GOSSELINK, J. G., AND R. E. TURNER. 1978. The role of hydrology in freshwater wetland ecosystems. Pages 63–78 *in* R. E. Good, D. F. Whigham, and R. L. Simpson, editors. Freshwater wetlands: Ecological processes and management potential. Academic Press, New York.

The key role of the hydrologic regime as a controller of wetland ecosystems is discussed. The source, velocity, renewal rate, and timing of the water in a wetland ecosystem directly controls the spatial heterogeneity of wetlands and the nutrient O_2 and the toxin load of the sediments. These secondary factors in turn control or modify such ecosystem characteristics as species composition and richness, primary productivity, organic deposition and flux, and nutrient cycles. Wetlands are classified according to their hydrodynamic regime, and trends in ecosystem response along a hydrodynamic gradient are discussed briefly.

269. GOTTGENS, J. F. 1994. Redistribution of organic sediments in a shallow lake following a short-term drawdown. Archiv fuer Hydrobiologie 130(2):179–194.

The impact of the lowering the water level (by short-term drawdown) on deposition and redistribution of organic sediments was studied in eutrophic Newnans Lake, Florida. Sediment transfer was determined by matching marker horizons in nine predrawdown cores with those in cores taken at the same sites after water level returned to normal. Marker horizons were located by either radioisotope analysis or direct field evidence of distinct stratigraphy. An average of 6.08 $g \cdot m^{-1} \cdot d^{-1}$ of organic material eroded from the littoral zone by lowering the water depth from 62 to 30 cm for 8 weeks. Littoral sediments with low bulk density eroded fastest, and bulk density of the remaining substrate increased by an average of 250%. Short-term drawdowns can greatly enhance erosion of fine littoral substrate. A record of redistribution of this material to the deeper portions of the lake was unclear. Of six profundal sites analyzed for this study, two showed evidence of sediment deposition due to drawdown. Since the resuspension of fine sediments may influence the ecology of a lake through habitat alteration, release of nutrients, high turbidity, and enhanced sediment oxygen demand, erosion processes must be considered when drawdowns are attempted.

270. GOTTGENS, J. F., AND T. L. CRISMAN. 1991. Newnans Lake, Florida: Removal of particulate organic matter and nutrients using a short-term partial drawdown. Lake and Reservoir Management 7(1):53–60.

Spillways at lake outlets are commonly employed to reduce water-level fluctuations and promote year-round lake access. However, stabilized water levels may cause accelerated accumulation of sediment on the lake bottom. This can change aquatic plant communities, cloud the water, and eliminate hard-bottom nesting areas for many sportfish. These effects may be particularly pronounced when spillway design does not allow for bottom water drainage and outflow is restricted to less turbid surface waters. Such a structure controls the single surface-outflow of shallow, algal-dominated Newnans Lake, Florida. A 90-day removal of this spillway flushed 60 metric tons (dry weight) of sediment (containing 15% total Kjeldahl nitrogen and 0.5% total phosphorus) from the lake. This quantity was small compared to the likely stores in the lake, but the removal was accomplished at no cost. Data suggest low lake stage at the start of dewatering, resulting in small hydraulic head and low flow through the lake system, depressed removal rates. Elevated concentrations of particulate organic matter, total Kjeldahl nitrogen, and total phosphorus were noted during the first month of dewatering when adequate head differential was still present. Storms stirred the water column and promoted flushing of resuspended matter. In situ and laboratory tests did not demonstrate net oxidative removal of organic matter from exposed areas of the lake bottom. The production of organic matter under high solar radiation and nutrient availability likely replaced material lost through oxidation. Consolidated sediments remained firm after reflooding, providing improved habitat for rooted macrophytes and fish spawning. Short-term partial drawdowns are inexpensive and effective in flushing organic matter and nutrients when they are initiated at high lake stage and coincident with frequent storms. Routine application of this management technique may produce a periodic rejuvenation of the lake ecosystem.

271. GOTTGENS, J. F., AND T. L. CRISMAN. 1993. Quantitative impacts of lake-level stabilization on material transfer between water and sediment in Newnans Lake, Florida. Canadian Journal of Fisheries and Aquatic Sciences 50:1610–1616.

Spillways at lake outlets reduce water-level fluctuations but may accelerate sedimentation in the lake. In eutrophic Newnans Lake, Florida, a transect of sedimentary profiles, dated with ^{210}Pb and ^{137}Cs by γ-ray spectroscopy, showed threefold increases in the accumulation rates of organic matter, total Kjeldahl nitrogen (TKN), and total phosphorus (TP) 1,200 m lakeward of a spillway since its construction in 1967. Concentrations of TKN and TP increased 3.5 and 2.4 times, respectively, in sediments deposited since 1967. These increases were progressively less at stations farther from the spillway. Postspillway accumulation of TP was focused toward the dam, whereas recent TKN deposition was similar lakewide. Flocculent sediment (> 90% water) accumulated at 1.4 cm/year. Dams designed to reduce water-level fluctuations may provide short-term benefits for lake access and navigation but in the long-term may accelerate deposition of nutrient-rich detritus, reduce lake volume, cloud the water, alter plant communities, and change lake productivity.

272. GOULDING, M. 1993. Flooded forests of the Amazon. Scientific American (March):114–120.

Flooded forests make up at least 150,000 of the 5 million km^2 of the Amazon rain forest. The lowland rivers fluctuate an average of 7 to 13 m/year, and in the central part of the basin, rising river water can penetrate as far as 20 km into the forest on either bank. The woods of the estuary are also subject to flooding, but on a daily rather than seasonal basis. Twice a day, tides push some of the Amazon River's huge freshwater discharge into the estuarine forests. For an average of 6 or 7 months/year, the lowland rivers rise and invade the enormous floodplain areas that border them. The forest becomes inundated with as much as 10 m of water; understory plants become completely submerged. Special adaptations permit the unique flora and the associated fauna of these flooded forests to survive such heavy inundation. Most flooded forests require at least a brief dry spell to survive. For the tidally flooded forest, this respite is provided by the low tides. The tree species of the inundated woodlands are unique and cannot be replaced by *terra firme* counterparts once they are gone. Indeed, it is reasonable to argue that the flooded forests have been more significant as gene pools for *terra firme* than vice versa. Floodplain trees can survive without flooding, as planting them in upland soils demonstrates. But upland species cannot tolerate long periods of aquatic immersions. Thus, it seems speciation occurred from floodplain to upland. Many of the animals that live in and depend on the flooded forests are also unique. The destruction of these woods could cause the greatest loss of freshwater fish known in human history.

273. GRAHAM, T. R., AND J. W. JONES. 1960. The biology of Llyn Tegid trout. Proceedings of the Zoological Society of London 139(4):657–683.

After outflows were controlled in 1955, water levels and the range of fluctuations decreased. Fish sampled in 1959–1960 exhibited a decrease in growth, condition, food ration, and caloric value of the diet. The standing crop of the bottom fauna in the littoral zone was reduced by decreased water levels, and this reduction was reflected by a decrease in the number and types of organisms eaten by trout. When water levels were high, plecopterans, tipulids, and molluscs composed most of the volume of trout diets. After water levels and fluctuations were decreased, stomachs contained mostly oligochaetes, chironomid pupae, and for the first time, zooplankton. Although the types of fish that trout ate differed under the two operational regimes, the volumes were similar.

274. GRAS, R., AND ST. J. LUCIEN. 1978. Duration and characteristics of juvenile development of some Cladocera from Lake Chad. Cahiers Orstrom Serie Hydrobiologie 12:119–136. (In French)

The relative duration of the juvenile period of *Moina* and *Diaphanosoma*, as estimated by two methods, was shortened by accelerated development and a decrease in the number of instars between 1968 (a high-water year) and 1973 (a low-water year). Improved nutritional conditions in the lake after the fall in water level apparently resulted in accelerated development. (From Biological Abstract 68:74005)

275. GREEN, B. W., D. C. BECKETT, A. C. MILLER, AND R. F. GAUGUSH. 1993. Comparison of macroinvertebrate assemblages from two backwater lakes in Pool 10 of the Upper Mississippi River. Page 51 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

We sampled the benthic invertebrate fauna of two Upper Mississippi River backwater lakes on July 20, 1991, using a petite Ponar grab. The two lakes, McGregor Lake and Thumb Lake, are located west of Prairie Du Chien in Pool 10, and are within a mile of each other. Ten inshore (nearshore) and 10 offshore samples were taken in each lake. The weight of particulate matter (mostly of plant origin) in the inshore and offshore sets of samples from Thumb Lake sediments were roughly equivalent. Mean weight of particulate matter in the McGregor Lake inshore samples was only l/5 of the Thumb Lake inshore samples; the weight of the offshore particulate matter in McGregor Lake was less than 1/100 of Thumb Lake's offshore samples. Marked differences existed in benthic invertebrate density and composition as well. Although *Hexagenia* nymphs were present in both lakes, densities of these mayflies were considerably less in McGregor Lake; e.g., offshore *Hexagenia* densities in Thumb Lake were approximately 50 times greater than the offshore densities in McGregor Lake. Larval chironomid densities were also greater in Thumb Lake. Offshore, chironomid densities in Thumb Lake were about 11 times the densities of McGregor Lake. A diverse chironomid fauna was present in the littoral zone of Thumb Lake. (Abstract only)

276. GREEN, R. E. 1988. Effects of environmental factors on the timing and success of breeding common snipe, *Gallinago gallinago*. Journal of Applied Ecology 25:79–93.

Seven plots of lowland wet grassland were systematically searched for snipe nests in 10 plot-years, and the outcome of nesting attempts was determined. Vegetation height and the availability of food were measured. Snipe feed on soil invertebrates by probing soil or mud with the bill, so prey density and the force required to probe the soil were measured. Soil was easier to probe when moist or waterlogged than when dry. The dates on which nesting started and on which replacement nesting ceased varied greatly between plot-years. The start of nesting could be delayed for up to 70 days by flooding. Nesting stopped later in plot-years when the soil remained moist and easy to probe. The number of chicks hatched per female over the whole breeding season was determined by the rate of failure of individual breeding attempts and the duration of the nesting season. Management of water levels to prolong the period during which snipe can probe the soil would increase breeding success.

277. GREEN, R. E., AND M. ROBINS. 1993. The decline of the ornithological importance of the Somerset Levels and Moors, England, and changes in the management of water levels. Biological Conservation 66:95–106.

A recent decline in populations of breeding waders, wintering waterfowl, and whimbrel (*Numenius phaeopus*) on spring passage at the Somerset Levels and Moors, England, is described. Studies of the distribution of breeding waders show the importance of high water tables and associated low-intensity grassland management techniques. The authors pose a hypothesis that bird populations have declined because of a lowering of water tables on the moors during their breeding season.

278. GREEN, W. E. 1947. Effect of water impoundment on tree mortality and growth. Journal of Forestry 45:118–120.

The author made observations on the Upper Mississippi River after dam construction in the 1930s. No species survived 4 years of constant flooding. In areas where the root crown was not permanently covered with impounded water, bottomland trees survived remarkably well. Some trees above the 2-ft contour have shown a continued decrease in growth following the stimulation of first impoundment and may eventually die. The author also presents information on the average annual growth before and after flooding for a number of species on high ground in the areas just above the 2-ft contour.

279. GREEN, W. E., L. G. MACNAMARA, AND F. M. UHLER. 1964. Water off and on. Pages 557–568 *in* J. P. Linduska, editor. Waterfowl tomorrow. U.S. Government Printing Office, Washington, D.C. 770 pp.

The authors discuss water-level manipulation and how it can increase habitat for waterfowl. An example of improved habitat is given for the Mississippi River at Lock and Dam 25 at Batchtown, Illinois. The authors noted that the characteristics of each site determine the extent frequency and the most desirable periods for drawdowns and reflooding. Partial exposure of the bottom is usually preferred to complete drainage.

280. GREENBACK, J. 1956. Movement of fish under the ice. Copeia 3:158–162.

Observation of fish movement beneath the ice was performed by a trapnetting experiment in Target Lake, near La Crosse, Wisconsin, in winter 1946–47. Target Lake is a backwater, lying close to the main channel of the Mississippi River, with an area of about 150 acres. It has a maximum depth of about 8 ft. An outlet, about 200 ft wide and only a few hundred feet long connects the lake with a large side channel of the river. The depth in most places in the outlet is less than 4 ft. The experiment was started on January 9, 1947, and concluded on February 20. During the 40 days of the experiment, a total of 3,328 fish were taken in the two nets. Over 80% of these consisted of three species—black crappie, yellow bullhead, and bowfin. Movements of fish were related to a reduction in light intensity. Other factors such as current, water temperature, and dissolved oxygen were largely ruled out. In this study, water levels remained almost stable, and currents were absent or small. Reference was made to a previous study where it was found that lowering the water level induced movement of fish out of the backwater with the current and into the river. This movement was active rather than passive. Movement was intensified by rapid drawdown. Certain species, such as bluegill and largemouth bass, tended to remain in the backwaters, where they became trapped by the lowered water level.

281. GREENBANK, J. T. 1945. Notes on pool drawdown in winter of 1944–45. Pages 5–6 *in* K. D. Keenlyne, editor. Upper Mississippi River Conservation Committee Investigational Reports.

The author observed Pools 3 to 8 on the Upper Mississippi River during winter 1944–45. At Pool 8, the drop in the water level was about 6 ft at the dam, and 2.5 to 3 ft at the control point at La Crosse, Wisconsin. Extreme drawdown on Pool 8 cut off many pockets, bays, and lakes entirely, with little or no water depth under the ice. The probability was high that the total loss of fish was enormous.

282. GREENBANK, J. T. 1946. Notes on pool drawdowns in winter of 1945–46. Pages 15–17 *in* K. D. Keenlyne, editor. Upper Mississippi River Conservation Committee Investigational Reports.

Observations on Pools 3 through 6 on the Upper Mississippi River were made during winter 1945–46. Pools 3 through 6 were gradually drained in the second and third weeks in December. The duration of lower water levels, especially in Pools 7 and 8, was relatively short compared with the preceding year. The observed fish kill was definitely and substantially less than in the previous winter.

283. GREENBANK, J. T. 1946. Effects of mid-winter drawdown of Upper Mississippi River on aquatic wildlife. Pages 17–24 *in* K. D. Keenlyne, editor. Upper Mississippi River Conservation Committee Investigational Reports.

The U.S. Army Corps of Engineers have found it necessary, for four consecutive winters, to withdraw water from the Upper Mississippi storage pools between Minnesota and Wisconsin to provide water downstream for navigation. These drawdowns have brought serious criticism from people living along the river and have raised official protests from bordering states. Grave concern has been felt over the effects of drawdowns on fish and animal life of the river on which many people depend for recreation, food, and livelihood. This report is a condensed summary of the findings of game and fishery biologists and technicians who have a bearing on the winter drawdown problems. Information is presented on the 4-year history of the drawdowns and the studies of the effects on fish and wildlife. The following conclusions were made: (1) The lowering of water levels in winter deprives fish and furbearers of a considerable amount of habitat that they usually inhabit during normal stages of the river and changes the surrounding environments severely for varying lengths of time. (2) Drawdowns definitely are harmful to muskrat populations when the lowering of the water allows ice cover to rest on mud bottoms, especially when periods of low water coincide with cold periods so that the mud also freezes. Ice covers are then unlikely to rise when water levels are restored. In mild winters and during drawdowns of brief duration, muskrat damage is lessened. (3) Although some oxygen depletion, and subsequently fish winterkills, is present in areas not subjected to drawdowns, lower water levels hasten the processes leading to fish destruction. (4) When drawdowns take place, they seem to have a more deleterious effect on such fishes as bass, bluegills, and crappies, than they do on yellow perch, pike-perch, catfish, and the rough or commercial fishes. (5) It is acknowledged that fish and muskrat destruction occurs in the river at other times of the year, or in the winter prior to drawdown in certain areas, or for a variety of reasons, and that canalization has probably alleviated fluctuations in water levels that formerly plagued wildlife in late summer, and that canalization has created additional areas suitable for fish life. Winter drawdowns nullify the advantages of the lock and dam systems, however, and create a hazard for aquatic populations at a most unfavorable time of year.

284. GREENBANK, J. T. 1947. Field notes on river drawdowns. Pages 38–39 *in* K. D. Keenlyne, editor. Upper Mississippi River Conservation Committee Investigational Reports.

In October 1947, the U.S. Army Corps of Engineers, at the request of the La Crosse (Wisconsin) Badger Sportsmen's Club, began drawing down the water in Pool 8 to facilitate repair work on the Goose Island Road. Some of the backwater pools and lakes were nearly completely drained. Hosts of small fish, such as young bullheads and bluegills, had been stranded and left to die on the mud or entangled in the weed beds. Few large fish were seen.

285. GRIFFITH, R. 1948. Improving waterfowl habitat. Transactions of the North American Wildlife Conference 13:609–618.

There are no definitive rules that can be recommended toward the treatment of a particular tract of wildlife habitat to increase its productivity for waterfowl. Stability of water level is not always the answer. Control of water level is important, however, for by proper manipulation of water level, plant successions may be controlled and the maximum yields of desirable food plants obtained. Insofar as marsh vegetation is concerned, proper manipulation and control of the water level is a method of cultivation that pays the highest dividends by way of increased seed production.

286. GRIMÅS, U. 1961. The bottom fauna of natural and impounded lakes in northern Sweden (Ankarvattnet and Blasjon). Institute of Freshwater Research Drottningholm Report 42:183–237.

The influence of lake regulation was studied by comparing the benthos of regulated Lake Blasjon with that of unregulated Lake Ankarvattnet. The annual amplitude of water-level fluctuation in Lake Blasjon was about 6 m, the drawdown occurring in winter. The littoral zone of the regulated lake consisted of a block bottom interspersed with gravel that was exposed by erosion. Erosion reduced transparency, and eroded materials were deposited on top of sediments in littoral regions below the drawdown limit, greatly altering their character. Water-level fluctuations significantly reduced the density of benthic animals. The abundance of benthos was greatest just below the limit of drawdown. The abundance of chironomids (midges) increased while densities of Crustacea declined. Densities of Cladocera initially increased after regulation but decreased after continuous erosion and loss of nutrients. Populations of *Gammarus* and other benthic invertebrates (e.g., insect larvae) that depend on an intact littoral zone were also greatly reduced.

287. GRIMÅS, U. 1962. The effect of increased water level fluctuation upon the bottom fauna in Lake Blasjon, northern Sweden. Institute of Freshwater Research Drottningholm Report 44:14–41.

The effects of increased annual water-level fluctuations (from 6 to 13 m) on benthos were evaluated. Densities of benthos were reduced 50% during 10 years of 6-m fluctuation and another 40% during 2 years of 13-m fluctuations. Increased fluctuation affected all of the fauna in the fluctuation zone and altered the balance among major taxa. Littoral benthos such as amphipods, larger insect nymphs, and gastropods decreased in abundance, while oligochaetes, nematodes, and pisidians increased in abundance. There was a short-term increase in the density of littoral crustaceans, but long-term fluctuation increased the abundance of chironomids and other animals that are not normally available as food for fish. Fluctuation caused changes in chironomid patterns of emergence, and consequently they apparently were less available as fish food than before fluctuations were increased. Freezing and drying of the substrate in the fluctuation zone may have been responsible for qualitative changes in the bottom fauna. Losses of aquatic bottom vegetation and organic deposits from the littoral zone were important factors limiting benthos abundance.

288. GRIMÅS, U. 1964. Studies on the bottom fauna of impounded lakes in southern Norway (Tunnhovdfjord, Paalsbufjord, and Rodungen). Institute of Freshwater Research Drottningholm Report 45:94–104.

Large insect larvae of the orders Plecoptera, Ephemeroptera, and Trichoptera were established in the littoral of the impounded lakes, in contrast with previous observations made in other regulated lakes. In exposed areas, insects were concentrated on old tree stumps. They also were abundant in the loose drift materials along shorelines. Quantitative benthos samples from Tunnhovdfjord were similar to those from other natural lakes in that the numerical abundance of benthos in the fluctuation zone was low. In unprotected areas, erosion and drawdown caused an inverted vertical distribution of animals, the maxima occurring just below the drawdown limit. In protected areas, the vertical distribution of benthos was similar to that observed in natural lakes (i.e., abundance was greater in the littoral zone than in deeper areas). Scattered areas of moss and submerged tree stumps supported more individuals than did eroded bottom deposits. The diverse shore fauna in Lake Rodungen was attributed to a slow rhythm of regulation and the restricted amplitude of the water-level fluctuations. Early years of regulation typically were unstable, with erosion adversely affecting benthos in the fluctuation zone and deeper regions. Over many years, however, leaching out of the fluctuation zone resulted in stabilization of conditions, and a more diverse fauna was established, although annual fluctuations still limited development. This study showed the importance of original forest vegetation in preserving the lake organisms that are important as fish food.

289. GRIMÅS, U. 1965. Inlet impoundments. An attempt to preserve littoral animals in regulated subarctic lakes. Institute of Freshwater Research Drottningholm Report 46:22–30.

The benthos of inlet impoundments adjacent to impounded natural lakes was studied to determine the suitability of inlets for fish-feeding areas. Inlet impoundments with their stable water levels supplemented the fish-food fauna of the reservoir littoral, which often is degraded by erosion and water-level fluctuation. The development of benthic species (e.g., *Gammarus lacustris*) that depend on migrations to deep water in winter seemed to be hampered in the shallow inlet impoundments. However, low winter temperatures and the rapid warming of shallow inlet impoundments in the spring seemed to benefit cladocerans. Littoral insects dominated the fauna of the inlet reservoirs and many of the large species were important as fish foods. Although the inlet impoundments did not counterbalance the loss of the original littoral, they preserved some littoral vegetation.

290. GRIMÅS, U. 1965. The short-term effect of artificial water level fluctuations upon the littoral fauna of Lake Kultsjon, northern Sweden. Institute of Freshwater Research Drottningholm Report 46:5–21.

Immediately after impoundment, the bottom fauna of Lake Kultsjon differed from that of older regulated lakes with a similar degree of fluctuation. Within the fluctuation zone, there were no areas of refuge to harbor large densities of benthos. Short-term regulations had a negative effect on fish-food organisms. The original littoral fauna, which was composed primarily of chironomids, became dominated by oligochaetes. The most significant short-term effect of regulation on benthos resulted indirectly from structural changes in the surface of the substrate. Desiccation and freezing directly decimated benthos inhabiting surfaces of attached plants or sediments.

291. GRIMÅS, U. 1967. Impounded lakes and river reservoirs: Two new ecosystems for the Swedish nature. Svensk Naturvetensk 1967:168–177.

Two types of storage basins are used to provide a continuous water supply during the year in northern Sweden (i.e., impounded lakes in the high mountains and river reservoirs in the immediate vicinity of power stations in the lower reaches of rivers). Impounded mountain lakes are characterized by great fluctuations in water level and river reservoirs by a relatively steady water level and variable rate of water flow. The effects of impoundment on phytoplankton, zooplankton, bottom vegetation, bottom fauna, and the feeding habits and production of fish have been studied. Changes in the abiotic environment that affect various communities also have been described. Production in impounded lakes and river reservoirs seems to follow two different lines (production is not favored in impounded lakes, as it is in river reservoirs). Several experiments have been started to establish new productive food chains in impounded lakes and to channel more biological production into desirable species of fish in river reservoirs. (Abstract adapted from Fraser 1972)

292. GRIMÅS, U., AND N. A. NILSSON. 1965. On the food chain in some north Swedish river reservoirs. Institute of Freshwater Research Drottningholm Report 46:31–38.

The food chain in Swedish river reservoirs is discussed and compared with that in impounded natural lakes. River reservoirs differ from impounded natural lakes in having relatively smaller, though perhaps more rapid, changes in water level. When water levels are stable, aquatic vegetation can develop throughout large portions of river reservoirs. The remains of original vegetation are important for production in inundated areas. The eurybenthic distribution of littoral animals in river reservoirs diminishes the importance of the upper littoral zone as a feeding area for fish.

293. GRIZZELL, R. A., JR. 1960. Fish and wildlife management on watershed projects. Transactions of the North American Wildlife Conference 25:186–192.

Strategies are discussed for managing fish, waterfowl, and upland game resources on small watershed projects. A slot or gate release for flood-retarding structures increases flexibility in effecting drawdown on watershed impoundments of 4 to 100 acres in surface area. Advantages of such a release structure and drawdown include the control of mosquitos, manipulation of fish populations, and control of water supply to downstream areas.

294. GROEN, C. L. 1977. Effects of water-level management on Milford Reservoir. Paper presented at the Kansas Chapter of the American Fisheries Society, February 26, 1977. 11 pp.

Water-level management on Milford Reservoir, Kansas, plays an important role in increasing numbers of forage fish, sport fish, and harvest. After overwinter drawdown increased the reservoir's flood capacity, refilling in spring lessened shoreline erosion and increased populations of red shiners, emerald shiners, and white bass, as well as the standing crops of young-of-year fishes. Multiple spawns of gizzard shad were observed. More walleyes, white crappies, and bluegills were creeled during the year after drawdown, and growth of sport fish probably improved.

295. GROEN, C. L. 1977. Water-level manipulation plans: 1977 review, 1978 proposals. Pages 1–82 *in* Kansas Fish and Game Commission, Topeka. 82 pp.

Water-level management plans were implemented on 13 of the reservoirs in Kansas. Since all bodies of water are unique and have different management objectives, different water-level management plans were formulated. Realized effects and benefits produced on certain reservoirs have been: (1) increased spawning success of sportfish, (2) increased recruitment of sportfish, (3) increased forage production, (4) increased growth rates of sportfish, (5) decreased rough fish production, 6) improved waterfowl conditions and harvest, (7) improved water quality, (8) increased fishing success, and (9) increased shoreline stabilization. Due to lack of early rainfall and then prolonged drought in fall, actual water levels often deviated from the planned levels in 1977. In some instances, undesirable vegetation, such as cockleburs, willows, and cottonwoods resulted from two successive early drawdowns. Nut sedge and other desirable vegetation seemed to be crowded out by these forms. In other instances, however, this type of vegetation stabilized shorelines and allowed growth of desirable vegetation.

296. GROEN, C. L. 1979. Water-level management plans. Kansas Fish and Game Commission, Topeka. n.p.

Enhanced fish populations, improved waterfowl conditions and increased water quality are all direct benefits of water-level management plans formulated by the Kansas Fish and Game Commission. Water uses range from recreation to navigation and irrigation. Agencies cooperating on water-level management plans include the Tulsa and Kansas City Districts of the U.S. Army Corps of Engineers, the Kansas Water Resources Board, the Kansas Parks and Resources Authority, and the Kansas Fish and Game Commission. Presently, 15 reservoirs possess water-level management plans for fish and wildlife. Kansas possesses many diverse reservoir types, and each reservoir represents a unique management situation. Factors such as morphology, flowage traces, fish and wildlife populations, vegetative types, and reservoir users are all considered during the formulation of the plans.

297. GROEN, C. L., AND T. A. SCHROEDER. 1978. Effects of water-level management on walleye and other coolwater fishes in Kansas reservoirs. Pages 278–283 *in* R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11.

Most Kansas reservoirs can be managed to sustain productive fisheries by recreating, to some extent, conditions in newly impounded lakes. This plan involves raising water levels in spring to improve spawning and nursery conditions by providing submerged herbaceous vegetation, which provides substrate, refuge, turbidity control, and nutrients. A midsummer drawdown follows to permit regrowth of vegetation in the fluctuation zone, to improve the availability of forage for piscivores, and to control populations of rough fish. Due to uncontrollable weather that may negate the benefits of water-level manipulation, plans may have to be implemented for several years to achieve desired results. Success depends greatly on the type and amount of vegetation that can be grown in the fluctuation zone. For early drawdowns, the seeding of Japanese millet and hybrid sudan–sorghum produces lush stands of vegetation valuable for fish habitat, turbidity control, and waterfowl food. Annual wheat or rye seeded in September or October provides good growth for late drawdowns. Water-level management has increased growth, recruitment, and harvest of walleyes and improved the forage base and survival of stocked walleye fry and northern pike fingerlings. Improved structure of fish populations and water quality also are attributed to water-level management. In Council Grove Reservoir, the proportion of harvestable-sized sport fish increased from 15.5% to

52.9% of the total number and from 30.3% to 44.1% of the total weight 2 years after water levels were manipulated. In Milford Reservoir, catch per unit of effort by fyke netting nearly doubled in 3 years. The relative abundance of walleyes, white crappies, river carpsuckers, and gizzard shad has increased in Milford Reservoir since water levels were first managed.

298. GRUBAUGH, J. W., AND R. V. ANDERSON. 1988. Spatial and temporal availability of floodplain habitat: Long-term changes at Pool 19, Mississippi River. American Midland Naturalist 119(2):402–411.

The 107-year record of daily water elevations for the Upper Mississippi River at Burlington, Iowa, was examined to assess changes in hydrologic patterns and floodplain availability resulting from dam and levee construction. After the completion of Lock and Dam 19 in 1913, mean low, mean high, and overall mean water levels significantly increased ($P < 0.05$). Floodplain habitat was permanently inundated. The establishment of extensive levee and drainage districts adjacent to Pool 19 resulted in additional loss of floodplain. Generalized annual hydrographs indicated the spring rise in water elevation had been shortened in the postdam period and an autumn rise evident in the predam hydrograph was absent in the postdam hydrograph. Temporal reduction in floodplain availability along with spatial losses caused by inundation and leveeing aggravates the situation for floodplain-dependent species.

299. GRUBAUGH, J. W., AND R. V. ANDERSON. 1989. Upper Mississippi River: Seasonal and floodplain forest influences on organic matter transport. Hydrobiologia 174:235–244.

Fine-particulate organic carbon (FPOC), dissolved organic carbon (DOC), and total organic carbon concentrations (TOC) were measured during five sampling periods in 1984 and 1985 above and below the floodplain forest area in navigation Pool 19 on the Upper Mississippi River. The greatest TOC transport occurred during peak floods and leaf fall. The peak flood transport was dominated by FPOC associated with the flushing of material from upland areas. Transport during autumnal leaf fall was predominantly DOC attributed to litter leaching. Seasonal DOC loads generally increased downstream except during the phytoplankton bloom when a decrease was associated with increase microbial metabolic activity. A downstream decline in FPOC and increasing DOC loads during peak flood characterized the mechanism of deposition and processing of FPOC on the floodplain. FPOC concentration was significantly correlated to discharge, and DOC concentrations were higher than FPOC except for peak flow. Significant downstream changes in TOC load suggest the importance of riparian vegetation as an influence on organic matter transport in large rivers.

300. GUILLORY, V. 1979. Utilization of an inundated floodplain by Mississippi River fishes. Florida Scientist 42:222–228.

In 1973, a study was conducted 8 km south of St. Francisville, Louisiana, in West Feliciania Parish. The life cycles of many lower Mississippi River fishes are related to seasonal fluctuations in water levels, particularly the annual flood pattern. When the floodplains are flooded, many fishes migrate from the main channel to the inundated areas for spawning and feeding. This study seeks to confirm that these flooded backwaters of the lower Mississippi River serve as important feeding and nursery areas for main channel fishes. The number of characteristic Mississippi River fishes remained low on the floodplain (< 12 species) until it was flooded and the number of river fishes increased to a peak of 32 species in July. As discharge decreased and the floodwaters receded, both the number and percent composition of river fishes decreased. Any physical destruction of floodplains, or any manipulation that hinders access to these habitats, could have an adverse effect on the fishery. Because the primary goal of fish management is the sustained yield of sport and commercial fisheries, protection or even restoration of floodplains should be a top priority in any management program for large rivers.

301. GULYAEVA, A. M. 1964a. Biology and fishery of lake smelt in Vodlozero. *In* Fisheries of Karelia. Petrozavodsk 8:144–148. (In Russian)

From 1934 to 1940, the catch of lake smelt decreased, probably as a result of increased water levels that displaced spawning grounds. A change in water conditions when the lake was converted into a temporary reservoir may have limited fish production. (From Referativmyi Zhurnal. Biologiya 1964, 24195; Biological Abstract 47:10690)

302. GULYAEVA, A. M. 1964b. Present day state of the reservoir fisheries in southern and central Karelia and prospects of their growth. *In* Fisheries of Karelia. Petrozavodsk 8:111–117. (In Russian)

In 1950–60, the annual catch of fish in lake reservoirs was 18% of the average catch in Karelian inland waters. Species composition of catches before and after regulation of the lakes Vodlozero, Vedlozero, Sandal, Vygozero, and Segozero is described. Poor catches are attributed to adverse effects of water-level fluctuation, humification, pollution, and unregulated fishing. Productivity of lake reservoirs probably can be raised considerably by ameliorative conservation and acclimatization measures. (From Referativmyi Zhurnal. Biologiya 1965, 1189; Biological Abstract 47:30646)

303. GUSEVA, K. A. 1958. The influence of water level regime of the Rybinsk Reservoir on the development of phytoplankton. Trudy Biologcheskoi Stantsii "Borok" Akademiya Nauk SSR 3:112–124. (In Russian)

Greatest development and abundance of phytoplankton was associated with high water levels that filled the reservoir completely and flooded large areas of terrestrial litter and detritus. Littoral areas contained the greatest biomass of phytoplankton (monthly mean, 7 mg L^{-1}). The development of plankton in the central portion of the reservoir was independent of water levels, and the biomass (2.2 mg L^{-1}) was lower than in the littoral zone. (From Referativmyi Zhurnal. Biologiya 1959, 38614; Biological Abstract 47:65732)

304. GUSTARD, A. 1984. The characterisation of flow regimes for assessing the impact of water resource management on river ecology. Pages 53–60 *in* A. Lillehammer and S. J. Saltveit, editors. Regulated Rivers. Engers Boktrykkeri, Norway.

The author outlines the need for generalized relations between streamflow and river biology that can be applied when reviewing the pattern of releases below impounding reservoirs. The work includes the study of the frequency, duration, and magnitude of both low and flood flows of more than 500 rivers in the United Kingdom. The results of current investigation into the main features of natural and artificial flow regimes are discussed. The estimation of the biological effects caused by changes in the flow regime should lead to improvements in the management of impounding reservoirs.

305. HALL, H. D., AND V. W. LAMBOU. 1989. Determining the value of bottomland hardwood riverine wetlands to fisheries. Pages 132–137 *in* The Association of Wetland Managers, Inc. Wetlands and river corridor management. Proceedings of the International Wetland Symposium, Charleston, South Carolina, July 5–9, 1989. Omnipress, Madison, Wisconsin.

A methodology is presented that can be used by field personnel to assess the relative ability of a bottomland hardwood site to furnish fishery habitat. The elements evaluated are permanent water habitat, access, flood regime, water quality, and floodplain habitat.

306. HALL, T. F., W. T. PENFOUND, AND A. D. HESS. 1946. Water-level relationships of plants in the Tennessee Valley with particular reference to malaria control. Journal of the Tennessee Academy of Science 21(1):18–59.

Information on seed germination, sprouting, survival, and growth form of littoral plants in relation to water levels is presented from a study of eleven reservoirs, three natural ponds, and two experimental pools in the Tennessee Valley during a 4-year period. Three major groups of herbs are recognized, based upon their water tolerance, namely: (a) terrestrial, (b) wetland, and (c) aquatic. Three major groups of woody species are recognized, based upon their water tolerance, namely: (a) intolerant, (b) moderately tolerant, and (c) tolerant. Various schedules for water-level management of littoral vegetation are discussed at length.

307. HALL, T. F., AND G. E. SMITH. 1955. Effects of flooding on woody plants, West Sandy dewatering project, Kentucky Reservoir. Journal of Forestry 53:281–285.

The tolerance of 39 woody species to periodic flooding was determined in Kentucky. All woody species were killed where the root crowns were periodically flooded more than 54% of the time during all the growing seasons the project had been in operation. However, these species subjected to less flooding at higher elevations showed varying degrees of tolerance with survival contours stratified over 12 vertical ft. The effects of flooding on woody plants are summarized graphically by plotting survival data for each species against the percentage of time of flooding during the growing season.

308. HARMS, W. R. 1973. Some effects of soil type and water regime on growth of tupelo seedlings. Ecology 54:188–193.

Two-year-old swamp tupelo (*Nyssa sylvatica* var. *biflora* [Walt.] Sarg.) and water tupelo (*N. aquatica* L.) grown in large tanks in a silty clay loam soil from a river swamp or a sandy loam soil from a nonalluvial headwater swamp were subjected to continuous flooding at depths of 20 cm above the soil surface with moving water, 20 cm above the soil surface with stagnant water, or at the soil surface with moving water. Height growth of water tupelo averaged 1.8 times greater and dry weight 2 to 3 times greater in the more fertile soil from the river swamp than in soil from the headwater swamp. Soil type had no effect on the growth of swamp tupelo. Growth and dry weight of both tupelos were poorest in the regime with stagnant water, which also had the highest CO_2 and lowest O_2 contents. Swamp tupelo grew 50 cm more in height in the surface-flooded regime with moving water than in either deep-flooded regime. Water tupelo in both regimes with moving water grew 37 cm taller than those in the stagnant regime.

309. HARRIS, M. D. 1975. Effects of initial flooding on forest vegetation at two Oklahoma lakes. Journal of Soil and Water Conservation 30:294.

Postflood surveys were made of hardwood trees in flood pools of Keystone and Oologah impoundments, Oklahoma. Inundation lasted 7–100 days, with the first 10 ft lasting 67–73 days. Flood damage was most severe in the first 10 ft above normal pool level. Above this, mortality of smaller trees and shrubs was greatest though most larger trees survived. Most trees that showed stress after inundation and were less than 10 inches in diameter and 25 ft tall eventually died. When properly planted and maintained, green ash, sycamore, cottonwood, buttonash, willow, mulberry, silver maple, bald-cypress, and river birch grow rapidly and are soon tall and large enough in diameter to withstand flooding.

310. HARRIS, S. W., AND W. H. MARSHALL. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44:331–343.

A study of vegetation changes associated with marsh drawdowns at Agassiz National Wildlife Refuge, Minnesota, revealed that the development of five types of vegetation on mudflats during the first year was influenced by seed availability, soil type and moisture, season and duration of drawdown, and amount of stranded algal debris. In the second year of drawdown, most areas developed greater numbers of upland and shoreline weeds and fewer emergents.

311. HARTLEB, C., J. D. MADSEN, AND C. W. BOYLEN. 1993. Environmental factors affecting seed germination in *Myriophyllum spicatum*. Aquatic Botany 45:15–25.

Seed germination of *Myriophyllum spicatum* was examined for 2 days at Lake George, New York, at depths of 1–5 m of water. In both days the highest rate of seed germination was observed at a depth of 5 m, with no significant difference in germination between depths of 1 and 3 m. Results reflected the need of a calm, undisturbed area for seeds to germinate.

312. HARTMAN, G. F. 1949. Management of central Wisconsin flowages. Wisconsin Conservation Bulletin 14:19–22.

During the creation of 50-odd shallow flowages in central Wisconsin during the middle and late 1930s, the fluctuation in water levels was considered highly undesirable, because most good aquatic food plants require a stable water level. However, observations over the years proved that essential to good management of artificially created ponds, especially those having poor soil and water, must be drained periodically. Drainage of flowages was also found to be the most efficient method of controlling undesirable aquatics when such plants take over all food growth of the ponds. Winter drawdowns are usually undesirable because of their harmful effect on the furbearers, and where normal, on the fish population. It is an efficient method, however, of reducing fish numbers where that is needed. During the first year following the drawdown of a trout pool, a much better distribution of these fish were found throughout the pool. This distribution occurred up to the middle of July, indicating that the drawdown bettered conditions for fish as well as plants.

313. HASSLER, T. J. 1969. Biology of the northern pike in Oahe Reservoir, 1959 through 1965. U.S. Bureau of Sport Fisheries, Wildlife Technical Paper 29:1–13.

Fish collected over 7 years were examined for variations in length, weight, growth, maturity, sex ratios, and year classes. After impoundment, strong year classes (1959, 1962, and 1965) were associated with high spring water levels that exceeded previous high levels and remained high throughout the summer.

314. HASSLER, T. J. 1970. Environmental influences on early development and year-class strength of northern pike in Lakes Oahe and Sharpe, South Dakota. Transactions of the American Fisheries Society 99:369–375.

Factors affecting early development and year-class strength were delineated by monitoring environmental variables and the survival of artificially fertilized ova and larvae of northern pike. Large year classes were associated with stable to rising water level and temperature, recently flooded vegetation, and calm weather during the spawning season; whereas, small year classes were related to abrupt decreases in water level. However, availability of suitable water level and substrate does not guarantee a strong year class, inasmuch as low water temperature, rapid fluctuation in temperature, high siltation (due to wind-induced turbulence), or a lack of suitable food may separately or in combination result in weak year classes.

315. HASSLER, W. W. 1955. The influence of certain environmental factors on the growth of Norris Reservoir sauger, *Stizostedion canadense canadense* (Smith). Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 9:111–119.

A number of environmental variables (i.e., agricultural growing season, number of days between the first and last 60 °F [15.6 °C] day, precipitation, solar radiation, air temperature, and water-level fluctuation) were examined in relation to the first-year growth of saugers. No significant correlation was found between changes in water level and first year growth of saugers, but the data suggest that a relation exists between first-year growth and a cycle of water-level changes. Because other factors (like population density) influence the relation, further evidence of the association between a cycle of water-level fluctuation and changes in first-year growth is needed.

316. HEERDT, G. N. J., AND H. J. DROST. 1994. Potential for the development of marsh vegetation from the seed bank after a drawdown. Biological Conservation 67(1):1–11.

In the inundated part of the Oostvaardersplassen, a marsh in The Netherlands, most of the emergent vegetation disappeared due to herbivore and erosion, resulting in a shallow lake. The emergent vegetation was successfully reestablished by means of a drawdown. A comparable flooded marsh was studied to describe its seed bank and to find out if it was possible to make an accurate prediction of the vegetation developments after a drawdown based on the Van der Valk model on succession in wetlands. Two different zones could be distinguished in the lake. These differed mainly in the number of seeds found, not in the species composition of their seed banks. The short-term prediction that *Typha latifolia* would become dominant did not always match the actual pioneer vegetation that developed; several different communities developed from similar seed banks. The long-term prediction that *Phragmites australis* would become dominant after 4 years of drawdown was fulfilled.

317. HEISEY, P. G., D. MATHUR, AND N. C. MAGNUSSON. 1980. Accelerated growth of smallmouth bass in a pumped storage system. Transactions of the American Fisheries Society 109:371–377.

In a 12-year study of smallmouth bass in Muddy Run Reservoir, a pumped storage impoundment in Pennsylvania, accelerated growth was related to the abundance of gizzard shad after their introduction in 1972. Drawdowns of 9 m day^{-1} or 15.6 m $week^{-1}$ (volume reduced 45%) increased the vulnerability of shad by concentrating both shad and bass. In the lower reservoir (Conowingo Pond), where water levels fluctuated $\leq$1 m each day, growth of smallmouth bass was not greatly improved after shad were introduced. Water-level fluctuations inhibited successful spawning of most fishes in all years except 1967, when water levels were constant in spring and early summer. In 1967, large numbers of forage fish were produced.

318. HEMAN, M. L. 1965. Manipulation of fish populations through reservoir drawdown, with emphasis on *Micropterus salmoides* (Lacepede). M.A. Thesis, University of Missouri, Columbia. 65 pp.

Water levels on Little Dixie Lake were lowered 8 ft in July 1964 to enhance the population of largemouth bass. Surface area was reduced 42% and volume 58%. Because water was released from the hypolimnion, the lake mixed at 86 °F (30.0 °C) and 7.2 mg L^{-1} of oxygen. Drawdown reduced the density of small- and intermediate-sized bluegills by leaving them stranded, by exposing them to increased predation, and by destroying nests. Largemouth bass fed more when less vegetation was present than when vegetative cover was abundant. Increased growth of all age classes of bass except young-of-year indicates that predation increased during and after drawdown. The harvest of bluegills increased greatly immediately after drawdown, whereas that of largemouth bass decreased. However, the harvest of bass was higher in the fall after drawdown than in the fall of the previous year. Growth of yearling and older bass accelerated in the year after drawdown, whereas the length attained by young-of-year bass by the end of the year decreased slightly (from 5.0 to 4.6 inches).

319. HEMAN, M. L., R. S. CAMPBELL, AND L. C. REDMOND. 1969. Manipulation of fish populations through reservoir drawdown. Transactions of the American Fisheries Society 98:293–304.

The effects of a midsummer drawdown (July 19–29) on growth of largemouth bass, total harvest, and the size composition of bluegills were examined in Little Dixie Lake, Missouri. In 10 days, water levels were lowered 2.4 m by releasing hypolimnial water. Surface area was reduced by 42%, volume by 58%, and the lake became isothermal at 30 °C. The relative weight of food in stomachs of largemouth bass increased by a factor of 2.7, and the percentage of empty stomachs decreased. The growth of largemouth bass, as indicated by scale reading, also increased after the drawdown. The harvest of bluegills increased immediately after drawdown and then decreased over the next 2 months. The harvest of largemouth bass was reduced in August but increased significantly in September and October. Drawdown presumably reduced the densities of fry and intermediate-sized bluegills by stranding them, increasing predation, and exposing nests.

320. HENSON, E. B., AND M. POTASH. 1977. Biological production and nutrient studies of Lake Champlain. International Joint Commission, International Champlain–Richelieu Board, University of Massachusetts. 58 pp.

An evaluation is made of the ecological significance of the distribution and abundance of higher plants, algae, zooplankton, and large invertebrates in a Lake Champlain wetland. The nutrient budget and cycle are examined. For the best growing conditions, water levels should be maintained at an elevation of 98.4 ft from late May through June and should not go below 97.4 ft. From July through the rest of the growing season, the water level should not be reduced below 95.1 ft. This level permits lateral movement of water through the emergent zone, thus providing needed nutrients, and also maintains an ample submergent–floating zone within the wetland. The submergent zone supports the greatest densities of macroinvertebrates that are used for food by fish. Lake levels maintained below 95.1 ft in winter will kill off much of the aquatic vegetation and increase decomposition in spring and summer. As a result, more nutrients will be released into the lake. (From Selected Water Resources Abstract 12[16]:W79-07741)

321. HESLER, L. S., AND A. L. GRIGARICK. 1992. Aquatic arthropods in California rice paddies: Effects of water-drainage versus continuous-flood regimes on abundance and species composition. Environmental Entomology 21:731–736.

In conjunction with experiments to evaluate water drainage as a control method for rice water weevil, *Lissorhoptrus oryzophilus*, studies were performed to compare the abundance and species composition of aquatic arthropods in two sets of continuously flooded and temporarily drained but reflooded rice, *Oryza sativa*, paddies. A total of 1,736 individuals representing 22 arthropod taxa was collected. Few differences in abundance were detected; however, *Notonecta* spp. were significantly more abundant in reflooded paddies. The percentage of similarity (PS) between paired treatments was 0.50 on all but one date; relatively high PS values on the first sampling dates suggest that the aquatic arthropod community is able to recover rapidly after reflooding. Several taxa seem to possess traits that enhance survival in a rice paddy subjected to temporary drainage. Implications are discussed for the wide-scale use of drainage on California rice acreage.

322. HESTAND, R. S., B. E. MAY, D. P. SCHULTZ, AND C. R. WALKER. 1973. Ecological implications of water levels on plant growth in a shallow water reservoir. Volume 2. Hyacinth Control Journal (June):54–58.

The authors discuss and recommend methods of water-level regulation for aquatic plants on the Oklawaha River in Florida. The authors conclude that an integrated management plan of water-level fluctuation with chemical or biological control, or both, will be required for proper management.

323. HIEBERT, T. I., H. F. BERNHARD, P. H. HOWE, AND D. R. HELMS. 1982. Sedimentation rates and standing stock estimates in selected sloughs of Pool 14 of the Mississippi River. Page 28 *in* Proceedings of the Mississippi River Research Consortium, Volume 15, La Crosse, Wisconsin, April 14–16, 1982.

Sedimentation rates in two selected sloughs in Pool 14 of the Mississippi River were estimated. One slough, which seemingly receives a high volume of flow during periods of elevated river stages, had a maximum water depth of about 0.3 m at normal pool elevation. The other location, which does not receive these high water flows, had a maximum water depth of 0.6 m at normal pool elevation. Sediment samples were analyzed for cesium-137 content. Results indicated that since 1954, up to 1.2 m of sediment have been deposited in the shallower slough and up to 0.6 m in the deeper site. Standing stock estimates of fish were made at these two sloughs and at a third slough having a maximum water depth of 2.4 m at normal pool elevation. This additional site was a cove that had been dredged. Rotenone surveys resulted in estimates of 96, 502, and 620 kg/ha at the 0.3, 0.6, and 2.4 m deep sloughs, respectively. These results indicate an apparent correlation between the lower standing stocks and the shallower slough. Sedimentation has resulted in the decline of the standing stock in this habitat and further reductions of standing stocks can be expected for this habitat if sedimentation continues. (Abstract only)

324. HILDEBRAND, S. G., EDITOR. 1980. Analysis of environmental issues related to small-scale hydroelectric development. 3. Water level fluctuation. Oak Ridge National Laboratory, Tennessee, ORNL/TM-7453. 132 pp.

The effects of water-level fluctuations on the limnology of small-scale hydropower reservoirs (25 MW or less) that operate in a store-and-release mode (peaking) are examined. Physicochemical effects include resuspension and redistribution of bank and bed sediment, leaching of soluble organic matter from littoral areas, and changes in water quality due to changes in thermal stratification or "trap efficiency"—that is, the percentage of total inflowing sediment (or nutrients) retained in the basin. Water-level fluctuations can potentially reduce standing crops, production, and diversity of aquatic animals by destroying habitat or altering its quality. The effects of changing water level in tailwaters of reservoirs also are discussed.

325. HILL, K. 1979. Manipulation of bass–bluegill populations by summer drawdown, Job 2: Summer drawdown of 50% on Meadow Lake. Pages 1–5 *in* Iowa Conservation Commission Project F-90-R-2.

The overall objective of this study was to manipulate the proportional stock density of a largemouth bass–bluegill population so 20%–35% of the bluegill, excluding those smaller than 3-inches are 6 inches or longer, and 45%–60% of the bass, excluding those smaller than 8-inches, are 12-inches or longer by reducing the water volume in Meadow Lake by 50% in midsummer. Summer drawdown to concentrate forage-sized bluegill and increase vulnerability to predation was the method of population manipulation. Partial or complete renovation could create an acceptable bluegill fishery, but a midsummer drawdown may obtain the same results more economically. The Iowa Natural Resources Council had to authorize a drawdown before a permit was obtained. Actual drawdown began on July 12, 1978, and water volume was reduced 50% by July 24, 1978. Bluegill and channel catfish pressure increased after the drawdown. A voluntary largemouth bass creel survey showed 21 largemouth bass were caught in 27 angler hours.

326. HOFFMAN, D. A., AND A. R. JONES. 1973. Lake Mead, a case history. Pages 220–233 *in* W. C. Ackermann, G. F. White, and E. B. Worthington, editors. Man-made lakes: Their problems and environmental effects. American Geophysical Union, Geophysical Monograph Series 17, William Byrd Press, Richmond, Virginia.

All aspects of the history of Lake Mead are discussed, including geology, climate, physical limnology, chemical limnology, ecology of the surrounding terrestrial area and the reservoir, hunting, fishing, and the relation of the reservoir to man. The general pattern of water-level fluctuation involves rising waters in spring and early summer and receding waters in fall and winter. Fishing was fair to excellent during the early years of impoundment, but declined after 1941. Investigations showed poor development of plankton and benthos. Historically, peak fishing success was noted following the years of 1952, 1957, 1958, and 1962—all years of high runoff and greatly increased lake levels. Spawning success was phenomenal when exceptionally high water levels covered wide expanses of brushy shoreline. After the construction of Glen Canyon Dam upstream, some control of water levels was gained and recommendations were made to maximize benefits to fish. A recommended management program called for steady water levels during spring spawning (April, May, and June) and then for rising water levels from July through September to enhance the overwinter survival of young-of-year game fishes by providing refuge in inundated plants.

327. HOFFMAN, G. R., AND L. D. STANLEY. 1978. Effects of cattle grazing on shore vegetation of fluctuating water level reservoirs. Journal of Range Management 31:412–416.

Shore vegetation around lakes Oahe and Sakakawea, mainstem Missouri River reservoirs, responds to a variety of limiting factors including water-level fluctuations and cattle grazing. Shore vegetation provides wildlife habitat, and spawning habitat for certain fishes, reduces erosion, adds to the aesthetic value of the shore environment, and provides forage for cattle grazing. The various species of shore vegetation are listed and comparisons are made between grazed and ungrazed plots. Cattle grazing and frequent inundation keep vegetation at an early serial stage. Minimizing both water-level fluctuations and cattle grazing for a 2-year period would permit considerably more shore vegetational development.

328. HOLČÍK, J., AND I. BASTL. 1976. Ecological effects of water level fluctuation upon the fish populations in the Danube River floodplain in Czechoslovakia. Acta Scientiarum Naturalium Academiae Scientiarum Bohemoslovacae Brno (10)9:1–46.

Species composition, abundance, and biomass of fish in the Danube River arm of Zofin were determined twice a year in 1969 and 1973. Results demonstrated the extreme importance of floodplains to fish communities. During periods of high water, fish invaded the floodplain, which operates as a spawning ground, a food source, a refuge (for resident mainstream fish), and a source for repopulating areas where spates have destroyed fish populations. Fish stocks and harvest are higher in streams with a floodplain than in those without.

329. HOLCOMB, D. E., AND W. L. WEGENER. 1971. Hydrophytic changes related to lake fluctuations as measured by point transects. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 25:570–583.

After dewatering, littoral vegetation moved lakeward and expanded its coverage from 9,000 to 10,500 acres in Lake Tohopekaliga, Florida. The distribution of vegetation was determined largely by the prevailing water levels within the basin, and the lakeward limit of perennial emergents was related to historically low water elevations. Many of the plants that increased after drawdown produced food for major sport fish and fish-food organisms, as indicated by the high standing crops of fish-food organisms present. Densities of water hyacinth (which was considered detrimental to the fishery) and other plants declined markedly after dewatering.

330. HOLCOMB, D. E., AND W. L. WEGENER. 1974. Response of floodplain vegetation to lake fluctuation. Florida Scientist, Quarterly Journal of the Florida Academy of Science. n.p.

The discharge of domestic sewage and lake-level stabilization caused by the alteration of natural hydrological patterns are two factors contributing to accelerated lake eutrophication in Florida. An extreme drawdown was conducted on 22,700-acre Lake Tohopekaliga in 1971 as an experimental management effort to reduce, moderate, or reverse environmental degradation occurring in the lake. As a portion of that broad study, the authors present data on the response of various plants to the drawdown and reinundation of the Tohopekaliga Basin during 1910–1974. They also discuss the critical role of aquatic macrophytes in relation to other biological communities in the lake. Plants discussed are classified loosely in three groups according to their observed response to fluctuating water levels: (1) terrestrial plants that cannot tolerate flooding, (2) terrestrial plants that can tolerate periodic flooding, and (3) aquatic plants that can tolerate or that may require periodic exposure.

331. HOLLAND, L. E., C. F. BRYAN, AND J. P. NEWMAN, JR. 1983. Water quality and the rotifer populations in the Atchafalaya River Basin, Louisiana. Hydrobiologia 98:55–69.

We compiled distributional and ecological information on the class Rotifera from both flood controlled and uncontrolled reaches of the Atchafalaya River Basin, a large river-swamp in the south-central United States. In the minimally altered lower basin, a variety of aquatic habitats within a small area resulted in a diverse rotifer community consisting of an average of 46 taxa. In contrast, an average of only 28 different taxa were collected in leveed upper basin habitats. As a result of cluster analysis, we were able to identify rotifer communities associated with areas of similar water quality. Variations in suspended solids, total dissolved solids, and organic carbon were most often significantly associated with variations in rotifer numbers from the lower basin. Seasonal flushing of backwater areas by mainstem waters is very important in maintaining the diversity of these lower basin rotifer communities.

332. HOOK, D. D. 1984. Adaptations to flooding with fresh water. Pages 265–294 *in* T. T. Kozlowski, editor. Flooding and plant growth. Academic Press, Orlando, Florida.

The author reviews the literature dealing with morphological, physiological, and biochemical solutions to the problem trees face in periodically flooded habitat.

333. HOOK, D. D. 1984. Waterlogging tolerance of lowland tree species of the South. Southern Journal of Applied Forestry 8:136–149.

Many tree species in the South are adapted to periodic or prolonged soil waterlogging. However, artificial disturbances of natural water regimes sometimes cause flooding to occur at abnormal times or the flood water to be deeper and waterlogging longer in duration than is normal. As a consequence, it is difficult for forest managers to predict how a species will respond to such disturbances or to decide how to manage an area where the water regime has been significantly altered. The author discusses some factors that influence the waterlogging tolerance of tree species, compiles several classification systems, indicates the pertinent literature, and offers a new, relative waterlogging-tolerance rating for southern lowland tree species.

334. HOOK, D. D., AND C. L. BROWN. 1973. Root adaptations and relative flood tolerance of five hardwood species. Forest Science 19:225–229.

Flooding experiments, in a growth chamber and a greenhouse, showed that height growth and root adaptations of yellow poplar, sycamore, green ash, sweet gum, and water tupelo were correlated with flood tolerance. All except yellow poplar could be spatially separated along a relative flood tolerance scale by the presence or absence of one or more root adaptations. Water tupelo and green ash could be separated only by degree of development of root adaptations.

335. HOOK, D. D., C. L. BROWN, AND P. P. KORMANIK. 1971. Inductive flood tolerance in swamp tupelo (*Nyssa sylvatica* var. *biflora* [Walt.] Sarg.). Journal of Experimental Botany 22(70):78–89.

Under flooding or anoxia, the newly initiated roots of swamp tupelo produce ethanol and lactic acid and oxidize their rhizosphere. Unflooded roots produce less ethanol than flooded roots and do not oxidize their rhizosphere. Oxygen enters the stem via the lenticels and seems to be diffused or transported via the cortex or phloem. Flooded roots had less suberization in the epidermis in the terminal 2-cm section and casparian strips were less evident than in the same sections in unflooded roots. Swamp tupelo roots tolerated 10% CO_2 without adverse effects, but 31% CO_2 reduced the initiation of new roots the rate of O_2 uptake, and the transpiration rate. Tolerance to high CO_2

around the root seemed to be related to the oxidation of the rhizosphere by new roots. The combined adaptations of accelerated anaerobic respiration in the absence of O_2, oxidation of the rhizosphere, and CO_2 tolerance of new roots seem to be sufficient conditions to account for flood tolerance in this species.

336. HOOK, D. D., O. G. LANGDON, J. STUBBS, AND C. L. BROWN. 1970. Effect of water regimes on the survival, growth, and morphology of tupelo seedlings. Forest Science 16:304–311.

The survival of swamp and water tupelo seedlings grown under six saturated soil–water regimes on the Santee Experimental Forest in South Carolina was nearly 100% in all water treatments. Height growth in moving water was about double that in comparable stagnant water treatments, and total dry weight growth was 2 to 5 times greater. Reduced height growth occurred under all water treatments in late May and early June, but the rate in moving water did not drop as low as in stagnant water treatments. Root growth was severely restricted in stagnant water, and the top/root ratio increased with the degree of flooding. Growth was correlated positively with pO_2 and negatively with pCO_2 in soil water. Lenticels proliferated on all flooded stems. Water roots developed on stems that were flooded continuously with moving water; such roots were more abundant on swamp tupelo (82%) than on water tupelo (17%).

337. HOOK, D. D., AND J. R. SCHOLTENS. 1978. Adaptations and flood tolerance of tree species. Pages 299–331 *in* D. D. Hook and M. M. Crawford, editors. Plant life in anaerobic environments. Ann Arbor Science Publishers, Michigan.

Tree species show a wide range in flood tolerance, from those that live with their roots and lower stems flooded continuously to those that cannot tolerate more than 3 or 4 days of flooding. Relative flood tolerance seems to be correlated to specific physiological adaptations—namely, accelerated anaerobic root respiration and the ability of species to oxidize their rhizosphere. The authors review the literature concerning these adaptations.

338. HOSNER, J. F. 1957. Effects of water upon the seed germination of bottomland trees. Forest Science 3:67–70.

Seeds of six species of bottomland hardwood trees were subjected to soaking in tapwater in a darkened root cellar at approximately 60 °F for periods varying from 4 to 32 days. Generally, red maple, silver maple, sycamore, and elm seeds failed to germinate while soaking in water but immediately upon removal germination was rapid and consistently high for all periods of time. For similar periods, the soaked seeds of sycamore and elm tended to have higher germination than the unsoaked check seeds. Cottonwood and willow seeds completed their germination in the water in 4 days of soaking. Many seedlings of both willow and cottonwood removed from the water after 32 days seemed as healthy and normal in all respects as seedlings germinated in sphagnum moss germinating beds from unsoaked seeds. It was concluded that, except possibly through indirect effects of siltation, the flooding of bottomland hardwoods up to periods of 32 days does not seem to have an appreciable effect upon the germination of the six species tested.

339. HOSNER, J. F. 1958. The effects of complete inundation upon seedlings of six bottomland tree species. Ecology 39:371–373.

This study suggests that floods in bottomland hardwood areas during the growing season exercise a selective effect upon the species of tree seedlings that survive. It seems that only willow seedlings can survive 32 days or more of complete inundation. Where complete submergence occurs for half that period, many ash, some redgum, and possibly a few boxelder can survive. Cottonwood and silver maple seedlings survive only with less than 16 days inundation. The rate of recovery of the surviving trees also varies. In general, the willow and ash recovered quickly, whereas the others showed the effects of submergence for longer periods.

340. HOSNER, J. F. 1960. Relative tolerance to complete inundation of fourteen bottomland tree species. Forest Science 6:246–251.

There is considerable variation in the ability of different bottomland species to withstand complete submergence. For the species tested, these relative tolerances to complete inundation indicate a definite range from most to least tolerant as follows: silver maple, buttonbush, boxelder, black willow, cottonwood, green ash, American elm, pin oak, sycamore, red maple, shumard oak, redgum, hackberry, and cherrybark oak. It seems reasonable to assume that high water in some bottomland areas exercises a selective killing effect on reproduction and thereby affects the makeup of individual stands. However, many species exhibit a greater or lesser tolerance to flooding than species–site relations indicate. This means that other factors also play an important part in determining the regeneration and succession of tree species in bottomland hardwoods. Water is most likely to become the limiting factor only on sites that are consistently flooded for fairly long periods during the growing seasons, such as true swamps, deep sloughs, and backwater areas.

341. HOSNER, J. F., AND S. G. BOYCE. 1962. Tolerance to water saturated soil of various bottomland hardwoods. Forest Science 8:180–186.

