Effects of Water Level Fluctuations and Regulation on Upper Great Lakes Nearshore Ecosystems: An Annotated Bibliography

Compiled by

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Introduction

This is an annotated bibliography of literature relating to the effects of water level fluctuations on ecosystems and biota of the Laurentian Great Lakes. This report was created in support of investigations into the potential ecosystem effects of altering the water level regulation of Lake Superior at the St. Marys River lock and dam system. Because such a change would most affect lakes Superior, Michigan, and Huron, we tried to concentrate on these lakes. However, we have included quite a bit of literature from lakes Erie and Ontario, where there has been more investigation of water level fluctuations (or lack thereof) and water level regulation. We have also included pertinent literature from around the world on effects of water level fluctuations in large lake and reservoir systems, primarily because of the paucity of pertinent literature for the upper Great Lakes.

Search parameters
Other groups and researchers are compiling information on physical, social, and industrial effects of altering upper Great Lakes water level regulation. We were tasked with finding information on likely ecosystem effects. We concentrated on coastal and nearshore areas as the most likely to be affected by water level fluctuations. Search terms (in various combinations) included:

Water level fluctuations, water level, lake level
Habitat
Great Lakes, Michigan, Superior, Huron, Erie, Ontario
Coastal wetlands, estuaries
Wetland hydrology
Littoral habitat
Biota: birds, piping plovers, macroinvertebrates, benthic macroinvertebrates, aquatic macrophytes, vegetation, algae, plankton, phytoplankton, zooplankton, periphyton,
amphibians, reptiles, mammals

We have included pertinent gray literature whenever we were able to discover it, but this bibliography primarily contains published literature. We searched using ISI Web of Knowledge, Google, and Google Scholar, and then individually searched the following on-line journal websites:

Journal of Great Lakes Research
Wetlands
American Water Resources Association
Limnology and Oceanography
Canadian Journal of Fish and Aquatic Sciences
Lake and Reservoir Management
Hydrobiologia
Hydrological Processes
Journal of the North American Benthological Society
Summary of literature topics found
Of the approximately 220 references included here, 134 deal directly with water level fluctuations while the rest provide general background information on Great Lakes nearshore and coastal ecosystems and biota. Of the 134 water level references, 30 are on the upper Great Lakes (3 for Superior, 16 for Michigan, and 11 for Huron), while 49 are on the lower Great Lakes (17 for Erie, 25 for Ontario, and 7 for the St. Lawrence River). The remaining water level fluctuation papers are more general in nature, with 31 on the Great Lakes in general and 24 on general information from other areas, often Europe. Besides indicating the water body pertaining to each reference, we have also categorized the papers by general topic beyond water level fluctuations. For those papers that deal directly with water level fluctuations, the majority discuss effects on invertebrates (42 papers) or vegetation, particularly wetland vegetation (40 papers). Fish (10 papers) and birds (12 papers) are the next most-discussed biota, with algae (3 papers) and amphibians (2 papers) having received little attention in the water level fluctuation discussions. The other subjects include contaminants (5 papers), water quality (2 papers), and wetland hydrology or water quality (11 papers).

There have been several review papers addressing the effects of water level fluctuations in the Great Lakes over the years, with the earliest reviewers finding the literature almost too scarce to use to draw conclusions. None of the reviews are specific to the upper Great Lakes, but several of them are specific to the lower lakes (EPA 2007, Hudon et al. 2006, Hudon and Carignan 2008). The most comprehensive overall review on water level fluctuations and their impact on the Great Lakes is by Wilcox et al. (2007), in which the authors take a very long time perspective (back into pre-history) to put water level fluctuations into context.

The most common theme of the review papers is coastal wetlands, either in general (Burton 1985, Keddy and Reznicek 1986, Keough et al. 1999, Minc and Albert 1998, Mortsch et al. 2006, Patterson and Whillans 1985) or discussing effects on wetland birds (McNicholl 1985, Prince et al. 1992, Steen et al. 2006). Bedford (1992) reviews literature on physical impacts of water level fluctuations and the Great Lakes on shorelines and tributaries. These review papers do a good job of summarizing the literature at the time they were written and are a good place to start for general information on the likely effects of water level fluctuations.

There have also been several journal special issues devoted to water level fluctuations or to Great Lakes coastal wetlands. Hydrobiologia devoted an issue (#539, 2005) to water level fluctuation effects on wetlands, and then another issue (#613, 2008) on water level fluctuation effects on lakes. Great Lakes coastal wetland special journal issues include Aquatic Ecosystem Health and Management 2004 issue 7 and Hydrobiologia 2008 issue 613. All of these should provide a number of papers with good background information on the issue of water level fluctuations or on an important Great Lakes coastal ecosystem, the coastal wetlands.

Gap analysis
In their white paper on ecosystem responses to water level fluctuations based on altering water level regulation, Ciborowski et al. 2009 listed a number of potential indicators of water level effects on Great Lakes ecosystems and biota. While we found some information, either background or specific to water level fluctuations, for many of these potential indicators, there were a number for which we found no information. These include:
• Effects on long-lived, wetland-obligate species
• Effects on most lake-oriented species of fish of interest (e.g., lake sturgeon, coaster brook trout)
• Effects on turtles, snakes, and their habitat
• Effects on beaver
• Effects on meadow and heather voles and their habitat
• Effects on wild rice
• Effects on benthic metabolism

Ciborowski et al. 2009 also listed a number of geographic areas of particular interest because they might be especially vulnerable to the effects of changing water level fluctuations, or because they might serve as good indicator areas. The table below summarizes our ability to link the literature we found with some of these areas.

Table 1. Locations of special concern for water level fluctuations for which references were found during search for information on the effects of water level fluctuations on Great Lakes ecosystems.

<table>
<thead>
<tr>
<th>Location</th>
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<tr>
<td><strong>Lake Huron:</strong></td>
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<tr>
<td>Georgian Bay</td>
<td>Keddy 1992; Seilheimer 2007; Wei 2007</td>
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<td>Manitoulin Island</td>
<td>Morbey 2008</td>
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<td>Saginaw Bay</td>
<td>Batterson 1991; Brady 1995; Burton 2002; Cardinale 1998; Fielder 2007;</td>
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<td></td>
<td>Ludwig 1993; Millie 2008; Wilcox 2002, 2008</td>
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<td><strong>Lake Michigan:</strong></td>
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<td>Green Bay</td>
<td>Brazner 1997; Frieswyk 2007; Karasov 2005; King 1999; MacKenzie 2004;</td>
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<td></td>
<td>Seileimer 2006; T’ulbure 2007</td>
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<tr>
<td>Eastern Lake Michigan</td>
<td>Cooper 2007; Wilcox 2002</td>
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<td><strong>Lake Superior:</strong></td>
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<td>South Bay (Munising)</td>
<td>Strand 2005</td>
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<td>Chequamegon Bay</td>
<td>Wilcox et al. 2008</td>
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<td><strong>Connecting channels:</strong></td>
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<tr>
<td>St. Marys River</td>
<td>Williams 1997</td>
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<td>Lake St. Claire &amp; river</td>
<td>Jaworski 1979</td>
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</table>

It is important to note that we restricted our search to effects of water level fluctuations, and only included other background literature if we stumbled across it in our search. We did not specifically search for background information on any of the potential indicators or geographic
areas of interest, so the lack of literature in this review should not be mistaken for a lack of existing literature or background data.

**Organization**
The annotated bibliography is organized alphabetically by first author’s last name. Each entry contains a copy of the abstract (where available) and our additional notes based on reading each paper. To aid readers in finding references on various topics, we have included a table (Table 2) at the beginning that lists the primary topic of each paper, whether it is general background information or specific to water level fluctuations, and what water body it pertains to. The table is sorted by primary topic (column 1). Any references that contain mathematical models or heuristic relationships are also identified.

Finally, the following abbreviations are used throughout the abstracts and our notes:

- **WLF** Water level fluctuations
- **GL** Great Lakes
- **SU** Lake Superior
- **MI** Lake Michigan
- **HU** Lake Huron
- **ER** Lake Erie
- **ON** Lake Ontario
- **SLR** St Lawrence River
- **SAV** Submerged aquatic vegetation
- **MMP** Marsh Monitoring Project
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<th>Topic</th>
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<th>Title</th>
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<td>algae</td>
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<td>Colonization and growth of attached algae at the Lake Michigan water line</td>
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<td>algae</td>
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<td>Growth and survival of Escherichia coli and enterococci populations in the macro-alga Cladophora (Chlorophyta)</td>
<td>Byappanahalli MN;Shively DA;Nevers MB;Sadowsky MJ;Whitman RL;</td>
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<td>Cylindrospermopsis in Lake Erie: Testing its Association with Other Cyanobacterial Genera and Major Limnological Parameters</td>
<td>Conroy JD;E.L. Quinlin;D.D.Kane;D.A.Culver;</td>
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<td>Physical variables driving epiphytic algal biomass in a dense macrophyte bed of the St. Lawrence River (Quebec, Canada)</td>
<td>Gosselain V;Hudon C;Cattaneo A;Gagnon P;Planas D;Rochefort D;</td>
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<td>An ecological review of Cladophora glomerata (Chlorophyta) in the Laurentian Great Lakes</td>
<td>Higgins SN;Malkin SY;Howard ET;Guildford SJ;Campbell L;Hiriart-Baer V;Hecky RE;</td>
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<td>Change in biomass of benthic and planktonic algae along a disturbance gradient for 24 Great Lakes coastal wetlands</td>
<td>McNair S.A.;</td>
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<td>Influence of environmental conditions on late-summer cyanobacterial abundance in Saginaw Bay, Lake Huron</td>
<td>Millie DF;Fahnenstiel GL;Dyble J;Pigg R;Rediske R;Klauer DM;Litaker RW;Tester PA;</td>
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<td>Regression and Weighted Averaging Models Relating Surficial Sedimentary Diatom Assemblages to Water Depth in Lake Ontario</td>
<td>Yang J;H.C.Duthie;</td>
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<td>Great Lakes wetlands as amphibian habitats: A review</td>
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<td>Field exposure of frog embryos and tadpoles along a pollution gradient in the Fox River and Green Bay ecosystem in Wisconsin, USA</td>
<td>Karasov WH;Jung RE;Vanden Langenbarg S;Bergeson TLE;</td>
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<td>Are Anurans of Great Lakes Coastal Wetlands Reliable Indicators of Ecological Condition?</td>
<td>Price SJ;Howsnewnki JM;Regal RR;Niemi GJ;Smith CR;</td>
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<td>The Importance of Spatial Scale for Conservation and Assessment of Anuran Populations in Coastal Wetlands of the Western Great Lakes, USA</td>
<td>Price SJ;Marks DR;Howsnewnki JM;Niemi GJ;</td>
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<td>Escherichia coli and enterococci at beaches in the Grand Traverse Bay, Lake Michigan: Sources, characteristics, and environmental pathways</td>
<td>Haack SK;Fogarty LR;Wright C;</td>
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<td>Beach Sand and Sediments are Temporal Sinks and Sources of Escherichia coli in Lake Superior</td>
<td>Ishii S;Ksoll WB;Hicks RE;Sadowsky MJ;</td>
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<td>Influence of Nearshore Water Dynamics and Pollution Sources on Beach Monitoring Outcomes at Two Adjacent Lake Michigan Beaches</td>
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<td>Initial Measurements of Benthic Photosynthesis and Respiration in Lake Erie</td>
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<td>Evaluation of geographic, geomorphic and human influences on Great Lakes wetland indicators: A multi-assembleage approach</td>
<td>Brazner JC;Danz NP;Niemi GJ;Regal RR;Trebitz AS;Howe RW;Howsnewnki JM;</td>
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<td>Monitoring waterbird abundance in wetlands: The importance of controlling results for variation in water depth</td>
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<td>Interactions Between Marsh Bird Population Indices and Great Lakes Water Levels: A Case Study of Lake Ontario Hydrology</td>
<td>Craigie GE;Timmermans STA;Ingram JW;</td>
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<td>Modelling wetland bird response to water level changes in the Lake Ontario-St. Lawrence River hydrosystem</td>
<td>Desgranges JL, Ingram J, Drolet B, Morin J, Savage C, Borcard D;</td>
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<td>A remote sensing analysis of coastal habitat composition for a threatened shorebird, the piping plover (Charadrius melodus)</td>
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<td>Breeding Bird Communities Across an Upland Disturbance Gradient in the Western Lake Superior Region</td>
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<td>Patterns of Predation on Passerine Nests in Marshes: Effects of Water Depth and Distance from Edge</td>
<td>Picman J, Milks MM, Leptich M;</td>
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<td>Avian responses to wetland vegetation cycles.</td>
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<td>Area and habitat relationships of birds in Great Lakes coastal wet meadows</td>
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<td>Birds in North American Great Lakes coastal wet meadows: is landscape context important?</td>
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<td>Assessing the sensitivity of wetland bird communities to hydrologic change in the eastern Great Lakes region</td>
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<td>Testing a fish index of biotic integrity to responses to different stressors in Great Lakes coastal wetlands</td>
<td>Bhagat Y, Ciborowski JH, Johnson LB, Uzarski DG, Burton TM, Timmermans STA, Cooper MJ;</td>
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<td>Increases in Fish Mercury Levels in Lakes Flooded by the Churchill River Diversion, Northern Manitoba</td>
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<td>Fish-Mediated Nutrient and Energy Exchange between a Lake Superior Coastal Wetland and its Adjacent Bay</td>
<td>Brazner JC;Danny K.Tanner;John A.Morrice;</td>
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<td>Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: a multivariate analysis of abiotic and biotic forcing factors</td>
<td>Brazner JC;E.W.Beals;</td>
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<td>A review of water level fluctuations on aquatic biota with an emphasis on fishes in ice-covered lakes</td>
<td>Cott PA;Sibley PK;Somers WM;Lilly MR;Gordon AM;</td>
<td>2008</td>
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<td>Modeling wetland plant community response to assess water-level regulation scenarios in the Lake Ontario-St. Lawrence River basin</td>
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<td>Plant Species Indicators of Physical Environment in Great Lakes Coastal Wetlands</td>
<td>Johnston CA; Bedford BL; Bourdagh M; Brown TN; Friesevky CB; Tulbure MG; Vaccaro L; Zedler JB;</td>
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<td>Partitioning vegetation response to anthropogenic stress to develop multi-taxa wetland indicators</td>
<td>Johnston CA; Ghioca DM; Tulbure M; Bedford BL; Bourdagh M; Friesevky CB; Vaccaro L; Zedler JB;</td>
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<td>Great Lakes vegetation dynamics: the role of fluctuating water levels and buried seeds</td>
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<td>The effects of natural water level fluctuations on N and P cycling in a Great Lakes marsh</td>
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<td>Flooding events and rising water temperatures increase the significance of the reed pathogen Pythium phragmitis as a contributing factor in the decline of Phragmites australis</td>
<td>Nechwatal J; Anna Wielgoss; Kurt Mendgen;</td>
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<td>Peintinger M; Prati D; Winkler E;</td>
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<td>Flora of a diked and an undiked southwestern Lake Erie wetland</td>
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<td>Distribution of the floating-leaf macrophyte Nelumbo lutea (American water lotus) in a coastal wetland on Lake Erie</td>
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<td>Quantification of Historical Changes of Submerged Aquatic Vegetation Cover in Two Bays of Lake Ontario with Three Complementary Methods</td>
<td>Zhu; B.D.G. Fitzgerald; S.B. Hoskins; L.G. Rudstam; C.M. Mayer; E.L. Mills;</td>
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<td>Vegetation changes in a Lake Erie marsh (Winous Point, Ottawa County, Ohio) during high water years.</td>
<td>Farney R; Bookhout T;</td>
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<td>Exotic and Invasive Aquatic Plants in Great Lakes Coastal Wetlands: Distribution and Relation to Watershed Land Use and Plant Richness and Cover</td>
<td>Trebitz AS; D.L. Taylor;</td>
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<td>Rapid invasion of a Great Lakes coastal wetland by non-native Phragmites australis and Typha</td>
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<td>Cattail invasion of sedge/grass meadows in Lake Ontario: Photointerpretation analysis of sixteen wetlands over five decades</td>
<td>Wilcox DA; Kowalski KP; Hoare HL; Carlson ML; Morgan HN;</td>
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<td>Historical Distribution and Abundance of Phragmites australis at Long Point, Lake Erie, Ontario</td>
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<td>Ecosystem response to changes in water level of Lake Ontario marshes: lessons from the restoration of Cootes Paradise Marsh</td>
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<td>Use and development of the wetland macrophyte index to detect water quality impairment in fish habitat of great lakes coastal marshes</td>
<td>Croft MV; Chow-Fraser P;</td>
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<td>The role of seed banks in the persistence of Ontario's coastal plain flora</td>
<td>Keddy PA; A.A. Reznick;</td>
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<td>Cumulative impacts of hydrology and human activities on water quality in the St. Lawrence River (Lake Saint-Pierre, Quebec, Canada)</td>
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<td>Climate Change and Great Lakes Water resources Responsiveness of Great Lakes Wetland Indicators to Human Disturbances at Multiple Spatial Scales: A Multi-Assemblage Assessment</td>
<td>Hall ND; Stuntz BB; Brazner JC; et al.;</td>
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<td>Biodiversity in protected coastal wetlands along the west coast of Lake Huron.</td>
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<td>Haack SK; Neff BP; Rosenberry DO; Savino JF; Lundstrom SC;</td>
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<td>Interactions Between Ground-Water and Wetlands, Southern Shore of Lake-Michigan, Usa</td>
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<td>Relative role of lake and tributary in hydrology of Lake Superior coastal wetlands</td>
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<td>Nutrient and hydrologic budgets of a great lakes coastal freshwater wetland during a drought year</td>
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<td>Seasonal, Interannual, and Spatial Variability in the Concentrations of Total Suspended Solids in a Degraded Coastal Wetland of Lake Ontario</td>
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<td>Modelling nutrient retention of a freshwater coastal wetland: Estimating the roles of primary productivity, sedimentation, resuspension and hydrology.</td>
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<td>Primary determinants of macrophyte community structure in 62 marshes across the Great Lakes basin: latitude, land use, and water quality effects</td>
<td>Lougheed VL;B.Crosbie;P.Chow-Fraser;</td>
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<td>Factors that regulate the zooplankton community structure of a turbid, hypereutrophic Great Lakes wetland</td>
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No abstract.
Notes: Michigan Natural Features Inventory publication describing the context, biotic diversity, and restoration and recovery efforts in Michigan’s coastal wetlands.

No abstract.
Notes: The International Upper Great Lakes Study team queried 67 GL scientists to identify species sensitive to WLF. Report lists common and rare, threatened and endangered species with annotated notes for each species listed.

Abstract: In this paper we explore the potential for developing plant-based indicators for key dimensions of wetland stress, including 1) hydrologic flow modification (through water-level regulation and diking), 2) water quality degradation (through nutrient loading and sedimentation), and 3) ecological structural breakdown or physical degradation. Based on a review of the literature, we identify species or species groups that potentially function as indicators of individual dimensions of anthropogenic stress and propose floristic metrics for monitoring wetland health. We then examine the utility of these metrics for evaluating wetland disturbance at both regional and local scales, utilizing a database of wetland sites spanning the entire U.S. Great Lakes shoreline. We conclude that multiple dimensions of wetland disturbance can be measured based on coverage values of key aquatic plants.
Notes: Identified plant species sensitive to various forms of wetland degradation, including natural water level fluctuations. Based on existing literature. *Typha* spp. are considered indicators of WLF dampening.

Abstract: A hydrogeomorphic classification scheme for Great Lakes coastal wetlands is presented. The classification is hierarchical and first divides the wetlands into three broad hydrogeomorphic systems, lacustrine, riverine, and barrier-protected, each with unique hydrologic flow characteristics and residence time. These systems are further subdivided into finer geomorphic types based on physical features and shoreline processes. Each hydrogeomorphic wetland type has associated plant and animal communities and specific physical attributes related to sediment type, wave energy, water quality, and hydrology
Notes: Hydrogeomorphic classification scheme for GL coastal wetlands: lacustrine, riverine, and barrier-protected with subcategories. Discusses hydrology, plants, and animals of each class as well as distinctive physical attributes (sediment, wave energy, water quality).

Abstract: Regulation of lake water level for power production and flood control is among the major anthropogenic disturbances in boreal aquatic ecosystems. In Finland, over 300 lakes, representing one third of the total inland water area of the country, are artificially regulated. To study the effects of regulation on lake littoral macroinvertebrate communities, samples were taken from upper stony littoral and from lower soft bottom littoral habitats of 11 lakes with different regulation amplitudes (wintertime fall in water level 1.19–6.75 m). Twelve unregulated (wintertime fall in water level 0.11–0.55 m) lakes with otherwise similar characteristics were used as a reference. Non-metric multidimensional scaling
ordinations showed that the composition of macroinvertebrate assemblages was strongly associated with the amplitude of water level regulation. Taxon richness also decreased with increasing intensity of regulation. Freezing and flushing of sediments in late winter are probably the most important factors leading to the impoverished littoral macroinvertebrate fauna. Invertebrates with long life cycle seem to be particularly vulnerable to unnatural water level fluctuation. Our results show that regulation of water level has a major impact on functionally significant lake littoral macroinvertebrates.

Notes: The authors studied the effect of water level regulation on macroinvertebrates from upper stony littoral and from lower soft bottom littoral habitats of 11 boreal lakes in Finland. Results showed that the composition of the assemblages was strongly associated with the amplitude of water level regulation, with clear differences seen between unregulated vs. regulated lakes. Taxon richness also decreased with increasing intensity of regulation. There were seasonal effects, with late winter freezing and flushing of sediments being the most important factors in declining macroinvertebrate abundance and richness. Longer lived macroinvertebrates were the most vulnerable to WLF.


Abstract: During the extremely dry period between 2000 and 2003, the water level of Lake Balaton decreased by 82 cm and 80% of the stony littoral, an important habitat for the zebra mussel (Dreissena polymorpha), became dry. A recovery period started in 2004 due to intense precipitation, which increased water levels in the lake. Seasonal and spatial variations of the relative abundance, population density, population structure and biomass of the zebra mussel and the relative abundance of the amphipod Chelicorophium curvispinum were monitored in the period of 2003–2005 at four different shoreline sections and in two different portions (on the bottom and near the surface portion of the rip-rap) of Lake Balaton. Along with these studies, a quantitative survey of mussel larvae found in the plankton and of the abundance of mussel feeding diving ducks were made. As a consequence of the water level fall, on the dried part of the stony littoral, numerous zebra mussel druses perished. Following the dry period in early 2004, the relative abundance of the mussel on the bottom stones was smaller than in 2003 and the bottom community was dominated by C. curvispinum. By the end of 2004 and during 2005, the water level returned to normal and the surfaces of the reinundated stones were conducive to the successful colonization of zebra mussels. Hence, they returned as the dominant fauna in 2005. The stones near the surface might provide a new substrate for the recruitment of zebra mussels, probably offering more suitable substrata for the settlement in 2005 than in 2003. Therefore, the new substrata available in 2005 may have encouraged better and more rapid zebra mussel colonization than before. Zebra mussels may be better competitors for new space than C. curvispinum. A minor change of water-level fluctuation in 2005 and the reduction in population size of the mussel feeding waterfowl could have contributed to the intensive spread of zebra mussel by 2005.

