Where nutrient control is not the answer: Lake Apopka and Lake Okeechobee, Florida
R. Bachmann, D. Canfield, and M. Hoyer
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004
Hundreds of millions of dollars have been spent on nutrient control as the dominant management strategy for two large, shallow, eutrophic lakes in Florida with little or no improvement in their water quality or fisheries. Starting in 1947 Lake Apopka switched from a macrophyte-dominated deepwater marsh with an outstanding largemouth bass fishery to a turbid, algae-dominated lake. The resuspension of a layer of flocculent sediments has prevented the reestablishment of the macrophyte habitat. A $100,000,000 program to reduce phosphorus inputs shows little sign of restoring the lake and its fishery. We propose an alternative to restore the largemouth bass fishery. The open waters of Lake Okeechobee, the largest shallow lake in the US, maintain a turbid state due to wave-driven sediment resuspension that results in no correlation between phosphorus concentrations and algal chlorophylls in the pelagic zone. A massive nutrient control program resulted in reductions in phosphorus inputs to the lake, yet phosphorus concentrations have increased rather than decreased. An experimental lowering of the water level in 2000 demonstrated that water level controls could rejuvenate macrophyte habitat important to the fisheries and seemed to be a more effective management technique for this lake than stringent phosphorus controls in the watershed.

Role of water level fluctuation in Meditteranean shallow lakes: case Turkish shallow lakes.
M. Beklioglu
THE 7th INTECOL INTERNATIONAL WETLANDS CONFERENCE IN UTRECHT, THE NETHERLANDS (JULY 25-30, 2004)
Functioning of shallow lakes is expected to be very sensitive to water level fluctuation (WLF) which is an influential element of hydrology. Relationship between the WLFs and occurrence of alternative stable states were investigated in five Anatolian shallow lakes of Turkey, which are under the influence of semi-arid to arid Mediterranean climate. Four of the study lakes shifted to submerged plant dominated state whilst the water levels were lower than that of the long-term average. In these lakes, the low water level periods created a flatter bottom with an increased morphometry index (Zmean/Zmax). One of the study lakes shifted to submerged plant dominated state at significantly high water level occurring winter. Furthermore, the same lake had increased morphometry index and lake surface area by 20% at the high water level period. In all the study lakes, shift to the submerged plant dominated state coincided with a significant decrease in the amplitude of the intra-annual fluctuations. Moreover, in all the study lakes, vegetated state was characterized by the presence of significantly high density of waterfowl, especially coot (Fulica atra) and the low biomass of carp (Cyprinus carpio). With the recovery of the vegetation, the lakes supported internationally important number of waterfowls, hence, conservation value of the lakes boosted. Consequently, the lakes received different protection status including Ramsar site, A-class wetland and Important Bird Area. In conclusion, water level fluctuations may have a profound impact in affecting bottom profile through determining the extent of littoral zone and the subsequent ecological interactions.

The roles of water level fluctuations and nutrients in determining macrophyte dominated state of Turkish shallow lakes: Lake Mogan a case study
M. Beklioglu and C. Tan.
International Conference on Limnology of Shallow Lakes, Balatonfüred, Hungary 25-30 May 2002
Lake Mogan is a large shallow lake (surface area: 550 ha, Zmax: 3.9 m; Zmean: 1.99 m).During the period of 1998–2001, the concentrations of total phosphorus (TP) and chlorophyll-a increased significantly (87±014 and 18.1±2.1 mg l-1, respectively) compared to the concentrations recorded in 1997 (73±10 and 9±1.1 mg l-1,respectively). However, the Secchi depth transparency remained high that in turn may have maintained the high coverage of submerged plants. Even though there was sign of deteriorations, the submerged plants persisted that can be attributed to 38 cm drop in the mean water level. Lake Mogan previously also had a shift from turbid water to macrophyte dominated clear water 30 years ago through the implementation of the flood control which led to 47 cm drop in the mean water level and 4–7 folds decrease in the amplitude of the water level fluctuations. This shift took place regardless of any significant change in the concentrations of nutrients. The shift to the submerged plant dominated clear water state increased the conservation value of Lake Mogan that 180waterfowl species were recorded and were dominated by coot and diving duck. Consequently, the lake qualifies as an Important Bird Area (IBA). Beyºehir, Marmara and Uluabat Lakes also provided evidence for the structuring role of the water level draw down through which lakes shifted to exclusively submerged plant dominated clear water state. In these lakes, 0.5 to 2 m drop in the spring water level due to sporadic drought, and decrease in the amplitudes of the water level fluctuations appeared to be the main reason behind the shift since the sparse vegetation state was recorded at low

availability of phosphorus. Through the shift to the submerged plant dominated state, ecological and conservation value of these lakes increased especially due to 10–15 folds increase in the waterfowl density that all the lakes qualify as IBAs and A class wetlands and Lake Uluabat has also been designated as a RAMSAR site since 1998. In sum, water level changes appear to play a structuring role in the ecology of Turkish shallow lakes.

Restoration of Lake Eymir, Turkey by biomanipulation and water level draw-down
M. Beklioglu,
International Conference on Limnology of Shallow Lakes,Balatonfüred, Hungary 25-30 May 2002
Over 25 years of raw sewage effluent discharge shifted Lake Eymir from a lake that had formerly submerged plants, dominated largely by Charophytes with 6–7m of outer depth of colonization, to turbid water state. Partial sewage effluent diversion undertaken in 1995 led to some reduction in the in-lake concentration of nutrients, which remained still very high (324 mg TP l-1 and 0.1 mg DIN l-1), and the water clarity expressed as Secchi depth was poor (111 cm). The surface coverage of submerged plants was limited (2.5 %). Domination of the fish stock by benthiplanktivorous tench and common carp and their top-down effect appeared to have been the reason for low water clarity and low vegetation cover. The removal of 57 % of the fish, which was accomplished within 1.5 years, led to 2.5 fold increase in the Secchi disk transparency. This was probably induced by the 4.5 fold decrease in inorganic suspended matter, as well as a significant reduction in the phytoplankton crop. However, a delay was recorded in the redevelopment of the submerged plants, whose coverage increased only to 6.2 % of the total surface area of the lake, probably due to the high coot biomass and their grazing effect (24±4 ind. ha-1). Nevertheless, in 2000, the coverage of submerged plants increased to about 48 % of the lake surface area with 86±22 % PVI, and this led to a major decrease in the in-lake concentrations of TP and DIN as recorded elsewhere. The Secchi depth also trebled. The density of large-bodied *Daphnia pulex* & *Arctodiaptomus bacillifer* increased 5 to 10-fold following the fish removal. In 2001, the signs of deterioration in the concentration of TP and DIN, and water clarity were experienced. Despite this, the submerged plants coverage increased to 90 % of the lake surface area though the PVI decreased to 47±29 % This can be attributed to 80 cm drop in the water level. The signs of instability appeared to be combated through water level draw-down.

Vegetation response to 2001 and 2002 summer drawdowns on Upper Mississippi River, pool 8
G. Benjamin and K. Kenow.
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004
After almost 70 years of impoundment the mosaic of river habitats on the Upper Mississippi River are disappearing. Investigations into the use of one tool, seasonal summer drawdowns, to increase the aquatic vegetation began in 1996 to 199 with small-scale backwater drawdowns. Positive results in density and diversity of emergent and submersed aquatic species led to a demonstration of the tool on a large-scale in Upper Mississippi River, Pool 8. An 18-inch drawdown was conducted during the summers of 2001 and 2002 resulting in about 2,000 acres of the pool substrate exposed. The drawdown likely contributed to an increase in deep marsh annual, shallow marsh perennial, wet meadow, submersed aquatic vegetation, wet meadow shrub, and shallow marsh annual communities in Pool 8. Arrowhead (Sagittaria latifolia and S. rigida), false pimpernel (Lindernia dubia), water stargrass (Heteranthera dubia), teal lovegrass (Eragrostis hypnoides), rice cutgrass (Leersia oryzoides) and chufa flatsedge (Cyperus esculentus) were the dominate species that developed on exposed substrates. Second year drawdown showed a 16-fold increase in arrowhead tuber production and a shift from annual aquatic plant communities to perennials aquatic plant communities. Submersed aquatic vegetation did not appear to be negatively effected by the two years of drawdown.