The ability of various species collected in southern Illinois to withstand completely saturated soils for periods of 15, 30, and 60 days was tested in the laboratory. The seedlings can be classified according to tolerance to water-saturated soil conditions as follows: tolerant-green ash, pumpkin ash, water tupelo, and willow; intermediate—eastern cottonwood, boxelder, red maple, silver maple, pin oak, and sycamore; intolerant—Shumard oak, cherrybark oak, American elm, willow oak, sweetgum, hackberry, and sugarberry. Thus, it seems reasonable to assume that the occurrence of continuously saturated soil conditions for long but varying periods in bottomlands results in a competitive advantage for certain species. The resultant reproduction of different species subsequently affects the species composition of bottomland stands associated with sites with different drainage conditions. However, some seedlings of all 17 species tested could be expected to be occasionally found in all bottomland stands except in deep swamps where flooding, except during prolonged dry periods, is continuous.

342. HOUSER, A., AND W. C. RAINWATER. 1975. Production of largemouth bass in Beaver and Bull Shoals Lakes. Pages 310–316 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

The growth of largemouth bass in Beaver (1968–73) and Bull Shoals (1969–73) Lakes was estimated from scale samples of bass collected by shoreline electrofishing. Production was greater in Beaver Lake (the newer reservoir) than in Bull Shoals Lake. Bass populations responded favorably to flooding and high inflow, but year classes were poor when water elevations and inflow were low. Production also decreased drastically when water levels were low. In Beaver Lake, production of the 1966 year class from age II through V was 20.4 lb acre^{-1}, in comparison with the 13.7 lb acre^{-1} for bass in the 1967 year class (at ages I through V). The difference between the total production

of the two year classes was attributed to differences in water level during their first year of life. In 1966, water levels dropped 10 ft by spawning time. The 1968 year classes in Beaver and Bull Shoals Lakes contributed more production than any others during the study period. In 1968, extreme flooding occurred in both lakes, and spawning and survival of young bass was excellent.

343. HOWARD-WILLIAMS, C. 1975. Vegetation changes in a shallow African lake: Response of the vegetation to a recent dry period. Hydrobiologia 47:381–397.

The author explains how the bed of Lake Chilwa in Malawi was colonized by plants during a recent dry period. *Aeschynomene pfundii* and *Diplachne fusca* were the principal colonizing species on the alkaline mudflats. The subsequent changes in the vegetation after the lake refilled are described. Although *Aeschynomene pfundii* survived the flooded conditions for 4 years, it eventually died out as seed germination could not occur underwater. The salinity of the lake during the low water and drying period prevented the lake bed from being extensively colonized by *Typha domingensis*.

344. HOWELL, C. J., G. J. BEGEMANN, R. W. MUIR, AND P. LOUW. 1981. The control of Simuliidae (Diptera, Nematocera) in South African rivers by modification of the water flow volume. Onderstepoort Journal of Veterinary Research 48:47–49.

It was found that the buildup of simuliid numbers after the construction of dams in the Vaal and Orange Rivers could be successfully prevented by periodic, artificially controlled reductions in the water levels in these rivers.

345. HUBBS, C. L., AND R. W. ESCHMEYER. 1938. The impoundment of lakes for fishing. Michigan Department of Conservation, Bulletin of the Institute for Fisheries Research 2. 233 pp.

Management techniques designed to increase the crops of valuable fishes in lakes are discussed. Major topics include the adjustment of environmental factors to enhance fisheries by control of water levels, weeds, and pollution, or by stocking, fertilizing or building artificial shelters. In general, stable water levels are preferred over fluctuating levels, which may limit spawning success. Biological effects of increasing or decreasing shoal areas are discussed.

346. HUBERT, W. A., AND J. N. KRULL. 1973. Seasonal fluctuations of aquatic macroinvertebrates in Oakwoods Bottoms Greentree Reservoir. American Midland Naturalist 90:177–185.

Oakwood Bottoms Greentree Reservoir is managed so as to attract waterfowl. Although acorns are the primary food of ducks utilizing these kinds of areas, macroinvertebrates also occur. Populations in permanent water areas (56 taxa) are distinctly different from populations in areas with temporary water conditions (20 taxa). The greatest number and biomass of invertebrates occurred from November to April with fingernail clams, amphipods, isopods, and pulmonate snails predominating. Sufficient quantities of macroinvertebrates are present to serve as a significant food source for waterfowl utilizing the reservoir during spring and fall migrations.

347. HUBERT, W. A., AND R. T. LACKEY. 1980. Habitat of adult smallmouth bass in a Tennessee River reservoir. Transactions of the American Fisheries Society 109:364–370.

The movement and distribution of radio-tagged smallmouth bass were evaluated for 4 years relative to water temperature, current velocity, turbidity, surface light intensity, reservoir elevation, bottom contours, substrate, and cover. Fluctuations in current velocity and reservoir levels influenced the depth distribution and movement of individuals. In Pickwick Reservoir, Tennessee, smallmouth bass moved to deeper water as current velocities increased. Bottom relief and cover were major variables affecting distribution and movement.

348. HUENER, J. D., AND J. A. KADLEC. 1992. Macroinvertebrate response to marsh management strategies in Utah. Wetlands 12:72–78.

The authors examined the response of aquatic macroinvertebrates to three marsh management strategies—conventional full pool management, full pool management with carp (*Cyprinus carpio*) control, and contour-furrowing (also with carp control). Significant differences in standing crops (both numbers and biomass) of invertebrates were observed among the three management strategies. The contour furrowed area had the highest standing crops of water column invertebrates, followed by the carp-controlled full pool area, whereas the conventionally managed area had the lowest standing crops. In the benthos, the two full pool areas (with and without carp) had higher standing crops than the contour furrowed area. Significant differences were noted in seasonal abundance, with all management practices having lowest densities of invertebrates in April and May. Implications for management include indications of the negative effects of carp and winter drawdowns on invertebrates in managed marshes.

349. HULSEY, A. H. 1956. Effects of a fall and winter drawdown on a flood control lake. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 10:285–289.

Drawdown of Lake Nimrod, Arkansas, in 1955–56 reduced the surface area by about 81%. More than 200,000 lb of rough fish (mostly smallmouth buffalo) were removed by commercial fishermen. A comparison of cove rotenone samples before and after drawdown showed an increased abundance of young-of-year black and white basses after drawdown, as well as a threefold increase in the standing crop of nonedible prey fishes (e.g., shads and minnows) and a 50% reduction in the biomass of edible forage species (buffalo and drum). The number of young catfish, common carp, and drum was reduced, but the abundance of young sunfishes and minnows increased. Sportfishing seemed to improve after drawdown (especially for white crappie), as indicated by boat dock owners. Because the primary purpose of Lake Ninrod was flood control, lowering water levels did not hinder any other beneficial use of the reservoir, and drawdown enhanced the reservoir fishery by improving water clarity and sport fish survival and harvest.

350. HULSEY, A. H. 1958. A proposal for the management of reservoirs for fisheries. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 12:132–143.

A fishery management plan for reservoirs is proposed that is dependent upon having a fish management pool and a tification is given to support the cost of having a cleared management pool in the bottom of the reservoir, as well as drainage facilities. A plan is also proposed for selective clearing of reservoir basins. The management program described is based on a philosophy of drastic manipulations of fish populations through fall and winter drawdowns, selective kills, partial kills, intensive sport and commercial fishing, and other management practices designed to favor the carnivorous fishes and reduce the total number and pounds of all fish so as to bring about a balance of the predator fishes with their food supply and maintain expanding fish populations. The drawdown is of paramount importance in the reservoir management scheme and, in the humid southeastern United States, it should begin immediately after Labor Day. The water level should be lowered to the fish management pool by October 15 or November 1. According to the size of the watershed, water levels can be allowed to return to normal after January 1. The cost of carrying out the management techniques in the fish management pool are minimal and most effective.

351. HUMPHRIES, R. L. 1961. Fishery research investigations. Small lake studies, 1960–61. North Carolina Wildlife Resources Commission, Raleigh. 17 pp.

Five small lakes in North Carolina were operated under fish management schemes in 1960 and 1961. Two lakes, Kinney Cameron and Crawford, were maintained as controls with no management being applied other than to allow public fishing. Two other lakes, Broadacres and Bagget's, were drained biennially and all small fish removed. Broadacres received this treatment in February 1961, having been previously drained in 1959. The remaining project lake, Crappie, was managed on a winter drawdown basis, being reduced in water volume by approximately 90% between November and February. The effects of biennial draining and culling are not clear, as controls were showing similar changes to drained lakes. No effects of winter drawdown are discussed, although data on angling pressure and success are presented.

352. HUMPHRIES, R. L. 1964. Small lake studies. North Carolina Wildlife Resources Commission, Federal Aid Project F-13-R. 32 pp.

Studies were conducted on many small, infertile lakes to determine the best type of regulations for angling and harvest, as well as the best procedures for stocking, manipulation of water levels, and associated operations. Low production in the small lakes—not unbalanced or overcrowded fish populations—was the factor most limiting fishing success. Winter drawdown was tested on Crappie Lake, but unfortunately the lake received fish from a washed-out pond, and results obtained must be viewed with caution. Fishermen on Crappie Lake caught more bluegills (per unit of effort) than fishermen on a control lake, but fewer than fishermen on another lake. Biennial draining of two lakes showed that the bass population could control the chubsucker population with the help of fish removal, but because chubsuckers supplied most of the food to bass, draining was believed to be detrimental.

353. HUNT, G. S., AND R. W. LUTZ. 1959. Seed production by curly-leaved pondweed and its significance to waterfowl. Journal of Wildlife Management 23:405–408.

For those areas where *Potamogeton crispus L.* is abundant and where water levels can be controlled, drawdown should be commenced shortly after the average last date when a killing frost would be expected. Water levels should be lowered so that 3-12 inches of water remain over the majority of the beds of this pondweed to stimulate greater seed production. Water depth should be maintained at a stable level throughout the growing season. If management is being practiced to provide food for dabbling ducks, water depths should not be increased following the growing season to a total of more than 12-18 inches in the areas where pondweed has mostly been produced, until near time for freezeup. If winters are severe, 1 to 3 ft more water should be added for a total depth of between 2 and 4.5 ft in order to avoid ice formation to the bottom.

354. HUNT, P. C., AND J. W. JONES. 1972. The effect of water level fluctuations on a littoral fauna. Journal of Fish Biology 4:385–394.

The abundance and species composition of littoral benthos in 1968–69 are compared with that recorded by other authors in 1951–52 and in 1957 and 1959. Water levels fluctuated 2 m before 1955, 4.3 m between 1955 and 1967, and about 2 m after 1967. In 1967–69, fluctuations were similar to those before 1955, except that lake levels were 3 m lower. Nevertheless, all major groups of animals recorded before fluctuations increased in 1955 were found in 1968–69, when fluctuations were reduced, and most were fully reestablished. Long-term effects of regulation included an increase in the total number and a decrease in the diversity of animals in the littoral zone. Numbers ranged from 1,504 to 6,488 organisms m^{-2} in 1951–52 and from 2,239 to 9,224 organisms m^{-2} in 1968–69. The 42% increase in numbers was accounted for by chironomids and oligochaetes exclusively. The gradual removal of silt by wave action and reestablishment of macrovegetation, after fluctuations in water level are reduced, should return the littoral zone to its original status, though it may take years. The reestablishment of *Gammarus pulex* and *Asellus meridianus* (perhaps the invertebrates most sensitive to water-level fluctuations) is indicative of decreased fluctuations in recent years. Comments on other major taxa are presented.

355. HUNT, P. C., AND J. W. JONES. 1972. The littoral fauna of Llyn Celyn, North Wales. Journal of Fish Biology 4:321–331.

Water-level fluctuations of up to 5.5 m and erosion caused by wave action created a uniformly barren littoral zone in which Lumbriculidae, Sphaeriidae, and Chironomidae were the only benthos present in significant numbers. As a result of the mortality of other benthic forms (mayflies, stoneflies, caddisflies, crustaceans), food and growth of trout were reduced.

356. HUNT, P. C., AND J. W. JONES. 1972. The profundal fauna of Llyn Tegid, North Wales. Journal of Zoology 168:9–49.

The seasonal distribution, abundance, and life cycles of benthic invertebrates of Llyn Tegid in 1968–69 are discussed, and the benthos and limnology of the lake are compared with that present in 1951–52, as documented by another biologist, before regulation reduced lake levels. Before regulation, the littoral zone of Llyn Tegid consisted of a gradually shelving rocky area. Lower mean lake levels after 1955 eliminated most of the littoral zone, leaving behind a steep-sided basin with a mud bottom. The profundal fauna increased significantly after 1951–52, primarily because of the increased abundance of oligochaetes and chironomids. Steep shorelines accelerated the fallout of organic matter to greater depths, and this acceleration may have accounted for the apparent increase in the production of profundal benthos. Terrestrial materials inundated during periods of high water were rapidly transported to the profundal zone.

357. HUPP, C. R. 1988. Plant ecological aspects of flood geomorphology and paleoflood history. Pages 335–356 *in* V. R. Baker, R. C. Kochel, and P. C. Patton, editors. Flood geomorphology. John Wiley & Sons, Inc., New York.

Floods have two long-term effects on bottomland woody vegetation. First, periodic floods of varying magnitude affect vegetation patterns, including the creation of new areas such as point bars for vegetation establishment such that suites of bottomland species with varying tolerances to flooding develop as bands parallel to the stream channel. Second, infrequent floods damage the bottomland plants such that their growth form reveals the effects of past floods either as outwardly evident stem deformations or as anomalous growth patterns in their serial tree ring sequence. Both vegetation patterns and vegetation damage allow for the interpretation of the hydrogeomorphic conditions on a bottomland site.

358. HUSTON, J. E. 1965. Investigation of two Clark Fork River hydroelectric impoundments. Proceedings of the Montana Academy of Sciences 25:20–40.

Ten years of fishery investigations conducted on Noxon Rapids and Cabinet George Reservoirs, Montana, are discussed. Cabinet George is a reregulating impoundment for Noxon Rapids and fluctuates little, whereas Noxon Rapids is a storage reservoir that fluctuated 5 ft weekly and 10 to 15 ft annually between 1958 and 1960. After 1961, Noxon Rapids was drawn down 35 to 40 ft in spring. Drawdowns reduced the surface area from 8,600 to about 5,500 acres. Before 1961 and a 33-ft drawdown, rooted and floating aquatic plants were abundant in littoral areas; after 1961, they were scarce. Aquatic vegetation was always present in Cabinet George Reservoir at depths of 5 to 20 ft and became more abundant after water levels were stabilized in 1961. Before 1961, rainbow trout were important to the fishery of Noxon Rapids but, after 1961, populations decreased, as indicated by catches of anglers and biologists. Fall-spawning species such as Dolly Varden, brown trout, and lake whitefish adapted to the altered environment, but few rainbow trout spawned successfully in Noxon Rapids.

359. HYNES, H. B. N. 1961. The effect of water-level fluctuations on littoral fauna. Verhandlungen Internationale Vereinigung Limnology 14:652–656.

In 1955, a dam was installed in the outlet of Llyn Tegid (Lake Bala), Great Britain, and annual water-level fluctuations increased from about 2 m (before 1955) to about 5 m thereafter. Typical fluctuations involved a winter minimum and summer maximum. The first dewatering stranded and killed enormous numbers of animals, including small fish—as did subsequent fluctuations. Although water-level fluctuations greatly altered the species composition of the community and completely or almost completely eliminated sponges, flatworms, leeches, gastropods, amphipods, mites, stoneflies, mayflies, some bugs, and caddisflies, the density of bottom animals was not reduced but increased along shorelines with sparse cover because of a great abundance of oligochaetes. Two new species of worms appeared and became abundant. Low water levels altered the littoral substrate significantly. Lower portions of stony shores were silty, and sheltered stone-covered shores gave way to gritty mud at about 1 m and to soft mud at greater depths.

360. IL´INA, L. K. 1962. Effect of the 1960 water level on the spawning of fishes in Rybinsk Reservoir. Byulleten' Instituta Biologii Vodokhranilischcha Akademii Nauk SSR 13:26–30. (In Russian)

Because water levels were 2 m lower in 1960 than in 1959, the spawn of many fishes deteriorated. Spawning success, as estimated from the proportion of fish with uncast spawn, agreed well with estimates based on the abundance of young-of-year fish. The loss of spawning areas had the greatest detrimental effect on the spawning of *Blicca* Bjoerkna, *Abramis brama*, *Leuciscus idus*, and *Esox lucius*; the spawning of *Rutilus rutilus* and *Perca fluviatilus* was largely unaffected. (From Referativmyi Zhurnal. Biologiya 17113; Biological Abstract 46:550).

361. IL´INA, L. K., AND N. A. GORDEYEV. 1972. Water-level regime and the spawning of fish stocks in reservoirs. Journal of Ichthyology 12:373–381.

A review of information on spawning conditions required by phytophilous fishes forms the basis for reconciling the interests of the fishing industry and those of other water users. Water levels are controlled primarily to generate power or to provide water for navigation and irrigation. Interests of the fishing industry typically oppose these "normal" operations, and no consideration is given to the needs of fish. Water-level fluctuations that destroy littoral vegetation important to fish spawning or that cause mass mortality of eggs have been documented. Winterkill caused by drawdown after ice formation has also been observed. Optimum spawning conditions, as outlined by many biologists, require high stable water levels in the spring, throughout the spawning season, followed by reductions of 1 m in the summer and 1 m just before reservoirs freeze over. Such a regime is not practical for all reservoirs in a chain because the lowering of levels in one reservoir merely raises them in the next reservoir downstream. Volume released without benefit to other users therefore must be progressively increased for downstream reservoirs. As reservoirs age, the "optimum" regime of water-level fluctuations required to benefit fish spawning may change. In the Rybinsk reservoir, for example, terrestrial vegetation will not grow on sands that remain after years of erosion of the banks and bottom. Because optimum water-level regimes vary among reservoirs, plans should be tailored for local conditions. Some aspects of the general outline for regulating water levels to benefit fish spawning have merit and should be considered. These include (1) the elimination of short-term reductions of water levels during fish spawning, (2) fall discharge of some water to prevent winterkill under ice, (3) the establishment of minimum pools, and (4) drawdown to uncover shallows of new reservoirs and lessen erosion. More emphasis must be placed on artificial propagation of fish.

362. IL´INA, L. K., AND A. G. PODDUBNYI. 1963. Water levels of the upper Volga Reservoirs and their control in the interest of hatcheries. Pages 47-56 *in* Fisheries of the inland waters of the USSR. Akademii Nauk SSR, Moscow. (In Russian)

Each reservoir on the Upper Volga is characterized by a particular water level whose fluctuation influences the environment of fish during the spawning and overwintering seasons. The abundance of various year-to-year classes is greatly affected by water-level conditions. With a water level exceeding that of the preceding year by 1.5 to 2.5 m, the fish yield in the Rybinsk Reservoir was high. In years of relatively low levels, the yield was average—sometimes even large—in comparison with preceding years in which the level was high. With very low water levels, the yield was average. Fish abundance was low in years when the maximum height of the water was somewhat lower than in preceding years. A drop in level during fall and winter affects fish production in two ways: (1) fish remaining in residual waters of the inshore zone after the drying up of flood waters die, and (2) following a substantial drop in water level during the period of ice cover, oxygen deficient waters fill the reservoir basin and cause the death of fish. It is recommended that the level of Rybinsk Reservoir remain unchanged from filling in spring until July. If filling cannot be accomplished, seasons of high water level should be alternated with seasons of low water level.

363. IOFFE, T. 1966. Formation and classification of the bottom fauna in U.S.S.R. reservoirs. Pages 18–224 *in* P. V. Tyurin, editor. The Storage Lakes of the U.S.S.R. and their importance for fisheries. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian)

The development of benthic invertebrate faunas in Soviet reservoirs is discussed. Topics include the origins, composition, quantitative development, seasonal changes, and enrichment of benthos. Water-level fluctuations in some reservoirs cause deposition of silt upon which herbaceous vegetation may develop. Periodic flooding of this type of vegetation improves the food resource for benthos, benthos production, and the productivity of the entire reservoir. For example, in Tsimlyanshoe Reservoir, shrub land flooded for 2 months contained 18,000 benthic organisms m^{-2}, with a wet weight of more than 315 g. A benthic biomass of 123 g m^{-2} was observed on tree surfaces in Rybinsk Reservoir. Decreased water levels exposed large areas of bottom and caused mass mortality of benthic invertebrates, especially when ice formed after winter drawdown.

364. IRVINE, J. R., AND P. R. HENRIQUES. 1984. A preliminary investigation on effects of fluctuating flows on invertebrates of the Hawea River, a large regulated river in New Zealand. New Zealand Journal of Marine and Freshwater Research 18:283–290.

An experiment with flow changing at 3, 9, and 18 $m^3\ s^{-1}\ h^{-1}$ on consecutive days failed to produce any measurable effect on benthic invertebrates in the regulated Hawea River, New Zealand, but did result in increased numbers of drifting chironomid larvae, trichopteran larvae, and oligochaetes compared to days when flow was stable. Drift densities were at least as high on the day when flow changed at 3 $m^3\ s^{-1}\ h^{-1}$ (minimum flow 15 $m^3\ s^{-1}$, maximum flow 30 $m^3\ s^{-1}$) as on subsequent days when flow changed at 9 and 18 $m^3\ s^{-1}\ h^{-1}$ (minimum flows both 15 $m^3\ s^{-1}$, maximum flows 60 and 105 $m^3\ s^{-1}$, respectively) indicating that rapid rates of change of flow may not necessarily cause more benthic invertebrates to enter the drift than slow rates of change. Fluctuating flows resulted in more animals entering the drift at a site 5 km below a control dam than at a site 0.8 km below the dam. Drift of noninvertebrate organic matter (mainly periphyton) showed similar patterns to invertebrate drift. It is suggested that most of the invertebrates displaced by the flow fluctuations were associated with periphyton in the river and, as such, these taxa may have been more prone to being swept away during flow increases than other invertebrate taxa.

365. IRWIN, W. H. 1956. The management of large impoundments for fish production. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 10:271–275.

Reservoir fertility is limited by the fertility of the watershed after impoundment, but initially bottomlands usually contain a large supply of detritus and living vegetation that decay and increase production at all trophic levels. Because the supply of fish food in established reservoirs seldom keeps pace with demand, much attention is given to techniques of increasing harvest. Techniques discussed here include advertisement, fishermen education, fish concentration (with brush shelters), commercial fishing, stocking predatory fishes, water-level fluctuation, rotenone treatment, and draining and filling. Drawdown can serve to concentrate fish for increased predation or to disrupt spawning of some species. Draining is a last resort but can increase fish production on refilling if terrestrial plants such as sorghum, oats, smartweed, and millet are established on exposed areas. Maintenance of a slow rate of water exchange after filling of the basin is important so that nutrients are retained as long as possible.

366. ISOM, B. G. 1971. Effects of storage and mainstream reservoirs on benthic macroinvertebrates in the Tennessee Valley. Pages 179–191 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

Various studies have demonstrated that stream benthos in new reservoirs may be limited or eliminated by increased siltation, decreased water flow, water-level fluctuation, low oxygen concentrations, increased hydrostatic pressure, or reduced light. Although typical stream faunas are virtually eliminated by impoundment, fishing in TVA impoundments improved 50-fold over that in the original rivers due to short food chains linking plankton to fish.

367. JACKSON, S. D., AND K. S. LUBINSKI. 1984. Effects of a short-term drought and subsequent low flows on fish activity in main channel border habitats of the lower Illinois River. Page 12 *in* Proceedings of the Mississippi River Research Consortium, Volume 16, La Crosse, Wisconsin, April 18–20, 1984.

Hoop nets were used to monitor fish activity in main channel border habitats of the lower Illinois River between June 15 and November 3, 1983. Species composition in the catch changed drastically at the onset of an unusual low flow period. Freshwater drum was the predominant species collected before July 20 when normal flow conditions prevailed, while black crappies and other centrarchids composed most of the catch during the following 3-month period. Total catch (lb/net-day) of all species did not appear to be affected by the low flow, but a comparison of day versus night collection results indicated that more and smaller fish were day-active, while fewer but larger fish were active at night. Total catch peaks, particularly during the low-flow period, closely followed days when backwater temperatures were several Celsius degrees higher than those in the main channel border. We concluded that during periods of low flow, lower Illinois River main channel borders provide suitable, if not preferred, habitat for species that are usually associated with backwaters. From a broader perspective, these results illustrate that functional roles of floodplain river habitats can be flow dependent even near the low end of the flow spectrum. (Abstract only)

368. JACKSON, S. D., AND K. S. LUBINSKI. 1985. Predicting main channel border velocities from navigation pool water levels. Page 14 *in* Proceedings of the Mississippi River Research Consortium, Volume 17, La Crosse, Wisconsin, April 17–19, 1985.

Summer and fall hoop net catches from 1980 through 1984 at Illinois River mile 3.0 indicated that crappies and bluegills utilized main channel border habitats when water velocities dropped below approximately 0.2 m/s. We explored the relations between lower Illinois River and Mississippi River Pool 26 water level gage readings and velocities to determine if velocities were predictable from a single gage reading or combination thereof, and if possible, to develop conversion factors for interpreting past and future habitat utilization in the absence of velocity measurements. Gage readings (in feet above MSL) at Hardin, Illinois (Illinois River mile 21.6), Winfield, Missouri, Grafton, Illinois and Lock and Dam 26 (pool; Mississippi River miles 241.2, 218.0, and 203.0, respectively), as well as elevation differences between Hardin and Grafton and Winfield and Dam 26 were independent variables in correlation and multiple regression analyses. Surface velocities at a lower Illinois River water quality monitoring station and velocities at the hoop net site, at the depth of the hoop net mouth (5 ft), were dependent variables. Best velocity predictions were made by using Hardin–Grafton elevation differences: (N = 112, r^2 = 0.76), $Vwq = (HG)(0.159) + 0.212$ where Vwq was the surface velocity at the water quality station and HG was the elevation difference between Hardin and Grafton water levels. Velocities at the hoop net mouths were typically about 76% of those at the water quality site. During extremely low Illinois River flows, stage increases in the Mississippi River actually forced Grafton water levels to higher elevations than those upstream at Hardin. (Abstract only)

369. JACKSON, S. W., JR. 1957. Comparison of the age and growth of four fishes from Lower and Upper Spavinaw Lakes, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 11:232–249.

Growth rates of gizzard shad, spotted sucker, largemouth bass, and white crappie from a new reservoir (Upper Spavinaw) and from an old reservoir (Lower Spavinaw) were compared. Prolonged drawdown and refilling of Lower Spavinaw Lake increased the growth rates of all species in a manner similar to that observed in the new Upper Spavinaw Lake after initial impoundment. Largemouth bass spawned successfully in the new lake after impoundment, at least during the first 2 years. A similar successful spawn was observed in the older lake after a 2-year drawdown and subsequent refilling. Lowering water level in fall and gradually raising it after largemouth bass spawn seem to greatly enhance reproductive success of bass. Large predators dominated the fish community in Upper Spavinaw Lake during early impoundment and in Lower Spavinaw Lake after drawdown. Seasonal changes in water level may simulate the impoundment of new reservoirs by providing conditions that favor more opportunistic species.

370. JANISCH, J. L. 1976. Fish management at Starve Hollow Lake, 1970–75. Indiana Department of Natural Resources. 10 pp.

Fall drawdowns of Starve Hollow Lake decreased surface area by 50% for 4 months. The creel survey revealed an increase in the average size of bluegills harvested, although the total numbers caught decreased. Fishing pressure and fishing success decreased. After 5 years of management, growth and condition factors of largemouth bass, bluegills, and channel catfish were better than average growth and condition factors for fish of southern Indiana. Desirable changes in the fish population were attributed to fall drawdowns and a 14-inch length limit for bass. Other management practices included the addition of structure and the stocking of channel catfish and northern pike.

371. JAWORSKI, E., C. N. RAPHAEL, P. J. MANSFIELD, AND B. B. WILLIAMSON. 1979. Impact of Great Lakes water levels on coastal wetlands. Department of Geography–Geology, Eastern Michigan University, Ypsilanti. n.p.

Field data regarding interrelationships between coastal landforms, wetlands, and lake level fluctuations were collected over a 2-year period in Lakes Michigan, Huron, St. Clair, and Erie. The geomorphology of seven study areas was mapped, and descriptive models of four coastal wetland types were developed. With the aid of aerial photography and field bisects, plant communities were identified, historical vegetation distributions mapped, and transects reconstructed. As the Great Lakes presently oscillate from one extreme to another over a hydroperiod of 8 to 12 years, water levels fluctuate 1 to 2 m and the total wetland area increases or decreases by 12.9%. A field model was developed that predicts the displacement of wetland plant communities on Dickinson Island as lake levels change periodically. Fluctuating water levels not only disrupt hydrarch succession, but inhibit senescence, which contributes to the high primary productivity so characteristic of freshwater wetlands.

372. JEARLD, A., JR. 1970. Fecundity, food habits, age and growth, length–weight relationships and condition of channel catfish, *Ictalurus punctatus* (Rafinesque), in an 3,300-acre turbid Oklahoma reservoir. M.S. Thesis, Oklahoma State University, Stillwater. 78 pp.

Various aspects of the life history of the channel catfish in Lake Carl Blackwell, Oklahoma, are discussed. Data are presented on fecundity, food, age and growth, length–weight relation, and condition. Decreased growth during the study coincided with decreasing water levels.

373. JENKINS, R. M. 1967. The influence of some environmental factors on standing crop and harvest of fishes in U.S. reservoirs. Pages 298-321 *in* C. E. Lane, Jr., editor. Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

Effects of nine environmental factors on standing crop and harvest of sport and commercial fishes in reservoirs were examined by regression. Factors considered were water-level fluctuation, shoreline development, storage ratio, area, mean depth, total dissolved solids, reservoir age, outlet depth, and growing season. As a single variable, water-level fluctuation had no significant effect on standing crop or harvest except in 70 carbonate and bicarbonate chemical-type reservoirs, where water-level fluctuation was negatively correlated with standing crop (r = -0.225; $P > F = 0.0047$). A multiple regression of commercial harvest on mean depth, water-level fluctuations (vertical), storage ratio (reservoir volume divided by average annual discharge), and growing season (average number of days between the first and last frosts of the year) was significant ($R^2 = 0.48$; $P > F = 9 \times 10^{-5}$) and was one of the four most useful equations developed. Sport-fish harvest was directly related to storage ratio, which in turn was inversely related to clupeid standing crop and commercial harvest.

374. JENKINS, R. M. 1969. Large reservoirs—management possibilities. Proceedings of the Midwest Conference of the Southeastern Association of Game and Fish Commissioners 36:82–89.

A number of fishery management practices for reservoirs are discussed, including fishing regulations, stocking, fertilization, optimum timber clearing, draining or population removal, aquatic weed control, brush shelters, artificial destratification, drawdown, and water-level manipulation. Drawdowns to aerate mud bottoms, to facilitate seeding of herbaceous vegetation and removal of rough fishes, and to concentrate forage should become increasingly useful to managers. Although uncontrolled water-level fluctuation may be harmful to sport fishes, soundly conceived and implemented schemes can be effective. Spring drawdowns are not compatible with the spawning requirements of black basses and crappies and have not been consistently successful in controlling the spawning of rough fishes. In suitable reservoirs, extreme drawdown followed by the planting of herbaceous plants on exposed mud bottoms, refilling, and stocking of desired species is one of the important management tools available to fishery managers today.

375. JENKINS, R. M. 1970. Reservoir fish management. Pages 173–182 *in* N. G. Benson, editor. A century of fisheries in North America. American Fisheries Society, Special Publication 7.

Efforts of fishery managers to meet increasing demands for angling on reservoirs are recounted. Drawdowns that reduce surface area by 10% to 80% in late summer or fall can be effective, especially when combined with fishery improvement techniques such as the planting of grasses and removal of rough fishes. Ideally, forage fishes are concentrated for predatory sport fishes as waters recede, and large portions of bottom areas are aerated. Although drawdown to control spawning of common carp and other rough fishes has produced erratic results, the drawdown and refilling of reservoirs improve water clarity and fishing success for 1 to 4 years. Pronounced rises in water levels in spring have been directly correlated with strong year classes of largemouth bass, white bass, and green sunfish and inversely correlated with strong year classes of bluegills and longear sunfish. Winter drawdowns have been effective in reducing populations of shad and small sunfishes. Short-term (2–3 months) drawdowns seldom produce measurable results. Although uncontrolled water-level fluctuation can be harmful to fish populations, carefully controlled changes in water level can be the most effective management tool available. Heavy growths of aquatic vegetation have been successfully controlled by increased fluctuation of water levels in shallow impoundments in which water levels were stable.

376. JENKINS, R. M. 1970. The influence of engineering design and operation and other environmental factors on reservoir fishery resources. Water Resources Bulletin 6:110–119.

The apparent effect of reservoir environmental variables (i.e., water-level fluctuation, mean depth, outlet depth, thermocline depth, surface area, storage ratio, shoreline development, total dissolved solids, growing season, and reservoir age) on the standing crop of fish in 140 large reservoirs was examined by partial correlation and multiple-regression analyses. Water-level fluctuation had a positive influence on the biomass of spotted gar, flathead catfish, black basses, and white crappies. It had a negative influence on the standing crops of gizzard shad, northern pike, pickerels, carpsuckers, and sunfishes. In reservoirs with a stable thermocline, the fluctuation of water levels had a significant positive influence ($P < 0.05$) on the standing crops of largemouth bass and white crappies.

377. JENKINS, R. M. 1973. Reservoir management prognosis: Migraines or miracles. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 27:374–385.

Problems and progress in the management of fisheries in reservoirs of the southern United States are reviewed. Trends in data on the standing crop of fishes in 172 reservoirs are discussed with reference to potential production of sport fishes and to physicochemical variables. Certain management techniques that involve manipulation of controllable environmental factors deserve more emphasis. Deliberate, long-term management of the fluctuation zone of reservoirs is a critical need, and quantitative measurements of natural vegetation in this zone should be made to determine which species of plants provide optimum spawning habitat and cover for desirable sport fishes. Cultivation of seasonally exposed portions of reservoirs should enhance the production of sport fish, other factors being equal. Fish attractors and standing timber have helped increase harvest but drawbacks exist (e.g., structures that have deteriorated from exposure during drawdown must be refurbished).

378. JENKINS, R. M. 1975. Black bass crops and species associations in reservoirs. Pages 114–124 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

The standing crop estimates based on sampling conducted by many fishery agencies involving recovery of fishes after rotenone application in coves or open water areas enclosed by block nets were analyzed. Correlation analyses revealed that certain reservoir characteristics were significantly related to bass crops. Spotted bass crops were positively related to average depth. Smallmouth bass crops were positively related to water-level fluctuations.

379. JENKINS, R. M., AND D. I. MORAIS. 1971. Reservoir sport fishing effort and harvest in relation to environmental variables. Pages 371–384 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

The effect of 10 environmental variables on sport fish harvest and angler effort were examined by logarithmic partial correlation and multiple-regression analyses. Independent variables included area, mean depth, outlet depth, thermocline depth, water-level fluctuation, storage ratio, shoreline development, total dissolved solids, growing season, and reservoir age. Harvests of black basses and sunfishes were inversely correlated with reservoir age, but the relation was not always obvious in single reservoirs because of occasional strong year classes. Vertical fluctuation of water levels was negatively related to the harvest of bullheads ($P < 0.20$) and white bass ($P < 0.05$).

380. JENSEN, K. W., AND P. AASS. 1958. Bottom conditions in regulated lakes. Jeger Fisker (2):44–45. (In Swedish)

Bottom conditions in 11 lakes, impounded for hydroelectric purposes, were studied for many years. Fishing, especially with seines and bottom nets, was difficult, expensive, and often impossible in impounded lakes, but the effect was modified by time. In Lake Namsvatn, which was impounded in 1906, the dead birch forest first disappeared in the late 1940s, but among bushes and trees, the birch is one of the species that seem to decompose quickest after impoundment. Fir and juniper decompose slowly, in spite of being covered every winter and lying dry every summer. In sheltered areas of Lake Namsvatn, juniper and even heather (*Calluna vulgaris*) that were killed in 1906 were still a nuisance to the gillnet fishery for trout and char in 1957. (Abstract adapted from Fraser 1972)

381. JEPPSON, P. 1957. The control of squawfish by use of dynamite, spot treatment, and reduction of lake levels. Progressive Fish-Culturist 19:168–171.

Adequate control of squawfish populations required an understanding of their ecology in each body of water and the successful destruction of adult fish and their young during spawning. Spawning in Hayden Lake occurred on wave-washed rubble from mid-June to mid-July, at depths less than 1 ft. Incubation lasted 7 to 8 days at water temperatures of 60 to 68 °F. A slight reduction in lake levels caused mortality by desiccation, and a drawdown of 2 inches per day for about a month after water temperatures reached 60 °F destroyed nearly all of the squawfish spawn in northern Idaho lakes.

382. JESTER, D. B. 1971. Effects of commercial fishing, species introductions, and drawdown control of fish populations in Elephant Butte Reservoir, New Mexico. Pages 265-285 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

From 1963 to 1970, managers implemented programs to harvest rough fish (smallmouth buffalo, common carp, and carpsuckers) commercially, to introduce white bass and walleyes, and to stabilize water levels during the spawning seasons of largemouth bass, white crappies, and black crappies. Larger populations of crappies or largemouth bass did not result from stabilized water levels, perhaps because of predation by flathead catfish. Crappie populations varied with large changes in the volume of water stored, responding to crowding and relief from crowding.

383. JESTER, D. B., AND B. L. JENSEN. 1972. Life history and ecology of gizzard shad, *Dorosoma cepedianum* (Le Sueur), with reference to Elephant Butte Lake. New Mexico State University Agricultural Experiment Station, Research Report 218. 56 pp.

All aspects of the life history of gizzard shad were examined, and growth was calculated. In 1964, 1968, and 1971, enormous numbers of gizzard shad died after the volume of the reservoir was greatly reduced (from 150,000 to 50,000 acre-feet) in July and August. Shad and many other fishes apparently died from nitrogen bubbles in their blood, which resulted from the activity of coliform bacteria. The bacterium *Aerobacter aerogenes* seemingly causes gas bubble disease only when fish are subjected to severe environmental stress such as crowding. Mortality was wavelike, proceeding down the reservoir from the upper reaches to the dam.

384. JOANEN, T., AND L. L. GLASGOW. 1965. Factors influencing the establishment of widgeon grass stands in Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners 19:78–92.

Both tank and pond studies at Grand Chenier, Louisiana, were performed after the Louisiana Wildlife and Fisheries Commission began an intensive waterfowl management program in 1954. Widgeon grass (*Ruppia maritima*) grew best in about 24 inches of water. No single factor was found to be more detrimental in the establishment or elimination of stands of widgeon grass than excessive or irregular water fluctuations. Six years after the impoundments were created, duck use increased by 600%.

385. JOHNSGARD, P. A. 1956. Effects of water fluctuation and vegetation change on bird populations, particularly waterfowl. Ecology 37:689–701.

The biotic effects of water fluctuation were studied in Grant County, Washington, during 1953–54. The areas studied were near O'Sullivan Dam, which was constructed between 1947 and 1951. The reservoir flooded many of the original sand dune potholes, and the water levels of those remaining have been materially affected. Flooding of the larger potholes greatly reduced total waterfowl production and forced breeding waterfowl to remain in smaller potholes. The smaller potholes have become much more productive. Attempts to preserve the original wildlife and vegetation of the area would be futile under present conditions of water fluctuation.

386. JOHNSON, D. L., AND R. A. STEIN, EDITORS. 1979. Response of fish to habitat structure in standing water. North Central Division, American Fisheries Society, Special Publication 6. 77 pp.

Papers in this symposium deal with the effects and importance of structure—defined as any material or condition that affords fish protection, food, security, or reference points by reducing light or providing a discontinuous substrate—to fishes in lentic systems. Structure may improve reproduction (by affording more spawning sites), accelerate growth (by increasing fish-food production and decreasing activity of fish), decrease mortality (by providing refuge for small fish), and increase harvest (by concentrating sport fishes). Changes in the amount and complexity of cover and how these changes influence predator–prey and other important relations that affect sport fish production and harvest are discussed in several papers. Because changes in the amount and complexity of structure can be controlled to some extent by manipulating water levels in reservoirs, papers in this symposium help to identify some of the ways in which water-level fluctuations influence fish communities.

387. JOHNSON, F. H. 1957. Northern pike year-class strength and spring water levels. Transactions of the American Fisheries Society 86:285–293.

Relation between spring water levels and the strength of year classes of northern pike (*Esox lucius*) produced in Ball Club Lake of north-central Minnesota are considered for 7 years between 1945 and 1952. The years are ranked according to water conditions, including height during spawning and fluctuation during egg incubation, and according to the strength of year classes produced as judged from their abundance in the darkhouse spearing catch. Comparison of these two rankings by a rank difference correlation shows a correlation of 0.61. It is concluded that a high spring water level during spawning and a small decline in the levels during egg incubation represent good conditions for the production of a strong northern pike year class.

388. JOHNSON, F. H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota, and connecting waters. Transactions of the American Fisheries Society 90:312–322.

Studies of the effects of substrate on the survival of walleye eggs revealed that survival to the eyed stage was greatest on gravel rubble bottoms (survival averaged 25%). Survival on a muck bottom was as low as 0.62%. Walleyes selected gravel bottoms when available, and most eggs were deposited at depths of 12 to 30 inches. The weak year class of 1958 may have resulted from low spring water levels that eliminated much of the preferred spawning area.

389. JOHNSON, F. H., R. D. THOMASSON, AND B. CALDWELL. 1966. Status of the Rainey Lake walleye fishery, 1965. Minnesota Department of Conservation Division of Game and Fish, Research Planning Investigational Report 292. 22 pp.

The walleye population of Rainey Lake was considerably lower in 1965 than in 1959, and the commercial catch (per 1,000 ft of net) was directly correlated with mean water levels during walleye spawning 4, 5, and 6 years earlier. A decrease in walleye stock followed 3 years of low spring water levels and poor reproduction. Spring water levels sufficient to inundate the best spawning shoals should be maintained every year.

390. JOHNSON, J. N. 1974. The effects of water level fluctuations on the growth, relative abundance, mortality, and standing crop of fishes in Lake Carl Blackwell, Oklahoma. M.S. Thesis, Oklahoma State University, Stillwater. 72 pp.

Decreased water levels from 1962 to 1967 were related to reduced growth of white crappies (age I), channel catfish (I, II, VI), and common carp (I and III). Increased growth of yearling and older white crappie probably resulted from increased availability of prey immediately after drawdown. Production of the littoral zone apparently was poor after drawdown, and this may have contributed to slow growth of young common carp. Improved growth of most yearling and older channel catfish and common carp was attributed to drawdown, which supposedly concentrated prey and thereby made them more accessible to predators. Decreased abundance of channel catfish, river carpsucker, and largemouth bass probably resulted from poor reproductive success due to fluctuation of water level during spawning seasons. Reduced populations of gizzard shad suggested that receding water levels increased their vulnerability to predators.

391. JOHNSON, J. N., AND A. K. ANDREWS. 1973. Growth of white crappie and channel catfish in relation to variations in mean annual water level of Lake Carl Blackwell, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 27:767–776.

A causal relation between water levels and the growth of crappies from 1962 to 1971 is documented. Decreased growth of yearling crappies between 1966 and 1971 has resulted from a reduced production of benthos in the littoral zone as water levels receded. Increased growth of yearling and adult crappies in the 1960s may have resulted from increased availability of prey fishes during and immediately after decreases in water level. Growth of channel catfish was not significantly correlated with mean water levels, but significant negative correlations were found between growth increments and mean water levels for 2-, 3-, and 6-year-old flathead catfish. Declining water levels reduced intra- and interspecific competition among young fishes by increasing predatory mortality of young catfish and by decreasing spawning success.

392. JOHNSON, R. R., AND J. J. DINSMORE. 1986. Habitat use by breeding Virginia rails and soras. Journal of Wildlife Management 50:387–392.

Habitat use by breeding Virginia rails (*Rallus limicola*) and soras (*Porzana carolina*) was studied in northwestern Iowa. The Virginia rail was found in water depths of 40.3 cm with a standard deviation of 29.1 cm and the sora in depths of 38.4 cm with a standard deviation of 16.1 cm. On marshes where drawdowns or other major habitat manipulation is contemplated, action should be initiated before April 15 to avoid disrupting territorial establishment in breeding, because little is known of rail nest site fidelity; therefore, partial drawdowns may be preferable. Although rails tolerate declining water levels after nest initiation, the effect of drawdown after nest initiation on renesting and broodrearing requires further attention. Reflooding in late August should provide attractive habitat for fall migrants.

393. JOHNSON, W. L. 1944. Limnological studies of a new artificial lake in southwestern Indiana. Ph.D. Thesis, University of Indiana, Indianapolis. 48 pp.

The draining of Greenwood Lake, Indiana, to a very low level in 1940 directly or indirectly caused the failure of the 1940 year class of black crappies and white crappies. The period of refilling in 1941 and 1942 was not favorable for growth. In fact, the drawdown period of 1940 probably was better for growth than the refilling period. Growth of crappies was greatly retarded after July 1940 through the fall due to crowding and perhaps accumulations of metabolic wastes. Poor growing conditions during reflooding of the reservoir probably resulted from poor production of fish-food organisms in Greenwood Lake.

394. JOHNSON, W. L. 1945. Age and growth of the black crappie of Greenwood Lake. Investigations of Indiana Lakes and Streams 2:298–324.

The age and growth rate of 1988 crappies from Greenwood Lake was determined. The time of annulus formation is discussed. Greenwood Lake began to fill in spring 1938 and became nearly full in June 1939. The lake drained in 1940 and filled again in 1941 and 1942. The 1939 growing season was more favorable for crappie growth than the growing season of any other year. Despite the retardation of growth in late summer caused by the draining of the lake, 1940 was more favorable for growth than either of the following 2 years. The lowering of the lake seems to have directly or indirectly caused the disappearance of the 1940 year class of black and white crappies. The retarded growth after July 1940 was probably the result of crowding the fish, which may have resulted in an accumulation of unoxidizable metabolic waste or other unfavorable physiological effects. High temperatures may have been contributory. Food competition and the effect of increased turbidity in foraging are discounted as possible causes.

395. JONES, W. E., AND J. H. SELGEBY. 1974. Invertebrate macrobenthos of Lake Oahe, 1968–69. U.S. Fish and Wildlife Service, Technical Paper 73. 11 pp.

The early faunal composition of benthos in Lake Oahe is described on the basis of 450 samples. Chironomids and oligochaetes predominated, numerically and gravimetrically. Greater abundance and biomass in certain areas (Moreau River Embayment) were attributed to large amounts of terrestrial vegetation that had recently been inundated.

396. JONES, W. W., N. O'REILLY, R. PITT, R. WEDEPOHL, D. KNAUER, AND S. PETERSON. 1986. Lake sediment management workshop summary. Pages 431–435 *in* G. Redfield, J. F. Taggart, and L. M. Moore, editors. Lake and reservoir management. Volume 2. Proceedings of the Fifth Annual Conference and International Symposium of the North American Lake Management Society, Geneva, Wisconsin, November 13–16, 1985.

Sediment consolidation techniques are designed to reduce sediment volumes in a lake. In response to a number of advertised commercial methods for reducing the volume of bottom muds, Wisconsin Department of Natural Resources performed a number of laboratory studies on the following methods: (1) bubbling air through the water, (2) adding ozone or hydrogen peroxide to the sediments, (3) adding nitrate to the sediments to act as an electron accepter, and (4) adding decomposed organisms. Methods 1 and 4 were ineffective in reducing sediment volume. Method 2 seems to be impractical as a management technique. Method 3 demonstrated some promise but would require additional research before it could be widely used as a management technique. Laboratory studies also demonstrated that approximately 50% of sediment can be reduced in volume if the sediments can be frozen. Sediment freezing would require drawing down lake level and fauna allowing the muds to freeze over the winter.

397. JUDD, J. B., AND S. H. TAUB. 1973. The effects of ecological changes on Buckeye Lake, Ohio, with emphasis on largemouth bass and aquatic vascular plants. Ohio Biological Survey, Biological Notes 6. 50 pp.

Buckeye Lake, Ohio, had fewer but larger largemouth bass in 1970 than in previous years, and the growth of bass was improved. Changes in the bass population resulted from ecological changes in the artificial lake after 1947. Clearing of the bottom and a decrease in the extent and number of aquatic macrophytes reduced the carrying capacity of the lake for largemouth bass. Before 1926, macrophytes expanded their range in the lake from late summer through November each year as the lake level was reduced. This annual expansion of vegetation ceased after 1926, because water levels were maintained at stable levels through November. Turbidity was increased as a result of decreased aquatic vegetation, clearing of the bottom, increased wave action, and increased plankton abundance.

398. JUNE, F. C. 1970. Atresia and year-class abundance of northern pike, *Esox lucius*, in two Missouri River impoundments. Journal of the Fisheries Research Board of Canada 27:587–591.

Atresia or intraovarian degeneration of eggs in northern pike was associated with low abundance of young-of-year and yearling pike in 1966–68. The high incidence of atresia in ovaries probably resulted from spawning interruptions that were associated with fluctuations in water level or temperature. Sudden lowering of water levels occasionally reduced the number of gravid females in spawning areas or prevented them from returning to spawning sites. A 1-m drop in water level in 6 hours seemingly reduced the percentage of females with normal ovaries from 94 to 28.

399. JUNE, F. C. 1974. Ecological changes during the transitional years of final filling and full impoundment (1966–70) of Lake Oahe, an upper Missouri River storage reservoir. U.S. Fish and Wildlife Service, Technical Paper 71. 57 pp.

Baseline data on the physicochemical limnology and plankton dynamics of Lake Oahe during filling of the reservoir are presented. Waters reached operational levels by 1967 and fluctuated an average of 3.9 m annually. Multivariate analyses indicated that zooplankton abundance at lower reservoir stations was inversely related to summer discharge of water. The inverse relation may have resulted from the loss of zooplankton or food of zooplankton through the dam. Water temperature and turbidity also were important factors affecting zooplankton abundance, and both water temperature and turbidity may be controlled occasionally by rates of water release.

400. JUNE, F. C. 1976. Changes of young-of-the-year fish stocks during and after filling of Lake Oahe, an upper Missouri River storage reservoir, 1966–1974. U.S. Fish and Wildlife Service, Technical Paper 87. 25 pp.

Trawling samples of young-of-year fishes in Lake Oahe showed that the abundance of most species increased while the reservoir was filling (yellow perch and emerald shiners were most abundant) but later declined. Abundance was especially high when water covered vegetation in spring and was maintained at stable levels through May or longer. After the reservoir was filled, littoral spawning and nursery habitats were degraded and reduced. As a result, the abundance of young-of-year fish decreased. Large populations of species favored by inundation are not likely to be produced under the regime of water-level fluctuation of the mid-1970s, but favorable spawning and nursery conditions (such as freshly flooded grass areas) will probably lead to the formation of occasional strong year classes.

401. 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 9:315–351.

Analysis of Amazonian freshwater fish exhibited great differences in water and fat content. Migratory species, which deposit huge amounts of eggs in a single spawning act, accumulate at high water level great amounts of fat in various parts of the body. Nonmigratory species, which spawn small quantities of eggs several times per year, show little or no seasonality in fat storage. Fat storage is related to the energy requirements of the species and is considered a very successful strategy by which many Amazonian fish species survive drastic environmental and related food supply changes, which are a result of the great monomodal water-level fluctuations of the Amazon and its big tributaries.

402. KADLEC, J. A. 1960. The effect of a drawdown on the ecology of a waterfowl impoundment. Michigan Department of Conservation Game Division, Report 2276. 181 pp.

Ecological effects of drawdown on Backus Lake were studied in three phases—predrawdown in summers 1956 and 1957, drawdown (4 ft) in summer 1958, and postdrawdown in 1959. Effects of drawdown on soil, water, vegetation, invertebrates, and waterfowl were evaluated. Soil and water studies showed a definite increase in nutrient concentrations in the water during drawdown. Soil nitrates also increased during drawdown due to aerobic nitrification, and high concentrations persisted until the spring of the first year of reflooding. Although the response of other nutrients was less obvious, solubility and plant growth did increase. Most nutrient changes diminished after reflooding for 1 year. Invertebrate populations were considerably reduced by reflooding. Many submerged and floating-leaved plants were reduced in number during the first year of reflooding, except for waterlilies, smartweed, and bushy pondweed. Emergent vegetation spread and increased in abundance as a result of drawdown. Populations of breeding waterfowl did not change greatly

during the study. Use of drawdown and its effectiveness as a management technique for marshes is discussed.

403. KADLEC, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267–281.

Backus Lake in Roscommon County, Michigan, was the site of a drawdown that began in mid-April 1958. During the growing season, water levels were approximately 8–10 inches lower than in previous years. Soil and water analysis indicated a definite increase in plant nutrients. A marked increase in soil nitrates occurred during the drawdown as a result of aerobic nitrification. Invertebrate populations were considerably reduced after the drawdown. Most emergent species spread and increased in abundance as a result of the drawdown, although wetland food production during the drawdown was disappointing.

404. KADLEC, J. A. 1986. Effects of flooding on dissolved and suspended nutrients in small diked marshes. Canadian Journal of Fisheries and Aquatic Sciences 43:1999–2008.

Flooding ten 5- to 7-ha diked marshes in the Delta Marsh, Manitoba, to about 1 m above natural marsh levels did not increase dissolved or suspended nutrient concentrations in the surface water. Dissolved forms of N and P increased in interstitial water, possibly as a direct or indirect effect of death of emergent macrophytes (e.g., cattail, *Typha* spp.) and associated changes such as wave action and detritus deposition. Concentrations of suspended N, P, and C decreased in surface water as a result of flooding, both in absolute terms and relative to concurrent increases shown by natural marsh controls. Concentrations of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, and Cl^{-}) did not change in response to flooding, but varied in time and space. A predicted decrease in the concentrations of major ions in interstitial water due to seepage of dilute surface water into the sediment was not detected.

405. KADLEC, J. A. 1990. Effects of deep flooding and drawdown on freshwater marsh sediments. R. R. Sharitz and J. W. Gibbons, editors. Freshwater wetlands and wildlife. Savannah River Ecology Laboratory, Aiken, South Carolina. n.p.

Water-level fluctuations are commonly used to manage marshes for wildlife. Drawdowns or temporary drainages are believed to increase decomposition of organic sediments, to increase the supply of nutrients available for macrophyte growth, and to consolidate highly aqueous sediments. As part of the Marsh Ecology Research Program sponsored by the Delta Waterfowl and Wetlands Research Station and Ducks Unlimited Canada, characteristics of bottom sediments were monitored through replicated planned sequences of deep flooding (1 m) and drawdown in 10 diked, experimental marshes within the Delta Marsh, Manitoba. Contrary to expectations, flooding and drawdown had little effect on decomposition as indicated by percent organic matter; pore water NH_4-N and soluble reactive P increased during flooding and decreased during drawdown.

406. KADLEC, J. A. 1993. Effect of depth of flooding on summer water budgets for small diked marshes. Wetlands 13(1):1–9.

Water budgets for 10 small, diked marshes in Manitoba, Canada, were constructed for each of the 6 ice-free months for 5 years. Water levels in the marshes were maintained at three levels by pumping: four marshes at the average level of the surrounding marsh, three at +30 cm, and three at +60 cm. Water levels were assigned so that surface water–groundwater relations were replicated. At normal levels, precipitation and evapotranspiration (ET) were the major input and output of water, respectively. Local groundwater–surface water relations accounted for 80% of the variability in water budgets. The fraction of the flooded area of the marsh occupied by emergent vegetation was only weakly related to ET, but as emergent vegetation decreased, ET increased.

407. KADLEC, J. A., AND W. A. WENTZ. 1974. State-of-the-art survey and evaluation of marsh plant establishment techniques: Induced and natural. Volume 1. Report of Research, Dredged Materials Research Program. U.S. Army Coastal Engineering Research Center, Fort Belvoir, Virginia, Contract Report D-74-9. 231 pp.

Knowledge of marsh and aquatic plant establishment was assessed by reviewing the literature and contacting agencies and individuals likely to have relevant information. In freshwater areas, water levels or depths, substrate, water quality, turbidity, and currents and wave action are particularly important to plant establishment. Aquatic and marsh plants propagate naturally by both seeds and vegetative parts. The propagules are dispersed by wind, water, animals, and man. By controlling various environmental factors, it is possible to promote and encourage the natural invasion and growth of aquatic and marsh plants, especially in freshwater systems. In many instances, plantings of aquatic and marsh plants are necessary to vegetate a new substrate. Seeding seems to be the least expensive procedure, but environmental conditions must be favorable or success will be low. Transplants usually provide faster establishment and are hardier than seedlings. The basic problems encountered in the establishment of aquatic and marsh plants are physically unsuitable substrates, nutrient deficiencies, polluted sediments, excessive wind or current action, excessive turbidity, unfavorable patterns of water-level fluctuations, and unfavorable water depths.

408. KALLEMEYN, L. W. 1987. Correlations of regulated lake levels and climatic factors with abundance of young-of-the-year walleye and yellow perch in four lakes in Voyageurs National Park. North American Journal of Fisheries Management 7:513–521.

The relations between year-class strengths of walleye *Stizostedion vitreum* and yellow perch *Perca flavescens*, as determined from seine catches of young-of-year, and regulated lake levels, air and water temperatures, and wind velocities during the spawning period of both species were studied in four lakes in Voyageurs National Park, Minnesota, from 1981 through 1985. Significant positive correlations were found between lake level and walleye year-class strength in three of the four lakes sampled. The correlation between lake level and yellow perch year-class strength, while generally positive, was significant in only one lake. Significant positive correlations were also found between thermal conditions during the 30-day period following ice-out and year-class strengths of walleye and yellow perch; the strongest year classes of both species were produced in years with higher, more stable temperatures. An alternative water management scheme is proposed that may enhance walleye and yellow perch reproductive success by providing higher lake levels earlier in spring.

409. KALLEMEYN, L. W., M. H. REISER, D. W. SMITH, AND J. M. THURBER. 1988. Effects of regulated lake levels on the aquatic ecosystem of Voyageurs National Park. Pages 133–146 *in* D. A. Wilcox, editor. Interdisciplinary approaches to freshwater wetlands research. Michigan State University Press, East Lansing.

A single hydropower facility and two small regulatory dams located outside Voyageurs National Park regulate water levels in the four large lakes that compose 96% of the park's water area. The present water management program utilizes greater-than-natural fluctuations in water levels on the one reservoir that encompasses three of the lakes to maintain less-than-natural fluctuations on the second reservoir. Additionally, the regulated lake levels differ from natural levels by usually peaking later,

remaining relatively stable throughout the summer rather than slowly declining and, on one reservoir, by declining 1.8 m rather than 0.6 m over the winter. This regulatory system was found to have an adverse effect on northern pike, common loon, red-necked grebe, beaver, and muskrat populations of the littoral zone and adjacent wetlands of the park. An alternative water management program is presented that would meet the biological requirements of these species by restoring more natural lake-level fluctuations. It is hypothesized that it would also have a positive effect on the other members of the aquatic community.

410. KAPLER, J. E. 1994. An analysis of flooding of the Mississippi River at Dubuque, Iowa. Pages 19–20 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

The flooding in 1993 in the Upper Midwest prompted an examination of past records in Dubuque, Iowa, to provide a better understanding of the problem. Records of flooding at Dubuque date back to 1851. Eight of the top ten flood crests recorded in Dubuque have occurred since 1951. The number of days the river was above flood stage has also increased in recent years. In the time that such records are available (123 years), the number of flood days in the second half of this period is 2.7 times that of the first half. The year 1993 was the most disastrous for flooding in the Upper Mississippi River Basin, with 60 days of flooding occurring at Dubuque. Flooding has become an increasing problem and factors affecting this are discussed. These factors include annual precipitation, deforestation, destruction of wetlands, changes in agricultural practices, and increasing urbanization. The problem of flooding cannot be alleviated only by attempting to contain the river within its channel. (Abstract only)

411. KARABIN-EJSMONT, J., T. WEGLENSKA, AND R. J. WISNIEWSKI. 1993. The effect of water flow rate on zooplankton and its role in phosphorus cycling in small impoundments. Water Science and Technology 28(6):35–43.

The attempt was made to determine the effect of water flow rate on zooplankton density, trophic structure, and the role of phosphorus regeneration by zooplankton in phosphorus sedimentation in four impoundments with a water exchange of less than 10 hours to 8–12 days. The formation of stagnant environments together with the increasing time of water exchange in impoundments created good conditions for the development of zooplankton communities. As a result, the rate of phosphorus regeneration was higher and the turnover time of the total and seston phosphorus was shorter in impoundments than in streams above impoundments. A hypothesis that the stations with a long time of water exchange could be a kind of a trap for nutrients excluded from cycling in running waters is validated.

412. KASTER, J. L. 1976. Benthic macroinvertebrates of the Big Eau Pleine, a fluctuating, central Wisconsin reservoir. Wisconsin Cooperative Fishery Research Unit, University of Wisconsin, Stevens Point. 137 pp.

Benthic macroinvertebrate distribution, abundance, and composition were observed in a fluctuating (7.7 m) central Wisconsin reservoir during 1973–74. Chironomidae and Oligochaeta represented 98% of the total fauna by number. The chironomid, *Chironomus plumosus*, and the oligochaete, *Limnodrilus* sp., each averaged 36% of the total benthic biomass. Annual mean numbers and biomass in areas exposed to atmosphere, exposed to ice cover, or remaining inundated were 3,025/m^2 (1.8 g/m^2), 4,311/m^2 (4.5 g/m^2), and 8,558/m^2 (16.0 g/m^2), respectively. A substantial portion of the benthic fauna was stranded and subsequently decreased rapidly in drying and frozen substrates exposed to atmosphere. Total benthic numbers and biomass were greatest immediately below the drawdown limit. Recolonization required 3 months (mid-March to mid-June 1974) to attain predrawdown values for numbers and biomass, and subsequently both were greater after reinundation than before the substrate was exposed. Recolonization of areas exposed to the atmosphere was greater in substrates containing large amounts of organic matter than in sandy areas containing little organic matter. Sorting and transportation of sediments redistributed organic materials from the regulated zone to below the drawdown limit, and macrophytes were eliminated from the regulated zone. When compared to other reservoirs and lakes, the density of benthos in the Big Eau Pleine Reservoir can be regarded as neither high nor low. However, when compared with nonfluctuating reservoirs, the number of Ephemeroptera, Plecoptera, Trichoptera, Amphipoda, and Gastropoda was low.

413. KASTER, J. L., AND G. Z. JACOBI. 1978. Benthic macroinvertebrates of a fluctuating reservoir. Freshwater Biology 8:283–290.

Benthic macroinvertebrate distribution, abundance, and composition were studied in a fluctuating (7.7 m) central Wisconsin reservoir during 1973–74. Chironomids and oligochaetes made up 98% of the total fauna by number. Mean annual biomass (gm^{-2}) in areas exposed to air, exposed to ice cover, and remaining inundated were 1.8, 4.5, and 16.0, respectively. A substantial portion of the benthic fauna was stranded and died rapidly in drying and frozen substrates exposed to air. Total benthic numbers and biomass were greatest immediately below the drawdown limit.