Notes: An intensive spread of zebra mussels occurred following a minor change in water level in Lake Balaton (Hungary) in 2005. This paper discusses potential reasons for the spread, which included decreases in waterfowl feeding on mussels and a minor change in water level that provided more suitable substrate.


Abstract: Both long-term and short-term changes occur in the water levels of Saginaw Bay wetlands. Long-term changes were associated with distribution of cattails and bulrushes in an emergent wetland on Defoe Reef south of Maisou Island in Saginaw Bay. These were mapped from aerial photographs covering the period 1941-1982. Each plant type decreased in area of distribution during high water between 1964 and 1982. These results suggest that long-term water level changes influenced the distribution and concomitant primary productivity of emergent wetland vegetation on Defoe Reef, and
may be one of the determinants of size and productivity of emergent wetlands elsewhere in the bay. Water level changes of 20-40 cm in 24 hr were commonly recorded in an emergent bulrush wetland on the shore of the bay northeast of Quanicassee. Effects of these short-term changes on bulrush distribution were not apparent. However, zonation of floating and submerged macrophytes was related to these changes. Short-term changes also affected the distribution of periphyton on bulrush shoots; low water levels restricted periphyton to 54% of the area of bulrush shoots that would have been available with a stable water level.

Notes: The authors used aerial photos from 1941-1982 to map cattail and bulrush extent during high and low-water periods in Saginaw Bay, Lake Huron, MI. Long-term changes in WL affect areal extent of emergent plants. Short-term changes create zonations in non-emergent plants and restrict periphyton growth to permanently submerged portions of plants.


Abstract: In a 2-year field study, abundance, biomass and community structure of benthic macroinvertebrates and their seasonal dynamics were assessed along the depth gradient in the stony littoral zone of Lake Constance, Central Europe. The macroinvertebrate community patterns differed significantly between the depth zones, partly because of species turnover, but mostly as a result of different dominance structures. These distinct differences should be considered when designing surveys of benthic invertebrates also for applied purposes, since sources of variation should be kept small and particularly on hard substrates, extensive efforts are required to obtain sufficient data for a powerful statistical analysis. A large seasonal variability in the macroinvertebrate communities of the eulittoral zone indicates a strong influence of physical disturbances, particularly of water-level fluctuations. The community pattern of the drift line samples was influenced by the previous development of the water level. The cumulated water-level fluctuations and their net tendency accounted for three quarters of the variation in a PCA. Since Lake Constance is the only large pre-alpine lake whose water level is not extensively regulated, the uniqueness of the littoral community should have implications for nature conservation measures.

Notes: Reports on the effects of water-depth and water-level fluctuations on the macroinvertebrate community structure of the littoral zone of Lake Constance (central Europe). Invertebrates were collected seasonally along depth zones in this large, unregulated lake. The lake has an annual 2 m water level fluctuation. The study examined how the previous month’s water levels affected benthic assemblages. Mobile macroinvertebrates take advantage of newly flooded areas as waters rise in the spring/summer for reduced competition and predation. They found, as expected, a much harsher physical environment in shallow water due to wave action and repeated exposure to the atmosphere. Although not intending to look for it, the authors saw a climate change signal. Water level fluctuations and influences accounted for 75% of the variation among macroinvertebrate assemblages.


Abstract: Wetlands and tributary confluences are susceptible to physical influences imposed by the Great Lakes, particularly through the effects of short and long-term water level fluctuations and accompanying transport disruptions including flow and transport reversals. With there being few, if any, direct field observations of these disruptions based upon velocity measurements, the objective of this paper is to review the possible physical effects on these regions by first, reviewing the relevant contributing physics known about the Great Lakes, second, contrasting possible marine estuary transport mechanisms with what little is published about the Great Lakes circumstances; and third, summarizing modeled results exemplifying these behaviors from a study of Sandusky Bay, Lake Erie. Because it exhibits the strongest response to storms and the clearest measureable signals resulting from them, attention is centered on
Lake Erie. In contrast to a typical research paper, the objective herein is to provide a summary of what is known and commonly accepted about these physics which can serve as a backdrop for the other papers in this special issue.

Notes: A review paper on the physical effects of the Great Lakes on tributaries and wetlands. Short and long-term water level fluctuations have a large effect on tributaries and wetlands. The author developed a model in Sandusky Bay to exemplify effects. A large number of GL wetlands are associated with tributary mouths and relatively flat floodplain regions, which are quite susceptible to WLF. Western Lake Erie is a good test case because of the shallowness of the depth and gradient, and the coastal plain’s low gradient. There are river flow reversals during storm events for tributaries on the western end of Lake Erie. Variability, rather than stability, is the rule for Lake Erie. Detailed information about Lake Erie flow patterns, with technical information on the physical forces. This paper summarizes a lot of the earlier literature on WLF in the Great Lakes and their causes (storm surges, etc).

Abstract: The large freshwater lakes of the world are an extremely valuable resource, not only because 68% of the global liquid surface fresh water is contained in them, but because of their importance to the economies, social structure, and viability of the riparian countries. This review provides decision makers with the knowledge of large lakes (greater than or equal to 500 km²) essential to establishing policies and implementing strategies compatible with sustainable development. This is achieved by considering the present state of the lakes, the extent of changes and factors causing them, long-term consequences of these changes, major threats and possible states of the lakes into the year 2025. Case studies of lakes are presented, namely the St Lawrence Great Lakes of North America as representatives of glacial scour lakes of North America, northern Europe and Asia, and the African Great Lakes as representatives of tropical tectonic lakes. Lake Baikal is also included because it is unique for its species, great age, and largest single volume of liquid surface fresh water. The Aral Sea is further included because of the ecological disaster following diversion of water away from its basin. The major impacts on large lakes are diversions, eutrophication, invasive species, land-use change, overexploitation of resources, and pollution. These impacts can or do affect all the representative lakes, but to varying degree. The St Lawrence Great Lakes have been severely impacted by eutrophication, land-use change, overfishing, invasive species and pollution. Eutrophication has been reversed for these lakes and constraints are now in place on land use change, such as shoreline alteration and destruction of wetlands. With the demise of most commercial fishing, overfishing is no longer as important. Invasive species have become a major problem as increasingly non-indigenous species gain access to the takes. Pollution continues as a major impact. These problems are likely to continue and seriously impact use of the resources as well as bring about changes in the biota. Among the African Great Lakes, invasive species are a major problem in Lake Victoria, and eutrophication associated with land-use change and overexploitation of resources is a growing problem. Many endemic species have been lost and many are threatened, so that species associations will have changed by 2025. The Aral Sea continues to disappear and in the future, the remaining largest part of it will continue to become increasingly saline and eventually disappear. A small body of water will remain as a freshwater lake with a productive, although small, fishery. Lake Baikal shows evidence of pollution in the southern basin and is likely to be impacted by land-use changes, primarily logging. Some non-indigenous species are present, but so far, they are not a major problem. Overexploitation of resources in the watershed could lead to adverse impacts on inshore waters. Overfishing has been recognized and appears under control. The major threat to Baikal is continued and growing pollution. Climate change and pollution are global problems that will affect all lakes, large and small. At present, while some warming has occurred, climate change appears not to have impacted large lakes. Present studies on the Laurentian Great Lakes predict possible major impacts. Pollution, especially from persistent toxic substances such as PCBs, is a global problem. Diversion of water out or
away from large lakes will become more of a threat as global human population growth continues and water supplies from rivers and ground water become depleted.

Notes: This review of the world’s large freshwater lakes, including GLs, describes major forcing factors and trends. Factors affecting the GL include overfishing, habitat alteration, invasive species, eutrophication, and pollution. Major concerns of this century are low lake levels and other impacts of climate change.


Abstract: Fish community composition often varies across ecoregions and hydrogeomorphic types within ecoregions. We evaluated two indices of biotic integrity (IBIs) developed for fish in Great Lakes coastal wetlands dominated (> 50% cover) by Typha (cattail) and Schoenoplectus (formerly Scirpus) (bulrush) vegetation. Thirty-three coastal wetlands dominated by either Typha or Schoenoplectus vegetation were sampled using fyke nets set overnight. These sites were selected to span anthropogenic disturbance gradients based on population density, road density, urban development, point-source pollution, and agricultural inputs (nutrients, sediments), measured using a GIS-based analysis of Great Lakes coastal land use. Sites subject to low levels of anthropogenic influence had high IBI scores. The Typha-specific IN showed a marginally significant negative correlation with population density and residential development ($r = -0.54$, $p < 0.05$; $n = 21$). The Schoenoplectus-specific IBI negatively correlated most strongly with nutrient and chemical inputs associated with agricultural activity and point-source pollution ($r = -0.66$ and -0.52, respectively; $p < 0.01$; $n = 30$). However, some relationships between IBI and disturbance scores were non-linear and likely exhibit a threshold relationship, particularly for Schoenoplectus dominant sites. Once a certain level of disturbance has been exceeded, a sharp change in fish community's composition and function occurs which is symptomatic of a degraded site. The IBI indices appear to indicate effects of some, but not all classes of anthropogenic disturbance on fish communities. Calibrating these measures against specific stress gradients allows one to interpret the sources of impairment, and thereby use the measures beyond a simple identification of impaired sites.

Notes: Fish IBI for GL coastal wetlands. Although the paper does not address water levels, it links fish with vegetative habitats and has IBI/metrics to assess condition. Compares condition to watershed land use, water quality, etc.


Abstract: Changes in populations of attached algae growing near the water line along the west shore of Lake Michigan were observed. Emphasis was placed on harbor populations with particular focus on the algae of Milwaukee Harbor during 1979 and 1980. Vertical zonation on rocks and harbor structures is documented and seasonal growth patterns and selected interrelationships are described. Of the three major filamentous algal forms present in this habitat, Bangia appears as a permanent resident, while Ulothrix may be considered a seasonal and opportunistic plant, responding rapidly to changes in water level. Cladophora is a perennial, but plants above a depth of approximately 30 cm tend to grow as annuals due to conditions of ice scour. It is suggested that seasonal and spatial variation in the abundance of particular species is related to the physical growth requirements of the species.

Notes: Paper reports on colonization and growth of attached algae at the Lake Michigan water line. Provides baseline information on zonation and physical requirements of various genera of attached filamentous algae.

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Abstract: Reservoir creation has often been inferred as a cause of elevated fish mercury concentrations. Increases in fish muscle mercury levels, occurring coincidentally with flooding, are documented for three lakes affected by the Churchill River diversion for which pre- and post-impoundment data were available. For example, northern pike (Esox lucius) and walleye (Stizostedion vitreum vitreum) muscle mercury levels from Southern Indian Lake, which was increased in surface area by 21% by flooding in 1976, increased from baseline values of 0.2–0.3 /g/g-1 prior to flooding to 0.5–1.0 /g/g-1 in 1978–82. Muscle mercury levels from predatory species (northern pike and walleye) from all 10 lakes tested in the Churchill, Rat, and Burntwood valleys flooded by the Churchill diversion are near to or exceed the current export marketing limit of 1.0 /g/g-1. Because mercury levels in fish from nearby unflooded lakes have not shown recent increases, atmospheric fallout of the metal does not appear to be the cause of the problem. Also, there are no known industrial sources of mercury in the area and no agricultural activity. Post-impoundment mercury levels in predatory fish appeared to be related to the flooded terrestrial area compared with pre-impoundment lake area. They were highest (1.15–2.90 /g/g-1) in Rat and Notigi lakes, which were increased in surface area by 282%, lower (0.60–1.53 /g/g-1) in lakes immediately below Notigi Reservoir, increased in surface area by 31–37%, and lowest (0.45–1.03 /g/g-1) in Southern Indian and Wuskwatim lakes, increased in surface area by 13–21%. Fish mercury levels responded quickly to impoundment, increasing noticeably within 2–3yr. Declines in mercury concentrations had not, in general, taken place within 5–8yr of impoundment, with the exception of lake whitefish (Coregonus clupeaformis) from Southern Indian Lake. It is hypothesized that observed fish mercury level increases were due to the bacterial methylation of naturally occurring mercury found in flooded soils.

Notes: Provides results of mercury levels in fish measured both pre- and post-impoundment in the Churchill River, N. Manitoba. Post-impoundment mercury levels in predatory fish appeared to be related to the flooded terrestrial area compared with pre-impoundment lake area. WLF related, but not the GL.


Abstract: Because Typha × glauca often dominates wetlands where humans have stabilized the natural hydrologic regime, we 1) compared its expansion rates where water levels were stabilized vs. fluctuating and 2) explored the potential for stabilized water levels to allow plants to accumulate more phosphorus (P) and increase growth. In three Wisconsin marshes, the area dominated by Typha expanded linearly over time, but rates were higher where water levels were stabilized than where they fluctuated naturally (based on nine aerial photos from 1963 to 2000). In a large wetland (412 ha) behind a dam, Typha × glauca expanded 81,152 m2/year, and clone diameters extended 3.9 ± 0.61 m/year. In contrast, a mixed stand (mostly T. angustifolia) in an upstream wetland with fluctuating water levels expanded only 2,327 m2/year, and clones extended only 2.5 ± 0.75 m/year. While various factors could have caused these differences, a separate two-factor experiment in outdoor microcosms supported the hypothesis that stabilized water levels alone can enhance T. × glauca spread. The experiment indicated that both stabilized water levels and P additions increased P accumulation and growth of T. × glauca. Constant inundation (5–10 cm deep) allowed T. × glauca to produce 56% more biomass (61.6 ± 4.0 g) than a regime with two drawdowns (39.4 ± 1.9 g; p < 0.001). Plants under constant inundation accumulated 0.15 ± 0.007 g P, which was 36% more than with one drawdown (0.12 ± 0.004 g; p < 0.001) and 67% more than with two drawdowns (0.09 ± 0.005 g; p < 0.001). Also as expected, the addition of 2 g P/m2 increased biomass 23% more than the control (57.8 ± 3.0 vs. 46.9 ± 3.0 g/plant; p = 0.02). Our microcosm results suggest that unavailable P can shift to a form that T. × glauca can use. Thus, internal eutrophication can augment rates of T. × glauca invasion.

Notes: The authors experimentally controlled water level in three inland wetlands and used aerial photos to measure Typha spp. extent. Additional mesocosm experiments were also performed under differing P loading and water level stabilization regimes. Typha spp. expansion was greatest when water level was stable. T. x glauca accumulated more P and produced more biomass under stable water levels.

Abstract: Wetland use by waterbirds is highly dependent on water depth, and depth requirements generally vary among species. Furthermore, water depth within wetlands often varies greatly over time due to unpredictable hydrological events, making comparisons of waterbird abundance among wetlands difficult as effects of habitat variables and water depth are confounded. Species-specific relationships between bird abundance and water depth necessarily are non-linear; thus, we developed a methodology to correct waterbird abundance for variation in water depth, based on the non-parametric regression of these two variables. Accordingly, we used the difference between observed and predicted abundances from non-parametric regression (analogous to parametric residuals) as an estimate of bird abundance at equivalent water depths. We scaled this difference to levels of observed and predicted abundances using the formula: ([observed-predicted abundance]/[observed+predicted abundance])+100. This estimate also corresponds to the observed:predicted abundance ratio, which allows easy interpretation of results. We illustrated this methodology using two hypothetical species that differed in water depth and wetland preferences. Comparisons of wetlands, using both observed and relative corrected abundances, indicated that relative corrected abundance adequately separates the effect of water depth from the effect of wetlands.

Notes: The authors developed a method for correcting waterbird abundance data for water depth variations in wetlands.


Abstract: Testate amoebae are common inhabitants of moist soils, wetland, and lacustrine habitats. They produce a decay-resistant test, or shell, which can be identified to species in most cases and recovered from sediments in quantities sufficiently large to permit estimation of relative abundance. The objectives of this study were to assess the potential of testate amoeba assemblages as paleoenvironmental and environmental indicators in two Lake Superior coastal wetlands and to determine if morphological variation in four common taxa (Arcella spp., Assulina spp., Centropyxis cassis type, and Nebela tincta-parvula-collaris group) is related to microenvironment. Study localities included ridge-swale wetland systems adjacent to Grand Traverse Bay and Tahquamenon Bay in the Upper Peninsula of Michigan. Testate amoeba assemblages from 74 microsites were compared with percent moisture, depth to water table, pH, porosity, depth of living moss, and associated moss and vascular plant species. Morphometric analysis (e.g., test length and aperture diameter) was conducted on 25 individuals from at least 10 microsites for each of the four selected taxa. Gradient analysis indicated that testate amoeba assemblages are primarily controlled by substrate moisture and pH, consistent with results from other regions. Transfer functions for pH and substrate moisture were developed using ‘jack-knifed’ validation procedures. Little relationship was found between microenvironmental parameters and morphological variation in the investigated taxa, except for the Nebela tincta-parvula-collaris group, where test size was significantly correlated with pH ($r^2 = 0.68$). Results indicate that wetland testate amoeba assemblages in these coastal wetland systems are sensitive environmental and paleoenvironmental indicators that can be used to monitor and reconstruct water-level or pH changes.

Notes: Testate amoeba assemblages in coastal wetlands can be used to monitor and reconstruct water-level and pH changes through time.


Abstract: We reconstructed Holocene water-level and vegetation dynamics based on pollen and plant macrofossils from a coastal lake in Upper Michigan. Our primary objective was to test the hypothesis that major fluctuations in Great Lakes water levels resulted in part from climatic changes. We also used
our data to provide temporal constraints to the mid-Holocene dry period in Upper Michigan. From 9600 to 8600 cal yr B.P a shallow, lacustrine environment characterized the Mud Lake basin. A Sphagnum-dominated wetland occupied the basin during the mid-Holocene dry period (similar to 8600 to 6600 cal yr B.P). The basin flooded at 6600 cal yr B.P as a result of rising water levels associated with the onset of the Nipissing I phase of ancestral Lake Superior. This flooding event occurred contemporaneously with a well-documented regional expansion of Tsuga. Betula pollen increased during the Nipissing II phase (4500 cal yr B.P). Macrofossil evidence from Mud Lake suggests that Betula alleghaniensis expansion was primarily responsible for the rising Betula pollen percentages. Major regional and local vegetational changes were associated with all the major Holocene highstands of the western Great Lakes (Nipissing I, Nipissing II, and Algoma). Traditional interpretations of Great Lakes water-level history should be revised to include a major role of climate.

Notes: The authors reconstructed Holocene water-level and vegetation dynamics from pollen and plant microfossils. They concluded that climatic changes played a large role in historical WLF in the GL.


Abstract: I tested the hypothesis that seiches in large lakes play a role similar to tides in marine system by exporting detrital carbon from coastal wetlands to adjacent open waters. The study was conducted at a wetland site located along the shore of the Lake Erie. Water samples were collected at the outlet of the marsh, during inflow and outflow events, over a 19-month period. Water isotopes were also measured in the lake and in the marsh to establish the magnitude of the mixing between the two water masses. On average, the concentrations of the outflow water samples was enriched by 7.3 mg DOC l-1 and 3.4 mg POC l-1 compared to the inflow water samples, while no difference observed in inorganic carbon fluxes. Organic carbon was exported during fall, winter and early spring which coincide with period of organic matter decomposition. Such a concept of outwelling is not new for marine ecosystem, but is demonstrated in this study for the first time in a large lake setting influenced by seiche events. Ultimately to understand the role that these fluxes may play in maintaining the integrity of the wetland-lake system, it will be necessary to investigate whether the detrital material exported from coastal freshwater wetlands is incorporated into the open lake foodweb.

Notes: Seiches in large lakes play a role in exporting detrital carbon from coastal wetlands out into the open water. Determining flux, however, is difficult. Geomorphology, structure, and orientation to the lake as well as vegetation are listed as factors that influence the magnitude of water and carbon fluxes from wetlands out into the open lake waters.


Abstract: Infestation by introduced zebra mussels has extirpated native unionids in many Great Lake habitats. Shallow areas in coastal wetlands are intermittently dewatered by seiches and seasonal water level changes, and we examined how water level fluctuations and sediment characteristics affected interactions among unionids and zebra mussels in a Lake Erie coastal marsh. In 2001 we sampled unionid distributions and measured zebra mussel colonization on PVC plates at 1 cm, 18 cm and >35 cm water depths. We found a diverse unionid community (15 species) with many juvenile unionids. Unionid densities (0.01 unionids/m²) were comparable to other coastal wetlands, but are lower than reported in offshore areas before zebra mussels were introduced. Zebra mussels colonized plates at >3000 individuals/m² in some locations. Although >60% of unionids had byssal threads on their shells, >75% of unionids had no attached zebra mussels. Therefore, zebra mussels are colonizing unionids, but are not surviving. Unionid numbers and zebra mussel colonization were low in shallow (1-35 cm) water depths, indicating that water level fluctuations limited their distributions. Only two species of unionids were collected in 1-17 cm deep areas, and areas that became mudflats in September had almost no unionids. Numbers of zebra mussels and unionids were not correlated with organic content or silt/clay content of
the sediments. Habitat characteristics shared by this wetland and other coastal wetlands that are important refuges of unionids include: a hydrological connection with the lake, areas deep enough for unionids to survive low water levels and soft sediments that allow unionid burrowing.

Notes: Paper examines how WLF and sediment characteristics affect unionids and zebra mussels in ER coastal wetlands. Unionids are better able to survive aerial exposure than zebra mussels, but predation also increases during low water levels. Because of this unionids appear to be surviving in ER coastal wetlands.

Abstract: In May-August 2002, we examined how seasonal water level changes and frequent wind-driven seiches limited the amount of habitat for zebra mussels (Dreissena polymorpha) in a Lake Erie coastal wetland. We counted numbers of veligers that colonized artificial substrates at different depths (1-17 cm, 18-34 cm and >34 cm below the water surface). Water levels decreased during the summer, and by August colonization plates set at 1-17 cm were exposed 85% of the time, plates set at 18-34 cm were exposed 15% of the time, but plates set at >34 cm were rarely exposed. The highest densities (numbers/m(2)) of colonization occurred in June (7176.1) and August (3119.5), and this bimodal pattern has been observed in other Great Lake habitats. Densities were highest at >34 cm depths (5552.7), intermediate at 18-34 cm (2802.1) and lowest at 1-17 cm (410.8). Veliger numbers on some plates in deep water levels were as high as 10,000/m(2), which are similar to densities in the Great Lakes. We also measured survivorship of adult mussels in wire mesh cages from 28 July to 25 August. Most (similar to 90%) adult zebra mussels survived in both 18-34 cm and >34 cm, water levels, but only similar to 2% survived in 1-17 cm water levels. We determined the percent of Crane Creek Marsh in each of the three water depth zones and estimated that water level changes prevent zebra mussels from inhabiting 62% of this coastal wetland. The low survival of zebra mussels may be a reason why abundant unionids have recently been found in this and some other Great Lake coastal wetlands.