Submerged macrophytes in shallow lakes and their importance for waterfowl.
Blindow, i., G. Anderson, et al. (1990)
Wetland Management and Restoration-Proc. Workshop., Sweden.
The numbers of both breeding and resting waterfowl have fluctuated drastically in several southern Swedish lakes over the last decades. In order to determine if these fluctuations are caused by variations in food availability, we studied submerged macrophtyes, invertebrates, fish and water chemistry in two lakes. One of them, Lake Takern, had high waterfowl abundance, in the other, Lake Krankesjon, the number of waterfowl had been low since the early 1970's. In Lake Takern the submerged macrophytes and macros-invertebrates were more abundant than in Lake Krakesjon. Furthermore, the growth rates of *Rutilus rutilus* (roach) and *Perca fluviatilis* (perch) were higher. The results indicat that fluctuations in waterfowl abundance are caused by changes in food availability. During the study, food availability started to improve in Lake Krakesjon. Submerged macrophytes expanded, followed by

increased macro-inverterate abundance, less turbid water and incresed numbers of breeding and resting waterfowl. The mean length of perch increased and thus also the potential influence of predatory fish on lower trophic levels. Submerged macrophytes are considered to be important for waterfowl directly as a food resource and indirectly by improving availability of other food resources (invertebrates, fish). Suitable management of this type of vegetation is briefly discussed. Water level fluctuations are considered as on the most important factors. In Lake Krankesjon, lower water levels during spring and summer are suggested to be the most probable reason for macrophyte expansion.

Ecosystem response to changes in water level in Great Lakes Marshes.
P. Chow-Fraser
THE 7th INTECOL INTERNATIONAL WETLANDS CONFERENCE IN UTRECHT, THE NETHERLANDS, July 25-30, 2004
A general understanding of how aquatic vegetation responds to water-level fluctuations is needed to guide restoration of Great Lakes coastal wetlands. In 1997, common carp (*Cyprinus carpio*) was removed from Cootes Paradise Marsh (L. Ontario) to reduce sediment resuspension and bioturbation, and thus regenerate marsh plants that had declined dramatically since the 1930s. Data from 1934 to 1993 were assembled to reassess the nature of the relationship between percent cover of emergent vegetation and water level. Areal cover of emergent vegetation declined non-linearly as water levels increased through the six decades, and this trend was confirmed for the dominant species, *Typha latifolia*, from detailed analysis of eight sets of digitised vegetation maps from 1946 to 1979. A modest recovery of emergent vegetation in 1999 following carp exclusion could have been predicted from declining water level alone. An unusually cool spring in 1997 delayed the migration of spawning planktivores into the marsh and resulted in a grazer-mediated clear-water phase that initiated a short-lived resurgence of the submersed aquatic vegetation (SAV) community in 1997, which became inhibited by the low water levels in 1999. Light conditions had been adequate to support SAV growth in the marsh, according to a published relationship between maximum depth of SAV colonization and light extinction coefficient. Since there had been no significant differences in the environment other than water depth and clarity, I suggest that wave disturbance and propagule burial associated with shallow water depths was the main reason for the disappearance of SAV in 2000.

Lake Puckaway Fishery Restoration Project—1978-1992.
Congdon, J. (1993)
Wisconsin Department of Natural Resources
Lake Puckaway was known as one of the finest hunting and fishing lakes in Wisconsin until the late 1960's. Anglers used the lake heavily year round coming long distances to try their luck on its near legendary fishing. Waterfowl hunter came after the abundant diving ducks, particularly the canvasback, that stopped to rest on the lake and feed during the fall southern migration. By the1950's, carp were recognized to be a serious problem, but as late as the early 1970's, fishing quality was still fairly good and lake use was heavy. However, the fishery began to decline precipitously as the carp population expanded. By 1976, the once abundant aquatic vegetation was nearly gone, the water was muddy brown, and angler use had declined to nearly nothing. Concerned lake users and residents as the Wisconsin DNR to develop a plan to restore the fishery waterfowl resource and water quality in Lake Puckaway. Implementation of a three phase plan involving partial drawdown of the lake, mechanical and chemical carp removal, and restocking of game fish species was begun in 1979. This report is a summary of the management program that was implemented and the results that have been achieved to restore the quality of the fishery and waterfowl resource on Lake Puckaway.

Significance of water level fluctuations for lake management
H. Coops
International Conference on Limnology of Shallow Lakes Balatonfüred, Hungary 25-30 May 2002
The regulation of water levels in Dutch lakes has been very extensive, leaving extremely little space for natural fluctuations. It is argued that the regulation has had a strong impact on ecological functioning of shallow lakes. We evaluate a number of probable impacts of a restored water-level regime. These impacts include effects on shoreline stability en emergent vegetation succession, biogeochemical processes, foodweb interactions, and biodiversity. The timing of low and high water levels and the morphology of the littoral zone are key factors. An assessment was made of the potential ecological effects of an enhanced water-level range in the Veluwemeer, a shallow eutrophic lake in the Netherlands.

Water-level management as a tool for the restoration of shallow lakes in the Netherlands
Coops, H. and S.H. Hosper 2002.
Lake and Reservoir Management 18(4):293-298.
Water-level fluctuations are among the major driving forces for shallow lake ecosystems. In the low-lying parts of tf the Netherlands, the water-level regime of lakes is strictly regulated. This is need for reducing risks of flooding and economic purposes, including maximum agricultural benefit. The fixation of water-level fluctuations, considering the functioning of (semi-)aquatic ecosystems. We review the benefits of natural water-level fluctuations, considering the impacts on nutrient inputs, nutrient concentrations, phytoplankton development and turbidity. In particular, the mediating role o submersed and emergent vegetation and filter feeders is addressed. The present government policy, to allow more space for water, presents a major challenge for combining flood prevention measures and ecological restoration. Restoration of natural water-level regimes, which is likely to lead to enhancement of water quality and biodiversity, may occur in two ways: (1) expanding the critical limits between which the water level is allowed to fluctuate annually, and/or (2) incidental recessions of the water level. It is stressed that ecologically-based water-level regimes should be incorporated into the context of multiple use of lakes.

Nutrient content and biomass of *Phragmites australis* in Lake Fertõ/Neusiedlersee
M. Dinka
International Conference on Limnology of Shallow Lakes Balatonfüred, Hungary 25-30 May 2002
The production of vigorous and die -back sites of the same reed belt, the reed growth and nutrient content of reed were studied to detect possible causes for reed degradation. Samples were collected from three vigorous and three die -back sites of Lake Fertõ/Neusiedler See from March to November in 1996 and 1997. Reed stands are compared when the biomass was maximal (August) in both years. Shoot density, total aboveground and underground biomass and their C, N, S, P contents were determined. Reed shoots were significantly shorter, thinner and had less internodium at the die -back sites than at the vigorous sites, where the aboveground biomass was 1.5–2.0, the LAI 1.7–2.5 times higher. The underground biomass was nearly the same at the vigorous sites and the die -back sites (except at site 5., which is covered by deep water). The amount of decaying underground biomass was less than 50 % of the total underground biomass at the vigorous sites, while it reached 75 % at the die -back sites. Different N, C, P and S concentrations were found on the studied reed organs (leaves, culms, rhizome, and roots). The N concentration of leaves, culms and rhizome was higher at the die -back sites, where the P concentration was the lowest. The N, P, C and S standing stock of the aboveground biomass was significantly lower at the die -back sites than at the vigorous sites. The P standing stock was significantly lower, the N standing stock significantly higher in the underground biomass of the die back sites than at the vigorous sites. Not more than 17 % of the total dry mass estimated from a given 1 m2 unit, 17 % of the C, 24 % of the N, 14 % of the S and 27 % of the P standing stock was found in the aboveground phytomass produced in the actual year. The aboveground biomass of the individual site was different between the years while the underground biomass remained relatively constant. The results indicate that not only biomass ratios but also nutrient cycling (biogeochemical processes) is characteristically different between the vigorous and the die -back sites.