414. KAWASE, M. 1981. Anatomical and morphological adaptation of plants to waterlogging. HortScience 16(1):30–34.

Most agricultural crops are mesophytes that require an environment that is neither too wet nor too dry for maximum growth and productivity. Once soil becomes waterlogged, air space is displaced with water. O_2 replenishment in the soil is very inefficient because of the slow diffusion of atmospheric O_2 into the waterlogged soil. Root systems are thus suddenly plunged into an anaerobic condition by waterlogging. If waterlogging continues for a long period, the reducing processes in the rhizosphere aggravate the plant condition. Waterlogging does not necessarily occur only when the soil is inundated. Rather, waterlogging often occurs when water fills a critical proportion of the soil air spaces, depending upon the species of plant involved. Such problems are prevalent in fields having poor drainage, that is, when underground and surface drainage is not adequate to remove water from the soil after a rain.

415. KEDDY, P. A., AND P. CONSTABEL. 1986. Germination of ten shoreline plants in relation to seed size, soil particle size, and water level: An experimental study. Journal of Ecology 74:133–141.

Lakeshore plants are distributed along a gradient of exposure to waves, from sheltered bays to exposed shorelines. Soil particle sizes vary along this gradient and may influence germination and early establishment. We therefore tested whether species with different-sized seeds germinate at different positions along a particle-sized gradient. In particular, we tested whether there was a shared preference over all species for one position on this gradient.

Seeds of 10 wetland plants *(Acorus calamus, Alisma plantago-aquatica, Bidens cernua, B. vulgata, Cyperus aristatus, Lythrum salicaria, Polygonum punctatum, Sagittaria latifolia, Scirpus americanus, Typha angustifolia)* were vernalized and then sown along a particle-size gradient with seven stages ranging from 0.125–0.250 to 8–16 mm. Two water levels, 1 and 4 cm below the soil surface, were provided. The proportion of seeds producing established seedlings was determined for each particle size and each species (n = five replicates).

In the drier treatment, 9 out of 10 species germinated differentially ($P < 0.05$) along the gradient. In the wetter treatment, only 3 out of 10 species so responded. Thus, soil particle size had most influence during drier conditions.

In both wet and dry treatments, those species that did respond significantly ($P < 0.05$) to the gradient had a shared preference for the fine soil ($P < 0.01$). The single exception was *Acorus calamus* in the dry treatment.

The species with the smallest seeds generally showed the greatest response to the gradient. Large-seeded species therefore had the broadest tolerances for variation in soil particle sizes.

On lakeshores, the fine particles associated with sheltered bays would allow the highest recruitment irrespective of seed size. These effects would be most pronounced during periods of low water. The zonation of adult plants was seemingly not produced by species with different-sized seeds requiring different soil particle sizes for maximum germination.

416. KEDDY, P. A., AND T. H. ELLIS. 1985. Seedling recruitment of eleven wetland species along a water level gradient: Shared or distinct responses? Canadian Journal of Botany 63:1876–1879.

Where many different plant species occupy an environmental gradient, the responses of their offspring to that gradient could show one of two patterns. All species could have similar requirements for maximum recruitment, in which case all would show maximum germination and emergence in the same region of the gradient ("shared responses"). Alternatively, each species could have different requirements for recruitment and therefore would show maximum recruitment in different regions of the gradient ("distinct responses"). The objective of this study was to test between these two alternatives in plants occurring along a water-level gradient. Seeds of 11 wetland species were allowed to germinate in sand along a gradient of water depth, ranging from 10 cm above to 5 cm below the substrate surface. *Scirpus americanus*, *S. validus*, *Sagittaria latifolia*, *Typha angustifolia*, and *Lythrum salicaria* showed no significant response to this gradient, while *Spartina pectinata*, *Polygonum punctatum*, *Bidens cernua*, *Acorus calamus*, *Alisma plantago-aquatica*, and *Eupatorium perfoliatum* did. However, the six species in the latter group did not exhibit shared preferences along the water depth gradient. These different recruitment patterns were consistent with adult distributions in the field. Most species showed some recruitment at all water levels examined, suggesting that they have broad tolerance limits for water level in the recruitment phase of their life history.

417. KEDDY, P. A., AND A. A. REZNICEK. 1986. Great Lakes vegetation dynamics: The role of fluctuating water levels and buried seeds. Journal of Great Lakes Research 12(1):25–36.

The objective of this study was to review the relation between fluctuating water levels and shoreline vegetation dynamics in the Great Lakes. Low water periods allow many plant species and vegetation types to regenerate from buried seeds. A review of published seed bank densities shows that some lakeshores have densities of buried seeds greater than 10^4 seeds m^{-2}, an order of magnitude greater than densities reported from prairie marshes. High water periods kill dominant species (e.g., *Typha* sp.), thereby creating gaps that other species can colonize during low water periods. High water also kills woody plants, thereby extending marshes landward. Fluctuating water levels therefore increase the area of shoreline vegetation and the diversity of vegetation types and plant species. Any stabilization of water levels would likely reduce marsh area, vegetation diversity, and plant species diversity. Four basic shoreline vegetation types (forest and shrub thickets, wet meadow, marsh, and aquatic) can be recognized; both wet meadow and marsh largely result from fluctuating water levels.

418. KEELEY, J. E. 1979. Population differentiation along a flood frequency gradient: Physiological adaptations to flooding in *Nyssa sylvatica*. Ecological Monographs 49(1):89–108.

Throughout the southeastern United States, the hardwood *Nyssa sylvatica* (sensu lato) is distributed along a soil moisture gradient from upland sites, which are never flooded, to floodplains, which are periodically flooded and drained, to permanently flooded swamps. Population differentiation with respect to flood tolerance and related physiological attributes was investigated by using a 1-year-old seedling growth in a greenhouse from seed collected along this gradient. Upland plants were very intolerant of flooded soils. Their root systems deteriorated, root respiration rates dropped and, after a year under such conditions, survival was poor and those that did remain were greatly stunted and had accumulated large concentrations of many nutrient elements. In contrast, swamp plants were quite tolerant of flooded soils. Upon flooding, parts of the original root systems were lost, but new roots were initiated that had an increased capacity for alcoholic fermentation.

419. KEELEY, J. W., J. L. MAHLOCH, J. W. BARKO, D. GUNNISON, AND J. D. WESTHOFF. 1978. Reservoirs and waterways: Identification and assessment of environmental quality problems and research program development. U.S. Army Engineer, Waterways Experiment Station, Vicksburg, Mississippi, Technical Report E-78-1. 152 pp.

This report describes the Civil Works Program of the Corps of Engineers (CE) and the need for comprehensive water resources development, including hydropower, water supply, navigation, recreation, and fish and wildlife. Environmental quality problems associated with civil works activities of the CE were identified and assessed, and a research program to address these problems was recommended. Six key areas of problems related to current practices and priority research needs were identified. It was recommended that the research program should involve applied research in conjunction with extensive field studies to verify and evaluate program results. A 30 million dollar, 6-year research program has been proposed to address the high priority problems. The several facets of the problem of water-level fluctuations in reservoirs are outlined—conflicts of environmental concerns with the major purposes of flood control, recreation, and power production. Water-level fluctuation often result in excessive turbidity associated with bank erosion and mudflats. Mudflat formation is associated with vegetative die-back, reducing the habitat available for fish and other wildlife and also destabilizing fine-textured sediments thereby causing increased turbidity. Increased BOD, nutrient loading, and malodor are some undesirable effects of the death of vegetation caused by fluctuating water levels.

420. KEITH, L. B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildlife Monographs 6:1–88.

A group of small impoundments in southeastern Alberta was studied from 1953 to 1957. Although water was diverted into the area, water supply and water levels in spring and summer were neither constant nor predictable. The author presents information on waterfowl food habits, breeding populations, nesting, food populations and productivity, and management potential.

421. KEITH, W. E. 1967. Turbidity control and fish population renovation on Blue Mountain Lake, Arkansas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:495–505.

Blue Mountain Reservoir, which was plagued with high turbidity and an overabundance of rough fishes 4-5 years after impoundment, was treated by fall–winter drawdowns, shad kills, the removal of commercial fishes, and the planting of rye grasses. Although these measures reduced the turbidity and improved fish populations, the benefits were short-lived. In 1965, treatments included drawdown; seeding of sorghum, sudan, and a sudan–sorghum hybrid; a rotenone kill of 95% of the fish; and restocking with selected game fishes. After the lake was refilled in 1966, waters remained relatively clear (12–14 inches visibility) except during floods. During early 1967, sport fishing was excellent. Population sampling of a cove with rotenone indicated larger numbers of crappies, channel catfish, freshwater drum, and shad. Crappies, white bass, buffaloes, common carp, freshwater drum, and shad exhibited increased rates of growth.

422. KEITH, W. E. 1974. Management by water level manipulation. Arkansas Game and Fish Commission, Little Rock. 25 pp.

Fish populations respond to water-level changes in a predictable way, whether fluctuations are natural (due to variation in runoff) or artificial (created by dams, diversions, or some other structure). Effects are most pronounced in impounded waters or low-water streams where vast flat areas (floodplains) are inundated during high water. Simulating natural seasonal and annual cycles of increasing and decreasing water levels is an effective way to optimize black bass production and manage fisheries in general. Water-level controls are most feasible on impounded waters. In the southern United States, the largemouth bass is the principal bass affected by this technique. Increased water levels just before, during, and for a short time after spawning increase the amount of desirable habitat for nearshore fishes and improve the productivity of impoundments. High water levels enhance spawning success, survival, growth, and recruitment. Controlled drawdowns can restrain the spread of nuisance aquatic vegetation, increase predator use of prey fishes, and accelerate nutrient recycling from bottom muds. Severe manipulation of water levels often conflicts with primary uses such as power generation or flood control. For many impoundments, the needs for different interests should be reevaluated periodically.

423. KEITH, W. E. 1975. Management by water level manipulation. Pages 489-497 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Significant increases in water level above normal elevations (1) flood terrestrial vegetation, which decays and releases nutrients that heighten overall productivity, (2) increase the availability of terrestrial fish-food organisms (e.g., insects and earthworms), (3) create excellent cover and desirable habitat for shoreline-dwelling fishes, and (4) stimulate the natural reproduction and growth of fishes, ultimately leading to the production of a strong year class. The flooding of herbaceous vegetation also precipitates colloidal particles and reduces turbidity. In Bull Shoals Lake, Arkansas, strong year classes of largemouth bass, as indicated by abundance of young-of-year collected in August (1954–74), were highly correlated with high water levels in the spring of the same year. Spawning and survival of forage fishes were also enhanced in years where water was high during the spring. As a result, young bass grew rapidly. Decreased water levels hinder or disrupt spawning and decrease the abundance of fish-food organisms. Nevertheless, planned and controlled drawdowns can help managers regulate aquatic vegetation and the number and spawning of rough fishes. Forage fish are forced from protective cover, thereby increasing their availability to predators. Numbers of stunted sunfish are reduced, and growth of harvestable-sized predators is improved. Aerated soils release nutrients upon reflooding, and bottom muds are usually consolidated. Refilling of a lake in the spring after a drawdown usually results in excellent reproduction by black basses.

424. KELLEY, J. R., JR., AND L. H. FREDRICKSON. 1991. Chufa biology and management. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.18. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Chufa emergence occurs a few days after the removal of surface waters, with peaks in aboveground biomass occurring as soon as 40 days after drawdown. Chufa can withstand short-term flooding as long as plants are only partly covered with water.

425. KELLEY, J. R., JR., M. K. LAUBHAN, F. A. REID, J. S. WORTHAM, AND L. H. FREDRICKSON. 1993. Options for water-level control in developed wetlands. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.8. U.S. Fish and Wildlife Service, Washington, D.C. n.p.

Water control structures and recommended specifications for the development of managed wetlands are discussed.

426. KENNEDY, M. L., J. P. NELSON, JR., F. W. WECKERLY, D. W. SUGG, AND J. C. STROH. 1991. An assessment of selected forest factors and lake level in raccoon management. Wildlife Society Bulletin 19:151–154.

The authors studied the relation of capture frequency of raccoons with water level on a large, on-site lake. Results of the hunt and water-level analysis indicated a strong relation between total harvest and water level. The study was conducted on the Reelfoot National Wildlife Refuge in Tennessee.

427. KIMSEY, J. B. 1958. Fisheries problems in impounded waters of California and the Lower Colorado River. Transactions of the American Fisheries Society 87:319–332.

Problems in and management of reservoirs in the western United States are discussed. In general, fish-food production in the littoral zone of impoundments is poor due to water-level fluctuations. Water-diversion or irrigation reservoirs like Lake Havasu usually have severe drawdowns during the growing season, which greatly limit fish production and reduce or eliminate aquatic plants. Large irrigation impoundments, such as Millerton Lake, usually fill in spring (at least until June), lose water through July or August, and reach their lowest elevations in fall. These annual fluctuations of up to 140 ft create a very unstable and sterile littoral zone after a few years. Although most reservoirs have poor benthos development and the sunfish are stunted, plankton development is good in open water. The decline in fisheries after an initial productive period of 2 to 5 years probably results from a loss of fertility (nutrients, vegetation, and detritus) inherent to new basins. After the initial phase, fish production depends mainly on the fertility of the watershed and basin. Most management practices are based on attempts to modify the decline of the fishery and maintain its quality as close as possible to that present during early impoundment. One technique suggested involves the establishment of a ground cover that perpetuates itself in the fluctuation zone, even though it may be submerged for considerable periods. Mats made of Bermuda or similar grasses provide a good substrate for benthos and release nutrients into the water.

428. KIRKLAND, L. 1963. Results of a tagging study on the spotted bass, *Micropterus punctulatus*. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 17:242–255.

The spotted bass fishery of Allatoona Reservoir, Georgia, is described on the basis of tag returns and a creel census. Factors affecting the capture rate of bass included season, surface temperature, water level, turbidity, and fishing pressure. Effects of turbidity and water levels were difficult to separate because turbidity was closely related to water level. A flood in mid-April greatly reduced the catch of spotted bass, and fewer tags were returned in this period. The fact that small or slow changes in water level did not seem to affect the catch rate suggests that increased turbidity was more important than water level.

429. KONONOV, V. A., N. S. MENYUH, AND A. M. PARADNIKOV. 1966. The Dnieper Reservoir. Pages 42–55 *in* P. V. Tyurin, editor. The Storage Lakes of the U.S.S.R. and their importance for fishery. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian).

Aspects of the hydrology, morphometry, chemistry, and biology of the Dnieper Reservoir are discussed. Water levels fluctuate sharply during spring floods in some sections of the reservoir, depending on the floodplain altitude, flood volumes, and daily rates of water discharge. For example, in the upper reaches, the water level fell 70 cm in 9 days and the spawning grounds and eggs of many fishes were left exposed to the air. The constantly changing shoreline in this reservoir prevents the formation of natural spawning grounds. Sharp, daily fluctuations of water level, combined with the dense growth of hard vegetation, make the shallow Samara branch unsuitable for spawning. Control of water levels on a daily basis is one of the measures needed to increase the yield of fish.

430. KOSHOV, M. M., AND N. V. TYUMENTSEV. 1961. The biological consequences of fluctuations in the level of Lake Baikal. Byulleten' Moskovskogo Obschestva Ispytatelei Prirody Otdel Biologicheskil 66(3):32–39. (In Russian)

After the Irkutsk hydroelectric station was constructed on the Angara River, Lake Baikal became a reservoir. High water levels increased the shallow littoral area and enhanced the reproduction of fish that spawn in tributary streams. Reproduction of fish was impaired in years of low water levels, and the fishing economy was severely damaged when water levels were decreased from 0.6 to 1.0 m for several years. A 0.6- to l.0-m reduction in water level decreased littoral area by more than 20,000 ha. The best fishing was obtained when the amplitude of fluctuations did not exceed 2 m for a long time. Periodic flooding and drying of soils resulting from 3- to 5-m fluctuations will seriously damage industrial fishing.

431. KOZLOWSKI, T. T. 1984. Plant responses to flooding of soil. BioScience 34:162–167.

Flooding of soil rapidly depletes soil oxygen and alters plant metabolism, thereby inhibiting growth. Reduced growth is preceded by stomatal closure; reduced photosynthesis, carbohydrate translocation, and mineral absorption; as well as altered hormone balance. Flood tolerance varies widely among plant species, cultivars, and ecotypes and is associated with both morphological and physiological adaptations.

432. KOZLOWSKI, T. T. 1984. Responses of woody plants to flooding. Pages 129–163 *in* T. T. Kozlowski, editor. Flooding and plant growth. Academic Press, Orlando, Florida.

In this literature review, the author discusses species distribution, composition, and succession in response to flooding in south-central lake states and the mangrove areas of the United States. He also discusses factors influencing the response to flooding and the nature of those responses.

433. KOZLOWSKI, T. T. 1985. Soil aeration, flooding, and tree growth. Journal of Arboriculture 11:85–96.

Roots require a supply of soil oxygen, water, and mineral nutrients. Oxygen is necessary to maintain aerobic root respiration so as to supply energy needed for mineral uptake, syntheses of protoplasm, and maintenance of cell membranes. In poorly aerated soils, the anaerobic respiration of roots does not release enough energy to maintain root functions. Furthermore, many phytotoxic compounds accumulate in poorly aerated soils. Inadequate soil aeration occurs commonly as a result of soil compaction, filling in with soil over roots, impermeable layers (e.g., pavements) around roots, and flooding of soil. Root growth in compacted soils is reduced not only because of unfavorable aeration and moisture conditions, but also because of high mechanical impedance of soil to root growth. Flooding results in elimination of soil oxygen, accumulation of CO_2, transformation of nitrogen, and production of toxic compounds. Physiological responses of trees to flooding include closing of stomata, reductions in the rate of photosyntheses and uptake of essential mineral nutrients, as well as alterations in plant growth hormones. These physiological changes lead to inhibition of tree growth. Because root growth is reduced more than shoot growth by flooding, drought tolerance often is reduced after the flood waters drain away. Flood tolerance varies widely among species. Important morphological adaptations for flood tolerance include (1) initiation of adventitious roots, which assist in the uptake of water and mineral nutrients, and (2) production of hypertrophied lenticels, which assist in aerating the stem and roots and serve as openings through which toxic compounds are released.

434. KRAMER, P. J. 1951. Causes of injury to plants resulting from flooding of the soil. Plant Physiology 26:722–736.

A series of experiments was performed to learn how flooding the soil in which plants are growing causes injury to or death of the shoots. Flooding is followed by a rapid reduction in transportation in the water absorbing capacity of the roots and is usually followed by more wilting of the shoots. It is believed that injury to the shoots of flooded plants is complex in origin and has several causes rather than resulting simply from interference with water absorption.

435. KRAMER, R. H., AND L. L. SMITH, JR. 1962. Formation of year-classes in largemouth bass. Transactions of the American Fisheries Society 91:29–41.

Early life history of largemouth bass (*Micropterus salmoides*) at Lake George and adjoining sloughs, Anoka County, Minnesota, is described. Bass spawning first occurred 2-5 days after mean daily water temperatures exceeded 60 °F. Two hundred sixty-six nests were found on needlerush, waterlily foots, humps of fibrous material, aquatic vegetation, and sand in 10 to 62 inches of water. Egg survival at time of hatching varied from 0% to 94%. The percentage of successful nests from a single spawning period varied from 0 to 100. Year-class strength was set after egg deposition and before fingerlings were 2 weeks old. Water temperature was directly related to egg survival and nest success. Wind was the most important single factor in year-class formation in Lake George. Egg survival was highest on needlerush and lowest on sand. Two-thirds of all successful nests were in water deeper than the median depth. Illumination, dissolved oxygen, total alkalinity, hydrogen ion concentration, cannibalism, predation, food habits, growth rate, and condition were not factors in determining year-class strength. Differences in median depth of nests among waters in West Slough were directly related to water-level fluctuations. As water level rose, median depth of nests increased. As water level fell, median depth decreased. The bass used the most suitable bottom available, regardless of changes in water depth.

436. KROGER, R. L. 1973. Biological effects of fluctuating water levels in the Snake River, Grand Teton National Park, Wyoming. American Midland Naturalist 89:478–487.

The effects of fluctuating water levels—which result from variation in the demand for irrigation water released through Jackson Lake Dam—on aquatic biota in the Snake River in Grand Teton National Park were observed. Unnaturally low water levels and sudden decreases in water flow exposed the stream bed and destroyed algae, invertebrates, and some fish, and probably limited the production of other fish occupying higher trophic levels. This report shows that rapid changes in water levels leave aquatic invertebrates and some fish stranded on the exposed stream bed.

437. KURATA, A. 1989. The effect of low water levels on the water quality of Lake Biwa. Hydrobiologia 176, 177:29–38.

Because of a lack of precipitation, water levels in Lake Biwa, Japan, were extremely low between the beginning of September 1984 and the end of February 1985. Sampling data suggest that, overall, there was little effect on lake water quality as a result of low water levels. However, remedial actions in the form of macrophyte removal may have had an important and beneficial effect on nearshore water quality in the southern basin of the lake.

438. KUSHLAN, J. A. 1976. Environmental stability and species diversity. Ecology 57:821–825.

On marshes of the Everglades, drastic seasonal fluctuation of water level is the most important factor affecting fish. By May, water levels often recede to the extent that most surface water disappears and only localized pools remain. Although the density of fish decreased during 27 months of high, stable water level, the biomass, average size, and diversity of fish increased. Populations of small omnivorous fishes were reduced, and populations of larger piscivores (especially centrarchids) increased because of immigration of piscivores from other areas. Under stable water levels, predation assumes the major role in restructuring the fish community. Fish communities of Everglades marshes are dominated by small omnivores during low water, when habitat is limiting, and by large predators during periods of high water.

439. KUSHLAN, J. A. 1976. Wading bird predation in a seasonally fluctuating pond. Auk 93:464–476.

Kushlan studied a pond in the southeastern part of the Big Cypress Swamp, Florida, with a maximum depth of 1.5 m during high water. In 1973, water level drops allowed wading birds to feed, which decreased the biomass standing crop of fish by 76%. In a comparable year when bird predation did not occur, the fish killed decreased the fish biomass by 93%. Wading bird predation may therefore function to reduce fish stocks to levels comparable with their survival during the dry season.

440. KUZNETSOV, V. A. 1971. The effects of regulated Volga flow on the reproduction of asp, blue bream, white bream, and bleak in the Sviyazh Bay of the Kuibyshev Reservoir. Voprosy Ikhtiologii 11:232–239. (In Russian)

Construction of the Kuibyshev Reservoir led to significant changes in the hydrology of the middle Volga. To determine the effects of the reservoir on fish, the reproduction of several species was studied during a 7-year period (1963–69) at Sviyazh Bay. The best adaptability in terms of reproduction was shown by asp and bleak, which began to deposit eggs on rocky regions, plants, and submerged roots. In addition, bleak began to spawn at greater depths. Populations of asp and bleak remained relatively high. Blue bream adapted fairly well to the new habitat conditions and started to deposit eggs in riverbank regions that were rich in plant life and well protected from winds. However, in years of low water, many eggs died, and the abundance of blue bream dropped sharply. White bream began to deposit eggs close to banks when waters began to rise (end of May to beginning of June) and thereby exhibited greater adaptability to changing water levels than did the blue bream. (From Biological Abstract 54:36435)

441. KUZNETSOV, V. A., AND N. I. FADEEV. 1979. Some characteristics of fish reproduction in parts of the Volga, U.S.S.R., before and after current regulation. Voprosy Ikhtiologii 19:93–102. (In Russian)

The condition of Kuibyshev Reservoir was studied in relation to water volume. In years when the reservoir was full and water levels relatively stable, reproduction was more successful in the reservoir than in the river. In years when spring water levels in the river were high, but levels in the reservoir varied, reproduction was more successful in the river than in the reservoir. (From Biological Abstract 69:63561)

442. LAMBOU, V. W. 1959. Fish populations of backwater lakes in Louisiana. Transactions of the American Fisheries Society 88:7–15.

Standing crops, predator–prey relations, and the effects of overflow are discussed. Alternate flooding and exposure of land has important effects on fish populations. Floods during the spawning season induce the production of large numbers of young-of-year fishes such as largemouth bass. Flooding presumably reduces competition for food, space, and spawning territory within and among species. The whole fish community expands in numbers and weight. Conversely, when waters are lowered, available food and habitat become limiting, although backwater lakes usually support large standing crops even during periods of low water. Fish in these lakes usually are in good condition and sport fishing remains of high quality even during low water. Fish of backwater lakes are considered fluctuating populations that are regulated by flooding and dewatering.

443. LANDERS, J. L., A. S. JOHNSON, P. H. MORGAN, AND W. P. BALDWIN. 1976. Duck foods in managed tidal impoundments in South Carolina. Journal of Wildlife Management 40:721–728.

From a study conducted during 1972–74 in South Carolina, the type of management and vegetation in diked, well-managed impoundments and major foods of ducks from these impoundments is presented. Management types included summer drawdown to saturated bed on typical alluvial soils, summer drawdown to saturated bed on peat soils, and thoroughly drained soils in growing season.

444. LANGLAIS, D., AND Y. BÉGIN. 1993. The effects of recent floods and geomorphic processes on red ash populations, upper St. Lawrence Estuary, Québec. Estuarine Coastal and Shelf Science 37:525–538.

The effects of recent floods on red ash (*Fraxinus pennsylvanica* Marsh.) forest margins were studied along the upper St. Lawrence Estuary in eastern Canada. The effects of recent floods are evidenced by three aspects of riparian red ash population structure: (1) a landward displacement of the lower limit of trees and the absence of regeneration, (2) a high frequency of recent injuries and irregular tree-growth forms developed as a reaction, and (3) the reduced radial-growth ring patterns that develop in partly uprooted trees.

445. LANTZ, K. E. 1974. Natural and controlled water level fluctuations in a backwater lake and three Louisiana impoundments. Louisiana Wildlife and Fisheries Commission, Fisheries Bulletin 11. 36 pp.

Changes in fish populations, aquatic vegetation, fish-food organisms, and physicochemical variables were assessed to evaluate the effectiveness of water-level manipulation as a management tool in shallow bodies of water. The control of aquatic macrophytes usually required drawdown each year for 2 or 3 years, but the responses of plants varied among species. Water-level fluctuations in the three reservoirs resulted in a gradual increase in total standing crop per acre and rapid increases in the numbers of harvestable-sized sport fish and in sport fish reproduction during the first 2 or 3 years of management. However, increases in standing crop (total and sport fish) and reproduction diminished after 4 or 5 consecutive years of treatment.

446. LANTZ, K. E. 1978. Largemouth bass studies in Toledo Bend Reservoir. Louisiana Department of Wildlife and Fisheries, Federal Aid Project F-28-R. 15 pp.

Spawning success and survival of young-of-year largemouth bass were evaluated for 3 years on Toledo Bend Reservoir, Louisiana and Texas. The rapid lowering of water levels in March and April 1975 and 1976 reduced spawning success, and poor year classes developed subsequently. In 1977, waters rose gradually throughout spring, creating ideal spawning conditions for largemouth bass. A strong year class developed in 1977.

447. LANTZ, K. E., J. T. DAVIS, J. S. HUGHES, AND H. E. SCHAFER, JR. 1964. Water level fluctuation—its effect on vegetation control and fish population management. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 18:483–494.

Three Louisiana lakes (Anacoco, Bussey, and Lafourche) are used as examples of water-level manipulation as a management practice. The effects of drawdown were evaluated by comparing pre- and postdrawdown standing crops of fish as estimated by rotenone sampling of enclosed 1-acre areas. A creel census also was conducted on two of the lakes (Bussey and Lafourche). Drawdowns in all three lakes were extremely effective in controlling aquatic vegetation. For example, the drawdown of Lake Anacoco reduced the surface area covered by aquatic macrophytes from 40% to 5%; in Bussey Lake, the reduction was from 32.0% to 1.4% in 1 year. Drawdown increased the standing crop and numbers of harvestable-size fish, while reducing the biomass of intermediate-sized fish (especially sunfishes) in Anacoco Lake. Similar results were observed in Bussey Lake, but the fish population changed somewhat (i.e., intermediate-sized shad were severely reduced and in the following year were replaced by an abundance of fingerlings). The slow refilling of Bussey Lake hindered the spawning of the black basses and crappies that year. In Lafourche Lake, drawdown rapidly increased the number of harvestable-sized predatory and nonpredatory game fish and decreased the number of intermediate-sized fish. However, because the water levels did not return to normal pool, spawning of predatory game fish failed for 2 years. The total harvest of fish from Bussey Lake increased in 1 year, though the catch in pounds per hour decreased. In Lafourche Lake, the harvest of fish decreased slightly after drawdown, perhaps due to the slow rate of refilling.

448. LAPITSKII, I. I. 1966. The Tsimlyanskoe Reservoir. Pages 13–29 *in* P. V. Tyurin, editor. The Storage Lakes of the U.S.S.R. and their importance for fishery. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian)

Fluctuation of water level and its effect on reservoir biota are among the many physical, chemical, and biological features of the reservoir that are discussed. Annual fluctuations in water level (up to 6.1 m) inhibit the development of aquatic vegetation, which in turn hinders the spawning of phytophilous fishes. When the water level declines below elevation 31.0 m, a winterkill of fish (primarily common carp) normally occurs in the upper portion of the reservoir, and the standing crop of benthos is severely reduced. During the first year after the reservoir was filled, fish of all species grew rapidly and attained sexual maturity at a younger age than usual. Growth decreased in the following years except for that of blue bream.

449. LATHWELL, D. J., D. R. BOULDIN, AND E. A. GOYETTE. 1973. Growth and chemical composition of aquatic plants in twenty artificial wildlife marshes. New York Fish and Game Journal 20:108–128.

Twenty 0.1-acre impoundments were constructed in New York on a Langford silt loam soil which is acidic in the surface horizons, although the underlying glacial till is neutral to mildly calcareous. The experiment was designed to measure the influence of water depth, soil reaction, and organic matter level on the growth of rooted aquatics. Water depths were varied from 1 to 3 ft by 0.5-ft increments. The authors discuss plant growth and species distribution, mineral composition, nitrogen, phosphorous, calcium, magnesium, potassium, iron, and manganese content.

450. LATHWELL, D. J., H. F. MULLIGAN, AND D. R. BOULDIN. 1969. Chemical properties, physical properties, and plant growth in twenty artificial wildlife marshes. New York Fish and Game Journal 16:158–183.

Physical and chemical measurements of water in bottom soils were made from 1960 to 1967 on 20 artificial marshes near Tompkins County Airport, New York, to determine factors that influence the growth of aquatic plants that are important as a food source for wildlife. Water depth was varied from 1 to 3 ft. Throughout the study, greater plant growth was observed in the shallower marshes.

451. LEES, J. C. 1964. Tolerance of white spruce to flooding. Forest Chronicles 40:221–224.

One and two-year-old white spruce seedlings growing in trays in the laboratory were immersed in water for periods of 3.5, 7, 10.5, and 14 days. Total mortality resulted from the 14-day immersion period, but a small percentage of seedlings survived the shorter periods and even repeated immersions for 3.5-day periods. Two-year-old seedlings were more tolerant of flooding than 1-year-old seedlings. The relation of these results to flooding of scarified seedbeds in the B-18a Mixedwood Section of Alberta is discussed.

452. LEWIS, G., AND D. ROBINSON. 1967. Drawdowns for species control. West Virginia Department of Natural Resources, Division of Game and Fish, Federal Aid Project F-10-R-8/9, Job 3-3. 6 pp.

Baker Lake (4 acres) and Warden Lake (36 acres) were drawn down in falls 1964 and 1965. Population estimates from rotenone samples in 1965 showed that the number of fingerling and intermediate-sized fish increased after the first drawdown in both lakes. Numbers and weight of harvestable fish increased in Baker Lake, but no fish of harvestable size were taken from Warden Lake. In 1966, the number and weight of all sizes of fish in both lakes decreased. The second drawdown (fall 1965) may not have been effective in enhancing fish populations; however, the accuracy of the estimates based on the rotenone samples of 1966 was questionable.

453. LEWIS, W. M. 1967. Predation as a factor in fish populations. Pages 386–390 in C. E. Lane, Jr., editor. Reservoir Fishery Resources Symposium. Reservoir Committee of the Southern Division, American Fisheries Society, Washington, D.C.

Findings concerning the vulnerability of different prey species to predation and the implications of their vulnerability to the management and production of sport fishes are discussed. Food consumption by sport fishes is believed to be limited to a maintenance level by the availability of highly vulnerable foods. As a result, the production of important sport fishes potentially can be improved by increasing the amount of highly vulnerable prey. New reservoirs presumably contain many species of forage that are exceptionally vulnerable, but which are eliminated or reduced to low levels by predation. Less vulnerable forage species such as bluegills become abundant as reservoirs age, and consequently, bass production declines. The success of drawdowns is probably related to increased vulnerability of forage fishes.

454. LIEFFERS, V. J., AND J. M. SHAY. 1981. The effects of water level on the growth and reproduction of *Scirpus maritimus* var. *paludosus* in Saskatchewan. Canadian Journal of Botany 59:118–121.

A greenhouse experiment was conducted to examine the effects of water depth on the growth and reproduction of *Scirpus maritimus* L. Plants grown at or above the water surface had higher shoot survivorship, greater numbers of vegetative tillers, and higher underground biomass, while seed production was small. With increasing water depth, plants had taller shoots and greater seed production but total biomass, numbers of vegetative tillers, and underground biomass were reduced. This shift from clonal growth to seed production with increasing water depth is interpreted as a strategy that permits survival of *S. maritimus* populations through the wet and dry climatic periods of the Canadian prairies.

455. LINDE, A. F., T. JANISCH, AND D. SMITH. 1976. Cattail—the significance of its growth, phenology, and carbohydrate storage to its control and management. Wisconsin Department of Natural Resources, Technical Bulletin 94.

A possible phenological and physiological basis for control has been suggested for use in cattail management work in Wisconsin. Control and management methods to be most effective must take into consideration the strengths and weaknesses of the plant. Maximum germination and production of seedling plants occurred on moist mudflats during severe water level declines such as occur during drawdowns. Shallow water of 6 inches or less may also produce new plants, but in lesser quantities.

Typha latifolia died out in water over 12 to 15 inches deep. Depths of 2.5 ft and greater may be detrimental to other *Typha* species.

456. LINDSTROEM, T. 1962. Life history of whitefish young (*Coregonus*) in two lake reservoirs. Institute of Freshwater Research Drottningholm Report 44:113–144.

Primary topics of this paper include life history events of young whitefish in reservoirs, but some discussion of lake regulation and water-level fluctuation is mentioned. With the exception of slightly accelerated growth of young in Lake Storavan after raised water levels in 1968, little evidence was obtained to indicate any effect of altered water levels on growth. Findings of other researchers, who have worked on impounded natural lakes, are discussed in relation to life history events of young whitefish and to the effects of water levels.

457. LOCKE, L. N., AND M. FRIEND. 1989. Avian botulism: Geographic expansion of a historic disease. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.2.4. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Fluctuating water levels during hot summer months is an important factor in the development and maintenance of avian botulism outbreaks.

458. LÖTMARKER, T. 1964. Studies on planktonic crustacea in thirteen lakes in northern Sweden. Institute of Freshwater Research Drottningholm Report 45:113–189.

Zooplankton densities in six regulated and seven unregulated natural lakes in Sweden were not significantly different, but there was a trend toward reduced abundance of zooplankters in lakes with whitefish (a planktivore). Regulation did seem to reduce numbers of *Daphnia longispina hyalina* and *Bosmina coregoni*. In newly impounded lakes, zooplankton production may be increased because of increased phytoplankton production and the addition of nutrients from flooded areas. In older regulated lakes, as in this study, zooplankton densities return to preimpoundment levels.

459. LOUCKS, W. L. 1987. Flood-tolerant trees. Journal of Forestry 85:36–40.

Silver maple, green ash, deciduous holly, American sycamore, eastern cottonwood, overcup oak, pin oak, black willow, and baldcypress are species of trees tolerant to intermittent flooding during the growing season. Boxelder, river birch, pecan, shagbark hickory, hackberry, eastern redbud, common persimmon, honeylocust, Osage-orange, red mulberry, bur oak, and American elm are intermediately tolerant. Bitternut hickory, black walnut, eastern redcedar, black cherry, blackjack oak, chinkapin oak, northern red oak, post oak, buckthorn, and black locust are intolerant. In order for species of trees to tolerate and survive long periods of floods, several factors must be considered. Duration of the flood, time of year, survival and growth of flooded roots, temperature and oxygen content of flood water, rate of recovery following drainage, and depth of water influences. Three water levels are critical: saturated soil with the soil surface wet but not covered by water, water covering the soil surface but not the foliage of a tree, and water covering the foliage. The mortality rate is less for trees in saturated soils than for those with water covering the soil. Injuries to trees are caused by current, wave action, floating debris, and deep deposits of soil left by floodwater.

460. LOW, J. B., AND F. C. BELLROSE, JR. 1944. The seed and vegetative yield of waterfowl food plants in the Illinois River Valley. Journal of Wildlife Management 8:7–22.

Seven hundred ninety plant samples were assayed from the Illinois River Valley between 1941 and 1942. Samples came from three lakes with stabilized water levels, seven lakes with semistabilized water levels, and nine lakes with fluctuating water levels. In 1942, sudden and extreme rises in the water levels inundated and killed innumerable beds of submerged aquatics such as sago pondweed, and so retarded the growth of duck potato millet that seed was reduced in many beds. Except for extreme floods that cover mature plants, most of the effects of higher water on emergent plants is during the early growing season when plants are small. Fluctuations then either delay growth or eliminate many plants and most conditions may affect the amount of seed produced. The best producers in lakes with stable water levels were bur-reed, buttonbush, and longleaf pondweed; in semistable lakes they were wild rice, pickerelweed, Walter's millet, and longleaf pondweed; and in those with fluctuating levels were the wild, Japanese, and Walter's millets. Optimum water depths for maximum seed production are given.

461. LUBINSKI, K. S., G. CARMODY, D. WILCOX, AND B. DRAZKOWSKI. 1991. Development of water level regulation strategies for fish and wildlife, Upper Mississippi River System. Regulated Rivers: Research & Management 6:117–124.

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

462. LUKIN, A. V., AND K. M. KURBANGALIEVA. 1965. The Sviyaga inlet of the Kuibyshev Reservoir and its role in fish production. Pages 3–30 *in* Results of large scale observations on the Sviyaga Bay fauna of the Kuibyshev Reservoir during the period of its formation. Kazansk University, Kazan. (In Russian)

Before regulation of the Volga flow, the estuarine section of the Sviyaga River was very important to sturgeon, sterlet, asp, and "undermouth" (*Chondrostroma nasus*) and was distinguished by an abundant food supply. By 1965, the Sviyaga inlet was a shallow body of water with a depth of up to 3 m. Water level, which had been falling since 1957–58, was very low in spring, dewatering and drying a large area each year and adversely affecting the natural productivity of fish that spawn in shallow water. Spawning success of bream (*Abramis*) and yellow perch was largely conditioned by the presence of a high concentration of young of different sizes, which led to cannibalism. Lower water levels also severely reduced the production of roach (*Rutilus*) and stint (*Osmerus*). Roach and yellow perch have acclimated to open parts of the reservoir. (From Referativmyi Zhurnal. Biologiya 1966, 21186; Biological Abstract 48:52909)

463. LYON, J. G., AND R. D. DROBNEY. 1984. Lake level effects as measured from aerial photos. Journal of Surveying Engineering 110:103–111.

Rising Lake Michigan water levels were found to negatively influence the amount of wetlands and beaches in the Straits of Mackinac area of Lake Michigan. The effects of long-term fluctuation in water levels were determined from measurements of wetlands and beaches on seven sets of historical aerial photographs (1938–1980). Analysis of aerial photographs demonstrated a 380-acre (154-ha) difference in total wetland and beach areas at the highest lake level sampled, as compared to the total at the lowest lake level sampled, or a range of 4 ft (1.2 m). A linear model between total wetland and beach areas and water levels ($R^2 = 0.93$) indicated an increase of 1 ft (0.3 m) would result in a decrease of 80 acres (32 ha) or 18% of the 439 acres (178 ha) of wetlands and beaches in the study area. This methodology, which includes measurements from historical aerial photographs, acquisition of small-format aerial photographs, and determination of local hydrological conditions, was useful for quantifying change in these lacustrine wetlands.

464. 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):1–11.

In summer (May–October), a positive relation was evident between lake water levels and chlorophyll *a* concentrations in littoral and littoral:pelagic interface regions of Lake Okeechobee. High water levels in synergy with the large size (1,830 km^2), shallow depth ($Z_x = 2.7$ m), and unique bottom configuration of Lake Okeechobee seemed to facilitate greater horizontal mixing and circulation, which resulted in higher phosphorus concentrations in a portion of the littoral zone. In shallow littoral regions where light penetration was sufficient, an empirical link between phosphorus and chlorophyll *a* was evident. East-to-west and north-to-south gradients of phosphorus extended from hard-bottom littoral regions to the open-water pelagic zone located over soft, phosphorus-laden flocculent muds, and these gradients were more pronounced at low lake levels. Phosphorus loading from tributaries affected algal concentrations in only a small portion of the lake. A higher water-level regulation schedule was implemented in 1978 to augment water supplies and this increased lake levels when precipitation was sufficient. A slightly lower lake level regulation schedule might reduce the frequency of hypereutrophic algal blooms in nearshore and littoral areas.

465. MAHER, R., AND C. THEILING. 1994. Fish response to extreme flooding on the lower Illinois River. Pages 23–24 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

The life history strategies of large river floodplain plants and animals have evolved around a predictable, seasonal cycle of flooding and drying. Floodplain fishes migrate to inundated terrestrial habitats to feed, spawn, and seek refuge from main channel currents. Channelization, impoundment for navigation, and floodplain constriction through levee construction have disrupted these annual hydrologic cycles. The extreme and extended flooding in spring and summer 1993 offered a rare opportunity to observe the migration of riverine fishes into flooded terrestrial habitats. Fish communities were sampled at three separate areas of the lower Illinois River floodplain. Each area contained four separate habitat types: a floodplain depression lake adjacent to the main channel, a forested area around the lake, an open area outside the forested area that was primarily agricultural, and the shoreline as the floodwaters rose and receded. A combination of gears was used to sample the fish community in each habitat type. Trammel nets, experimental gill nets, and large and small diameter hoop nets were used in all habitats. Shoreline and forested habitats were also sampled with an AC electrofishing boat and Wisconsin style fyke nets. Young-of-year fishes were collected in shoreline habitats with minnow fyke nets and seines. A total of 52 species were collected in the three study areas. Fish density and species richness were highest in shoreline habitats. Catch rates were highest in the shoreline habitats for bluegill (*Lepomis macrochirus*), followed by gizzard shad (*Dorosoma cepedianum)*, black crappie (*Pomoxis nigromaculatus*), golden shiner (*Notemigonus chrysoleucas*), and largemouth bass (*Micropterus salmoides)*. Common carp (*Cyprinus carpio*) was the most abundant species in all other habitats. Channel catfish (*Ictaluris punctatus*) catch rates were highest in the forested areas. The duration of the flood allowed nest-building sunfishes enough time to successfully spawn. This was reflected in high catches of young-of-year largemouth bass and bluegill. Whether or not the fish produced during summer flooding are recruited into the breeding population will help answer some of the questions regarding factors limiting floodplain fish production. Restoration efforts should center around restoring the natural hydrologic cycle, such practices would enhance the natural reproduction of many floodplain river fishes and greatly reduce the need for supplemental stocking. (Abstract only)

466. MAISENHELDER, L. C., AND J. S. MCKNIGHT. 1968. Cottonwood seedlings best for sites subject to flooding. U.S. Department of Agriculture, Forest Service Tree Planting Notes 19(3):15–16.

An area often flooded by Mississippi River backwaters was studied in 1964 to compare the cuttings and seedlings of *Populous deltoides*. Rooted seedlings were found to be preferable on areas likely to be flooded after cottonwoods were planted and before they begin height growth.

467. MAKHOTON, YU M. 1977. Effectiveness of fish spawning in Kuibyshev Reservoir and factors determining it. Voprosy Ikhtiologii 17:27–38. (In Russian)

Studies were conducted from 1960 to 1972 on the success of fish reproduction in the Kuibyshev Reservoir. The principal cause of lower-than-projected fish catches for the reservoir was the absence of necessary conditions for reproduction of most of the commercial fishes. The effect of different environmental factors varied, but water level was a major determinant of fish productivity. Special measures were considered necessary to increase commercial fish catches in the reservoir. (From Biological Abstract 65:45143)

468. MALECKI, R. A., J. R. LASSOIE, E. RIEGER, AND T. SEAMANS. 1983. Effects of long-term artificial flooding on a northern bottomland hardwood forest community. Forest Science 29:535–544.

Two 120-ha bottomland hardwood impoundments located on the Montezuma National Wildlife Refuge in central New York were subjected to at least 12 years (1965–78) of continuous spring flooding (i.e., mid-March to late June). Mean water depth during flooding was 27-30 cm. Comparisons of the flooded areas with a control area and with data provided before the period of flooding showed little change in the composition of the major tree species present. Tree seedling survival favored red maple *(Acer rubrum)*, a species capable of reproducing vegetatively as well as by seed germination, over that of red ash *(Fraxinus pennsylvanica)*, swamp white oak *(Quercus bicolor)*, and American elm (*Ulmus americana)*. Among the herbaceous species, arrow arum *(Peltandra virginica)*, swamp loosestrife *(Decodon verticillatus)*, and *Bidens* spp. increased dramatically in mean density and frequency of occurrence, whereas less flood- and shade-tolerant species such as ferns were reduced. Growth rates of the major tree species in the impoundments were slower than those of trees sampled in a nearby bottomland hardwood stand with natural water-level fluctuations. Evidence of foliar stress in the overstory canopy of the flooded impoundments was apparent from analysis of aerial infrared transparencies. This was especially noted in one impoundment that retained water for a longer period due to soil type, topography, and dike design.

469. MALLIK, A. U., AND R. W. WEIN. 1986. Response of a *Typha* marsh community to draining, flooding, and seasonal burning. Canadian Journal of Botany 64:2136–2143.

A *Typha* marsh community was subjected to draining and seasonal burning treatments to control the growth of emergent aquatics. Treatments resulted in an increase in total number of species after 3 years. Cover and frequency of *Aster novi-belgii*, *Lycopus uniflorus*, *Epilobium watsonii*, *Brachythecium salebrosum*, *Pleurozium schreberi*, and *Cladonia cristatella* increased appreciably on the drained side, whereas those of *Carex* spp., *Lysimachia terrestris*, *Epilobium palustre*, *Pellia epiphylla*, *Sphagnum squarrosum*, *Drepanocladus exannulatus*, and *Helodium blandowii* increased on the flooded side. Draining plus summer burning produced the lowest cover, stem density, plant height, and stem base diameter of *Typha*. An attempt was made to interpret the effects of disturbance on the natural paludification process that leads to the development of patches of fen within the marsh.

470. MANCI, K. M., AND D. H. RUSCH. 1988. Indices to distribution and abundance of some inconspicuous waterbirds at Horicon Marsh. Journal of Field Ornithology 59:67–75.

Over a 2-year period, Virginia rails were not detected in dry cattail, and marsh wren densities were lower in that habitat than in wet cattail habitats.

471. MANDOSSIAN, A., AND R. P. MCINTOSH. 1960. Vegetation zonation on the shore of a small lake. American Midland Naturalist 64:301–308.

Duck Lake is a small, dystrophic lake in Kalamazoo County, Michigan. It is almost round, quite shallow, and has no outlet or inlet. The exposure of two very different types of substrate, sand and muck, as a result of lowered water levels over the last 10 years afforded an opportunity to study the composition and distribution of the vegetation occupying the newly exposed areas. The first 4 m in either case are dominated by the same species, *Hydrocotyle umbellata* and *Hemicarpha micrantha*. The water level and perhaps physical or chemical characteristics of the water are apparently the primary factors influencing the vegetation in these segments of the transects. This is suggested by the gradual diminution in the importance of the two major dominants in each successive meter away from the water's edge. Beyond the fourth meter, the vegetation on sand and muck become increasingly dissimilar so that by the last comparable meter, the seventh, there is little or no similarity between the vegetation on the two substrates. In this zone, the difference in the substrate, especially the ability of the muck to hold and supply water more effectively than the sand, becomes of primary importance. Hydrophytes such as *Nuphar advena* and P*otamogeton natans* persist much farther from the water's edge on the muck than on sand. *Nuphar* persists to the ninth meter on the muck bottom, whereas on the sand it persists only to the third meter as depauperate specimens.

472. MARKOSYAN, A. K. 1969. Benthic productivity of Lake Sevan. Pages 146–152 *in* B. Golek, editor. Transactions of the Sixth Conference of Biology Inland Waters, June 10–19, 1957. U.S. Department of Commerce, Israel Program Science Translation Catalog 5136. (Translated from Russian)

The lowering of water levels of Lake Sevan by more than 10 m exposed more than 85 km^2 of bottom area and greatly altered the hydrochemical regime and biology of the largest mountain lake in the U.S.S.R. Before water levels were lowered, the lake bottom consisted of a stony gravel littoral zone (to 2 or 3 m); a zone of sand, moss, and *Chara*; and a deeper zone of mud. Benthos of the littoral zone were most diverse and supported a good trout fishery before water levels were reduced. Reduced water levels exposed most of the stony littoral zone, and, because mud sediment then extended to the water's edge, sediments were suspended by wave action, and turbidity increased greatly. The oxygen content of the water was reduced 10%–20%. Certain bacteria and phytoplankton populations increased exponentially, and zooplankton biomass in July increased from 0.77 g/m^3 in 1947 to 1.36 g/m^3 in 1956. The solid belt of moss and *Chara* at depths between 7 and 15 m was reduced to isolated patches. Total benthic biomass (metric tons) increased from 6,150, before water levels were lowered, to 40,500 afterwards. Increases in the 10- to 40-m zone were due to increased abundance of chironomids and oligochaetes. The biomass in the 0- to 10-m zone decreased somewhat because the biomass of gammarids was reduced 23%. Because gammarids composed 90% of the trout food, the increase in benthic biomass (mostly inaccessible chironomids and oligochaetes) probably did not result in a more productive fishery.

473. MARTIN, C. C. 1978. Evaluation of the effects of winter drawdowns on the fish populations of Delaware ponds. Delaware Division of Fish and Wildlife, Completion Report F-28-R-4. 22 pp.

The objective of the study was to decrease the numbers of overabundant forage fishes and stimulate the growth of predator fishes through manipulation of water levels. Five ponds were subjected to winter drawdowns during the 3-year period 1975–78. The drawdowns extended from mid-December to March 1, primarily for the purpose of controlling weeds. A 60% exposure of the pond bottom was attempted but was not achieved on all ponds due to excessive precipitation. Although fish populations subjected to winter drawdowns did not exhibit consistent trends in growth or structure, some changes were noted in each pond. The success of vegetation control was not a definite clue as to how the fish population responded to the drawdown. The objective of the program to decrease forage fishes and stimulate the growth of predator fishes was not fulfilled. It is thought that extreme drawdowns at intervals of 3 to 5 years would be more effective than annual drawdowns in Delaware, as it seems that the large year classes of game fish produced following the first drawdown are cropped off during the second drawdown. Drawdowns begun November 1 should allow better utilization of forage fish before feeding slows appreciably.

474. MARTIN, D. B., L. J. MENGEL, J. F. NOVOTNY, AND C. H. WALBURG. 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 effects of water level on the early life history of fish in Lake Francis Case, South Dakota, were studied by comparing the abundance, growth, diet, and food supply (zooplankton) of selected species in a low-water year (1974) and a high-water year (1975). Young of 21 fish species were collected. Yellow perch (*Perca flavescens*), white bass (*Morone chrysops)*, buffaloes (two *Ictiobus* species), and centrarchids were significantly more abundant in net catches in 1975 than in 1974. Flooded shoreline vegetation in 1975 apparently enhanced spawning success by providing a more suitable substrate and protective cover for early life stages. First-summer growth of the four most abundant fishes (yellow perch, buffaloes, and white bass) did not change significantly between years. Standing crops of the larger zooplankton (calanoids and daphnids) decreased during the high-water year, perhaps because of predation by age-0 fish. Standing crops of the smaller zooplankton species such as *Bosmina longirostris* and *Chydorus sphaericus* increased during the high-water year, as did the overall diversity of the zooplankton community. The authors concluded that the management of water levels in Missouri River main-stem reservoirs to include one high-water year out of every three would greatly enhance the lake's fishery resources. It was recommended that water levels be kept lower than normal for one or two growing seasons while terrestrial vegetation became established where slope and substrate permitted. In the third year, water levels could be raised in spring and maintained over the submerged vegetation for as long as possible.

475. MARTIN, J., AND A. BOUCHARD. 1993. Riverine wetland vegetation: Importance of small-scale and large-scale environmental variation. Journal of Vegetation Science 4:609–620.

The purpose of this study was to evaluate the relative importance of small-scale variation in abiotic factors and large-scale spatio–temporal variation on the distribution of wetland vegetation of a section of the Upper St. Lawrence River in Québec. Vegetation data have been classified with agglomerative clustering into 11 community types, from *Acer rubrum*, *Acer saccharinum*, and *Fraxinus* swamps; to scrubs dominated by *Salix petiolaris*, *Alnus rugosa* var. *americana*, or *Myrica gale*; to *Typha*, *Typha/Lythrum*, *Carex lacustris,* and *Calamagrostis canadensis* marshes. Canonical Correspondence Analysis suggested that peat thickness and water level are the most important abiotic variables correlated with plant community composition. As a whole, small-scale variation accounts for 25.6% of the species variation. Another 21.6% is explained by large-scale variation based on location data summarizing large-scale spatial distribution, and historical landscape dynamics differentiated into (a) no net loss of wetlands, (b) net loss of wetland, and (c) changes within wetlands, which are correlated with the actual variation in herbaceous and scrubby vegetation. Time lag between a relative stabilization of species distribution and the reduction of natural disturbances (water-level fluctuations and fires) could be a possible cause of the importance of spatio–temporal variables and the undetermined portion of species variation.

476. MARTIN, N. V. 1955. The effect of drawdowns on lake trout reproduction and the use of artificial spawning beds. Transactions of the North American Wildlife and Natural Resources Conference 20:263–271.

Studies of the effects of drawdowns on lake trout reproduction in three Ontario lakes showed that reduced water levels during spawning in October stranded eggs and larval fish. Reduced water levels before spawning were unfavorable, because fewer spawning sites were available and trout were forced to spawn in less desirable areas, where egg mortality was high (due to predation by bullheads and natural causes). Artificial spawning beds, installed to help alleviate problems associated with water-level fluctuation, were only marginally successful. Only one of three artificial beds constructed on Lake Shirley was used by lake trout for spawning. This bed was positioned near a previous spawning ground, which suggests that lake trout may require some kind of stimulus to initiate spawning, such as familiarity with the area or an odor.

477. MARTIN, N. V. 1957. Reproduction of lake trout in Algonquin Park, Ontario. Transactions of the American Fisheries Society 86:231–244.

The spawning grounds and reproduction of lake trout (e.g., behavior, sex ratios, egg distribution, incubation, and hatching) are described and major causes of egg loss such as fungus infection, predation, and water-level fluctuation are identified. Some loss of eggs was observed because of drawdown in late fall and winter when spawning occurs. In Lakes Shirley and Hays, drawdowns exposed considerable areas (up to 200 yd^2 in Lake Shirley) of potential spawning ground before the spawning season.

478. MARTIN, R. G., AND R. S. CAMPBELL. 1953. The small fishes of the Black River and Clearwater Lakes, Missouri. Pages 45–66 *in* The Black River studies. University of Missouri, Columbia.

Small fishes of the Black River were sampled by seining before the formation of Clearwater Lake. The effects of impoundment on the fish fauna were studied in detail. Environmental conditions in the new reservoir were judged to be highly favorable for successful spawning and high survival of fry. Food in the form of drowned terrestrial invertebrates and benthos was abundant, cover and space were plentiful, and predation was low. Water-level fluctuations affected the abundance of different fish species during the spawning period. Largemouth bass, white crappies, and gizzard shad increased in abundance after spring 1950, when water levels were high but relatively stable. In June and most of July, water levels dropped almost 1 ft/day and may have reduced the overall abundance of bluegills, longear sunfish, and bluntnose minnows.

479. MARTIN, R. G., N. S. PROSSER, AND R. H. STROUD. 1978. Evaluation of planning for fish and wildlife: Carlyle Lake project. U.S. Army Corps of Engineers, Washington, D.C. 103 pp.

Predicted value of the postimpoundment sport fishery was extremely low, partly because of expected fluctuations of water level. By 1977, pool fluctuation during spring spawning period was identified by the Corps of Engineers as the primary factor limiting fish populations, particularly those of black bass and sunfish.

480. MARTIN, R. G., N. S. PROSSER, AND R. H. STROUD. 1979. Evaluation of planning for fish and wildlife: Keystone Lake project. Prepared by the Sport Fishing Institute for the U.S. Army Corps of Engineers, Washington, D.C. 107 pp.

Recommendations pertinent to wildlife resources made in 1961 by the U.S. Fish and Wildlife Service are evaluated. Reservoir water-level fluctuations substantially reduced waterfowl foods such as smartweed and millet, and prolonged floods 9 years after impoundment eliminated green trees at the margin of the reservoir. Pool fluctuations adversely affected largemouth bass. Bass production was greatest in seasons when water levels were relatively stable.

481. MASSARELLI, R. J. 1984. Restoration techniques: Methods and techniques of multiple phase drawdown—Fox Lake, Brevard County, Florida. Pages 498–501 *in* Lake and reservoir management. Proceedings of the Third Annual Conference, Knoxville, Tennessee, October 18–20, 1983. U.S. Environmental Protection Agency, Washington, D.C., EPA 440/5/84-001.

Multiple-phase drawdowns have been suggested as a possible restoration technique for controlling the aquatic weed *Hydrilla* and for consolidating sediments. Brevard County, in cooperation with the Florida Game and Fresh Water Fish Commission, implemented such a program in 1979–80. Fox Lake is a small 44.5-ha (110-acre) freshwater lake in Brevard County on Florida's east coast. This lake, the location of a major regional park, had become unusable to boaters and fishermen due to an excessive growth of *Hydrilla*. In addition to the *Hydrilla*, the lake had minimal fish and wildlife benefits due to a thick layer of unconsolidated muck. While the use of proper technique is important, the restoration of Fox Lake required methods that would ensure full community support and the cooperation of other agencies and local elected officials. Techniques must be flexible enough to meet unforeseen or changing conditions. The Fox Lake project demonstrated that lake restoration projects with maximum and innovative use of local resources can be completed with minimal effects on local government budgets.

482. Mathur, D., and T. W. Robbins. 1979. Food of the white crappie, *Pomoxis annularis* Rafinesque, in two new impoundments. Proceedings of the Pennsylvania Academy of Science 53:34–36.

Diets of white crappies in two new impoundments (Muddy Run Lake and an adjacent pumped-storage pond) differed significantly. Large white crappies ate more fish than plankton in the lake, but in the pond the plankton-feeding phase of crappies was prolonged and few fish were eaten. Because water levels of Muddy Run Lake remained stable, forage fish reproduced adequately and were abundant and available to crappies. In contrast, water levels of the pumped-storage pond fluctuated widely and limited forage-fish reproduction. White crappies are opportunistic feeders, eating the most abundant and available foods.

483. Mauck, P. E. 1970. Food habits, length-weight relationships, age and growth, gonadal-body weight relationships, and condition of carp, *Cyprinus carpio* (Linnaeus), in Lake Carl Blackwell, Oklahoma. M.S. Thesis, Oklahoma State University, Stillwater. 73 pp.

Life history and growth information about common carp are presented and discussed to provide fishery managers with knowledge pertinent to managing a reservoir with a large population of common carp. Growth of yearling common carp was not affected by prolonged drought, but growth increased significantly over previous years when lake levels increased.

484. Mayhew, J. 1977. The effects of flood management regimes on larval fish and fish food organisms at Lake Rathbun. Iowa Conservation Commission, Fisheries Section, Technical Series 77-2. 46 pp.

Regression analyses revealed three significant relations as follows: (1) flushing rate explained 77% of the variability in the density of young-of-year gizzard shad, (2) flushing rate explained 94% of the variation in copepod density, and (3) water temperature explained 74% of the variation in copepod density. Flushing rate and temperature were significantly correlated, but the effect of flushing rate on copepod density probably was greater than that of temperature, inasmuch as water temperature was affected by flushing rate. Data strongly suggest that the relation between flushing rate and gizzard shad abundance controls the most important path of energy flow and that zooplankton density is influenced by shad abundance. Growth of shad is density dependent. Thus, by manipulating flushing rates to increase shad density it may be possible to increase the length of the period when young-of-year shad are vulnerable to predators. The ideal water-retention time is about 1 year for Lake Rathbun.

485. McAfee, M. 1977. Effects of water drawdown on the fauna in small coldwater reservoirs. Journal of the Colorado–Wyoming Academy of Science 9(1):9–10. (Abstract)

The effects of drawdown on primary production, invertebrate abundance, and fish abundance and condition were examined by comparing two cold-water reservoirs with stable water levels with two other cold-water reservoirs where water levels were drawn down. Primary production was low in all impoundments and varied only slightly among them. Densities of invertebrates were relatively high in one stable and one drawdown reservoir, as were fish densities and condition factors. Drawdown either had no demonstrable effects on reservoir biota or the effects were small in relation to differences in reservoir productivity, as determined by other variables (e.g., drainage area or water chemistry).

486. McCammon, G. W., and C. Von Geldern, Jr. 1979. Predator–prey systems in large reservoirs. Pages 431–442 *in* H. Clepper, editor. Predator–prey systems in fisheries management. Sport Fishing Institute, Washington, D.C.

Although the potential for increasing yields of fish from coldwater reservoirs is low, possibilities are good for improving fisheries in existing warmwater reservoirs by developing techniques for manipulating relations between predator and prey fishes. The authors review findings about some of the most promising techniques for managing predator–prey relations of reservoir fishes. Literature is cited to establish the importance of high and stable water levels for improving spawning success of sport fishes and increasing survival of young-of-year bass. Planting vegetation in the fluctuation zone can also enhance reproductive success of largemouth bass by providing cover when vegetation is flooded. Juvenile bass were six times more abundant in flooded beds of ladysthumb than in unvegetated areas of Millerton Lake. "Wattling" experiments (burying cigar-shaped bundles of willows in rows parallel to shorelines) were successful in protecting bass from adverse wave action and soil erosion. After inundation, willow slips sprout and create a shield. Drastic drawdowns during late summer, fall, and winter at intervals of 5 to 10 years should increase predator use of available prey.

487. McCarraher, D. B. 1959. The northern pike–bluegill combination in north-central Nebraska farm ponds. Progressive Fish-Culturist 21:188–189.

Quality pike fishing was produced in two farm ponds by stocking northern pike and bluegills. Summer drawdown of 4 to 8 ft impaired neither the recruitment of bluegills nor the food habits or growth of pike.