Notes: The authors examined how seasonal water level changes and seiches limited zebra mussel habitat from May-August 2002 in an ER coastal wetland. They estimated that water level changes in Crane Creek Marsh prevent zebra mussels from inhabiting 62% of the wetland. Adult survivorship in shallow water depths dropped sharply when exposure frequency increased from 4-6% in the first 2 weeks to 16-17% of the time in weeks three and 4. The low survival of zebra mussels may be one reason why abundant, native unionids have been able to survive.

Abstract: We investigated the seasonal cycles and spatial distribution of zebra mussels (Dreissena polymorpha) in a coastal marsh in Saginaw Bay, Lake Huron, from 1993 to 1995. This marsh was characterized by a sandy substrate and ice scour which removes emergent vegetation each winter. Due to this lack of permanent substrates, we expected that populations in the marsh would only be maintained during the ice free season, with recruitment from open waters responsible for recolonization each year. Instead, we found that substrate independent clusters over-wintered in the zone of emergent vegetation and were the source of recruitment to the marsh. Peak larval production occurred during July of both years with greatest densities between 300 and 350 m from shore. Settlement of these larvae onto Scirpus stems occurred by late August, accounting for the greatest numbers of mussels attached to stems. Mussel abundance was highest between 300 and 450 m from shore, but was very low inshore of 300 m. Losses of attached mussels from Scirpus stems reduced abundances by as much as 80% by the end of September 1994 despite the fact that the stems were still intact and healthy. The greatest losses occurred between 300 and 400 m from shore, while mussel abundance was increasing at the bayward edge of the emergent vegetation. The high abundance of larvae and attached juveniles near the center of the marsh, as well as
the high loss of attached mussels in this area, may be related to a recently described form of horizontal stratification in coastal wetlands.

Notes: The authors investigated mussel colonization and survival of zebra mussels in Saginaw Bay (HU), Michigan. Though mussel populations were expected only to be maintained in the ice free season, they were able to overwinter on emergent vegetation (Scirpus) in deeper water beneath ice cover.


Abstract: East-German lowland lakes are highly susceptible to climatic changes, as most lakes are groundwater fed and strongly dependent on the balance of precipitation and evapotranspiration in their catchments. As a significant decrease of precipitation at least during summer is forecasted, a substantial and permanent reduction of lake water levels can be expected. Water-level fluctuations will predominantly affect the eulittoral zone where submerged tree roots form an important habitat type in lowland lakes that will become unavailable for eulittoral invertebrates. Hence, we compared the invertebrate community from eulittoral root habitats with those of infra littoral habitats to test which components of the invertebrate community would be potentially affected by the loss of root habitats, and whether infra littoral habitat types could mitigate these effects. Species richness did not significantly differ between eulittoral roots and the infra littoral habitat types. Community composition of roots significantly differed from that of coarse woody debris, sand and stones but not from reed habitats. Abundances of Coleoptera, Trichoptera and abundances of piercer, predator, shredder and xylophagous species were significantly lower on sand than on roots. Conversely, there were no significant differences in community measures between reed and root habitats except abundances of Coleoptera. Our results suggest that the loss of eulittoral root habitats will cause a significant alteration of the littoral invertebrate community. This could be mitigated if unimpaired reed habitats are available in the infra littoral zone which may serve as a refuge for most species typical for root habitats. Our results need to be verified by direct observations, especially as the extent of future water-level fluctuations is currently not assessable and might be more severe than assumed.

Notes: Paper documents loss of eulittoral tree root macroinvertebrate habitat due to lower water levels.


Abstract: From May to September in 1990 and 1991, 24 coastal wetland and beach sites in Green Bay, Lake Michigan, were sampled to investigate abiotic and biotic factors influencing fish assemblages; half the sites were modified by human developments, and half were relatively undeveloped. The greatest assemblage differences were observed among regions, but there also were strong differences among assemblages from different habitats. Degree of development had less of an effect on site differences, although assemblages at undeveloped wetlands were unique, and those from developed and undeveloped sites in the upper bay were relatively distinct. The most influential abiotic factors were turbidity, reflecting the trophic gradient in the bay, and a suite of variables associated with macrophyte coverage and diversity, which were critical components of nursery habitats for the primarily immature fishes we captured. The volatile and unpredictable nature of shoreline habitats in the Great Lakes apparently precluded competition and predation from having a strong organizing role. This study demonstrates that undeveloped wetlands are a valuable and intensely utilized fish habitat, particularly as nursery areas that should receive special consideration in ecosystem management plans for the Great Lakes.

Notes: Twenty-four coastal wetland and beach sites in Green Bay, Lake Michigan, WI were sampled to investigate abiotic and biotic factors influencing fish assemblages. The most influential abiotic factor was turbidity, reflecting the trophic gradient in the bay. Other influential factors included a suite of variables
associated with macrophyte coverage and diversity. Though WLF was not addressed directly, both turbidity and macrophyte coverage and diversity have been affected WLF in other coastal wetlands.


Abstract: Little has been done to quantify fluxes of organisms, nutrients, and energy between freshwater coastal habitats and adjacent offshore waters or to evaluate the ecological implications of these exchanges on a whole-lake basis. To test the hypothesis that fish-mediated transport might play an important role in the flux of nutrients and energy between coastal wetlands and adjacent lake waters, net carbon, nitrogen, phosphorus, and energy fluxes were estimated in forage fish between a Lake Superior coastal wetland and an adjacent bay. This was accomplished by sampling fish at the inlet/outlet of Bark Bay Slough for 1 week per ice-free month in 1995. Average carbon, nitrogen, and phosphorus content of the 20 species analyzed was 45.1, 11.3, and 2.45% of dry-weight, respectively. Estimates of organism, nutrient, and energy movement revealed a net export from the slough to the adjacent Bark Bay, due largely to emigration of YOY yellow perch, *Perca flavescens* (> 40,000 individuals), YOY northern pike, *Esox lucius* (> 600 individuals), and yearling emerald shiner, *Notropis atherinoides* (> 8,000 individuals) in June and July, and YOY brown bullhead, *Ameiurus nebulosus* (> 500 individuals) in October. Since these fish movements resulted in relatively small fluxes of nutrients (1,376 g carbon, 335 g nitrogen, 73 g phosphorus) and energy (65,100 kJ) from the wetland to the lake, the most significant influence of forage fish emigration on Lake Superior may be through subsequent trophic interactions in nearshore habitats. However, assessment of the significance of the nutrient and energy results awaits a more complete budget for these ecosystems.

Notes: The authors studied fish-mediated transport of nutrients and energy between coastal wetlands and adjacent lake waters. They sampled fish at the inlet/outlet of Bark Bay Slough, SU. Estimates of organisms, nutrients, and energy showed a net export from the slough to the bay. This export potential lends support to the idea that coastal wetlands may be “centers of organization” (Steedman and Regier 1987) in the GL, and may have more ecological influence on the lakes than that predicted from their size alone. However, the authors caution that a more complete budget needs to be developed for these systems. Indirectly related to WLF through water level regulation’s effects on coastal wetlands and connections between wetlands and the GL.


Abstract: Developing effective indicators of ecological condition requires calibration to determine the geographic range and ecosystem type appropriate for each indicator. Here, we demonstrate an approach for evaluating the relative influence of geography, geomorphology and human disturbance on patterns of variation in biotic indicators derived from multiple assemblages for ecosystems that span broad spatial scales. To accomplish this, we collected abundance information on six biotic assemblages (birds, fish, amphibians, aquatic macroinvertebrates, wetland vegetation, and diatoms) from over 450 locations along U.S. shorelines throughout each of the Great Lakes during 2002–2004. Sixty-six candidate taxon- and function-based indicators analyzed using hierarchical variance partitioning revealed that geographic (lake) rather than geomorphic factors (wetland type) had the greatest influence on the proportion of variance explained across all indicators, and that a significant portion of the variance was also related to response to human disturbance. Wetland vegetation, fish and bird indicators were the most, and macroinvertebrates the least, responsive to human disturbance. Proportion of rock bass, *Carex lasiocarpa*, and stephanodiscoid diatoms, as well as the presence of spring peepers and the number of insectivorous birds were among the indicators that responded most strongly to a human disturbance index, suggesting they have good potential as indicators of Great Lakes coastal wetland condition.
Ecoprovince, wetland type, and indicator type (taxa vs function based) explained relatively little variance. Variance patterns for macroinvertebrates and birds were least concordant with those of other assemblages, while diatoms and amphibians, and fish and wetland vegetation were the most concordant assemblage pairs. Our results strongly suggest it will not be possible to develop effective indicators of Great Lakes coastal wetland condition without accounting for differences among lakes and their important interactions. This is one of the first attempts to show how ecological indicators of human disturbance vary over a broad spatial scale in wetlands.

Notes: The authors report on a survey of biota at 276 GL coastal wetlands. They assessed the responsiveness of 66 candidate indicators to human disturbance. Data would provide background information on many sites as baseline for WLF studies.

Abstract: Empirical relationships between recession rate of bluffs and precipitation, storm frequency, lake level, deep water wave power, and wave impact height are derived for two Lake Michigan shoreline reaches in Wisconsin. Recession rates are determined from digital orthophotos constructed using historical aerial photographs at least once every decade from the 1940s to present. The recession measurements represent spatial averages of rates measured at increments of 10-20 m along the shoreline over a distance of about 500–700 m. The temporal variations in recession rates over intervals ranging between 6 and 17 years were determined for the toe and crest at the sites with high (30–45 m) bluffs and for the crest, but not the toe at the site with low (9–11 m) bluffs. Trends in precipitation, storm frequency, and deep water wave power show weak relationships with changes in bluff recession rate. Both the toe of the high bluffs and the crest of the low bluffs show temporal recession-rate patterns that closely match the changes in the average lake-water level. The crest of the high bluffs recedes at a rate that is relatively insensitive to lake level changes. The annual average of the peak monthly wave-impact height appears to be the best predictor of bluff recession rate over the intervals studied.

Notes: Authors report on factors controlling rates of bluff recession at two sites on Lake Michigan. They estimated bluff recession rates since 1940 using aerial photos. Recession rate patterns for crests of low bluffs and toes of high bluffs closely match changes in average lake level. Crests of high bluffs recede at rates relatively insensitive to lake level changes. Annual average peak monthly wave-impact height is the best predictor of bluff recession rates.

Abstract: Invertebrate communities from different coastal marsh-plant communities were compared along wave-exposure gradients using data from 1994, 1998 and 1999. Data were subjected to correspondence analyses to search for patterns in invertebrate communities in relation to plant-community structure and wave exposure. In 1994, quantitative plant- and sediment-invertebrate samples were taken from nine habitats: four from inland, subsurface-connected marshes and five from littoral, emergent marshes. In 1998, sweep-net samples were taken from 13 plant communities: six on the exposed and seven on the protected side of an island. In 1999, 2–3 plant communities/sites were sampled with sweep nets from four sites around the Bay so that intersite differences between inner, less-exposed and outer, more-exposed habitats could be examined. In all three studies, correspondence analyses separated inland, protected or inner sites from littoral, exposed or outer sites, suggesting differences in invertebrate-community structure. For example, Hydracarina and Asellidae occurred in large numbers in inland sites, but were less common or absent from exposed, littoral sites. Littoral marshes also separated along an exposure gradient with Tanytarsini and Orthocladiinae collectors of organic particles occurring in very high numbers in outer, exposed areas where organic particles from the pelagic zone entered the marsh. Certain plant-community types clustered together (e.g. wet meadow and Scirpus) while others,
such as Typha, stands clustered according to exposure to waves suggesting the importance of both plant-community structure and wave exposure in determining invertebrate-community structure. We present a conceptual model that suggests that invertebrates in Great Lakes’ marshes are distributed along gradients of decreased mixing of pelagic water and increases in sediment organic matter from outer to inner marsh and between littoral and adjacent inland marshes. Some invertebrates do best on one end of these gradients, while the majority are generalists found across habitat types.

Notes: Semi-quantitative (1998-1999) and quantitative (1994) study of the benthic invertebrate community of two marsh complexes in Saginaw Bay, HU. Plant community structure and wave exposure play important roles in structuring the macroinvertebrate community. They suggest a conceptual model showing how GL invertebrate communities are distributed along gradients of decreased pelagic water mixing and changes in sediment organic matter.


Abstract: Northern Lake Huron marshes are among the most pristine wetlands in the Great Lakes. Almost 200 invertebrate taxa were collected from eight of these marshes from 1997 through 2001. Our objective was to explore relationships between wave exposure (fetch), plant community zones and invertebrate community composition using exploratory data analysis of invertebrate relative abundance. Effective fetch, an exposure measure which integrates fetch along three directions, ranged from 0.4 to 33.3 km. Invertebrates were collected with dip nets from wet meadow, Typha, and inner and outer Scirpus zones from 3 very protected (fetch <1 km), 3 protected (fetch 1–10 km) and 2 exposed (>10 km) marshes. Correspondence analyses of invertebrate relative abundance did not plot invertebrate communities of wet meadows along fetch gradients even though 7 of 30 common taxa were significantly (p < 0.05) correlated with fetch. After removing wet meadow data, correspondence analyses of data from remaining plant zones plotted marshes according to fetch with very protected and exposed sites at opposite ends of U-shaped gradients. Most taxa were generalists, occurred in marshes in all exposure categories, and plotted in the middle of correspondence analyses plots. Characteristic taxa plotting at the very protected end of the gradient included Gammarus, Crangonyx, Caecidotea, Chironomini, Tanytarsini, most Gastropoda and Sphaeridae. Characteristic taxa plotting at the most exposed end included Sigara, Trichocorixa, Naididae (Stylaria), Tubificidae, and Bezzia. We present a conceptual model of potential changes in invertebrate community composition along gradients of wave exposure. In very protected marshes, organic sediments, detritus, and plant density are higher and dissolved oxygen is lower than in exposed marshes. Conditions are too harsh for some taxa found in very protected marshes.

Notes: Analysis of benthic invertebrates collected from eight northern HU marshes from 1997-2001, comparing abundance to fetch across a gradient of protected to exposed sites. In protected marshes, organic matter, detritus and plant densities are higher and dissolved oxygen is lower than in exposed marshes. Marsh invertebrate communities consist of many generalists that occur across all plant zones regardless of wave exposure and a smaller number of specialists that are found on either end of the exposure gradient. Even though wave exposure is low in wet meadows and Typha zones, there are still species correlated with fetch. They conclude that fetch and plant community composition are important parameters in understanding habitat requirements for coastal wetland invertebrates, with fetch being important for comparisons among wetlands and plant composition for determining species along exposure within individual wetlands.


Abstract: Lake Huron protected (barrier-protected) wetlands occur within 1 km of the lake, in swales, interdunal ponds, and other shallow depressions. These wetlands are not directly connected via surface water to Lake Huron, although their hydrology is influenced by lake levels. Biodiversity in them has not
been well documented. We compiled plant and animal species occurrence data from published and unpublished sources for the U.S. coast of Lake Huron. Many data sources were reports written by the authors and/or by scientists of the Michigan Natural Features Inventory. Species occurrence data were supplemented with data from published wetlands literature and dissertations and theses. We did not do a thorough compilation for Canadian wetlands and only added limited Canadian data from the "Ontario Great Lakes Coastal Wetlands Atlas." We estimate that total species richness exceeds 1400 species with about an equal number of plants and animals (600-700 species each). We documented the occurrence of 466 macrophytes in Lake Huron's protected marshes, fens, and swamps and estimated total plant species richness to be > 600. Invertebrate species richness was estimated to be 500-600 with more than half of these being macroinvertebrates (> 0.5 mm) and the remainder being microinvertebrates (< 0.5 mm). Vertebrate species richness was estimated to be > 200 as follows. Fish species richness was estimated to be < 10 because of low oxygen, periodic dry periods, and lack of surface water connection to Lake Huron. Amphibian species richness was estimated to be > 20 with 10 frogs and toads and 7 salamander species documented. Reptile species richness was estimated to be > 20 based on very limited data and published distribution maps with > 10 turtle species and > 10 snake species but no lizards in Lake Huron marshes (although 4-5 lizard species occur on sandy ridges near swale marshes). More than 50 mammal and 80 bird species were estimated to occur in protected wetlands.

Notes: They compiled plant and animal species occurrence data from published and unpublished reports on U.S. HU protected wetlands. Species richness was determined for vertebrates, invertebrates, and plants. Projections of declining water levels due to climate change will cause many wetlands to migrate offshore, isolating shallow areas of lacustrine wetlands. These species richness data will aid in convincing the public of the values of these habitats.


Abstract: Many of the wetlands within the Great Lakes basin have already been converted to other uses. For example, 47% or 7.5 of 16 million ha of wetlands had been destroyed in Michigan, Minnesota and Wisconsin by 1980. These three states account for 77% of the total wetland areas in glaciated regions of the United States. Most of these wetlands are inland with only a small percentage classified as coastal wetlands. For example, 3.3% of Michigan's 1.3 million ha or 42,840 ha were classified as coastal wetlands. These wetlands are often considered to be modulators of events between land and water. Some of the fluctuations ascribed to them include: (1) acting as a natural filter to protect the water quality of the Great Lakes from nutrients and toxic materials; (2) acting as flood storage areas to reduce the magnitude of flood damage; (3) acting as areas of concentrated primary and secondary production which may serve as food chain support for near-shore Great Lakes communities; (4) acting as recharge areas for groundwater; and (5) serving as habitat and/or nursery areas for fish, mammals, game and non-game birds as well as invertebrates and ectothermic vertebrates. The present 7-10 year cycle of water level fluctuation results in low periods in lake level which are about 1.75 m lower than the high. The difference between low and high water can have profound effects on the plant communities of coastal marshes. At low water levels, open water decreases from almost 50% of wetland area to about 15%. At high water levels near 177 m in 1975, much of the area of the marsh was occupied by open water/submergent vegetation or emergent vegetation. As water level increases, inundated areas will support considerable emergent and/or submergent productivity including the associated epiphytic plant productivity. As this material rapidly decomposes, the overlying water dissolved oxygen concentrations will decrease, especially in winter when oxygen production by plant photosynthesis is limited. Alternate fluctuations in water level in marshes could result in a situation analogous to that resulting from seasonal re-oxygenation of bottom waters in dimictic eutrophic lakes. Litter accumulation was greatest under lowest water conditions due to known slower decomposition rates in sedge meadows. The impact of water level
Changes on some bird and mammal populations have been well documented for inland emergent marshes. Few such data are available for the Great Lakes, and almost no data are available for fish populations.

Notes: Review of the literature available at the time on the effect of WLF on GL coastal marshes.


Introduction: Agencies regulating water levels need numerical information as to the water level needs by the biological resources. An approach is suggested in this paper to deal with the difficulty in quantitatively evaluating changes in wetlands caused by water-level regulations. This approach includes using the median historic water-level profile to establish a seasonal picture, identifying the biologically significant range of needed long-term fluctuations, and setting each year’s curve (goal) as the median water-level curve within the long-term minimum and maximum curves as dictated by the past year’s water supply and predicted conditions for the coming year.

This paper suggests using a macro-scale approach for the identification of a range of desirable WLF for each of the GL.


No abstract.

This paper provides information on the responses of wetland communities to WLF in two ON wetlands. They used GIS and aerial photography from 1938 to 1989 to map the extent and type of wetland vegetation. The emergent plant communities showed a decline with increased water levels.


Abstract: A habitat classification system was used to describe aquatic habitat and evaluate habitat degradation in Lake Ontario. Primary consideration was given to physical loss or disruption of habitat availability; because habitat availability was treated as a functional entity, disruptions or stresses caused by chemical or biological sources were included. Data on biological, chemical, and physical anthropogenic changes were scattered, patchy, and disjointed. Therefore, the Delphi technique was used to evaluate the degree of functional habitat impairment for 29 habitats. The criteria for the impairments were the severity of the ecological impact (shift in trophic transfer efficiency) and its permanence (short > decades > permanent). The amounts of functional degradation were averaged by habitat categories (N = 88) for each habitat and multiplied by the estimated areal proportion of that habitat in the ecosystem. We estimated that during 1970-1990, Lake Ontario's ecosystem health was degraded by 58%. Impairments were caused almost equally by anthropogenic stresses from biological (loss of indigenous and introduction of exotic species), chemical (persistent toxins), and physical (dredge-fill, damming, and water-level regulations) sources. Our finding is consistent with a late 1980s study that used lake trout (Salvelinus namaycush) as an indicator of ecosystem health.

Notes: The authors assessed functional impairments to the habitats of ON ecosystems in terms of anthropogenic changes. Impairments were caused almost equally by anthropogenic stresses from biological (loss of indigenous and introduction of invasives), chemical (persistent toxins), and physical (dredge-fill, damming, and water level regulation) stressors.

Abstract: The macro-alga Cladophora glomerata is found in streams and lakes worldwide. High concentrations of Escherichia coli and enterococci have been reported in Cladophora along the Lake Michigan shore. The objective of this study was to determine if Cladophora supported growth of these indicator bacteria. Algal leachate readily supported in vitro multiplication of E. coli and enterococci, suggesting that leachates contain necessary growth-promoting substances. Growth was directly related to the concentration of algal leachate. E. coli survived for over 6 months in dried Cladophora stored at 4°C; residual E. coli grew after mat rehydration, reaching a carrying capacity of 8 log CFU g-1 in 48 h. Results of this study also show that the E. coli strains associated with Cladophora are highly related; in most instances they are genetically different from each other, suggesting that the relationship between E. coli and Cladophora may be casual. These findings indicate that Cladophora provides a suitable environment for indicator bacteria to persist for extended periods and to grow under natural conditions.

Notes: The authors found that Cladophora provides a suitable environment for indicator bacteria to persist for extended periods and to grow under natural conditions. Pertains to beach monitoring and beach closure work.