Changes in the water-cover and macro-vegetation of the lower Zala valley over the last two centuries: a GIS perspective
Z. Dömötörfy, D. Reeder, P. Pomogyi
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
Cartographic surveys of Austro-Hungary began in earnest in the second half of the Eighteenth Century and provided the essential framework for planning the river regulation and land reclamation of the vast wetlands then existing in the Carpathian Basin. The level of Lake Balaton was lowered in 1863 and the first drainage works in the lower Zala valley were completed in 1865; the combined effect was that the waterbalance of the Kis-Balaton wetlands was dramatically changed and the macrovegetation profoundly affected. By the end of the Nineteenth Century the surface waters of the area had almost disappeared. Following further extensive channel works and levee construction, completed in 1925, all that remained was a large reed-bed with two small water-bodies lying at the deepest point. It was soon realized that these wetlands played a vital role in maintaining the water-quality of Lake Balaton, by trapping sediment and excess nutrients: thus siltation and eutrophication in the western basin of the lake began to be a serious problem. Also the importance of the rich natural environment of the Kis-Balaton, with its large populations of water-birds, was recognized: however it was also obvious that the areas of surface water, on which these natural assets depended, were constantly becoming smaller. In the 1950s the central part of the area was established as the Kis-Balaton nature reserve and by the 1980s it was decided to re-create the wetlands through artificial flooding. This had further profound effects on the macro-vegetation. Our research is an attempt to

summarize the quantitative and qualitative changes in the macro-vegetation of the study-area over the past two centuries. Water-level data are extant from the early 19th Century onwards and by applying these values, from selected historical times, to a digital elevation model it is possible to demonstrate the extent of the water-covered area and in many places its depth. Thus we can make assumptions on the nature and extent of the vegetation at various points in time and compare these with the results of contemporary physical surveys, from the earliest concise cartographic attempts, through the first aerial surveys of the 1930s to modern infra-red photographic technology.

Relationship Between Abundance of Largemouth Bass and Submerged Vegetation in Texas Reservoirs

P.P. Durocher, W.C. Provine, and J.E. Kraai.

Survey data from 30 Texas reservoirs, collected between 1976 and 1978 as part of the Dingell-Johnson Reservoir Management Project, were analyzed to determine which factors affected largemouth bass (Micropterus salmoides) standing crops and their recruitment to harvestable size. A highly significant, positive relationship ($P < 0.01$) was found between percent submerged vegetation (up to 20%) and both the standing crop of largemouth bass and numbers being recruited to harvestable size. The relationship seemed to be linear within the range of values observed. Any reduction in submerged vegetation below 20% of the total lake coverage resulted in a decrease in recruitment and standing crop of largemouth bass. Conversely, to increase standing crop and recruitment of largemouth bass more than 10 in long in reservoirs having little or no cover, a program to increase submerged vegetation either through introductions or water-level manipulation should be implemented.

Aquatic macrophyte growth in a turbid windswept lake.
Engel, S. and S.A. Nichols (1994).
Journal of Freshwater Ecology 9(2):97-109.
The water turbidity developed when high water destroyed wild rice beds (*Zizania palustris* var. *palustris*), allowing winds to suspend soft sediment, uproot surviving plants, and circulated nutrients. Suspended sediment and phytoplankton blooms reduced secchi disk visibility to less than 30 cm. These conditions left 61% of the water surface barren of rooted plants and forced surviving pondweeds to grow in peculiar ring or loop formations. With ice-out in mid-April and dense phtoplankton blooms by June, Rice Lake macrophytes had just 4-6 week to sprout and reach the water surface—a growth window too short for most northern species.

Restoring Rice Lake at Milltown, Wisconsin.
Engel, S. and S.A. Nichols (1994).
Madison, Wisconsin, Wisconsin Department of Natural Resources.

Wind and high water, after decades of erosion and runoff from farms and municipal wastewater treatment plant, converted a clear lake bordered by wild rice into a turbid one dominated by phytoplankton. Rice Lake at Milltown, a 52 ha (128 acre) kettle in northwestern Wisconsin, had northern wild rice (*Zizania palustris var. palustris*), waterfowl, and panfish until the mid-1970's. Then the rice almost disappeared and people up fishing and swimming. Now wind, bullheads (*Ameirus spp.*), and green algae (Chlorophyceae) keep the water turbid. How these changes occurred in Rice Lake was studied from August 1987 through October 1991. Water turbity created a depauperate macrophtye flora offshore, dominated by water lilies (*Nuphar variegatum* and *Nympaea tuberosa*), sago pondweed (*Potamogeton pectinatus*), and floating-leaf pondweed (*P. natans*). Because secchi disk transparency decrease each June to about 32 cm, macrophytes had bare 4-6 weeks to sprout and float leaves befor being shaded. Under such poor conditions, dry weight staning crop of all submersed macrophyte clumps averaged just 6-12g/m^2. Wild rice planted each fall from (0.5 acres in 1988; 2.0 acres in 1989) sprouted well and formed emergent shoots by July. But muskrates (*Ondatra z. zibethicus*) nipped most shoots ad must be controlled for wild rice to set seed and return. Then wild rice can blunt wind that creates turbidity and can store nutrients that would otherwise wash into downstream Balsam Lake.

Effects of carp, *Cyprinus carpio* L., on communities of aquatic vegetation and turbidity of waterbodies in the Lower Goulburn River Basin.
Fletcher, A.R., A.K. Morison, et al. (1985)
Aust. J. Mar. Freshw. Res. 36:311-327.

Densities of carp, ranges of turbidity, and details of communities of aquatic vegetation from 1979 to 1982 are given for several waterbodies in the Goulburn River valley including the Broken River, near Shepparton, Victoria. The turbidity values at all sited were high, typical of Austalian inland waterbodies. There was no association between high carp densities and high turbidity, and population of carp did not appear to increase turbidity. Observed turbidity increases at each site appeared to be related to hydrological changes. Fluctuation of water levels was also an important factor determining the extent of aquatic vegetation communities. However circumstantial evidence is present that shallow-rooted and soft-leaved aquatic vegetation such as *Potamogeton spp*. have been reduced by carp.

Wetland and Riparian Habitats; A non-game management overview. In Management of Nongame Wildlife in the Midwest: A Developing Art.
Fredrickson, L.H. and F. Reid (1986).
North Central Section, The Wildlife Society:59-96.
The authors discuss wildlife use of wetlands wher water is drawn down for management. Drawdowns attract a diversity of foraging birds and increase food availability by concentrating foods in smaller areas and at water depth within the foraging range of target wildlife. As dewatering progresses, deep water species are replace by those adapted to exploit foods in shallow water. For example, waterfowl like shovelers and pintaails use marshes with water that is 8-10 inches deep, whereas sandpipers, rails, snipe, yellow legs, and bitterns use water about three inches deep.

The Fox Lake experience: can hypertrophic lakes be restored?
P. Garrison, and L. Stremick-Thompson
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004
Fox Lake, a large shallow lake in southern Wisconsin, has experienced various restoration efforts during the last 4 decades. During the early 1950s, the lake shifted from a clear water macrophyte dominated phase to a turbid one dominated by algae. In 1966 the fishery was completely eradicated and for about ten years water clarity improved. Most recently, a drawdown of about 1.5 feet was conducted in 1997, without eradication of the existing fishery. The 1997 drawdown resulted in an increase in emergent vegetation for about 2 years but there was not an improvement in submergent vegetation or water clarity. A comprehensive fishery survey was conducted after the drawdown. In addition, efforts to remove benthivorous carp, control harvest of predatory gamefish, and increase recruitment of gamefish populations through stocking were also addressed as part of this project. Overall, post-drawdown catch-per-effort (CPE) for all game, pan, and rough fish decreased from pre-drawdown fish surveys. The panfish fishery remains dominated by planktivorous crappie, and the carp population was not significant reduced by the efforts of this project. The whole lake fish eradication conducted in 1966 was most beneficial for improving water quality. The 1997 drawdown may have been less successful because it was not severe enough to stimulate submergent vegetation growth, and high levels of nutrients delivered from the watershed may have been a confounding factor.