488. McClendon, E. W. 1976. Conflicts and capabilities associated with regulating the Missouri River main stem reservoir system to enhance the fishery resource. Pages 148–157 *in* J. F. Osborn and C. H. Allman, editors. Instream flow needs. Volume 2. Western Division, American Fisheries Society, Bethesda, Maryland.

Six major reservoirs on the Missouri River have been operated for over 20 years for flood control, power generation, navigation, irrigation, water supply, water quality control, recreation, and fish and wildlife. During the filling of most of the reservoirs, operations were of little consequence to the fishery, as new areas of vegetation were being inundated each year, and reproduction and survival were excellent for most important fish species. After 1967, however, when all impoundments reached capacity, special operations required to enhance fisheries often conflicted with primary uses (e.g., power, flood control, or irrigation). Special operations that relate to water levels include scheduling releases to (1) raise water levels and inundate vegetated areas in spring, (2) dewater areas to permit the growth of vegetation for future inundation, and (3) maintain steady or rising waters from early spring to early summer to enhance fish reproduction. By scheduling releases of the larger upstream storage reservoirs, normal fluctuations in water level in lower impoundments were successfully altered in many years to inundate terrestrial vegetation in early spring (instead of midsummer) to provide suitable spawning habitat for northern pike. Because this technique requires 2 years (1 year to allow vegetation to develop and 1 year for spawning) and sometimes fails to produce successful year classes of pike, emphasis has been shifted toward management to enhance spawning of forage fishes. Successful spawning of forage fishes results when water levels rise from early spring through early summer.

489. McConville, D. R. 1993. A spatial assessment of fish collection sites in Pool 8, Upper Mississippi River. Page 65 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

Fish data have been collected at 17 locations in Pool 8 since 1989. These locations, representing 10 different ecotypes, were sampled under the auspices of the Long Term Research Monitoring Program. The goal of this project has been to utilize spatial analyses tools to gain an understanding of the spatial character in the immediate proximity of sampling locations. In particular, this project shows how a geographic information systems analysis (GIS) can add additional detail that might be used to help analyze and understand fisheries data. Additionally, it shows how GIS can help assess and quantify spatial heterogeneity within the river system. Data layers queried included 1989 and 1991 6-class land cover coverages, a 10-class bathymetry coverage, and a 7-class sediment coverage. The data layers were derived from the Environmental Management Technical Center's spatial database for Pool 8. To understand the spatial character, concentric rings of 100, 200, and 300 m radius were generated around the geocoordinate center of each site. Preliminary analyses indicate that substantial spatial diversity exists. This is shown to be both within and between ecotypes as well as temporally between years. (Abstract only)

490. McDermott, R. E. 1954. Effects of saturated soil on seedling growth of some bottomland hardwood species. Ecology 35:36–41.

Seedlings of sycamore, river birch, American elm, winged elm, red maple, and alder that had just developed their first true leaves were subjected to saturated soil conditions of varying time intervals followed by intervals of soil moisture at and above field capacity under conditions of approximately half sunlight and high soil temperatures. Comparisons of height growth in 10-day periods after the most favorable soil treatment (days) and height growth in 10-day periods after the most stunting, soil-saturated treatment were made. After subjection to a sustained saturated substratum with subsequent well-drained conditions, river birch and red maple seedlings recover very rapidly, sycamore rapidly, and American elm and winged elm at a moderate rate. The growth rate of alder seedlings is accelerated by short intervals of soil saturation, and their growth is not significantly changed by sustained saturation intervals up to 32 days. The relative degree of recovery from stunting induced by previously saturated soils of young seedlings of alder, river birch, sycamore, American elm, and winged elm may be indicative of their successional relations and ultimate stand composition in bottomlands.

491. McDonald, M. E. 1955. Cause and effects of a die-off of emergent vegetation. Journal of Wildlife Management 19:24–35.

Increased water levels in marshes along Lake Erie caused a die-off of *Typha angustifolia*, *T. glauca*, *Scirpus fluviatilis*, *S. Acutus*, *S. validus*, *Carex stricta*, and *Phragmites communis* in winters 1945–46 and 1951–52. Some stands of *T. angustifolia* and individual shoots of *T. glauca* survived the first die-off and partly recovered the area by vegetative propagation. The second submergence killed out a wide belt of vegetation behind the former, but some stands survived. The die-off areas were occupied by a succession of submerged aquatic plants, floating-leaf forms, and wild rice. A period of falling water level occurred after the first die-off, and during that time exposed mudflats were colonized by a variety of wetland plants, including the reed marsh species. Eventually an increase in *T. glauca* in comparison with *T. angustifolia* occurred due to more rapid vegetative reproduction.

492. MCGRAGOR, R. L. 1948. First year invasion of plants on an exposed lake bed. Transactions of the Kansas Academy of Science 51:324–328.

Tonganoxie Lake, in Leavenworth County State Park, Kansas, a 175-acre lake, was drained in December 1946. For several years, the lake was a popular fishing area but during the last few seasons prior to 1946 the fishing became steadily worse. The lake was drained in order to study the lake basin. In fall 1947, the lake was again allowed to fill. Subsequent to drainage it was found that siltation was limited in most areas to just a few inches, although in some areas it measured several feet. During May and June, seedlings began to appear on the lake bed in great numbers. A study of invading plants was made in July. From the beginning of the study, it was apparent that *Polygonum lapathifolium* L. was the dominant plant flora of the lake bed and formed a dense growth over nearly the entire exposed surface. Several species formed localized colonies here and there over the lake bed. A number of other species were found scattered around the lake area. Tree seedlings were found mostly at the water level that occurred at the time the seeds of trees were shed.

493. MCKEE, K. L., I. A. MENDELSSOHN, AND D. M. BURDICK. 1989. Effects of longterm flooding on root metabolic response in five freshwater marsh plant species. Canadian Journal of Botany 67:3446–3452.

Five freshwater marsh plant species exhibited different root metabolic responses when flooded to three water depths in field macrocosms. The capacity for alcoholic fermentation (as indicated by alcohol dehydrogenase activity) increased and remained at a relatively high level in the roots of the least flood-tolerant species, *Scolochloa festucacea*, but was not stimulated significantly or only temporarily in the more tolerant species, *Scirpus acutus, Scirpus validus, Typha glauca,* and *Phragmites australis*. During the first month of flooding, alcohol dehydrogenase activity showed a positive relation with flooding depth and a negative relation with soil redox potential. Malate accumulated in the roots of *S. acutus, S. validus,* and to a lesser extent in *P. australis* in response to flooding; concentrations showed a significant positive relation with water depth and a significant negative relation with soil redox potential during the first month of flooding. Differences in root metabolism among the five species were still evident after 1 year of continual flooding. Root specific gravities and air space cross-sectional volumes demonstrated potential species differences in root resistance to oxygen movement and root oxygen volume, respectively. The results suggest that the observed metabolic response reflected differential aeration of the roots resulting from differences in root structure and soil oxygen demand (reducing power).

494. MCLACHLAN, A. J. 1970. Some effects of annual fluctuations in water level on the larval chironomid communities of Lake Kariba. Journal of Animal Ecology 39:79–90.

The influence of water-level fluctuation on the larval chironomid community of Lake Kariba, Africa, was studied on gradually sloping shorelines. During periods of stable water levels, densities peaked in the shallows and diminished rapidly with increasing depth. Rising water levels reduced the number of species present near the shoreline, but increased the biomass of chironomids and altered their distribution. The numbers and weights of chironomids increased markedly in the 20-cm zone as water levels rose, primarily because of the presence of one large species (*Chironomus transvaalensis*). Despite a recession of the waterline by as much as 1.5 km in 4 months and the stranding of many larvae (up to 2,825 larvae m^{-2}), no significant quantitative changes in species composition or density were found. As water levels rise, oxygen tensions decrease and nutrients may be "injected" into the system. Results suggest that the invasion of new areas is primarily by oviposition, perhaps supplemented by some migration of larvae. Fluctuations of water levels are expected to be important to the lake's ecology.

495. MCLACHLAN, A. J. 1974. Development of some lake ecosystems in tropical Africa, with special reference to the invertebrates. Biological Reviews 49:365–397.

Ecological changes in new lakes in tropical Africa are discussed. Two large man-made lakes (Volta and Kariba) provide most of the material for this review. Two phases of development are recognized: "filling," characterized by sudden appearances of organisms and rapid growth of plant and animal populations; and "postfilling," characterized by the development and exploitation of existing habitats (e.g., beaches and mudflats). The role of water-level fluctuation in postfilling phases of development also is considered. Water levels result in an interaction between the terrestrial and aquatic ecosystems, providing new habitat such as flooded trees (at least in shallow areas). Water-level changes impede the establishment of rooted aquatic plants and the development of shorelines (formation of beach areas and mud habitat). Effects of fluctuations are more pronounced in gradually sloping or shelving areas. Drawdown on Lake Kariba, where water levels over gradually shelving areas receded as much as 2 km, stranded chironomid larvae (up to 200 mg m^{-2}). Because losses were rapidly made up by oviposition at the receding waterline, the benthos were relatively unaffected by drawdown. During periods of low water, dense growths of grass developed on mudflats and the feces of large game animals accumulated. Upon reflooding, dissolved oxygen decreased, and concentrations of potassium, nitrate, and phosphate increased in shallow water. The biomass of chironomids (especially one species) increased greatly. The annual interaction between the terrestrial and aquatic system, brought about by water-level fluctuations, may be of considerable importance to the nutrient economy of lakes. Inundated grasses that develop during low water release large quantities of organic materials and nutrients into the water.

496. MCLACHLAN, A. J. 1977. The changing role of terrestrial and autochthonous organic matter in newly flooded lakes. Hydrobiologia 54:215–217.

Newly flooded lakes pass through two phases (flooding and postflooding). During the flooding of lakes, mud-dwelling organisms depend on terrestrial organic matter for food. After inundation is complete, diets immediately shift to include more autochthonous-based foods. Gut contents of 500 insects (primarily chironomids)—collected from lakes Kariba and Chilwa, Africa, and from Ladyburn Lough in England, during filling and postfilling phases—were examined. Reduced biomass of benthos after the filling of lakes was associated with a change in diet from terrestrial detritus to algae. The percent of allochthonous organic matter in diets decreased from 93% to 64% in Lake Chilwa and from 89% to 52% in Ladyburn Lough. Biomass (mg dry weight m^{-2}) declined from 2,967 to 1,051 in Lake Chilwa, from 1,558 to 708 in Ladyburn Lough, and from 2,911 to 215 in Lake Kariba.

497. MCLACHLAN, S. M. 1970. The influence of lake level fluctuation and the thermocline on water chemistry in two gradually shelving areas in Lake Kariba, Central Africa. Archiv fuer Hydrobiologie 66:499–510.

When flat areas covered with grasses and animal dung were flooded to a depth less than 20 cm, alkalinity, conductivity, carbon dioxide, and potassium increased considerably, while pH and dissolved oxygen concentration decreased. By contrast, no significant changes in these variables were observed when water levels decreased. The decomposition of grass and dung seemingly used oxygen and released nutrients and was largely responsible for chemical changes. The extent of observed changes depended partly on the amount of grass and dung inundated. Chemical changes were more pronounced over gently sloping shorelines than they were over steep rocky shorelines, because more area was inundated by fluctuations, and the growth of plants was far more extensive.

498. McLeod, K. W., L. A. Donovan, N. J. Stumpff, and K. C. Sherrod. 1986. Biomass, photosynthesis, and water use efficiency of woody swamp species subjected to flooding and elevated water temperature. Tree Physiology 2:341–346.

Seedlings of water tupelo (*Nyssa aquatica* L.), bald cypress (*Taxodium distichum* [L.] Richard) and buttonbush (*Cephalanthus occidentalis* L.) and cuttings of black willow (*Salix nigra* Marshall) were established in pots and included in a complete factorial experiment with three water temperatures (maximums of about 30, 35, or 40 °C) and three water levels (maximum flood depth was 6 cm above soil level). Flooding for 3 months at 30 °C reduced the dry weight of roots and shoots in all species except water tupelo. At 40 °C, however, flooding significantly reduced the growth of water tupelo as well as the other species. High water temperatures reduced stomatal conductance and photosynthetic rates in water tupelo and black willow, but not in the other species. In combination with flooding, high temperature reduced water use efficiency in all species except buttonbush and most sharply in water tupelo.

499. McKnight, S. K. 1992. Transplanted seed bank response to drawdown time in a created wetland in east Texas. Wetlands 12:79–90.

Sediment was transplanted from a 13-year-old created wetland on a nonacid mine in east Texas into a constructed experimental basin to examine seed bank response to four drawdown regimes. The success of the transplanted seedbank in vegetating the experimental wetland was assessed by measuring species richness, seedling density, and above-ground biomass. April drawdown produced the greatest species richness (29), stem density (1,851.0 stems m^{-2}), and aboveground biomass (769.3 g m^{-2}), followed by the unflooded water regime. June and August drawdowns produced less emergent vegetation than the other treatments, but three submergent species were produced prior to drawdowns. Results indicate that the use of transplanted species-rich wetland soil subjected to early spring drawdown is a very effective technique for establishing wetland vegetation on disturbed sites in east Texas. Excavating relatively few widely spaced narrow strips of soil from the donor wetland caused only slight decreases in vegetative cover during the subsequent growing season.

500. Meeks, R. L. 1969. The effect of drawdown date on wetland plant succession. Journal of Wildlife Management 33:817–821.

A 7-year study was begun on the Winous Point Shooting Club, Clinton, Ohio, in 1956 to determine the effect of drawdown date on plant succession. An 80-acre marsh was diked into four units, one of which was drained yearly in mid-March, one in mid-April, one in mid-May, and one in mid-June. All the units were reflooded during September. Plant succession followed the same general trend on all units, going from semiaquatic species to predominantly annual weeds. Fewer years were required with early drawdowns for annual weeds to replace semiaquatic species.

501. Megonigal, J. P., and F. P. Day. 1992. Effects of flooding on root and shoot production of bald cypress in large experimental enclosures. Ecology 73:1182–1193.

Continuous flooding is usually considered more physiologically stressful to hydrophytes than periodic flooding, but for bald cypress and other extreme hydrophytes there is a trade-off between flood tolerance and drought tolerance. If dominated by hydrophytes, a soil that is continuously flooded with shallow water may support higher productivity than a periodically flooded soil that frequently dries to the wilting point. Bald cypress is not consistently affected by saturation or flooding. Bald cypress and water tupelo may have a narrow range of tolerance for wet and dry extremes. The varied responses of these species to flooding treatments in microcosm studies may reflect the wide variety of conditions that researchers consider "flooded" or "drained." The relatively short duration of these studies may also have contributed to variations in the growth response.

502. Merendino, M. T., and L. M. Smith. 1991. Influence of drawdown date and reflood depth on wetland vegetation establishment. Wildlife Society Bulletin 19:143–150.

In summer 1989, the authors examined the effects of four reflood depths on vegetation establishment during four drawdowns conducted in summer 1988 at the Delta Marsh, Manitoba, Canada. Vegetation established with different drawdown dates (May 15, June 15, July 15, and August 15, 1988) was subjected to four reflood depths (0, 15, 30, and 50 cm) in summer 1989. Our objective was to determine if flood tolerance of wetland vegetation was affected by drawdown date the previous growing season. Early season drawdowns (May and June) allow perennial plants time to develop rhizomes capable of producing shoots under flooded conditions. Alkali bulrush and hardstem bulrush in early drawdowns (May and June) could tolerate deeper (30–50 cm) flooding than in late (July and August) drawdowns (0–15 cm). Flooding of 50 cm nearly eliminated young hardstem bulrush plants from our drawdowns. Although alkali bulrush commonly grows in water 50 cm deep, young plants in all but the May 15 drawdown of our study were eliminated by 50 cm of flooding. Floral initiation was delayed as water depth increased. Flowering occurred earlier in the May 15 drawdown at all reflood depths. May drawdowns maximize shoot, cover, and seed production of desirable species (alkali bulrush and hardstem bulrush) during the first season and allow deeper (30–50 cm) flooding the following year, thereby providing the most habitat for breeding waterfowl and their broods. Late drawdowns (July and August) should be drawn down for a second year, or only shallowly flooded.

503. Merendino, M. T., L. M. Smith, H. R. Murkin, and R. L. Pederson. 1990. The response of prairie wetland vegetation to seasonality of drawdown. Wildlife Society Bulletin 18:245–251.

The objective of the study was to evaluate the effect of four drawdown dates (May 15, June 15, July 15, and August 15) on the recruitment of species from the seedbank at the Delta Marsh in south-central Manitoba, Canada. Season of drawdown affected the abundance, species richness, and flowering of wetland vegetation. Overall shoot densities were highest in the May 15 drawdown, with alkali bulrush the dominant species. The number of flowering shoots was highest in the May 15 drawdown. Cattail dominated the June 15 drawdown, and purple loosestrife reached maximum densities. Midsummer drawdowns (July 15) and late-summer drawdowns (August 15) were characterized by low species abundance and absence of seed production. Drawdowns on May 15 provide best results for food (seed) availability and vegetative cover for waterfowl.

504. MERNA, J. W. 1964. The effect of raising the water level on the productivity of a marl lake. Proceedings of the Michigan Academy of Science 49:217–227.

In 1957, a dam installed on Big Portage Lake (Michigan) raised the water level 3 ft and increased the area from 335 to 435 acres. Aquatic vegetation in the lake in 1959 consisted of *Scirpus* sp. and scattered beds of *Nymphaea odorata*; few plants were at depths exceeding 5 m. Before 1946, 20 species of plants were present, and 10 were common. The range of total phosphorus increased for a year after water levels were raised and alkalinity decreased, though not significantly. The numerical abundance of benthos decreased significantly ($P < 0.01$) after lake levels were raised (from an average of 100 organisms ft^{-2} to 40 organisms ft^{-2}). Qualitatively, benthos samples were similar before and after the water-level change. Growth of bluegills, largemouth bass, and black crappies increased, perhaps because of greater zooplankton production. The average length attained by all ages of bluegills, largemouth bass, and black crappies was longer in 1959 than in 1953–54.

505. MERRY, D. G., AND F. M. SLATER. 1978. Plant colonization under abnormally dry conditions of some reservoir margins in mid-Wales. Aquatic Botany 5(2):149.

The pioneer community of the exposed reservoir margins contained plants of several ecological provenances growing largely at random over the drawdown zone. Maximum diversity was consistently encountered in the midsection of each transect, which, it is suggested, reflects both optimum growing period and conditions for the maximum number of individuals and species of both bryophytes and higher plants to develop. The mud community, although a pioneer, was the effective maximum attainable in the existing environmental regime and could appear at the same place on successive occasions. Reservoir margins represent an ephemeral and irregularly occurring habitat, colonized, at least in this investigation, by species not usually found in quantity in the area when reservoirs are full. It is suggested that many plant seeds remain viable beneath the water for a year or more following inundation. In years of severe water depletion, this pioneer turf no doubt helps to stabilize the marginal alluvium and restrict its subsequent erosion on refill.

506. MEYER, B. S., F. H. BELL, L. C. THOMPSON, AND E. J. CLAY. 1943. Effect of depth of immersion on apparent photosynthesis in submerged aquatic vascular plants. Ecology 24:393–399.

A study was made of the relative rates of apparent photosynthesis of five species of aquatic plants when immersed at a series of depths ranging to 10 m in Lake Erie. In all five species, the rate of apparent photosynthesis decreases less rapidly with depth of immersion than does the light intensity. In all of the species except *Najas flexilis*, for which the value is slightly higher, the compensation point is less than 2% of the sunlight intensity on clear, summer days. The results indicate that *Vallisneria americana* can survive at lower light intensities than any of the other four species.

507. MIKULSKI, J. ST. 1978. Value of some biological indices in case histories of lakes. Verhandlungen Internationale Vereinigung Limnology 20:992–996.

Biological indices based on remains of fossilized zooplankton and benthos are developed to permit an evaluation of historical changes in lake basins. Lake-level oscillations influence relations between pelagic and littoral zones. The index, ILL = Bosminidae minus Daphnidae minus Chydoridae, closely reflects water-level oscillations caused by rainfall, as established on the basis of geological and geomorphological investigations. This index may also be useful in recounting oscillations in water level caused by flow variations or activities of man.

508. MILLAR, J. B. 1973. Vegetation changes in shallow marsh wetlands under improving moisture regime. Canadian Journal of Botany 51:1443–1457.

Changes in species composition and plant cover were studied in relation to moisture regime over a 10-year period in 71 shallow marsh wetlands in the grassland and parkland regions of Saskatchewan. Decreases in density of the shallow marsh emergents *Polygonum coccineum*, *Carex atherodes*, *Scolochloa festucacea,* and *Eleocharis palustris* occurred with greater-than-normal water depth at the start of the growing season, but 2 or more years of continuous flooding were required to eliminate emergent cover completely and convert the wetland to open water. Repeated fall reflooding also resulted in the complete elimination of emergent species. Changes in species composition occurred when basins were grazed and as vegetation reestablished after cultivation but no changes followed mowing or burning. *Alopecurus aequalis, Beckmannia syzigachne, Glyceria grandis,* and *G. pulchella* are designated as "disturbance" species on the basis of their response to soil-exposing events. Presence of small amounts of deep marsh emergents in shallow marsh wetlands is not considered a reliable indicator of wetter moisture regime. Species composition of rooted submergents in a wetland can be used as an indicator of its moisture regime. Shallow marsh wetlands in basins of 1 acre (0.41 ha) or less experienced little year-long flooding and converted to open water only under atypical conditions. Larger wetlands required basin depths in excess of 36 inches (96.4 cm) to have any amount of year-long flooding and to convert to open water. These basin size and depth criteria have applications in habitat evaluation by waterfowl managers.

509. MILLER, K. D., AND R. H. KRAMER. 1971. Spawning and early life history of largemouth bass (*Micropterus salmoides*) in Lake Powell. Pages 73–83 *in* G. E. Hall, editor. Reservoir fisheries and limnology. American Fisheries Society, Special Publication 8.

The spawning time, habitat, and early life history of largemouth bass is described, with emphasis on embryo survival, growth, and feeding by fingerlings. An index to year-class strength based on shoreline seining was developed, but its value is questionable until validated by estimates of year-class strength based on a creel census. The mean depth of nests at time of construction increased from 1.6 to 4.5 m in 1968 and from 1.5 to 2.9 m in 1969, as water levels rose continuously. Strong winds and wave action destroyed nests in water less than 1.5 m deep, but nests in deeper water or protected from waves by boulders or ledges were unaffected. Cover was limited to certain depth strata and was more limiting to successful nesting than was water depth over the nests.

510. MILLER, R. B., AND M. J. PAETZ. 1959. The effects of power, irrigation, and stock water developments on the fisheries of the south Saskatchewan River. Canadian Fish Culturist 25:13–26.

Power projects on high-altitude lakes and rivers that have large-scale water-level fluctuations (e.g., 35 ft in Lakes Minnewanka and Spray; 43 ft in Lower Kananaskis Lake) do not support good sport fisheries. Although physical and chemical conditions and plankton are affected little, the bottom fauna is greatly reduced. Trout growth typically is arrested at a weight of about 1 pound, the weight at which the fish normally convert from a diet of plankton to one of benthos. Power projects on rivers and streams of Saskatchewan have not increased sport-fish production over that existing before impoundment. Fluctuating water levels rule out any useful management scheme. Irrigation impoundments and diversions at altitudes lower than those of power projects are more fertile (due to rich soils) and warmer, and are subjected to smaller drawdowns. As a result, irrigation, stock-water, and diversion reservoirs often develop valuable commercial fisheries for northern pike and whitefish and sport fisheries for pike. Small reservoirs of these types with coarse fish provide good pike angling and those without coarse fish often have good trout fisheries. Winterkills created by the drawdown of small trout reservoirs may provide a better population balance among trout of different sizes.

511. MILLS, H. B., W. C. STARRETT, AND F. C. BELLROSE. 1966. Man's effect on the fish and wildlife of the Illinois River. Illinois Natural History Survey, Urbana, Biological Notes 57. 24 pp.

The authors make comparisons that relate measurable changes in fish and wildlife populations on the Illinois River and its bottomland lakes to human activity during the past 75 years. Included in the review are observations based on water-level changes caused by the diversion of Lake Michigan waters into the river in 1900 to the building of locks and dams.

512. MIRANDA, L. E., W. L. SHELTON, AND T. D. BRYCE. 1984. Effects of water level manipulation on abundance, mortality, and growth of young-of-year largemouth bass in West Point Reservoir, Alabama–Georgia. North American Journal of Fisheries Management 4:314–320.

The management of water levels provides one of the most cost-effective means of managing a fish community. Water-level manipulation was examined from 1977 to 1981 on the Chattahoochee River as a potential management technique for increasing recruitment of largemouth bass (*Micropterus salmoides*) in a reservoir where prey availability and utilization were major factors influencing the largemouth bass population. Raising the water level above normal summer pool inundated terrestrial vegetation and provided cover for young-of-year (YOY) largemouth bass. A positive relation was observed between early survival of YOY largemouth bass and water level during the spawning period. In the postspawning period, survival rate and abundance of YOY were related directly to water level, but growth was inversely affected. Average standing stock of YOY largemouth bass in August was similar during the 5 years of study, indicating the system supports a particular biomass, and growth decreased when greater number of young were added through enhanced survival. Results of this study suggest that, unless carrying capacity and food availability for YOY largemouth bass are increased concurrently with water level, use of this technique may not result in a strong year class.

513. MITCHELL, C. C., AND W. A. NIERING. 1993. Vegetation change in a topogenic bog following beaver flooding. Bulletin of the Torrey Botanical Club 120(2):136–147.

Vegetation change was documented along three permanent transects after nearly three decades of beaver flooding. The anchored forested wetland community was killed and replaced by a minerotrophic fen vegetation, whereas minimal change occurred within the tall scrub-shrub, dwarf shrub, and open meadow communities. Along all transects, tree cover was reduced two- to fivefold, whereas low heath shrub cover, especially *Chamaedaphne calyculata* and *Kalmia angustifolia*, increased. Herbaceous cover, primarily sedges, increased, especially in the newly created fen. Within the floating mat communities, the evergreen ericaceous shrubs and scattered stunted *Picea mariana* and *Larix laricina* persisted as did the herbaceous bog flora. Species richness showed little change from 1960 to 1988, although there was a floristic shift toward more hydric species. Flooding differentially affected the vegetation pattern favoring more minerotrophic species in some areas, but did not seem to threaten the typical bog flora.

514. 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.

Reproduction was adversely impacted by rising water levels through temperature reduction and by lowering water levels through nest destruction. Successful nesting was observed only during periods of water stability in March and June. Springtime water-level manipulation is an essential part of reservoir operation. Staged drawdowns are recommended to minimize impact on largemouth bass nesting. At initiation, the mean depth of 36 guarded nests was 1.1 m. Nest depth was dramatically altered as water levels dropped and 55% of the nests were abandoned within 2 days after egg deposition. All nests were abandoned and/or destroyed by wave action or desiccation within 6 days. In springtime, fluctuation is an essential part of reservoir operation. It would be desirable to fluctuate water in stages with at least 3 weeks between major periods of fluctuation. This procedure would be more favorable than long, gradual drawdowns or buildups.

515. MITCHELL, S. F. 1975. Some effects of agricultural development and fluctuations in water level on the phytoplankton productivity and zooplankton of a New Zealand reservoir. Freshwater Biology 5:547–562.

Daily phytoplankton productivity in Lake Mahinerangi increased from 76 mg carbon m^{-2} in 1964–66 to 210 mg m^{-2} in 1968–70. Although none of the three dominant zooplankters increased in abundance, densities of two less abundant taxa increased substantially. About 78% of the variation in hourly primary productivity during 1964–66 was explained by the equation $Y = 3.3326\ x_1 + 0.1635\ x_2 + 0.1381\ x_3 - 13.6933$, where Y = hourly production (mg carbon m^{-3}), x_1 is water level at the dam (in feet), x_2 is temperature (°C), and x_3 is day length (h). Estimates of productivity for two dates in 1969 were about three times as high as rates for corresponding dates in 1965—as was expected from differences in water level and temperature. When compared with actual measurements of production in 1968–70, predicted values agreed well with observed values, but not all of the variation was explained. Undoubtedly the effects of changes in water level are complex, and it is not surprising that a multiple-linear-regression model did not explain more of the variability. Rates determined experimentally in November 1968 and on all but one date after April 2, 1969 were typically twice as high as calculated rates.

516. MOEN, C. T., D. L. SCARNECCHIA, AND J. S. RAMSEY. 1989. Paddlefish movements and habitat use in Pool 13 of the Upper Mississippi River during a drought year. Page 12 *in* Proceedings of the Mississippi River Research Consortium, Volume 21, La Crosse, Wisconsin, April 27–28, 1989.

In spring and summer 1988, radio transmitters with an expected battery life of 2.5+ years were surgically implanted in 35 paddlefish (*Polyodon spathula*) in Pool 13 of the Upper Mississippi River. Fish locations were intensely monitored during late March through May in an attempt to locate and describe spawning areas. Because of abnormally low spring runoff, the gates were not opened and tagged fish were unable to pass upstream through Lock and Dam 12. Sampling for paddlefish eggs and larvae in likely spawning and rearing areas was unsuccessful. During the period May to August 1988, the habitat variables of water surface temperature, general substrate type, and water velocity (at 30.5 cm below the surface, at 0.6 × depth, and at 30.5 cm from bottom) were measured at 57 paddlefish locations. For the year, 33 tagged paddlefish were located and general habitat type was identified 812 times. Paddlefish movements and habitat use in 1988 are presented and compared with the results of a 1980/1981 paddlefish radiotelemetry study conducted in Pool 13 during higher water levels. (Abstract only)

517. MOEN, C. T., D. L. SCARNECCHIA, AND J. S. RAMSEY. 1992. Paddlefish movements and habitat use in Pool 13 of the Upper Mississippi River during abnormally low river stages and discharges. North American Journal of Fisheries Management 12:744–751.

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

518. MOEN, T. E. 1974. Population trends, growth, and movement of bigmouth buffalo, *Ictiobus cyprinellus*, in Lake Oahe, 1963–70. U.S. Fish and Wildlife Service, Technical Paper 78. 19 pp.

Bigmouth buffalo populations, which declined irregularly from 1964 to 1970 in Lake Oahe, were dominated by three strong year classes (1959, 1960, and 1962). Successful reproduction was associated with inundation of shoreline vegetation during spring and early summer. Growth of fish was rapid in the first few years of impoundment, but later declined. Because Lake Oahe reached normal pool in late 1967, future flooding of terrestrial vegetation probably will be infrequent, and populations of bigmouth buffaloes are expected to decline further. Commercial harvest of bigmouth buffaloes depleted the 1962 year class.

519. MOFFETT, J. W. 1943. A preliminary report on the fishery of Lake Mead. Transactions of the North American Wildlife Conference 8:179–186.

The environment of Lake Mead during the early years of impoundment is described, as well as the fishery in 1940 and 1941. No aquatic macrophytes were expected to develop in the lake because of poor soil fertility and anticipated water-level fluctuations of 65 ft. In spring 1941, the game fish of Lake Mead were in poor condition for the first time since impoundment. It is likely that the spawn of 1940 was interrupted by some environmental factor, and young bass and bluegills provided most of the food for predators. High water levels in spring 1941 resulted in an excellent spawn of bass and bluegills and the condition of large bass improved rapidly. A recommendation was made to stabilize water levels during April, May, and June and prevent drops of 5 to 10 ft, which would undoubtedly destroy many bass and bluegill nests.

520. MOHLENBROCK, R. H. 1983. Annotated bibliography of the aquatic macrophytes of the Upper Mississippi River covering the area from Cairo, IL, to St. Paul, MN. U.S. Fish and Wildlife Service Ecological Services Field Office, Rock Island, Illinois, Contract 14-16-0003-83-041. 240 pp.

The Fish and Wildlife Interagency Committee (FWIC) provides technical advisory support to the River Resources Coordinating Team on fish, wildlife, and environmental matters. One of the FWIC's initial concerns was to understand the potential impacts of increased navigation traffic on the aquatic macrophytes of the Upper Mississippi River. However, before this could be done, some basic information needed to be collected to identify the existing database and future study needs. In this regard, this report summarizes all relevant published and unpublished literature on the aquatic macrophytes of the Upper Mississippi River. It should provide a useful tool for the development of future plans of study to evaluate potential effects of navigation.

521. MOON, H. P. 1935. Flood movements of the littoral fauna of Windermere. Journal of Animal Ecology 4:216–228.

A quantitative study of the littoral fauna was made at Lake Windermere, England, as water levels fluctuated. The more active members of the fauna, e.g. *Ecdyonurus* sp., *Isopteryx* sp., and *Gammarus pulex*, move on to the flooded area exceedingly quickly. An area covered by the flood for only 8 hours can usually be expected to contain a small fauna. The fauna is extremely sensitive to changes in level of the lake. A rise in level of only 2.5 cm is sufficient to bring about a movement of the fauna. Given sufficient time the littoral fauna would ultimately colonize a flooded area completely. The main check on extensive colonization is the change of substratum associated with the terrestrial character of the flooded area. For example, experiments showed that the absence of stones checks the movement of *Ecdyonurus* onto grass. The evidence suggests that it is food shortage that checks the initial movement of the fauna. Only after the appearance of an algal growth can the main mass of the fauna colonize the inundated area.

522. MOON, H. P. 1956. Observations on a small portion of a drying chalk stream. Proceedings of the Zoological Society of London 126:327–333.

The author studied a small stream habitat as it was drying. Rotting *Oedogonium* and wet mud were the primary habitats studied. *Coleoptera*, *diptera*, *myriapoda*, and *oligochaeta* were the primary groups found. A high water table acted as insurance against the complete drawdown, which would have left the animals stranded. After a number of flood events, it was some time before the faunal of the algal masses recovered, and after a number of such events, the association of beetles was never completely restored.

523. MULLAN, J. W., AND R. L. APPLEGATE. 1965. The physical–chemical limnology of a new reservoir (Beaver) and a fourteen-year-old reservoir (Bull Shoals) located on the White River, Arkansas and Missouri. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 19:413–421.

The limnology of two impoundments was compared to determine whether differences in fertility were associated with reservoir age. No significant differences were detected in commonly measured chemical variables, but differences may not be detectable if nutrients are assimilated as soon as they become available. Slightly higher concentrations of N, P, dissolved organic matter, and some trace elements in the new reservoir (Beaver Lake) may indicate greater availability of nutrients than in the 14-year-old reservoir (Bull Shoals).

524. MULLAN, J. W., AND R. L. APPLEGATE. 1967. Centrarchid food habits in a new and old reservoir during and following bass spawning. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:332–342.

Stomach contents of selected species of centrarchids (longear and green sunfish, bluegills, and largemouth and spotted basses) in Beaver Lake (a new reservoir) and Bull Shoals Lake (an old reservoir) indicated that food was abundant only in the new impoundment. Sunfish in both reservoirs ate substantial quantities of terrestrial foods, but sunfish in Beaver Lake ate more than those in Bull Shoals Lake. In Beaver Lake, rising waters flooded new areas and greatly increased the supply of terrestrial animals, such as earthworms. The percentage of food volume composed of terrestrial invertebrates from May to June 1965 in Beaver Lake was as follows for 4- to 8-inch fish: 67.9% (bluegills), 61.1% (green sunfish), 76.2% (longear sunfish), 58.4% (largemouth bass), and 39.9% (spotted bass). In Bull Shoals Lake, these percentages were 18.4% (bluegills), 23.6% (green sunfish), 18.6% (longear sunfish), 0.6% (largemouth bass), and 0.8% (spotted bass).

525. MULLAN, J. W., AND R. L. APPLEGATE. 1970. Food habits of five centrarchids during filling of Beaver Reservoir, 1965–66. U.S. Fish and Wildlife Service, Technical Paper 50. 16 pp.

Stomach contents of largemouth bass, spotted bass, bluegills, green sunfish, and longear sunfish were examined during the first 2 years of filling of Beaver Lake, Arkansas. The greatest volumes of food were observed in fish collected during the winter and spring months when water levels rose and flooded terrestrial areas for the first time. Terrestrial organisms were major foods (by volume) during these seasons, especially for basses 101–200 mm long (26%–76%) and sunfishes longer than 100 mm—bluegills (70%–98%), green sunfish (ca. 50%), and longear sunfish (ca. 84%). The volumes of food were smallest in the late fall (except in large bass), following a decline in food volume that began when water levels stabilized in June. Earthworms composed 78.3% and insects 15.7% of the total volume of terrestrial foods in stomachs of centrarchids from January through June.

526. MUNRO, D. A., AND P. A. LARKIN. 1950. The effects of changes to natural water levels and water courses on wildlife. Transactions of the British Columbia Natural Resources Conference 3:267–272.

The effect of an increase in lake level depends on the basin configuration; in general, area and depth are inversely correlated with productivity. Waters less than 30 ft deep are the most productive of fish-food organisms and, therefore, a serious loss of productivity occurs when water levels rise more than 30 ft and gently sloping usually productive areas are confined to deep water. By contrast, when extensive shoal areas are flooded, productivity may increase. The type of substrate flooded greatly influences the development of aquatic plants that provide essential cover and areas productive of food organisms for fish and waterfowl. Decaying vegetation also is productive of such food organisms but may degrade aesthetic qualities and accessibility for hunters and fishermen. Seasonal lowering of lake levels may eliminate nearshore plants and animals or strand eggs of valuable fishes such as sockeye salmon and kokanee (fall). Extensive, rapid increases of levels in the spring (April, May, and June) may result in losses of eggs of nesting waterfowl or fish.

527. MUNRO, W. T. 1967. Changes in waterfowl habitat with flooding on the Ottawa River. Journal of Wildlife Management 31:197–199.

Changes in riparian vegetation and in waterfowl numbers were studied after a permanent, 6-ft rise in the water level of the Ottawa River, Quebec. The pioneering aquatic plants were river bulrush (*Scirpus fluviatilis*), floating and large-leaved pondweeds (*Potamogeton natans*, *P. amplifolius*),

marsh cinquefoil (*Potentilla palustris*), and scarlet knotweed (*Polygonum coccineum*). After flooding, vegetation was less abundant in water less than 36 inches deep and more abundant in water 37–60 inches deep. Only in flooded hardwood forest was the development of vegetation after flooding influenced more by the previous vegetation type than by the depth of water. The number of breeding waterfowl increased from 1.4 to 6.5 pairs per mile.

528. NASH, L. J., AND W. R. GRAVES. 1993. Drought and flood stress effects on plant development and leaf water relations of five taxa of trees native to bottomland habitats. Journal of the American Society for Horticultural Science 118:845–850.

The response of red maple (*Acer rubrum* L.), sweetbay magnolia (*Magnolia virginiana* L.), black tupelo (*Nyssa sylvatica* Marsh.), bald cypress (*Taxodium distichum* [L.] Rich.), and pawpaw (*Asimina triloba* [L.] Dunal.) were studied for responses to drought and flooding. Sweetbay magnolia, as well as bald cypress, may merit increased use for extremes of soil–water content occurrence. Growth of both taxa was reduced by flooding. Red maple and black tupelo are quite sensitive to flooding, and their growth was reduced by severe drought.

529. NEAL, R. A. 1963. Black and white crappies of Clear Lake, 1950–1961. Iowa State Journal of Science 37:425–445.

Water levels may have directly or indirectly altered the balance between white crappies and black crappies in Clear Lake by influencing the amount of turbidity and vegetation present. Black crappies were the more abundant species in the lake from 1948 to 1956, but by 1961, white crappies, which supposedly are more tolerant of turbidity, predominated. Condition factors of white crappies remained fairly constant, whereas those of black crappies declined. Mean water levels, which declined after 1956, were correlated with black crappie abundance ($a = 0.01$). Water levels and Secchi disk readings were also correlated. At low water levels, wave action seemingly increased turbidity, and little vegetation (preferred by black crappie for spawning) was inundated. Crowding caused by decreased water levels between 1955 and 1959 may also have had an effect.

530. NEAL, T. J. 1977. A closed trapping season and subsequent muskrat harvests. Wildlife Society Bulletin 5:194–196.

A 50:50 ratio of open water and emergent vegetation is generally accepted as a desirable goal in marsh management, because it not only provides good conditions for nesting and broodrearing of waterfowl but is ideal for hunting as well. Periodic marsh drawdowns may be the only practical way to maintain productivity of both waterfowl and muskrats.

531. NEBOL'SINA, T. K., N. S. ELIZAROVA, O. V. ROENKO, AND L. P. ABRAMOVA. 1971. Number of commercial fish in the Volgograd Reservoir and measures for increasing their productivity. Trudy Saratovskogo Otdeleniya Gosudarstvennogo Nauchno-Issledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozyaistva 10:129–175. (In Russian)

The population of commercial fishes in the Volgograd Reservoir reached a maximum in 1956, nine times greater than that in 1959. The reproductive efficiency of most species remained low as a result of constant unfavorable variation in water level. Some species such as bream (*Abramis*) and pike-perch (*Stizostedion*), which are adapted to spawning at great depths in the open part of the reservoir, preserved their numbers at a relatively high level. After construction of the Saratov

Hydroelectric Power Station in 1968–69, reproductive conditions deteriorated sharply, particularly in the upper portion of the reservoir. As a means of increasing fish reproduction in the middle and lower portions of the reservoir, shallow-water artificial spawning grounds like those used in Dniepr River reservoirs are proposed. (From Referativmyi Zhurnal. Biologiya 1971, 91211; Biological Abstract 54:18930)

532. NEEL, J. K. 1963. Impact of reservoirs. Pages 575–593 *in* D. G. Frey, editor. Limnology in North America. University of Wisconsin Press, Madison.

A general discussion is presented on reservoirs and their limnology. Operations may be modified to alter water levels and thereby benefit fish and waterfowl. Examples include seasonal discharge regulations that may allow flooding of desirable waterfowl areas or cause sudden drops of water levels that will discourage spawning of undesirable fish. A chain of reservoirs offers numerous advantages over a single impoundment, in part by enabling greater control of releases (and therefore water levels) in selected reservoirs. Drawdowns may dry large areas of bottom for various periods of time and expose silt deposits to bed and bank erosion.

533. NEELY, W. W. 1965. How long do duck foods last under water? Transactions of the North American Wildlife and Natural Resources Conference 21:191–198.

Field trials on the deterioration of duck foods were started in 1953 in Colleton County, South Carolina. In the southeastern states, duck fields are usually flooded about October 15 to November 1 and drained the latter part of the following March. The rate of deterioration when underwater is an important consideration in the selection of duck foods to be grown in practical management. There is little point in having a high-yielding food that rots away within a few weeks. The percentage of deterioration of some selected species of seeds after 90 days underwater include: Soybeans (*Glycine max*) 86%, pearlmillet (*Pennisetum glaucum*) 73%, cowpeas (*Vigna sinensis*) 59%, German or combine peas (*V. sinensis* var.) 58%, Jap millet (*Echinochloa crusgalli* var. *frumentacea*) 57%, corn (*Zea mays*) 50%, Jap buckwheat (*Fagopyrum esculentum* var.) 45%, kegari (*Sorghum vulgare* var.) 42%, browntop millet, strain #1 (*Panicum ramosum*) 36%, tory peas (*Vigna sinensus* var.) 33%, chicken corn (*Sorghum vulgare* var. *drummordii*) 23%, giant foxtail (*Setaria magna*) 22%, smartweed (*Polygonum pensylvanicum*) 21%, domestic rice (*Oryza sativa*) 19%, smartweed (*P. densiflorum*) 16%, browntop millet, strain #2 (*Panicum ramosum*) 15%, anil indigo (*Indegofera suffruticosa*) 14%, tearthumb (*Polygonum sagittatum*) 9%, smartweed (*Polygonum setaceum*) 9%, oriental smartweed (*Polygonum orientalis*) 6%, acorns (*Quercas nigra*) 4%, sesbania (*Sesbania exaltata*) 4%, Florida bullgrass (*Paspalum floridanum*) 2%, beakrush (*Rhynchespera cerniculata*) 2%, and bulrush (*Scirpus robustus*) 1%. The percentage of deterioration was computed by weighing the samples before and after exposure.

534. NEEVES, R. J. 1975. Factors affecting fry production of smallmouth bass (*Micropterus dolomieui*) in South Branch Lake, Maine. Transactions of the American Fisheries Society 104:83–87.

A study of the early life history of smallmouth bass during the summers of 1971 and 1972 was directed toward determining what factors affect the production of smallmouth bass fry. A drop in water level was considered to be the primary cause for lower nesting success in 1971 than in 1972. Three of 15 nests were abandoned after 3 days of windy weather and a water-level decline of 23 cm. A 9-cm increase in water level in 1972 had no apparent effect on spawning success. Nest attendance by an adult male, to prevent high egg predation by other species of fish, was mandatory for successful fry production.

535. NEILL, C. 1990. Effects of nutrients and water levels on emergent macrophyte biomasss in a prairie marsh. Canadian Journal of Botany 68:1007–1014.

Nitrogen and phosphorus fertilizers were added over two growing seasons to marshes dominated by whitetop grass (*Scolochloa festucacea*) or cattail (*Typha glauca*) in a prairie lacustrine marsh to assess nutrient limitation and the interaction of nutrient limitation with water depth. For each species, stands were selected at the deep and shallow extremes of its water depth range. Water levels were high during the first year of fertilization and low during the second year, exposing the fertilized stands to a variety of water depths. Nitrogen limited growth in whitetop and cattail marshes. Water level, by controlling whether the soil was flooded or the water table was below the soil surface, affected growth and the degree of nitrogen limitation. In whitetop marshes, nitrogen increased biomass more when the soil was flooded or when standing water was deeper. In cattail marshes, nitrogen increased biomass more under intermediate water depths (approximately 0–20 cm) than under more deeply flooded (20–40 cm) or dry conditions. Nitrogen reduced biomass in whitetop marshes the second year, seemingly because growth was inhibited by fallen litter from the previous year. Nitrogen did not limit cattail marsh biomass in the driest locations during a year of low water levels. Phosphorus caused a small increase in growth of both species after 2 years. Changes of nitrogen limitation with flooding suggest that annual water-level fluctuations, by creating alternating flooded and dry conditions, may influence the primary production of emergent macrophytes through effects on nitrogen cycling.

536. NEILL, C. 1990. Effects of nutrients and water levels on species composition in prairie whitetop (*Scolochloa festucacea*) marshes. Canadian Journal of Botany 68:1015–1020.

Nitrogen and phosphorous fertilizers were added over two growing seasons to whitetop marshes growing at the shallow and deep extremes of whitetop's water depth range at the Delta Marsh in Delta, Manitoba. Water levels influenced both the biomass of the understory species and its potential response to nutrient additions. The biomass of understory species during both years was lower in deeper water.

537. NEILL, C. 1992. Life history and population dynamics of shoots of whitetop (*Scolochloa festucacea*) under different levels of flooding and nitrogen supply. Aquatic Botany 42:241–252.

Tagged shoots of the perennial grass whitetop (*Scolochloa festucacea* [Willd.] Link) were followed in a seasonally flooded prairie marsh at Delta, Manitoba, Canada, under different treatments of flooding and nitrogen (N) addition to examine how these factors influenced the timing and magnitude of shoot emergence, flowering, and mortality. Deep flooding (10–20 cm of water during most of the growing season) increased the total number of shoots that emerged during early spring, the number and percentage of flowering shoots, and total biomass and net primary production compared with shallow flooding (flooded for only several days with less than 5 cm of water). Shoot emergence during July and August was high under deep flooding, but absent under shallow flooding. These new shoots produced during late summer under deep flooding accounted for 56% of the total difference in annual production of unfertilized marsh between shallow and deep flooding. Shoot mortality was low during early summer and increased during July and August at both levels of flooding. Shoot turnover was similar (19%–22%) between flooding treatments in the absence of fertilization. Nitrogen increased shoot mortality under both levels of flooding, but effects were greater under shallow flooding and generally restricted to late summer. Nitrogen availability enhanced shoot growth, but did not change the basic pattern of shoot dynamics, indicating that environmental factors other than N availability were largely responsible for controlling differences in production between deep- and shallow-flooding regimes.

538. NEILL, C. 1993. Seasonal flooding, soil salinity, and primary production in northern prairie marshes. Oecologia 95:499–505.

The author investigated the coupling of flooding, soil salinity, and plant production in northern prairie marshes that experience shallow spring flooding. The results suggest that spring flooding controls whitetop production by decreasing soil salinity during spring and by buffering surface soils against large increases of soil salinity after midsummer water level declines. This mechanism can explain higher marsh plant production under more reducing flooded soil conditions and may be an important link between intermittent flooding and primary production in other wetland ecosystems.

539. NELSON, J. C., C. H. THEILING, AND R. E. SPARKS. 1993. Effects of navigation dams on water regimes: Hydrologic changes at navigation Pool 26, Mississippi River. Page 40 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

The annual hydrograph of a natural or undisturbed temperate large floodplain river system is characterized by a seasonal flood pulse. Normally, flooding expands main river channels into backwater and floodplain habitats. The degree of annual spatial and temporal expansion of aquatic habitats is an important factor regulating ecosystem productivity, community composition, and energy pathways. Like many rivers worldwide, hydrologic patterns within the Upper Mississippi River System have been severely altered by the construction and operation of navigation dams. We assessed hydrologic changes at navigation Pool 26 resulting from impoundment and dam operating procedures that utilize a midpool control point. Analysis of the 74-year record of daily water levels indicated that completion of Lock and Dam 26 in 1938 significantly increased ($P < 0.05$) mean low, mean high, and overall mean water levels. Mean and minimum daily water levels were more constant in the postdam era, and the seasonal flood pulse more attenuated. Constancy accounted for 76% of the postdam predictability of 0.91 (sensu Colwell, 1974, where predictability, P, ranges from 0, completely random, to 1.00, completely predictable), whereas seasonal periodicity accounted for 69% of the predam P of 0.70. Postdam seasonal flood pulse amplitudes increased with distance upstream from the dam. Close to the dam the flood pulse was actually inverted: water levels dropped as flow increased. Some implications of these hydrologic changes are: (1) reductions in spatial and temporal availability of floodplain habitats to riverine organisms, (2) abrupt water level changes in lower pool reaches during critical life stages of some river fishes, and (3) artificially low river stages in middle and lower pool reaches that encourage floodplain development and result in greater economic losses when inevitable high flows occur. These adverse hydrologic conditions could be alleviated by moving water-level control points from midpool sites to the dam and formulating water-level management strategies that mimic the natural hydrologic regime. (Abstract only)

540. NELSON, J. S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River System, Alberta. Journal of the Fisheries Research Board of Canada 22:721–753.

Data from surveys (1936 to 1961) indicated changes in the abundance and distribution of fishes after hydroelectric development on the Kananaskis River, Alberta, and the introduction of new fish species. Changes in the physicochemical environment and invertebrate fauna in the reservoirs seemed to be of secondary importance to interactions among fishes in causing changes in species distributions and abundance. Contrary to findings in Swedish reservoirs (e.g., that fluctuating water levels increase the abundance of fish that eat plankton and decrease the abundance of benthos feeders), densities of benthophagous fish did not decrease, probably because of the high densities of chironomids that inhabited flooded areas.

541. NELSON, R. W., G. C. HORAK, AND J. E. OLSON. 1978. Western reservoir and stream habitat improvements handbook. U.S. Fish and Wildlife Service, Office of Biological Services 78/56. 250 pp.

Guidelines are provided for selecting effective habitat improvement measures that may be considered by administrators, biologists of fish and game agencies, and engineers of construction agencies. Some 286 individual improvement measures that historically have been successful are discussed, and potentially effective measures are presented. Topics of potential relevance to the effects of water level on reservoir fishes include the following: selective clearing, exposed area planting, stage filling, fluctuation control, seasonal manipulation, minimum pools, and dam discharge systems. Fluctuation control often severely limits other uses, such as power generation, irrigation, or flood control. Recommendations for fluctuation control were general, and actual costs in terms of water lost to other users could not be evaluated. A scheme for seasonal manipulation of water levels is presented. The regime was originally proposed by biologists of the Kansas Fish and Game Commission [see Groen and Schroeder 1978].

542. NELSON, W. R. 1968. Reproduction and early life history of sauger, *Stizostedion canadense*, in Lewis and Clark Lake. Transactions of the American Fisheries Society 97:159–166.

Of the environmental variables monitored, water-level fluctuations in the Missouri River between Fort Randall Dam and Lewis and Clark Lake greatly influenced the reproductive success of saugers. Maximum egg survival occurred at depths 4 ft below the minimum water level in the river. Year classes were above average when mean daily fluctuations were less than 3 ft and below average when fluctuations exceeded 3 ft. Year-class strength was significantly correlated with water-level fluctuation ($r = -0.72$; $P < 0.02$) and apparently was determined before young-of-year entered Lewis and Clark Lake. Abundance of larvae was 15 times greater in 1965, when water-level fluctuation over spawning grounds was 2.67 ft/day, than in 1963 when the fluctuation was 4.44 ft/day.

543. NELSON, W. R. 1974. Age, growth, and maturity of thirteen species of fish from Lake Oahe during the early years of impoundment, 1963–68. U.S. Fish and Wildlife Service, Technical Paper 77. 29 pp.

Growth, as determined from scales, is described for 13 species of fish: goldeye, northern pike, common carp, river carpsucker, smallmouth buffalo, bigmouth buffalo, white bass, white crappie, black crappie, yellow perch, sauger, walleye, and freshwater drum. Inundation of terrestrial areas was associated with the rapid growth of fishes, and increased reservoir depth, which reduced the extent of the littoral, was associated with reduced growth. Water-level fluctuations during the growing season had no discernible effect on growth rates. Decreased growth rates of sport fishes may be related to reduced forage (primarily yellow perch).

544. NELSON, W. R. 1978. Implications of water management in Lake Oahe for the spawning success of coolwater fishes. Pages 154–158 *in* R. L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Special Publication 11.

After the filling of Lake Oahe in 1958, newly flooded prairie grasses provided ideal spawning and nursery habitat for northern pike and yellow perch. Large populations of these two species developed until 1967, when the operational level of the impoundment was reached. Because spawning substrates consisting of prairie grasses were destroyed by water-level fluctuations and wave action, populations of both species declined after 1967. Future diversions of water that are expected to reduce inflows will hinder spawning of saugers and decrease the average lake level. Reduced lake levels will adversely affect spawning habitat in the reservoir. If sport fish populations are to be maintained, reservoir spawning areas must be protected and enhanced artificially, and minimum stream flows in the spring must be maintained.

545. NELSON, W. R., AND C. H. WALBURG. 1977. Population dynamics of yellow perch (*Perca flavescens*), sauger (*Stizostedion canadense*), and walleye (*S. vitreum vitreum*) in four main stem Missouri River reservoirs. Journal of the Fisheries Research Board of Canada 34:1748–1763.

The development of three percid populations in the four lower main stem Missouri River reservoirs is described. Saugers were the most abundant percid initially, but their populations declined because spawning habitat in rivers decreased and water clarity increased. Year-class strength of saugers was primarily determined by fluctuations in water levels over spawning areas in tailwaters. Growth of yellow perch and saugers was most rapid during the first few years of impoundment. Two primary factors affecting the year-class strength of yellow perch in Lakes Oahe and Francis Case were spring water levels and the amount of terrestrial vegetation inundated during the spawning season; combined, these two factors accounted for 79% of the variation in year-class strength of the species. The abundance of young walleyes was correlated with water levels ($r = 0.62$; $P < 0.1$). The future abundance of all three species will most likely depend on reproductive success as influenced by precipitation, water levels, water-exchange rate, and siltation.

546. NETH, P. C. 1978. An analysis of the International Champlain-Richelieu Board proposal for water level regulation in Lake Champlain. Pages 1–62 *in* New York State Department of Environmental Conservation.

A review of documentation supporting the International Champlain-Richelieu Board's recommendations and criteria for water-level regulation in Lake Champlain was completed. The review yielded a number of conclusions concerning the expected impacts of regulation on fish, wildlife, and wetland resources and the suitability of support studies. A loss of more than 22% of the wetlands in the basin by the proposed water-level regime is considered irreplaceable. Losses in the grass and sedge meadow would approach 100%. Northern pike spawning would be adversely affected to a considerable degree. It is felt that estimates of wetland acreage are not reliable. Wetlands losses were not assigned dollar values in the benefit/cost estimates. Additional shortcomings of the board's recommendations and criteria are noted. A careful and comprehensive review and analysis of the literature on the effects of water-level fluctuations on the natural productivity of wetlands is urged. The literature cited section is a valuable guide to a complex legal, institutional, biological, resource-use problem.

547. NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION. 1977. Lake Champlain fisheries investigations: United States waters. International Joint Commission, International Champlain-Richelieu Board, University of Massachusetts. 229 pp.

Healthy northern pike populations exist throughout Lake Champlain wetlands, but tend to be more dominant in the low-gradient wetlands located near the northern portions of the lake. Flooded terrestrial vegetation such as grasses and grass–brush–tree combinations and emergent aquatic plants were preferred substrates for spawning. Water levels above elevation 30.0 m during the spawning period were required for access to, and flooding of, preferred substrates for egg deposition. If lake-level regulation is implemented, inundation of this habitat for 40–50 days at least once every 3 years should ensure egg and fry survival. Dropping water levels during the critical egg and spawning period would have an adverse effect on northern pike production. Reduction of lake elevations from 31.0 to 29.5 m would eliminate about 42% of the 37,500 mapped wetlands now existing. (From Selected Water Resources Abstract 12[16]:W79-07743)

548. NEWROTH, P. R., AND R. J. SOAR. 1986. Eurasian watermilfoil management using newly developed technologies. Pages 252–257 *in* G. Redfield, J. F. Taggart, and L. M. Moore, editors. Lake and reservoir management. Volume 2. Proceedings of the Fifth Annual Conference and International Symposium of the North American Lake Management Society, Geneva, Wisconsin, November 13–16, 1985.

In several lakes where eurasian watermilfoil is established, late drawdown facilitates tillage treatments, but observation has shown that drawdown must be combined with desiccation to kill the root crowns.

549. NEWSOME, R. D., T. T. KOZLOWSKI, AND Z. C. TANG. 1982. Responses of *Ulmus americana* seedlings to flooding of soil. Canadian Journal of Botany 60:1688–1695.

The flooding of soil induced several physiological, morphological, and growth changes in 12- or 13-week-old *Ulmus americana* L. seedings. Among the early responses to flooding was stomatal closure, without subsequent reopening, in leaves that were fully expanded by the time flooding was initiated. However, flooding did not induce stomatal closure of leaves that completed expansion during the flooding period. Flooding greatly accelerated production of ethylene by stems. Other responses to flooding included stem swelling; production of hypertrophied lenticels and abundant adventitious roots on submerged portions of the stem; reduction in leaf formation and expansion; and inhibition of dry weight increment of leaves, stems, and roots. Some of the morphological responses to flooding seemed to be associated with accelerated ethylene production. The much greater reduction in root growth over leaf growth in flooded seedlings will create leaf water deficits and predispose seedlings to drought injury after the floodwaters recede.

550. NICHOLS, S. A. 1974. Mechanical and habitat manipulation for aquatic plant management—a review of techniques. Wisconsin Department of Natural Resources, Technical Bulletin 77. n.p.

Harvesting and habitat manipulation techniques, along with the requisite biology and planning, are reviewed with regard to managing nuisance aquatic plant growths. Harvesting has beneficial ecological implications as it removes the problem biomass from the water, and its cost and effectiveness have the same magnitude and variability in results as does chemical treatment with herbicides. Habitat manipulation involves a somewhat broad array of management techniques and includes shading with dyes and black sheeting, dredging, sand or gravel blanketing, overwinter drawdown, and nutrient limitation. Of these techniques, overwinter drawdown, dredging to a depth beneath the photic zone, and shading with black plastic sheeting seem to be effective treatments. Sand and gravel blanketing show initially encouraging but short-lived results. The results of dyes and nutrient limitation yield rather inconclusive results. A list of aquatic plants compiled from the literature, which can or cannot be controlled by drawdown, is provided. The data are said to be remarkably consistent between authors. Flooding may also control some emergent species, such as cattail, as well as some submergent species.

551. NICHOLS, S. A. 1975. Impact of overwinter drawdown on aquatic vegetation of Chippewa Flowage, Wisconsin. Transactions of the Wisconsin Academy of Science 63:176–186.

The Chippewa Flowage in northwestern Wisconsin has undergone overwinter drawdown for the past 50 years. Increased drawdown decreases the size of the littoral zone and forces species into shallower water. Over the period of 50 years, it seems that the plant species have segregated themselves to the point where drawdown is the stable condition. The variety of plant species is greater at the present than it was reported to be in 1932. Some of the highest diversity areas had the greatest amount of drawdown. Most water-level changes do not occur during the growing season. Various species of aquatic vegetation are listed by degree of effect caused by drawdown.

552. NICHOLS, S. A. 1975. The use of overwinter drawdown for aquatic vegetation management. Water Resources Bulletin 11:1137–1148.

Overwinter drawdown can be a useful technique for aquatic plant management. Its effectiveness depends largely on the susceptibility of nuisance species to drawdown. A single overwinter drawdown provided good control of aquatic plants in a flowage dominated by *Potamogeton robbinsii*. Little additional control was gained by a second drawdown the following winter. Rapid reinvasion of plants after drawdown ceased dictates continued management. To avoid fish kills caused by low dissolved oxygen levels, caution is advised when using overwinter drawdown. The growth of *Zizania aquatica* was not negatively influenced by drawdown. The influence on water quality of nutrient release from decaying vegetation and exposed bottom sediments was uncertain.

553. NICHOLS, S. A. 1979. Macrophyte biology to management techniques: Bridging the information gap. Pages 63–78 *in* J. E. Breck, R. T. Prentki, and O. L. Loucks, editors. Aquatic plants, lake management, and ecosystem consequences of lake harvesting. Institute for Environmental Study, University of Wisconsin, Madison.

Information about macrophyte biology as it relates to present or proposed management techniques is assessed. Light-limitation techniques by means of dredging and overwinter drawdown that limits water and exposes plants to cold temperatures have general management applicability. Substrate management techniques have resulted in short-lived changes in the areas where they have been tried so they do not seem to have general applicability for macrophyte management. Aquatic plants controlled by drawdown are *Asclepias incarnata*, *Ceratophyllum demersum*, *Myriophyllum* spp., *Nuphar* spp., *Nymphaea* spp., *Pontederia cordata*, *Potamogeton amplifolius*, *Potamogeton robbinsii*, *Potentilla palustris*, and *Sagittaria heterophylla*. Aquatic plants with little control by drawdown are *Acorus calamus*, *Anacharis canadensis*, *Brasenia schreberi*, *Eleocharis acicularis*, *Lemna* spp., *Potamogeton natans*, *Potanogeton richardsonii*, *Potamogeton zosteriformes*, *Ranunculus tricophyllus*, *Sagittaria latifolia*, *Scirpus americanus*, *Sparganium chlorocarpum*, *Spirodela polyrhiza*, *Utricularia vulgaris*, and *Vallisneria americana*. Aquatic plants increased by drawdown are *Glyceria borealis*, *Leersia oryzoides*, *Megalodonta beckii*, *Najas flexilis*, *Polygonum coccineum*, *Potamogeton diversifolius*, *Potamogeton epihydrus*, *Potamogeton foliosus*, *Potamogeton gramineus*, *Polygonum natans*, *Salix interior*, *Scirpus validus*, *Sium suave*, and *Typha latifolia*.