Abstract. Great Lakes coastal wetlands are widely recognized as areas of concentrated biodiversity and productivity, but the factors that influence diversity and productivity within these systems are largely unknown. Several recent studies have suggested that the abundance and diversity of flora and fauna in coastal wetlands may be related to distance from the open water/macrophyte edge. We examined this possibility for three faunal groups inhabiting a coastal wetland in Saginaw Bay, Lake Huron. We sampled crustacean zooplankton and benthic macro-invertebrates at five distances from open water in the summer 1994, and fish at three distances from open water in 1994 and 1995. We found significant spatial trends in the total abundance and diversity of zooplankton and fish, as well as the diversity of benthic macro-invertebrates. Zooplankton abundance and taxa richness were highest at intermediate distances from open water in a transition zone between the well-mixed bayward portion of the wetland, and the non-circulating nearshore area. Benthic macro-invertebrate taxa richness increased linearly with distance from open water. In contrast, fish abundance and species richness declined linearly and substantially (abundance by 78%, species richness by 40%) with distance from open water. Of the 40 taxa examined in this study, 21 had significant horizontal trends in abundance. This led to notable differences in community composition throughout the wetland. Our results suggest that distance from open water may be a primary determinant of the spatial distributions of numerous organismal groups inhabiting this coastal wetland. Several possible reasons for these distributions are discussed.

Notes: The authors sampled zooplankton and benthic invertebrates at five different distances from open water in a Saginaw Bay, HU coastal wetland. Distance from open water may be the primary determinant of spatial distribution for many invertebrates. Connectedness between wetland habitat and open water is imperative to maintain community structure.


Abstract: Over the past half century, habitat changes have significantly affected production of northern pike (Esox lucius), especially in the Great Lakes basin. Loss of wetlands, reduction of shoreline cover and structure, cultural eutrophication, and siltation have negatively affected water transparency, abundance of macrophyte habitat, and even body condition. We review recent habitat restoration programs conducted in the Great Lakes basin to reverse this trend. However, assessment has usually been inadequate to evaluate their success. Spawning and nursery requirements (first year of life) are examined, using a system for classifying and ranking major physical characteristics and requirements.
Depth of nursery habitat is directly correlated with fish size and age. Spawning habitat is usually less critical or limiting but more easily manipulated and restored than nursery or juvenile-adult habitats. Year-class strength over 22 yr in eastern Lake Ontario was correlated positively with midsummer temperature and negatively with late summer–early fall water elevation; also, the largest year-class appeared immediately after catastrophic winterkill of a predator, white perch (Morone americana). Both implicate nursery rather than spawning associations. Adult abundance is related to the extent of macrophyte cover, which is optimal from 35 to 80% but inversely related to body size.

Notes: A review of habitat restoration efforts in the GL basin and effects on northern pike production. Potential life history impacts due to climate change include a possible increase in nearshore habitat in the GL for cool-water fishes (Meisner et al. 1987) such as northern pike. This could make shallow embayments less optimal as juvenile and adult habitat, but potentially more suitable as nursery habitat. Effects on wetland vegetation and subsequent effects on pike are also discussed.


Abstract: During the early 1900s, more than 90% of the surface area of Cootes Paradise Marsh was covered with emergent vegetation; currently, less than 15% of the surface is covered with aquatic vegetation and the remainder is wind-swept, turbid, open water. The loss of emergent cover is significantly correlated with mean annual water levels that increased more than 1.5 m over the past 60 years. Species diversity and the percent cover of the submerged macrophyte community also declined dramatically after the 1940s, coincident with decreased water clarity and increased nutrients from pollution by sewage and stormwater effluent. Phosphorus levels in the marsh dropped ten-fold after the sewage plant was upgraded to a tertiary-treatment facility in 1978; however, there was no measurable improvement in water clarity, in spite of a decrease in chlorophyll concentrations. Long-term changes in the composition of the planktonic, benthic and fish communities accompanied changes in water clarity, nutrient status and macrophyte cover. Phytoplankton changed from a community dominated by diverse taxa of green algae and diatoms during the 1940s, to a less diverse community dominated by a few taxa of green and blue-green algae in the 1970s, then to a much more diverse community recently, including many taxa of green algae, diatoms and chrysophytes; however, because water turbidity continues to be high, and algae tolerant of low light levels are now very abundant. Daphnia, which were prominent during the 1940s (especially in the vegetated sites) were replaced in the 1970s by smaller zooplankton such as the cladoceran, Bosmina, and several rotifer species including Brachionus, Asplanchna and Keratella. In the recent survey conducted in 1993 and 1994, small-bodied forms still dominate the turbid open-water areas, while medium-sized cladocerans such as Moina were common near macrophyte beds. Generally, total herbivorous zooplankton biomass tended to be highest next to Typha beds and declined with increasing distance from the plants. Conversely, biomass of edible algae at these sites increased with distance from the macrophytes. Species diversity of aquatic insects declined dramatically over the past 40 years, from 57 genera (23 families and 6 orders) in 1948, to 9 genera (6 families and 3 orders) in 1978, to only 5 genera (3 families and 2 orders) in 1995. The diverse benthic community present 5 decades ago has now been replaced by a community consisting primarily of chironomid larvae, oligochaetes and other worms associated with low-oxygen environments. These successional changes illustrate the impact of natural (fluctuating water levels) and anthropogenic (deterioration in water quality) stressors on the character of the biotic communities, and reveal the complex interactions among the various trophic levels and the abiotic environment as degradation and remediation proceeded.

Notes: The authors assessed areal coverage of vegetation from 1932-1993, and water quality, phytoplankton, zooplankton, and benthic invertebrate communities from 1993-1999 in Cootes Paradise marsh, an urban coastal wetland in ON. High water levels in the 1940s and 1950s caused initial loss of wetland vegetation and regrowth was prevented by degraded water quality, encroaching human
development, and invasive species introductions (carp and Typha). High turbidity and an altered food web have prevented the reestablishment of emergent vegetation. Authors note that one problem with past WLF studies is that they rarely extend beyond years or decades which is inappropriate because WLF cycles last from 7-10 years.

No abstract.
Notes: This is a SOLEC 1998 background paper on the identification of “Eco-Reaches” of GL coastal wetlands that have high biodiversity value.

Abstract: A 4-year (1993 through 1996) monitoring program examined the distribution of total suspended solids (TSS) in Cootes Paradise Marsh, a shallow (mean depth of 70 cm), degraded, drowned river mouth marsh of Lake Ontario. Monthly meteorological and hydrographical data from 1986 through 1996 revealed a hydrologically dynamic system that exhibited large seasonal and interannual variation with respect to precipitation amount, discharge volume, and water levels; the prevailing winds were shown to be oriented along the length of the marsh. Interannual variation in TSS concentrations was inversely related to mean seasonal water levels that fluctuated 45 cm over the 11 years. In a stepwise regression analysis, planktonic chlorophyll-a concentration only explained 2% of the variation in TSS, while inorganic and non-algal organic solids explained 70% and 18%, respectively. Mean seasonal water turbidity increased significantly with mean seasonal wind speed at 17 sampling stations during 1993 and 1994. Runoff from a summer rainstorm more than doubled water turbidities at the mouth of all three creeks over the first 36 hours. In enclosure experiments, water turbidity increased proportionately with biomass of benthivorous fish (especially common carp, Cyprinus carpio). When wind and carp disturbance were compared simultaneously in the field, wind speed accounted for 41% of the variation in turbidity while presence of carp explained an additional 21%. The overall temporal and spatial distribution of TSS in the marsh reflected changes in water level, wind activities, onset of rain events, and fish disturbance that acted in concert to keep Cootes Paradise Marsh extremely turbid throughout the summer.
Notes: Documents seasonal and spatial variability in turbidity in Cootes Paradise Marsh, a degraded ON coastal wetland. Interannual variation in TSS was inversely related to water level, with wind and fish-induced resuspension, tributary loading, and algal growth driving the increase in TSS.

Abstract: A general understanding of how aquatic vegetation responds to water-level fluctuations is needed to guide restoration of Great Lakes coastal wetlands because inter-annual and seasonal variations often confound effects of costly remedial actions. 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 re-assembled from the literature to relate percentage cover of emergent vegetation to mean summer water level. A non-linear regression equation explained close to 90% of the variation compared with 80% for a non-linear equation, and this trend was confirmed for the dominant species, Typha latifolia. A modest recovery of emergent vegetation in 1999 following carp exclusion could have been predicted from declining water level alone, without invoking any effects of the biomampulation. An unusually cool spring in 1997 delayed the migration of spawning planktivores into the marsh. This resulted in a grazer-mediated clear-water phase that coincided with a resurgence of the submersed...
aquatic vegetation (SAV) community in 1997, which declined again in 1999 when low water levels occurred. Even though decrease in water level was significantly related to increased suspended solids and greater light attenuation, light conditions appeared to have been adequate in marsh embayments to support SAV growth, according to a published relationship between maximum depth of SAV colonization and light extinction coefficient. I suggest that wave disturbance and propagule burial associated with shallow water depths may have been the main reasons for the decline of the SAV in 1999 and 2000.

Notes: The author’s goal was to determine the response of a GL coastal wetland (Cootes Paradise Marsh, ON) to carp exclusion by accounting for the confounding effects of water level variation. Specific factors discussed are changes in water clarity and the growth of submerged aquatic vegetation.


Abstract: Data from a nearshore sediment core and a deep-water sediment core from the central basin of Lake Erie reveal shifts in sediment properties and stable isotope composition of shell carbonate between ca. 4,600 and 3,500 C-14 yrs BP. Radiocarbon dates are corrected for the hardwater effect by subtracting 670 years based on a modem calibration for the central basin. Silt content increased in the deep water core at 4,600 and again, slightly, at 3,900 C-14 yrs BP. Sand size increased in the nearshore core at 3,500 C-14 yrs BP. delta O-18 of shell carbonate increased and delta C-13 decreased in both cores between about 4,200 and 3,500 C-14 years BP. Magnetic susceptibility and percent calcite decreased sharply and percent organic carbon increased slightly in the deep water core beginning at 4,000 C-14 yrs BP. Most of the changes in sediment properties and stable isotope composition of shell carbonate occurred between 4,200 and 3,900 C-14 yrs BP. They coincide in time with the Nipissing II highstand of Lake Nipissing, in the Huron and Michigan basins, and with evidence for higher-than-present lake levels in Lake Erie. The changes in proxy data are interpreted as evidence for an influx of surface water as drainage from the Upper Great Lakes was rerouted through Lake Erie. There is little evidence in the sediment proxy record for changes in Lake Erie during the earlier Nipissing I highstand or the middle Holocene transition in regional climate. A 9,000-year composite stable isotope record for the central basin shows that the sediment cores document a transformation in drainage that established the modern hydrologic system for the lake. High lake level induced a seasonal hypolimnion, setting the stage for the low pH, oxygen-depleted bottom waters of today.

Notes: Sediment cores from ER with a 9,000-year composite isotope record showed that a permanent shift in the hydrology and character of the lake set the stage for its current-day hypolimnion and deep-water anoxia.


Abstract: We report the first documented observation of the potentially toxic cyanobacterium Cylindrospermopsis in Lake Erie and Sandusky Bay in 2005 (0.043-1.326 mg L-1 wet weight, 16-1,942 trichomes mL-1) and quantify the physical and chemical parameters and the cyanobacterial community composition contemporaneous to its occurrence. We hypothesize that the high temperature, low light intensity, and high nutrient content of Sandusky Bay, a shallow, drowned river mouth along the southwestern shore of Lake Erie, provides an ideal habitat for Cylindrospermopsis. This is consistent with published laboratory and field studies that show these physical and chemical conditions facilitate Cylindrospermopsis growth. Using multivariate statistics, we found that Cylindrospermopsis biomass correlated with high temperatures and shallow depths, conditions often found in Sandusky Bay. Light climate and nutrient concentrations were not associated with Cylindrospermopsis biomass, most likely because the light climate did not systematically change during the season and because nutrients exceeded demand. We propose that Cylindrospermopsis will increase in importance in Lake Erie, as previous
research on climate change in the Great Lakes region predicts future higher water temperatures and lower water levels.

Notes: First documentation of *Cylinderspermopsis* in ER, Sandusky Bay. Factors favorable to the growth of this potentially toxic cyanobacterium include higher water temperatures and lower water levels.


Abstract: Lake Michigan drowned river-mouth wetlands have a unique geomorphology and hydrology. Macroinvertebrate communities in these systems respond to multiple biotic and abiotic factors that are not well understood. In June and August 2003, we sampled macroinvertebrate communities at 22 sites in four Lake Michigan drowned river-mouth wetlands. Sites were distributed along gradients of anthropogenic disturbance, vegetation, and sediment type. The relative influences of anthropogenic disturbance, vegetation, and sediment type on macroinvertebrate community composition were determined using non-metric multidimensional scaling (NMDS) and multi-response permutation procedures (MRPP). The depth of organic deposits best explained the gradients revealed with NMDS and MRPP for both sampling dates. The MRPP did not detect differences in community composition among vegetation types and wetlands with different levels of anthropogenic disturbance. These results suggest that 1) macroinvertebrate community structure in Great Lakes drowned river-mouth habitats is influenced substantially by sediment characteristics, and 2) anthropogenic practices that affect the deposition of organic sediment in coastal wetlands (e.g., eutrophication and hydrologic manipulation) will likely affect macroinvertebrate community structure.

Notes: The authors’ objective was to describe macroinvertebrate communities of MI drowned river mouth wetlands, relating them to vegetation type, organic sediment, water depth and anthropogenic disturbance (primarily changes in hydrology). Analyses showed the community structure was most related to sediment characteristics, which are influenced by hydrology.


No abstract.

Notes: This is the introduction to a special issue on WLF and wetlands.


Abstract: The effects of water level fluctuations on fish and other aquatic biota, with an emphasis on winter water withdrawal in northern regions is reviewed. Water demands for population growth and development are adding pressure on water reserves, particularly when coupled with changing climatic conditions. Water level fluctuations can have adverse effects on the environment, most notably to hydrologic and biotic processes ranging in magnitude from the micro-scale to landscape level. Water level management of lakes and reservoirs can affect all forms of aquatic biota. The severity of effect is dependent on the magnitude, duration and timing of the fluctuation, and the species exposed. In northwestern Canada and northern Alaska, water is withdrawn from water bodies to construct ice-roads and other winter based developments. Biota in small, isolated water bodies are particularly sensitive to reductions in winter water levels. Water withdrawals can reduce the oxygen available to overwintering fish, while reduced water levels can reduce habitat for fish and furbearers, and freeze littoral areas killing plants, invertebrates, and fish eggs. Regulatory winter water withdrawal thresholds have been developed in the Northwest Territories and Alaska and continue to be refined as new data becomes available. The use of thresholds can help minimize or avoid negative impacts to the environment,
particularly fish, from winter water withdrawal activities. Many different factors may influence the effect that winter water withdrawal has on a water body, such as basin shape, substrate and location. More research is warranted to better understand the linkages between anthropogenic and natural water level fluctuations and their combined effect on aquatic ecosystems. A general decision support system is proposed for minimizing risk to aquatic life from winter water withdrawal activities.

Notes: Documents the effects of WLF on fish and other aquatic biota, with an emphasis on winter water withdrawal in lakes and reservoirs in NW Canada and N. Alaska. Effects depended on magnitude, duration, and timing of withdrawals.

Abstract: A brief review is provided in some advances in understanding the ecology of pike Esox lucius Linnaeus over the last 10 years. Based on long-term studies and manipulative, often short-term experiments (laboratory, field and mesocosms) several established theories have been supported, as well as new concepts developed. Despite their wide distribution pike show low levels of polymorphism and divergence indicative of a recent common ancestral population. Recent genetic studies, however, indicate a single refugium in North America compared to several refugia in Europe. Pike are found in rivers, lakes and weakly saline waters. Variables such as growth and mortality are mainly affected by factors such as temperature, water transparency, productivity, availability of prey and density of pike and other predators. In choice of habitat pike have been shown to support the ideal free-distribution theory. The importance of macrophyte habitat in the life history of pike has been reconfirmed and pike have been shown to be flexible in response to water clarity. Pike are extremely 'plastic' in choice of prey types, prey size and in response to prey behaviour (e.g. they are unaffected by shoal size). Predation by pike not only affects abundance and biomass of prey (including younger and smaller pike through cannibalism which plays a major role in population dynamics, other fishes and invertebrates) but also evolution and adaptation of their morphology (in particular body shape) and behaviours. There appears to be no relationship between stock and recruitment. Recruitment is influenced by several abiotic factors in lakes and rivers. Pike play a major role in structuring freshwater communities and have been used in stocking programmes to improve water quality (biomanipulation). Many new concepts have been developed in pike behaviour in maximizing these stocking programmes both in biomanipulation and fisheries management. Despite many recent advances in understanding the ecology of pike, particularly at the individual level, developments in quantifying and modelling the role of pike as a top predator in large ecosystems have been limited, probably due to the difficulties of sampling natural populations.

Notes: This is a review of northern pike ecology. Growth and mortality are mainly affected by temperature, water transparency, productivity, prey availability, and the density of pike and other predators. The importance of macrophyte habitat in pike life history was confirmed.

Abstract: Seasonal and annual hydrologic variability is necessary for maintenance of suitable nesting and foraging habitats for a variety of wetland dependent bird species, especially at wetlands associated with large water bodies. Lake Ontario hydrology has been altered by water regulation controls in the St. Lawrence River since 1959. This has resulted in reduced within- and among-year amplitude and variability in Lake Ontario water levels and has altered temporal water level patterns. In 2000, the Lake Ontario – St. Lawrence River Study Board began a five-year study for the International Joint Commission to review the current water regulation criteria, and if deemed appropriate, alter the current criteria to better meet the diversity of interests that occur within this region. Water regulation criteria as it relates to and influences environmental values and specifically coastal wetland biotic communities have been identified as a priority aspect of the five year study. Seven years of Marsh Monitoring Program (MMP) data were used to compare 1) how occurrence and abundance of marsh bird species at Lake Ontario
coastal marshes differ from those at non-Lake Ontario coastal marshes, 2) correlations of annual Great Lakes water level indices with annual wetland bird species abundance indices during the breeding period, 3) patterns of agreement between direction of annual changes of lake levels and those of species abundance indices, and 4) temporal patterns of basin-wide and basin-specific annual lake levels and proportional marsh habitat indices. Marsh bird species route occurrence and mean abundance indices for all survey years were lower at Lake Ontario coastal routes than at Great Lakes basin coastal routes combined. Several marsh nesting bird species' annual abundance indices for Great Lakes basin coastal routes correlated positively with water level indices, either directly or with the previous year's water level indices (American Bittern, Black Tern, Common Moorhen, Forester's Tern, Least Bittern, Marsh Wren, Pied-billed Grebe, Sora and Virginia Rail). Conversely, annual abundance indices of some marsh bird species known to inhabit dryer marsh edges or that nest on dry ground correlated negatively with Great Lakes basin water level indices (Common Yellowthroat, Song Sparrow, Willow Flycatcher and Yellow Warbler). Temporal proportional habitat coverage did not appear to track lake levels, however, MMP habitat collection techniques are basic and may not lend themselves to temporal comparison of overall habitat diversity and spatial heterogeneity. Because changes to natural hydrologic regimes could have marked effects on wetland dependent bird species richness and/or regional species-specific population status, results are discussed as they pertain to how Lake Ontario water level regulation may be influencing coastal marsh bird communities.

Notes: Seven years of Marsh Monitoring Program (MMP) data were used to compare, among other things, correlations of annual GL water levels with breeding bird populations, correlations between WL changes and species abundance indices, and temporal WL pattern correlations with marsh habitat indices. There is a focus on ON water level regulation effects on wetland birds.


Abstract: Indices have been developed with invertebrates, fish, and water quality parameters to detect the impact of human disturbance on coastal wetlands, but a macrophyte index of fish habitat for the Great Lakes does not currently exist. Because wetland macrophytes are directly influenced by water quality, any impairment in wetland quality should be reflected by taxonomic composition of the aquatic plant community. We developed a wetland macrophyte index (WMI) with plant presence/absence data for 12 7 coastal wetlands (154 wetland-years) from all five Great Lakes, using results of a canonical correspondence analysis (CCA) to ordinate plant species along a water quality gradient (CCA axis 1). We validated the WMI with data collected before and after the implementation of remedial actions plans (RAPs) in Sturgeon Bay (Severn Sound) and Cootes Paradise Marsh. Consistent with predictions, WMI scores for Sturgeon Bay were significantly higher after the implementation of the RAP. Historical data from Cootes Paradise Marsh were used to track the declining condition of the plant community from the 1940s to 1990s. Subsequently, when remedial actions had been implemented in 1997, the calculated WMI scores showed improvement, but when the presence of exotic species (WMIadj) was accounted for, improvements in ecological integrity of the aquatic-plant community were no longer evident. We show how WMI scores can be used by environmental agencies to assess the historic, current, and future ecological status of wetland ecosystems in two Canadian national parks, Point Pelee National Park and Fathom Five National Marine Park.

Notes: Discussion on how aquatic vegetation can be used in the wetland macrophyte index (WMI) to indicate human-induced degradation of coastal marshes in all the GL. WMI was validated with Coote Paradise Marsh (ON) water clarity, turbidity and TSS. Any bias due to WLF effects are accounted for because data were collected over the entire GL basin over a nine-yr period (1996-2005). WMI was developed specifically for coastal systems that have a hydrological link to a large lake or bay.

Abstract: The submerged limnetic community in Lake Ontario includes algae, bryophytes, and about 30 species of angiosperms. Their distribution is accurately known in some areas but not lake-wide, and a whole-lake survey is recommended. In nutrient cycling, submergents act as sinks during the summer; metals and metalloids occur in high concentrations in tissues from some areas. Known herbivores include invertebrates, fish, and waterfowl. Stands are necessary for many fish taxa as breeding or nursery habitats, and for waterfowl, but may be damaged by carp (Cyprinus carpio). Stability has been affected by water levels, sedimentation, wave and ice movement, invasive species, herbivory, eutrophication and turbidity, and contaminants. Recovery after control of P loading has occurred in Irondequoit Bay but is delayed by turbidity in the Bay of Quinte.

Notes: A discussion of the submerged limnetic community in ON and research needs. SAV stability has been affected by water levels, sedimentation, wave and ice movement, invasive species, herbivory, eutrophication, turbidity, and contaminants.


Abstract: Shoreline habitats in the Kingston basin have experienced continual change on a wide range of time scales, as a result of physical, chemical, and biotic stresses of both natural and anthropogenic origin. Not all change can or should be controlled. From a management perspective, stresses can be usefully subdivided into those that originate from the lake as a whole (e.g., water-level and-chemistry changes, introduction of exotic species) and those originating from the adjacent land area (e.g., point-source contamination and sedimentation). Stresses from the lake cannot be controlled locally, whereas those arising from terrestrial activities are more easily managed. Slow rates of change are less likely to have dramatic effects than rapid change, but a small change can have catastrophic effects if it exceeds the threshold tolerance of an ecosystem. Dramatic alterations to the entire ecosystem can also occur if a single, important species (e.g., a macrophyte) is adversely affected, because of complex feedback responses between the various components of the system. Thus, management strategies should focus on those areas that are particularly susceptible to land-based stress and on stresses that are most likely to exceed the tolerance of key components of an ecosystem.