Effects of stabilized water levels in Lake Manitoba on the natural history of Delta Marsh in south-central Manitoba, Canada
G. Goldsborough and D. Wrubleski
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004.
Delta Marsh, on the shore of Lake Manitoba in south-central Manitoba, has become highly turbid over the past four decades. The shift from a former clear state is due, in part, to the stabilization of lake water levels in 1961. Our studies over the past six years have documented other changes, including a loss of submersed macrophytes and emergent plant islands from marsh bays, deteriorating water quality, and encroachment of hybrid cattails into shallow inshore areas. We have quantified gross morphometric changes in ponds around the periphery of the marsh, over a 50-year period, using a time series of aerial photographs. Temporal changes in the distribution of marsh vegetation were mapped using high-resolution infrared imagery. In 2003, dramatic seed bank recruitment coincided with the lowest water levels in nearly a century. A proposal by a multi-stakeholder group is presently advocating the partial deregulation of Lake Manitoba as a remedial measure for Delta Marsh and other coastal wetlands; the process by which consensus was achieved will be discussed.

Limnology of temperate shallow lake in last stage before dry up
A. Górniak, M. Baranowski, P. Zieliñski
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002

Gorbacz Lake (area 44 ha), situated in the regional water divide in NE Poland, was mires shallow lake. Lake completely dried up cause of catchment melioration and climatic condition consequence in year 2000. Surrounding bog and fen areas created dystrophic lake ecosystem with pH < 6 and EC < 100 µS/cm. In the last stage of lake existence, macroions and nutrient concentrations were posit ively correlated with the water column thickness. High DOM concentration, relatively aliphatic, was accompanied by low water colour. The chlorophyll a concentrations increased with decreasing lake water level caused by benthos algae enrichment. Cyanobacteria and Chlorophycea dominated in phytoplankton with a strong space diversity. Zooplankton (mean 47 ind./L) was represented by 13 taxons, mainly detritovories *B. longirostris* and *Asplanchna* sp. It is interesting that in the dystrophic lake with low calcium concentrations and dy type of bottom sediments *Anadonta cygnea* was noticed. Our investigations have documented that in the last stage, dystrophic lake represents specific ecosystem with taxons mixture originated from different trophic statues and not being evolved to eutrophic system as previously presented in lakes ontogeny schemes.

Aquatic vegetation and largemouth bass population responses to water level variations in Lake Okeechobee, Florida (USA)
K. Havens, D. Fox, S. Gornak, C. Hanlon
THE 7th INTECOL INTERNATIONAL WETLANDS CONFERENCE IN UTRECHT, THE NETHERLANDS, July 25-30, 2004
A five-year study examined responses of submerged aquatic vegetation (SAV), emergent vegetation, and largemouth bass (*Micropterus salmoides*) to variations in water level in a large subtropical lake. Water levels initially were high and the SAV and emergent vegetation had low spatial extent and biomass. Largemouth bass had low density and failed to recruit age-0 fish. In spring 2000, the lake was lowered by discharging water from major outlets, and this was followed by a regional drought. Water levels dropped by 1 m, and there was widespread development of *Chara* lawns and increased water clarity. Complexity of the SAV was low and there was no substantive improvement in bass recruitment. In 2001 the SAV continued to be dominated by *Chara* and again there was no fish response. In 2002, water levels increased to a moderate depth, vascular SAV increased in biomass and spatial extent, and the community developed high structural complexity. Emergent aquatic plants developed dense stands along the shoreline. These conditions were favorable to largemouth bass, which displayed a 3-fold increase in density, and a strong recruitment of age-0 fish for the first time in over five years. Bass recruitment success declined slightly in 2003, when high water returned and SAV was reduced by 30%.

Impact of water level fluctuations on St. Lawrence River aquatic vegetation
Christiane Hudon
Can. J. Fish. Aquat. Sci./J. Can. Sci. Halieut. Aquat. 54(12): 2853-2865 (1997)
Historical records of average seasonal water levels in the St. Lawrence River over the past 80 years reveal cyclic variations of up to 1 m above (1976) and 1 m below (1965) present levels. These variations are probably related to climatic conditions in the basin. Over the same period, the vertical range of seasonal water levels decreased from 2.2 to 1.5 m because of discharge regulation. Exposure of new substrate during periods of extreme low water levels may facilitate the invasion of aggressive and (or) exotic species. In Lake Saint-Pierre, a strong negative relationship was observed between seasonal water level and the percentage of emergent plant cover. Under low water levels, the lake becomes a large (387 km^2) marshland that could support a high plant biomass (286 times 10^3 t) whereas under high water levels, the lake shifts to a vast (501 km^2) open-water body with a lower predicted plant biomass (117 times 10^3 t). A model of the major anthropic and climatic forces acting on water levels is also presented; it describes aquatic plant biomass allocation and species diversity under different water level conditions.

A Model Study on the Role of Wetland Zones in Lake Eutrophication and Restoration .
Janse, J.H.; Ligtvoet, W.; Van Tol, S.; Bresser, A.H.M.
The Scientific World Journal, 1(S2):605-614 2001
Shallow lakes respond in different ways to changes in nutrient loading (nitrogen, phosphorus). These lakes may be in two different states: turbid, dominated by phytoplankton, and clear, dominated by submerged macrophytes. Both states are self-stabilizing; a shift from turbid to clear occurs at much lower nutrient loading than a shift in the opposite direction. These critical loading levels vary among lakes and are dependent on morphological, biological, and lake management factors. This paper focuses on the role of wetland zones. Several processes are important: transport and settling of suspended solids, denitrification, nutrient uptake by marsh vegetation (increasing nutrient retention), and improvement of habitat conditions for predatory fish. A conceptual model of a lake with surrounding reed marsh was made, including these relations. The lake-part of this model consists of an existing lake model

named PCLake[1]. The relative area of lake and marsh can be varied. Model calculations revealed that nutrient concentrations are lowered by the presence of a marsh area, and that the critical loading level for a shift to clear water is increased. This happens only if the mixing rate of the lake and marsh water is adequate. In general, the relative marsh area should be quite large in order to have a substantial effect. Export of nutrients can be enhanced by harvesting of reed vegetation. Optimal predatory fish stock contributes to water quality improvement, but only if combined with favourable loading and physical conditions. Within limits, the presence of a wetland zone around lakes may thus increase the ability of lakes to cope with nutrients and enhance restoration. Validation of the conclusions in real lakes is recommended, a task hampered by the fact that, in the Netherlands, many wetland zones have disappeared

Influence of water level changes on the spawning migration of pikeperch (*Sander lucioperca*) in Lake Võrtsjärv, Estonia
A. Järvalt, T. Feldman, A. Kangur, and P. Nõges
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
L. Võrtsjärv is a large (area 270 km2) shallow (average depth 2.8 m) eutrophic lake. The mean annual amplitude of fluctuation in the water level of L. Võrtsjärv has been 1.34 m, the absolute long-term range is 3.08 m. In a long-term period the water level of L. Võrtsjärv has shown a sinusoidal fluctuations alternated with a duration of 25–30 years. The main inflow, the Väike Emajõgi River, enters the narrow southern end of lake. During 1992–1997 2–3 % of the spawning stock of pikeperch L. Võrtsjärv migrated upstream to Väike Emajõgi River. Due to the extremely low water level in 1996–1997 the area of macrophytes has extended remarkably. The shallow western part and especially the southern end of lake was fully grown with *Nuphar lutea* and *Potamogeton lu cens*. In the end of April when the water temperature is risen over 8 C0 pikeperch starts to migrate to the river via the traditional migrating route alongside western shore and narrow southern end to Väike Emajõgi River. In 1998–2001 the abundance of migrating fish decreased up to 3 times (gill-nets CPUE). Pikeperch as a pelagic fish prefers open water and common migrating route is closed by dense vegetation.