554. NICHOLS, S. A. 1986. Community manipulation for macrophyte management. Pages 245–251 *in* G. Redfield, J. F. Taggart, and L. M. Moore, editors. Lake and reservoir management. Volume 2. Proceedings of the Fifth Annual Conference and International Symposium of the North American Lake Management Society, Geneva, Wisconsin, November 13–16, 1985.

Drawdown, as a management tool, may favor or discourage different species. The emergents usually increase with drawdown, because mudflats provide a good seedbed. Many of the floating-leaved species are discouraged by winter drawdown. Drawdown is easy and inexpensive if proper control structures exist.

555. NICHOLS, S. A. 1991. The interaction between biology and the management of aquatic macrophytes. Aquatic Botany 41:225–252.

The author reviews the literature including water-level fluctuations for managing aquatic macrophytes. Management is defined as controlling nuisance aquatic species and restoring or restructuring aquatic plant communities. Producing stable, diverse, aquatic plant communities containing a high percentage of desirable species is the primary management goal. Although water levels can be raised or lowered, the author found that drawdowns were the most feasible and most often used fluctuation method.

556. NILSSON, C. 1984. Effect of stream regulation on riparian vegetation. Pages 93–105 *in* A. Lillehammer and S. J. Saltveit, editors. Regulated Rivers. Engers Boktrykkeri, Norway.

The natural water-level regimes of unregulated rivers in northern Sweden have resulted in the formation of diverse and productive types of riparian vegetation, all of them differentiated into more or less distinct belts. Drastic manipulation of the water level, as in reservoirs, leads to an ultimate destruction of the natural vegetation, although some of the species may be able to recolonize the new shorelines, and additions to the flora, especially of weed species, also occur. Both the species density and the standing crop of the new vegetation, however, are much lower than those of the original one. The structure and species composition of a riparian vegetation whose former habitat has been laid permanently dry remain more or less the same for many years afterwards, but a succession to a forest vegetation ultimately occurs, with a consequent decrease in species diversity.

557. NILSSON, C., A. EKBLAD, M. GARDFJELL, AND B. CARLBERG. 1991. Long-term effects of river regulation on river margin vegetation. Journal of Applied Ecology 28:963–987.

The effects of river regulation on river margin vegetation were evaluated by comparing two parallel seventh-order rivers, one natural and the other strongly regulated, in northern Sweden. Prior to regulation, both rivers had similar vegetation. No difference between the natural and the regulated river was found in width and height (relative to the summer low-water level) of the river margin, number of substrates, and mean annual discharge. Frequency distributions of species differed in that the regulated river had fewer frequent and more infrequent species. Species richness and the percentage of cover of vegetation were both lower per site in the regulated river. The proportion of annual plus biennial species richness was higher and that of perennial species richness lower along the regulated river. Reservoirs retaining preregulation river margins and remnants of their former vegetation, and stretches with a modest flow regulation, were most floristically similar to the natural river. Regression equations including eight independent variables explained 10%–77% of the variation in species richness in 13 groups of plants and in plant cover for two vegetation layers. Presence of preregulation river margin vegetation, water-level regime, height of the river margin, and mean annual discharge were the most important variables for species richness, while water-level regime, mean annual discharge and substrate fineness were most important for plant cover. In most cases, values of species richness were higher in natural sites and in regulated sites with remnants of preregulation river margin vegetation, whereas they decreased with increasing height of the river margin. The percentage of cover of ground vegetation was highest in natural sites with a fine-grade substrate.

558. NILSSON, N. A. 1961. The effect of water-level fluctuations on the feeding habits of trout and char in the Lakes Blasjon and Jormsjon, northern Sweden. Institute of Freshwater Research Drottningholm Report 42:238–261.

The effects of water-level fluctuation were examined by comparing preregulation information on benthos and fish with postregulation data on feeding by trout and char and by comparing the food habits of fish in regulated and unregulated natural lakes. After regulation in both lakes, trout ate more terrestrial insects and fish, perhaps because the abundance of native benthos was reduced and the littoral areas had deteriorated. Char, which feed to a large extent on plankton and forage over wider areas than trout, were less affected by fluctuating water levels. In comparing a regulated and unregulated lake, the following differences were noted: (1) *Limnaea* and *Trichoptera* were eaten more frequently in the unregulated than in the regulated lake; (2) *Gammarus*, which was very important to trout and char in the unregulated lake, was entirely lacking in the regulated lake; (3) *Eurycercus lamellatus* (Plecoptera) and terrestrial insects were eaten more frequently in the regulated than in the unregulated lake; and (4) young char were more important as food for trout in the regulated than in the unregulated lake.

559. NILSSON, N. A. 1964. Effects of impoundment on the feeding habits of brown trout and char in Lake Ransaren (Swedish Lappland). Internationale Verhandungen Vereinigung Limnologie 15:444–452.

The effects of regulation were examined by using previously published information concerning the effects of regulation on allochthonous organisms, zooplankton, prey fishes, and benthos and by comparing the food of brown trout and char, before and after regulation. Regulation initially floods new areas, provides a temporary surplus of terrestrial invertebrates as fish food, and increases zooplankton production. Some prey fishes have strong year classes during the early years of impoundment. Littoral benthos usually declines drastically after impoundment. Damming results in increased fish predation on allochthonous organisms and zooplankton. Drawdown increases consumption of zooplankton and prey fish by trout. Fish predation on benthos decreases after drawdown, and different taxa of benthos are eaten.

560. NILSSON, N. A. 1966. The effect of hydro-electric power utilization on Swedish fishery. Pages 10–22 in Limnologisymposion, Limnologiska Foreningen i Finland, Helsinki.

Research mainly by the Salmon Research Institute and the Institute of Freshwater Research, Drottningholm, indicates that the loss of salmon reproduction after dam construction has been successfully compensated for by stocking of hatchery-reared smolt. In impounded lakes, water-level fluctuations damage food resources of fish, and thus exert adverse effects on growth and possibly on survival. In the lower courses of rivers, where water-level fluctuations are less extensive, a relatively large amount of food is present. Adverse effects primarily alter the fish fauna (from salmonids to coarse fish). Experiments are being made to compensate for damage by introducing glacial relicts and exotic fish species. The most promising results have been reached with the introduction of the North American lake trout. (Abstract adapted from Fraser 1972)

561. NOBLE, R. E., AND P. K. MURPHY. 1975. Short term effects of prolonged backwater flooding on understory vegetation. Castanea 40:228–238.

From 1970 to 1971, a bottomland hardwood forest along the Mississippi River in Tensas Parish, Louisiana, was sampled before and after a prolonged backwater flood. The understory vegetation was killed or completely defoliated by 105 days of flooding in water depths varying from 8 to 16 ft; however, trees and vines remained green when above the floodwater level. These species showed a vigorous sprouting and growth pattern immediately after the flood because the roots remained healthy. Understory vegetation occurring naturally within the lower Mississippi River floodplain has the capacity to recover to its preflood cover within 43 days after prolonged backwater flooding.

562. NOHARA, S., AND T. TSUCHIYA. 1990. Effects of water level fluctuation on the growth of *Nelumbo nucifera* Gaertn. in Lake Kasumigaura, Japan. Ecological Research 5:237–252.

Investigations were made of the growth of *Nelumbo nucifera*, an aquatic higher plant, in a natural stand in Lake Kasumigaura. A rise of 1.0 m in the water level after a typhoon in August 1986 caused a subsequent decrease in biomass of *N. nucifera* from the maximum of 291 g d.w./m^2 in July to a minimum of 75 g d.w/m^2. The biomass recovered thereafter in shallower regions. The underground biomass in October tended to increase toward the shore. The total leaf area index (LAI) is the sum of LAI of floating leaves and emergent leaves. The maximum total LAI was 1.3 and 2.8 m^2/m^2 in 1986 and 1987, respectively. The LAI of floating leaves did not exceed 1 m^2/m^2. The elongation rates of the petiole of floating and emergent leaves just after unrolling were 2.6 and 3.4 cm/day, respectively.

563. NURSALL, J. R. 1953. The early development of a bottom fauna in a new power reservoir in the Rocky Mountains of Alberta. Canadian Journal of Zoology 30:387–409.

The benthos of Barrier Reservoir, Alberta, were sampled for 2 years shortly after impoundment began. The bottom fauna was greatly affected by the rapid replacement of water, periodic fluctuations of water level, and a marked deposition of sediment. Typical annual fluctuations of water level began with a drawdown in late March or early April and continued to the seasonal low in May. Spring runoff then refilled the reservoir. Many benthic animals (e.g., the midge larvae *Chironomus* and *Tanytarsus*) preferred certain depths, and fluctuating water levels frequently altered the depth of water over bathymetric bands of organisms. Fluctuations were slow enough so that distinct bathymetric bands of certain organisms remained evident during most of the year.

564. ODOM, R. R. 1977. Sora (*Porzana carolina*). Pages 57–65 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C.

Preservation of wetland habitat is essential if sora numbers are to be maintained at a healthy level. The nests of sora are well hidden in the vegetation and are suspended inches above the water level.

565. ORTH, D. J. 1978. Computer simulation models for predicting population trends of largemouth bass (*Micropterus salmoides*) in large reservoirs. Proceedings of the Oklahoma Academy of Science 58:35–43.

Two computer simulation models of population dynamics of largemouth bass are described. Model I simulates population trends on the basis of an equilibrium population exhibiting constant fecundity and age-specific survival. Analysis of this model indicates that the density of bass is most sensitive to variations in survival of age 0, age I, and age II bass, in that order. Multiple regression equations, with mean water level during May spawning and water-level fluctuation since the end of the previous growing season as predictor variables, resolved 88.2% of the observed variation in year-class strength—estimated as young-of-year (YOY) abundance on August 13—and 86.7% of the observed variation in bass mortality from egg to age I in Lake Carl Blackwell. Model II also simulates population dynamics of bass but accounts for the effects of reservoir water level and water-level fluctuation on survival of the YOY. Predictions of the number of yearling recruits from Model II closely agree with population estimates for Lake Carl Blackwell.

566. ORTH, D. J. 1980. Changes in the fish community of Lake Carl Blackwell, Oklahoma, (1967–1977) and a test of the reproductive guild concept. Proceedings of the Oklahoma Academy of Science 60:10–17.

Changes in numerical density, areal biomass, and diversity of fishes in coves of Lake Carl Blackwell were estimated over a 10-year period. The hypothesis that fishes using similar reproductive strategies to exploit the same resources exhibit similar trends in abundance was not substantiated every year. Some fishes within the same reproductive guild had similar trends in abundance during the 7 years they were examined, as did some species from different guilds. However, other species within the same reproductive guild had different trends in abundance. Dramatic changes in density may have been related to changes in water level, habitat, and biota.

567. OSBORN, T. C., D. B. ERNST, AND D. H. SCHUPP. 1981. The effects of water levels and other factors on walleye and northern pike reproduction and abundance in Rainy and Namakan Reservoirs. Minnesota Department of Natural Resources, Division of Fish and Wildlife, St. Paul, Section of Fisheries Investigational Report 374. n.p.

The walleye population in Minnesota waters of Rainy Lake has increased from the depressed levels of abundance observed in the mid-1960s. Growth rates have decreased and the mean age of walleyes caught in test nets has increased. The effect of changes in the regulation of spring water levels, instituted in 1969, was examined to see if the increased abundance of walleye was the result of higher water levels at time of spawning. No significant correlation between spring water levels and walleye abundance 5 years later could be detected for the years after the regulation change. There is some evidence that reduction in exploitation may have been associated with the increased abundance of walleye. The abundance of brood stock and of progeny 5 years later was significantly correlated. In the lakes of the Namakan Reservoir, no positive relation between mean spring water levels and subsequent abundance of walleye and northern pike could be detected. There was some evidence in these lakes that rising water levels in the first half of May benefited northern pike reproduction.

568. OSBORNE, P. L., J. H. KYLE, AND M. S. ABRAMSKI. 1987. Effects of seasonal water level changes on the chemical and biological limnology of Lake Murray, Papua New Guinea. Australian Journal of Marine and Freshwater Research 38:397–408.

Lake Murray, with a surface area of 647 km^2 and a high-water convoluted shoreline 2,038 km long, is the largest lake in Papua New Guinea and exhibits marked seasonal fluctuations in water level. The fall in water level of 4 m between April and December 1982 was accompanied by a marked rise in pH (from 5.3 to 9.6), conductivity (from 12 to 100 $\mu S\ cm^{-1}$), total hardness (from 80 to 400 μm) and filterable residue (from 11 to 45 mg L^{-1}). In November 1982, maximum production of phytoplanktonic oxygen was 1,120 mg $O_2\ m^{-3}\ h^{-1}$ at the surface but declined sharply with depth because of light attenuation by suspended solids. It was much higher than that recorded in April 1982 (250 mg $O_2\ m^{-3}\ h^{-1}$). The long shoreline and the shallowness of the lake result in a very large littoral zone. Diurnal variation in oxygen concentrations during periods of high water level indicated that the littoral zone is a very productive area of the lake. However, when the water level is low, the lake is surrounded by a wide expanse of barren mud.

569. OSIPOVA, V. B. 1979. Ecology of wild carp, *Cyprinus carpio*, of the Cheremshansk arm of the Kuibyshev Reservoir, Russian SFSR, U.S.S.R. Voprosy Ikhtiologii 19:936–939. (In Russian)

A discussion is presented of the dynamics of winter and spring migrations of wild carp as a function of the condition of brood stock in the low-water years of 1971 and 1976, and the high-water years of 1972 and 1974. Statistical differences in condition factors of fish during low- and high-water years are evaluated. The best fed specimens spawned at lower water temperatures (15–16 °C) than did specimens in poorer condition (19–20 °C), when water levels fluctuated between 4 and 5 cm per day. (From Biological Abstract 70:63602)

570. PARAGAMIAN, V. L. 1977. Fish population development in two Iowa flood control reservoirs and the impact of fish stocking and floodwater management. Iowa Fisheries Research, Technical Series 77-1. 59 pp.

The abundance, age, and size distribution, reproduction, and growth of major species of fish were monitored in Lake Red Rock and Lake Rathbun, Iowa, after impoundment. Species composition and stocking were also evaluated, as were the effects of reservoir operations. In 1973, high water levels in spring resulted in the production of strong year classes of bass and bullheads in Lake Red Rock and of bluegills, crappies, and largemouth bass in Lake Rathbun. Increased populations of white bass, crappies, and bigmouth buffaloes in Lake Red Rock were related to high water levels in 1974. Increased storage volume accelerated the growth of fish in Lake Rathbun more than in Lake Red Rock, because Rathbun has more littoral area at higher elevations.

571. PARKER, J. 1949. The effects of flooding on the transpiration and survival of some southeastern forest tree species. Plant Physiology 25:453–460.

The effects of flooding were studied on loblolly pine, red cedar, cypress, white oak, swamp chestnut oak, red oak, ash, overcup oak, and dogwood. In general, for all species studied except cypress, those that grow on soils flooded for long periods are injured as quickly by flooding as species that grow on drier sites.

572. PARSONS, J. W. 1957. Fishery management problems and possibilities on large southeastern reservoirs. Transactions of the American Fisheries Society 87:333–355.

Four types of southeastern reservoirs (flood control, power, storage, and mainstream) are described, as are their typical water-level regimes and problems associated with inefficient and selective harvest of fish. Damages to fisheries in tailwaters and tributary streams are also discussed. Water levels in multipurpose reservoirs are controlled largely by needs for power, navigation, and flood control. Therefore the manipulation of levels for fishery management must be weighed against other uses, especially when the regime requested conflicts with normal operations. Many fishermen and dock operators on southeastern reservoirs believe that receding water levels in the spring reduce the success of fishermen. Because fish caught in the spring constitute nearly half of the total annual harvest, severe drawdown during this season may reduce the annual harvest. Stable levels in the spring may improve fishing. Rapid spring drawdowns are also detrimental because they may expose bass nests or leave them in shallow water, where nest desertion increases. Rapid drawdown in late spring or early summer may be used to control overly abundant sunfish populations, but stable water levels should be maintained during this period if production of young sunfish limits the bluegill fishery. In one reservoir in Tennessee, fluctuations in water level offered a reliable method to control common carp spawning. Before drawdowns are used for this purpose, however, biologists should verify that populations of common carp are hindering sport fish production. Water-level fluctuations exceeding 2 ft/month in storage reservoirs during the spring and early summer should be avoided whenever possible. The greatest opportunity for developing fisheries in flood-control impoundments is to establish a large, seasonal conservation pool to provide additional capacity. Water levels can then be lowered in the fall to provide space for floodwater.

573. PARSONS, J. W., AND C. C. CROSSMAN. 1955. An example of state and federal cooperation in establishing water control for fisheries management purposes. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 9:108–110.

A description is presented of the benefits that accrued to fisheries in two Tennessee Valley reservoirs (Dale Hollow and Center Hill) and their associated tailwaters as a result of manipulation of operational regimes, as agreed upon by the Tennessee Game and Fish Commission and the U.S. Army Corps of Engineers. A 3-year study indicated that water-level stabilization, or at least the elimination of drawdowns exceeding 2 ft during the spawning period, would decrease the mortality of largemouth bass eggs caused by stranding nests. Previously, many nest sites were stranded by rapid drawdowns in June.

574. PARSONS, J. W., AND J. B. KIMSEY. 1954. A report on the Mississippi threadfin shad. Progressive Fish-Culturist 16:179–181.

Because it seems that the threadfin shad (*Dorosoma petenense*) is not dependent upon unstable littoral zones for their fluctuating waters, this fish may be an answer to the forage fish problem in fluctuating reservoirs.

575. PATERSON, C. G., AND C. H. FERNANDO. 1969. Macroinvertebrate colonization of the marginal zone of a small impoundment in eastern Canada. Canadian Journal of Zoology 47:1229–1238.

Colonization of the macroinvertebrate fauna along the margin of Laurel Creek Reservoir was studied from first filling in spring 1967 until the reservoir was drained in mid-October of the same year. Of the species collected, 62% were facultative, having populations in the lotic environment before impoundment. Colonization was an active process that accelerated as water temperature increased. In spring 1968, the marginal fauna was very similar to that of the previous year, although colonization was more rapid as a result of the overwintering of many limnophilic species.

Overwintering of several marginal macroinvertebrates resulted in a larger number of taxa and greater standing crop in April.

576. PATERSON, C. G., AND C. H. FERNANDO. 1969. The effect of winter drainage on reservoir benthic fauna. Canadian Journal of Zoology 47:589–595.

Winter draining of Laurel Creek Reservoir, southern Ontario, exposed benthos for 168 to 176 days. Sediments were frozen to depths greater than 20 cm for 100 days. This exposure destroyed much of the benthic fauna, but freezing of the substrate also eliminated oligochaetes, nematodes, and oribatoid mites, and reduced the chironomid fauna. Small numbers of one caddisfly, two molluscs, and one chironomid survived freezing. *Glyptotendipes barbipes* survived better than other organisms; its numbers were reduced 54%–88% by exposure. Survival probably was greater for organisms located in deeper layers of sediment than for those located within 20 cm of the surface. Three species (one caddisfly and two chironomids) pupated and emerged from exposed substrates.

577. PATERSON, C. G., AND C. H. FERNANDO. 1969. The macroinvertebrate colonization of a small reservoir in eastern Canada. Verhandlungen Internationale Vereinigung Limnology 17:126–136.

Information is presented on the colonization of benthos in Laurel Creek Reservoir, a 64.8-ha impoundment in Ontario, and the effects of depth, substrate, and reservoir aging on colonization discussed. Sources for and mechanisms of colonization are also described. The biomass of benthos in this shallow reservoir decreased with increasing mean depth as the reservoir filled. Areas of grassland supported greater densities of benthos than areas of woodland at similar depths. The stripping of organic debris greatly reduced the initial populations of benthos.

578. PATERSON, C. G., AND C. H. FERNANDO. 1970. Benthic fauna colonization of a new reservoir with particular reference to the chironomidae. Journal of the Fisheries Research Board of Canada 27:213–232.

Laurel Creek Reservoir was filled in March 1967 and drained between mid-September and October. Examination of the benthos 2 weeks after the dam was closed revealed that it was composed of submerged terrestrial organisms and creek-derived species. Although the density of terrestrial animals was small, their biomass was sufficient to maintain a fish fauna immediately after the reservoir was filled and before the reservoir benthos became established. Drainage disrupted changes in populations. Many limnophilic species overwintered in the frozen substrate, remaining pools, or Laurel Creek. Upon refilling, terrestrial organisms were absent and the species that had successfully overwintered rapidly dominated the benthic community.

579. PATRIARCHE, M. H. 1953. The fishery in Lake Wappapello, a flood-control reservoir on the St. Francis River, Missouri. Transactions of the American Fisheries Society 82:242–254.

Data are presented on the fish and fishery in Lake Wappapello after its impoundment in 1941 until 1951. Fish abundance, standing crop, growth (of eight species), and harvest were assessed. Water levels in the lake were fairly stable in April and May 1948, 1949, and 1951. In 1950, however, spring water levels dropped 10 ft in 24 days and another 10 ft in 10 days. The reproduction of white crappies and largemouth bass was better in 1951 than in 1950, but results for other species were not conclusive. The spawning of common carp, buffaloes, black basses, and crappies may have been curtailed as a result of the rapidly receding water levels in 1950.

580. PATRIARCHE, M. H., AND R. S. CAMPBELL. 1958. The development of the fish population in a new flood-control reservoir in Missouri, 1948 to 1954. Transactions of the American Fisheries Society 87:240–257.

Changes in species composition, abundance, growth, reproductive success, and harvest of fishes in Clearwater Lake, Missouri, are described for the first 7 years of impoundment. Growth of most fishes (smallmouth bass excepted) was most rapid in the first year of impoundment and declined thereafter. In 1952, receding water levels had a detrimental effect on the spawning success of largemouth bass and on the survival of many species. The 2 years of most successful spawning were marked by stable or rising water levels during the spawning period. Small fluctuations in water level in 1954 seemingly had no significant impact on the abundance of young bass, as estimated by shoreline seining.

581. PAYANDEH, B. 1973. Analyses of a forest drainage experiment in northern Ontario. 1. Growth analysis. Canadian Journal of Forest Research 3:387–398.

A growth analysis of a forest drainage experiment carried out over 40 years in northern Ontario is presented. It is based on remeasurement data obtained in 1969 from 38 growth plots established following drainage in 1929 and from increment cores and sectioned trees. Results indicate that both annual tree diameter and height growth increased significantly after draining; that tree growth before draining was related to site quality only, while after draining it was also related to tree vigor and distance of water flow from the nearest ditch; that both stand diameter and height growth were related to site index, stand age, and initial stocking; and that stand basal area and volume growth were, in addition, related to a product sine function of distance of water flow from the ditch, peat moisture, decomposition, and depth. Both individual tree and stand growth responded well to draining, with younger and more vigorous trees that were growing on better-quality sites showing the greatest response. For a given site, growth response was not greatest for trees and stands nearest the ditch, but for those some distance away.

582. PAZDERIN, V. P. 1966. The effect of water level on fish culture in the Kama Reservoir. Trudy Ural'skogo Otdeleniya Sibirskogo Nauchno-Issledovatel'skogo Instituta Rechnogo Rybnogo 7:225–231. (In Russian)

A winter drawdown of 7 m at Kama Reservoir reduced reservoir area by one-third and damaged fish populations. Drying of part of the bottom hindered the accumulation of biogenes; no productive biological processes occurred there. Also, oxygen-deficient water flowing from drying marshes killed fish, as ice forced fish into constricted depressions on the bottom. Despite reduced fish abundance, catches in sections with favorable O_2 conditions increased for a time because fish congregated there. The reservoir level was unfavorable for most fishes except for bream (*Abramis brama*) and pikeperch (*Stizostedion vitreum*), and even they lacked spawning grounds. A 0.5-m drop in water level during the third, 10-day period of June would ensure a higher yield of fish without hindering navigation or power production. (From Referativmyi Zhurnal. Biologiya 1968, 11174; Biological Abstract 49:108944)

583. PEARSONS, T. N., H. W. LI, AND G. A. LAMBERTI. 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 five reaches of a desert stream in north-central Oregon was determined before and after a summer flash flood and two spring floods. One reach in each of two other streams that were unaffected by the first flood was used as a reference system. Successful recruitment of different fish species depended, in part, on flood timing. Young-of-year of species that spawn in early spring were more negatively affected by early spring floods than by summer floods. Species that spawn later in the season were more negatively affected by summer flooding.

584. PECK, J. H., AND M. M. SMART. 1985. Bibliography to Upper Mississippi River aquatic and wetland plant literature. Proceedings of the Iowa Academy of Science 92(2):78–84.

A comprehensive bibliography of 308 references by 270 authors was prepared to provide access to the literature on aquatic and wetland plants of the Upper Mississippi River. The references treated the taxonomy, floristics, ecology, wildlife biology, limnological role, and management programs on macrophytes present in the navigation channel, backwater, and floodplain of the Upper Mississippi River, which stretches from Minneapolis, Minnesota, southward some 1,380 km to Cairo, Illinois. Articles, serials, books, agency reports, agency contracted studies, theses, and dissertations are included.

585. PELTIER, W. H., AND E. B. WELCH. 1969. Factors affecting growth of rooted aquatics in a river. Weed Science 17:412–416.

In 1967, field studies on the Holston River in the Tennessee Valley produced evidence that excessive aquatic plant growths are caused in part by water depth.

586. PELTIER, W. H., AND E. B. WELCH. 1970. Factors affecting growth of rooted aquatic plants in a reservoir. Weed Science 18:7–9.

Water samples were taken from Pickwick Reservoir from 1965 through 1968 and the nitrogen and phosphorus content determined. The nitrogen and phosphorus content over a period of 3 years was not related to the year-to-year plant growth. Physical and climatic data were obtained from 1961 through 1968, and it was found that available light was controlled by the amount of rainfall and ensuing reservoir elevation during the critical plant growth period in April and May. Available light was correlated with the 2 years of severe infestations.

587. PELZMAN, R. J. 1980. Impact of Florida largemouth bass, *Micropterus salmoides floridanus*, introductions at selected northern California, U.S.A., waters with a discussion of the use of meristics for detecting introgression and for classifying individual fish of intergraded populations. California Fish and Game 66:133–162.

Populations of largemouth bass in Folsom Lake, New Hogan Reservoir, Lake Amador, Lake Isabella, and Clear Lake, California, possessed a wider spectrum of performance capabilities (i.e., reduced susceptibility to angling, rapid growth, and larger mean size) after the inclusion of desirable genetic traits from Florida bass. This is advantageous in reservoirs where heavy angling pressure, water-level fluctuations, and competition between young bass and prey fishes hinder the maintenance of a bass production.

588. PENFOUND, W. T. 1953. Plant communities of Oklahoma lakes. Ecology 34:561–583.

The plant populations of 32 lakes in Oklahoma were investigated during the summers of 1948, 1949, and 1950. Of lake basin factors, the amplitude of water levels and turbidity are the most important in determining the distribution of lake plants. The parts of the lake basins investigated were drift lines, flood surcharge zone, summer pool level, recession zone, and continuous water area. A total of 48 plant communities was observed, distributed according to habitat as follows: terrestrial, 13; wetland, 15; and aquatic, 20. Of the herbaceous communities in the flood surcharge zone, terrestrial aggregations were the most numerous.

589. PERRIN, C. 1976. Effects of water level manipulation of black bass spawn and survival—Greers Ferry Lake. Arkansas Game and Fish Commission, Little Rock. 9 pp.

Since Greers Ferry Lake was impounded in 1962, the spawning success of black basses has fluctuated from year to year, and above average spawns have been associated with high water levels throughout the spawning season. High water levels also improved the reproduction of shad, which undoubtedly increased the survival of bass and permitted the development of strong year classes of bass. Data indicate that water levels that are higher than those of the previous year may often produce similar results. In 1976, a strong year class was produced when water was held 2 ft above power pool. Remarkably, this success was obtained in a year when some conditions for spawning were relatively poor (below-average temperature and frequent passage of frontal systems).

590. PERRY, S. A., AND W. B. PERRY. 1986. Effects of experimental flow regulation on invertebrate drift and stranding in the Flathead and Kootenai Rivers, Montana, USA. Hydrobiologia 134:171–182.

Studies were conducted to determine the effects of experimental manipulations of discharge on invertebrate drift in two regulated rivers in northwestern Montana, USA. During these studies, the discharge regime in the Flathead River was characterized by frequent flow fluctuations, while in the Kootenai River high discharge was maintained for much longer periods before flow was reduced to minimum discharge. The magnitude of the response of invertebrates to disturbance was different in the two rivers, in part because of the different frequencies of flow changes. Midstream invertebrate drift increased an order of magnitude during increasing discharges in the Flathead River but was not substantially increased during decreasing discharges. When the prior discharge regime had been sustained at high levels in the Kootenai River, invertebrate drift densities as high as 300,000/100 m^3 were measured along the shoreline following reductions in discharge, both immediately after flow began to decrease and after dark on the same day. There was also more recolonization of shoreline areas and more stranding of insects following dewatering of nearshore regions when there had been sustained high discharge levels prior to the flow reduction. More insect stranding occurred during a faster rate of decrease in discharge (50,000 to 100,000 organisms m^{-2}).

591. PETERSON, D. L., AND F. A. BAZZAZ. 1984. Photosynthetic and growth responses of silver maple (*Acer saccharinum* L.) seedlings to flooding. American Midland Naturalist 112:261–272.

Flooding affected several growth parameters of silver maple (*Acer saccharinum* L.) seedlings. Root biomass and leaf area were sharply reduced. Photosynthetic rates of recently germinated seedlings decreased significantly after 21 days of root-flooding and after only 3 days of submersion. In some treatments, reduced net photosynthesis/transpiration ratios after flooding indicated a decline in water use efficiency. Seedlings submersed in water containing suspended sediments had lower rates of photosynthesis than plants submersed in clear water. The timing of flooding treatments (spring vs. late summer) had no apparent effect on the pattern of decline in net photosynthesis. Two-year-old seedlings had a greater capacity for net photosynthesis after flooding than recently germinated seedlings, suggesting that recovery of normal physiological function after flooding is an important survival feature of older silver maple seedlings. Duration of flooding is the most important characteristic of the flood cycle affecting the survival and establishment of silver maple seedlings in floodplain habitats.

592. PETKEVICH, A. N. 1963. Biological bases for a rational fishery on Lakes Baraba and Kulunda. Pages 13–22 *in* The development of Siberian Lake fisheries. Novosibirsk. (In Russian)

Feeding and reproductive conditions for fish worsened as a result of periodic fluctuations in water level that periodically obstructed the movement of fish to and from spawning inlets. Inlets become shallow and narrow as a result of declining water levels. (From Referativmyi Zhurnal. Biologiya 1964, 7159; Biological Abstract 46:23414)

593. PETR, T. 1975. On some factors associated with the initial high fish catches in new African man-made waters. Archiv fuer Hydrobiologie 75(1):32–49.

The time required to fill reservoirs varies greatly, and fish populations seem to respond more favorably to prolonged than to rapid filling. Inundation of several virgin floodplains during prolonged filling of lakes provides a tremendous supply of nutrients. Secondary production over gradually sloping shallow areas is greatly increased. Periphyton and associated invertebrates on submerged terrestrial plants are important foods for fish. Fish prefer submerged forests to open or cleared areas. Drawdown and reflooding kills terrestrial vegetation, and subsequent wave action causes erosion.

594. PEZESHKI, S. R. 1993. Differences in patterns of photosynthetic responses to hypoxia in flood-tolerant and flood-sensitive tree species. Photosynthetica 28:423–430.

The effects of continuous soil hypoxia on stomatal conductance (g_s) and net photosynthetic rate (P_N) in seedlings of *Taxodium distichum*, *Quercus lyrata*, and *Q. falcata* var. *pagodifolia* were studied under a controlled environment. Soil oxygen deficiency induced significant stomatal closure and reduction of P_N in oak species within 1–3 days. This response pattern continued, resulting in average daily values of g_s reduced 85 and 40% within 14 days in *Q. falcata* and *Q. lyrata*, respectively, in comparison with control plants. During the same period, P_N reduced 96 and 71% in *Q. falcata* and *Q. lyrata*, respectively, in comparison with control plants. In *T. distichum*, however, g_s and P_N were reduced 18 and 33% by day 8. Significant recovery g_s and P_N was noted in *T. distichum*. By day 14, g_s had recovered to 91% and P_N to 92% of control plants. In oak species, however, P_N remained significantly lower than in control plants without any apparent recovery. The regain of photosynthetic activity and stomatal functioning in flood-tolerant species seems to be an important flood-tolerance characteristic allowing these species to function under flooded soil.

595. PIECZYN'SKA, E. 1972. Production and decomposition in the eulittoral zone of lakes. Pages 271–285 *in* Z. Kajak and A. Hillbricht-Ilkowska, editors. Productivity problems of freshwaters. Polish Science Publishing, Warszawa, Poland.

Primary sources of organic matter in the eulittoral (a transition zone between minimum and maximum water-level elevations) are described. The extent of the eulittoral, and therefore the influence of this highly productive zone on total lake productivity, depends on the configuration of the shoreline terrace, shoreline development, and water-level fluctuations. In Lake Mikolajskie, algal biomass was six times higher in the eulittoral than in the pelagic zone, and primary production was 11.6 times greater. Sources of organic matter in the eulittoral were primary production (2,100 kcal m^{-2} $year^{-1}$), autochthonous organic matter (4,860 kcal m^{-2} $year^{-1}$), and terrestrial organic matter (1,940 kcal m^{-2} $year^{-1}$). Decomposition provides the most rapid supply of organic matter from the eulittoral to other parts of the lake, and the period and extent of the supply depends greatly on changes in water level. Water levels also affect decomposition.

596. PIERCE, L. L., J. WALKER, T. I. DOWLING, T. R. MCVICAR, T. J. HATTON, S. W. RUNNING, AND J. C. COUGHLAN. 1993. Ecohydrological changes in the Murray-Darling Basin. 2. A simulation of regional hydrological changes. Journal of Applied Ecology 30:283–294.

Regional scale changes to the hydrological cycle of the Murray-Darling Basin (MDB) in Australia have occurred as a result of European settlement 200 years ago. The replacement of deep-rooted perennial plants (trees) by shallower rooting plants (pastures and cropping) is of particular significance in altering water tables and causing waterlogging and secondary salinization. The purpose was to locate the areas at risk of waterlogging and salinization as a result of tree clearing. To achieve this, present-day evaporation (ET) from 0.8% of the MDB (7,750 km^2) is compared with ET from a reconstruction of the pre-European condition. The spatial geographical database for the 155- × 5-km study area consisted of vegetation, soils, climate, and topographic information at 1.6- × 1.6-km cell resolution (3,072 individual cells for each data layer).

597. PIERCE, P. C., J. E. FREY, AND H. M. YAWN. 1963. An evaluation of fishery management techniques utilizing winter drawdowns. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 17:347–363.

Fifteen small impoundments (2 to 500 acres) were manipulated by several management techniques or combinations thereof and results were evaluated. Nine ponds, reduced to about 25% of their original size, exhibited no improvement in bluegill fishing, though the numbers of intermediate-sized bream were reduced. Bluegills were emaciated in the spring after winter drawdown in ponds with few bottom organisms. Recolonization of dried areas by benthos after reflooding was slow, but reflooding improved bass spawning. Seining and culling of intermediate-sized bluegills after drawdown in the winter decreased the growth and reproduction of the species and increased that of bass. Gill netting a pond after a winter drawdown was effective as a selective method of reducing the numbers of golden shiners and thereby rebalancing the fish populations.

598. PIERCE, R. B., D. W. COBLE, AND S. D. CORLEY. 1985. Influence of river stage on shoreline electrofishing catches in the Upper Mississippi River. Transactions of the American Fisheries Society 114:857–860.

The number of fish and fish species caught per unit of electrofishing effort along main-channel shorelines in Pool 13 of the Upper Mississippi River were inversely related to water level. Four species contributed predominantly to the relation between catch rate and water level: bluegill *Lepomis macrochirus*, freshwater drum *Aplodinotus grunniens*, white bass *Morone chrysops*, and sauger *Stizostedion canadense*. There was no relation for common carp *Cyprinus carpio* or shorthead redhorse *Moxostoma macrolepidotum*.

599. PITLO, J., JR. 1990. Study 1. An evaluation of largemouth bass populations in the Upper Mississippi River: Largemouth bass habitat requirements. Fish and Wildlife Division, Iowa Department of Natural Resources, Federal Aid to Fish Restoration Annual Performance Report, Mississippi River Investigations Project F-109-R-6. 71 pp.

Four hundred fifty observations were obtained from radio-tagged fish during 1990 in Pool 12 of the Upper Mississippi River. Mean water depth occupied by radio-tagged largemouth bass during the year was 2.1 ft. This compared to 3.2, 2.7, 2.6, 3.2, and 2.9 ft between 1985 and 1989, respectively. Radio-tagged largemouth bass were found in water depths that ranged from 1.5 to 4 ft nearly 80% of the time.

600. PLOSKEY, G. R. 1981. Factors affecting fish production and fishing quality in new reservoirs, with guidance on timber clearing, basin preparation, and filling. Prepared by the U.S. Fish and Wildlife Service, National Reservoir Research Program, for the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi, Technical Report E-81-11. 68 pp.

A literature review is made concerning fishery development and decline, factors relating to the filling of reservoirs, and factors related to structures.

601. PLOSKEY, G. R. 1982. Fluctuating water levels in reservoirs; an annotated bibliography on environmental effects and management for fisheries. Prepared by the U.S. Department of the Interior, Fish and Wildlife Service, for the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi, Technical Report E-82-5. 134 pp.

This bibliography lists 361 annotated references dealing directly or indirectly with the effects of water-level fluctuations on the physical, chemical, and biological components of lakes and reservoirs. Emphasis is placed on references pertaining to fish management in reservoirs, but many related topics are included.

602. PLOSKEY, G. R. 1986. Effects of water-level changes on reservoir ecosystems, with implications for fisheries management. Pages 86–97 *in* G. E. Hall and M. J. Van den Avyle, editors. Reservoir fisheries management: Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland.

Over 350 papers published since 1930 compose the extensive literature about the effects of water-level changes on aquatic biota. Most of the literature details single pre- and posttreatment studies evaluating effects on species of plants, invertebrates, or fish. Although some conflicting results have been obtained, fishery managers have developed successful management plans by relying on the consensus of published observations. Most managers seek to (1) draw down water levels in late summer or fall, (2) establish terrestrial vegetation by seeding or allowing for recolonization, (3) flood vegetation in spring, and (4) maintain high water for as much of the growing season as possible. Variations of this general plan, with regard to magnitude, duration, and timing have been used, but the literature suggests that only broad manipulations on seasonal or annual time scales yield significant benefits. Long-term data replicating several management and recruitment events are needed to develop predictive models. Comprehensive models are probably lacking today because manipulation and evaluation are expensive, multiyear efforts. However, sound predictions will become increasingly important to justify future requests for modified reservoir operations.

603. PLOSKEY, G. R., M. C. HARBERG, G. J. POWER, C. C. STONE, D. G. UNKENHOLZ, AND B. WEIDENHEFT. 1993. Assessing impacts of operations on fish reproduction in Missouri River reservoirs. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Technical Report EL-93-21. n.p.

This report describes a method for predicting impacts of system-operating alternatives on fish reproduction in six Missouri River reservoirs (Fort Peck, Sakakawea, Oahe, Sharpe, Francis Case, and Lewis and Clark). Two environmental alternatives allowed for seasonal variation in water-level or hydrologic patterns among years. These alternatives, which provided a year of high water to one of the three largest reservoirs on a rotating basis, produced similar reproductive indices in most years. However, the alternative allowing the greatest summer drawdown produced six exceptionally high RI values and yielded more years with above-average indices than the alternative that limited drawdown. These results are significant because a strong year class of fish can persist for about 5 to 8 years, and sport fish may dominate the catch of anglers for 3 to 5 years. Alternatives that limit annual drawdown are desirable only for severe drought periods when the fish reproduction and reservoir fisheries are both adversely affected by low water.

604. POFF, N. L., AND J. V. WARD. 1991. Drift responses of benthic invertebrates to experimental streamflow variation in a hydrologically stable stream. Canadian Journal of Fisheries and Aquatic Sciences 48:1926–1936.

Field experiments were conducted in the regulated upper Colorado River to assess drift responses of lotic macroinvertebrates to streamflow manipulations. In each of three seasons, drift was collected in one control and two experimental riffles. On the first day, no flow manipulations occurred. Six hours before sunset on the second day, streamflow was simultaneously reduced and elevated in two experimental riffles with instream diversion structures. Following flow elevation, both mean daily drift density and drift rate generally increased for 13 taxa across all seasons. Flow reductions generally induced elevated drift densities for most taxa, but drift rates declined for some taxa. Patterns of diel drift periodicity were less frequently modified by flow manipulations. Taxa with typical nocturnal peaks in drift activity (*Baetis* spp., *Epeorus longimanus, Triznaka signata)* generally maintained this pattern despite some increases in diurnal drift. For a few taxa, modification of diel drift patterns occurred, either as nocturnal decreases following reduced flow *(Paraleptophlebia heteronea*, *Ephemerella infrequens)* or as diurnal drift increases in response to either elevated flow *(Lepidostoma ormea*, Chironomidae larvae) or reduced flow (Simuliidae). With some exceptions, observed drift responses could be used to suggest active versus passive processes of drift entry.

605. POLLOCK, C. W. 1965. A study of the young-of-the-year largemouth and smallmouth bass in Dale Hollow Reservoir, Tennessee. M.S. Thesis, Tennessee Technical University, Cookeville. n.p.

Populations of young largemouth and smallmouth bass were examined to evaluate growth, condition, and food habits. Diets of young largemouth and smallmouth bass consisted mainly of plankton at first but gradually were dominated by insects. Young largemouth bass converted from a diet dominated by insects to one dominated by fish by August 5. Most forage fish were concentrated in dense growths of bushy pondweed (*Najas* sp.) located at the heads of coves. Young largemouth bass were unable to prey effectively on the forage fishes until a drawdown forced prey fishes out of the cover and into open water.

606. POSEY, L. E., JR. 1962. Changes occurring in the fish population of Black Bayou Lake following an increase in water level. Louisiana Academy of Science 25:93–108.

In winter 1954–55, water levels of Black Bayou Lake were raised 4 ft (nearly doubling the surface area) to improve fishing and to control aquatic vegetation. Cutgrass and parrot's feather were reduced or killed by deeper water, but the effect on parrot's feather, fanwort, and bladderwort was only temporary. Initially, the standing crop of fishes declined (from 59 to 26.7 lb/acre) as a result of the greatly increased area. In 1956, however, the standing crop of fishes increased to 70.4 lb/acre. Shad production increased from 7.1% of total fish production in 1954 to about 73.8% in 1959; production of largemouth bass decreased from 16.3% to 1% of the total. Raising lake levels seemingly did not benefit the sport fishery and may have degraded it.

607. POSPICHAL, L. B., AND W. MARSHALL. 1954. A field study of sora rail and Virginia rail in central Minnesota. Flicker 26:2–32.

The authors studied five ponds in St. Paul, Minnesota, in 1950. Sora and Virginia rails nested in cover composed primarily of cattail, with soras averaging 21.6 cm of water at the nest and Virginia rails averaging 21.2 cm. Broods utilize the cover at the nest site for a short period and then move to shallow waters and border vegetation of the ponds. Trapping operations seem to indicate a differential use of border vegetation, with more Virginia rails utilizing the moist, grassy areas surrounding the ponds.

608. POTAPOV, A. A. 1959. The overgrowth of reservoirs under different water levels. Botanicheskii Zhurnal 44:1271–1278.

The water level is a basic factor influencing the overgrowth of reservoirs. Thus, large fluctuations in level on the Rybinsk Reservoir, which reach 1.5–2 m from year to year, inhibit the intensive growth of hydrophytes and, on the other hand, aid the spreading of amphibious plants (*Polygonum amphibium*, *Agrostis stolonizans*, and others). In years when the water level is low, the shore zone becomes overgrown with weedy annuals (*Bidens tripartita*, various species of *Polygonum*, *Alopecurus aequalis*, and others). Large fluctuations in the level of Rybinsk Reservoir are the reason for the weak overgrowth of its shore zone. A more constant level is characteristic of the Istrinsk Reservoir; from 1953 to 1957 the amplitude of its fluctuations did not exceed 0.8 m. In recent years, *Phragmites communis*, *Scirpus lacustris*, *Nymphaea candida*, and other hydrophytes have become very widespread there. In reservoirs that have the most constant water-level systems, vegetation is especially rich. The draining of the water during the course of the season there leads to a change in seasonal appearance. The growth of hydrophytes is extremely undesirable in reservoirs used for drinking, and on the other hand, is beneficial in all other reservoirs used for the propagation of fish and waterfowl.

609. POWER, M. E., R. J. STOUT, C. E. CUSHING, P. P. HARPER, F. R. HAUER, W. J. MATTHEWS, P. B. MOYLE, B. STATZNER, AND I. R. WAIS DE BADGEN. 1988. Biotic and abiotic controls in river and stream communities. Journal of the North American Benthological Society 7:456–479.

In this review of the literature, the authors discuss five areas of research that might help explain the distributional abundance of the biota in the world's rivers and streams and predict how that biota will respond to changes in fluvial ecosystems. One of the main areas of research discussed is the response of lotic biota to discharge fluctuations, including the processes that mediate community recovery after resets caused by spates or droughts.

610. PRECODA, N. 1991. Requiem for the Aral Sea. AMBIO 20(3–4):109–114.

Heavy withdrawals of irrigation water from the Syr and Amu, the Aral Sea's two main tributaries, have for all practical purposes eliminated their spills and led to a sharp decrease in the level of the sea. This and the disruption of ecological equilibrium in this immense region have had catastrophic consequences for both the inhabitants of the region and for the environment. The circumstances leading up to and important features of some of the principal consequences are described.

611. PRIEGEL, G. R. 1970. Reproduction and early life history of the walleye in the Lake Winnebago region. Wisconsin Department of Natural Resources, Technical Bulletin 45. 105 pp.

The early life history of walleyes in Lake Winnebago and connecting waterways was examined to determine what factors affect spawning success, egg development, and fry survival. Egg development and fry survival were affected by water-level fluctuations, but because spawning areas were large and numerous, year-class strength was not limited by egg or fry mortality. Even when high mortality occurred in some areas, other areas made up the difference. Controlled burning is considered essential to curtail plant succession and retain desirable grasses needed for successful spawning. Eggs spawned in 1963 on Spoehr's Marsh either did not hatch or dried up after water receded; in 1964, the water level was low and the marsh was not available as a spawning ground. From 1960 to 1967, no successful hatch developed from the marshes along the Fox River because water levels dropped greatly. Receding waters often resulted in the stranding and death of fry.

612. PROPHET, C. W. 1970. Limnological features of Lyon County Lake after drainage and reflooding. Southwestern Naturalist 14(3):317–325.

Variations in physicochemical conditions, primary productivity, and the relative abundance and composition of zooplankton were studied from 1963 through 1967 to assess changes in these variables during and immediately after reflooding of Lyon County Lake, Kansas. No significant differences were found in dissolved oxygen or phosphate content in successive years, although mean oxygen concentrations were lower in the last year than in the first. Gross primary production recorded from April 1966 to April 1967 was lower than that of the 2 previous years. Chlorophyll, organic seston, and phosphate also decreased during the fourth year. Cladocerans and copepods were nearly 10 times more abundant in the first 2 years following reflooding of the basin than they were in the last 2 years. In the 4-year study, average annual zooplankton biomass was high in the first and second years after filling the lake (13.01 g dry weight m^{-3} and 13.63 g m^{-3}) and significantly lower in the next 2 years (1.29 g m^{-3} in 1965–66 and 1.44 g m^{-3} in 1966–67).

613. PROPHET, C. W., N. YOUNGSTEADT, AND L. SCHNITTKER. 1966. Limnology of Lyon County State Lake during reflooding, April 1964–March 1966. Transactions of the Kansas Academy of Science 69(3–4):214–225.

In March 1963, studies of the limnology of Lyon County Lake were initiated during a reflooding period that followed draining of the lake in 1962. Refilling of the lake was slow (32 months). There was no direct evidence of a surge in production or increase in the nutrient base due to decomposition of submerged vegetation, perhaps because of the slow filling process. Specific conductance and bicarbonate alkalinity increased only slightly. Mean gross primary production was low compared with that in other aquatic communities (however, 52.6% of all individual estimates exceeded 200 mg of oxygen m^{-2} $hour^{-1}$).

614. PROSSER, N. S., R. G. MARTIN, AND R. H. STROUD. 1978. Evaluation of planning for fish and wildlife, Council Grove Lake Project. U.S. Army Corps of Engineers, Washington, D.C. 69 pp.

Planning efforts and interagency cooperation are evaluated for the water resources development of Council Grove Reservoir, Kansas. Beginning in 1970, water levels were manipulated to benefit fish and wildlife according to the following regime: (1) On July 1, the lake level is lowered up to 4 ft to permit the growth of vegetation in the drawdown zone; (2) in fall, levels are raised 1 ft to attract waterfowl; (3) after the waterfowl season, levels are lowered 1 ft, and (4) in spring, levels are raised 4 ft to benefit fish spawning. Improved fish populations were documented by netting samples; successful reproduction of walleyes and several centrarchids occurred every year after 1972.

615. PROULX, G., J. A. MCDONNELL, AND F. F. GILBERT. 1987. The effect of water level fluctuations on muskrat, *Ondatra zibethicus*, predation by mink, *Mustela vison*. Canadian Field-Naturalist 101:89–92.

A study of mink (*Mustela vison*) food habits and movements was undertaken incidental to studies on muskrat (*Ondatra zibethicus*) at Luther Marsh, Ontario, 1978–80. In summers 1978–79, when water level was low, mink went deep into the marsh and preyed on aquatic birds and muskrats. In 1980, with high water levels, mink movements seemed to be restricted to the marshland edge; they preyed mostly on crayfish and meadow voles (*Microtus pennsylvanicus*). The 1979–80 winter scat analysis indicated that muskrats were the major mink food item in frequency and volume.

616. PYROVETSI, M., AND E. PAPASTERGIADOU. 1992. Biological conservation implications of water-level fluctuations in a wetland of international importance: Lake Kerkini, Macedonia, Greece. Environmental Conservation 19(3):235–244.

A new high dam was constructed in 1982 at Kerkini Lake in Greece. Operation of the new dam resulted in changes in the flooding regime, with severe effect on the biotic resources of the wetland, especially by water level increases of more than 5 m in less than 4 months during spring, which is the critical growing and breeding season. Wetland heterogeneity and the mosaic structure of water–land vegetation were thereby lost. Riparian forest is diminishing in area and declining in productivity. The Reed Swamp with emergent macrophytes has been lost and wet meadows have also disappeared. Loss of habitat is reflected in the marked decline in the densities of migratory waterbird populations and in drastic shrinkage in the populations of breeding species. Similar effects are observed in the dramatic decline of fish species diversity and abundance.

617. QUENNERSTEDT, N. 1958. Effect of water level fluctuation on lake vegetation. Internationale Vereinigung fuer Theoretische und Angewandte Limnologie Verhandlungen 13:901–906.

The author discusses the effects of lake-level fluctuations on the ecology of Benthic Lake vegetation in lakes of Sweden and Lappland. The author indicates that the rooted vegetation is severely damaged and all the vascular plants are exterminated if the water-level variations exceed a certain value for each individual lake. The nature of the lake vegetation (macro- and microphytes) can thus be totally changed by artificial water-level fluctuations, even if the transparency and chemical constitution of the water remain unaltered. The many different changes observed are related to the abundance or scarcity of various species.

618. RADER, R. B., AND J. V. WARD. 1988. Influence of regulation on environmental conditions and the macroinvertebrate community in the upper Colorado River. Regulated Rivers: Research & Management 2:597–618.

The influence of stream regulation on environmental conditions and concomitant alterations of macroinvertebrate community structure was determined from field studies conducted in September 1981–June 1983 at three sites on the upper Colorado River. Site 1 (reference site) was located above Granby and Shadow Mountain Reservoirs, a deep-release storage impoundment, whereas sites 2 (regulated site) and 3 (recovery site) were located 0.4 and 4.0 km, respectively, below the dam. Although macroinvertebrate diversity was reduced at the regulated site compared to both the reference and recovery sites, the number of taxa (43) was considerably higher than values reported from studies of other regulated streams in the Rocky Mountains. Macroinvertebrate mean annual density in the regulated site was 20 times higher than at the reference site and slightly higher than at the recovery site. The regulated site was characterized by the absence of heptageniid mayflies; reductions in stoneflies, caddisflies, shredders, and predators; and high densities of *Baetis* spp., *Ephemerella infrequens,* chironomids, and noninsect taxa. Many of these faunal changes are attributed to alterations in the temperature regime induced by regulation and to changes in the source and temporal sequencing of organic detritus. Although the number of annual degree days was actually greater below the dam than above the reservoir, other components of the thermal regime were severely altered by regulation. At the regulated site, the primary source of coarse, organic detritus was autochthonous (decaying algae) with a vernal pulse, in contrast to the typical autumnal pulse of allochthonous leaf litter. There was no evidence that the greater substrate permeability and flow predictability below the dam directly influenced the reduction of species.

619. RADER, R. B., AND J. V. WARD. 1989. Influence of impoundments on mayfly diets, life histories, and production. Journal of the North American Benthological Society 8:64–73.

We investigated the influence of stream regulation on the dietary composition, life histories, and production of four mayfly species *(Drunella grandis*, *Ephemerella infrequens*, *Paraleptophlebia heteronea,* and *Baetis tricaudatus*) at three sites in the upper Colorado River. Sites (unregulated, intensely regulated, and recovery) were selected based upon degree of regulation (i.e., upstream, 0.4 km downstream, and 4.0 km downstream from a deep-release reservoir). Although levels of food abundance (diatom density and sedimentary detritus) varied between sites, the dietary compositions of *B. tricaudatus* (primarily diatoms) and *P. heteronea* (detritus) did not change. However, *D. grandis* and *E. infrequens* consumed diatoms downstream from the reservoir, whereas their diet was strictly detritivorous at the upstream site. The number of degree days and mean annual water temperatures at the downstream sites were greater than at the free-flowing, unregulated site. *Baetis tricaudatus* responded to regulated conditions by higher rates of development, altered voltinism, and extended emergence. *Ephemerella infrequens* and *P. heteronea* were univoltine at each site. However, development of *E. infrequens* and *P. heteronea* was poorly synchronized and emergence was extended at both downstream sites. *Drunella grandis* was univoltine and well synchronized with a short emergence period at each site. Life history flexibility, in rates of egg development, growth, maturation, and emergence, at the population level may be determined by a lack of dependence by individuals upon temperature or photoperiod cues to synchronize the developmental process. Annual production estimates at downstream sites were higher for all four species than at the upstream site. Annual production of *D. grandis* (15.38 g/m^2) at the recovery site and of *E. infrequens* (15.89 g/m^2) at the regulated site are the highest production estimates recorded for mayflies.

620. RAINWATER, W. C., AND A. ROUSER. 1975. Relation of physical and biological variables to black bass crops. Pages 306–309 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

The standing crop of black basses in Beaver and Bull Shoals Reservoirs varied greatly over the periods sampled (1966–73 in Bull Shoals; 1963–73 in Beaver). An exceptional increase in both standing crop and numbers of black basses in Beaver Lake in 1973 occurred when water levels were unusually high, but standing crop was not significantly correlated with water-level fluctuations, abundance of young-of-year shad, or rate of inflow from 1963 to 1973. By contrast, the biomass and numbers of black basses in Bull Shoals Lake were highly correlated with inflow, mean seasonal lake elevations, and the standing crops of young-of-year threadfin and gizzard shad. The reproductive success of black basses in Bull Shoals from 1966 to 1973 was significantly correlated ($P < 0.01$) with fluctuation of water levels during the 3-month spawning season. Strong year classes were produced in years when water levels rose or were already high. A higher rate of survival of young-of-year bass over other years was attributed to accelerated growth and to refuge provided by flooded shoreline vegetation.

621. RAMSEY, D. L., AND B. E. PIERCE. 1979. Summersville Reservoir study. West Virginia Reservoir Investigation, West Virginia Department of Natural Resources, Federal Aid Project F-11-R-17, Job I-2. n.p.

The fish in Summersville Reservoir were monitored to determine the effects of forage and predatory fish introductions and to measure the influence of modified water levels on the fishery. An increased winter pool level (55 ft higher than normal) was implemented for five winters to reduce fish loss through the dam. Before the initiation of higher winter levels, many fish (particularly walleyes) were found dead downstream from the dam. The sport fishery at Summersville Reservoir improved during the last 4 years, and a hypolimnial trout fishery was maintained in summers when cold waters were not depleted by normal drawdown.

622. RAMSEY, D. L., AND B. E. PIERCE. 1979. Sutton Reservoir study. West Virginia Reservoir Investigation, West Virginia Department of Natural Resources, Federal Aid Project F-11-R-17, Job I-1. n.p.

Sutton Reservoir was sampled to determine the results of introductions of forage and predatory fish and to measure the influence of modified water levels on the fishery. Losses of fish through Sutton Dam during winter drawdown were substantial and, as a result, stocking of muskellunge, northern pike, walleyes, and trout were largely unsuccessful. The summer pool was held 3 ft lower than normal to reduce the magnitude and abruptness of downstream water releases. Although the reduced summer pool level reduced losses of fish through the dam, it reduced the surface area, productive littoral area, overhanging shoreline vegetation, and submerged shoreline cover; it also accelerated shoreline erosion and increased turbidity.

623. RASMUSSEN, J. L., EDITOR. 1979. A compendium of fishery information on the Upper Mississippi River. Upper Mississippi River Conservation Committee (UMRCC) Fisheries Compendium. 259 pp.

A review of ecological considerations is presented for fish and mussels in the Upper Mississippi River.

624. RAWSON, D. S. 1958. Indices to lake productivity and their significance in predicting conditions in reservoirs and lakes with disturbed water levels. Pages 27–42 *in* P. A. Larkin, editor. Investigation of fish power problems. H. R. MacMillan Lectures in Fisheries, University of British Columbia.

A review is presented of the limnology and management of fisheries in fluctuating reservoirs in British Columbia. Emphasis is placed on case histories of reservoirs in the Canadian Rockies. Because scientific data, methods, and understanding are limited, predictions of productivity from descriptive variables such as area, mean depth, shoreline development, and water levels are crude at best. Productivity among fluctuating reservoirs varies greatly. Therefore, more careful pre- and postimpoundment studies are needed.

625. REA, N., AND G. G. GANF. 1994. Water depth changes and biomass allocation in two contrasting macrophytes. Australian Journal of Marine and Freshwater Research 45:1459–1468.

The response of *B. arthrophylla* and *T. procerum* in pot experiments to depth and depth changes provided insight into how plants survive fluctuating water levels. At 0 cm depth, most biomass was placed belowground, which can be interpreted as the placement of resource-acquiring tissues (roots, rhizomes) in resource (nutrients, space)-supplying environments. At 50 and 100 cm, the placement of biomass into shoots recognized the need for a higher supply of aboveground resources (light, inorganic carbon, oxygen). However, the responses of the two species to flooding or exposure differed. Rhizome storage supported an increase in the number and height of *B. arthrophylla* stems when flooded by 50 cm but this species was unable to counteract submergence to 100 cm without the critical loss of root mass. The slow turnover rate of the cuticularized *B. arthrophylla* stems indicates that biomass needs to be allocated above water as well as aboveground. Other responses indicated that this species may be better suited to seasonally fluctuating rather than permanent water levels. *T. procerum* dealt with water-level changes via morphological plasticity. Along with the rapid growth and turnover of the spongy leaves, its shoot and total mass were maintained primarily from resources in the tubers.

626. REGEHR, D. L., F. A. BAZZAZ, AND W. R. BOGGESS. 1975. Photosynthesis, transpiration, and leaf conductance of *Populus deltoides* in relation to flooding and drought. Photosynthetica 9(1):52–61.

Single intact leaves of *Populus deltoides* reached saturating irradiance at 1,500 µeinstein m^{-2} s^{-1}. At 30 °C, the photosynthetic rate was 26 mg CO_2 dm^{-2} h^{-1}. Photosynthesis increased with increasing CO_2 concentration, reaching an asymptote at 1,000 vpm. Complete inundation of the root system for 28 days reduced photosynthesis by 50%. Recovery occurred within 1 week after the end of flooding. The species is very sensitive to drought, with photosynthesis falling from maximum between −3 and −8 bar leaf water potential to near zero at −11 bar. Trends in transpiration rate and leaf conductance are similar to those of photosynthetic rate.

627. REID, F. A., J. R. KELLEY, JR., T. S. TAYLOR, AND L. H. FREDRICKSON. 1989. Upper Mississippi Valley wetlands—refuges and moist-soil impoundments. Pages 181–201 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Technical University Press, Lubbock.

Intensive management can increase the carrying capacity to mitigate some of the habitat loss in the Upper Mississippi Valley. Habitat management for emergent wetlands include marsh and moist-soil techniques. Development considerations include floodwater source, flooding, and dewatering network, pumps and levees; the size and number of impoundments; and the juxtaposition of habitat types.

628. Reznicek, A. A., and P. A. Keddy. 1985. Lake level effects as measured from aerial photos (a discussion). Journal of Surveying Engineering 111(2):167–170.

The authors discuss a paper by Lyon and Drobney (1984). They are concerned that the analysis presented by Lyon and Drobney was misleading and inaccurate. They raise questions dealing with the author's model predicting wetlands as a function of water level. A closure is also included by Lyon and Drobney.

629. Rideout, S. G., and P. H. Oatis. 1975. Population dynamics of smallmouth and largemouth bass in Quabbin Reservoir. Pages 216–221 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

The catch of smallmouth bass and largemouth bass over 20 years is examined and related to boating effort, water-level fluctuations, legal restrictions, and to the catch of other warm-water fishes in Quabbin Lake, Massachusetts. Largemouth bass and pickerels were more affected by water-level fluctuation than other species, and white perch seemingly were not influenced by water-level changes. Because the east arm of the reservoir was shallow, several thousand acres of largemouth bass habitat were eliminated when water levels fell below the 20-ft mark. A sharp increase in water levels in 1972–73 may have been detrimental to fishing success, because inundated brush provided cover that reduced the effectiveness of anglers. Elimination of restrictions on bass angling during the spawning season has no discernible effect on angling quality.

630. Ridley, J. E., and J. A. Steel. 1975. Ecological aspects of river impoundments. Pages 565–587 *in* B. A. Whitton, editor. River ecology. Blackwell, Oxford, England.