Notes: Paper’s focus is on management decisions for coastal wetlands over a wide range of time scales due to natural and anthropogenic chemical and biotic stresses. These stresses can be lake (WLF included) and/or land based. Generally, only land-based stresses can be addressed with management strategies. Management action should focus on those areas that are particularly susceptible to land-based stresses, and on stresses most likely to exceed the tolerance of key components of an ecosystem.


Abstract: This contribution outlines the philosophy and procedures adopted in a major European research project focused on the development of video systems in support of coastal zone management. The CoastView project has developed video-derived coastal state indicators (CSIs) that directly facilitate management decisions. Coastal State Indicators are defined here as, “a reduced set of issue-related parameters that can simply, adequately and quantitatively describe the dynamic-state and evolutionary trends of a coastal system.” The process of defining useful CSIs involves close interaction between coastal managers, scientists and policy makers. Even with frequent formal discussions and colloquia between these parties the process of defining useful indicators frequently fails. An approach [Van Koningsveld, M., 2003. Matching specialist knowledge with end-user needs. PhD thesis, University of
Twente, Enschede, The Netherlands, 173 p.] is described in this paper which guarantees the effectiveness of the resulting CSIs, and enhances the communication process between scientist and coastal managers. Some practical examples of the frame of reference are given by way of illustration and a detailed description is given of the procedure adopted within the CoastView project for defining and evaluating CSIs. The philosophies and methodologies used during the three year CoastView project have proved successful and provide a valuable template on which to base future research projects focusing on end-user oriented research.

Notes: A description of CoastView, a coastal video monitoring program that aims to 1) develop coastal indicators (CSI) that are directly related to management issues, 2) develop improved video systems for delivering CSI to managers in a timely manner, 3) develop algorithms for estimation of CSIs and 4) to ground truth measurements for video-derived CSIs. Coastal video allows for remote assessment of waves, currents, sediment transfer, and morphological change.


Abstract: Lake Ontario and St. Lawrence River (LOSL) wetland bird abundance and diversity are greatly influenced by lake and river hydrology. Our study used an interdisciplinary ecosystem approach, blending avian and plant ecology, ecohydraulic, statistical ecology and modelling to evaluate potential impacts of water level fluctuations on indicator species representative of the wetland breeding bird assemblages in the entire LOSL freshwater system. Multi-year (2000-2003) bird surveys captured bird distribution and density in wetland habitats under varying degrees of water inundation, depth and fluctuation. Analyses revealed strong associations between estimated breeding pair densities and plant communities, water depth, and degree of water level fluctuation during the breeding season for a suite of wetland bird species using marsh, wet meadow, shrub swamp and treed swamp habitats. These quantitative associations were used to develop wetland bird performance indicators for use in a LOSL water regulation review study. Several bird species also nest at or near the water surface and are thus vulnerable to nest flooding or stranding. Changes to the seasonal hydrology of Lake Ontario and St. Lawrence River that result in an increased frequency or magnitude of these nest failure events may have a significant impact on regional population sustainability. Long term nest record databases were analyzed to create nesting flooding and stranding probability equations based on water level increases and decreases during the breeding season. These species-specific nesting relationships were incorporated into a reproduction index. Many breeding bird species were strongly associated with specific wetland plant communities. Predicted habitat suitability, as measured by estimated breeding pair density, can also change significantly within a specific wetland plant community based solely on changes in water depth during the breeding season. Three indicator species, black tern, least bittern and Virginia rail were selected as key environmental performance indicators for alternate regulation plan comparisons. Water regulation criteria should be such that the long term diversity and abundance of wetland plant communities and frequency of spring flooding in marsh habitats during breeding are not reduced. Magnitude and frequency of water level change during the nesting season (May-July) can also adversely impact reproductive success of many wetland bird species. As such, regulation criteria that increase the seasonal magnitude and frequency of water level change may be detrimental to the long term viability of certain regional breeding bird populations.

Notes: The authors used an interdisciplinary approach to evaluate potential impacts of WLF on indicator species representative of wetland breeding birds in the ON-SL system. Many breeding species are strongly associated with specific wetland plant communities, and water regulation criteria should insure that long-term wetland plant diversity and abundance as well as spring flooding in marsh habitats is not be reduced. The magnitude and frequency of WL change during the nesting season can adversely affect reproductive success, so WL criteria that increase these factors may harm breeding bird populations. If water level criteria cannot be altered to diminish known environmental impacts, then measures should be
taken to protect habitat and diversity from other human disturbances. Several key indicator species for WLF are named.


Abstract: Tessier-type (1979) sequential extractions for heavy metals (Cd, Cr, Cu, Fe, Mn, Pb, and Zn) were conducted on sediments from two wetland sites, one inundated and the other drained, within the Indiana Dunes National Lakeshore (IDNL), NW Indiana, with the objective of (i) evaluating extraction techniques on organic-rich sediments, (ii) determining the geochemistry and mobility of potentially biotoxic trace metals in a contaminated environment, and (iii) considering the implications of different restoration strategies on the potential for heavy metal remobilization. Long and repeated extractions were needed to effectively degrade the organic-rich sediments (up to 75% of the sediment by mass). Analysis of sulfur fractionation revealed that it was predominantly sequestered along with the organically bound fraction (renamed oxidizable). Metal recovery was good with the sum of the extractant steps typically within 20% of the total metal concentration determined after total microwave digestion. Results showed metal fractionation to be both metal- and site-specific. The oxidizable fraction is dominant for Cu, Cr, and Fe (>65% of the nonresidual fraction for almost all samples) and overall is most important also for Cd and Pb. The iron/manganese oxide fraction is important for Pb, Mn, and Zn, particularly at the drained site. The carbonate bound fraction is relatively insignificant at both sites, except for Cd and Mn, although it is more important at the drained site. The exchangeable fraction is significant in the uppermost sediments at the drained site, particularly for Cd (3-24%), Pb (3-14%), and Zn (36-45%); whereas, for the inundated site, it ranged only from 0 to 1% Zn, with no detectable Cd or Pb. Chromium, Cu, and Fe exist in forms not likely to be remobilized, whereas Cd, Mn, Pb, and Zn are potentially mobile if drained wetland sites are reflooded (and pH and redox potential altered). Simple mass balance calculations illustrate the potential for the removal of 84 375 kg of exchangeable Zn if currently drained sites across the IDNL are reflooded, with concentrations in water draining into Lake Michigan as high as 5 ppm.

Notes: Heavy metal extractions were performed on sediments from permanently inundated and drained wetlands within the Indiana Dunes National Lakeshore (MI) with several objectives in mind, including considering the implications of reflooding previously drained areas that might result in heavy metal mobilization. Results of this study indicate the easily exchangeable Zn in IDNL wetland sediments could be delivered to MI. This is of particular importance when developing wetland restoration plans.


No abstract.

Notes: This is a SOLEC 1996 background paper on the nearshore waters as significant natural elements of the GL. The major objective of SOLEC 1996 was to examine the effects of human activity (land-use practices) on the GL coastal ecosystem. Includes a discussion of WL and flow regulation and states that the majority of impact will be on coastal wetlands (also see Maynard and Wilcox 1997).

**EPA 2007. Detroit River-western Lake Erie basin indicator project.**


No abstract.

Notes: A review of potential effects of lower water levels on western ER. Declining lake levels will significantly affect Sandusky Bay by altering littoral and sublittoral habitats, thus permanently altering fish and benthic invertebrate community structure lakewide. Seasonal timing and connectivity, food web dynamics, and the distribution, structure, and composition of fish communities could also be affected.
Abstract: High, uncontrolled water levels in Lake Erie marshes that occurred in late 1972 altered the distribution and abundance of plant communities. Large areas of moist-soil species, cattails (Typha angustifolia, T. latifolia), rose mallow (Hibiscus palustris), emersed plants (e.g., Sagittaria, Scirpus, Cyperus, Carex), blue-joint grass (Calamagrostis canadensis), and annual weeds (e.g., Impatiens, Mimulus, Bidens) were eliminated and replaced largely by open water. With fewer lush stands of food plants available, the attractiveness of the marshes to migrating ducks declined. Population levels of muskrats (Ondatra zibethica) decreased because food and cover plants were lacking. Numbers of breeding waterfowl were reduced due to inundation of nesting sites in upland grassy meadows.
Unable to get reprint.

Abstract: Despite uncertainty in all levels of analysis, recent and long-term changes in our climate point to the distinct possibility that greenhouse gas emissions have altered mean annual temperatures, precipitation and weather patterns. Modeling efforts that use doubled atmospheric CO2 scenarios predict a 1-7 degrees C mean global temperature increase, regional changes in precipitation patterns and storm tracks, and the possibility of "surprises" or sudden irreversible regime shifts. The general effects of climate change on freshwater systems will likely be increased water temperatures, decreased dissolved oxygen levels, and the increased toxicity of pollutants. In lotic systems, altered hydrologic regimes and increased groundwater temperatures could affect the quality of fish habitat. In lentic systems, eutrophication may be exacerbated or offset, and stratification will likely become more pronounced and stronger. This could alter food webs and change habitat availability and quality. Fish physiology is inextricably linked to temperature, and fish have evolved to cope with specific hydrologic regimes and habitat niches. Therefore, their physiology and life histories will be affected by alterations induced by climate change. Fish communities may change as range shifts will likely occur on a species level, not a community level; this will add novel biotic pressures to aquatic communities. Genetic change is also possible and is the only biological option for fish that are unable to migrate or acclimate. Endemic species, species in fragmented habitats, or those in east-west oriented systems will be less able to follow changing thermal isolines over time. Artisanal, commercial, and recreational fisheries worldwide depend upon freshwater fishes. Impacted fisheries may make it difficult for developing countries to meet their food demand, and developed countries may experience economic losses. As it strengthens over time, global climate change will become a more powerful stressor for fish living in natural or artificial systems. Furthermore, human response to climate change (e.g., increased water diversion) will exacerbate its already-detrimental effects. Model predictions indicate that global climate change will continue even if greenhouse gas emissions decrease or cease. Therefore, proactive management strategies such as removing other stressors from natural systems will be necessary to sustain our freshwater fisheries.
Notes: The purpose of this review is to present current knowledge about climate change and its potential effects on freshwater fish populations. These effects include changes in habitat, including in lakes and streams, and include not only changes in temperature, hydrology, and eutrophication, but also effects on physiology in freshwater fishes world-wide.

Abstract: The Saginaw Bay walleye population (Sander vitreus) has not fully recovered from a collapse that began in the 1940s and has been dependent on stocking with only limited natural reproduction. Beginning in 2003, and through at least 2005, reproductive success of walleye surged to unprecedented levels. The increase was concurrent with ecological changes in Lake Huron and we sought to
quantitatively model which factors most influenced this new dynamic. We developed Ricker stock-
recruitment models for both wild and stock fish and evaluated them with second-order Akaike's
information criterion to find the best model. Independent variables included adult alewife (Alosa
pseudoharengus) abundance, spring water temperatures, chlorophyll a levels and total phosphorus levels.
In all, 14 models were evaluated for production of wild age-0 walleyes and eight models for stocked age-
0 walleyes. For wild walleyes, adult alewife abundance was the dominant factor, accounting for 58% of
the variability in age-0 abundance. Production of wild age-0 fish increased when adult alewives were
scarce. The only other plausible factor was spring water temperature. Predictably, alewife abundance
was not important to stocked fish; instead temperature and adult walleye abundance were more
significant variables. The surge in reproductive success for walleyes during 2003–2005 was most likely
due to large declines in adult alewives in Lake Huron. While relatively strong year classes (age-1 and up)
have been produced as a result of increased age-0 production during 2003–2005, the overall magnitude
has not been as great as the initial age-0 abundance originally suggested. It appears that over-winter
mortality is higher than in the past and may stem from higher predation or slower growth (lower
condition for enduring winter thermal stress). From this it appears that low alewife abundance does not
assure strong walleye year classes in Saginaw Bay but may be a prerequisite for them.

Notes: Beginning in 2003, the reproductive success of walleyes in HU increased to unprecedented levels.
Possible reasons for this surge are discussed, including interactions with alewife population levels, over-
winter stress, and predation.

Finkelstein, S. A., and A. M. Davis. 2006. Paleoenvironmental records of water level and climatic
changes from the middle to late Holocene at a Lake Erie coastal wetland, Ontario, Canada.
Quaternary Research 65:33-43.
Abstract: Pollen and diatom assemblages, and peat stratigraphies, from a coastal wetland on the
northern shore of Lake Erie were used to analyze water level and climatic changes since the middle
Holocene and their effects on wetland plant communities. Peat deposition began 4700 cal yr B.P. during
the Nipissing 11 transgression, which was driven by isostatic rebound. At that time, a diatom-rich wild
rice marsh existed at the site. Water level dropped at the end of the Nipissing rise at least 2 m within 200
yr, leading to the development of shallower-water plant communities and an environment too dry for most
diatoms to persist. The sharp decline in water level was probably driven primarily by outlet incision, but
climate likely played some role. The paleoecological records provide evidence for post-Nipissing century-
scale transgressions occurring around 2300, 1160, 700 and 450 cal yr B.P. The chronology for these
transgressions correlates with other studies from the region and implies climatic forcing. Peat inception
in shallow sloughs across part of the study area around 700 cal yr B.P. coincides with the Little Ice Age.
These records, considered alongside others from the region, suggest that the Little Ice Age may have
resulted in a wetter climate across the eastern Great Lakes region.

Notes: Pollen and diatom assemblages and peat stratigraphies from a coastal wetland along northern ER
were used to analyze historical water levels and climatic changes since the mid-Holocene. Large and
rapid WLF resulted in a significant reorganization in wetland plant communities during the Nipissing rise.

Abstract: Changes in the water level of lakes, either natural or man-made, are important environmental
perturbations for euliittoral benthic fish communities. In outdoor mesocosm experiments, we tested the
effects of decreasing shelter availability due to autumn lake-level decrease on the behavior and the
growth of two littoral benthic dwellers, the juvenile burbot and the stone loach. The two species showed
significantly different changes in behavior when shelter availability decreased. Burbot built up a distinct
hierarchy when shelter became sparse, with larger fish being significantly more successful in competing
for suitable shelter than smaller conspecifics. The hierarchy, however, ceased when shelter availability
decreased below a certain level. The largest fish then increasingly abandoned shelter use, while smaller
fish persisted with their sheltering behavior. Stone loach, in contrast, showed no hierarchical order or size-related shelter use. Only burbot showed a significant relationship between the ability to occupy the preferred shelter and the somatic growth. These two species provide an example of different strategies to deal with environmental perturbations like lake-level decrease, with the stenoeccious, dominant strategy of the burbot and the euryoccious, evasive strategy of stone loach. The results demonstrate the importance of conducting behavioral studies under as natural conditions as possible.

Notes: Reports results of mesocosm experiments testing the effect of lower water levels and subsequent reductions in shelter availability on two common benthic dwellers in Northern European lakes, the burbot (Lota lota) and the stone loach (Barbatula barbatula). The relationship between behavioral and growth responses to altered water depth are discussed. Not specific to the GL basin or biota.

Abstract: Water-level change is integral to the structure and function of Great Lakes coastal wetlands, and many studies document predictable relationships between vegetation and water level. However, anthropogenic stressors, such as invasive species, land-use change, and water-level stabilization, interact to shift the historical cycle (of native vegetation migration up- and down-slope) toward dominance by invasive Typha species. Knowing from earlier studies that water-level stabilization alters the historical vegetation cycle, we asked if similar shifts can occur where water levels are not stabilized. Using historical aerial photographs of three coastal wetlands (in Lake Michigan's Green Bay, Wisconsin), we determined that habitat dominated by Typha species has expanded to eliminate wet meadow habitat. Between 1974 and 1992, linear regressions showed strong, significant relationships of both meadow area ($R^2 >= 0.894; p < 0.02$) and marsh area ($R^2 >= 0.784; p < 0.05$) to water level in all three wetlands. In 2000, meadow area was below that predicted by the historical pattern due to the landward advance of marsh habitat during a year of decreasing water levels. In the same period, land use in the wetland watersheds converted from agriculture to urban. Urbanization and the replacement of native Typha latifolia by the invasive hybrid Typha x glauca may have overwhelmed the beneficial impact of water-level fluctuation. The documentation of vegetation shifts, as herein, is an essential step in the process of preserving and restoring ecological integrity.

Notes: The authors used historical (1960-2000) aerial photo interpretation to assess changes in wetland vegetation in three anthropogenically-stressed embayment wetlands in Green Bay, MI. Low water periods allowed expansion of Typha-dominated habitat and eliminated wet meadow habitats. Land-use change and invasive species are dual stressors and could overwhelm the beneficial effects of WLF. WLF are necessary, but not sufficient, to preserve and restore ecological integrity. The authors urge more widespread monitoring of vegetation change using aerial photo interpretation.

Abstract: Dominant species play key roles in shaping community structure, but their behavior is far from uniform. We speculated that recognition of different behaviors (determined objectively) would be an indicator of the condition of plant communities. We developed a species dominance index (SDI) to identify dominant species and compare their behavior across multiple spatial scales. The SDI is based on three attributes (mean cover, mean species suppression, and tendency toward high cover), and it identifies up to 38 dominants within 74 Great Lakes coastal wetlands. Dichotomizing each of the attributes in a 2x2x2 matrix produced seven dominant behaviors, or forms, all of which occurred in Great Lakes wetlands. Species showed different dominant forms among locations and aggregation scales. Showing predominantly "monotype" form, invasive Typha was the taxon that was most often dominant in the samples. By quantitatively measuring dominance and describing dominance form, SDI can add insight into community change and is a useful addition to indicators of community condition.
Notes: The authors developed a species dominance index (SDI) to identify dominant plant species and compare their behavior across multiple time scales. The SDI is based on mean cover, mean species suppression, and tendency toward high cover. The index identified 38 dominants within 74 GL coastal wetlands. The invasive Typha was the most dominant taxa encountered. SDI, based on seven forms of dominance, could have utility as an objective indicator of condition over time.


Abstract: Changing levels of the Laurentide Great Lakes over the past 14.5 ka have strongly influenced development of surrounding coasts. One of the most striking geomorphic features inherited from earlier levels is the presence of several dozen coast-normal flooded river valleys that occur along the eastern margin of the lake basin. Westward flowing rivers deeply cut through preexisting terraced fluvial deposits and Pleistocene glacial outwash during the Chippewa lowstands between 10 and 8 ka BP. Freshwater estuaries were formed as these valleys were flooded during the post-late Chippewa transgression, and as rivers graded their fluvial terraces to Nipissing levels. More recent (~5 ka BP) attainment of somewhat lower lake levels has been accompanied by regressive progradation of most estuarine deltas. Two freshwater estuaries, Manistee Lake and Pentwater Lake, in northwest Michigan were examined in detail. Both are partially filled with post-late Chippewa sediment comprising terrigenous and organic fluvial, deltaic, and estuary-center facies that comprise an almost complete record of Holocene sedimentation in these settings. Stratigraphic successions in either estuary consist of a transgressive-regressive fluvial-deltaic-estuarine sequence deposited over the past 10,000 years. A typical section consists of basal fluvial-deltaic sand, thick (> 20 m) transgressive dark brown lake mud (gyttja), regressive interbedded prodelta sand and mud often containing abundant pebble to cobble size wood debris, and highstand fluvial-deltaic sand of modern deltas. These sequences represent change in Lake Michigan water level during the post-late Chippewa transgression, the Nipissing highstand and stillstand, and the post-Nipissing regression.

Radiocarbon dates of allochthonous organic material in Manistee Lake indicate an abrupt decrease in accumulation of terrigenous components at about 3.1 ka, and relatively invariant sedimentation rates at about 4.5 m/ka since that time.

Notes: The authors’ goal was to document the spatial and temporal distribution of depositional processes in two HU-MI estuaries by examining surface and subsurface sediment samples. Depositional histories of these two estuaries are linked to changes in flux of terrigenous and organic material, and to the changes in estuary water depth.


Abstract: Littoral benthic macroinvertebrate communities in lake reservoirs often are exposed to repeated fluctuations in water level, but little is known of the effects of drawdown on benthic community composition. We compared the taxonomic composition and spatial patterns of benthic macroinvertebrate communities in sediments of littoral areas in a reservoir with >30 y of seasonal drawdowns (Sooke Lake Reservoir [SLR]) and a natural lake with little seasonal change in water levels (Shawnigan Lake [SHL]). Contrary to our predictions, macroinvertebrate density and biomass usually were greater in SLR than in SHL. In SLR, densities and biomasses of macroinvertebrates, especially Chironomids, were higher below the drawdown exposure zone than in the upper littoral area. Chironomids with r-selected survival strategies (i.e., smaller size) or desiccant-resistant stages appeared well suited to the fluctuating environment of littoral zones in reservoirs. Orthocladiinae, Chironomini, Tanytarsini, and Tanypodinae dominated at sampling sites immediately below the drawdown exposure zone in SLR, whereas only Orthocladiinae dominated at deeper sites. Warm water from an expanded epilimnion apparently extended the distribution of Diamesinae farther from shore in SLR than in SHL. Chironomini generally were the
dominant macroinvertebrate taxon in SHL, and the relative biomass of Diamesinae increased with depth. Distributions of oligochaetes and nematodes extended farther from shore in SLR than in SHL. These contrasting benthic macroinvertebrate communities indicate that variable drawdown regimes could have significant impacts on benthic food webs and the transfer of energy and nutrients to the pelagic area.

Notes: The paper compares the taxonomic composition and spatial patterns of benthic macroinvertebrate communities in sediments of reservoir littoral areas when exposed to repeated WLF. The study took place in two British Columbia reservoirs. Results indicate that variable drawdown regimes could have significant impacts on benthic food webs and the transfer of energy and nutrients to the pelagic zone. Not specific to Great Lakes water level issues.