Development of the cladoceran community in Dallund Sø, Denmark, during the last 7000 years – based on macrofossils in the sediment
L. Sander Johansson, E. Bradshaw, E. Jeppesen, and P. Rasmussen
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
The historical changes in lake ecosystems, caused by human activities, can be elucidated by palaeoecological analyses of the sediment. A sediment core of 13 m (representing approx. 7000 years) from Dallund Sø, a lake impacted by human activities for at least the last 6000 years, was thoroughly analyzed for several physical and biological variables. We present the analysis of cladoceran fragments and relate it to the data from terrestrial pollen, diatoms, diatom-inferred P-level and the minerogenic input (a proxy for soil erosion). The cladoceran fragments indicate, that the ecosystem of the lake was rather stable until 1000 BC. Hereafter, the absolute number of fragments and the share of macrophyte associated cladocerans increased. These results correspond well with other parameters, showing that high erosion led to a dramatic decline in the water level at 1000 BC, and an expansion of aquatic macrophytes. Later, from 1200 AD to the present, the total number of fragments increased further, and the macrophyte associated cladocerans almost disappeared. This coincides with a period of increasing P-concentration, and is an indication of a decline in the water quality. Moreover, a shift occurred from a large proportion of *Daphnia* to exclusive dominance by *Bosmina*, indicating an increase in fish predation at this time.

Effects of a drawdown on a waterfowl impoundment.
Kadlec, J. A. (1962)
Ecology 43(2):267-281.
This report covers an evaluation of pilot drawdown of the Backus Lake flooding project in north-central lower Michigan and its effect on vegetation, waterfowl, soil, water, and bottom fauna. A marked increase on soil nitrate occurred during the drawdown as a result of aerobic nitrification. Invertebrate populations, a potential food supply for waterfowl, were considerable reduced after the drawdown. The plant species composition was not notably affected. Most emergent species spread and increased in abundance as a result of the drawdown. Waterfowl utilization of the area increased in the late summer of 1959. Use by breeding waterfowl increase in 1960 when the newly developed emergent cover was available.

Restoration of Canvasback Migrational Staging Habitat in Wisconsin.
Kahl, R. (1991)

Madison, Wisconsin, Wisconsin DNR

Throughout the 1900's degradation of staging habitat in the Upper Midwest, including several sites in the southeastern half of Wisconsin, led to large concentration of migrating canvasbacks on limited habitat alone the Upper Mississippi River (UMR) from the mid-1960's to the late 1980's. This reliance on just a few habitats left a major segment of the North American population of canvasbacks susceptible both to catastrophic events affecting the health of the birds and to the degradation of the last remaining quality habitats. Thus the development of alternative staging habitats must be addressed if this segment of the North American population is to remain secure. This report: (1) assesses present status of canvasback staging populations and habitat in Wisconsin, (2) describes goals for management of canvasback staging populations and habitat, (3)outlines the research strategy necessary to formulate management plans for restoration of staging habitats in the southeastern half of Wisconsin, and (4) outlines an ecosystem approach to managing large, shallow lakes, which typify canvasback staging habitat. Information was compiled during 1985-1990. Primary sources of information included a literature review, discussion with natureal resource personnel from several agencies, a review of Wisconsin DNR file data, and preliminary results of a DNR Bureau of Research study on the status of canvasback staging populations and habitats, which began in 1985.

Historical accounts indicated that Lakes Koshkonong and Puckaway atracted large numbers of migrating canvasbacks in the late 1800's and early 1900s. Census data indicated that lake Poygan, Winneconne, and Butte de Mortes hosted peak fall population ranging from 8,000 to 77,000 in the 1950's and early 1960's. Lake Mendota attracted 61,000 in 1954. These sites apparently fulfilled the critical habitat requirement of migrating canvasbacks; large littoral areas supporting an abundance of readily accessible foods, especially American wildcelery, sago pondweed, and macrobenthos, as well as large open-water areas providing refuge from disturbance. Most canvasbacks stopped using these lakes after habitat quality decline due to nonpoint and point source pollution, high and fluctuating water levels, wave action, introduction of common carp and resulting unbalanced fish communities, and human disturbance. Although North America's eastern population of canvas backs declined during the mid-1980's to levels below those occurring in the mid-1960's, staging populations using lakes in the southeastern half of Wisconsin declined much more precipitously. From the late 1960's to the mid-1980's no site survey in the south eastern half of Wisconsin had peak fall population greater than several hundred to several thousand. Peak weekly populations for 15 sites in the southeaster half of Wisconsin ranged from 160 to 2,198 in fall and 4,850 to 10,215 in spring, 1985-1990. Lake Poygan typically attracted the most canvasbacks during this period. In contrast Pools 7-8 of the UMR attracted peak fall populations exceeding 60,000 during 1973-84, and this trend continued into the late 1980's.

From 1979-1984, canvasback use-days on Pools 7-9 of the UMR averaged about 2.5 million annually. In the southeastern half of Wisconsin, annual use-days for the 15 sites averaged about 1000,000 and ranged from 45,000 to 159,000 from 1986-89. Based on federal and state collaboration, a regional goal was proposed that called for redistributing about 50% of the use-days from Pools 7-9 to other staging habitats. Wisconsin DNR established the goal of providing for 625,000 use-days and redistributing about 20% of the annual use-days from the UMR Pools. Wisconsin's goal requires the provision of about 240 ha of wildcelery, 180 ha of sago pondweek, or 1,815 ha of macrobenthos beds on each of the 3 sites. Furthermore, management strategies should address boating disturbance where necessary through lake-use restrictions. Sites apparently having the greatest potential for management and restoration include Lakes Poygan, Winneconne, Butte des Morts, Koshkonong, Puckaway, and Beaver Dam. Of these sites, only Lake Poygan, with 355 ha of wildcelery presently provides more than 10-20 ha of relatively dense wildcelery of sago pondweed. Limit data and circumstantial evidence suggests that Lake Poygan, Winneconne and Butte des Morts support relatively low populations of the macrobenthos species important to canvasbacks, while Lakes Koshkonong and Beaver Dam may support moderate to high densities of macrobenthos.

Due to inadequate baseline data and uncertainty about the source of factors contributing to habitat degradation on these sites, specific management plans cannot be developed with additional research. The proposed research strategy includes acquiring data on present status of canvasback populations and habitat quality; determining limiting factors (and their sources) for aquatic macrophytes, macrobenthos, and disturbance; and evaluating restoration techniques for each of the 6 study sites. Most of the suggest factors limiting the abundance of submerged macrophytes and macrobenthos have system-wide and often watershed-wide causes that also affect fish, other wildlife, and water resources. Many of these limiting factors and their management strategies are outlined in an appendix on shallow lake management. The information present in this report should be useful to managers formulating plans for managing canvasbacks as well as any other species associated with shallow lake ecosystems.

An addendum briefly describes a significant decline in wildcelery and macrobenthos that occurred in most pools of UMR in 1988-89 after this report was prepared. This decline reinforces the need for Wisconsin to quickly achieve the goals for restoration of staging habitat and to expand the goals and restoration strategy to include the UMR.

Aquatic macrophyte ecology in the Upper Winnebago Pool Lakes.
Kahl, R. (1993)
Madison, Wisconsin, Wisconsin DNR

The primary factors limiting overall abundance of macrophytes during this study likely included high spring-summer water levels, abnormal timing and magnitude of water level fluctuations and turbidity. Consistently high water levels in May and June of 1975-84 probably controlled abundance of most emergent macrophytes system-wide. Rapidly rising water levels during the floating-leaf stage through June and early July apparently determine system wide abundance of wildrice. A revised water level management plan implemented in 1982 failed to reduce late spring and early summer water levels. Low light availability (restricted by water turbidity and epiphyte communities) apparently was the ultimate limiting factor determining long-term system-wide abundance of submerged macrophytes to maximum depths of 55-61 inches in Lake Poygan and 47-53 inches in Lake Butte des Morts. These maximum depth limits approximated the 5% photic zone for Lake Poygan (57-67 inches) and the 5-10 photic zone for Lake Butte des Morts (46-60 inches). However, because of consistently high turbidity through the study, late spring, and early summer water levels determined the amount of lake bottom within the photic zone, and thus the annual abundance of submerged macrophytes. Primary sources of turbidity for Lake Butte des Morts included the Fox River, the Wolf River at Winneconne, lesser tributaries, and in-lake phytoplankton populations. For Lake Poygan, in-lake sources and lesser tributaries accounted for most turbidity.