The authors review the literature providing information on the function and morphometry of impoundments, seasonal change in water quality, factors affecting biota, mathematical modeling, artificial mixing systems for water supply impoundments, and the downstream effects of impoundments on rivers.

631. Riel, A. D. 1965. The control of an overpopulation of yellow perch in Bow Lake, Strafford, New Hampshire. Progressive Fish-Culturist 27:37–41.

After a dam was constructed on Bow Lake, New Hampshire, this 1,198-acre lake was drawn down in fall. For years, fall drawdown to the original lake level forced perch into open water where they were subjected to increased predation. In later years, water levels were more constant, because less water stored behind the dam was used. After fall drawdowns were eliminated or reduced, yellow perch became overabundant, and other means of control had to be developed. Control by netting and destruction of eggs is discussed.

632. Riley, T. Z., and T. A. Bookhout. 1990. Response of aquatic macroinvertebrates to early-spring drawdown in nodding smartweed marshes. Wetlands 10:173–185.

The effects of early spring water-level reduction on aquatic macroinvertebrate populations were studied from 1986 to 1988 in four nodding smartweed (*Polygonum lapathifolium* L.) marshes on the Ottawa National Wildlife Refuge and the Magee Marsh State Wildlife Area in northwestern Ohio.

Water depths in two marshes were maintained at normal (> 40 cm) overwinter levels, then were reduced in early April each year to approximately 50% (20 cm) of overwinter depth. Water levels in two other marshes were allowed to fluctuate naturally throughout the study period. Aquatic invertebrate density and biomass were sampled from late March through mid-June in the water column, in the benthos, and on the surfaces of nodding smartweed plants. Invertebrate levels (activity, density, and biomass) in the water column were higher ($P < 0.05$) in shallow marshes than in deep marshes. Benthic invertebrate levels in all marshes were low compared with invertebrate levels in the water column. Water-level reduction in smartweed marshes did not significantly increase benthic or periphytic invertebrate levels in shallow marshes over those in deep marshes.

633. RISOTTO, S. P., AND R. E. TURNER. 1985. Annual fluctuation in abundance of the commercial fisheries of the Mississippi River and tributaries. North American Journal of Fisheries Management 5:557–574.

The authors attempt to explain the annual variations in fish catches from the Mississippi River basin from 1954 to 1976. They analyze National Marine Fisheries Service catch per unit effort data for the total basin, four regional subbasins, and 18 basin states for total catch and for the 7 most important commercial species. Because seasonal flooding, temperature, and floodplain development are the major environmental factors influencing the abundance of fishes in floodplain rivers elsewhere in the world, the authors examined the relation between yield and (1) average monthly water temperature; (2) maximum river stage, days above floodstage, day-feet above floodstage, and the Palmer Drought Index as indices of flooding; and (3) the acreage of bottomland hardwoods. 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. The catch per unit effort per hectare of bottomland hardwoods increased from south to north. Water temperatures during spring and winter were inversely related to the catch of several species. A multiple regression model to predict annual variation was developed. The fishery of the whole basin fluctuated by 25% during the period studied, presently being fished at near-optimum annual levels of effort (about 11,000-12,000 fishermen), and catch (30,000 metric tons). Estimates of optimum annual levels of effort (7,000-8,000 fishermen) and catch (11,000 metric tons) were also made for the lower Mississippi River basin fishery.

634. ROBBINS, T. W., AND D. MATHUR. 1976. The Muddy Run pumped storage project: A case history. Transactions of the American Fisheries Society 105:165–172.

The effects of pumped-storage operations on fish populations in Conowingo Pond (the lower pond) and Muddy Run Pumped Storage Pond (the upper pond) are discussed. Water-level fluctuations in Muddy Run limit the effective reproduction of nest-building fishes. Recruitment to Muddy Run depends largely on a transfer of fishes from Conowingo Pond during pumping. Bluegills and pumpkinseeds spawn in one location of the fluctuating pond (a quarry 9 m below full pool), which retains water even after the level of Muddy Run falls below that elevation.

635. ROBEL, R. J. 1961. Water depth and turbidity in relation to growth of sago pondweed. Journal of Wildlife Management 25:436–438.

A vegetation production study was initiated in river marshes in summer 1959. Vegetation water samples were collected from 42 sampling sights. Strong correlations were found between vegetation production and water depth, water depth and turbidity, and turbidity and vegetation production.

Deeper water is observed to support larger crops of aquatic vegetation. These deeper waters also contain less suspended matter. The author recommended inundating the marsh to a depth exceeding 9 inches.

636. ROBEL, R. J. 1962. Changes in submerged vegetation following a change in water level. Journal of Wildlife Management 26:221–224.

Following a preliminary vegetation survey of a Utah marsh in 1959, the water depth was raised 3 inches in the 1961 growing season. Vegetation surveys were conducted late in summers 1959 and 1961. Vegetation production increased by 32% in the shallow areas but decreased by 35% in the deeper areas. Other changes included an increase in the size of the marsh, an increase of sago growth near waterfowl habitats, and a more luxuriant growth of alkalai bulrush.

637. RODHE, W. 1964. Effects of impoundment on water chemistry and plankton in Lake Ransaren (Swedish Lappland). Verhandlungen Internationale Vereinigung Limnology 15:437–443.

The effects of rising water levels and initial impoundment were evaluated by comparing water chemistry, phytoplankton, and zooplankton in newly impounded lakes and natural lakes. Dam construction and burning of brush along the shore temporarily increased the level of phosphate and primary production. Though primary production increased in the first year, algal biomass remained the same. In the second and third years of impoundment, the standing crop and production of algae and zooplankton doubled or tripled. Increased productivity must have resulted from the input of nutrients from flooded or eroded terrestrial areas. Observed changes in phosphate, total phosphorus, and total nitrogen were small, probably because the nutrients were rapidly assimilated. Increased phytoplankton and zooplankton production seemed to corroborate this hypothesis.

638. ROGALA, J. T., AND J. H. WLOSINSKI. 1992. Development of a spatial data base of longitudinal water level fluctuations within selected navigation pools of the Upper Mississippi River. Page 59 *in* Proceedings of the Mississippi River Research Consortium, Volume 24, La Crosse, Wisconsin, April 30–May 1, 1992.

Water surface coverages at various discharges were created in a geographic information system (GIS) for Navigation Pools 4, 8, 13, and 26 on the Mississippi River. Data for the coverages were obtained from actual water surface measurements recorded over an 18-year period and from backwater curves computed by the U.S. Army Corps of Engineers. Data were positioned into a template of river miles created in a GIS to produce water surfaces at discharges of interest. These coverages in themselves depict spatially the changes that occur in water surfaces. Water surface coverages were then overlaid with bathymetry coverages to estimate spatial changes in habitat and volume as the discharge varies. (Abstract only)

639. RØRSLETT, B. 1984. Environmental factors and aquatic macrophyte response in regulated lakes—a statistical approach. Aquatic Botany 19:199–220.

Depth and relative elevation need to be carefully distinguished in lakes with an appreciable fluctuation of water levels. Water-level schedules determine the actual vegetational response; thus the total probability of distribution of water levels should replace the regulation height or mean annual range of water-level variation in an analysis of response features. Submerged macrophyte communities respond to increasing the extent of regulation, that is larger annual water-level variation, along two response pathways: (1) a reduction in community diversity and organization pattern, and (2) the peak community performance is shifted into deeper waters.

640. ROSEBERRY, D. A. 1950. Game fisheries investigations of Clayton Lake, a mainstream impoundment of the New River, Pulaski County, Virginia, with emphasis on *Micropterus punctatus* (Rafinesque). Ph.D. Thesis, Virginia Polytechnical Institute, Blacksburg. 235 pp.

Stocks of game fishes, their condition, age and size composition, and standing crop were studied. Seasonal changes in the distribution and behavior of fish were documented. Water levels were normally reduced by about 2 ft in February, but this drawdown did not significantly interfere with spawning of black basses or fry survival. Annual water-level fluctuation was about 8 ft; combined with wave action, it caused extensive shoreline erosion and thereby increased turbidity. Of the black basses, the largemouth bass seemed the most affected by altered water levels because it generally spawned in shallower water than the other species. The slow growth of fish during their first 2 years of life was attributed to a lack of aquatic plants and sparse invertebrate fauna in the fluctuation zone.

641. ROSEBERRY, D. A. 1951. Fishery management of Claytor Lake, an impoundment on the New River in Virginia. Transactions of the American Fisheries Society 80:194–209.

The fish population, harvest, and fishery management of Claytor Lake, Virginia, in 1948 and 1949, are described. The shore zone did not develop a high population of plant or animal forms because the water level of the lake was variable and steep, rocky shores were wave swept. The abundance of bluegills, the principal forage fish of larger piscivores, was limited by low production of invertebrates in the littoral zone. As a result, the standing crop of sport fish was consistently low. The fish productivity of the lake could perhaps be increased by increasing fertility or by altering the species composition of fishes so that plants and invertebrates are preyed upon more efficiently. The introduction of gizzard shad was recommended.

642. ROSS, S. T., AND J. A. BAKER. 1983. The response of fishes to periodic spring floods in a southeastern stream. American Midland Naturalist 109:1–14.

The movement of fishes onto a fringing floodplain in southeastern Mississippi on the Upper Black Creek System was studied by seining and trapping during five spring floods. The authors collected 26 species from the inundated floodplain; the known channel fauna is 42 species. Species numerically dominant on the floodplain were *Fundulus olivaceus*, *F. notti*, *Gambusia affinis*, *Notropis welaka*, *N. texanus*, *N. roseapinnis*, *Lepomis macrochirus*, *L. cyanellus*, and *L. marginatus*. Catch-per-effort in traps was generally greatest on the upper floodplain during the day and greatest nearer the channel at night. Night activity of fishes on the floodplain seemed low. Several species, which we termed flood-quiescent forms, were common in the channel (e.g., *Lepomis megalotis* and *Percina nigrofasciata*), but did not exploit the floodplain. Activity (as catch per trap-hour) of *P. nigrofasciata* was negatively correlated with flood-induced turbidity. A flood-exploitative species, *Notropis texanus*, had higher population abundance during 3 high-flow years than in 3 low-flow years, suggesting that spring flooding may exert significant control over fish community structure.

643. RUNDLE, W. D., AND L. H. FREDRICKSON. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildlife Society Bulletin 9:80–87.

Soil and water were manipulated on four man-made impoundments to attract rails, shorebirds, or waterfowl. Postbreeding rails were attracted by shallow flooding in late summer. Only robust vegetation that developed in early spring or withstood overwinter action by ice and feeding waterfowl provided cover for spring migrant rails. Shorebirds were attracted by drawdowns in spring, summer, and fall, and to disking and flooding in summer. Some waterfowl were attracted to impoundments managed for rails and shorebirds. Impoundments managed for waterfowl food production attracted < 50% of available shorebird species and provided suitable habitat for rails and shorebirds in spring only.

644. RUNNSTROM, S. 1951. The population of char, *Salmo alpinus*, Linne, in a regulated lake. Institute of Freshwater Research Drottningholm Report 32:66–78.

The level of Lake Torron was raised 8.25 m between 1937 and 1940 by the construction of a dam at the outlet. Water-level fluctuations caused the loss of littoral aquatic vegetation (Isoetes) and forced char to use new spawning sites formed by shoreline erosion, which exposed suitable stone and gravel substrates. Although up to 50% of the spawn was dried and lost by declining water levels, the losses did not affect year-class strength. The mean weight and growth of char increased during the first few years of regulation and then declined greatly. The decisive factor controlling char yields was the limited production of fish food, as determined by water-level fluctuations and not by apparent limitations to reproduction.

645. RUNNSTROM, S. 1952. The population of trout, *Salmo trutta*, Linne, in regulated lakes. Institute of Freshwater Research Drottningholm Report 33:179–198.

The spawn of trout in rivers between regulated natural lakes in Sweden was frequently destroyed by regulation that caused tailwaters to dry up. After regulation, the total catch of trout decreased relative to catches of other species. Extensive stocking of trout fry and fingerlings in the lakes was not successful in improving trout populations. Even with natural reproduction severely reduced, recaptures of marked trout that had been stocked were consistently less than 5% of the total population. Maintenance of minimum flows and the construction of fish ladders were suggested as ways of decreasing the damage of regulation.

646. RUNNSTROM, S. 1955. Changes in fish production in impounded lakes. Verhandlungen Internationale Vereinigung Limnology 12:176–182.

Changes in the abundance, standing crop, and mean weight of char in Lake Torron, Sweden, was examined to document the effects of fluctuations in water level on fish production. Annual 13-m fluctuations in water level ultimately eliminated littoral macrophytes and severely reduced the biomass of benthos. In the first year after lake damming, secondary production of most communities flourished, only to decline rapidly in successive years. There was no decrease in the number of fish harvested after regulation, in spite of the rather large proportions of eggs that were desiccated and killed by receding waters in winter. The mean weight of fish harvested increased following regulation (probably in response to improved trophic conditions caused by flooding) but thereafter progressively declined to below preimpoundment levels.

647. RUNNSTROM, S. 1964. Effects of impoundment on the growth of *Salmo trutta* and *Salvelinus alpinus* in Lake Ransaren (Swedish Lappland). Verhandlungen Internationale Vereinigung Limnology 15:453–461.

Field studies indicated fairly early that the abundance of fish species that spawn along shorelines were not reduced because of poor recruitment. Even if a high percentage of roe was destroyed by receding water levels, the number of fry remaining was sufficient to fulfill recruitment. These data suggest that regulation limits fish production by limiting food. In a number of lakes, growth of fishes accelerates during filling of the reservoir, but sharply declines thereafter. The fast growth of fish in the first year or two of impoundment can be attributed to good nutritive conditions and the production of strong year classes. Effects of water-level fluctuation usually are reflected in slow fish growth but can be masked by changes in climatic conditions such as relatively higher temperatures or longer growing seasons. The stocking of trout proved unprofitable: the weight of the catch was much less than the weight of the fish stocked.

648. SALYER, J. T. 1958. Factors associated with the decline of the largemouth bass, *Micropterus salmoides* (Lacepede), in San Vicente Reservoir, San Diego County, California. M.A. Thesis, San Diego State University, San Diego, California. 103 pp.

In addition to other possible problems confronting largemouth bass (lack of spawning habitat and cover) in San Vicente Reservoir, the harvest of bass apparently reduced predation on bluegills and allowed the bluegill population to increase greatly. The large population of bluegills may have limited the reproductive success of all centrarchids by preying on eggs and fry. Rapid drawdowns were recommended in late June and early July to control the spawning of bluegills by destroying their nests. Another recommendation was to maintain stable water levels during bass spawning, at least until mid-May. Increased bass fishing success in 1955 may have been related to stable water levels present when bass spawned in spring 1953.

649. SATHER, J. H. 1958. Biology of the Great Plains muskrat in Nebraska. Wildlife Monographs 2:1–35.

The Great Plains muskrat (*Ondatra zibethicus cinnamominus*) was studied in north-central Nebraska from 1948 through spring 1952. The author noted that for a sustained harvest at optimum levels it seems that water control structures are required.

650. SAYRE, M. W., AND W. D. RUNDLE. 1984. Comparison of habitat use by migrant soras and Virginia rails. Journal of Wildlife Management 48:599–607.

Censuses were conducted along transect lines on Mingo National Wildlife Refuge in southeastern Missouri. Water depth was found to be an important factor influencing habitat use by migrant sora and Virginia rails. Virginia rails preferred saturated to shallowly flooded sites and were often flushed near a soil/water interface. Virginia rails were rarely flushed from sites where water was less than 15 cm deep. The distribution of migrant soras relative to the water depth was less restrictive than that of Virginia rails. Soras showed a preference for water depths of 5–15 cm but often used deeper water sites. Saturated and shallowly flooded sites were also used to some extent by soras. Shallowly flooded areas with tall, dense vegetation interspersed with drier, saturated sites provide optimum habitat for migrant Virginia rails and are also used to some extent by soras. Soras will use fairly deep water sites if emergents are present, but shallower depths seem to be preferred. In fall, manipulation of water levels to provide access to maturing seedheads of annual grasses or smartweeds may be beneficial for soras.

651. SCHLÜTER, U. B., AND B. FURCH. 1992. Morphological, anatomical, and physiological investigations on the tolerance to flooding by the tree *Macrolobium acaciaefolium*, characteristic of the white- and blackwater inundation forest near Manaus, Amazonas. Amazoniana 12(1):51–69.

Young trees of the legume species, *Macrolobium acaciaefolium*, can survive submerged in the Central Amazonian inundation forest near Manaus, Amazonas, during floods lasting as long as 312 days. This paper describes the environmental conditions to which these plants are exposed during the terrestrial, or emersion, and during the aquatic, or submerged phases in the white- and blackwater inundation forests. It also provides information on the anatomical, morphological, and physiological adaptations that make survival under these adverse conditions possible.

652. SCHLÜTER, U. B., B. FURCH, AND C. A. JOLY. 1993. Physiological and anatomical adaptations by young *Astrocaryum jauari* Mart. (Arecaceae) in periodically inundated biotopes of central Amazonia. Biotropica 25(4):384–396.

Young plants of the palm, *Astrocaryum jauari*, are well-adapted anatomically and physiologically to hypoxic conditions. Annual inundation for as long as 300 days, at water temperatures of 28 °C, produce neither leaf loss nor rotting of the roots. At a depth of 1.2 m beneath blackwaters, the leaves in the crowns of the plants show little decrease in the amount of chlorophyll. In contrast, submersion to an equal depth in whitewater produces a loss of chlorophyll. Photosynthetic oxygen production decreases to less than 30% of the terrestrial rate in plants submerged beneath blackwater and to less than 10% in plants submerged in whitewater. Ethanol production compensates for temporary energy deficits. Respiration by the roots is greatly reduced but does not cease during inundation. A well-developed aerenchyma permits gas transport from the branches to the roots. A cylinder of stone cells and sclerenchyma fibers in the outer periphery of the primary bark prevents the collapse of the root aerenchyma due to reduced pressure within the roots and increasing external pressure as water depth rises.

653. SCHMIDT, A., P. VETTER, AND T. CLAFLIN. 1993. The vertical distribution of fossil fingernail clams in selected backwater areas in Navigation Pool 8, Upper Mississippi River. Page 73 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

The relatively recent disappearance of the fingernail clam *Musculium transversum* from several pools of the Upper Mississippi River has caused concern among biologists. A study conducted in Pool 8 in 1977 demonstrated fingernail clam populations exceeding 2,500/m^2. By 1989, these populations had declined to less than 20/m^2 in the same areas. The objective of our study was to estimate the actual time of their disappearance. The authors collected core samples from Pool 8 in the same areas as sampled in the 1977 and 1989 studies. The cores were collected to a depth of approximately 20–40 cm and divided into 1-cm sections. Each section was examined for remnant clam shells and analyzed for Cesium-137 to date the sediment. Preliminary data indicate that remnant shells are unevenly distributed in the cores. The maximum depths at which shells were found vary between 20 and 36 cm. (Abstract only)

654. SCHNEIDER, R. F., AND J. A. LITTLE. 1973. Rise and fall of Lake Apopka: A case study in reservoir management. Pages 690–694 *in* W. C. Ackermann, G. F. White, and E. B. Worthington, editors. Man-made lakes: Their problems and environmental effects. American Geophysical Union, Geophysical Monograph Series 17, William Byrd Press, Richmond, Virginia.

Lake Apopka was a typical, clear, shallow groundwater-fed lake in central Florida until man sought to render it more useful for industrial and agricultural purposes. In the 1920s, waste materials began to be dumped into the lake. The waste load increased in the following decades. Control structures were built in the 1950s to stabilize the lake's water levels for the benefit of agriculture. Efforts to improve fisheries by poisoning overpopulations of gizzard and threadfin shad accelerated the eutrophication problem. Restoration plans, besides control of allochthonous nutrient sources, include lake drawdown to expose large areas of lake bottom to oxidation and compaction or other stabilization of the rich sediments.

655. SCHROEDER, L. D., D. R. ANDERSON, R. S. POSPAHALA, G. G. W. ROBINSON, AND F. A. GLOVER. 1976. Effects of early water application on waterfowl production. Journal of Wildlife Management 40:227–232.

Records of nests and broods on the Monte Vista National Wildlife Refuge, Colorado, suggested that waterfowl production was high in years when water was available prior to spring migration. If sufficient water was not available until after spring migration, low production could be expected. To test this hypothesis, we divided a 241-ha habitat unit on the refuge into two plots; the experimental plot was flood-irrigated 2 weeks before the peak of spring waterfowl migration and the control plot was flood-irrigated 2 weeks after the peak of migration. This treatment was applied alternately to the plots during two 3-year periods and one 2-year period. Numbers of nests and production of mallards (*Anas platyrhynchos*), pintails (*A. acuta*), shovelers (*A. clypeata*), teals (*A. discors, A. crecca,* and *A. cyanoptera*), and gadwalls (*A. strepera*) were significantly greater ($P < 0.05$) on one plot when early water was applied. The inability to draw down water levels sufficiently on the other plot was believed to be the reason duck production was not significantly greater on both plots during years of early water application. Economic and management implications are presented.

656. SCHRYER, F., V. EBERT, AND L. DOWLIN. 1971. Determination of conditions under which northern pike spawn naturally in Kansas reservoirs. Kansas Forestry, Fish and Game Commission, Federal Aid Project F-15-R-6, Job C-3. 37 pp.

A complete record is presented of northern pike stocking in Kansas. Natural reproduction and recruitment of northern pike cannot be expected to occur frequently enough after the early years of impoundment to maintain fishable populations. Supplemental stocking of fish 7 to 11 inches long is required. Several factors are responsible for unsuccessful reproduction, but all of them are related to water-level fluctuations. Extreme fluctuations can increase turbidity, which is detrimental to egg and fry survival. The development of dense terrestrial vegetation in late summer or early fall (during low water) and inundation of this vegetation for 3 or 4 months, beginning in early to mid-March, provide conditions for the successful reproduction of northern pike.

657. SCHUELLER, M. D. 1989. Microhabitat utilization of a main channel border island complex by young-of-the-year fishes. Page 20 *in* Proceedings of the Mississippi River Research Consortium, Volume 21, La Crosse, Wisconsin, April 27–28, 1989.

Young-of-year fishes in the main channel island environment of the Upper Mississippi River were examined to determine critical biotic and abiotic factors that influence their distributions. A main channel island complex was selected for study because it offered a continuum of suspected microhabitat factors. Fish were collected from eight sites around Dakota Island, Pool 7, by bag seine on three consecutive days every other week from May through October 1987. The microhabitat measurements taken included water quality (temperature, D.O., pH, conductivity, turbidity), vegetation characteristics (type, density, estimated percent cover), and current and depth profiles. Nearly 40,000 fish of 30 species were collected. Sites differed not only in total catch per unit effort based on analysis of variance, but also in community structure based on clustering methods. Stepwise discriminate analyses indicate, for example, that vegetation densities and estimated percent surface cover are the principal factors controlling the presence or absence of bluegill in the island environment. A model was generated that correctly predicted bluegill presence in 70% of the observations based on *Vallisneria americana* densities and estimated percent surface cover. These functions should be useful tools for predicting distributions of key species in other areas of the river. (Abstract only)

658. SCHULTZ, C. A. 1966. Age and growth studies. Fisheries investigations on flood control reservoirs. Mississippi Game and Fish Commission, Federal Aid Project F-6-R, Job 3. 47 pp.

Major variations in the growth of white crappies, spotted bass, and largemouth bass coincided with simultaneous variations in the abundance of forage fishes and drastic fluctuations in water levels. Annual fluctuations in water levels were similar in magnitude and pattern for Sardis, Enid, and Grenada Reservoirs. Growth was rapid when spring water levels reached maximum elevations in 1961 and 1964, and slowest when water levels were lowest (1959 and 1963). When water levels were high in 1962, only young fish grew rapidly. High spring water levels seemingly increased the chances of rapid growth during the rest of the year, as drawdown of all reservoirs was to about the same level each year, though growth rates varied. Fish sampling with rotenone showed a positive relation between water-level fluctuations and the reproduction of shad and minnows, although other factors undoubtedly are involved.

659. SCHULTZ, C. A. 1966. Evaluation of macrobenthos recovery on dewatered flats with relation to vegetative cover types. Fisheries investigations on flood control reservoirs. Mississippi Game and Fish Commission, Federal Aid Project F-6-R, Job 11. 7 pp.

Macrobenthos on mudflats in Sardis Reservoir, Mississippi, were sampled periodically after reflooding of these previously dewatered areas. After 8 days of inundation in February 1966, chironomids and *Chaoborus* averaged 85 organisms m^{-2}. From 1 April to 30 May 1966 (48-107 days of inundation), an average of 139 organisms m^{-2} were present. *Chaoborus* and chironomids were no more abundant after several months of flooding than after 2 weeks. Permanently inundated areas supported an average of 281 organisms m^{-2} in the period November 1965–February 1966. Although sampling periods for permanently inundated and seasonally inundated mudflats were not directly comparable, benthos on seasonally inundated mudflats did not seem to attain the densities observed on permanently flooded areas. Benthos numbers in different types of cover (cypress, buttonbush, and smartweed) were similar; density seemed to be more closely related to the type of substrate than to the type of vegetation present.

660. SCHULTZ, C. A. 1966. Fisheries investigations on flood control reservoirs. Pages 72–81 *in* Evaluation of macrobenthos recovery on dewatered flats with relation to vegetative cover types. Mississippi Game and Fish Commission.

The flood control reservoirs in the headwaters of the Yazoo River System are operated in a way that causes drastic fluctuations in water levels. The topography of the reservoir areas is such that large acreages are alternately flooded and dewatered by these fluctuations. This study was designed to investigate the speed of recovery of macroscopic benthic organisms in dewatered flats and to determine the relation of recovery with the different types of vegetative cover that are characteristic of these areas. Sardis Reservoir, representative of all the reservoirs in this system, was chosen for the study. The data indicate that a significant degree of recovery is made soon after the reflooding of dewatered areas occurs. It was found that Tendipedidae may be less subject to seasonal variations among organisms sampled and may therefore be the best indicator of rate of recovery. There was no indication that organisms are influenced by types of vegetative cover. However, bottom type may be a factor. Fewer organisms were recovered from hard, clay bottom.

661. SCULLION, J., AND A. SINTON. 1983. Effects of artificial freshets on substratum composition, benthic invertebrate fauna, and invertebrate drift in two impounded rivers in mid-Wales. Hydrobiologia 107:261–269.

Artificial discharges of water from reservoirs caused a sixfold and threefold increase in discharge in the R. Tywi and R. Elan, respectively, but did not significantly alter particle size composition (by weight) and the porosity of the substratum or the organic matter content of fine particles (< 0.5 mm). Freshets in both rivers resulted in a consistent, though not significant, reduction in total densities of invertebrates and the densities of many major taxa and abundant species. During the freshet in the R. Elan, maximum concentration and total load of suspended solids were about 11 and 35 times greater, respectively, than prerelease values, whereas invertebrate drift was dominated by Chironomidae (65%) and Plecoptera (25%). Total numbers and densities of drifting chironomids increased immediately in response to the flow increase; in contrast, numbers and densities of plecopterans increased later, during the night.

662. SCULLY, R. J. 1972. Physical chemical parameters and gill net catches at four flood plain habitats on the Kafue Flats, Zambia. M.S. Thesis, University of Idaho, Moscow. 59 pp.

The catch of fishes in floodplain areas varied with time and habitat. Dissolved oxygen tensions were more closely related to the catch of fish than to other physicochemical factors monitored, and oxygen concentration was largely a function of the length of time areas were inundated and the type and quantity of aquatic vegetation present.

663. SEABLOOM, R. W., AND J. R. BEER. 1963. Observations of a muskrat population decline in North Dakota. Proceedings of the North Dakota Academy of Science 17:66–70.

During 1956 and 1957, a study was conducted of populations of the great plains muskrat (*Ondatra zibethica cinnamominus*) dwelling in four marshes in Towner County, North Dakota. The mean water depth for the marshes at the beginning of the study was 27 inches. The lack of winter snow cover resulted in heavy mortality of the resident muskrat population due to thick ice. Lack of spring runoff caused three of the marshes to completely dry up while the other held 17 inches of water. Associated with the declining water levels on the study area marshes, there seemed to be a general abandonment of shallow water areas and bank dens in favor of house construction in deeper water. Shifts in population structure were noted: the most prominent was a reduction in the proportion of juveniles in the regional population. Impaired reproductive activity of adults, poor survival of young, or both may have caused the shift in age ratios.

664. SEFTON, D. F. 1976. The biomass and productivity of aquatic macrophytes in navigation Pool 8 of the Upper Mississippi River. M.S. Thesis, University of Wisconsin, La Crosse. 175 pp.

After studying the productivity of aquatic macrophytes in Pool 8 of the Upper Mississippi River, the author concludes that aquatic macrophytes can be expected to increase greatly in the backwaters if the present trends of sedimentation decrease in depth and eutrophication continue.

665. SENA GOMES, A. R., AND T. T. KOZLOWSKI. 1980. Effects of flooding on *Eucalyptus camaldulensis* and *Eucalyptus globulus* seedlings. Oecologia 46:139–142.

Flooding for up to 40 days induced morphological changes and reduced the growth of 6-week-old *Eucalyptus camaldulensis* and *E. globulus* seedlings. However, the specific responses to flooding varied markedly between these species and with duration of flooding. Both species produced abundant adventitious roots that originated near the tap root and original lateral roots, but only *E. camaldulensis* produced adventitious roots on submerged portions of the stem. Flooding induced leaf epinasty and reduced total dry weight increment of seedlings of both species but growth of *E. globulus* was reduced more. In both species, dry weight increment of shoots was reduced more than dry weight increment of roots, reflecting compensatory growth of adventitious roots. Adaptation to flooding seemed to be greater in *E. camaldulensis* than in *E. globulus*. The importance of formation of adventitious roots in flooding tolerance is emphasized.

666. SENA GOMES, A. R., AND T. T. KOZLOWSKI. 1980. Growth responses and adaptations of *Fraxinus pennsylvanica* seedlings to flooding. Plant Physiology 66:267–271.

Flooding induced several physiological and morphological changes in *Fraxinus pennsylvanica* seedlings, with stomatal closure among the earliest responses. Subsequent changes included: a reduction in dry weight increment of roots, stems, and leaves; formation of hypertrophied lenticels and production of adventitious roots on submerged portions of the stem above the soil line; leaf necrosis; and leaf abscission. After 15 days of stomatal closure as a result of flooding, stomata began to reopen progressively until stomatal aperture was similar in flooded and unflooded plants. Adventitious roots began to form at about the time stomatal reopening began. As more adventitious roots formed, elongated, and branched, the stomata opened further. The formation of adventitious roots was an important adaptation for flooding tolerance as shown by the high efficiency of adventitious roots in the absorption of water and in the high correlation between the production of adventitious roots and stomatal reopening.

667. SERRUYA, C., AND U. POLLINGHER. 1977. Lowering of water level and algal biomass in Lake Kinneret. Hydrobiologia 54:73–80.

Water levels of Lake Kinneret decreased rapidly from 1972 to 1975 as a result of drought. The lowering of the lake produced a number of events: (1) It reduced the volume-to-area ratio, which in turn increased the input of mechanical energy (wind) per unit volume, which accelerated heat transfer by increasing the volume of water mixed; (2) it decreased the volume of the hypolimnion as thermocline depth increased; (3) it increased concentrations of nutrients due to decay of organics, improved the solubility of salts such as calcium phosphate, and increased the release of orthophosphate because of more effective oxidation of sediments at turnover; (4) it altered the species composition of algae (diatoms and green algae replaced *Peridinium*); and (5) it reduced algal biomass because of a lower biomass-to-phosphorus ratio and the fact that diatoms and green algae were grazed by zooplankton, whereas *Peridinium* was not.

668. SHARONOV, I. V. 1958. Fish culture in Lake Sevan following draining operations. Rybnoe Khozyaistvo 8:31–34. (In Russian)

The lowering of water levels of Lake Sevan reduced the spawning area of *Salmo ischchan*, *Coregonus lavaretus*, *Varicorhinus capoeta sevangi*, and *Barbus goktshchaicus*. Fish being harvested were recruited from populations spawning in tributaries or raised in hatcheries. Culture operations are described. (From Referativmyi Zhurnal. Biologiya 1960, 6528; Biological Abstract 46:9755)

669. SHARONOV, I. V. 1963. The effect of the water level on the formation of fish stocks in the Kuibyshev Reservoir. Materials first science technical conference for the study of Kuibyshev Reservoir. Kuibyshev 3:126–132. (In Russian)

Low-value fishes are replacing valuable commercial fishes because the present water-level regime adversely affects the reproduction of valuable species. At low water levels in winter, many fish are killed by suffocation. Sediments in shallow areas are dried and frozen. Requirements for reproduction seem to be less stringent for fishes of low value than for the valuable species, and conservation measures to remove low-value fishes by netting and predator control should be implemented. (From Referativmyi Zhurnal. Biologiya 1964, 5156; Biological Abstract 46:14422)

670. SHEAFFER, W. A., AND J. G. NICKUM. 1986. Backwater areas as nursery habitats for fishes in Pool 13 of the Upper Mississippi River. Hydrobiologia 136:131–140.

Samples of larval and juvenile fishes were collected at two depths weekly during spring and summer 1983 near the mouths of backwater areas in Pool 13 of the Upper Mississippi River. The study was conducted to determine the relative value of these habitats as nursery areas for fishes present and to note any interactions that might occur between the backwaters, which are being rapidly lost to siltation and the main channel. The larvae and juveniles collected represented 13 families divided into 27 lower taxa. Cyprinidae, Clupeidae, and Sciaenidae made up 90% of the total catch. Both larvae and juveniles were more abundant near the surface than near the bottom. Densities differed greatly among the three backwater areas studied. Larval fishes were grouped on the basis of their relative abundance in the backwaters or main channel. Overall, more larvae were captured in the backwaters than in main-channel habitats, indicating that backwaters were more productive. In the main channel, densities were greater downstream from the mouths of the backwaters than upstream, possibly indicating that (1) larval fish drifted out of the backwater areas, (2) water rich in nutrients or zooplankton that flowed into the main channel created productive downstream sites that were used as nursery areas, or (3) adult fishes selected downstream sites as spawning areas. Juvenile forms were more abundant in the backwater areas than in the main-channel habitats, some bottom-dwelling fishes excepted. The backwater areas were judged to be important nursery areas for larval and juvenile fishes, and seemed to benefit downstream main-channel sites. Any loss of these habitats would be detrimental to the Mississippi River as a whole.

671. SHEARER, L. A., B. J. JAHN, AND L. LENZ. 1969. Deterioration of duck foods when flooded. Journal of Wildlife Management 33:1012–1015.

Eighteen kinds of seeds readily eaten by waterfowl were submerged in flooded fields to determine the percentage of deterioration. Both bulrush and smartweed were suited to long-term flooding conditions.

672. SHELDON, R. B., AND C. W. BOYLEN. 1977. Maximum depth inhabited by aquatic vascular plants. American Midland Naturalist 97:248–254.

To document maximum depth limits for a number of aquatic species, a study was undertaken from 1973 to 1975 to determine the distribution, abundance, and limiting depth for 28 species of rooted macrophytes found in Lake George, New York. This lake offered a good ecological situation for study because of its oligotrophic status, exceptionally high water clarity, and species diversity of submergent plants. There are presently 224 aquatic plant species known to occur in or on the periphery of Lake George in less than 1 m of water. At 1-m depth, the number of emergent and submergent species is reduced to 51; therefore, water depth has a pronounced effect on the diversity of species present. Light is also usually considered a factor limiting depth reached by vascular plants. Generally, maximum depth for growth depends upon the depth at which the light intensity falls below the light-compensation point for photosynthesis as well as the quality of light penetrating to any given depth. Therefore, it is difficult to distinguish between the effects upon plant growth due to increasing depth or light availability.

673. SHIELDS, J. T. 1955. Carp control through water drawdowns, Fort Randall Reservoir, South Dakota. South Dakota Department of Game, Fish, and Parks, Federal Aid Project F-1-R-5. 10 pp.

By predicting when common carp began heavy spawning and requesting a drawdown of lake levels, some success was obtained in controlling common carp populations. Temperature apparently is the primary stimulant for spawning, but rising waters that flood grassy or weedy areas seem to have some effect. Eggs are adhesive and cling to vegetation in shallow areas (0.5–2 ft deep). When water levels were reduced rapidly in 1955, no egg survival was evident during the heaviest spawning. During a second drawdown in 1955, no spawning success was observed. Poor year classes of common carp in 1954 and 1955 were attributed to poor hatching success as a result of timely rapid drawdown of water.

674. SHIELDS, J. T. 1957. Carp control through water drawdowns, Fort Randall and Gavins Point Reservoirs, South Dakota. South Dakota Department of Game, Fish, and Parks, Federal Aid Project F-1-R-7. 10 pp.

Poor reproduction of common carp in the main body of Fort Randall Reservoir, South Dakota, was attributed to rapid drawdown of water during the spawning period. About two-thirds of the spawn hatched before a 1.5-ft drawdown, but the rest were destroyed. Poor survival of fry was believed to be the result of poor food availability or other biological conditions caused by reduced water levels during a critical stage of fry development. Planned drawdowns from 1955 to 1957 may also have adversely affected the reproduction of gars and buffaloes. Poor reproduction of all species of fish in Gavins Point Reservoir probably resulted (directly or indirectly) from periodic reductions of water level throughout the summer.

675. SHIELDS, J. T. 1957. Experimental control of carp reproduction through water drawdowns in Fort Randall Reservoir, South Dakota. Transactions of the American Fisheries Society 87:23–33.

Major spawns of common carp were predicted by sampling, gonad inspection, and monitoring of water temperatures to permit the use of rapid drawdown as a method of controlling the abundance of carp. Spawning was induced by rapidly rising water that inundated shallow vegetated areas, at the appropriate temperature. In 1955, levels were reduced 1.5 ft in 5 days. Freshly spawned eggs were located in areas less than 1 ft deep, and receding waters exposed and killed most of them. Because many carp spawned in the upstream end of the reservoir, where drawdown had less effect, significant numbers of young carp were caught later in the season. However, survival of young carp was poor because the drawdown seemingly upset some biological condition (such as food availability) at a critical stage in the life of fry. The year classes of carp produced in the drawdown years of 1955, 1956, and 1957 were relatively weak, suggesting that planned drawdowns were primarily responsible for limited reproduction.

676. SHIELDS, J. T. 1958. Fish management problems of large impoundments on the Missouri River. Transactions of the American Fisheries Society 87:356–362.

Major management problems identified in six large Missouri River reservoirs include inadequate harvest, development of efficient commercial gear and markets, and overabundant populations of undesirable fishes. Planned manipulation of water levels is a powerful management tool, especially in the integrated system of Missouri River reservoirs where increased flexibility of reservoir operations may allow manipulation of water levels for fish management. Drawdown may be used to control spawning of rough fishes or to improve the spawning conditions for desirable fishes. Production of fish-food organisms can be increased by raising water levels to flood naturally or artificially vegetated areas.

677. SHIPLEY, B., P. A. KEDDY, AND L. P. LEFKOVITCH. 1991. Mechanisms producing plant zonation along a water depth gradient: A comparison with the exposure gradient. Canadian Journal of Botany 69:1420–1424.

A 15-month field experiment was performed in the emergent zone of a freshwater riverine marsh along the Ottawa River, Canada, to determine whether the mechanisms producing plant zonation along the exposure gradient of freshwater shorelines also accounted for the zonal pattern along the water depth gradient. Three species (*Carex crinita*, *Acorus calamus*, and *Typha angustifolia*) were chosen, having contiguous distributions along a gradient of water depth. Ramets of each were planted within and beyond the field distributions of each, both in the presence and in the absence of the natural vegetation of each site. There was strong evidence of a differential response between species. There was also no evidence that the water depth gradient represents a general gradient of decreasing productivity; rather, there was a qualitative change below the low-water level. These results are contrary to previously published results obtained along the exposure gradient of freshwater shorelines, where the effects of plant interference do vary both along the exposure gradient and among species.

678. SHIPLEY, B., AND M. PARENT. 1991. Germination responses of sixty-four wetland species in relation to seed size, minimum time to reproduction, and seedling relative growth rate. Functional Ecology 5:111–118.

Three germination attributes (lag time, maximum germination rate, and final germination proportion) were measured for 64 species of herbaceous wetland plants. The environmental conditions approximated the drawdown environment known to stimulate germination in wetland plants: a period of cold stratification followed by position of the seed on the surface of wet, but not inundated, substrate in the presence of light and with a 20/30 °C daily temperature cycle. Correlations were sought between the three germination attributes and average individual seed weight, seedling relative growth rate and a categorical variable indicating minimum time to reproduction (annuals, facultative annuals, and obligate perennials). Average seed weight was not correlated with any of the three germination attributes. Seedling relative growth rate was negatively correlated with time to initiation of germination. Species capable of setting seed their first year (annuals and facultative annuals) initiated germination sooner, a larger proportion germinated per day once germination began, and a larger proportion of seeds had germinated by the end of the experiment in comparison with species that require more than 1 year to set seed (obligate perennials). A discriminant analysis showed that the time to initiation of germination could accurately classify 89% of the perennial species as being either facultative annuals or obligate perennials.

679. SHIRLEY, K. E., AND A. K. ANDREWS. 1977. Growth, production, and mortality of largemouth bass during the first year of life in Lake Carl Blackwell, Oklahoma. Transactions of the American Fisheries Society 106:590–595.

Mark–recapture methods were used to evaluate first-year recruitment, growth, net production, and mortality of largemouth bass in the 1972 and 1973 year classes. The 1972 year class was a failure, whereas the 1973 year class was highly successful. Differences in the number, growth, and production of largemouth bass in both year classes were directly related to differences in water level in the 2 years. In 1973, water levels rose and inundated terrestrial vegetation. Flooding improved growth and lessened mortality by providing a temporary increase of food in the form of terrestrial invertebrates, by increasing cover (flooded terrestrial vegetation) for nests and nursery areas (by reducing wave action and predation), and by increasing nutrient levels (from decaying vegetation).

680. SHORT, R. A., AND J. V. WARD. 1980. Leaf litter processing in a regulated Rocky Mountain stream. Canadian Journal of Fisheries and Aquatic Sciences 37:123–127.

The processing of alder (*Alnus tenuifolia*) was investigated in fall and winter to determine the influence of stream regulation on leaf litter processing. Study sites were the Colorado River below Granby Dam and the Fraser River, an unregulated tributary. Although numbers of macroinvertebrates per leaf pack were generally similar, there were obvious differences in the species composition. Eight of the taxa collected in the Fraser River leaf packs were not found in the Colorado River samples. Six taxa were collected only from the Colorado River. These differences undoubtedly relate to the effects of stream regulation. Inputs of coarse particulate organic matter (CPOM) are normally reduced below dams (which accounts for reduced shredder populations) since instream transport from upper reaches is eliminated. Therefore, CPOM probably plays a minor role in the energetics of regulated stream reaches. Regulated streams are characterized by large standing crops of autotrophs, which likely provide the major portion of the food base. Enhanced microbial processing at higher temperatures provides at least a partial explanation for the rapid processing of leaf litter below Granby Dam. It is also possible that surficial scraping by the large numbers of *E. infrequens* significantly contributed to weight loss of Colorado leaf packs. Elevated temperature may increase leaf weight loss by increasing feeding activities of macroinvertebrates. It is not known whether the findings of the present study are applicable to regulated streams in other regions or even to other lotic systems in the Rocky Mountains. The proliferation of dams necessitates a fuller understanding of the effects of stream regulation and provides a setting for testing and developing basic theories of stream ecology.

681. SIDLE, J. G., D. E. CARLSON, E. M. KIRSCH, AND J. J. DINAN. 1992. Flooding: Mortality and habitat renewal for least terns and piping plovers. Colonial Waterbirds 15(1):132–136.

Nest initiation was always possible for the least tern (*Sterna antillarum*) and threatened piping plover (*Charadrius melodus*) from 1986 to 1990 along the Platte River, Nebraska. Some flooding of the nests was recorded annually with most mortality in 1990. For mortality to be severe, nesting habitat must be available early and most birds must nest before a high flow occurs. Sustained high flows during spring through summer prevent birds from nesting, because habitat is always inundated. High flows early in the nesting season will not affect many nests. Likewise, high flows late in the season will not affect many nests, and chicks could survive if some portion of the nesting sandbars remain exposed.

682. SIEFERT, R. E. 1969. Biology of the white crappie in Lewis and Clark Lake. U.S. Bureau of Sport Fisheries and Wildlife, Technical Paper 22. 16 pp.

The life history of the white crappie in Lewis and Clark Lake is described. No relation between year-class strength and water-level fluctuations was documented, but survival of white crappie nests may have been adversely affected by water-level fluctuations when crappies nested in shallow water because of lower than normal water temperatures during the spawning season.

683. SIGAFOOS, R. S. 1964. Botanical evidence of floods and floodplain deposition. Pages 1–35 *in* U.S. Geological Survey, Professional Paper 485-A.

Methods of identifying past floods have been developed from a study of the form and age of parts of trees growing on the floodplain of the Potomac River near Washington, D.C. The date of deposition of sediment can be learned from the study of the structure of wood in the buried part of tree trunks, and the approximate thickness of the deposit can be determined by measuring to the level of the original tree base. Anatomical characteristics of the wood of roots exposed by erosion of the banks and the floodplain provide data for ascertaining the year that the roots were first exposed. The methods can be used to determine the occurrence of floods and floodplain deposition on streams draining areas at least as small as 4 mi^2.

684. SILKER, T. H. 1948. Planting of water-tolerant trees along margins of fluctuating-level reservoirs. Iowa State Journal of Science 22:431–447.

A thorough sampling was made of 1,100 acres of water-tolerant tree plantations, 5 to 12 years old, along the margins of fluctuating reservoirs on the lower Tennessee River. Data on survival, height, and adaptation of trees to changing water tables and to soil and ground cover conditions were obtained for bald cypress, water oak, willow oak, green ash, red gum, tupelo, southern white cedar, and sycamore. Results were presented for two kinds of reservoir-margin planting sites.

685. SILVERTSEN, E. 1962. Namsvatn—Fishery biological investigations after regulation of the lake. Pages 37–66 *in* Kongelige Norske Videnskabers Selskab., Museet Arbok. (In Norwegian)

Lake Namsvatn in central Norway was raised 13 m in 1952 for hydroelectric development. Investigations of stomach contents of brown trout and char in 1945 and in 1951–61 showed that *Gammarus pulex* disappeared after impoundment, while densities of *Lepidurus glacialis* increased. Trout ate primarily insects, whereas char diets were dominated by entomostraca. The average size and condition of trout was stable throughout the study. The average weight of char increased from 238 g in 1951 to 273 g in 1953 and then decreased successively to only 132 g in 1961. Decreased size was correlated with decreased condition and an increase in the number of mature char. Tagging

experiments showed that char moved over the entire lake, whereas trout were more locally bound. (Abstract from K. W. Jensen, Vollebekk, Norway, as adapted from Fraser 1972)

686. SIMONS, D. B. 1979. Effects of stream regulation on channel morphology. Pages 95–111 *in* J. V. Ward, and J. A. Stanford, editors. Ecology of regulated streams. Plenum, New York.

The design of dams, diversion structures, and river-training works requires detailed evaluation of the effects these structures impose on watersheds and river systems. An adequate analysis of river systems and the impacts of water-resources development requires the calculation of (1) the total sediment load that enters the reservoir, (2) the characteristics of the sediment, including size distribution, specific weight, and density of the deposited sediment as a function of time, (3) the pattern of deposition of sediment in the reservoir as a function of time and space, (4) the effect of pool fluctuations on sediment storage, (5) the trapping efficiency of the reservoir, (6) backwater effects on flood stage and sediment deposition, (7) the rate of loss of live and dead storage, (8) the useful life of the reservoir, (9) possible means of bypassing sediment, (10) aggradation rates and magnitudes upstream from impoundments, (11) rate and magnitude of channel degradation below the dam, (12) channel stabilization requirements both upstream and downstream, and (13) the effects of river development on water quality and on the biomass of the system.

687. SINGLETON, J. R. 1951. Production and utilization of waterfowl food plants on the east Texas Gulf Coast. Journal of Wildlife Management 15:46–56.

In only one instance was there sufficient information to determine the effects of water level on productivity. One plot of southern bulrush in a brackish pond with a semistabilized water level was the highest producer among the five plots of southern bulrush, thus indicating that stability of water is a limiting factor on productivity. Water depth on this key plot varied from 9 to 18 inches, whereas water depths on the four other plots varied from zero to 17 inches.

688. SIPP, S. K., AND D. T. BELL. 1974. The response of net photosynthesis to flood conditions in seedlings of *Acer saccharinum* (silver maple). University of Illinois, Forest Research Report 74-9:1–2.

Ideal conditions for the establishment of silver maple in the floodplain environment seem to include (1) bare mineral soil available with adequate moisture in the 2 weeks following seed fall to ensure seed germination, (2) adequate soil moisture without extended periods of soil saturation or flooding to ensure plant establishment, (3) successful overwintering, and (4) spring floods of minimal duration to ensure that established seedlings are not overtopped by floodwaters for extended periods of time. First-year seedling mortality seems to be mostly a function of the direct influence of the response of the species to the physical environment rather than the limiting effect of modification of the physical factors by competition pressures of neighboring plants.

689. SIVER, P. A., A. M. COLEMAN, G. A. BENSON, AND J. T. SIMPSON. 1986. The effects of winter drawdown on macrophytes in Candlewood Lake, Connecticut. Pages 69–73 *in* G. Redfield, J. F. Taggart, and L. M. Moore, editors. Lake and reservoir management. Volume 2. Proceedings of the Fifth Annual Conference and International Symposium of the North American Lake Management Society, Geneva, Wisconsin, November 13–16, 1985.

Between 1980 and 1983 dense beds of the macrophyte *Myriophyllum spicatum* L. became well established throughout Candlewood Lake, Connecticut, at the expense of a once diverse native flora.

In 1983–84 and 1984–85. winter drawdowns of 2 and 2.7 m, respectively, were attempted to control the densities and further spread of the *M. spicatum*. After the initial drawdown, weed biomass was reduced by more than 90% in shallow sites; however, little change in densities occurred in deeper areas. The deeper drawdown resulted in a further reduction in *M. spicatum* densities, although it remained the dominant plant at depths greater than 2.5 m. *Najas minor allioni* became the dominant macrophyte in shallow areas, presumably developing from seeds.

690. SMIRNOFF, N., AND R. M. M. CRAWFORD. 1983. Variation in the structure and response to flooding of root aerenchyma in some wetland plants. Annals of Botany (London) 51:237–249.

The structure and response to flooding of root cortical aerenchyma (air space tissue) in a variety of wetland (flood-tolerant) species was investigated and compared with some flood-intolerant species. In some species, aerenchyma consisted of enlarged, schizogenous intercellular spaces and in others aerenchyma formation involved lysigeny. Two types of lysigenous aerenchyma were distinguished. In the first, the diaphragms between lacunae were arranged radially and consisted of both collapsed and intact cells. In the second type, which was confined to the Cyperaceae, the radial diaphragms contained intact cells; stretched between them were tangentially arranged diaphragms of collapsed cells. Flooding in sand culture generally increased root porosity (air space content) although there were exceptions. The flood-intolerant species *Senecio jacobaea* produced aerenchyma but did not survive long-term flooding. Among the flood-tolerant species, *Filipendula ulmaria* did not produce extensive aerenchyma even when flooded. *Eriophorum angustifolium* and *E. vaginatum* produced extensive aerenchyma under drained conditions, which was not increased by flooding. In *Nardus stricta*, root porosity was increased by low nutrient levels as well as by flooding.

691. SMIRNOV, A. F. 1964. The importance of the fisheries in the reservoirs of North Karelia. *In* Fisheries of Karelia. Petrozavodsk 8:123–129. (In Russian)

The anticipated development of fish stocks in flooded lakes in basins of Lovskoe and Pyaozerskoe Reservoirs is discussed. Favorable feeding conditions for ciscoes, smelts, and other young fishes will be created by increased input of organic matter and increased zooplankton populations. Sea trout, trout, and whitefish populations (typical lake and river forms) should decline. During early years of flooding of the new impoundments, the reproduction of pike, perch, and roach should be excellent, and bream (*Abramis*) abundance will increase after the shore zone is established. After the construction of a hydroelectric power plant in Pyaozerskoe Reservoir, the water level of Topozero Lake will be reduced 20%, and low water in fall and winter will probably hinder the spawning of ciscoes, char, lake whitefish, and spring-spawning fishes. (From Referativmyi Zhurnal. Biologiya 1965, 4186 and Biological Abstract 47:75781)

692. SMITH, D. W., AND R. O. PETERSON. 1988. The effects of regulated lake levels on beaver in Voyageurs National Park, Minnesota. U.S. Department of the Interior, National Park Service, Midwest Regional Office, Omaha, Nebraska, Research/Resources Management Report MWR-11. 84 pp.

Beavers in Voyageurs National Park, Minnesota, were studied to determine the effects of a winter water drawdown of 2 m (3 m annually) behind hydroelectric dams. Active beaver lodge density was greatest on the drawdown lake Kabetogama, and was increasing at a higher rate on Kabetogama than on the slight drawdown lake Rainy. Beavers living in the drawdown environment abandoned their lodges over winter, but stayed in the lodge vicinity. The use of food caches of aquatic vegetation was less in the drawdown areas. Above-ice foraging in winter and spring abandonment of the fall–winter homesite were more common in the drawdown environment. Family size and kit production were lower in the drawdown and poor habitat locations, and adult body size was less at the poor habitat location. Beavers living in the drawdown environment came through winter in poor condition. Winter drawdown was hypothesized to interfere with reproductive behavior. Overwinter mortality was not widespread, but some did occur due to starvation. Springtime wolf predation due to low water levels was believed to be the major beaver mortality factor, but was estimated not to exceed 25%. Beaver–forest relations were also discussed. Management recommendations were to change water management to approximate a more natural fluctuation. Total yearly fluctuation should not exceed 1.5 m, and winter drawdowns should not exceed 0.7 m.

693. SMITH, D. W., AND R. O. PETERSON. 1991. Behavior of beaver in lakes with varying water levels in northern Minnesota. Environmental Management 15(3):395–400

We studied the effects of winter water drawdowns (2.3 m) on beavers in Voyageurs National Park, Minnesota. Our study was designed to sample areas within the park that differed in water drawdown regime. Lodges were counted and beavers were livetrapped and radio-implanted to study behavior, movements, and mortality. Active beaver lodge density, determined by aerial survey between 1984 and 1986, was greatest along the shoreline of the drawdown reservoir. In winter, beavers living on the drawdown reservoir spent less time inside their lodges than did beavers from stable water environments, foraged more above ice, and were unable to fully use stored food. Only one case of starvation in the drawdown reservoir was documented, but beavers in reservoirs that were drawn down survived winter in poorer condition than did beavers living in areas in which water levels remained high. In spite of an increasing population and lack of widespread mortality, winter water drawdowns did alter beaver behavior. To reduce these effects, total annual water fluctuation should not exceed 1.5 m, and winter drawdown should not exceed 0.7 m.

694. SMITH, J. 1975. Evaluation of fish populations in Greenleaf Lake. Oklahoma Department of Wildlife Conservation, Federal Aid Project F-26-R, Job 2. 73 pp.

Because previous surveys indicated overabundant populations of rough fish and stunted game fish, this study was designed to evaluate the combined effects of drawdown, rough-fish removal, rye planting, and stocking of 17,000 catchable-sized catfish. Other management measures included the construction of 27 brush shelters and the stocking of largemouth bass. The lake was lowered 18.5 ft below normal pool in September 1966 and was refilled in February 1967. Growth of most species improved after refilling the lake, and the sport fishery apparently improved for 3-4 years before returning to predrawdown conditions. Because many management techniques were employed, effects of the drawdown alone cannot be evaluated.

695. SMITH, L. M., AND J. A. KADLEC. 1983. Seed banks and their role during the drawdown of a North American marsh. Journal of Applied Ecology 20:673–684.

The size and species composition of the seed banks were compared among six vegetation types (*Typha* spp., *Scirpus acutus*, *S. maritimus*, *Distichlis spicata*, *Phragmites australis*, and open water sites) in a North American marsh. Persistent seed banks were estimated from 25 soil samples (20 × 20 × 4 cm deep) within each vegetation type. Samples were exposed to moist-soil (no standing water) and submerged (4 cm depth) conditions in a greenhouse. More species germinated in the moist-soil treatment (24) than in the submerged treatment (12). *Typha* spp. and *Scirpus acutus* sites had the greatest number of species germinate, and S. *acutus* sites also had the highest seedling density. Open water sites had few species and low seedling densities. *Scirpus* spp. seedlings were found primarily in *Scirpus* spp. seed bank samples, whereas *Typha* seedlings were found in high densities in all emergent vegetation types *(Scirpus* spp., *Typha* spp., and *Phragmites australis)*. Mudflat species (e.g., *Chenopodium rubrum)* were found at higher densities in *Scirpus acutus* sites. Kendall's rank correlation tests indicated that shoot densities in the field and seedling densities in the greenhouse tests of samples from the same vegetation types were not similar during marsh drawdown. The frequency of marsh plant species shifted as the water table fell (drawdown) with emergent plant species decreasing and mudflat species increasing. In the field, salinity increased and soil moisture decreased during drawdown. The watering of seed bank samples in the greenhouse maintained lower salinities and higher soil moisture than in vegetation types in the field. Rather than a complete drawdown for the establishment of marsh plants in the area studied, maintaining a few centimeters water depth will keep salinities low, allow germination of at least 12 species, and prevent the establishment of *Tamarix* pentandra.

696. SNOW, H. E. 1971. Harvest and feeding habits of largemouth bass in Murphy Flowage, Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 50. 25 pp.

The harvest and food habits of largemouth bass were analyzed from 1955 through 1969, a period of liberal fishing regulations and compulsory creel census. Crayfishes were the most important food consumed by bass before winter drawdown; bullheads were selected as food by bass and bluegills were not. After drawdown, which reduced growths of aquatic vegetation and seemingly the populations of crayfish, bass ate more bluegills. Drawdown may be used to increase selective predation on bluegills in lakes where bullheads or crayfish are abundant.

697. SOJDA, R. S., AND K. L. SOLBERG. 1993. Management and control of cattails. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.13. U.S. Fish and Wildlife Service, Washington, D.C. 8 pp.

Recruitment of cattails occurs only during the dry stage. Cattail seeds will not germinate under more than 0.5 inches of water. A summer drawdown will enhance cattail stem densities by stimulating germination. In general, 3–4 ft of water over the tops of existing shoots in spring will cause high plant mortality.

698. SOONG, T. W., AND N. G. BHOWMIK. 1993. Characteristics of waves and drawdown generated by barge traffic on the Upper Mississippi River System. Page 38 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

Waves and drawdown are two physical phenomena that are induced by vessels' movements. In the Upper Mississippi River System (UMRS), larger vessels like barge-tows maneuver in restricted waterways, thus amplifying the magnitudes of waves and drawdown for a longer duration. The Illinois State Water Survey (ISWS) research team has conducted an investigation on physical forces associated with barge traffic on the UMRS for the past 3 years and has found that waves and drawdown are major causes for disturbed turbidity levels in the nearshore zones. Increased turbidity levels can be detrimental to aquatic habitat. Barge-induced waves and drawdown can be affected by variables in four categories: (1) barge configurations (type, loading, and grouping); (2) maneuvering characteristics (speed, direction, and distance); (3) local geomorphology (cross-sectional depth, width, and shape, as well as reach meandering); and (4) local flow characteristics (discharge and ambient flow velocity). On the basis of data collected from 77 events at several sites along the Illinois and Mississippi Rivers, the maximum wave height was found to vary between 0.025 and 0.35 m, with the most frequent occurrence at 0.05 m. Similarly, the maximum drawdown ranged from 0.025 to 0.3 m, with most frequent occurrence at 0.05 m. The ISWS team is investigating the mechanisms and factors for creating large waves and drawdown on the UMRS. However, they have found that there seems to be a stronger correlation between the blocking ratio, length, speed, and distance with the magnitudes than with the other variables. (Abstract only)

699. SPARKS, R. E. 1992. Risks of altering the hydrologic regime of large rivers. Pages 119–152 *in* J. Cairns, Jr., B. R. Niederlehner, and D. R. Orvos, editors. Predicting ecosystem risk. Advances in modern environmental toxicology. Volume 20. Princeton Scientific Publishing Company, Inc., New Jersey.

Water regimes in virtually all the large rivers of the world are either intentionally regulated by dams and other structures or inadvertently affected by deforestation, agriculture, and urbanization. The environmental effects of altering water regimes too often seem as unwelcome surprises because: (1) the dynamic nature and interaction of the physical and biological components of river ecosystems are not understood and (2) some of the effects are long term and long range. Risks are more likely to be considered and reduced if projects are broadly conceived in the context of managing a complex, dynamic system that fulfills many natural functions (e.g., the transport of water, sediment, and nutrients and the maintenance of deltas and estuaries) and human services, many of which have not been included in traditional analyses of costs, benefits, and risks in narrowly conceived economic development projects. Disciplines that should be represented on planning teams, in addition to economists and engineers, include fluvial geomorphologists, hydrologists, rural sociologists, fisheries ecologists, and systems ecologists with experience on large rivers. Epidemiologists should be included when waterborne diseases are likely to be a problem. The risks of losing attributes of the river–floodplain system (the floodpulse, floodplain habitats) that sustain fish and wildlife populations and local economies (e.g., floodplain agriculture and aquaculture and recreational, commercial, and subsistence fisheries) should be evaluated by considering what it would cost to replace (if replacement is even feasible) or maintain these services. Risk analysis should extend to economies that may be distant but directly affected by the local project, as in the Nile and Mississippi deltas where coastlines eroded and fisheries declined due to the trapping of sediments and nutrients behind upstream dams. In view of the accumulated worldwide experience with effects of water resource developments and watershed manipulations, there is little excuse now for failing to evaluate risks during planning stages of projects, including projects that mitigate damage already present.

700. SPARKS, R. E., P. B. BAYLEY, S. L. KOHLER, AND L. L. OSBORNE. 1990. Disturbance and recovery of large floodplain rivers. Environmental Management 14(5):699–709.

Disturbance in a river–floodplain system is defined as an unpredictable event that disrupts structure or function at the ecosystem, community, or population level. Disturbance can result in species replacements or losses or shifts of ecosystems from one persistent condition to another. A disturbance can be a discrete event or a graded change in a controlling factor that eventually exceeds a critical threshold. The annual flood is the major driving variable that facilitates lateral exchanges of nutrients, organic matter, and organisms. The annual flood is not normally considered a disturbance unless its timing or magnitude is "atypical." The record flood of 1973 had little effect on the biota at a long-term study site on the Mississippi River, but the absence of a flood during the

1976–1977 Midwestern drought caused short- and long-term changes. Body burdens of contaminants increased temporarily in key species because of increased concentration resulting from reduced dilution. Reduced runoff and sediment input improved light penetration and increased the depth at which aquatic macrophytes could grow. Developing plant beds exerted a high degree of biotic control and were able to persist, despite the resumption of normal floods and turbidity in subsequent years. In contrast to the discrete event that disturbed the Mississippi River, a major confluent, the Illinois River, has been degraded by a gradual increase in sediment input and sediment resuspension. From 1958 to 1961, formerly productive backwaters and lakes along a 320-km reach of the Illinois River changed from clear, vegetated areas to turbid, barren basins. The change to a system largely controlled by abiotic factors was rapid and the degraded condition persists.