Abstract: Aquatic plants were sampled in five coastal wetlands of northern Lake Huron during July 1996, 1997, and 1998. Mean annual water levels of Lake Huron changed during this period from 176.37 m (below the long-term average) in January 1996 to above average water levels of 176.83 m in July 1996 to 177.19 m in July 1997 and then declined to 176.88 m by July 1998. Boundaries of plant zones as indicated by distribution of the 1–3 dominant species along permanently established transect points across the wetland did not shift spatially over this 3-year period. Instead, relative abundance (percent of total stems per three 0.25 m² quadrats per plot) and presence/absence of plant species responded individually to water level changes within major zones. In 1996, the first season sampled, the wet meadow had recently been inundated by rising water level. In 1997, after more than a year of above average and rising water levels, emergent stem densities were reduced in the Carex/Calamagrostis (sedge/blue-joint) dominated wet meadow and mixed transition sedge, narrow-leaved cattail, and hardstem bulrush (Carex, Typha angustifolia, and Schoenoplectus acutus) dominated zones compared to stem densities in 1996. Stem densities remained low in 1998, even though water levels dropped 31 cm from 1997 levels. The relative dominance (% of stems/3 quadrats/plot) and presence/absence of some plant species changed rapidly in the wet meadow zone in response to increases in water levels in 1997 and to decreases in water levels in 1998. In contrast, changes in emergent species were minimal in the deeper emergent zone dominated by hardstem bulrush. We conclude that temporary flooding and drying in response to water level changes are critical to maintaining a diverse array of plant species in the wet meadow zones of these marshes. Furthermore, short-term water level changes do not affect the relative spatial position of major plant zones within the marsh nor the relative abundance of emergent species in the deepest zone.

Notes: Aquatic plants communities were sampled in five northern HU coastal wetlands during a three-year period (1996-98) when water levels were fluctuating. Two years of rising levels were followed by lower levels in the third year allowing for an assessment of plant community response during a short-term event. Community changes did not lead to the lake to upland zonation (emergent-transition-wet meadow zones) shifts described by Burton (1985) possibly due to the short duration of the higher water levels. Results suggest that the process of zone shifting does not involve entire plant assemblages moving up or down en masse but rather differential responses by individual species create a changing mosaic of plant community composition within each zone. This suggests that temporary flooding is crucial to maintaining the diversity in the wet meadow zone and likely contributes to the overall diversity in the wetland. Long-term flooding would result in reduced plant diversity in the wet meadow habitats.


Abstract: Wetlands are land-water systems which characterize shoreline interfaces of most water bodies. Wetlands are lands where ‘the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or support the growth of hydrophytes.’ The deep water end of the continuum is marked by the growth limit of emergent macrophytes. It grades into 'deep-water habitats,' which are
dominated by submerged aquatic macrophytes. The upland limit is exceeded when soils are no longer 'hydric' in classification, and the predominating vegetation is terrestrial rather than hydrophytic. Studies along the eastern shoreline of Lake Ontario and the St. Lawrence River have emphasized the continuity of physical environmental conditions and the intergradation of dominant plant species between adjacent wetland and shallow-water littoral systems. Consequently, a 'wetlands continuum' dominated by aquatic macrophytes, both submerged and emergent, is considered to represent an ecologically useful concept. This continuum spans a range of environments from the deep water limit of submerged aquatic macrophytes to the upland contact. The practical delineation of 'wetlands' and 'deep-water habitats' according to the occurrence of emergent hydrophytes is not seen to be at variance with this concept. Four broad categories of wetland systems are presented: (1) barrier and lagoon systems; (2) embayed wetlands; (3) streamside wetlands; and (4) island and school systems. The effects upon the hydrologic regime of seasonal variation, water level, snowpack and ice are discussed. (See also W87-07431) (Lantz-PTT).

Notes: This summary of studies along the eastern shore of ON at SLR emphasizes the continuity of physical environmental factors on vegetation found between coastal wetlands and littoral zones. Studies occurred simultaneously with high water levels of 1974 and a subsequent die-off of aquatic vegetation. Emergent vegetation experienced the greatest impact. Contains a discussion on WLF impacts during winter.

Abstract: The variables affecting epiphyton biomass were examined in a sheltered, multispecies macrophyte bed in the St. Lawrence River. Alteration of light penetration, resulting from the presence of dense macrophytes forming a thick subsurface canopy, primarily determined epiphyton biomass. Seasonal decrease of water levels also coincided with major increases in biomass. Plant morphology was the next important variable influencing epiphytic biomass, whereas the contribution of other variables (sampling depth, macrophyte species, relative abundance of macrophytes, and temperature) was low. Groups of lowest epiphyte biomass (0.1-0.6 mg Chla g[-1] DW) were defined by the combination of a low percentage of incident light (<13% surface light) and simple macrophyte stem types found below the macrophyte canopy. Highest epiphyte biomass (0.7-1.8 mg Chla g-[1] DW) corresponded to samples collected in mid-July and August, under high irradiance (> 20% surface light) and supported by ramified stems. Our results suggest that epiphyton sampling should be stratified according to the fraction of surface light intensity, macrophyte architecture, and seasonal water level variations, in decreasing order of influence.

Notes: The physical variables (light, depth, and macrophyte architecture) affecting epiphyton biomass were studied in a sheltered, multispecies macrophyte bed in the SLR. Light penetration plays a key role, with higher epiphyte biomass observed when light penetration is greater. The highest epiphyte biomass recorded coincided with maximum macrophyte and metaphyton biomass and a sharp decrease in water level. Reasons for this are unclear but one possible explanation was that metaphyton were accidentally included in the epiphyton sampling.

Abstract: Great Lakes wetlands have lost much of their historical extent, structure and function. Their transformation was influenced by a number of factors acting over a period of decades including modifications in the basin's hydrology (watershed drainage, dikes, lake levels), biology (exotic species), geology (sediment transport and composition), and chemistry (water quality). The relative importance of each of these catalysts likely varied from region to region and depended on pre-settlement conditions and natural variability in the marshes, both generally unknown. We applied geographic information systems
(GIS) technology to a 120-year record (1872–1991) of images of a 2,000-ha marsh system along the southwestern shore of Lake Erie, Ohio, USA. Long-term variability in aggregate characteristics of wetland vegetation was linked with environmental changes and human impact in three regions representing (1) a naturally existing open marsh with the lowest relative topographical elevation, (2) an open marsh with a protected exposure to the lake and higher elevation, and (3) a diked marsh with manipulated water levels. The deep, open marsh lost half of its emergents, and a third of its patchiness and edge habitat in the early 1900s, when severe watershed degradations accompanied relatively low Lake Erie water levels. Nearly all remaining emergents were eliminated between 1940 and 1991 in this open marsh, following progressively higher lake levels. In the protected open marsh, the extent of emergents fluctuated with lake levels until 1977, and declined severely since then during sustained high lake levels. Habitat parameters varied little until recent decades, but declined markedly thereafter. The diked marsh maintained pre-1900 conditions for emergent plants, patchiness, and habitat edge; variability was linked to breached dikes and the presence/absence of marsh management. No landward re-establishment of the entire marsh complex since 1873 was evident on the 10 images studied. We propose the interaction of three forcing functions as the principal mechanism controlling the historical and current distribution of aquatic plants in southwestern Lake Erie marshes. These factors, collectively referred to as the landward advance paradigm (LAP), include (1) the restricted ability of the marshes to advance landward, (2) sustained above-average lake levels, and (3) the presence of carp (Cyprinus carpio) in wetlands with silt and clay sediments. Management focused on enhancing the role of Lake Erie wetlands should consider these landscape-level alterations and attempt to maximize wetland functions within the context of the LAP.

Notes: A 120-yr record of images for an ER coastal marsh system (maps and aerial photos from 1872-1991) were examined for long-term variability in marsh habitat characteristics and links to environmental changes and human impacts. Key environmental disturbances that occurred during this time span included WLF, dikes, watershed degradations, and the introduction of carp. The authors identify three forcing functions as the principal mechanism controlling the historical and current distribution of plants in SW ER marshes and refer to them as the Landward Advance Paradigm (LAP). The three factors are 1) the restricted ability of the marshes to advance landward, 2) sustained above-average lake levels, and 3) the presence of carp in wetlands with silt and clay sediments.


Abstract: Nest predation has been identified as the primary mechanism contributing to reduction of reproductive success for the marsh-breeding red-winged blackbird (Agelaius phoeniceus). Differences in rates of nest predation have been linked to nest site characteristics within a wetland, primarily water depth. However, the relationship between the landscape surrounding these habitats and the probability of nest predation is uncertain. Moreover, factors associated with reproductive success could be a potentially powerful indicator of ecological condition in wetland habitats. We investigated the influence of landscape pattern on nest success by monitoring 366 red-winged blackbird nests in 11 coastal wetlands along the south shore of Lake Superior. Of the 366 nests, 39% were successful, 56% failed, and 5% were abandoned or lacked sufficient evidence to determine nest fate. Nest predation accounted for over 93% of total failures. Predation rates ranged from 31% to 97% among the 11 wetland sites. We modeled nest predation using multi-model logistic regression analysis and the Akaike information criterion to identify and parameterize influential variables derived from the nest site, wetland, and landscape surrounding each wetland. Our results indicated that landscape variables comprised over 50% of model prediction weight in 15 of the 17 models. Nest failure was highest at sites within an urban/residential landscape matrix. Reproductive success could be a good indicator of the ecological health of Great Lakes wetlands.

Notes: Red-winged blackbird nest predation rates were studied in 11 south SU coastal wetlands to assess the connection between predation rates and landscape pattern. Results indicated that nest site vegetation
was an important component while water depth had a marginal effect on nest fate. However, the lack of an effect due to water level may have been an artifact of the low variability of water depth throughout the study. Characteristics of the surrounding landscape and its effect on nest predators also influence nest predation.


Abstract: This study quantified *Escherichia coli* (EC) and *enterococci* (ENT) in beach waters and dominant source materials, correlated these with ambient conditions, and determined selected EC genotypes and ENT phenotypes. Bathing-water ENT criteria were exceeded more frequently than EC criteria, providing conflicting interpretations of water quality. Dominant sources of EC and ENT were bird feces (10^8/d/bird), storm drains (10^7/d), and river water (10^11/d); beach sands, shallow groundwater and detritus were additional sources. Beach-water EC genotypes and ENT phenotypes formed clusters with those from all source types, reflecting diffuse inputs. Some ENT isolates had phenotypes similar to those of human pathogens and/or exhibited high-level resistance to human-use antibiotics. EC and ENT concentrations were influenced by collection time and wind direction. There was a 48-72-h lag between rainfall and elevated EC concentrations at three southern shoreline beaches, but no such lag at western and eastern shoreline beaches, reflecting the influence of beach orientation with respect to cyclic (3-5 d) summer weather patterns. In addition to local contamination sources and processes, conceptual or predictive models of Great Lakes beach water quality should consider regional weather patterns, lake hydrodynamics, and the influence of monitoring method variables (time of day, frequency)

Notes: The authors correlated *E. coli* and *Enterococci* bacteria to ambient conditions in MI beaches. Although not directly WLF related, seiches and wind-driven currents can affect the contribution of bacteria from local sources. Adequate understanding of the sources and environmental processes should include consideration of beach orientation to regional weather patterns, regional and local hydrodynamics, the nature, timing, and magnitude of local bacterial inputs and the interactions between these factors.


Abstract: Historically, the high potentiometric surface of groundwater in the Silurian/Devonian carbonate aquifer in Monroe County, MI resulted in discharge of highly mineralized, SO4-rich groundwater to the Lake Erie shoreline near both Erie State Game Area (ESGA) and Pointe Mouillee State Game Area (PMSGA). Recently, regional groundwater levels near PMSGA have been drawn down as much as 45 m below lake level in apparent response to quarry dewatering. From August to November of 2003, we conducted preliminary studies of groundwater flow dynamics and chemistry, shallow take water chemistry, and fish and invertebrate communities at both sites. Consistent with regional observations, groundwater flow direction in the nearshore at ESGA was upward, or toward Lake Erie, and shallow nearshore groundwater chemistry was influenced by regional groundwater chemistry. In contrast, at PMSGA, the groundwater flow potential was downward and lake water, influenced by quarry discharge seeping downward into nearshore sediments, produced a different lake and shallow groundwater chemistry than at ESGA. Although the invertebrate and young fish community was similar at the two sites, taxonomic groups tolerant of degraded water quality were more prevalent at PMSGA. Sensitive taxa were more prevalent at ESGA. We propose a conceptual model, based on well-described models of groundwater/seawater interaction along coastal margins, to describe the interconnection among geologic, hydrologic, chemical, and biological processes in the different nearshore habitats of Lake Erie, and we identify processes that warrant further detailed study in the Great Lakes.
Notes: The role of groundwater in GL coastal wetlands is discussed. The paper compares water quality, fish, and benthic invertebrate communities in two ER coastal wetlands that differ in the source of water from nearby water tables. Relative contribution is controlled by lake level fluctuations (storm surges, seiches, seasonal level changes) as well as by bedrock and rock composition within the basin. Results indicate that regional groundwater may directly affect nearshore GL environments, and the authors urge further analysis.

Abstract: Climate change is certain to put additional stress on freshwater resources in the United States. In the Great Lakes region, climate change may lead to lower lake levels, impacts on fisheries and wildlife, changes in Great Lakes shorelines, and reduction of groundwater supplies. Climate change will also create severe water shortages in other parts of the country, potentially raising new pressures to divert Great Lakes water to other regions. As the Great Lakes and other regions struggle with loss of water supplies, demand for water is expected to increase unless water conservation laws and policies are adopted.

Notes: The first part of this report focuses on how climate change will impact water resources. It begins with a brief summary of climate change science. They then explore what a changing climate will mean for the GL, including possible lowering of lake levels, impacts on fisheries and wildlife, changes in shorelines, and reduction of groundwater supplies. The authors then focus on policies to reduce greenhouse gas emissions that cause climate change, and policies to adapt to the unavoidable impacts on water resources.

Abstract: Amphibians are highly adapted for life in wetland habitats. They form a major component of wetland faunas, and being both prey and predator, they are important in ecosystem functioning. Wetlands provide aquatic habitats that amphibians require for breeding, development, foraging, hibernation and refuge, and they form an interface with essential adjacent upland habitat. The size and type of wetlands as well as their spatial configuration and local structural characteristics are important features of these habitats for amphibian use. Because of their dependence on water, use of both aquatic and terrestrial habitat, permeable skin, and other biological characteristics, amphibians are considered to be excellent indicators of ecosystem health. Amphibians have a tremendous diversity of natural history characteristics and species differ in their patterns of habitat and microhabitat selection. Over 30 species of amphibians occur in wetlands within the Great Lakes basin and an increasing trend in species richness exists from north to south across the region. Since European settlement, this region has lost over 50% of its wetlands. Loss rates of coastal and inland wetlands exceed 90% in some areas. Many restoration efforts are underway across the region but losses still exceed gains. No species have been extirpated from the entire basin but numerous local extirpations have occurred. However, nearly half of the species are officially designated as being of conservation concern somewhere in the basin. A more realistic estimate suggests that at least 2/3 of species are of concern. Habitat loss is reported as the primary cause of decline for 60% of species and habitat degradation by pollution is cited for 43% of the fauna. Considering the extent of wetland loss across the basin it seems reasonable to assume a similar magnitude of amphibian population loss. The current conservation status of amphibians indicates that Great Lakes wetlands are unhealthy ecosystems.

Notes: Review of the status of the GL amphibian community. Provides a general review of the association between amphibians and wetland habitats. The author concludes that the current conservation status of amphibians indicates that GL wetlands are unhealthy ecosystems. The fundamental wetland characteristics affecting amphibians are area, hydroperiod, spatial configuration, and adjacent upland habitats. Hydroperiod influences numbers and sizes of metamorphosing individuals, but also determines
which species successfully develop and, ultimately, species richness. Fluctuating water levels and drought associated with climate warming may have important impacts.


*Abstract:* Five hypotheses explaining variations in growth and recruitment were tested statistically with data from a study of yellow perch, *Perca flavescens*, 1950-83. Recruitment was not a function of water temperature during spawning, hatching or the first year, but was a function of lake water levels. Growth was not related to average water temperatures or degree-days, but was inversely correlated with the abundance of year-classes.

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*Abstract:* Coastal wetlands of Lake Erie fall into three categories, depending on the type of protection available to the wetland vegetation: (1) coastal lagoons behind barrier beaches, (2) managed marshes protected by earthen and rip-rap dikes, and (3) estuarine tributary mouths. At one time the most important protection was that afforded by barrier bars or other natural shoreline features which formed quiet lagoons and embayments. Very few natural wetlands of this type still exist in Lake Erie. Most of the lagoon-type coastal marshes, if they have not been drained or filled or engulfed by the lake, have been replaced by the second type: managed-waterfowl marshes which are now protected by earthen rip-rap dikes. The third type of protection is the natural isolation from lake storms provided by the estuaries of virtually all of the tributaries entering Lake Erie, particularly at the western end. Large wetlands have developed along most of the estuaries where disturbance has been minimal. Estuarine coastal marshes currently form the majority of the naturally protected wetlands bordering western Lake Erie.

Notes: Places coastal wetlands of ER into three classes: 1) barrier beach protected coastal lagoons; 2) dike protected managed marshes; and 3) estuarine tributary mouths. ER bathymetry and hydrology are discussed in the context of coastal wetlands. There is also a detailed description of the function and value of ER coastal wetlands in terms of habitat, economic value, and physical functions.


*Abstract:* We compared the standing vegetation, seed banks, and substrate conditions in seven pairs of diked and undiked wetlands near the shores of Lake Michigan and Lake Huron, North America. Our analysis tested the null hypothesis that construction of artificial dikes has no effect on the vulnerability of Great Lakes coastal wetlands to non-native and native invasive species. Both the standing vegetation and seed banks in diked wetlands contained significantly more species and individuals of invasive plants. In addition, diked wetlands exhibited significantly higher levels of organic matter and nutrient levels, and significantly higher average pH. Two pervasive non-native invasive species in the Great Lakes region, *Lytthrum salicaria* (purple loosestrife) and *Phalaris arundinacea* (reed canary grass) were significantly more abundant in diked wetlands. *Typha* spp. (cattail) also formed a much higher percent vegetation cover in the diked wetlands. Our results support the view that diking of shoreline wetlands modifies natural hydrologic regimes, leading to nutrient-rich aquatic environments that are vulnerable to invasion. The shallower, more variable water levels in non-diked wetlands, on the other hand, appear to favor another undesirable invasive species, *Phragmites australis* (common reed grass).

Notes: A comparison of vegetation, seed banks, and substrate conditions between diked and undiked MI-HU coastal wetlands. Diked wetlands contained significantly more species and numbers of invasive plants, as well as higher levels of organic matter and nutrients, and higher pH. The authors argue that diking of these wetlands has altered hydrologic regimes, causing nutrient-rich habitats that are susceptible
to invasion. However, some shallower, un-diked wetlands appear susceptible to a different invasive, *Phragmites australis*. Restoration of these wetlands by removing dikes to restore the natural hydrological regime could promote a more natural community less vulnerable to invasives.


**Abstract:** *Cladophora glomerata* (L.) Kütz. is, potentially, the most widely distributed macroalga throughout the world’s freshwater ecosystems. *C. glomerata* has been described throughout North America, Europe, the Atlantic Islands, the Caribbean Islands, Asia, Africa, Australia and New Zealand, and the Pacific Islands. *Cladophora* blooms were a common feature of the lower North American Great Lakes (Erie, Michigan, Ontario) from the 1950s through the early 1980s and were largely eradicated through the implementation of a multibillion-dollar phosphorus (P) abatement program. The return of widespread blooms in these lakes since the mid-1990s, however, was not associated with increases in P loading. Instead, current evidence indicates that the resurgence in blooms was directly related to ecosystem level changes in substratum availability, water clarity, and P recycling associated with the establishment of dense colonies of invasive dreissenid mussels. These results support the hypothesis that dreissenid mussel invasions may induce dramatic shifts in energy and nutrient flow from pelagic zones to the benthic zone.

Notes: The return of widespread *Cladophora glomerata* in the GL has been due primarily to the spread of dreissenid mussels. NOT WLF-related.


**Abstract:** Water-level fluctuations (WLF) of lakes have temporal scales ranging from seconds to hundreds of years. Fluctuations in the lake level generated by an unbalanced water budget resulting from meteorological and hydrological processes, such as precipitation, evaporation and inflow and outflow conditions usually have long temporal scales (days to years) and are here classified as long-term WLF. In contrast, WLF generated by hydrodynamic processes, e.g., basin-scale oscillations and travelling surface waves, have periods in the order of seconds to hours and are classified as short-term WLF. The impact of WLF on abiotic and biotic conditions depends on the temporal scale under consideration and is exemplified using data from Lake Issyk-Kul, the Caspian Sea and Lake Constance. Long-term WLF induce a slow shore line displacement of metres to kilometres, but immediate physical stress due to currents associated with long-term WLF is negligible. Large-scale shore line displacements change the habitat availability for organisms adapted to terrestrial and aquatic conditions over long time scales. Short-term WLF, in contrast, do not significantly displace the boundary between the aquatic and the terrestrial habitat, but impose short-term physical stress on organisms living in the littoral zone and on organic and inorganic particles deposited in the top sediment layers. The interaction of WLF acting on different time scales amplifies their overall impact on the ecosystem, because long-term WLF change the habitat exposed to the physical stress resulting from short-term WLF. Specifically, shore morphology and sediment grain size distribution are the result of a continuous interplay between short- and long-term WLF, the former providing the energy for erosion the latter determining the section of the shore exposed to the erosive power.

Notes: Lake Constance (Europe) study that focuses on the impact of short- and long-term WLF on littoral ecosystems, with an emphasis on the combined effects of both. The interaction of WLF on different time scales amplifies their overall impact on the ecosystem. Long-term WLF change the habitat exposed to the physical stresses that result from short-term WLF. Shore morphology and sediment grain-size distributions are a result of the interaction of both, with short-term providing erosional energy and long-term determining the section of shore exposed to this erosive power.

Abstract: We use bird distributions in non-forested coastal wetlands of the Great Lakes to illustrate a new, conceptually explicit method for developing biotic indicators. The procedure applies a probabilistic framework to derive an index that best "fits" an observed assemblage of species, based on preliminary information about species' responses to human environmental disturbance. Among 215 coastal wetland complexes across the U.S. portion of the Great Lakes, 23 bird species were particularly sensitive (positively or negatively) to a multivariate environmental disturbance gradient ranging from 0 (maximally disturbed) to 10 (minimally disturbed). Species like sandhill crane (Grus canadensis) and sedge wren (Cistothorus platensis) showed strong negative relationships with human disturbance, while others like common grackle (Quiscalus quiscula), American robin (Turdus migratorius), and European starling (Sturnus vulgaris), showed strong positive relationships with disturbance. The functional shapes of these biotic responses were used to determine indices of ecological condition (IEC) for new sites. Values of IEC were highly correlated with the environmental gradient, but deviations from a 1:1 relationship reveal novel insights about local ecological conditions. For example, sites dominated by invasive plant species like Phragmites australis tended to yield IEC values that were lower than expected based on the environmental gradient. This framework for calculating ecological indicators holds significant potential for other applications because it is flexible, explicitly linked to a disturbance gradient, and easy to calculate once standardized biotic response functions are documented and made available for a region of interest.