Sediments and undesirable fish-primarily carp and freshwater drum – may be important sources of nutrient than external sources leading to high phytoplankton and epiphytic communities. Wave action and undesirable fish probably have a greater impact on submerged macrophytes in the UWPL by contributing to turbidity than through direct physical damage to plants. Injure to new shoots and rhizomes by wave action, boats, and undesirable fish may restrict expansion of establish stands or prevent re-establishment of perennial emergents in some locations. Furthermore, wave action severely erodes unprotected shorelines, adjacent marshes, and shallow littoral sediments. Management recommendations are (1) revise the water level management plan by establishing a new spring-summer target level under 2.5 ft. at the Oshkosh gage, but allow periodic seasonal and anuual fluctuations above and below this level to simulate seasonal and longer-term drought and flooding phases of a natural hydrologic cycle; also moderating winter-drawdowns; (2) continue research to identify sources of turbidity and nutrients, especially from nopoint sources including tributaries, lakeshore and side-channel developments, sediments, wave action, and undesirable fish; (3) determine factors limiting expansion of existing emergent macrophyte stands, especially long-term and short-term fluctuations, wave action, boats, and undesireable fish; (4) develop and implement watershed and lake management plans, including large-scale breakwater projects to reduce water turbidity and improve water level management; (5) monitor water quality, macrophytes, and shoreline erosion to evaluate management efforts; and (6) evaluate harvest and planting techniques for propagules of macrophyte species important to these lakes.

The effects of the long dry periods on the water quality of Lake Velence (Hungary)
István Kóbor, Erzsébet Takács
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
Lake Velence is a 10–12 thousand years old, mosaic -like lake shallow lake in Hungary. The lake area is 24.5 km2, 10.2 km2 is covered by reed. The upsilting lake was recovered between 1960 and 1987, large open waters (recreational areas) and natural reservation area were created. To stabilize water level, two reservoirs were constructed on the major inflow. Due to this measures the trophic level of the lake has been decreased, became much better for meeting recreational purposes. In the early 90’s the water level dramatically decreased according to a long dry period. It also caused a significant water quality change. At the same time toxic blue-green algal blooms occurred in the lake, the dominant species was *Microcystis aeruginosa.* We investigated the effects of the hydrological, meteorological and other factors and parameters on the water quality, and on the occurrence and bloom formation of *Microcystis.* Some parameters of the sediment, like phosphorous forms and number of

Microcystis colonies were also measured. We found that the water quality changes were mainly associated with the evaporation and increasing salt content. The inflow water quality affected only a relatively small part of the lake. The bloom formation of *Microcystis aeruginosa* was independent from the water quality, except the nutrient load. The algal biomass and the frequency of bloom did not correlate, only the short term meteorological conditions were relevant.

Top-down control and alternative buffer mechanisms promoted by *Egeria densa* in a subtropical shallow lake
G. Lacerot, M. Meerhoff, L. Rodríguez-Gallego, J. Gorga, C. Kruk, F. Quintans, N. Mazzeo, M. Loureiro, and D. Larrea.
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
Submerged plants are thought to affect negatively phytoplankton crops by a number of mechanisms, including nutrient and light limitation, enhancement of top-down control by offering diurnal refuge for zooplankton against visual predation and by favouring piscivores. In 1998, Laguna Blanca, a yellow-brownish shallow lake in Uruguay, suffered a severe water level reduction that determined a massive fish kill and an extensive colonisation by *Egeria densa*. Nowadays, a clear water phase is established in the system despite the fish community being restricted to two small omnivorousplanktivorous fish: *Jenynsia multidentata* and *Cnesterodon decemmaculatus*. The analysis of sites with and without macrophyte coverage allowed us to propose alternative direct or indirect mechanisms associated to *E. densa* for the maintenance of clear water. The water column had low to intermediate nutrient concentrations, whereas phytoplankton community was highly diverse with a moderate biomass (mean Chl a = 10.6 µg l-1). The zooplankton community was dominated by copepods and low algal biomass values were associated to the highest cladoceran abundance in spring (*Diaphanosoma birgei* and *Chydorus* spp.). Macrophyte PVI represented 28–39 % of the lake volume (annual mean biomass = 174 gDW m-2), and fish and mediumsized zooplankton (except for the calanoid copepod *Notodiaptomus incompositus*) were significantly associated to submerged macrophyte beds. In spite of the high biomass and density of omnivorous-planktivorous fish (11.5 gFW m-2, 13 fish m-2), zooplankton explained most of phytoplankton variation. The medium-sized zooplankton decline coincided with fish reproductive events and the concomitant density increase during summer. The following stronger predation pressure by juvenile omnivorous fish seemed to diminish the macrophyte efficiency as zooplankton refuge. As chrolophyll a was non-detectable in periods when cladocerans had less importance, *E. densa* "bottom-up" mechanisms would also be present contributing to the clear water maintenance. Besides the usually described nutrient and light limitation by shade, the internal production of coloured dissolved organic matter could enhance the observed "top-down" effect.

The Heron Lake restoration project: big watersheds, big lakes, tough challenges.
R. Markl
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004.
Heron Lake is a large 3,238 ha (8,000 acre) shallow lake with a 1,178 square kilometer (455 square mile) watershed. Over 90% of the watershed is intensively drained agricultural land. Water depths, in the lake, average 0.8 meters (2.5 feet), though there can be regular sustained bounces to depths of over 2.4 meters (8 feet). Historically, Heron Lake has had considerable use by migrating diving ducks (reported 700,000 Canvasbacks (Aythya valisineria)). Changes in watershed land uses, nutrient discharges, flood flows, water level management (higher water levels), climatic conditions, dominant in-lake vegetation species, and carp introduction, among other things, have lead to a serious decline in water quality, desirable vegetation, and bird use. Around 1989, dissenting factions agreed that something must be done. Support and funding started traditional mending processes, including watershed treatments (buffer strips, wetland restorations, permanent vegetation plantings, best management practices, etc), wastewater treatment plant improvements, improved water level management (lower water levels), control of undesirable fish and stocking of desirable fish. Though some success has been observed, the road is long. Often times, the opinions/desires/needs of the human factions do not agree with each other, the wildlife needs, or the applied management practices.

Effects of water level regulation on littoral vegetation of Lake Bourget (France)
André Miquet
THE 7th INTECOL INTERNATIONAL WETLANDS CONFERENCE IN UTRECHT, THE NETHERLANDS, July 25-30, 2004
As in most Alpine lakes, reedbeds have strongly declined over the last century in area (about 50 % in the last 50 years in Lake Bourget), physiognomy and sanitary condition. This was due to an addition of factors, all of which have been magnified by the recent (1982) Water Regulation Program. Lower level during vegetation season has

permitted brush encroachment, which is accelerated by the restriction of fluctuation, causing floating wastes to accumulate constantly on the same shoreline. Higher water level in early autumn inhibits the mineralization of organic matter, the germination of *Phragmites* (but not of *Schoenoplectus*), and also reed vegetative horizontal extension. Overall, lower mean level and smaller water fluctuation concentrate erosion both on sediments by wave action, and on reed stems by floating objects. Due to water stability storms always occur at the same waterlevel, which aggravates erosion impact and impedes the cicatrization of littoral vegetation. A re-negociation of the Water Regulation Program is initiated in regard to the Water Directive: while the elevation of spring-summer level seems impossible, for hydraulic and political reasons, the lowering of autumn levels could be achieved, but limited for the sake of navigation and dependent on rainfall. However, the social demand for scheduled water-calendars prevents any yearly adaptation to climatic conditions; thus, in spite of the historic opportunity given by the draught in summer 2003, and due to a "perfusion" from the Rhône River, Lake Bourget did not lose a single millimeter.