701. SPARROW, R. A. H. 1966. Comparative limnology of lakes in the southern Rocky Mountain Trench, British Columbia. Journal of the Fisheries Research Board of Canada 23:1875–1895.

Standing crops of plankton were related to oxygen deficits and perimeter-to-area ratios in nine lakes. Although primary factors such as mean depth, climate, and total dissolved solids may be important in influencing productivity in broad geographical areas, other factors (e.g., water-level fluctuation, perimeter-to-area ratios, basin shape, and the size and nature of the drainage area) modify the expression of the primary factors within a restricted geographic region. Lazy and Horseshoe Lakes have seasonal water-level fluctuations that may contribute to the low-to-moderate standing crops of benthos. Rooted macrophytes, which increase the production of benthos, also were lacking in Lazy and Horseshoe Lakes, possibly because of the amplitude of water-level changes.

702. SPOHRER, M. L. 1975. Marsh management for wildlife: A bibliography with abstracts. Louisiana Cooperative Wildlife Research Unit, Baton Rouge, Special Publication 1. n.p.

Citations in this review are grouped into two classes, general marsh management and species management. The species of major concern were ducks, geese, rails, gallinules, snipe, nutria, muskrat, otter, raccoon, mink, woodcock, rabbits, deer, amphibians and reptiles, and nongame birds.

703. SQUIRES, L., AND A. G. VAN DER VALK. 1992. Water-depth tolerances of the dominant emergent macrophytes of the Delta Marsh, Manitoba. Canadian Journal of Botany 70:1860–1867.

The growth (shoot height, cumulative shoot length, shoot density, above- and belowground biomass) of seven emergent species growing at five different water depths was measured for 2 years. These species belonged to three different ecological classes: (1) upper marsh species (*Carex atherodes*, *Scolochloa festucacea*, and *Phragmites australis*) that occupy sections of the water-depth gradient that are only seasonally flooded in the Delta Marsh; (2) lower marsh species (*Typha glauca* and *Scirpus lacutris* spp. *glaucus*) that occupy permanently flooded areas; and (3) drawdown species (*Scirpus lacustris* spp. *validus* and *Scirpus maritimus*) that become established temporarily during drawdowns. Upper marsh species could not adjust their shoot length if they were growing in water deeper than 20 cm. Lower marsh species were able to do this in water up to 70 cm deep. All three types survived for 1 or 2 years in water too deep for long-term persistence.

704. SREENIVASAN, A. 1966. Limnology of tropical impoundments. 1. Hydrological features and fish production in Stanley Reservoir, Mettur Dam. Internationale Revue der Gesamten Hydrobiologie 51:295–306.

The impact of physicochemical features on fish production in Stanley Reservoir, India, is discussed. Fish yield was relatively low (21.3 lb/acre), but had not declined with increased reservoir age. Although nutrients were constantly leached out and discharged downstream, plant growth was frequently lacking because of rapid fluctuations in water level. The littoral zone was sterile. Rapid fluctuations also seemed to adversely affect fish spawning. Discharge of plankton-rich surface waters when water levels were high and rates of water exchange were generally rapid limited productivity. Limited drawdown may help retain nutrients and plankton.

705. SREENIVASAN, A. 1974. Limnological features of a tropical impoundment, Bhavanisagar Reservoir (Tamil Nadu), India. Internationale Revue der Gesamten Hydrobiologie 59:327–342.

Physicochemical features of Bhavanisagar Reservoir are described and related to primary production and harvest of fish. The only factors likely to negatively affect fish populations and yield are the absence of monsoons (and therefore fish spawning) and parasitic infections.

706. STANLEY, L. D., AND G. R. HOFFMAN. 1975. Further studies on the natural and experimental establishment of vegetation along the shorelines of Lake Oahe and Lake Sakakawea, lakes of the mainstem Missouri River. University of South Dakota, Department of Biology, Vermillion. 116 pp.

Vegetation development along the Lake Oahe shoreline from 1972 through 1974 consists of a series of successional sequences. Zone 1 vegetation, that above the highest water level, consists of a group of related plant communities ranging from near pristine to highly disturbed. Zone 2 vegetation consists of all those shoreline plant communities below the highest water level ranging from exposed mudflats to serial communities that have survived inundation or are situated higher than the highest water level attained in 1971. Species that tolerate flooding to the greatest extent include *Phalaris arundinacea* (reed canarygrass), *Agropyrov smithii* (western wheatgrass), *A. cristatum* (crested wheatgrass), *A. elongatum* (tall wheatgrass), *Alopecurus arundinaceous* (garrison creeping foxtail), *Beckmannia syzigochne* (American sloughgrass), *Poa pratensis* (Kentucky bluegrass), and *Hordeum jubatam* (foxtail barley). This conclusion is based on field observations and on laboratory inundation tests for periods up to 30 days. Cattle grazing is an important limiting factor in retarding shoreline vegetation development. The author believes that knowledge is sufficient to prescribe conditions that will maximize shoreline vegetation development, should a management decision be made to do so.

707. STARRETT, W. C., AND A. W. FRITZ. 1965. A biological investigation of the fishes of Lake Chautaugua, Illinois. Illinois Natural History Survey, Bulletin 29:1–104.

The relative abundance, biomass, and commercial harvest of fishes of Chautaugua Lake were studied from 1950 to 1959. Water level probably was the most important factor affecting the dynamics of fish populations in the lake. During periods of low stable water levels, sago pondweed became abundant, turbidity decreased, large populations of benthic insects developed, and many bluegills and crappies were collected by seining. When vegetation was abundant in low-water years, the carrying capacity for fish probably was greater than in years of high or fluctuating water levels. Water levels affected the needs of fish such as food, cover, space, and spawning. In 1 year, several largemouth bass nests were stranded when water levels fell. Receding water levels also destroyed many common carp eggs. High turbidity, associated with high water, may have hampered the feeding of some fishes. Water levels affected the growth and condition of bluegills, crappies, and possibly other species. The growth index of bluegills was negatively correlated with water levels ($r = -0.46$) as was the coefficient of condition ($r = -0.81$). The condition of white crappies and black crappies was negatively correlated with summer water levels ($r = -0.79$ and -0.73, respectively). Similar but less significant relations were found for the growth and condition of channel catfish. The growth rates and condition of freshwater drum were independent of water levels.

708. STARRETT, W. C., AND P. L. MCNEIL, JR. 1952. Sport fishing at Lake Chautaugua, near Havana, Illinois, in 1950 and 1951. Illinois Natural History Survey, Biological Notes 30:1–31.

The creel survey of 1950–51 revealed that angler success was influenced by water levels, season, and the relative abundance of various fishes. Fishing success in general, and for freshwater drum and channel catfish in particular, improved with rising water levels. Fishing for bass, however, was best when water levels were falling or low and stable.

709. STARZYKOWA, K. 1972. Populations of Cladocera and Copepoda in dam reservoirs of southern Poland. Acta Hydrobiologica 14:37–55.

The composition of crustacean zooplankton was influenced by the rate of water exchange in reservoirs. In general, more euplankton was present in large reservoirs with standing water than in reservoirs with swiftly flowing water; littoral species were most abundant in the reservoir at Wisla-Czarna, which had a rapid rate of water exchange. Zooplankton production was influenced by the rate of water exchange and reservoir age.

710. STEENIS, J. H., AND J. WARREN. 1959. Management of needlerush for improving waterfowl habitat in Maryland. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 13:296–298.

In 1952, the authors investigations on needlerush (*Juncas roemerianus*) control were started in Maryland. The objectives were to develop and refine procedures for control, then find how best to apply these procedures as a tool for improving waterfowl habitat. Marshes dominated by needlerush can be improved for waterfowl by flooding and herbicidal treatments that create an interspersion of marsh and open water suitable for the growth of submerged food plants. Continuous flooding of treated areas prevents reinvasion of needlerush.

711. STEPANOVA, N. A. 1966. The Katta-Kurgan Reservoir. Pages 108–119 *in* P. V. Tyurin, editor. The Storage Lakes of the U.S.S.R. and their importance for fishery. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian)

An overview of the Katta-Kurgan Reservoir is presented, and many topics such as purpose, geography, geology, and climate of the area are included. Discussion of the reservoir proper includes topics on morphometry, hydrology, chemistry, and biology. Due to marked fluctuations in water level, the Katta-Kurgan Reservoir is almost devoid of higher aquatic vegetation. The density of benthos is low and concentrated in deep sections. Marked water-level fluctuations that expose extensive areas of bottom have limited the biomass of benthos.

712. STEWART, R. W. 1967. The development of a management program for Spruce Run Reservoir. New Jersey Conservation Department Report. 13 pp.

When Spruce Run Reservoir, New Jersey, was drawn down in spring and summer 1966, receding water levels (1 ft/week) adversely affected the spawning of bluegills and pumpkinseeds by dewatering nests. Sunfishes spawned from about mid-June, when water temperatures reached 77 °F, to mid-July. Reproduction of largemouth bass (May 20–June 20), which began when water temperatures reached 65 °F, was almost complete before the drawdown and therefore was largely unaffected by receding waters.

713. STEWART, R. W. 1971. Survey of Spruce Run Reservoir. New Jersey Division of Fish, Game, and Shellfisheries, Federal Aid Project F-23-R-6, Job I-5. 44 pp.

This baseline study described the physicochemical characteristics, harvest statistics, and data on fish populations of Spruce Run Reservoir, New Jersey, from 1965 to 1969. Water levels declined significantly in summer and fall of each year except 1967. Dewatering destroyed much of the aquatic vegetation (primarily *Elodea*) and suppressed its growth. The lack of vegetation seemed to provide predators with easier access to prey fishes.

714. STEWART, R. W. 1979. Survey of Rising Sun Lake. New Jersey Division of Fish, Game, and Shellfisheries, Federal Aid Project F-23-R-14, Job I-9. 10 pp.

Data are presented on the physicochemical limnology and the development of fish populations of Rising Sun Lake in 1978. Terrestrial vegetation, which developed when water levels were low in spring 1977, affected O_2 tensions and water clarity throughout summer 1978, after the lake was filled in spring. However, oxygen tensions were at least 4 mg Q^{-1} at depths above 15 ft, and no deleterious effects on fish resulted.

715. STROMBERG, J. C., B. D. RICHTER, D. T. PATTEN, AND L. G. WOLDEN. 1993. Response of a sonoran riparian forest to a 10-year return flood. Great Basin Naturalist 53(2):118–130.

In March 1991, a 10-year return flood on the Hassayampa River located in the Sonoran Desert caused floodwaters between 2.64 ± 0.20 m and 0.47 ± 0.31 m in the highest floodplain zone. Plants on high floodplains have low mortality. *Populus fremontii* and *Salix gooddingii* "pole" trees and saplings were on less aggraded floodplains and sustained varying mortality depending on floodplain elevation and depth of flood waters. Survivorship of shrub species also corresponded to floodplain elevation.

716. STROUD, R. H. 1948. Growth of the basses and black crappie in Norris Reservoir, Tennessee. Journal of Tennessee Academy of Science 23(1):31–99.

Growth of black basses and black crappies from Norris Reservoir from 1942 to 1946 was determined by the scale method. All species studied grew rapidly during the first 3 years of impoundment, but growth rates slowed in the fourth or fifth and sixth years. Growth improved in the seventh year and decreased again in the eighth and ninth years. Changes in growth were correlated with a long-term cycle of spring and early summer water levels. Rapid growth occurred when water levels flooded exposed areas of the littoral zone. Beneficial effects of fluctuation seemed to result from the addition of organic nutrients from decaying terrestrial vegetation that developed when waters were low. The presence of vegetation undoubtedly enhanced the survival of young fishes.

717. STUBE, M. 1958. The fauna of a regulated lake. Institute of Freshwater Research Drottningholm Report 39:162–224.

An extensive survey of plant and animal life before and after regulation of Lake Borgasjon formed the basis for evaluating the effects of annual 18-m fluctuations in water level. Most emphasis centered on the periphyton in the summer before regulation, but benthos and fish also were sampled. In the third year of regulation, belts of aquatic vegetation and benthos in the delta area had completely disappeared. The dominant taxa of benthos shifted from a community dominated by Phyllopoda, Ephemeroptera, Oligochaeta, Diptera, and Trichoptera before regulation to one dominated by Nematoda, Oligochaeta, and Diptera after regulation. Trout that flourished in the delta before regulation (perhaps because of the abundant vegetation that provided refuge), no longer inhabited the area after regulation. After 5 years of fluctuation, char invaded the former delta. Stomach analyses indicated that char consumed more planktonic food than did trout, and that trout diets were dominated by benthos (mayfly and caddisfly larvae). Bottom samples of 1954 indicated that regulation had reduced the abundance of benthos. Growth of trout increased immediately after regulation began, due to the addition of flooded terrestrial foods, but decreased after 1955.

718. SUMMERFELT, R. C. 1975. Relationship between weather and year-class strength of largemouth bass. Pages 166–174 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Observations presented support the hypothesis that year-class strength of largemouth bass is related to weather, especially frontal systems. In Lake Carl Blackwell, Oklahoma, where extreme variations in the abundance of young-of-year bass occur, limiting environmental factors included a sharp decline in water temperature (which can result in nest desertion) and wind action. Spawning success was greatest when weather (wind and air temperature) and factors affected by weather (water temperature, water level, and turbidity) were stable. Water levels strongly influenced year-class strength. When surface area was reduced by 50% in 1972, recruitment of young bass was negligible. Water levels may have caused disjunct spawning, exposed nests, or increased the effect of wave action and temperature change at nest sites.

719. SUMMERFELT, R. C., AND K. SHIRLEY. 1975. Methods for early estimates of largemouth bass year-class strength. Oklahoma Department of Wildlife Conservation, Final Report Dingell-Johnson Project F-15-R-11. n.p.

The objectives of this study on Lake Carl Blackwell, Oklahoma, were (1) the evaluation of two methods by which numbers of young-of-year largemouth may be effectively estimated prior to July 1, (2) the commencement of a long-term study of the relation between the numbers of young-of-year largemouth bass estimated on June 1 and July 1 to numbers of young-of-year largemouth bass estimated on October 1, and (3) the commencement of a long-term study of the relations between year-class recruitment and variation in several weather, physicochemical, and biological variables between April 1 and June 1 to determine probable cause for mortality during the first 14 days after egg deposition. Methods of collection were rotenone poisoning of selected unenclosed transects and the use of a Wegener ring. A comparison of estimates of young-of-year bass indicated variable mortality throughout the first year of life. No significant correlation could be found between numbers of YOY largemouth bass and any single physical parameter measured.

However, stratification of the littoral zone into windswept areas, intermediate areas, and protected areas revealed that in the July 1974 sample, for example, windswept areas accounted for 16 YOY bass, intermediate areas 17, and protected areas 144. Wave action seems to be a major limiting factor in YOY largemouth bass production. Large numbers of YOY bass were usually obtained in transects with extensive stands of aquatic macrophytes and organic substrate.

720. SUMMERFELT, R. C., AND K. E. SHIRLEY. 1978. Environmental correlates to year-class strength of largemouth bass in Lake Carl Blackwell. Proceedings of the Oklahoma Academy of Science 58:54–63.

The density of young-of-year largemouth bass in an area of suitable habitat was determined in August for 11 consecutive years and considered to be representative of year-class strength. Year-class strength was positively correlated with water level, change in water level, and turbidity and was negatively correlated with water hardness, alkalinity, and pH. The four smallest year classes occurred when water levels decreased in May and June. The strongest year classes occurred in years when water levels where high and flooded terrestrial areas, thereby simulating conditions present in new impoundments. Water levels were negatively correlated with hardness and alkalinity. Turbidity occasionally was affected by changes in water level.

721. SVARDSON, G., AND G. MOLIN. 1973. The impact of climate on Scandinavian populations of the sander, *Stizostedion lucioperca* (L.). Institute of Freshwater Research Drottningholm Report 53:112–139.

Yields of sander in six lakes are discussed, as are the climatic factors that affected their population dynamics in Lakes Hjalmaren and Malaren from 1955 to 1972. The strength of 15 year classes in the separate lakes fluctuated in a similar manner, indicating a climatic influence. Year-class strength was correlated with temperatures during some summer months (especially June through August) and was associated with high water levels in spring. The two best year classes occurred in years when water levels were highest in spring. High water in May 1966 also produced a very dominant year class of pike in Lake Malaren. In lakes where sander numbers are low for years until they suddenly explode in a single strong year class, water levels may be an important factor regulating reproductive success.

722. SWANSON, G. A. 1967. Factors influencing the distribution and abundance of *Hexagenia* nymphs (Ephemeroptera) in a Missouri River reservoir. Ecology 48:216–225.

The abundance and distribution of burrowing mayfly nymphs were affected by a number of factors including season, depth, current, wind, substrate, and water levels. Substrates normally inhabited by *Hexagenia* nymphs were not disturbed by fluctuations of water level except in shallow bays and backwater areas. From May to September, the maximum range of fluctuations was 1.5 m. Nymphs may have responded to minor, slow drawdowns by migrating over the bottom. A normal drop of water levels in Lewis and Clark Lake limited the abundance of nymphs by exposing reservoir substrates to increased wave action.

723. SWANSON, G. A., AND M. I. MEYER. 1977. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. Journal of Wildlife Management 41:426–433.

Foods consumed by breeding blue-winged teal (*Anas discors*) before and after a hydrological change are compared on a study area located in the glaciated prairie pothole region of south-central

North Dakota. Food selection shifted from a diet high in snails consumed on seasonal wetlands to one dominated by midge larvae consumed on semipermanent lakes entering a drawdown phase. Total invertebrate contribution to the diet was similar for the two periods and varied from 89% (1967–71) to 97% (1973).

724. SWARZENSKI, C. M., E. M. SWENSON, C. E. SASSER, AND J. G. GOSSELINK. 1991. Marsh mat flotation in the Louisiana Delta Plain. Journal of Ecology 79:999–1011.

Vertical mat movement in relation to surface water fluctuation was measured for 1 year at three marshes differing in dominant emergent vegetation and location in the Mississippi River delta plain of coastal Louisiana. The freshwater marsh, dominated by *Panicum hemitomon*, floated directly with ambient water levels, provided they were high enough to float the mat. Water levels varied by about 70 cm and mat movement by 55 cm. An intermediate-salinity march closer to the Gulf of Mexico and dominated by *Sagittaria falcata* moved 35 cm vertically during the study period, and water levels moved 70 cm. A brackish marsh, dominated by *Spartina patens*, moved only 3 cm in response to about 40 cm of vertical water movement. The freshwater marsh floated throughout the year, provided ambient water levels were high enough, and mat movement followed water-level movement directly.

725. SWEE, U. B., AND N. R. MCCRITMON. 1966. Reproductive biology of the carp, *Cyprinus carpio* L., in Lake St. Lawrence, Ontario. Transactions of the American Fisheries Society 95:372–380.

Temperature and water levels were major environmental factors affecting the spawning of common carp and the survival of their eggs in marsh areas. Frequent summer fluctuations of water levels of 6 to 12 inches destroyed millions of eggs by exposure, but reproduction was not completely controlled by fluctuations. Examination of gonads revealed that males could release sperm over an extended period of time, and experiments showed that females could spawn twice. Although no population estimates were made, spot poisoning showed that a substantial number of young-of-year common carp hatched at various times in May, June, and July and survived at least until midfall.

726. SWENSON, W. A., G. D. HEBERLING, D. J. ORR, AND T. D. SIMONSON. 1989. Fishery resource of the Upper Mississippi River and relationship to stream discharge. Journal of the Minnesota Academy of Science 55(1):144–148.

Fish population data collected through the Northern States Power Company monitoring program near its plants at Monticello and Becker, Minnesota, were analyzed to describe species diversity, changes in recreational fishing, fishing success, and the influence of stream discharge on smallmouth bass year-class success and abundance. The work is part of a more extensive effort to develop a model applicable in managing the Upper Mississippi River to meet the growing needs of recreation, agriculture, communities, and industry. Analysis of these data shows 48 species to be present, and that smallmouth bass, *Micropterus dolomieui*, is the most important game species in the growing recreational fishery. Comparison of smallmouth bass year-class strength estimates with stream discharge for the period 1973–1987, indicates strong year classes develop during years characterized by low spring and summer discharge.

727. SYLVESTER, R. O., AND R. W. SEABLOOM. 1965. Influence of site characteristics on quality of impounded water. Journal of the American Water Works Association 57:1528–1546.

Inundation of vegetation and bottom areas with fertile soils may produce undesirable water quality by (1) ion exchange through clay and humic colloids; (2) microbial degradation of organic matter from soil or vegetation, thereby releasing dissolved materials, CO_2, and minerals; (3) the leaching of organic and mineral compounds that enhance algal growth; and (4) microbial activity at the soil–water interface, thereby creating anoxic conditions and altering the products of decay processes. The three effects of soils on water quality are physical (color, turbidity, taste, odor), chemical (pH, dissolved solids, and gases), and biological (enhanced growth of algae and other aquatic organisms). Most changes are associated with the decomposition of organic matter in soil and water. Howard A. Hanson Reservoir was studied to document effects of basin characteristics (site preparation, vegetation, and soils) and filling regime on reservoir water quality. Soil organic content was most responsible for undesirable effects on overlying water, but its effects depended on time, temperature, and light. The effect of organic content was proportional to the age or state of decay of organics. Repeated leaching of soils by flushing (rapid water exchange) reduced the effect of organic soils on water quality. Wood, bark, grasses, leaves, and ferns have a high biological oxygen demand and adversely affected water quality.

728. TAN, L. W., AND R. J. SHIEL. 1993. Responses of billabong rotifer communities to inundation. Hydrobiologia 255/256:361–369.

Billabongs are remnants of past river meanders along Australia's low-gradient floodplains. Daily plankton collections were taken from a billabong of the River Murray for 2 weeks prior to inundation in March 1990, and continued for 10 days after flooding. Quantitative responses of the plankton community and the component species were analyzed against measured environmental variables and between species. Rotifers and copepod nauplii were the predominant net plankton (>53 μm). Significant negative or positive responses to inundation were detected for most common taxa of 63 rotifer species recorded. A fourfold dilution from intrusion of river water masked rapid population increases. Opportunistic responses to inundation seem to be a survival strategy in the highly unpredictable billabong environment.

729. TANG, Z. C., AND T. T. KOZLOWSKI. 1982. Some physiological and morphological responses of *Quercus macrocarpa* seedlings to flooding. Canadian Journal of Forest Research 12:196–202.

Flooding for 30 days induced several changes in *Quercus macrocarpa* Michx. seedlings, with stomatal closure among the earliest responses. Stomata remained more closed in flooded than in unflooded plants during the entire experimental period. Leaf water potential was consistently higher in flooded than in unflooded plants. Other responses to flooding included the acceleration of ethylene production by stems; formation of hypertrophied lenticels on submerged portions of stems; growth inhibition, with greatest reduction in roots; and formation of a few adventitious roots on submerged portions of the stem above the soil line. Some of the morphological responses to flooding, especially formation of hypertrophied lenticels, seemed to be associated with increased ethylene production. *Quercus macrocarpa* seedlings adapted poorly to flooding as shown by failure of stomata to reopen after an early period of flooding and low capacity for production of adventitious roots. The much greater inhibition of root growth than shoot growth by flooding will reduce drought tolerance after floodwaters recede.

730. TANNER, W. D., AND G. O. HENDRICKSON. 1954. Ecology of the Virginia rail in Clay County, Iowa. Iowa Bird Life 24:65–70.

Virginia rail nests were shallow, basket-like structures built of dead leaves or stalks of the species of marsh plants available at the nest site. Materials used were lake sedge, river bulrush, tussock sedge, cattail, bur-reed, and rivergrass. The nests were suspended a few inches above the water surface from stalks of emergent plants. Water depth ranged from 6 to 18 inches with a mean of 12.1 inches and a standard deviation of 3.2 inches. On a second year study, the water depth ranged from 11.5 to 22 inches with a mean of 14.8 inches and a standard deviation of 3.2 inches. It seems likely that this species responds not to water depth as such but rather to the plant community that is influenced by water depth.

731. TANNER, W. D., JR., AND G. O. HENDRICKSON. 1956. Ecology of the sora in Clay County, Iowa. Iowa Bird Life 26:78–81.

At 26 occupied sora nests in 1951, the mean average water depth was 12.8 inches, ranging from 5 to 20 inches with a standard deviation of 3.4 inches. In 1952 at six nests, the mean depth was 18.9 inches ranging from 13 to 23 inches with a standard deviation of 3.7 inches.

732. TER HEERDT, G. N. J., AND H. J. DROST. 1994. Potential for the development of marsh vegetation from the seed bank after a drawdown. Biological Conservation 67:1–11.

In the inundated part of the Oostvaardersplassen, a marsh in The Netherlands, most of the emergent vegetation disappeared due to herbivory and erosion, resulting in a shallow lake. The emergent vegetation was successfully reestablished by means of a drawdown. A comparable flooded marsh was studied to describe its seed bank and to find out if it was possible to make an accurate prediction of the vegetation developments after a drawdown based on the Van der Valk model on succession in wetlands. Two different zones could be distinguished in the lake. These differed mainly in the number of seeds found, not in the species composition of their seed banks. The short-term prediction that *Typha latifolia* would become dominant did not always match the actual pioneer vegetation that developed; several different communities developed from similar seed banks. The long-term prediction, that *Phragmites australis* would become dominant after 4 years of drawdown, was fulfilled.

733. TESKEY, R. O., AND T. M. HINCKLEY. 1977. Impact of water level changes on woody riparian and wetland communities. Volume 1. Pages 1–30 *in* Plant and soil responses to flooding. U.S. Fish and Wildlife Service, Office of Biological Services 77/58.

The physiological effect of changes in water level (i.e., submersion, flooding, or soil saturation) on a tree depends on its tolerance (i.e., a tree's ability to maintain its present root system as well as its ability to produce adventitious roots), the soil conditions present, and the nature, timing, and duration of the water-level change. The authors examined these aspects of a tree's response for trees in general.

734. TESKEY, R. O., AND T. M. HINCKLEY. 1977. Impact of water level changes on woody riparian and wetland communities. Volume 2. Pages 1–46 *in* The southern forest region. U.S. Fish and Wildlife Service, Office of Biological Services 77/59.

The authors review the literature and group tree species into very tolerant, tolerant, intermediately tolerant, and intolerant groups. Information is also divided into flood periods during the growing season, the dormant season, and year-round. Changes in water table level refer to changes from some indefinite depth below rooting zone to within the rooting zone.

735. TESKEY, R. O., AND T. M. HINCKLEY. 1977. Impact of water level changes on woody riparian and wetland communities. Volume 3. The central forest region. U.S. Fish and Wildlife Service, FWS/OBS 77/60. 36 pp.

The authors review the literature and group tree species into very tolerant, tolerant, intermediately tolerant, and intolerant groups. Information is also divided into flood periods during the growing season, the dormant season, and year-round. Changes in water table level refer to changes from some indefinite depth below rooting zone to within the rooting zone.

736. TESKEY, R. O., AND T. M. HINKLEY. 1978. Impact of water level changes in woody riparian and wetland communities. Volume 4. Eastern deciduous forest region. U.S. Fish and Wildlife Service, FWS/OBS 78/87. 54 pp.

The authors review the literature and group tree species into very tolerant, tolerant, intermediately tolerant, and intolerant groups. Information is also divided into flood periods during the growing season, the dormant season, and year-round. Changes in water table level refer to changes from some indefinite depth below rooting zone to within the rooting zone.

737. TESKEY, R. O., AND T. M. HINKLEY. 1978. Impact of water level changes in woody riparian and wetland communities. Volume 5. Northern forest region. U.S. Fish and Wildlife Service, Office of Biological Services 78/88. n.p.

The authors review the literature and group tree species into very tolerant, tolerant, intermediately tolerant, and intolerant groups. Information is also divided into flood periods during the growing season, the dormant season, and year-round. Changes in water table level refer to changes from some indefinite depth below rooting zone to within the rooting zone.

738. TESKEY, R. O., AND T. M. HINKLEY. 1978. Impact of water level changes in woody riparian and wetland communities. Volume 6. Plains and grassland region. U.S. Fish and Wildlife Service, FWS/OBS 78/89. 29 pp.

The authors review the literature and group tree species into very tolerant, tolerant, intermediately tolerant, and intolerant groups. Information is also divided into flood periods during the growing season, the dormant season, and year-round. Changes in water table level refer to changes from some indefinite depth below rooting zone to within the rooting zone.

739. TEVERSHAM, J. M., AND J. SLAYMAKER. 1976. Vegetation composition in relation to flood frequency in Lillooet River Valley, British Columbia. Catena (Cremlingen-Destedt, Ger.) 3:191–201.

On a 20-km reach of the floodplain of Lillooet River, British Columbia, groupings of plant species were determined by analyzing data from one hundred thirty-eight 100 square km^2 quadrats. Four pioneer species and four forest species groupings were isolated and shown to be related to both sediment size and flood frequency. Five species were significantly correlated with elevation: mature *Populus trichocarpa* (black cottonwood); mature and immature *Thuja plicata* (redcedar); and the shrubs *Viburnum pauciflorum*, *Cornus stolonifera* (red-osier dogwood), and *Spirea douglasii* (hardhack). Frequency and mean cover data (analyzed separately for 82 quadrats in the stable reach and for 56 quadrats in the unstable reach) confirmed the restriction of these species to certain height classes. The indicator species tended to be restricted to higher height classes above datum in the stable reach in comparison with the unstable reach. Attempts to predict flood frequency in the unstable reach by standard hydrologic methods failed. Indicator plant species associated with height classes as a surrogate for flood frequency were used to define a developmental model for vegetation on the floodplain.

740. THEILING, C., P. GANNON, AND J. TUCKER. 1994. Invertebrate response to extreme flooding on the lower Illinois River. Page 22 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

Aquatic macroinvertebrates link river–floodplain producers (trees, grasses, aquatic macrophytes, and algae) and secondary consumers (vertebrate and invertebrate). Macroinvertebrates occur in all permanent and ephemeral aquatic habitats and many have reproductive strategies that allow them to exploit ephemeral habitats. In river–floodplain ecosystems, ephemeral habitats are produced with predictable regularity (i.e., spring flooding) as river floodwaters encroach laterally across the floodplain. When floodwaters inundate terrestrial habitats, plants become a food source for invertebrate detritivors. Plentiful food resources promote high population densities, which ultimately benefit predator populations. The flood pulse concept theorizes that invertebrate densities should be greatest at the "moving littoral zone," or the land/water interface of rising floodwaters, where the greatest food resources are available. We sampled nektonic and epiphytic invertebrates using vertical plankton net tows along transects perpendicular from shore to test this theory on the lower Illinois River. Extreme flooding occurred on the lower Illinois River between June–September 1993. Water surface elevations during the flood exceeded normal river elevations by 7 m. The entire lower Illinois River floodplain was inundated and was colonized by aquatic invertebrates. We sampled randomly selected transects in three predetermined areas of the lower Illinois River. Approximately 10 stations were sampled per transect with triplicate net tows. We spaced them such that shallow sites would be weighted more heavily because of suspected differences in species composition and abundance. The transects typically started in terrestrial grass communities, crossed an expanse of open water overlying floodplain habitats, and ended in the gallery forests ringing permanent backwaters of the lower Illinois River. Invertebrate density was much higher near the shore than at deeper stations ($P = 0.0001$ for all comparisons) as was the Shannon-Weaver species diversity index. When examined by vegetation type, density was significantly higher in grass habitats than open water of forest habitats within and among all three areas ($P = 0.0001$ for all comparisons). The same relation and significance level occurred for comparisons of the Shannon-Weaver species diversity index. Densities and species diversity also differed for comparisons of estimated vegetation coverage (percent area). Invertebrate densities were highest when vegetation coverage was greater than 50%, species diversity was different among ranks of percent vegetation coverage within and among areas ($P = 0.0001$ for all comparisons), but there was no clear relation between percent vegetation coverage and species diversity. This study provides some interesting preliminary results from an investigation of the utility of the flood pulse concept on the lower Illinois River. Our results indicate that flooding produces high river–floodplain invertebrate production. We suggest that river–floodplain natural resource managers promote the restoration of natural flood and low flow cycles to take advantage of this high productivity. We further suggest that the restoration of floodplain habitats including native prairies is important for maximizing invertebrate production. (Abstract only)

741. THEILING, C. H., R. J. MAHER, AND R. E. SPARKS. 1992. Ecological changes associated with changing water regimes. Page 46 *in* Proceedings of the Mississippi River Research Consortium, Volume 24, La Crosse, Wisconsin, April 30–May 1, 1992.

Navigation Pools 2–6, 8–10, and 24–26 on the Upper Mississippi River (UMR) are controlled at a midpool hinge while the others are controlled at the dam. The dams that operate at a midpool hinge have a wide range of drawdowns, with the Melvin Price Dam (Pool 26) being the most extreme. Pools in the St. Paul District have drawdowns of 0.5-1 ft, Dam 16 in the Rock Island District has a maximum drawdown of 1 ft and Dams 24, 25, and 26 have drawdowns of 3.7, 4.3, and 6.6 ft, respectively. Dams in the St. Louis District are unique in the degree to which they draw down the pools to control flooding upstream. Long Term Resource Monitoring (LTRM) began on Pool 26 in 1988, and sampling sites were established throughout the pool. During the short time these sites have been monitored, severe ecological changes have occurred in the impounded areas that can be directly related to changes in the water levels. Both 1988 and 1989 were drought years in the Upper Mississippi Basin and were characterized by a level hydrograph at the Pool 26 dam. In contrast, 1990 and 1991 were years in which spring floods and the operation of the dam gates caused fluctuations in the hydrograph. Water levels were lowered at the dam, exposing sites for long periods, to accommodate expected flood waters and reduce flooding upstream. Water quality data show significantly lower water velocities and turbidities and higher Secchi disk transparencies in spring 1989 than spring 1991. Data from 1990 indicate this to be a transition year in which changes were moving toward 1991 conditions, but not as extreme in degree. The occurrence of high, clear and slow moving water through the springs of 1988 and 1989 allowed the establishment of lush aquatic vegetation beds in the bay area above the dam. Vegetation in 1989 was a diverse mix of submersed aquatics and lotus. By summer 1991, this community had been replaced by wetland plants, primarily smartweed. Fish communities responded to the changing water levels and associated changes in water quality and vegetation. The fish community in 1989 was dominated by bluegill and black crappie, typical lentic fish. In 1990, the fish community was still dominated by bluegill and crappie, but showed increasing numbers of typical lotic fish, gar, and white bass. Fish samples in 1991 were dominated by gar, white bass, and carp, while lentic fish were nearly absent. Natural fluctuations in the water regime and pool manipulations from 1988–1991 had strong influences on water quality, vegetation and fish in the downstream reaches of Pool 26. Operating rules at navigation dams may be reviewed as to the applicability of dam control to benefit fish and wildlife. (Abstract only)

742. THEILING, C. H., AND E. RATCLIFF. 1994. The great flood of 1993: Causes, consequences, and impact on water quality in the lower Illinois River. Page 21 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

Record flooding throughout the Upper Midwest in spring and summer 1993 caused tremendous personal and economic hardship for human inhabitants of the river–floodplain ecosystem. The same event, however, may have provided significant benefits for other river– floodplain inhabitants. Record flooding was caused by average April rains that grew stronger into May and culminated in June and July; rainfall exceeded normal by 150%–200% at most locations monitored. The atypical rainfall was caused by the junction of a southeastern high pressure system stalling at a low pressure system coming from the West. The pattern allowed the jet stream to dip down out of Canada causing heavy rains throughout the Midwest. The resulting floods on the Mississippi River and its tributaries were unlike anything seen by people of this era; in fact, one must go back to 1844 to find similar flood stages. Millions of acres of agricultural and urban property were damaged as floodwaters overtopped or broke through levees. Entire towns were engulfed, and larger cities were effected by damage to municipal infrastructure. Damage estimates exceeded $10 billion and the U.S. Congress authorized over $6 billion in financial aid to those hurt by the flood. Those creatures better adapted to the vagaries of the river may benefit, however, from the potential for land acquisitions and restoration. The concentration of agricultural chemicals was expected to decrease because of the huge volume of water being transported. When measured at several points in the Mississippi River Basin, Atrazine and nitrogen concentrations either were similar to or exceeded previous records. The total Atrazine load delivered to the Gulf of Mexico exceeded the 1992 load by 235% and the nitrogen load exceeded 1992 levels by 112%. The increase in loads delivered was due to the occurrence of flooding during the planting season and because of the large areal extent of heavy rains. On the lower Illinois River, water surface elevations reached a record 134.7 m above sea level. Average flood heights are about 1 m greater than "controlled pool" elevations, but during this flood event elevations were 7 m greater. We sampled randomly selected sites at shoreline and open water locations and recorded ancillary data regarding habitat conditions. Physical, chemical, and biological aspects of water were monitored on the rise and the fall of the flood. Parameters discussed here are dissolved oxygen, conductivity, pH, Secchi disk transparency, temperature, turbidity, current velocity, and depth. Analyses of chemical and biological data will proceed when data becomes available from laboratories. Sediment oxygen demand was measured at several locations. Physical data was compared to data collected over the 5 previous years at three sites in the same area sampled during the flood. Of the variables compared, only temperature, turbidity, and current velocity were similar to measurements made during the June to October period of the previous years. For all other variables measured, 1993 measurements stood out as unique among the 6-year record. Of special interest were very low dissolved oxygen levels (mean = 4.3 ppm, n = 88) throughout the study area. The flood was certainly devastating to human communities and to the structures they built in the floodplain. The effects of the flood on the rest of the ecosystem is yet to be determined. Although it was a great human tragedy, this flood has forced policy makers to reconsider modern floodplain management. The result of postflood recovery may yield substantial environmental benefits. (Abstract only)

743. THOMAS, A. G., AND J. M. STEWART. 1969. The effect of different water depths on the growth of wild rice. Canadian Journal of Botany 47:1525–1531.

The purpose of this 1967 study in one of the several large rice beds in the Long Point marshes, Norfolk County, Ontario, was to measure the growth parameters of plant height, number and area of leaves, and dry weights of leaf, stem, root, and flower to determine the influence of water depth on the morphology and life cycle of wild rice. These growth parameters are most vulnerable to water-level fluctuation during the first of the three phases of growth. For this reason, the decline of wild rice in many areas of Ontario is attributed to either excessively low or high water levels during the critical submersed and floating leaf stages when the plants are most susceptible to mechanical damage by wind and wave action.

744. THOMPSON, D. Q. 1989. Control of purple loosestrife. *In* Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.11. U.S. Fish and Wildlife Service, Washington, D.C. 6 pp.

Mortality of 100% was reached by completely covering seedlings with water for 5 weeks. Seedlings with parts of the plant above the water surface grew vigorously and survived flooding.

745. THOMPSON, D. Q., R. L. STUCKEY, AND E. B. THOMPSON. 1987. Spread, impact, and control of purple loosestrife (*Lythrum salicaria*) in North American wetlands. U.S. Fish and Wildlife Service, Fish and Wildlife Research 2. 55 pp.

The authors provide a review of the literature concerning water manipulation for the control of purple loosestrife.

746. THOMPSON, J. D. 1964. Age and growth of largemouth bass in Clear Lake, Iowa. Proceedings of the Iowa Academy of Science 71:252–258.

Age composition and growth of 281 largemouth bass were determined from scales collected from 1947 to 1963. Growth rate was below the average for the 17-year period in 1957–60, when water levels were decreasing and the lake volume was 30% below normal. Annual growth was correlated with water levels but not with temperature or turbidity.

747. THURBER, J. M., R. O. PETERSON, AND T. D. DRUMMER. 1991. The effect of regulated lake levels on muskrats, *Ondatra zibethicus*, in Voyageurs National Park, Minnesota. Canadian Field-Naturalist 105(1):34–40.

Population characteristics and radio-marking of muskrats from two water regimes were used to assess the effects of regulated lake levels in Voyageurs National Park, Minnesota. Annual water fluctuations in Rainy Lake and Kabetogama Lake average 1.0 and 2.7 m, respectively, with high water in summer and early fall followed by a winter drawdown. During 1985–1987, significantly greater muskrat density was indicated in Rainy Lake based on spring 1986 sign survey, fall 1986 trapnight success, and house counts for 1985–1986 and 1986–1987. All other density estimates indicated greater numbers in Rainy Lake. Muskrat weights differed significantly between areas in spring 1986; other body measurements did not differ significantly. Survival of radio-marked muskrats was very low in both areas, especially during freeze-up in early winter.

748. TIMMONS, T. J., AND W. L. SHELTON. 1980. Differential growth of largemouth bass (*Micropterus salmoides*) in West Point Reservoir, Alabama Georgia, USA. Transactions of the American Fisheries Society 109:176–186.

A bimodal length–frequency distribution of young largemouth bass, evident by fall 1977, resulted from differences in the availability of suitable-sized prey, rather than from disrupted spawning as caused by fluctuations in water temperatures or lake levels.

749. TOTH, L. A. 1993. The ecological basis of the Kissimmee River restoration plan. Florida Scientist 56(1):25–51.

This review synthesizes over 40 years of studies on the ecological resources of the Kissimmee River. Prior to 1962, the Kissimmee River ecosystem supported diverse fish and wildlife populations including waterfowl, wading birds, and a nationally recognized fishery. The historical floodplain consisted of a mosaic of broadleaf marsh, shrub, and prairie wetland communities. Between 1962 and 1970, the river was channelized and transformed into a series of impounded reservoirs. The physical effects of channelization, including alteration of the system's unique hydrologic characteristics, largely eliminated the wetland and fish and wildlife values of the river and floodplain. Attendant "restoration" studies, including the recently completed demonstration project that documented habitat, water quality, and avian, fish, and invertebrate responses to water-level manipulations; reestablished floodplain inundation; and reintroduced flow; confirmed the feasibility of restoring both the structure and functions of the historical Kissimmee River ecosystem. The integration of available data on prechannelization resources, effects of channelization, and restoration-related studies forms the basis of the present plan to restore the ecological integrity of the Kissimmee River.

750. TOTH, L. A., J. T. B. OBEYSEKERA, W. A. PERKINS, AND M. K. LOFTIN. 1993. Flow regulation and restoration of Florida's Kissimmee River. Regulated Rivers: Research & Management 8:155–166.

Channelization of the Kissimmee River in central Florida destroyed or degraded most of the fish and wildlife habitat once provided by the river and its floodplain wetlands. Between 1984 and 1989, a demonstration project was conducted to evaluate the feasibility of restoring the river's biological resources. Reintroduction of flow through remnant river channels improved river channel habitat diversity and led to favorable responses by fish and invertebrate communities. However, results indicated that more complete restoration of biological attributes will require the reestablishment of historical inflow characteristics. Because of the flood control regulation schedule of its headwater lakes, present river discharge regimes are pulse-like, include extended periods of low or no flow, and have high and low flow periods that are out of phase compared with typical seasonal patterns that occurred before channelization. These flow characteristics will preclude effective river restoration by contributing to chronic low dissolved oxygen regimes and repetitive fish kills, interfering with fish reproduction, and limiting floodplain inundation.

751. TRIPLETT, J. R., D. A. CULVER, AND G. B. WATERFIELD. 1980. An annotated bibliography on the effects of water-level manipulation on lakes and reservoirs. Ohio Department of Natural Resources, Federal Aid Project F-57-R, Study 8. 50 pp.

This bibliography lists 348 annotated references dealing directly or indirectly with the effects of water-level fluctuations on the physical, chemical, and biological components of lakes and reservoirs. Emphasis is placed on references pertaining to fish management in reservoirs, but many related topics are included. Many references are included in this report with little or no change.

752. TURNER, L. M. 1930. The 1926–1927 floods and the Illinois River valley vegetation. Transactions of the Illinois State Academy of Science 22:95–97.

Near the La Grange Locks and Dam, hundreds of acres of pin oaks, elms, and cottonwoods were killed. The herbaceous growth was temporarily annihilated, but it was reestablished within 7 days after the flood was gone due to the numerous water-resistant seeds buried in the mud. Deposition of alluvial soil ranged from a few inches to a few feet and smothered a number of trees.

753. TYURIN, P. V. 1961. Effect of the water-level regime in reservoirs on the formation of fish stocks. Izvestiya Gosudarstvennogo Nauchno-Issledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozvaistva 50:395–410.

Three types of reservoirs are recognized in relation to their seasonal decline of water level. Reservoirs with stable water levels throughout the year are the most favorable for raising fish, but those that have maximum water levels in spring and an appreciable summer, fall, and winter drawdown are also favorable, at least in principle. Commercially valuable fish such as bream (*Abramis*), common carp, and pike spawn in spring in shallow-water areas (0.2–1.0 m) with soft vegetation. Reservoirs with stable water levels during the open season and large drawdown in winter are unfavorable for natural reproduction.

754. TYURIN, P. V. 1966. Piscicultural classification of reservoirs and procedures for determining fish yield. Pages 225–238 *in* P. V. Tyurin, editor. The Storage Lakes of the U.S.S.R. and their

importance for fishery. U.S. Department of Commerce, Israel Program Science Translation Catalog 1638-50. (Translated from Russian)

A system to classify reservoirs according to fish harvest and a method of estimating fish yield from the standing crop of fish foods are presented. Two factors adversely affecting fish yield are wave action and seasonal and long-term fluctuations in water level that increase shore erosion. The growth of aquatic vegetation is impeded as a result of these factors, and the biomass of benthos and plankton is low. These shortcomings are compensated for in part by the high yield of nearshore area (2–3 times that in natural lakes). Large, annual water-level fluctuations adversely affect fish yield, whereas stable levels or fluctuations less than 0.5–1.0 m are favorable. In late summer or fall, a drawdown exceeding 1 m is favorable, and no drawdown is unfavorable. In winter, no drawdown is favored and considerable winter drawdown is believed to be harmful. Diurnal and weekly fluctuations greater than 10 cm during the spawning season were classified as adverse; the lack of daily or weekly fluctuations was deemed favorable.

755. UHLER, F. M. 1944. Control of undesirable plants in waterfowl habitat. Transactions of the North American Wildlife Conference 9:295–303

Water-level manipulation is one of five categories described by the author for the control of undesirable plants in waterfowl habitat. The author concludes that the control of extensive areas of undesirable marsh plants by raising or lowering water levels offers one of the most successful and practical procedures in the management of waterfowl habitats. Prolonged maintenance of water levels stabilized at a depth of 1 ft has been found very useful in controlling sweetflag and reed. A permanent depth of 1.5 ft aided greatly in eliminating cattails and water levels maintained at a depth of 2 ft helped in eliminating dense growths of sawgrass.

756. UHLER, F. M. 1956. New habitats for waterfowl. Transactions of the North American Wildlife Conference 21:453–469.

In 1955 at the Patuxent Research Refuge near Laurel, Maryland, more than 60 kinds of shore birds, marsh birds, and waterfowl, including 20 species of ducks and 3 kinds of geese and whistling swans, utilized experimental impoundments in an area that had practically no waterfowl habitat a few years ago. A biennial drawdown was preferred to an annual dewatering, because the latter procedure permits an excessive development of undesired plants that tend to choke out more valuable food plants. When the drawdown is alternated so that a full pool is maintained in each impoundment every other year, the vigor of the pest plants is greatly retarded and much of the undesired growth eliminated during the years when the impoundments are kept completely flooded. Adequate gate and spillway capacity to handle the heaviest precipitation without any extensive buildup of water levels is essential for preventing the flooding of nests and for forestalling damage to food plants.

757. U.S. ARMY CORPS OF ENGINEERS. 1973. Operation of Cougar Lake Project and construction of McKenzie River Salmon Hatchery, McKenzie River. EIS-OR-73-1918-F. n.p.

The proposed action consists of the continuation of present policies governing the operation of the Cougar Lake Project for flood control, power generation, low-flow augmentation, and recreation. The construction of a new fish hatchery is designed to replace runs of spring chinook salmon eliminated by Cougar Dam. Reservoir drawdown exposes bare banks to erosion, drains nutrients

from the reservoir, contributes to bank erosion downstream, and lowers stream temperature thereby hindering the spawning activity of salmon.

758. U.S. ENVIRONMENTAL PROTECTION AGENCY. 1992. In Florida, Corps of Engineer's Kissimmee River restoration aims to return to pre-channelization environmental conditions. Pages 1–27 *in* EPA News-Notes Office of Water (WH-553), Washington, D.C.

In the Kissimmee River, the flood control project drained covered area with material dredged during canal construction and converted areas to canal for about 20,000 of the original 35,000 acres in the floodplain wetland. Now, 20 years after construction of the project was completed, the Corps of Engineers has completed a feasibility report and an environmental impact statement that calls for the environmental re-creation of the Kissimmee River and return of its original meandering state, estimated cost is some $422 million dollars.

759. VAN DER VALK, A. G., AND C. B. DAVIS. 1976. The seed banks of prairie glacial marshes. Canadian Journal of Botany 54:1832–1838.

Hyde Park succession is basically an autogenic process in ponds with stable water levels, but an alogenic process in prairie marshes with unstable water levels. The type of vegetation present at any time is primarily a function of water level, while its flouristic composition is a function of the makeup of the seedbank. Substrate samples for the study were taken in 1975 in water less than 1.5 m deep at 8 marshes or littoral zones in Iowa.

760. VAN DER VALK, A. G., AND C. B. DAVIS. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59:322–335.

Sampling revealed that there are three types of species present in prairie marsh seed banks in north-central Iowa: emergent species such as *Typha*, *Scirpus*, *Sparganium*, and *Sagittaria*, which germinate on exposed mudflats or in very shallow water; submersed and free-floating species such as *Lemna*, *Spirodela*, *Ceratophyllum*, *Naias*, and *Potamogeton*, whose dormancies or turions can survive on exposed mudflats up to a year and which germinate when there is standing water; and mudflat species such as *Bidens*, *Cyperus*, *Polygonum*, and *Rumex*, which are ephemerals whose seeds can only germinate on exposed mudflats during periods when no standing water exists in the marsh because of drought or water-level manipulation. When the marsh refloods, these species are eliminated from the visible marsh flora. Primarily because of fluctuating water levels and muskrat damage, prairie marshes have cyclical changes in their vegetation during which mudflat, emergent, or submersed and free-floating species replace each other as the dominant type of species in a marsh.

761. VAN VOOREN, A. 1981. Relative utilization of Mississippi River habitats as fish nursery areas. Iowa Conservation Committee, Project 81-III-C-11:103–122. n.p.

The relative utilization of very specific habitats by major young-of-year fish species was made in Pools 16 and 18 of the Mississippi River. Maximum depth is given for eight different sampling sites, which included sloughs, main channel borders, and side channels. The results did little to quantify differences in the relative utilization of habitats due to depth. Some of the shallowest stations sampled, however, were among the most utilized. A shallow station had a maximum depth of 2 ft.

762. VAN VOOREN, A. R. 1982. Relative utilization of Mississippi River habitats as fish nursery areas. Page 37 *in* Proceedings of the Mississippi River Research Consortium, 15th Annual Meeting, La Crosse, Wisconsin, April 14–16, 1982.

Eight specific shallow-water habitats in backwater, side channel, and main channel border areas of the Mississippi River were sampled for young-of-year utilization during 1980 and 1981. Young-of-year of 42 species were documented. Species diversity index and species richness exhibited positive correlations with percent silt in the substrate ($r = 0.48$ and 0.71, respectively) and strong negative correlations with current velocity ($r = -0.73$ and -0.91, respectively). Over one-third of the species were found at only one or two sites due to their high degree of habitat specificity and/or uncommon status. The more cosmopolitan species also exhibited varying degrees of preference for nursery habitat, with distribution between sites differing significantly for many. Dredge spoil areas were the poorest nursery habitat, but were utilized by channel catfish. Low-current and lentic environments with predominantly silt substrates in backwater and main channel border areas were the most important nursery habitat. Such sites, when combined with the presence of rooted aquatic vegetation, seemed to be critical nursery habitat for several important sport species. (Abstract only)

763. VANDERFORD, M. J. 1977. The effects of water level fluctuations on muskrat survival in marshes. U.S. Fish and Wildlife Service, St. Paul Field Office, Minnesota. n.p.

The author presents a literature review on the effects of high water levels, effects of low water levels during winter, effects of low water levels during summer, and benefits of stable water levels. Increased water levels in a marsh can have serious adverse effects on resident muskrats, especially when the increase occurs after overwintering lodges have been constructed in late fall. Reduced water levels in a marsh can greatly reduce a muskrat population's chance of surviving the winter. The vast majority of muskrats that are forced out of their home range in winter by high or low water levels die before finding new refuges. Extremely low water levels in a marsh during summer or early fall causes muskrats to become very vulnerable to predation. Relatively stable water levels substantially enhance the health and productivity of muskrat populations.

764. VEITH, G., AND C. CONWAY. 1972. The depletion of oxygen in selected basins of the Chippewa Flowage during ice cover. Appendix N. University of Wisconsin and Wisconsin Department of Natural Resources, Chippewa Flowage Investigations, Part 3A. n.p.

The data obtained from these lakes during one winter were examined to formulate a conceptual model that would enable judgments to be made regarding the effect of water withdrawal from the shallow impoundments on the oxygen status of the water. On the basis of the available data, the authors suggested that (1) The depletion of oxygen in Scott Lake is due largely to the sediment demand and, although the oxygen concentration was not reduced to critical levels, increased water depth would greatly increase the volume of water containing more than 6 mg/L oxygen. (2) The depletion of oxygen in new Rice Lake is due largely to the transport of water across the reducing sediments during drawdown as well as the extremely shallow water layer that results from drawdown. Minimizing the withdrawal of water would likely decrease the oxygen removed from the system and greatly increase the volume of oxygenated water. (3) The depletion of oxygen in Crystal Lake is due largely to the large sediment demand and the mixing processes resulting from lake morphology. Since the water depth is not greatly affected by drawdown, it is likely this lake would contain large oxygen deficits regardless of water use practices. Therefore, high oxygen levels might be maintained only by mechanical aeration or physically modifying the sediments interface with layers of sand, clay, or plastic.

765. VELASQUEZ, C. R., AND R. A. NAVARRO. 1993. The influence of water depth and sediment type on the foraging behavior of whimbrels. Journal of Field Ornithology 64(2):149–157.

Prey-size selection by whimbrels (*Numenius phaeopus*) feeding on an intertidal polychaete was investigated to determine how different substrate conditions affect the foraging of whimbrels feeding on an intertidal mudflat. Whimbrels preying almost exclusively on large polychaetes (*Perinereis gualpensis*) in an estuarine mudflat in Chile (Queule River estuary) were studied. Birds were highly selective: the average prey size found on droppings was 53.6 $\pm$ 3.7 SE mm (n = 914) total body length, and 95% of them were larger than 40 mm. Whimbrels obtained their prey almost exclusively by deep probing because large worms were found mainly at depths below 3 cm in the substrate. Observations of feeding whimbrels were made in five sediment conditions: shallow water, sediment covered by a 2–10 cm water layer, water film, sediment covered by a water film < 2 cm deep, wet sand with no water layer, dry sand, and mud. Foraging was significantly more successful in sandy areas than in muddy areas. This result corresponded with an observed lower density of large polychaetes (> 40 mm) in the mud. Within sandy areas, whimbrels had the highest foraging success rate in wet sand.

766. VENNIE, J. G., AND G. H. SHAW. 1979. Agricultural runoff and reservoir drawdown effects on nutrient dynamics of a eutrophic reservoir. Paper presented at the North American Lake Management Conference, April 16–18, 1979.

The 2,800 ha Big Eau Pleine Reservoir in Wisconsin has experienced excessive algal blooms and winter fish kills since its construction in 1935. The well-drained, highly agricultural basin provides ideal conditions for heavy nutrient loading. Phosphorus loading occurs primarily during snow melt and early spring runoff. Phosphorus levels drop off after a bloom of blue-reen algae in early spring, but increase again in early summer and remain high throughout the growing season. This increase is attributed to resuspension of settled phosphorus by wave action during reservoir drawdown and from small amounts of anaerobic release during early drawdown. Depletion of oxygen occurs rapidly following ice cover and becomes almost complete when winter drawdown reaches the level where bottom sediments are scoured and resuspended, adding to the biochemical oxygen demand of the water. It is predicted that control of nutrient runoff will be required to improve the trophic status of this lake.

767. VESTER, G. 1972. The physiology of flooding tolerance in trees. Transactions of the Botanical Society of Edinburgh 41:556–557.

The ability of some trees to cope with water-logged soil seems to be associated with the accumulation of nontoxic anaerobic end products. The ratio of $^{14}CO_2$ fixation by roots of 1-year-old seedlings in nitrogen and in air accurately predicts the degree of flood-tolerance by seedlings as old as 2.5 years. Thus, tree seedlings with a better control mechanism for a fairly high nitrogen:air ratio of CO_2 fixation by their roots are more likely in nature to withstand the stress of a surplus water supply.

768. VIOSICA, P., JR. 1952. Growth rates of black basses and crappie in an impoundment of northwestern Louisiana. Transactions of the American Fisheries Society 82:255–264.

Rapid growth of several species of fishes, including the largemouth and spotted basses and the black crappie, was observed during three successive summers, 1949–1951, in a reservoir at Springhill, Louisiana. The basin is filled in April and drained in September or October. Young-of-year largemouth bass grew to sizes ranging up to 13.8 inches and up to 24.5 oz during the retention period. Black crappie grew up to 9.8 inches and 12 oz during a 6.5-month retention period. No submerged aquatic plants develop in the basin over the period from October to March when it is filled with a dilute, industrial effluent known as "blackwater." Sunlight penetration is only about 2 inches. Any organic matter is mineralized by anaerobic conditions. As few macroinvertebrates are present in the basin after refilling with oxygenated water pumped from the stream, young-of-year fish shift early in life to a fish diet, and phenomenal growth rates are the result. The periodic recycling of nutrients rejuvenates the basin annually. The food chains are shortened and conditions are favorable for the rapid growth of desirable fishes. Food chains are highly autotrophic.

769. VOELZ, N. J., AND J. V. WARD. 1990. Macroinvertebrate responses along a complex regulated stream environmental gradient. Regulated Rivers: Research & Management 5:365–374.

Samples were collected year-round over a 1-year period at sites located downstream from a hypolimnetic-release reservoir on the Blue River, Colorado, to examine macroinvertebrate responses along a complex environmental gradient induced by river regulation. Six sampling sites were established in riffles downstream of the dam using approximately a geometric progression starting at 0.25 km. Ordination techniques were used to elucidate macroinvertebrate distributional patterns along the complex environmental gradient. The detrended correspondence analysis showed a sequential faunal gradient with the most rapid change occurring within the first 2.0 km below the impoundment. Detrended canonical correspondence analysis was used to relate faunal distributions to downstream changes in environmental variables. Downstream decreases in periphyton standing crop and minimum temperatures, and downstream increases in food resources and maximum temperatures, were identified as the major variables structuring faunal assemblages. The combined use of different gradient analysis techniques proved useful for identifying distinct macroinvertebrate distributional patterns and the environmental variables that may be responsible for these patterns.

770. VOELZ, N. J., AND J. V. WARD. 1991. Biotic responses along the recovery gradient of a regulated stream. Canadian Journal of Fisheries and Aquatic Sciences 48:2477–2490.

Samples were collected year-round over a 1-year period at six sites located downstream from a reservoir with a hypolimnetic release on the upper Colorado River to examine the longitudinal patterns of macroinvertebrates along an environmental gradient induced by river regulation. The impoundment had only minimal effects on river chemistry, and chemical variables did not exhibit a distinct downstream gradient. The results of this study, when compared with research conducted in a free-flowing and other impounded rivers, indicated the predictability of some longitudinal patterns and the recovery potential of regulated lotic systems.

771. VOESENEK, L. A. C. J., F. J. M. M. VAN OORSCHOT, A. J. M. SMITS, AND C. W. P. M. BLOM. 1993. The role of flooding resistance in the establishment of *Rumex* seedlings in river flood plains. Functional Ecology 7:105–114.

This study deals with resistance to complete submergence of seedlings of *Rumex acetosa*, *R. crispus*, and *R. palustris*. Seedlings of *R. crispus* and *R. palustris* seemed to be more resistant to flooding than those of *R. acetosa* under both field and greenhouse conditions. Younger seedlings of all species were able to survive a longer flooding period than older ones. When completely submerged, the three *Rumex* species showed a low, but significant, photosynthetic activity. In *R. crispus* and *R. palustris*, photosynthetically produced oxygen is released by the roots. Excised *Rumex* root tips have a low hypoxia tolerance, but that of *R. acetosa* was the lowest. This correlates with a high rate of ethanolic fermentation in both *R. crispus* and *R. palustris* and a low rate in *R. acetosa*. The overall resistance to flooding of *Rumex* seedlings established from field, greenhouse, and laboratory experiments showed a relation with their site distribution in a flooding gradient of the river Rhine.

772. VOGELE, L. E. 1975. Reproduction of spotted bass, *Micropterus punctulatus*, in Bull Shoals Reservoir, Arkansas. U.S. Fish and Wildlife Service, Technical Paper 84. 21 pp.

Environmental requirements of spotted bass for spawning and their reproductive potential were evaluated from underwater observations along a steep bluff and in shallow coves of Bull Shoals Reservoir from 1966 to 1971. In years of low water, nest densities were greatest along the bluff. In 1968 and 1969, when high water afforded heavy cover (in the form of flooded terrestrial vegetation) to spotted bass nesting in coves, bass did not spawn along the bluff.

773. VOGELE, L. E., AND W. C. RAINWATER. 1975. Use of brush shelters as cover by spawning black basses (*Micropterus*) in Bull Shoals Reservoir. Transactions of the American Fisheries Society 104:264–269.

Brush shelters placed along the shoreline were observed during the spawning of three species of black bass to evaluate preferences for sheltered and unsheltered habitat. During the study, rising water levels flooded shoreline vegetation, which furnished abundant cover for late-spawning bass and for schools of fry. When shelters were no longer the most obvious cover available, fry also used the vegetation. Half the schools of fry observed were in flooded terrestrial vegetation.

774. VOIGHTS, D. K. 1976. Aquatic invertebrate abundance in relation to changing marsh vegetation. American Midland Naturalist 95:313–322.

The relation between invertebrate populations and vegetative cover was studied in several Iowa marshes during the peak of the avian nesting season. Shallow water with emergent and floating dead vegetation produced the most isopods, planorbid snails, and physid snails. Physid snails had another abundance peak in areas where submerged plants were found below dense, free-floating plants. Midges reached greatest abundance in more open habitats somewhat protected from the wind. Amphipods were the most numerous invertebrate taxa and were most abundant in dense beds of submerged vegetation. Cladocera and copepods were most common in quiet pools with little vegetation. Total invertebrate abundance increased as the emergent vegetation was replaced by submerged vegetation, but maximum numbers occurred where beds of submerged vegetation were interspersed with stands of emergent vegetation.