Notes: The author used bird distributions in non-forested GL coastal wetlands to illustrate a new, conceptually-explicit method for developing biotic indicators.


Abstract: 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 km²) marshland that could support a high plant biomass (286 x 10³ t) whereas under high water levels, the lake shifts to a vast (501 km²) open-water body with a lower predicted plant biomass (117 x 10³ 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.

Notes: The author used long-term records of average monthly water levels to characterize the major hydrological changes that took place over 80 years in SLR wetlands and describes present plant distribution, biomass, and species composition that resulted from the cumulative effects of these past conditions. Includes a model of anthropogenic and climatic forces acting on water levels.


Abstract: The sensitivity of Vallisneria americana Michx. as an indicator species of metal concentrations was assessed through the examination of its spatial (between- and within-site) and temporal (short- and long-term) variability. Eight macrophyte beds located in the St. Lawrence and Ottawa rivers were selected to contrast metal concentrations found in plants exposed to different types of waters, upstream and downstream of their confluence, in the Greater Montreal urban area. Comparisons among sites revealed higher metal concentrations, both in water and in plant tissues, at sites exposed to Ottawa River...
"brown" waters than at sites exposed to St. Lawrence River "green" waters. Within each site, samples represented a broad range in terms of water depths, exposure to current, incident light intensity, and total plant biomass. At all sites, metal concentrations in plant tissues were lowest in the shallow water found in sheltered, dense beds of submerged aquatic vegetation and increased in deep, open-water areas beyond the limits of dense vegetation. This persistent gradient may result from local differences in plant growth rates, exposure to currents, and (or) metal bioavailability. The use of a sampling strategy designed to control for within-site (depth-balanced) variability makes it possible to measure spatial and (or) temporal differences on the order of 20% whereas unbalanced sampling designs may lead to erroneous conclusions. Significant reductions in metal concentrations in plant tissue were observed both between 1994 and 1996 (Fe, Mn, Pb, Zn, N) and between 1976 and 1996 (Cd, Cr, Pb, Zn, N). Particular care must be given to sampling design if V. americana is to be used as a biological indicator of further long-term reductions in metal concentrations.

Notes: The author assessed the sensitivity of Vallisneria as an indicator of metal concentrations in eight macrophyte beds along SLR.


Abstract: The effects of a 1-m drop in average water levels in 1999 on species composition and biomass were documented for a St. Lawrence River wetland and compared with a similar episode in 1931. These observations highlight the manifold effects of past and future water level fluctuations on St. Lawrence River wetlands and faunal habitats, resulting from natural hydrologic variability, climate change, and (or) human intervention. In 1931 and 1999, waters were 2-3 degrees C warmer than the previous 10-year average. Low water levels markedly altered wetland vegetation: various Gramineae (including Phalaris arundinacea and Phragmites australis) and facultative annual species invaded previously marshy areas. Submerged species previously found in shallow waters were replaced on dry ground by annual terrestrial plants; Alisma gramineum colonized emergent waterlogged mudflats. The low water levels of 1999 induced a spatially discontinuous plant biomass that was richer in terrestrial material than in previous years (1993-1994). In comparison with the 1930s, recent surveys indicate a decline of assemblages dominated by Equisetum spp. and Najas flexilis and a rise of those dominated by Lythrum salicaria, Potamogeton spp., and filamentous algae. These shifts reveal the additional effects of nutrient enrichment, alien species, and shoreline alteration accompanying a change from a mostly agricultural to a mostly urbanized and industrialized landscape.

Notes: Study of the effect of a 1-m drop in average water levels in 1999 on species composition and biomass in a SLR wetland.


Abstract: Historical changes (1961-2002) in the distribution of herbaceous wetland plant associations were inferred from the hydrological regime of Lake Saint-Pierre, a 312 km(2) broadening of the St. Lawrence River (Quebec, Canada), to assess the cumulative effects of human interventions and climatic variability. Relative abundance index (height x percent cover) of wetland plants in 630 field quadrats sampled at 13 sites (1999-2002) were used to derive a model predicting the occurrence of nine herbaceous plant classes with a 71% (24-84%) accuracy. Wetland types included seasonally dry (meadows), mudflats and wet (low marshes and submerged) assemblages. Over the 1961-2002 period, the total surface area of Lake Saint-Pierre herbaceous wetlands ranged between 11 (in 1972) and 128 (in 2001) kin 2 and was negatively correlated (Spearman r = -0.86, p < 0.0001) to average water level during the current growing season. Within-season variability and level conditions over the previous season defined 5 marsh assemblages characterized by different species composition, relative abundance.
and diversity. Significant hydrological variables included quadrat elevation, water depth, number of days flooded and depth variability experienced over the current and/or previous growth seasons. The hydrological model suggests that for a given level, wetland plant assemblages differed markedly whether the multi-year sequence of water levels was rising or falling. Lake Saint-Pierre alternated between three broad-scale wetland configurations, dominated by meadows and open marsh with floating-leaved vegetation (in the 1960s), scattered tall Scirpus marshes (in the 1970s and early 1980s) and closed marsh with aggressive emergents (since 1996). The strong response of Lake Saint-Pierre wetlands to hydrological conditions in the current and previous growth seasons underlines their vulnerability to future water level variations resulting from regulation and climate variability.

Notes: Historical changes (1991-2002) in the distribution of herbaceous wetland plant associations of Lake Saint-Pierre, SLR, were inferred from the past hydrological regimes to assess the cumulative effects of human disturbance and climate changes. The strong wetland plant response to hydrological conditions illustrates their vulnerability to WLF and climate variability.


Abstract: The International Joint Commission has recently completed a five-year study (2000-2005) to review the operation of structures controlling the flows and levels of the Lake Ontario - St. Lawrence River system. In addition to addressing the multitude of stakeholder interests, the regulation plan review also considers environmental sustainability and integrity of wetlands and various ecosystem components. The present paper outlines the general approach, scientific methodology and applied management considerations of studies quantifying the relationships between hydrology and wetland plant assemblages (% occurrence, surface area) in Lake Ontario and the Upper and Lower St. Lawrence River. Although similar study designs were used across the study region, different methodologies were required that were specifically adapted to suit the important regional differences between the lake and river systems, range in water-level variations, and confounding factors (geomorphic types, exposure, sediment characteristics, downstream gradient of water quality, origin of water masses in the Lower River). Performance indicators (metrics), such as total area of wetland in meadow marsh vegetation type, that link wetland response to water levels will be used to assess the effects of different regulation plans under current and future (climate change) water-supply scenarios.

Notes: This paper outlines the general approach, scientific methodology, and applied management considerations of studies quantifying the relationships between hydrology and wetland plant occurrences in ON and SLR.


Abstract: The International Joint Commission has recently completed a five-year study (2000-2005) to review the operation of structures controlling the flows and levels of the Lake Ontario - St. Lawrence River system. In addition to addressing the multitude of stakeholder interests, the regulation plan review also considers environmental sustainability and integrity of wetlands and various ecosystem components. The present paper outlines the general approach, scientific methodology and applied management considerations of studies quantifying the relationships between hydrology and wetland plant assemblages (% occurrence, surface area) in Lake Ontario and the Upper and Lower St. Lawrence River. Although similar study designs were used across the study region, different methodologies were required that were specifically adapted to suit the important regional differences between the lake and river systems, range in water-level variations, and confounding factors (geomorphic types, exposure, sediment characteristics, downstream gradient of water quality, origin of water masses in the Lower River). Performance indicators (metrics), such as total area of wetland in meadow marsh vegetation type, that link wetland
response to water levels will be used to assess the effects of different regulation plans under current and future (climate change) water-supply scenarios.

Notes: An assessment of the combined effects of hydrology and human activities on water quality in SLR.


Abstract: The Duluth Boat Club (DBC) beach, located in the Duluth-Superior Harbor of Lake Superior, is frequently closed in summer due to high counts of *Escherichia coli*, an indicator of fecal contamination. However, the sources of bacteria contributing to beach closure are currently unknown. In this study, we investigated the potential sources of *E. coli* contaminating the DBC beach by using modified rep-PCR (HFERP) DNA fingerprinting. Over 3,600 *E. coli* strains were obtained from 55 lake water, 25 sediment, and 135 sand samples taken from five transects at the DBC beach at 11 different times during the summer through fall months of 2004 and 2005. Potential sources of *E. coli* at this beach were determined by using a known-source DNA fingerprint library containing unique *E. coli* isolates from wildlife, waterfowl, and treated wastewater obtained near Duluth, MN. Amounts *E. coli* in the samples were enumerated by membrane filtration counting, and the presence of potentially pathogenic *E. coli* was determined by using multiplex PCR. *E. coli* counts in all samples increased during the summer and early fall (July to September). While *E. coli* in spring samples originated mainly from treated wastewater effluent, the percentage of *E. coli* from waterfowl increased from summer to fall. DNA fingerprint analyses indicated that some *E. coli* strains may be naturalized, and autochthonous members of the microbial community in the beach sand and sediments were examined. However, multiplex PCR results indicated that <1% of the *E. coli* strains at the DBC was potentially pathogenic. Our results also suggest that wave action may influence the early colonization and homogeneous distribution of *E. coli* in beach sand and the subsequent release of sand or sediment-borne *E. coli* into lake water. Taken together, these results indicate that sand and sediment serve as temporal sources and sinks of human and waterfowl-derived *E. coli* that contribute to beach closures.

Notes: Results of a two-year investigation of the seasonal variation of *E. coli* concentrations in water, sand, and sediment along a beach in the Duluth-Superior Harbor (SU). Besides identifying 3,600 strains of *E. coli*, results also suggest that wave action may influence the early colonization and homogenous distribution of *E. coli* in beach sand and subsequent release into lake water.


Abstract: Habitat loss and fragmentation are global anthropogenic threats to aquatic ecosystems and biodiversity. Animal distribution and behavior are affected by changes in the geometry and structure of their environment. Therefore, predicting the effects of fragmentation on species assemblages requires a working knowledge of how individual species respond to habitat patches and boundaries. We measured the distribution and behavior of fishes in a northern Great Lakes coastal marsh in Mismer Bay, Lake Huron, a naturally patchy ecosystem. Using various sampling techniques, including mark-recapture and direct observation by snorkeling, we determined the relationship between fish species distribution, biotic and abiotic patch characteristics, and patch area. For dominant species we determined habitat utilization, mobility patterns, and behavioral patterns within patches and at boundaries. Fish abundance was related strongly to average water depth and the percent cover of floating and emergent macrophytes. Minimum patch area to maintain species assemblages was 128 m² for individual patches and 400 m² for major patches combined. Fishes that were widely distributed, highly mobile, and most abundant were expected to be least affected by increasing isolation and configuration. Given all results, we expected four species to be least affected overall by fragmentation in Mismer Bay: bluntnose minnow (*Pimephales notatus*), brook stickleback (*Culea inconstans*), common shiner (*Luxilus cornutus*), and rock bass.
Notes: The authors determined the relationship between fish species distribution, biotic and abiotic patch characteristics, and patch area in a HU coastal marsh in Mismer Bay. WLF, though not directly assessed, may influence the fragmentation of available cover. Fish abundance was strongly related to average water depth and the percent cover of floating and emergent macrophytes. Four species were shown to be least affected by overall fragmentation were bluntnose minnow, brook stickleback, common shiner, and rock bass.


Abstract: Field measurements were collected over a two-year period at seven study areas along Lakes Michigan, Huron, St. Clair, and Erie. Surface landforms were mapped, and models of the four coastal wetland types were developed. With the aid of aerial photography and field bisects, the zonal plant communities were identified and three historical distribution maps were constructed which represented various lake level conditions. Field data indicate that water level, wave energy, and substrate type are important factors in determining the shifting of plant communities in response to lake level fluctuations. A plant community displacement model reveals that most of the shrub and some of the meadow communities tend to persist at any lake level, but that emergent, floating-leaved, and submerged aquatics are displaced by other communities or by open water. As the plant communities shift in response to water level changes, the value and function of the wetland system changes. Although diking may protect coastal wetlands from wave erosion and inundation during high water, as well as provide protection from polluted land drainage, structural management reduces the multiplicity of wetland uses and functions, particularly with regard to fish habitat values and hydrological functions.

Notes: A detailed report discussing the interrelationships between coastal landforms, wetlands, and lake level fluctuation. Data were collected during 1977-1978 in seven GL coastal wetlands (two in LM, two in HU, one in Lake St Clair and two in western ER). Vegetation was mapped and aerial photographs used to map historical vegetation distributions. A field model was developed to predict displacement of wetland plant communities at one of the sites during the hydroperiod of 8-12 years over which GL water levels fluctuate. Changing water levels both disrupt both hydrarch succession and inhibit senescence, which contributes to the high primary productivity found in these freshwater habitats. Wetland geomorphology was also mapped. Coastal landforms and offshore slopes contribute to the development and maintenance of these coastal wetlands. Diking and other structural management practices that are meant to protect wetlands from water level extremes may reduce their functional diversity particularly with regard to fish habitat and hydrologic functions.


Abstract: Plant taxa identified in 90 U.S. Great Lakes coastal emergent wetlands were evaluated as indicators of physical environment. Canonical correspondence analysis using the 40 most common taxa showed that water depth and tussock height explained the greatest amount of species-environment interaction among ten environmental factors measured as continuous variables (water depth, tussock height, latitude, longitude, and six ground cover categories). Indicator species analysis was used to identify species-environment interactions with categorical variables of soil type (sand, silt, clay, organic) and hydrogeomorphic type (Open-Coast Wetlands, River-Influenced Wetlands, Protected Wetlands). Of the 169 taxa that occurred in a minimum of four study sites and ten plots, 48 were hydrogeomorphic indicators and 90 were soil indicators. Most indicators of Protected Wetlands were bog and fen species which were also organic soil indicators. Protected Wetlands had significantly greater average coefficient
of conservatism (C) values than did Open-Coast Wetlands and River-Influenced Wetlands, but average C values did not differ significantly by soil type. Open-Coast and River-Influenced hydrogeomorphic types tended to have sand or silt soils. Clay soils were found primarily in areas with Quaternary glaciolacustrine deposits or clay-rich tills. A fuller understanding of how the physical environment influences plant species distribution will improve our ability to detect the response of wetland vegetation to anthropogenic activities.

Notes: Plant taxa identified in 90 U.S. Great Lakes coastal emergent wetlands were evaluated as indicators of physical environment including hydrogeomorphic indicators. They suggest that a fuller understanding of how the physical environment influences plant species distribution will improve our ability to detect the response of wetland vegetation to anthropogenic activities.


Abstract: Emergent plants can be suitable indicators of anthropogenic stress in coastal wetlands if their responses to natural environmental variation can be parsed from their responses to human activities in and around wetlands. We used hierarchical partitioning to evaluate the independent influence of geomorphology, geography, anthropogenic stress on common wetland plants of the U.S. Great Lakes coast and developed multi-taxon models indicating wetland condition. A seven-taxon model predicted condition relative to watershed-derived anthropogenic stress, and a four-taxon model predicted condition relative to within-wetland anthropogenic stressors that modified hydrology. The Great Lake on which the wetlands occurred explained an average of about half the variation in species cover, and subdividing the data by lake allowed us to remove that source of variation. We developed lake-specific models for all the Great Lakes except Lake Ontario, which had no plant species with significant independent effects of anthropogenic stress. Plant responses were both positive (increasing cover with stress) and negative (decreasing cover with stress), and plant taxa incorporated into the lake-specific models differed by Great Lake. The resulting models require information on only a few taxa, rather than all plant species within a wetland, making them easier to implement than existing indicators.

Notes: The authors developed vegetation-based indicators of GL coastal wetland condition utilizing only plants that respond to anthropogenic stressors using the statistical tool of hierarchical partitioning. Next they related those responsive taxa to measures of anthropogenic stress to formulate vegetation-based environmental indicators. The resulting models, though based on only a few taxa, needed to be lake-specific.


Abstract: 1. Predictive models of impact are needed for the risk assessment of invasive species. One such species is the Eurasian zebra mussel (Dreissena polymorpha), a fouling bivalve that overgrows and kills native mussels (Unionidae) in many North American lakes and rivers. The level of mortality in a native mussel population increases with the fouling intensity - i.e. the mean number of zebra mussels attached to each native mussel. 2. We conducted a multi-site survey within the St Lawrence and Richelieu rivers (Quebec, Canada) to determine whether zebra mussel fouling intensity can be predicted from environmental variables. We found fouling intensity to be positively correlated with calcium concentration [Ca2+] and negatively correlated with sediment size, but not affected by local macrophyte cover. 3. A multiple regression model that includes calcium concentration and sediment size explains 86% of variation in fouling intensity across all sites. 4. Analysis of data from invaded sites in North America and Europe revealed a nonlinear relationship in which fouling intensity increases with calcium concentration up to an asymptotic threshold of 24 mg L-1 Ca2+. 5. Our results suggest that the community-level impacts of zebra mussels are mediated by abiotic environmental variables and gradients in these variables may provide local habitat refugia for native mussels.
Notes: This study aimed to determine if fouling intensity of zebra mussels on native unionids can be predicted by a number of environmental variables including calcium concentrations, ambient substrate quality, and the abundance of submerged macrophytes. Calcium concentration and substrate or sediment size explained 86% of the variation observed in fouling intensity. Not WLF related.


Abstract: Future changes to climate in the Great Lakes may have important consequences for fisheries. Evidence suggests that Great Lakes air and water temperatures have risen and the duration of ice cover has lessened during the past century. Global circulation models (GCMs) suggest future warming and increases in precipitation in the region. We present new evidence that water temperatures have risen in Lake Erie, particularly during summer and winter in the period 1965-2000. GCM forecasts coupled with physical models suggest lower annual runoff, less ice cover, and lower lake levels in the future, but the certainty of these forecasts is low. Assessment of the likely effects of climate change on fish stocks will require an integrative approach that considers several components of habitat rather than water temperature alone. We recommend using mechanistic models that couple habitat conditions to population demographics to explore integrated effects of climate-caused habitat change and illustrate this approach with a model for Lake Erie walleye (Sander vitreum). We show that the combined effect on walleye populations of plausible changes in temperature, river hydrology, lake levels, and light penetration can be quite different from that which would be expected based on consideration of only a single factor.

Notes: The authors looked at the effect of increasing water temperature due to climate change on ER walleye populations. Evidence is presented that water temperatures have risen in ER, and global circulation model results suggest lower annual runoff, less ice cover, and lower lake levels. An assessment of the likely effects of climate change will require an integrative approach that considers other habitat components rather than just water temperature alone and not be limited to the effects on thermal habitats alone. The authors believe that plausible scenarios of future habitats that are consistent with climate change scenarios should be combined with mechanistic models that link physical habitat to fish population dynamics. One approach involves using plausible changes to future basin hydrology and lake levels (Mortsch and Quinn. 1996) together with models of reproduction and lacustrine habitat quality to examine the consequences for walleye due to anticipated changes to several features of their habitat. The value of these mechanistic models will be not in their predictive capability but as a way to better understand what is not known about fish habitat and population dynamics.


Abstract: Correspondence analysis was used to partition fish species associated with the open water of each of the five Great Lakes and nine coastal wetlands for which data were available. Included in the analysis were 113 species in 25 families. Three species complexes were suggested: a Great Lakes taxocene (31 species); a transitional community which utilized open water, nearshore, and wetlands (35 species); and a wetlands taxocene, comprised of 47 species found to be closely associated with coastal wetlands. The wetland species split into two main groups: permanent residents (e.g., brown bullhead Ictalurus nebulosus, mudminnow Umbra lima, longnose gar Lepisosteus osseus) and migratory species. Migratory species included three subgroups: (1) those that spawned in the wetlands and then left (e.g., northern pike Esox lucius, common carp Cyprinus carpio, white sucker Catostomus commersoni, walleye Stizostedion vitreum), (2) those that used the wetlands as a nursery area (e.g., northern pike, gizzard shad Dorosoma cepedianum, spottail shiner Notropis hudsonius), and (3) those that migrated into the wetland from other wetlands or a Great Lake for shelter, spawning sites, or food; as part of the sustaining process of dispersal of young; or as part of wandering behavior (e.g., burbot Lota lota, rainbow smelt Osmerus mordax, rainbow trout Oncorhynchus mykiss). It was found that most remaining
coastal wetlands are degraded or altered to some degree, and are dominated by a characteristic silt- and turbidity-tolerant fish fauna (e.g., common carp, gizzard shad, goldfish Carassius auratus, and brown bullhead). Nevertheless, even degraded wetlands still functioned as important fish habitat by exporting large quantities of fish, first to avian, piscine, and mammalian food chains through predation, and second to the Great Lakes as young-of-the-year sport and forage fish. The research implies that a wetland must maintain a connection with a Great Lake to promote and enhance efficient fish utilization of the high productivity of marshes; that additional resilience is provided to species which spawn in wetlands since they can produce two cohorts (one in wetlands and one in the Great Lakes), and that fluctuating water levels are important in sustaining habitat diversity and productivity.

Notes: Summarizes available data and establishes a foundation for determining whether there are characteristic fish species associated with various wetland types in GL coastal zones and how they change if these habitats are degraded. The research implies that a wetland habitat must maintain a connection to the open lake to facilitate fish utilization of high productivity marshes. Additional resilience is provided to a species which spawns in wetlands because it can produce two cohorts (one wetland and one GL). WLF are important in sustaining habitat diversity and productivity.

Abstract: We raised embryos and tadpoles of green frogs (Rana clamitans melanota) and leopard frogs (R. pipiens) in situ along a contamination gradient in the Fox River/Green Bay ecosystem (WI, USA). Differences in exposure were reflected by significant positive regressions between concentrations in sediment and in frogs of polychlorinated biphenyl (PCB) congeners and some heavy metals (Cd, Cr, and Pb), which could have predictive value for estimating exposure of amphibians to contaminants in this ecosystem and, perhaps, in others. On average, non-ortho-substituted coplanar PCBs made up a very small percentage (average, 0.2%) of the PCB congeners in all samples analyzed, with larger fractions accounted for by mono- and di-ortho congeners (average, 19%) and routine congeners (average, 81%). Hatchability of frog embryo batches and anuran species richness at the sites were negatively correlated with level of contamination, but tadpole growth and survival were not. Sediment and tissue levels of PCBs and metals generally were correlated with each other, confounding the association of effects on frogs with any particular contaminant. It is also plausible that high levels of un-ionized ammonia (NH3) reduced hatching success of green frog, but not leopard frog, embryos in the field enclosures. Other environmental factors that were present but unmeasured in the field, such as ultraviolet-B radiation as well as water flow and level fluctuations, might have caused differences in hatching success at the field sites.
Notes: Green and leopard frog embryos and tadpoles were raised in situ along a contamination gradient in the Fox River/Green Bay (Wisconsin) MI ecosystem. Negative correlations between hatchability and anuran species richness and contaminant levels were seen, but not for tadpole growth and survival. Several environmental factors were not measured, such as UV-β radiation, water flow as well as level fluctuations, that may have caused these differences. WLF may have affected embryo viability by either altering the diffusion distance between embryos and contaminated sediments or by causing increased suspended sediments.