Climate-driven phytoplankton changes in a large shallow temperate lake
T. Nõges, and P. Nõges
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
In Lake Võrtsjärv (270 km2, mean depth 2.8 m) cyanobacteria build up 2/3 of theaverage phytoplankton biomass (B) during the ice-free period (May–October). On average 75 % of the cyanophyte biomass is formed by 4 filamentous species: *Limnothrix planktonica, L. redekei*, *Planktolyngbya limnetica* and *Aphanizomenon skujae.* Centric diatoms from the genera *Aulacoseira* and *Cyclotella* dominate in the biomass of diatoms. The 35-year database revealed that phytoplankton biomass was quite closely correlated with lake depth (D), and North Atlantic Oscillation index in winter (NAOw) was positive ly correlated with D. Spring B of major phytoplankton groups were positively correlated with NAOw and winter air temperature, and negatively with the end of the ice-cover. The spring B was not related to D. The duration of the ice-cover was crucial for filamentous cyanophytes, but for diatoms the relationship was weak and insignificant as diatom blooms started to develop in sufficient light conditions already under the ice. In summer and autumn, D determined the biomasses of major phytoplankton groups. This can be considered as and indirect effect of NAOw which determined the water level throughout the whole year. The percentage of *L. redekei* among other filamentous cyanophytes was related with winter temperature, ice-cover duration and NAOw generally in the same way as the biomasses of major phytoplankton groups. However the strong positive correlation with D throughout all seasons was most remarkable. As a dim light species *L. redekei* is favoured by steep light gradients. In L. Võrtsjärv its biomass increased from year to year since the late 1970s and reached its maximum at high water period at the end of the1980s. In L. Võrtsjärv where the light conditions as well as phosphorus availability get worse in deeper water, filamentous *Limnothrix* species are most successful in competition for light and phosphorus while the share of nitrogen fixing species (mainly *A. skujae*) among cyanobacterial filaments decreases together with the increasing D. During low water periods, *A. skujae* is clearly favoured by improved phosphorus availability (decreased N/P ratio) and better light conditions.

The extreme flood of 1999 at Lake Constance: starting point of a new reed die-back?
W. Ostendorp, M. Diens, K. Schmieder
International Conference on Limnology of Shallow Lakes Balatonfüred, Hungary 25-30 May 2002
In May and June 1999 strong precipitations in the catchment area of Lake Constance caused an extreme flood in the lake. It was the third highest flood since the beginning of regular water mark records in 1816/17. Lake Constance is the only large lake in the Northern Alps whose water le vel regime is not significantly modified by man. Hence, extreme flood events are natural features in this lake, which the littoral vegetation has to cope with. In this contribution the effects of the 1999 extreme flood on lakeside *Phragmites australis* (Poaceae) reeds are discussed reporting the first results from a three years monitoring project which documents the initial damage of the reeds and the regeneration process, using aerial photo interpretations combined with GISanalyses, and field investigations on stand structure, biomass production, belowground carbohydrate storage, sediment quality, and stressor abundance. Since the flood rose five weeks earlier then under normal circumstances, the reed belts were affected in their very early growth period. The lakeside reed belt exhibited a high patchiness of stand structure types ranging from nearly unaffected stands to complete die -back sites. Five gradual degrees of damage were separated on the basis of CIR air-photos, the corresponding plots were digitised and the total areas of the different classes were calculated using GIS. Permanent quadrates were established at 50 locations, covering all degrees of damage and a wide range of environmental conditions. Many aspects of culm morphology, shoot density, bio mass production, nutrient economy, and carbohydrate storage in the rhizomes were affected in the first season after the flood. The water level curve in 1999 can be compared with the extreme flood in 1965 when ca. 74 % of the reed belt area below the mean

low water line was lost. A good part of this loss did not rehabilitate till 1998. Similar effects may be expected following the 1999 flood, and the effects on the littoral ecosystem in Lake Constance is presently a matter of speculation. The findings are discussed in context with clonal strategies of rehabilitation and re-occupation of the former stand area.

Changes in macrovegetation in the Second Stage of the Kis-Balaton Water Protection System, with a special regard to thepartial operation of the “Ingói-berek” area
P. Pomogyi, and Z. Dömötörfy
International Conference on Limnology of Shallow Lakes. Balatonfüred, Hungary 25-30 May 2002
The Kis-Balaton Water Protection System is located at the mouth of the Zala River. The main goal of its construction is the retention of nutrients from Lake Balaton. Its first part, the Hídvégi-Pond (24 km2) is operating since 1985. Construction works of the second part, the Fenéki-Pond (57 km2) started in 1985, and are ongoing. Partial operating a part of it with an area of 16 km2 (so-called Ingói-Berek) started in autumn 1992. The vegetation mapping is based on colour infrared aerial (CIR) photos, carried out annually. The vegetation maps have been preparing in the last 3 years by GIS methods based on the digital CIR orthophotos. The larger part of the original vegetation of the Hídvégi-Pond was covered by *Carex-*, *Deschampsia* - and *Solidago* dominated communities. The ditches were covered only by aquatic macrophytes. Before the implementation approximately 40 % of the Fenéki-Pond was covered by different *Phragmition*, 30 % by *Magnocaricion*, and 4 % by *Lemno-Potamea* associations, respectively, while 90 % of the Ingói-Berek was covered by aquatic and marshy vegetation. Subassociations of *Scirpo-Phragmitetum typhetosum, caricetosum*, and *thelypteridetosum* were the most dominant. These show that the reedcharacterised stands were already in a late phase of succession, indicating the presence of drier conditions. After the flooding the Ingói-Berek changes in the macrovegetation occurred rapidly. In its upper part the *Carex* dominated stands decreased during 2–3 years; their area was covered later by *Sparganio-Glycerietum – Lemno-Utricularietum – Ceratophylletum submersi* associations and at present followed by either *Polygonetum amphibii* or *Ceratophylletum submersi polygonetosum*. At the same time in the middle and the lower part of this area, the reed dominated stands have also changed: the *Scirpo-Phragmitetum caricetosum* changed to “*hydrocharetosum*” subassotiations (with different subdominance of aquatic plants), while the vegetation structure of the so-called floating-marshes has not changed. Knowledge of the earlier vegetation allows us to influence the direction of the changes. At the Fenéki-Pond the objective is to maximise the area of wetland vegetation. To achieve this it is proposed to gradually raise the water level, by 15–20 cm per year. It can be concluded that the vegetation mapping together with the study of the geographical and historical past of the region are necessary to plan any rehabilitation works, especially with a purpose to retain nutrients from Lake Balaton.

Upper Mississippi Valley Wetlands Refuges and moist-soil impoundments.
Reid, F., J. Kelley, et al. (1989)
Habitat Management for Migrating and Wintering Waterfowl in North America. L. Smith and R. Kaminski. Lubbock, Texas Tech University Press:181-202.
This paper is one of 21 chapter in this comprehensive book on wetland management for waterfowl. The chapters are presented by flyways. Fredrickson’s paper was presented in the Mississippi flyway where he has a long research history working on riverine riparian wetlands. He and his co-authors write about habitat management for emergent wetlands including marsh and moist-soil techniques. Developing a good duck marsh includes using a floodwater source, flooding and dewatering to promote plant growth, controlling water with pumps and levees, impounding water in ponds of the right size, and locating ponds and marshes near habitat types that promote waterfowl use. The data on water level control relates to shallow lakes in the north central states.

Distribution and biomass of submered macrophytes in Neusiedlersee.
Schiemer F. and M. Prosser (1976).
Aquatic Botany 2: 289-307.
Within the area of the open, reed-free zone in Neusiedlersee there exists a clearly define region *with Myriophyllum spicatum* L. and *Potamogeton pectinatus* L. Phytosociological estimates, quadrant counts and direct harvest methods have been combined over a 3-year period in order to estimate the extent, density and production characteristics of the zone. Quantitative studies have been concentrated on the northern part of the lake, which the previous surveys had indicated as the major zone of macrophyte growth. Evidence is present for a distinct inshore-offshore distribution of *M. spicatum.* The interaction of wave action and sedimentation rates of fine inorganic material is consider to be principally responsible for this pattern as well as for the overall distribution of both species. However, the distribution pattern of *P. pectinatus* shows a lesser degree of dependence upon such factors.