775. VON GELDERN, C. E., JR. 1971. Abundance and distribution of fingerling largemouth bass, *Micropterus salmoides*, as determined by electrofishing at Lake Nacimiento, California. California Fish and Game 57:228–245.

Findings are summarized on the efficiency of electrofishing for fingerling bass, the effort required to obtain meaningful indices of abundance, and the factors controlling the abundance and distribution of fingerling bass in Nacimiento Reservoir. Large numbers of fingerlings were collected in years when water levels were stable or rising during the spawning period, when the elevations of surface waters were high in April and May, and when the densities of threadfin shad were low. Poor year classes of 1966 and 1968 were associated with declining water levels between May and June, but there was no evidence of exposed nests before the hatching and development of sac fry. The distribution of brush and other forms of cover were such that more cover was available when water levels were high. Increased cover may have provided increased shoreline stability by reducing wave action and thereby enhancing the survival of eggs and fry. Although the production of large year classes in alternate years suggests that yearling bass may have depressed fingerling survival, the effect is considered minor. An inverse relation between the abundance of fingerling bass and adult threadfin shad suggests that food competition is an important factor limiting bass year classes.

776. VON GELDERN, C. E., JR., AND D. F. MITCHELL. 1975. Largemouth bass and threadfin shad in California. Pages 436–449 *in* H. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Early introductions of threadfin shad in California reservoirs were generally successful, resulting in increased forage for predators and increased production by black basses. Several studies discussed show that shad compete with young bass for food (primarily zooplankton) and that survival of young-of-year bass is greatly reduced as a result. Age-0 shad did not provide forage for bass that hatched late in the spawning season. Management programs to improve survival of young-of-year bass are recommended. Reducing water-level fluctuations during the spawning season is one measure that is expected to improve survival of newly hatched bass.

777. WADE, P. M. 1990. Physical control of aquatic weeds. Pages 93–135 *in* A. H. Pieterse and K. J. Murphy, editors. Aquatic weeds: The ecology and management of nuisance aquatic vegetation. Oxford Science Publishing, Oxford University Press, New York.

A review of the literature is made concerning the alteration of water levels as a physical control for aquatic weeds.

778. WAJDOWICZ, Z. 1964. The development of ichthyofauna in dam reservoirs with small variations in water level. Acta Hydrobiologica 6:61–79.

The development of fish populations in the Goczalkowice and Kozlowa Gore Reservoirs—two large, shallow impoundments with stable water levels—is described. In reservoirs, water-level fluctuations play a decisive role in the formation of fish populations. In reservoirs with slight water-level fluctuations (unlike those with extensive fluctuations), the decline of northern pike is gradual after its exponential expansion during the years of reservoir filling. The rapid and extensive development of pike populations results from excellent spawning conditions when rising water levels inundate grassy terrain. Fluctuations in water level, loss of original turf, and angling all reduce populations. In stable reservoirs, shallow areas develop aquatic and semiaquatic vegetation that provides new spawning areas for pike. The loss of rheophilic fishes is complete and more rapid in reservoirs with stable water levels than in those with fluctuating levels.

779. WAJDOWICZ, Z. 1979. Development of the ichthyofauna in the cascade of the San River. Acta Hydrobiologica 21:73–90.

The development of the fish fauna in reservoirs at Solina and Myczkowee, Poland, was studied by analyzing fish harvest. These two mountain impoundments have high, long-term and daily water-level fluctuations that influence the species composition and relative abundance of fish.

780. WALBURG, C. H. 1972. Some factors associated with fluctuation in year-class strength of sauger, Lewis and Clark Lake, South Dakota. Transactions of the American Fisheries Society 101:311–316.

Strength of sauger year classes in Lewis and Clark Lake has fluctuated widely since the reservoir was inundated in 1956. Year classes were above average in years when power-peaking operations (at Fort Randall Dam, during the spawning season) and water exchange rate (of Lewis and Clark Lake in June) were minor. About 80% of the variation in year-class strength (estimated from catches of fish of age 7 or older) was explained by changes in four variables: (1) water level over spawning grounds, (2) reservoir water temperature in June, (3) the rate of water exchange, and (4) the minimum daily air temperature for 21 days after initial spawning.

781. WALBURG, C. H. 1976. Changes in the fish population of Lewis and Clark Lake, 1956-1974, and their relation to water management and the environment. U.S. Fish and Wildlife Service, Research Report 79. 34 pp.

Sampling of fishes in Lewis and Clark Lake from 1956 to 1974 indicated that both abundance and the number of species decreased. After 1969, a decrease in the rate of water exchange from 10 to 4 or 5 days was harmful to fish populations, partly because larval fish were discharged through the dam. The abundance of young-of-year fishes was directly related to the water exchange time ($P < 0.02$, $r = 0.73$), as was the catch of young fish by trawl ($P < 0.05$, $r = 0.68$). The year-class strength of freshwater drum and channel catfish was correlated with the mean rate of water exchange in July-August. Water levels late in the 1956–1974 period were low and variable from March 1 through July 15. This regime had a detrimental effect on spawning success of nearshore spawners such as gizzard shad, emerald shiners, white bass, white crappies, and yellow perch. The spawning success of nest builders such as white crappies was especially poor when water levels fluctuated in spring, but was good in years when levels were stable or rose slightly. Year classes of fishes requiring inundated terrestrial vegetation were poor after normal operations (i.e., low, irregular water levels in spring and summer) were established. Spawning success of some species was unaffected by water level (e.g., freshwater drum, which spawn pelagically; channel catfish, which spawn at depths exceeding those influenced by fluctuations in water level; and walleyes and saugers, which spawn in the Missouri River). Although the reproduction of walleyes and saugers was unaffected, the low abundance of young forage fish—a direct result of water-level fluctuations—may have influenced their growth and survival. Decreased growth of saugers paralleled the decreased abundance of small fishes in the reservoir.

782. WALBURG, C. H. 1977. Lake Francis Case, a Missouri River reservoir: Changes in the population in 1954–75, and suggestions for management. U.S. Fish and Wildlife Service, Technical Paper 95. 12 pp.

Twenty-three years of study of Lake Francis Case have documented a decreasing abundance of fish; 12 species were abundant in the 1950s, compared with only eight in the 1970s. Changes in the species composition and abundance were determined by reproductive success, as affected by water-level fluctuations and changes in spawning habitat. Water levels during spring and summer are determined primarily by reservoir operations and the amount of snowfall. In low-water years,

such as those in 1968–70, terrestrial and semiaquatic vegetation invaded shallow-water areas of embayments. When this vegetation was flooded in high water years such as 1971—especially in May and June—excellent spawning and nursery conditions resulted in the production of enormous numbers of young-of-year (YOY) fishes. The annual catch of YOY fish from 1966 to 1975 was significantly correlated with changes in water levels between May and June ($r = 0.80$; $P < 0.01$). The abundance of YOY yellow perch and walleyes was closely correlated with water-level changes. Investigations demonstrated the detrimental effect of fall drawdowns on periphyton and benthos, and showed that the maintenance of high water levels in fall significantly increased the standing crop of benthos. A 3-year cycle of pool-level management is recommended, as follows: maintenance of relatively low water levels for 2 consecutive years to encourage the development of shoreline vegetation, followed by high spring water levels maintained through July of the third year. Some independence from primary use requirements might be obtained in one reservoir if the series of Missouri River impoundments were operated as a system.

783. WALBURG, C. H., AND W. R. NELSON. 1966. Carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo in Lewis and Clark Lake, Missouri River. U.S. Fish and Wildlife Service, Technical Paper 69. 30 pp.

Information on the age composition, growth, reproduction, and food habits of four species of fish in Lewis and Clark Lake is presented. Strong year classes of all species were produced in the first 2 years of impoundment, but later year classes were weak. Rising water levels during the spawning period seemingly are important to the successful spawning of common carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo. Unsuccessful spawns were attributed to existing practices of water-level management, which resulted in low or fluctuating levels during the spawning season.

784. WALBURG, C. H., J. F. NOVOTNY, K. E. JACOBS, W. D. SWINK, T. M. CAMPBELL, J.. M. NESTLER, AND G. E. SAUL. 1981. Effects of reservoir releases on tailwater ecology: A literature review. U.S. Department of the Interior for the U.S. Army Engineer Waterways Experiment Station, Mississippi, Environmental and Water Quality Operational Studies, Technical Report E-81-12. 189 pp.

A review is presented of the often contradictory literature describing the effects of release waters on the tailwater environment and biota. The physical and chemical conditions found in tailwaters downstream from warmwater and coldwater discharge impoundments are compared and contrasted to those found in natural streams. Reservoir discharges modify the physical, chemical, and biological characteristics of the stream ecosystem. Physical and chemical characteristics in tailwaters are primarily determined by the depth, volume, and schedule of water releases. The magnitude of change is related to the type of reservoir and to the design and operation of outlet structures. The structure of the biotic community reflects the physical and chemical conditions existing in a particular tailwater. The community is composed of organisms, including nonnative species, that are adapted to this environment. The effects of the tailwater environment on the life history, physiology, and abundance of selected species are described.

785. WALKER, K. F. 1979. Regulated streams in Australia: the Murray-Darling system. Pages 143–163 *in* J. V. Ward, and J. A. Stanford, editors. The ecology of regulated streams. Plenum, New York.

The author reviews the literature and presents information on the ecological knowledge that supports river management in Australia.

786. WALKER, K. F. 1985. A review of the ecological effects of river regulation in Australia. Hydrobiologia 125:111–129.

Responses to hydrologic change are an important theme in lotic ecology, and data for Australian rivers are accumulating in a rapid, but ad hoc manner. Recent contributions are arranged according to the major drainage divisions, which provide reasonably coherent environmental units. The eastern coastal rivers are exploited for storage, power generation, and waste disposal, and Tasmanian rivers are regulated to serve hydroelectric power schemes. Most information refers to the Murray-Darling river system, which supplies irrigated agriculture in semiarid inland areas of southeastern Australia and is intensively regulated by dams, weirs, and barrages. The Murray's flows are overcommitted, if variability is taken into account, and there are environmental problems (e.g., erosion and salinity) associated with irrigation. The effects of regulation are seen also in the changed distributions of plants and animals associated with the Murray and its floodplain. In Australia, the national effort is uncoordinated because research and management are developing independently of one another. Ecologists must become involved in the planning and implementation of strategies that are consistent, as far as possible, with offstream and instream needs.

787. WALKER, K. F., A. J. BOULTON, M. C. THOMS, AND F. SHELDON. 1994. Effects of water-level changes induced by weirs on the distribution of littoral plants along the River Murray, south Australia. Australian Journal of Marine and Freshwater Research 45:1421–1438.

In 1988, a survey was made of the River Murray between Locks 2 and 4 (153 river km) to determine whether the distributions and relative abundances of littoral plants are influenced by water-level variations associated with weir operations. Of 20 recorded plant species, some, including *Cyperus* sp. and *Myriophyllum verrucosum*, occurred in regions downstream of each weir and hence were exposed to maximal variation in river levels. Others, notably *Typha* spp., favored the regions above each weir, where levels are comparatively stable. The influences of physical channel characteristics such as bank slope, bank erosion, and sediment composition and of other environmental factors were not clear. These effects may have been obscured by differences in the natures of the two pools and by a tendency for factors correlated with the water-level gradients to be reset at each weir. Changes in the flow behavior of the river since 1990 suggest that these survey data may later prove useful in evaluating the effects of high turbidities associated with regulated flows from the Darling River.

788. WALKER, K. F., AND M. C. THOMS. 1993. Environmental effects of flow regulation on the lower River Murray, Australia. Regulated Rivers: Research & Management 8:103–119.

Before regulation, flows in the lower River Murray were highly variable, as for most rivers in semiarid regions. Major floods promoted large-scale recruitment of flora and fauna in riverine and floodplain communities, and seasonal floods maintained lower levels of recruitment. The regime changed with the construction of 10 low-level weirs in 1922–35, supplemented by the effects of dams in upstream areas. Flows remain variable but are much reduced in volume (about 44%). Low flows (100–300 Gl per month) have decreased fivefold and moderate flows (500–1,500 Gl per month) have increased twofold. Although the magnitude of peak seasonal flows has been diminished, the timing of flows is unaffected. The effects differ in the valley and gorge sections of the river, depending on local development of the floodplain and associated wetlands. The weirs have flooded once-temporary wetlands and contributed to problems of salinization. Weir operations cause daily stage fluctuations that diminish downstream, and the channel is developing a stepped gradient as a consequence of active deposition and erosion. Regulation has limited exchanges between the river and its floodplain, changed the nature of the littoral zone, and generally created an environment inimical to many native species, notably fish. The key to rehabilitation may be to restore a more natural balance of low and medium flows, but this may be unrealistic given the needs of irrigators and other water users. Despite its evolutionary history of wide spatial and temporal variation, the Murray river–floodplain ecosystem evidently cannot accommodate these forms of disturbance.

789. WALKER, K. F., M. C. THOMS, AND F. SHELDON. 1992. Effects of weirs on the littoral environment of the River Murray, South Australia. Pages 271–292 *in* P. J. Boon, P. Calow, and G. E. Petts, editors. River conservation and management. John Wiley & Sons Ltd., England.

The authors review the literature on the effects of weir operations including the physical and biological environment. Biological and environmental areas considered were habitat patchiness, littoral plants, snags, macroinvertebrates, and fish.

790. WALLSTEN, M., AND P. FORSGREN. 1989. The effects of increased water level on aquatic macrophytes. Journal of Aquatic Plant Management 27:32–37.

The water level at Lake Tamnaren, Sweden, was lowered by 0.5 m between 1950 and 1954. The aquatic macrophytes propagated in great numbers. By 1973, the aquatic vegetation covered 80% of the lake area. In 1977, the water level of the lake was increased by 0.5 m and the propagation area of vegetation diminished. By 1983, vegetation covered only 14% of the lake area.

791. WALTERS, C., L. GUNDERSON, AND S. C. HOLLING. 1992. Experimental policies for water management in the Everglades. Ecological Applications 2(2):189–202.

Marshland drainage and water regulation have greatly altered the Florida Everglades. One of the most visible ecological effects has been a drastic decline in nesting populations of wading birds, and several specific hypotheses have been advanced to explain the decline. Recent efforts at ecological restoration have concentrated on reestablishing more natural seasonal hydropatterns in freshwater marsh areas now used extensively by the wading birds. However, nesting colonies were originally concentrated along the estuarine mangrove edge of the system rather than around upstream marshes. Hydrological simulation models have been used to reconstruct what hydrological conditions might have been like in the natural system, and these simulations indicate that freshwater pools near and flows to the estuary have been drastically reduced, especially late in the annual spring drying season.

792. WARD, J. V. 1976. Effects of flow patterns below large dams on stream benthos: A review. Pages 235–253 *in* J. F. Osborn, and C. H. Allman, editors. Instream Flow Needs Symposium. American Fisheries Society, Bethesda, Maryland.

The variously modified flow patterns below dams are considered in relation to the effects on ecological factors of importance to the benthic communities of receiving streams. Species composition and diversity are considerably modified by upstream impoundments. Benthic standing crop may be enhanced or reduced, largely depending on the flow regime. Daily flow fluctuations, if not too severe, may be associated with dense benthic populations as long as a relatively constant seasonal flow pattern is maintained. Little is known regarding subtle, sublethal effects of dams on life-cycle phenomena and biotic interactions and more data are needed on preferences of important fish food species. Any flow regime that significantly reduces habitat diversity should be avoided. A diverse substrate with silt-free interstices will considerably reduce deleterious effects of periods of reduced flow, fluctuating flow and high current velocity. In establishing flow, criteria for benthos, each dam must be considered individually.

793. WARD, J. V., AND J. A. STANFORD. 1984. The regulated stream as a testing ground for ecological theory. Pages 23–38 *in* A. Lillehammer, and S. J. Saltveit, editors. Regulated Rivers. Oslo University Press, Norway.

Regulated streams have several attributes that make them especially suitable systems for testing ecological theory. Dams with multilevel release depth capabilities that impound large, deep, stratified reservoirs offer the greatest potential for experimental manipulation of the downstream lotic environment. Release depth and discharge, singly and in concert, exert direct and indirect control over a myriad of environmental variables of primary importance to stream organisms. Control of discharge provides the opportunity to manipulate the severity, duration, and seasonal timing of simulated drought and flood events, enabling analysis of successional processes, colonization phenomena, and resiliency properties of lotic ecosystems. The modification of colonization vectors by stream regulation (e.g., truncation of downstream drift and upstream migration) allows an examination of lotic recovery phenomena in the context of island biogeography. Selective depth withdrawal allows considerable control over the downstream thermal regime. For example, manipulation of diel thermoperiods may provide insight into the ecological importance of phase relations between temperature and light under field conditions. Because of the relatively gradual downstream changes in environmental conditions over short distances, regulated streams offer excellent opportunities for studies of gradient analysis (i.e., the distribution of species along spatial habitat gradients). These and other special attributes of regulated streams make them ideal locations for testing a variety of hypotheses at the species (e.g., niche theory), population (e.g., ecotype concepts), community (e.g., competitive exclusion), and ecosystem (e.g., nutrient spiralling) levels of organization.

794. WARD, J. V., AND J. A. STANFORD. 1993. Research needs in regulated river ecology. Regulated Rivers: Research & Management 8:205–209.

In this review of the literature, the authors conclude that research and expertise in regulated stream ecology will increasingly be needed as the rational basis for flow criteria to conserve, protect, and enhance the societal values of regulated rivers worldwide.

795. WATERS, I., AND J. M. SHAY. 1992. Effect of water depth on population parameters of a *Typha glauca* stand. Canadian Journal of Botany 70:349–351.

The response of a *Typha glauca* stand to a water depth gradient was studied in a small marsh pond in Delta Marsh, Manitoba. Weekly density counts and height measurements were made from May to October 1986 in permanent quadrats at five depths from 25 to 100 cm. Shoot mass was estimated from shoot height using a regression model based on destructive analyses. Shoot density declined significantly from 41 shoots/m^2 at 25 cm to 12 shoots/m^2 at 85 cm but increased at 100 cm to 38 shoots/m^2. Shoot mass increased in shoots growing at water depths from 25 to 65 cm, resulting in relatively constant stand biomass over this depth range. Stand biomass declined at 85 cm and reached its maximum (1,789.8 g/m^2) at 100 cm. Frequency distributions of shoot size categories

based on height deviated from normality and were negatively skewed at all depths, with the greatest skewness occurring at 100 cm. These population parameters were interpreted as evidence of a plastic population response to water depth.

796. WEBB, J. F., AND D. D. MOSS. 1967. Spawning behavior and age and growth of white bass in Center Hill Reservoir, Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 21:343–357.

From October 1965 to March 1967, studies were conducted to document spawning behavior, age and growth, and food of white bass in the headwaters of Center Hill Reservoir, Tennessee. A drop in lake level (4 ft in 22 days) exposed and destroyed millions of white bass eggs in 1966. Perhaps stable water levels during spawning would have improved the 1966 year class. Walleye eggs also were exposed, but few were seen.

797. WEBER, D. T. 1968. Narrows pre-impoundment investigations. Colorado Department of Game, Fish, and Parks, Progress Report for the Federal Aid Project F-41-R-2. 56 pp.

The principal emphasis in this study was preimpoundment sampling of fish populations of the South Platte River near the proposed dam and the formation of preliminary recommendations for fishery management of the proposed reservoir. The effect of water-level fluctuations is discussed briefly, based on published information. A 15-year analysis of the hydrology of the South Platte River suggests that water levels rise from November to June and decrease from July through October. Receding water levels are expected to influence the survival of certain species, if they recede during spawning. Most game species are expected to spawn successfully if colder waters do not delay spawning into the fall drawdown phase. The author suggests that the spawning time of most species can be estimated by knowing reservoir water temperatures, and that the water levels can be controlled more precisely to enhance or control the reproductive success of selected species.

798. WEGENER, W., AND D. HOLCOMB. 1972. An economic evaluation of the 1970 fishery in Lake Tohopekaliga, Florida. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:628–634.

In 1970, the Florida legislature provided for a table of values for fish killed by water pollution. These data were applied to standing crop estimates to determine the monetary value of the 1970 fishery in 27,000 acre Lake Tohopekaliga, Florida. The limnetic portion of the fishery was valued at $4,335,120 or $321.12 per acre. The littoral portion was valued at $12,266,636 or $1,333.33 per acre. Although the littoral zone has a considerably higher value and is vital for the renewal of the fishery resource, it is continually subjected to accelerated encroachment and piecemeal destruction by a variety of means. Monetary estimates such as these enable biologists to express biological facts in terms of more conventional market pricing techniques when considering water-use policies. A concurrent creel survey showed an annual net value returned to fishermen of $560,008; they harvested 17.3 fish per acre per year valued at $24.35. An increase in standing crops due to water-level manipulation can be translated into monetary values utilizing these figures.

799. WEGENER, W., AND V. WILLIAMS. 1974. Algae monitoring studies. Florida Game and Fresh Water Fish Commission, Federal Aid Project F-29, Job 5. 28 pp.

Responses of algae populations to dewatering and reflooding of Lake Tohopekaliga, Florida, were variable. Diversity of green and blue-green algae increased when littoral areas were initially

flooded. Diversity of other major groups remained essentially the same. Bloom conditions became more frequent as the study progressed (especially for blue-green algae), as a result of increased nutrient concentrations that originated from sewage effluent.

800. WEGENER, W., AND V. WILLIAMS. 1974. Extreme drawdown, a working fish management tool. Florida Game and Fresh Water Fish Commission, Federal Aid Project F-29-R. 11 pp.

Fishery data collected from Lake Tohopekaliga, Florida, indicated that drawdown seemingly funneled energy flow into the fishery, inasmuch as standing crops and yields of fish increased after drawdown. Some benefits derived from drawdown were short-lived, and therefore extreme drawdowns should be repeated about every 7 years.

801. WEGENER, W., AND V. WILLIAMS. 1974. Fish population responses to improved lake habitat utilizing extreme drawdown. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 28:144–161.

Water levels of Lake Tohopekaliga, Florida, were limited to a 3-ft annual fluctuation by the Central and Southern Florida Flood Control District. In 1971, a drawdown that exposed 50% of the lake bottom was effected to improve the sport fishery and water quality of the 22,700-acre reservoir. The drawdown pool was maintained for 6 months, and refilling of the reservoir to normal pool required another 6 months. Water levels continued to rise above normal pool throughout the following year. Fish samples from coves (by application of rotenone within a blocked area) indicate that littoral standing crops increased from 191 to 455 lb/acre within 2 years after the basin was reflooded. Biomass of sport fish almost doubled, though forage fish accounted for a higher percentage of community biomass after the reflooding of the impoundment. Numbers of harvestable-sized sport fish increased, as did the monetary value of the fishery (by 37%). Chain pickerel was the only sport fish that was adversely affected by dewatering. Bluegill populations declined during drawdown and early reflooding, but strong year classes were produced in spring of the next 2 years (1972 and 1973). Redear sunfish seemed to benefit by dewatering and low water levels.

802. WEGENER, W., AND V. WILLIAMS. 1974. Fish population studies. Florida Game and Fresh Water Fish Commission, Federal Aid Project F-29, Job 1. 28 pp.

Drawdown and reflooding of Lake Tohopekaliga, Florida, has had little effect on the condition of black crappies, bluegills, and redear sunfish. Overall, success of anglers increased from 1.6 fish/hour before drawdown to 3.0 afterward. Low water levels limited access, and total effort and harvest remained below predrawdown levels. Effort and harvest of largemouth bass consistently increased after drawdown and reflooding, although the success rate of anglers remained unchanged. Harvest of black crappies declined substantially and remained low until 2 years after the drawdown (winter 1973–74), when harvest exceeded predrawdown levels and angler success was the highest observed during the study. Harvest and effort by panfish anglers declined during and after reflooding of the lake, but success increased slightly.

803. WEGENER, W., AND V. WILLIAMS. 1974. Organic deposition studies. Florida Game and Fresh Water Fish Commission, Federal Aid Project F-29, Job 4. 18 pp.

Dewatering reduced the depth of organic sediments by 50% to 80%. New organic materials deposited after reflooding consisted primarily of decomposing water hyacinth and algae.

Observations on sediment decomposition indicated that improved condition of littoral sediments will last only a few years; this shows the importance of frequent drawdowns in the future. Appreciable amounts of CO_2 were released from drying organic sediments.

804. WEGENER, W., AND V. WILLIAMS. 1974. Water chemistry studies. Florida Game and Fresh Water Fish Commission, Federal Aid Project F-29, Job 6. 22 pp.

Concentrations of most chemical constituents increased during drawdown and decreased as Lake Tohopekaliga, Florida, was refilled, though concentrations on refilling of the lake were higher than before drawdown. Although most physical and biological characteristics improved after drawdown, water quality deteriorated due to sewage-plant discharges into the lake.

805. WEGENER, W., AND V. WILLIAMS. 1977. The effect of extreme lake drawdown on largemouth bass populations. Paper presented at the Big Bass Seminar, December 2–4, 1977. Florida Game and Fresh Water Fish Commission, Tallahassee. 25 pp.

Largemouth bass reproductive success, survival, and growth rates improved after a 7-ft drawdown of Lake Tohopekaliga, Florida. Flocculent organic sediments in exposed areas were reduced 50% to 80%. Desirable aquatic vegetation expanded and became more diverse. As a result, production of fish-food organisms was stimulated: within 1 year, numbers of amphipods per standard sample unit (five net sweeps = ca. 1.38 m^3) increased from 178 to 465; grass shrimp increased from 2.6 to 65.8, water boatmen from 0 to 61.1; and crayfish from 0 to 0.2. Standing crop of fishes increased 138% in 3 years, from 191 to 455 lb/acre. Bass biomass increased from 35 to 60 lb/acre in the first year after drawdown. Angler harvest of largemouth bass decreased slightly during the drawdown of 1971, but increased thereafter and peaked in 1975. The harvest was four times greater than in 1970. On this basis, extreme drawdown is recommended every sixth year. The number of bass caught during reflooding of Lake Kissimmee increased 18% over that before the drawdown.

806. WEGENER, W., V. WILLIAMS, AND T. D. MCCALL. 1974. Aquatic macroinvertebrate responses to an extreme drawdown. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 28:126–144.

Water levels of Lake Tohopekaliga, Florida, were drawn down 7 ft from the maximum pool elevation in 1971, exposing 50% of the basin bottom for 6 months. Because of drought, the lake was not completely refilled for an entire year. Drawdown improved littoral substrate and increased the density and diversity of aquatic macrophytes and benthos. After reflooding of the basin, the density of benthic macroinvertebrates per square foot increased from 98 to 244 (limnetic), 154 to 250 (littoral), and from 304 to 1,364 (on or associated with macrophytes). Densities returned to levels characteristic of the pretreatment period within 2 years. The decline in numbers was associated with increases in the number of fish and invertebrate predators. Sport fishes that ate macroinvertebrates nearly doubled in weight, from 151 to 236 lb/acre in the littoral zone and from 34 to 54 lb/acre in the limnetic zone.

807. WELCOMME, R. L. 1985. River fisheries. FAO Fisheries Technical Paper 262. 330 pp.

Information dealing with water levels and reservoir systems is presented in an extensive review of the literature.

808. WELCOMME, R. L., AND D. HAGBORG. 1976. Towards a model of a floodplain fish population and its fishery. FAO/UNDP (TA). n.p.

A model is developed that describes the way in which the fish populations of African rivers and their fisheries are influenced by the different types of flood regime. Ichthyomass and fish catch are dependent on both the extent of flooding during high water and the amount of water remaining in the system during the dry season. The relative number and individual weight of fish are determined by the intensity of flooding, whereas the total number surviving to the next year depends more on the low water regime. Catch per unit effort falls with increasing difference between areas flooded at high and low water. A negative log–log relation exists between catch and the ratio of maximum area flooded to minimum area of water remaining in the system. This relation of catch-to-flood ratio may form the basis for a general index for the evaluation of both year-to-year variations within a floodplain and differences between floodplains. Lines of equal catch are also derived for various combinations of high and low water areas; these might be used as guidelines for the hydrological management of tropical floodplains.

809. WELLER, M. W., AND L. H. FREDRICKSON. 1973. Avian ecology of a managed glacial marsh. Living Bird 12:269–291.

This paper reports observations made from 1964 to 1971 on an experimentally managed 400-acre marsh, Rush Lake, in Palo Alto County, Iowa. One of the major objectives of the study was to clarify typical marsh habitat cycles to allow optional use of natural systems in management for marsh wildlife. Dominant emergent and submergent vegetation and bird and muskrat populations were studied to determine the extent and pattern of short-term vegetation change and its effect on bird populations. Water levels were lowered to initiate revegetation of an open marsh and levels then were regulated to maintain maximal use by birds and muskrats. High water and muskrats had eliminated vegetation from Rush Lake during 1959 to 1962. A drawdown was employed to induce plant germination. Water levels were lowered in spring 1963, but little germination occurred because of the large volume of water. A successful drawdown was achieved early in 1964 and levels were held low until fall 1964. Following successful germination of a great variety of moist-soil and aquatic plants, water levels were raised to flood the entire marsh bottom but only dampen the surviving cattail beds at the perimeters.

810. WELLING, C. H., R. L. PEDERSON, AND A. G. VAN DER VALK. 1988. Recruitment from the seed bank and the development of zonation of emergent vegetation during a drawdown in a prairie wetland. Journal of Ecology 76:483–496.

(1) Patterns of recruitment of five emergent species from the seed bank along a height gradient in an experimental wetland complex during a period with no standing water (drawdown) are described in relation to the development of zonation. The drawdown was preceded by 2 years in which water levels were maintained at 1 m higher than normal, which destroyed most of the emergent vegetation.

(2) Zonation of established, adult emergents was shown by the separation of peak frequencies of different species along the height gradient and the occurrence of only one species in 64% of quadrats sampled.

(3) For four emergent species, the distribution of seedlings along the height gradient during drawdown were similar to the preflooding distributions of adult plants. *Scirpus larustris* and

Typha spp. both had peak abundances of seedlings and adults at lower heights than those of *Scolochloa festucacea* and *Carex atherodes*. The seedlings of the fifth species, *Phragmites australis*, reached their maximum density at a height well below that at which adult plants were most frequently encountered prior to deep flooding.

(4) Seedlings of *Scirpus lacustris*, *Typha* spp., and *Phragmites australis* all had maximum densities at the same height. Seedlings of *Scolochloa festucacea* and *Carex atherodes* also reached maximum densities at about the same height. Seedlings of more than one species were found in 81% of the permanent quadrats sampled.

(5) For a given species, the difference in heights between permanent quadrats where maximum densities of seedlings occurred and seed bank samples with maximum densities of germinable seeds was generally no more than 20 cm; most distributions were unimodal. Along the height gradient, differences in environmental conditions seem to have had less effect than the distribution of seeds on the distribution of seedlings.

(6) These differences in distributions along the height gradient and frequencies of monodominant stands between seedlings and adult plants imply that postrecruitment processes play a major role in the development of zonation patterns in the wetland studied.

811. WELLING, C. H., R. L. PEDERSON, AND A. G. VAN DER VALK. 1988. Temporal patterns in recruitment from the seed bank during drawdowns in a prairie wetland. Journal of Applied Ecology 25:999–1007.

We describe temporal patterns in seedling recruitment of seven wetland plant species in a Canadian prairie marsh. Recruitment occurred during artificial drawdown or drainage of diked marshes. Two-year and 1-year drawdown treatments initiated in different years are compared. Within a season, most seedlings were recruited during June when soil moisture was high, temperature was moderate, and conductivity was low. Differences between drawdown treatments in first-year recruitment of certain species seem to be due to differences between years in soil moisture and temperature, not differences in densities of seeds in the soil prior to drawdowns. Far fewer emergents but more mudflat annuals were recruited during the second year of the 2-year drawdown than during the first. Considerable mortality occurred during the second year in seedlings of emergent species established in the first year of the 2-year drawdown. The implications of these results for management of wetlands as waterfowl habitat are discussed.

812. WHITE, D. S., AND S. J. WHITE. 1977. The effect of reservoir fluctuations on populations of *Corbicula manilensis* (Pelecypoda: Corbiculidae). Proceedings of the Oklahoma Academy of Science 57:106–109.

Fluctuations in water level greatly reduced populations of the Asiatic clam in Lake Texoma, Oklahoma. Clams were most numerous near the shore in 2–30 cm of water. A drop in water level from August through February 1976 stranded so many clams that their shells formed wind rows along beaches. Laboratory experiments showed that clams exhibited 50% mortality after 4 days of desiccation, 75% after 6 days, and 90% to 98% after 10 days.

813. WHITEHOUSE, J. W. 1971. Some aspects of the biology of Lake Trawsfynydd, a power station cooling pond. Hydrobiologia 38:253–288.

In Lake Trawsfynydd, Wales, water levels fluctuated ±1.5 m above mean sea level in response to water discharge for generating electric power. Beginning in 1962, the lake also provided cooling water for a nuclear power plant. Rising and falling lake levels intermittently exposed and reflooded the shore and prevented the growth and survival of aquatic macrophytes and the development of littoral benthos. There was no true profundal fauna, and the abundance of sublittoral benthos (chironomids and oligochaetes) was patchy. Zooplankton did not seem to be affected by fluctuating water levels.

814. WHITLOW, T. H., AND R. W. HARRIS. 1979. Flood tolerance in plants: A state-of-the-art review. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, Technical Report E-79-2. 161 pp.

Both the basic aspects of flood tolerance in plants and the applied aspects of establishing vegetation on reservoir shorelines are discussed through a comprehensive literature review. Flooding imposes complex stresses on many vascular plants, most of which arise from the depletion of oxygen in the flooded soil. Soil anoxia results in conditions that favor reduction reactions and anaerobic metabolism, which lead to the formation of ions in reduced valence states and organic acids and gases in concentrations exceeding those in aerobic soils. Changes in pH accompanying soil reduction may also alter nutrient availability. Plants avoid or mitigate these flooding stresses by either transferring oxygen into their roots via anatomical modifications in the shoot and/or by utilizing anaerobic respiration pathways in their roots. In addition to a plant's ability to withstand soil anaerobiosis, plant age, plant size, flood depth, flood duration, flood timing, substrate composition, wave action, and other factors determine survivorship when plants are flooded. Studies are reviewed that correlate these factors with species tolerances. A detailed summary of research relating directly to reservoir revegetation is provided, and species tolerances are assessed for each of the Army Corps of Engineers Divisions. Techniques for the establishment of vegetation around reservoirs are discussed, as are examples of species mortality prediction and impact assessment. Additional work is required concerning the integrated plant response to flooding, refined species tolerance assessments, reservoir revegetation techniques, and the selection of species suitable for reservoir environments.

815. WICKLIFF, E. L. 1932. Are newly impounded waters in Ohio suitable for fish life? Transactions of the American Fisheries Society 62:275–277.

Fish productivity of 12 Ohio impoundments was compared on the basis of physical, chemical, and biological variables. Substantial populations of crustaceans and algae were found in all reservoirs, regardless of reservoir age. The number of benthic animals was as high in new as in old reservoirs. Detrimental effects of fluctuating water levels are mentioned in relation to fish spawning and the establishment of aquatic vegetation.

816. WIEBE, A. H. 1938. Limnological observations on Norris Reservoir with special reference to dissolved oxygen and temperatures. Transactions of the North American Wildlife Conference 3:440–457.

Thermal stratification and the distribution of dissolved oxygen, free carbon dioxide, pH, and total alkalinity were studied in Norris Reservoir. A dissolved oxygen minimum at 40 ft was caused by subsurface movements of stagnant water from the head of the reservoir to the dam. These subsurface movements were accelerated by drawdown. In fall, as drawdown continued, the depth of the thermocline and oxygen minima increased due to the influx of fresh water from inflows.

Eventually the thermocline disappeared and summer stratification ended before the normal fall turnover.

817. WIEBE, A. H. 1960. The effects of impoundments upon the biota of the Tennessee River system. Seventh Technical Meeting, 1958. International Union for Conservation of Nature and Natural Resources, Technical Report 4:101–117.

Operations of reservoirs on the Tennessee River are described. Effects of impoundment on invertebrates, fisheries, and waterfowl are discussed. Water levels are manipulated to provide for flood control, hydropower generation, and mosquito control. Annual patterns of water-level fluctuation are related mainly to the hydrological cycle—waters usually rise to a maximum in March due to spring rains and recede to some minimum level in December. The extent of drawdown varies greatly among reservoirs—from less than 10 ft in mainstream reservoirs to as much as 150 ft in storage reservoirs during severe drought. By maintaining water at some constant level late into the growing season, terrestrial plants that provide mosquito habitat do not develop in dewatered areas, and fish spawning and early growth stages of fish benefit.

818. WILCOX, D. B. 1987. Effects of river discharge on tailwater habitat at Lock and Dam 3, Upper Mississippi River. Pages 78–90 *in* Proceedings of the Forty-Third Annual Meeting of the Upper Mississippi River Conservation Committee, Winona, Minnesota, March 10–12, 1987.

A numerical hydraulic model was used to make maps of current velocity at different levels of river discharge. These maps were then compared with maps of substrate type and depth to inventory basic physical habitat. (Abstract only)

819. WILCOX, D. A., AND J. E. MEEKER. 1991. Disturbance effects on aquatic vegetation in regulated and unregulated lakes in northern Minnesota. Canadian Journal of Botany 69:1542–1551.

The effects of water-level regulation on aquatic macrophyte communities were investigated by comparing two regulated lakes in northern Minnesota with a nearby unregulated lake. Natural annual fluctuations of about 1.8 m were replaced with fluctuations of 1.1 and 2.7 m in the regulated lakes, and the timing of water-level changes was also altered. Quadrats were sampled along transects that followed depth contours representing different plant habitats in the unregulated lake. Ordinations showed that the macrophyte communities at all sampled depths of the regulated lakes differed from those in the unregulated lake. The unregulated lake supported structurally diverse plant communities at all depths. In the lake with reduced fluctuations, only four taxa were present along transects that were never dewatered; all were erect aquatics that extended through the entire water column. In the lake with increased fluctuations, rosette and mat-forming species dominated transects where drawdown occurred in early winter and disturbance resulted from ice formation in the sediments. The natural hydrologic regime at the unregulated lake resulted in intermediate disturbance and high diversity. There was either too little or too much disturbance from water-level fluctuations in the regulated lakes, both resulting in reduced structural diversity.

820. WILCOX, D. A., AND J. E. MEEKER. 1992. Implications for faunal habitat related to altered macrophyte structure in regulated lakes in northern Minnesota. Wetlands 12(3):192–203.

Water-level regulation has altered the plant species composition and thus the structure of nearshore aquatic macrophyte communities in two regulated lakes in northern Minnesota is compared with a nearby unregulated lake. Results of previous faunal studies in the regulated lakes were used as a

basis for assessing the effects of vegetation changes on faunal communities. The unregulated lake, with mean annual water-level fluctuations of 1.6 m supported structurally diverse plant communities and varied faunal habitat at all depths studied. Mean annual fluctuations on one regulated lake were reduced to 1.1 m, and dense beds of four erect aquatic macrophytes dominated the 1.75-m depth that was never dewatered. We suggest that this lack of plant diversity and structural complexity resulted in diminished habitat for invertebrates, reduced availability of invertebrates as food for waterbirds and fish, reduced winter food supplies for muskrats, and reduced feeding efficiency for adult northern pike, yellow perch, and muskellunge. Mean annual fluctuations in the other regulated lake were increased to 2.7 m, and rosette and mat-forming species dominated the 1.25-m depth that was affected by winter drawdowns. We suggest that the lack of larger canopy plants resulted in poor habitat for invertebrates, reduced availability of invertebrates as food for waterbirds and fish, and poor nursery and adult feeding habitat for many species of fish. In addition, the timing and extent of winter drawdowns reduced access to macrophytes as food for muskrats and as spawning habitat for northern pike and yellow perch. In regulated lakes throughout the world, indirect effects on aquatic fauna resulting from the alteration of wetland and aquatic macrophyte communities should be considered when water-level management plans are developed.

821. WILLIAMS, D. C., J. ROGALA, J. BARKO, AND S. ROGERS. 1994. Depth effects on the distribution of aquatic plants in Pool 8 of the Upper Mississippi River System. Page 11 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

Analysis of Geographic Information System overlays of plant distribution and bathymetry showed that distribution patterns of both emergent and submerged vegetation were closely related to depth through Pool 8. Depth distribution thus accounted for most of the differences in plant distribution in the upper, middle, and lower pool. The depth relation is seemingly related to light penetration as related to Secchi disk transparency. There was no preliminary evidence that wind-generated turbidity in the lower pool affected the depths reached by submergent plants in that area. (Abstract only)

822. WILLS, D. 1970. Chufa tuber production and its relationship to waterfowl management on Catahoula Lake, Louisiana. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 24:146–153.

Chufa (*Cyperus esculentus*) was studied at Catahoula Lake, Louisiana, between 1962 and 1966. Production of chufa is dependent upon the annual drawdown of the lake to a dry condition. Any permanent pooling of water on the lakebed will destroy the value of chufa as a waterfowl food.

823. WILSON, K. A. 1960. Effects of water level control on muskrats. North Carolina Wildlife Resources Commission. 5 pp.

During the 13 years (1947–1959) that muskrat house counts have been made on the Northwest River and Tice marshes, stable water levels of 1 to 6 inches normally support from three to seven times as many muskrats as marsh subjected to water-level fluctuations.

824. WILSON, K. D. 1959. Report of the second fall and winter drawdown on Blue Mountain Lake. Arkansas Game and Fish Commission, Federal Aid Project F-1-R. 8 pp.

The second drawdown of Blue Mountain Lake, Arkansas, was designed to aerate bottom muds, remove rough and commercial fishes, concentrate forage fishes for greater predation by sport fishes, and allow seeding of rye grasses. Preliminary results indicate that the drawdown augmented low flows downstream and improved the flood-control capacity of the impoundment, at least for 1 year. Fishing on the main body of the lake decreased greatly during drawdown, but remained relatively stable in upstream areas. Population samples contained a larger proportion of predators (by number and weight) than samples taken a year before drawdown. Fishing pressure may have become less seasonal, as suggested by a poll of boat-dock operators.

825. WILSON, K. V. 1973. Changes in floodflow characteristics of a rectified channel caused by vegetation, Jackson, Mississippi. U.S. Geological Survey, Journal of Research 1:621–625.

Extreme changes in velocity, stage, and Manning's roughness coefficient, *n*, were observed during the first year after canalization of Hanging Moss Creek at Jackson, Mississippi. Additional changes were observed during the following 8 years. The channel, constructed in summer 1963, had a 50-ft-wide bottom, 2:1 side slopes, and a 12-ft depth. In March 1964, average velocities of 7.8 ft/s were measured at a 5.5 depth in the clean channel and Manning's *n* was computed to be 0.022. In October 1964, the average velocity was 3.2 ft/s at a 5.5-ft depth and Manning's *n* was 0.045. The channel was then lined with fairly thick vegetation consisting of small willows, weeds, and grass. In October 1970 (summer foliage existing), the average velocity was 2.0 ft/s at a 5.5-ft depth and Manning's *n* was 0.07. Willow trees, 8 to 10 ft high, then lined the channel. In March 1971 (barren foliage), Manning's *n* was 0.05. In March 1972 (barren foliage), Manning's *n* was increased to 0.07. These observations indicate that the commonly used values of Manning's *n* for channel rectification (0.02–0.03) are low and that the carrying capacity of earthen channels may be reduced 50% as a result of only 1 year's growth of vegetation and 70% as a result of 8 year's growth. The carrying capacity during summer foliage is approximately two-thirds the carrying capacity during barren winter foliage.

826. WILSON, S. D., R. J. MOORE, AND P. A. KEDDY. 1993. Relationships of marsh seed banks to vegetation patterns along environmental gradients. Freshwater Biology 29(3):361–370.

The relation of the seed bank to the vegetation of a freshwater marsh was studied along gradients of water depth and soil organic matter content. Characteristics examined included standing crop, seedling density, and species composition, distribution, and richness. The seed bank differed from the vegetation in that 9 of 27 species were present in both, abundant seed-bank species were uncommon as adults, and adults showed different distributions along a gradient of soil organic matter content, whereas their seeds were most abundant in soils with high organic matter. The seed bank resembled the vegetation in that separate multivariate analyses of the communities revealed that variation in the species composition of each was significantly correlated with water depth and soil organic matter content. Further, species richness in both communities decreased with water depth and increased with soil organic matter. Last, the standing crop of the vegetation and the number of seedlings both decreased with water depth and increased with soil organic matter. Consideration of spatial patterns and environmental gradients revealed more similarities between vegetation and seed banks than were obtained by comparing species lists. The results suggest that artificial stimulation of seed bank germination for management purposes will not produce vegetation changes as large as those suggested by differences in species lists.

827. WLOSINSKI, J. H. 1994. The changing relationship between discharge and water levels in the open river portion of the Upper Mississippi River. Page 17 *in* Proceedings of the Mississippi River Research Consortium, Volume 26, La Crosse, Wisconsin, April 28–29, 1994.

The U.S. Geological Survey and the U.S. Army Corps of Engineers have measured daily discharges and water surface elevations at three sites on the main stem of the Upper Mississippi River. Data for these two variables are available since 1861, 1933, and 1942 at St. Louis, Missouri, Thebes, Illinois, and Chester, Illinois, respectively. Analysis included provisional data from the Flood of 1993. These long-term daily datasets were analyzed to evaluate changes in the relationship between the two variables. Analysis was performed by developing regression equations of water surface elevations and discharges at each station on a yearly basis. Data for years with relatively low *R*-squared values were investigated for possible errors. At St. Louis, the station with the longest record, water surface elevations associated with relatively low discharges (50,000 cfs) have dropped approximately 8 ft over the period of record. However, water surface elevations associated with relatively high discharges (780,000 cfs) have risen about 8 ft over the period of record. The decline in water surface elevations at low discharges has been somewhat gradual, but the increase in water surface elevations at high discharges seems more abrupt, with the greatest change occurring between 1927 and 1947. Changes in the relationship are discussed as they pertain to data collection methods and the history of watershed practices and floodplain management on the Upper Mississippi River. (Abstract only)

828. WLOSINSKI, J. H., AND L. HILL. 1993. Spatial and temporal variations in water level fluctuations in the Upper Mississippi River. Page 43 *in* Proceedings of the Mississippi River Research Consortium, Volume 25, La Crosse, Wisconsin, April 22–23, 1993.

Variations in water-level fluctuations were investigated for over 115 gages located on the main stem of the Upper Mississippi River between river miles 2 to 854. Yearly fluctuations, calculated from the highest and lowest reading for a station for the year, were based on data collected daily between 1972 and 1990. A positive relation was found as a function of location within a pool, with fluctuations averaging 11.3 ft for all tailwaters to 4.4 ft just above the dams. Among pools, tailwater fluctuations generally increased from north to south, from approximately 6 to 20 ft. Fluctuations also increased in a southerly direction for gages just above the dams, although the relation was not as strong. Different management schemes among pools may have confounded results at the dams. In the open river, yearly fluctuations averaged 29.3 ft over a 19-year period for 23 gages. Daily fluctuations were investigated by using data from 1990. Daily values were obtained by subtracting the reading taken at approximately 6:00 a.m. on consecutive days. The same relations were found for daily fluctuations among pools as were found for yearly fluctuations. In the tailwaters, daily fluctuations from north to south varied from approximately 0.2 to 0.5 ft. Average daily fluctuations above the dams were around 0.2 ft. (Abstract only)

829. WLOSINSKI, J. H., D. J. KRZOSKA, AND K. L. LUBINSKI. 1992. Variations in water level fluctuations within navigation pools of the Upper Mississippi River. Page 61 *in* Proceedings of the Mississippi River Research Consortium, Volume 24, La Crosse, Wisconsin, April 30–May 1, 1992.

Water-level fluctuations during a year vary widely at different locations within each navigation pool of the Upper Mississippi River. Fluctuations are greatest in the tailwater areas, with the lowest fluctuations usually occurring just above the dam. Differences between yearly high and low water elevations can be as much as five times greater in tailwater areas compared with lower parts of the pool. Variations in the extent of water-level fluctuations within a pool vary as a function of the type of water year (wet versus dry) and the management scheme implemented by the Corps of Engineers for each particular pool. In some areas of a pool, management schemes do not allow inundation of lands during dry years, even during the spring flood pulse. In the lower parts of pools, which are regulated using a midpool primary control point, water levels may remain stable or actually drop with increasing discharge. Variations in water-level fluctuations within a pool make it difficult to generalize the effects of hydrologic events on the ecosystem. (Abstract only)

830. WOLF, K. E. 1955. Some effects of fluctuating and falling water levels on waterfowl production. Journal of Wildlife Management 19:13–23.

Three areas in northern Utah and southern Idaho were studied from April through September 1951. The data obtained from the broad study indicated little or no difference in survival between the areas of falling, stable, and fluctuating water levels.

831. WONES, A. G., AND G. L. LARSON. 1991. The benthic macroinvertebrate community in a coastal sand dune lake relative to habitat and changing lake levels. Hydrobiologia 213:167–181.

The benthic macroinvertebrate community (BMI) in Carter Lake, Oregon, a freshwater coastal dune lake without a surface outlet, was investigated in May and October 1986. Fifty-three invertebrate taxa were identified, including three euryhaline crustacean species (*Corophium spinicorne, Gnorimosphaeroma oregonensis lutea*, and *Acanthomysis awatchensis*). *Corophium spinicorne* dominated the BMI communities of the littoral zones and sphaeriid clams dominated the deepwater community. The lake level dropped about 2.5 m between April and October. Based upon this decline, the lake bottom was divided into four major habitats: a sandy temporarily submerged littoral zone (A); a sandy submerged littoral zone (B); a middepth zone of mixed mud and sand and the macrophyte, *Nitella* (C); and a deep zone (D) with soft mud. The average density of BMI was highest in the littoral zones (A and B) in May and in zone B in October (zone A was dry). The lowest density occurred in zone D. In May, BMI biomass was highest in the littoral zones, but the biomass was highest in the middepth zone in October. The middepth zone had the most diverse community.

832. WOOD, R. 1951. The significance of managed water levels in developing the fisheries of large impoundments. Journal of the Tennessee Academy of Science 26(3):214–235.

Progress in developing fish and wildlife resources associated with impoundments has been impeded by a scarcity of sound techniques for management and by the fact that most management programs designed to enhance fisheries conflict with those designed to enhance wildlife. Programs to enhance fish and wildlife resources frequently conflict with the primary purpose of the project and with malaria control. To provide a basis for further study, the author reviewed literature published before 1950 pertaining to water-level fluctuation and its relation to basic fertility of impoundments, fish populations and management, and increased yields of fish. Productivity of reservoirs depends on the fertility of the watershed and the availability of essential plant nutrients from bottom soils. Management of water levels to alternately expose and flood bottom soils can be a valuable method for maintaining productivity of large impoundments, especially if plants are introduced or permitted to grow on exposed soils, thereby enhancing the release of nutrients from soils. Upon reflooding, available nutrients and improved clarity of waters result in increased productivity. Fishing success and quality depend on the type of fish present and the productivity of the reservoir. The best fishing is provided by expanding populations (which are characteristic of new impoundments and which provide the best management possibilities) and by balanced populations, especially if most of the biomass is composed of game fishes. Drawdown has been effective in restoring the balance between predators and prey and between rough and game fishes, either by itself or as a facilitative technique. The composition of fish present will depend not only on the initial populations but also on habitat conditions for spawning and feeding and on rates of harvest. Habitat favorable to desirable fish populations may be produced by the management of water levels. Manipulation of water levels may be used to increase fishing success and fish yield by concentrating sport fish around preferred habitat such as newly inundated areas or structures.

833. WOOD, R., AND D. W. PFITZER. 1960. Some effects of water-level fluctuations on the fisheries of large reservoirs. Seventh Technical Meeting, 1958. International Union for Conservation of Nature and Natural Resources, Technical Report 4:118–138.

Speculation, concepts, and experiments concerning the effects of water-level fluctuation on fish and fisheries are reviewed to evaluate the progress of biologists in developing an understanding of the relations. Fish population data from five reservoirs with different patterns of fluctuation are presented. Data suggest that fish are affected by the season, frequency, stage, and duration of fluctuations, as well as by basin morphology. Different aspects of fluctuations (time, duration, rate, magnitude, and direction of changes) affect the productivity, species composition, and predator–prey ratios of fish communities. Evidence suggests that the ratio of area at maximum pool to that at minimum pool is a good indicator of sport fish productivity in most of the reservoirs discussed. High ratios indicate a great deal of overflow over relatively shallow areas, whereas low ratios indicate steep-sided basins. The effects of water levels seemingly depend more on the time and duration of flooding than on the degree of vertical fluctuation. Fertility of soils and basin topography are factors enhancing the effects of water-level fluctuations. When employed discreetly and carefully, the manipulation of water levels can be an effective tool for fishery managers.

834. WOOD, W. L., M. T. STOCKBERGER, AND L. J. MADALON. 1994. Modeling beach and nearshore profile response to lake level change. Journal of Great Lakes Research 20(1):206–214.

The design of beach and nearshore change models entails a thorough understanding of the complex physical processes involved and the proper application of appropriate simplifying concepts. A large set of beach and nearshore profile data from southern Lake Michigan has been used to evaluate the widely applied equilibrium profile concept. Results of this study show that the profile form $h = Ax^m$ is appropriate for use in describing the average profile found in southern Lake Michigan. Values for the coefficient m varied from 0.3 to 1.1. Equilibrium profile adjustment to lake-level change was found to lag either a rise or a fall in lake level. The lag period could not be determined, but seems to be on the order of years.

835. WRIGHT, J. C. 1950. The limnology of Atwood Lake, a flood control reservoir. Ph.D. Thesis, Ohio State University, Columbus. 157 pp.

A large volume of information is given on all aspects of the limnology of Atwood Lake, Ohio, with special reference to the effects of limnological factors on the production of sport fishes. Atwood Lake was drained in October 1964 to reduce the large population of common carp and to improve sport fish production. When the lake was refilled to conservation pool, it was stocked with bluegills, largemouth bass, yellow perch, and channel catfish. Productivity at all trophic levels was low prior to draining, but zooplankton biomass and growth rates of fish increased after water levels rose in 1947 and inundated large amounts of organic matter. Standing crops of zooplankton were high in

1948 but declined in 1949. Productivity—not the activity of carp—is believed to be the factor limiting sport fish production.

836. WRIGHT, J. C. 1954. The hydrobiology of Atwood Lake, a flood-control reservoir. Ecology 35:305–316.

A 2-year study of the physical, chemical, and biological characteristics of Atwood Lake, Ohio, provided the basis for evaluating game-fish production and the effects of draining the reservoir. Draining in 1946 revealed that fish populations consisted primarily of emaciated black crappies and white crappies, stunted bluegills, common carp, and gizzard shad. A small population of largemouth bass was present. Phytoplankton standing crops were low throughout the study, but phytoplankters were more abundant in 1949 than in 1948, the first year after refilling. When water levels rose in 1947, large amounts of organic matter were available to zooplankton. Zooplankton standing crops were high in summer 1948, particularly in areas flooded for the first time. Decreased zooplankton biomass in 1949 seemingly was related to continued decay of inundated organic matter. The biomass of benthos was low throughout the study and correlated to the low production of phytoplankton. After the lake was reflooded, the growth of fish was rapid in the first year but declined in the second year. Largemouth bass was the only species that grew fast enough to provide good fishing.

837. YAKOVLEVA, A. N. 1971. Natural reproduction of fish in the Volgograd Reservoir. Trudy Saratovskogo Otdeleniya Gosudarstvennogo Nauchno-Issledovatel'skogo Instituta Ozernogo i Rechnogo Rybnogo Khozyaistva 10:107–128. (In Russian)

Upper, middle, and lower zones of the Volgograd Reservoir were differentiated according to hydrological properties. Natural reproduction of fish was more efficient in the upper and middle zones than in the lower zone. Drops in the reservoir water level each spring disrupted spawning. In the middle zone, intensive erosion of shores and the resulting weak development of water plants adversely affected fish production. A decrease in water level by 1–1.5 m caused egg mortality and delayed spawning. The reservoir conditions were more favorable for Volga pike-perch, pike, and perch than for lithophilic and phytophilic fish, except for bream, catfish, and white bream. Among commercially valuable fish, wild carp, and pike had very low spawning efficiencies. (From Referativmyi Zhurnal. Biologiya 1971, 91210; Biological Abstract 54:18931)

838. YAMASAKI, S., AND I. TANGE. 1981. Growth responses of *Zizania latifolia*, *Phragmites australis*, and *Miscanthus sacchariflorus* to varying inundation. Aquatic Botany 10:229–239.

Zizania latifolia Turcz., *Phragmites australis* (Cav.) Trin. ex. Steud., and *Miscanthus sacchariflorus* Benth. are the three main species, in that sequence, constituting zonations from deeper water to drier areas along river banks and lake shores in central Japan. Their growth responses were studied by transplanting them in an 8-m sloping field, constructed in a wet area. The driest and flooded ends of the slope were 60 cm above and 60 cm below the water level, respectively. Each species was planted in an area 1.7 × 8 m at a density of 35–36 plants m^{-2} in early October 1975. Shoot length, density, and some soil characteristics were measured from 1976–1978. When the yields were estimated in midsummer, best growth of the three species overlapped in the drier plots, showing a clear contrast with that of the natural distribution. When considering the yield or plant height in late spring, however, best growth occurred in the same sequence as in the natural distribution. This result suggests that optimal growth in the early growth stages is critical for the development of the natural distribution patterns when these species are grown together, because initial dominance in height is advantageous for subsequent competition.

839. YANOSKY, T. M. 1982. Effects of flooding upon woody vegetation along parts of the Potomac River floodplain. U.S. Geological Survey, Professional Paper 1206:1–21.

A two-part study along the Potomac River floodplain near Washington, D.C., was undertaken to investigate the effects of flooding upon woody vegetation. Floods abrade bark, damage branches and canopies, and often uproot trees. The first study was of vegetation in five monumented floodplain plots, which differed in the frequency and severity of flood flow over a 10-year period. Basal area and survival of trees seem to be related to velocity of flood flow, which in turn is related to flood magnitude and channel shape. However, the effects of flooding also depend on the nature of the floodplain surface and size and growth habit of vegetation. In the second study, a catastrophic flood following Hurricane Agnes in June 1972 was found to cause large-scale changes in the age, form, and species composition of floodplain forests below Great Falls, Virginia. The effect of the flood depended primarily on the flow regime of the river; destruction was greatest in areas exposed to the maximum flood force, and minimal at sheltered locations. Age determinations from dead trunks and surviving trees suggest that most trees in severely damaged areas started to grow after the last great flood, which occurred in 1942. Trees along sheltered reaches survived several previous catastrophic floods. In addition, species varied in their ability to withstand damage from the Hurricane Agnes flood. The least likely to recover were species growing on infrequently flooded surfaces, which may explain, in part, their absence at lower floodplain altitudes.

840. YANOSKY, T. M. 1982. Evidence of floods on the Potomac River from anatomical abnormalities in the wood of flood-plain trees. U.S. Geological Survey, Professional Paper 1296:1–42.

Ash trees along the Potomac River floodplain near Washington, D.C., were studied to determine changes in wood anatomy related to flood damage. Samples were collected as cross sections, and anomalous growth was compared with flood records from 1930 to 1979. Collectively, anatomical evidence was detected for 33 of the 34 growing-season floods during the study period. Evidence of 12 floods prior to 1930 was also noted. Trees damaged after the transition from earlywood to latewood growth typically formed "flood rings" of enlarged vessels within the latewood zone. Trees damaged during the earlywood-growth interval developed flood rings within, or contiguous with, the earlywood zone. Both patterns are assumed to have developed after refoliation of flood-damaged crowns.

841. YEAGER, L. E. 1959. Effect of permanent flooding in a river-bottom timber area. Illinois Natural History Survey, Bulletin 25(2):33–65.

The effect of water impoundment on timber was studied over an 8-year period, 1939–1946, at the junction of the Mississippi River and Illinois River. Sizable tracts of timber were affected by the Alton Dam impoundment, first pooled in 1938. Water-level fluctuations were extreme over very short periods. The rate of dying in tree species and the succession of aquatic vegetation was studied. Among timber species, pin oak was most susceptible to injury from flooding and white ash was most resistant. Changes in populations of birds and mammals were noted.

842. YOAKUM, J., W. P. DASMANN, H. R. SANDERSON, C. M. NIXON, AND H. S. CRAWFORD. 1980. Habitat improvement techniques. Pages 329–403 *in* S. D. Schemnitz, editor. Wildlife Management Techniques Manual. Fourth edition revised. The Wildlife Society, Washington, D.C.

The authors outline water-level control techniques for habitat manipulation practices. Management techniques are provided for pondweed, smartweed, duck potato, spike sedges, duckweeds, coontail, grasses, and alkali bulrush.

843. ZAREMBA, R. E., AND E. E. LAMONT. 1993. The status of the Coastal Plain Pondshore community in New York. Bulletin of the Torrey Botanical Club 120(2):180–187.

The Coastal Plain Pondshore plant community occurs in New York in central and eastern Long Island on glacial moraine and outwash deposits. These open grass and sedge-dominated communities are maintained by seasonally and annually fluctuating water levels that alternately expose and flood gradually sloping, sandy pond margins. High water levels prevent shrubs from colonizing the broad, open shorelines. This dynamic plant community supports one of the highest concentrations of rare species in the state. Threats to the community and conservation strategies are also discussed.

844. ZIMMERMAN, J. L. 1977. Virginia rail (*Rallus limicola*). Pages 46–56 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C.

Virginia rails build their nests in shallow sedge and cattail belts over the water. Flooding is believed to be one of the major causes of nest loss.

845. ZIMMERMAN, J. L. 1984. Distribution, habitat, and status of the sora and Virginia rail in eastern Kansas. Journal of Field Ornithology 55(1):38–47.

The mean water depth with no Virginia rails was 7.7 cm; mean depth with one to five rails was 9.2 to 15.5 cm.

846. ZWEIACKER, P. L., R. C. SUMMERFELT, AND J. N. JOHNSON. 1972. Largemouth bass growth in relationship to annual variations in mean pool elevations in Lake Carl Blackwell, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 26:530–540.

Growth of first- and second-year largemouth bass was related to mean annual water levels, as water levels declined from 1962 through 1967. The relation was positive in first-year bass ($r = 0.85$; $P < 0.035$) and negative for second-year bass ($r = -0.95$; $P < 0.004$). It was hypothesized that the growth of small bass declined because of the negative effect of dewatering on invertebrates in the littoral zone. The increased growth of second-year bass probably resulted from a greater vulnerability of forage fish to fish predators as water levels receded. Growth rates of third- and fourth-year bass were not significantly correlated with declining water levels.

Subject Index

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.