Computation of the total biomass and annual production of macrophytes within the lake are presented and a comparison is attempted between the status of macrophyte production with Neusidlersee and that estimated for other shallow lakes. The constant reduction in extent of the macrophyte belt during the obervation period is discussed in relation to the artificial increase in water level and eutrophication phenomena (significantly increase phytoplankton and epiphytic algae) during recent years

Shallow lake restoration: Big Muskego 1996-2004
E. Schumacher, S. Beyler, and T. Zagar.
Ecology and Management of Shallow Lakes Symposium, 134th Annual Meeting of The American Fisheries Society, August 22nd – 26th 2004.
Prior to our project, 900- hectare Big Muskego Lake was mired in a turbid, algae-dominated state for decades. After elimination of treated sewage effluent in 1984, it remained turbid; generating little recreation associated with fisheries and wildlife. Intent on shifting the lake's environment to a macrophyte-dominated, clear water state, we began our project in Fall, 1995 with an 18- month water level drawdown. We removed the carp (Cyprinus carpio) dominated fish population, restocked 20 native fish species, enacted restrictive fishing regulations to promote bio-manipulation of algae-grazing zooplankton and constructed a mechanical and electrical carp barrier to prevent carp re-colonization. Post project we have seen marked improvement in Trophic State Index values and electrofishing catch per unit of effort of desirable native fish. In a hemi-marsh mosaic of interspersed cattails and open water, desirable macrophytes now dominate the environment. Despite a partial winterkill of the fish population and re-colonization by carp, the lake remains in the clear-water state. Recognizing the "new" value of the lake, Big Muskego has been designated as one of the few remaining "Land Legacy" areas in Southern Wisconsin and remaining riparian open space is being preserved cooperatively by the City of Muskego and Wisconsin Department of Natural Resources.

Effects of water level fluctuations on biogeochemical processes in littoral zones of shallow lakes
S. Sollie, J.T.A. Verhoeven, H. Coops
THE 7th INTECOL INTERNATIONAL WETLANDS CONFERENCE IN UTRECHT, THE NETHERLANDS, July 25-30, 2004
Water levels in the shallow lakes in the central part of The Netherlands (IJsselmeer and Randmeren) are maintained for agriculture, navigation and safety. The resulting water regime is counter-natural, with high water levels in summer and low levels in winter. In combination with steep slopes, this prevents the development of wide helophyte zones. Such zones are able to enhance water quality due to an increased nutrient retention. The quantitative importance of this aspect has, however, not been investigated thoroughly. The goal of this research is therefore to investigate the influence of different water levelregimes and fluctuations (and shore morphometry) on the importance of littoral zones in enhancing water quality.The set-up of the study involves a combination of correlative field surveys and causal analytical mesocosm and microcosm studies in the greenhouse and the laboratory for quantifying biogeochemical processes in littoral zones. The data collected will be used to validate existing models, like PCLake and to add new modules to these models. Finally, the models developed will be used to calculate the outcome of different scenarios in terms of water level management and morphometry of the littoral zone on water quality enhancement.

The Managed Recession of Lake Okeechobee, Florida: Integrating Science and Natural Resource Management
Steinman, A., K. Havens, and L. Hornung. 2002.
Conservation Ecology **6**(2): 17.
Resource management decisions often are based on a combination of scientific and political factors. The interaction of science and politics is not always apparent, which makes the decision-making process appear arbitrary at times. In this paper, we present a case study involving Lake Okeechobee, a key environmental resource in South Florida, USA, to illustrate the role that science played in a high-profile, highly contentious natural resource management decision. At issue was whether or not to lower the water level of Lake Okeechobee. Although scientists believed that a managed recession (drawdown) of water level would benefit the lake ecosystem, risks were present because of possible future water shortages and potential environmental impacts to downstream ecosystems receiving large volumes of nutrient-rich fresh water. Stakeholders were polarized: the agriculture and utility industries favored higher water levels in the lake; recreation users and businesses in the estuaries wanted no or minimal discharge from the lake, regardless of water level; and recreation users and businesses around the lake wanted lower water levels to improve the fishery. Jurisdictional authority in the region allowed the Governing Board of the South Florida Water

Management District to take emergency action, if so warranted. Based on information presented by staff scientists, an aggressive plan to release water was approved in April 2000 and releases began immediately. From a hydrological perspective, the managed recession was a success. Lake levels were lowered within the targeted time frame. In addition, water quality conditions improved throughout the lake following the releases, and submerged plants displayed a dramatic recovery. The short-term nature of the releases had no lasting negative impacts on downstream ecosystems. Severe drought conditions developed in the region during and following the recession, however. Severe water use restrictions were implemented for several months. There also were impacts to the local economy around the lake, which depends heavily on recreational fishing; use of boat launch areas was curtailed because of the low water levels in the lake. This case study provides an example of how science was used to justify a controversial decision. Although the environmental basis for the decision was validated, unexpected or unpredictable climatic results led to socioeconomic challenges that offset the environmental successes.

Water-level fluctuations in northern prairie wetlands
Arnold G. van der Valk
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Oscillatory water-level fluctuations are reversible changes in water levels around a longterm mean. Because there has been no standard set of terms to describe oscillatory water-level changes, some suitable terminology is proposed based primarily on their range and frequency. Long-term water-level studies in prairie wetlands and proxy data (e.g., tree rings) for them indicate that oscillatory water-level changes have occurred for thousands of years. Changes in prairie wetland vegetation caused by oscillatory waterlevel fluctuations are called wet-dry cycles. During the wet phase of the cycle, higher than normal water levels can result in the near elimination of emergent species. During the dry phase, prairie wetlands can go completely dry, a drawdown. During drawdowns, the vegetation recruited from the seed bank in areas free of standing water is dominated by terrestrial annuals and seedlings of emergent species. During the transition from the dry to wet phase of the cycle, annual species are eliminated from the vegetation and emergent species initially increase in abundance. Observational and experimental studies of individual wetland species during wet-dry cycles have focused on the seed germination requirements and the flooding tolerances of emergent species. These have confirmed observations made during field studies and have added little to our understanding of vegetation changes during wet-dry cycles. A number of assembly-rule models of wet-dry cycles have been developed. When adequate data are available, the latest quantitative models can accurately predict changes in composition and distribution of emergent vegetation during all or parts of a wet-dry cycle.

Vegetation abundance in lowland floodplain lakes: importance of surface area, age and connectivity
G. J. Van Geest, F. C. J. M. Roozen, H. Coops, A. D. Buijse, R. R. Roijackers, M. Scheffer
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We analyzed the vegetation structure of 215 lakes in the floodplain of the lower river Rhine in relation to environmental variables related to hydrological connectivity, lake morphometry, lake age and land use on adjacent land. The frequency distribution of the cover of submerged macrophytes deviated significantly from the normal distribution, implying that submerged macrophytes were either almost absent or quite abundant in lakes. Multiple logistic regression indicated that the probability of submerged macrophyte dominance decreased markedly with the surface area, depth and age of the lakes. The surface area effect occurred independently of the depth. Also, a negative relationship to long-term inundation duration by the river was found. Nymphaeid cover showed a distinct optimum with respect to mean lake depth. Nymphaeids are almost absent in lakes shallower than 0.5 meter. In contrast to what was found for submerged plants, the probability of occurrence of nymphaeids increased with lake age. Nymphaeids were also positively related to the proportion of lake area drawn down in summer, and negatively related to cattle grazing and the presence of trees on adjacent land. Helophytes showed largely the same pattern as nymphaeids. The probability of helophyte occurrence increased with lake age, and decreased with presence of trees, cattle grazing, surface area, use of manure and mean lake depth. In all cases the critical level of one factor (e.g. mean lake depth) depended on other factors (e.g. surface area or age of lake). Thus, in the present study, small lakes tend to remain dominated by submerged macrophytes till a greater depth than large lakes, and helophytes colonize smaller lakes at an earlier phase. The effect of river dynamics is only modest in our data-set. This may be due to the fact that, unlike in most other floodplain systems described in the literature, most of our lakes are rarely inundated during the growing season and experience only moderate current velocities during inundation periods.

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Lake Christina (Butler and Hanson)

Coops and Vander Velde 1996;

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