Abstract: Seed banks are important in wetland vegetation, but their role on lakeshores has received little attention. The influence of seed banks on lakeshore vegetation was investigated near eastern Georgian Bay in Ontario, where there is a rich shoreline and aquatic flora. Some lakeshore species found there can be considered "coastal plain disjuncts" similar to those of southwestern Michigan and adjacent Indiana, and central Wisconsin. Matchedash Lake in Simcoe Co., Ontario, has a particularly rich assemblage of
these shoreline species. Based on short-term records, and aging of drowned stumps, we demonstrated that yearly mean water levels can and have changed by more than a meter. Such water-level fluctuations partly result from beaver dams on the single outlet stream. Vegetation data collected in a low-water phase (1976) document a rich shoreline flora, largely absent in the present (1979) high-water phase. During this latter high-water phase, we collected 15 sediment sample units from each of six water depths (0-1.5 m). The sample, representing 0.32 m2 of lake bottom, was planted out in a greenhouse; 3,149 seedlings representing 41 species of vascular plants emerged. Six (Rhedia virginica, Rhynchospora capitellata, Panicum spreutum, Xyris difformis, Polygonum careyi, Linum striatum) are rare in Ontario. Estimated seed banks for individual species were as high as 6,500 seeds m-2. If another low-water phase occurs, a rich shoreline flora should again develop. We hypothesize that water-level fluctuations are essential to the long-term survival of these species.

Notes: The influence of seed banks on lakeshore vegetation was investigated in Matchedash Lake near Georgian Bay, ON where water levels were controlled primarily by beaver dams at the lake outlet. Historical water levels were determined from drowned tree stumps. Vegetation during low water had been examined from 1971-1979. Sediment sampling from different water level regimes yielded seeds for germination studies. Vegetation collected in the low water phase showed a rich flora which was largely absent during the 1979 high-water phase. The authors hypothesize that WLF are essential to the long-term survival of desirable shoreline species.


Abstract: The objective of this study was to review the relationship 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 which 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.

Notes: This is a review of existing knowledge on the relationship between fluctuating water levels and shoreline vegetation dynamics in the GL. Low water periods allow many plant species to regenerate from buried seed. High water periods kill dominant species, creating gaps which other species can colonize during the subsequent low water periods. High water also kills trees allowing for landward marsh expansion. Overall, WLF increase the area of shoreline vegetation and plant diversity. Efforts to stabilize WLF could have the opposite effect. The authors classify four basic shoreline vegetation types: forest and shrub thickets, wet meadow, marsh, and aquatic. WLF lead to the formation and maintenance of wet meadow and marsh habitats.


No abstract.

Presents a simple model that relates the area of wetlands to the amplitude of WLF and some examples that verify aspects of the model. Not specific to the GL.
Abstract: The water depth in marshes occurring along Lake Michigan is largely controlled by fluctuations of the Lake Michigan water level. The role of water level in controlling the distribution and cycling of N and P in emergent (Sparganium eurycarpum, Scirpus validus, and Typha latifolia) and wet meadow (Calamagrostis canadensis, Carex stricta, and Carex aquatilis) communities of a Lake Michigan river mouth marsh was studied. Nutrient uptake was determined from biomass sampling and tissue analysis. Community distribution at various lake stages was determined from aerial photographs. Emergent shoot biomass contained 82 kg N/ha and 13.4 kg P/ha while wet meadow vegetation contained 48 kg N/ha and 5.7 kg P/ha. This difference is primarily attributable to the lower mean production of the wet meadow communities. During 1983, the aerial extent of emergent and wet meadow vegetation was 30 ha and 41 ha respectively and the emergent communities contained a total of 22% more N and 45% more P than the wet meadow communities. Decomposition is slower in the wet meadow zone and the large litter biomass in these stands contains as much N and only 14% less P than the short biomass of this zone. Between 1965 and 1983 the water level fluctuated over 1.75 m which greatly altered plant zonation.

Notes: The role of WL in controlling the distribution and cycling of N and P in emergent and wet meadow communities of a MI river mouth marsh was studied. WLF greatly altered plant zonation.

No abstract.
A discussion of the importance of WLF to wetland ecosystems using data from the Mink River embayment on western LM (Door Peninsula, WI). Annual patterns of WLF are somewhat more predictable on LM than long-term. Short-term WLF are caused by seiches and to a minor extent, lunar tides. Detailed descriptions of long-term, intermediate and short-term effects on deep and shallow water vegetation are given. Stabilization of water levels for either long-term control of the average level or for control of seasonal fluctuations would be expected to change the pattern of structure and succession in coastal wetlands.

Abstract: Gauging the impact of manipulative activities, such as rehabilitation or management, on wetlands requires having a notion of the unmanipulated condition as a reference. An understanding of the reference condition requires knowledge of dominant factors influencing ecosystem processes and biological communities. In this paper, we focus on natural physical factors (conditions and processes) that drive coastal wetland ecosystems of the Laurentian Great Lakes. Great Lakes coastal wetlands develop under conditions of large-lake hydrology and disturbance imposed at a hierarchy of spatial and temporal scales and contain biotic communities adapted to unstable and unpredictable conditions. Coastal wetlands are configured along a continuum of hydrogeomorphic types: open coastal wetlands, drowned river mouth and flooded delta wetlands, and protected wetlands, each developing distinct ecosystem properties and biotic communities. Hydrogeomorphic factors associated with the lake and watershed operate at a hierarchy of scales: a) local and short-term (seiches and ice action), b) watershed / lakewide / annual (seasonal water- level change), and c) larger or year-to-year and longer (regional and/or greater than one-year). Other physical factors include the unique water quality features of each lake. The aim of this paper is to provide scientists and managers with a framework for considering regional and site-specific geomorphometry and a hierarchy of physical processes in planning management and conservation projects.
Notes: This review focuses on providing an organization of the current understanding of the physical factors underlying the natural variation present in GL coastal wetland ecosystems to better guide management efforts. A framework for organizing coastal wetlands is presented that considers dominant physical features configured along a continuum of hydrogeomorphic types: open coastal wetlands, drowned river mouth and flooded delta wetlands, and protected wetlands. These hydrogeomorphic factors work at a hierarchy of scales from local and short-term, to watershed, lakewide, and annual to larger and greater than annual scales. Management plans must consider this hierarchy of natural factors on a site-specific basis.


Abstract: Regulation of water flow constitutes the most important hydromorphological burden to Finnish lakes. The total area of regulated lakes is nearly 11,000 km², equalling one-third of the total area of Finnish inland waters. Extensive research projects have been carried out since the end of the 1980s to find out opportunities to mitigate harmful effects of the regulation of watercourses. A water-level fluctuation analysis tool, known as Regcel, has been developed to study water level data and to identify the most significant impacts. Results of the Regcel analysis give an overall picture of the impact of lake regulation in northern climate. The model is based on relationships between the water-level fluctuation and factors related to environmental, social, and economical effects. Regcel has been used in 12 Lake Regulation Development Projects in Finland. In this article, we show how the Regcel model was applied in two cases.

Notes: A WLF analysis tool, Regcel, is used to study water level data and to identify ecological and human impacts. The model is used to assess WLF in regulated and unregulated Finnish inland lakes. Regcel variables include aquatic macrophytes, benthic fauna, and fish and waterfowl with magnitude of spring flood, vertical extension of Carex, magnitude of winter drawdown, minimum water depth in the Carex zone, and water level rise during bird nesting season. Algorithms are included.


Abstract: The nearshore benthic communities on the Canadian side of Lake Ontario were surveyed in 1991 at depths of 5 and 20 m, and compared to data obtained in 1981 at the same depths and locations. The comparison was made to determine if the nearshore community reflected known reductions in nutrient concentrations over the 10-year period. The study also was designed to determine the extent to which natural environmental factors such as depth, substrate, fetch, and the likelihood of upwelling alter responses of benthic communities to improvements in water quality. In general, both 5 and 20-m communities reflected the reductions in nutrient concentrations and were indicative of the improved conditions. In 1981 at 5 m, worms were the most dominant group, accounting for 79% of the total fauna. Chironomidae (9%), Gastropoda (4%), Amphipoda (3%), and Sphaeriidae (2%) were subdominant. In 1991 at 5 m, the dominance of worms in the total fauna was reduced to about 15%, while chironomids increased to 34%, amphipods to 27%, gastropods to 18%, and sphaeriid darns to 4%. Similar to 5 m, the fauna at 20 m in 1981 were dominated by worms (65%), while chironomids (10%), amphipods (15%), and sphaeris (8%) were less dominant. In 1991 at 20 m, the fauna remained dominated by worms but their proportion of the total numbers declined to 48%. At the same time, the proportion of chironomids increased to 20%, amphipods decreased to 7%, gastropods increased to 3%, and sphaeriids increased to 21%. With this data set a variety of indices of benthic community composition were calculated based on lowest-practical-level identifications. Relationships between changes in these indices and habitat features were explored. Upwelling and substrate type modified the response of the benthic community at 20 m, and are thus important factors to consider in future designs examining whole lake changes in benthic...
community composition. In contrast changes in benthic community indices over time at 5 m were unrelated to the type of substrate, fetch or upwelling. As a result, future surveys of 5-m benthos require data from only one substrate type and do not require stratification of study designs by fetch or upwelling. Zebra mussels were found along the western shoreline of Lake Ontario in this 1991 survey in low abundances (averaged 730 indiv/m[2]), as well as sporadically along the northern shore. At these low abundances, zebra mussels had no significant effects on changes in benthic community composition.

Notes: The authors’ objective was to characterize changes in the nearshore benthic fauna on the northern shore of ON during a 10-yr period (1981-1991). They investigated depth, substrate, fetch, and the likelihood of upwelling, and how these factors influenced change in benthic community structure. Observed changes appeared to reflect changes in water chemistry during this period. The magnitude of change varied with depth. Zebra mussels were not a factor during this period.


Abstract: Insects of Great Lakes coastal wetlands have received little attention in spite of their importance in food webs and sensitivity to anthropogenic stressors. We characterized insect communities from four coastal wetlands that spanned the length of a trophic gradient in Green Bay during spring and summer of 1995. We sampled flying insects using sticky traps in dense emergent, sparse emergent, and open water-submergent vegetation zones within each wetland and estimated numerical abundance, biomass (mg dry weight) and taxonomic composition. We found that insect abundance and biomass were distributed differently among vegetation zones within wetlands along the gradient during both spring and summer. Insect abundance was highest at oligotrophic Portage Marsh during spring and lowest in wetlands toward the lower (southern), eutrophic end of the bay. Biomass did not differ consistently along the trophic gradient but increased with increasing emergent vegetation cover in three of four wetlands during both seasons. Ordination revealed distinct gradients in community structure on both regional (i.e., upper, middle, and lower Green Bay) and local (vegetation zones within wetlands) scales. Wetlands sorted in order of trophic status during both seasons, primarily due to abundant small Chironomidae, such as trophic-sensitive Heterotrissocladius changi, in middle and upper bay wetlands. Chironomidae also were a dominant component of open water-submergent assemblages in all wetlands. Lower bay wetlands were characterized by fewer but larger Chironomidae (e.g., Chironomus spp.), as well as Ceratopogonidae, Calliphoridae, and Ephydridae, which were most abundant in stands of emergent vegetation. Our results suggest that eutrophy in the lower bay may contribute to relatively poor foraging conditions for insectivorous fish and young waterfowl during spring, and they demonstrate the utility of using insect communities to assess environmental degradation, such as excessive nutrient loading, in coastal wetlands of the Great Lakes.

Notes: The authors investigated insect community response to the trophic gradient in Green Bay, MI and associated differences in macrophyte habitat structure. Dense emergent vegetation zones supported more insect biomass than open water in three of the four wetlands sampled. This paper is indirectly related to WLF because of the differences found in insect communities between densely and sparsely vegetated wetlands.


Abstract: Historical and geospatial data were used to identify the relationships between water levels, wetland vegetation, littoral drift of sediments, and the condition of a protective barrier beach at Metzger Marsh, a coastal wetland in western Lake Erie, to enhance and guide a joint federal and state wetland restoration project. Eleven sets of large-scale aerial photographs dating from 1940 through 1994 were interpreted to delineate major vegetation types and boundaries of the barrier beach. A geographic information system (GIS) was then used to digitize the data and calculate the vegetated area and length of barrier beach. Supplemented by paleoecological and sedimentological analyses, aerial photographic
interpretation revealed that Metzger Marsh was once a drowned-river-mouth wetland dominated by sedges and protected by a sand barrier beach. Extremely high water levels, storm events, and reduction of sediments in the littoral drift contributed to the complete destruction of the barrier beach in 1973 and prevented its recovery. The extent of wetland vegetation, correlated to water levels and condition of the barrier beach, decreased from a high of 108 ha in 1940 to a low of 33 ha in 1994. The lack of an adequate sediment supply and low probability of a period of extremely low lake levels in the near future made natural reestablishment of the barrier beach and wetland vegetation unlikely. Therefore, the federal and state managers chose to construct a dike to replace the protective barrier beach. Recommendations stemming from this historical analysis, however, resulted in the incorporation of a water-control structure in the dike that will retain a hydrologic connection between wetland and lake. Management of the wetland will seek to mimic processes natural to the wetland type identified by this analysis.

Notes: An historical analysis (1940-1994) of vegetation type and extent was conducted for Metzger Marsh in western ER. The drowned-river mouth wetland lost its protective sand barrier beach from high water levels, storm events, and loss of sediments in littoral drift. Wetland extent declined after the barrier beach was lost. When managers decided to construct a dike to prevent further loss of wetland area this historical evidence convinced them to maintain a hydrologic connection between the wetland and the lake.

Abstract: This review summarizes the comparatively sparse information on the community structure, population dynamics, secondary productivity, and trophic relationships of invertebrates in coastal wetlands of the Laurentian Great Lakes. Community structure is discussed in terms of separate but interrelated communities comprising the zooplankton, zoobenthos, epiphytic invertebrates, and neuston. The composition and dynamics of these communities are controlled by a complex set of interacting and continuously changing biotic and abiotic factors. Much additional research is required before a fundamental understanding of invertebrate ecology in Great Lakes coastal wetlands can be achieved. Particular research needs include elucidation of geographic differences in community structure and dynamics within and among wetlands of the same and contrasting types; the influence of micro- and macro-habitat differences and environmental stresses on invertebrate communities; the contribution of invertebrates to energy and materials flow in wetland food webs; the interactions of wetland invertebrates with the adjoining lake biota; the role of invertebrates in nutrient and pollutant transformations and cycling within the wetlands; the impact of changing land uses in wetland watersheds and of wetland alteration on the invertebrate communities, and the consequential impacts of these changes on the ecology of the lakes; and the impact on wetland invertebrate communities of predation pressure and competition from exotic species.

Notes: Paper provides information on community structure and ecology of aquatic invertebrates (benthic, planktonic, and epiphytic) of GL coastal wetlands; research needs are identified.

Abstract: Shoreline wetlands in the Great Lakes basin are susceptible to frequent changes in vegetation composition due to fluctuations in climate and water level. Although water-level changes occur naturally and are essential to maintain productivity, the magnitude and rate of these changes can have a significant effect on the wetland ecosystems. From a management and scientific viewpoint, it is important to be able to map and monitor these long-term changes. Using Long Point on Lake Erie as a test site, the goal of this research study is to refine methods for using multiple dates of Landsat imagery to map and monitor wetlands over a relatively long period of time. Landsat images covering the period from 1976 to 1999 are used to produce multitemporal normalized difference vegetation index (NDVI) images. Two change-
detection methods, postclassification comparison and multitemporal data clustering, were selected to
determine patterns of change in the Long Point wetlands over the 23 year period. These patterns are
compared with lake water levels and Palmer drought severity index (PDSI) data recorded over the same
time period. Results show that large sections of the shallow marshes of Long Point have experienced an
increase in the amount of emergent vegetation over the period of study. This occurred simultaneously
with downward trends in lake water level and PDSI values. Unlike the postclassification comparison
approach, the multitemporal data clustering technique provides a method to observe fluctuations in NDVI
over the entire time period.

Notes:
composition for a threatened shorebird, the piping plover (Charadrius melodus). Journal of Coastal
Research 24:719-726.
Abstract: Most migrant shorebirds require coastal and estuarine habitat in the nonbreeding season and
their overwinter survival is contingent upon the composition and quality of these winter sites. The
purpose of this study was to investigate the relationship between the distribution and abundance of the
piping plover, a federally threatened and endangered shorebird, and its nonbreeding habitat along the
Gulf of Mexico coastline. We identified sites consistently used by wintering piping plovers and quantified
landscape and anthropogenic features within a subset of those locations. Using published literature, we
documented that piping plovers consistently winter at 49 locations on the U.S. Gulf of Mexico coast
(Marco Island, Florida to Padre Island, Texas). At 31 sites, we conducted a remote analysis of aerial
photos for 11 features (e.g., intertidal area, urban area, beach). Linear regression was used to test
correlations between plover abundance and landscape characteristics. We found that certain shoreline
features (e.g., landform, inter-tidal area, total area) and measures of urbanization (e.g., urban area,
length of roads) were significantly correlated, positively and negatively, respectively, with piping plover
abundance across the Gulf of Mexico coastline. This information is critical to prevent or mitigate
negative impacts of urbanization and subsequent coastal landscape change on shorebird populations
Notes: The authors identify coastal features important to winter nonbreeding piping plover along the Gulf
of Mexico.
Lee, H., D. A. Reusser, J. D. Olden, S. S. Smith, J. Graham, V. Burkett, J. S. Dukes, R. J.
Piorkowski, and J. McPhedran. 2008. Integrated monitoring and information systems for managing
Abstract: Changes in temperature, precipitation, and other climatic drivers and sea-level rise will affect
populations of existing native and non-native aquatic species and the vulnerability of aquatic
environments to new invasions. Monitoring surveys provide the foundation for assessing the combined
effects of climate change and invasions by providing baseline biotic and environmental conditions,
although the utility of a survey depends on whether the results are quantitative or qualitative, and other
design considerations. The results from a variety of monitoring programs in the United States are
available in integrated biological information systems, although many include only non-native species,
not native species. Besides including natives, we suggest these systems could be improved through the
development of standardized methods that capture habitat and physiological requirements and link
regional and national biological databases into distributed Web portals that allow drawing information
from multiple sources. Combining the outputs from these biological information systems with
environmental data would allow the development of ecological niche models that predict the potential
distribution or abundance of native and non-native species on the basis of current environmental
conditions. Environmental projections from climate models can be used in these niche models to project
changes in species distributions or abundances under altered climatic conditions and to identify potential
high-risk invaders. There are, however, a number of challenges, such as uncertainties associated with
projections from climate and niche models and difficulty in integrating data with different temporal and
spatial granularity. Even with these uncertainties, integration of biological and environmental information systems, niche models, and climate projections would improve management of aquatic ecosystems under the dual threats of biotic invasions and climate change.

Notes: The importance of monitoring surveys in assessing combined effects of climate change and invasive species in aquatic environments.


Abstract: Water-level fluctuations (WLF) in lakes and rivers, especially their extent, frequency and duration, are dominant forces controlling the functioning of these ecosystems. In particular, WLF play an important role in the lake's littoral and aquatic-terrestrial interface processes. WLF may take place on different spatial and temporal scales under natural conditions but water levels have been artificially modified in regulated lakes, and their impacts are expected to be enhanced within the actual global change scenarios with forthcoming management problems. This article presents an overview on the literature published on this important topic since 1991 by using journals indexed in the ISI Web of Knowledge. The overall objective was to examine temporal and spatial trends in publications on WLF, the specific aspect of WLF concerned and their main effects. Throughout the article we have used case studies to illustrate different effects of WLF on the variety of lake habitats and indicators that have been studied. Overall, the number of papers published on the subject since the 1990s has risen steadily, when less than ten papers were published each year; until 2006 and peaking in 2005. The greatest number of papers on WLF has been carried out in Europe and North America (c. 73%). These data also showed that the effects of WLF have not been studied equally for different groups of organisms. There is a greater interest on macrophytes, which are the most studied group of organisms (18.4% of the papers). Nearly 7% of the papers deal with algae, and zooplankton and invertebrates account for a 7% followed by fish. WLF effects on ecosystems are very complex, and the biological effects in lakes are greatest in shallow water and littoral areas, where even small changes in water levels can result in the conversion of large areas of a standing-water environment in air exposed habitats. Finally, these data might serve to highlight knowledge gaps still existing on this topic and, in particular, some of the approaches that can potentially contribute to solve several of these lacunae are explored.

Notes: An annotated bibliography about WLF on lakes. Most studied are effects on macrophytes, followed by algae, zooplankton and macroinvertebrates, and fish. Much less published are models, although these are needed to understand effects. Effects on birds and mammals are also less published. Biological effects are greatest in shallow water and littoral areas, where large areas can be dewatered. Effects on biota include alteration of wave activity, reworking of substrates, and habitat alteration, which can lead to changes in productivity. Changes include physical (transparency, sedimentation, erosion), effects on species, and ecosystem effects (carrying capacity, biodiversity). Plants were most often used as indicators. Drawdowns often increase erosion and cause contaminated sediments to be resuspended. In shallow lakes, drawdowns often increase littoral/SAV zone. Drawdowns can also change water chemistry. Decreased water levels lead to a longer stratification period (modified by basin morphometry), and might change lake circulation. High levels cause wetland loss, wave-impacted shoreline, increase shoreline erosion, and require shoreline hardening to protect human structures. Floral response can have a lag time of decades. It is important to consider depth, duration, and frequency of inundation changes. Changes in vegetation lead to changes in most biota. Unregulated lakes have more diverse plant communities at all depths while lakes with reduced WLF have less diverse plant communities. Intra- and inter-annual water level variability is important to maintaining vegetative diversity. Reduced variability also reduces diatom diversity, especially for epiphytic diatoms. Direct effects on invertebrates and zooplankton include loss of taxa that are unable to withstand dry periods, but most effects are indirect through habitat alteration, with strongest effects in cobble and macrophyte habitats. Low water at the wrong times adversely affects fish, with indirect effects through macrophyte changes. There is some evidence that water level dynamics alter mercury cycling, raising the amount in fish. Effects on birds were again mediated through macrophytes.
and habitat, with the timing of fluctuations during the breeding season being particularly critical. If larger areas are dewatered more often, there may be a change in P cycling, releasing more phosphate. There may also be an increase in wetland anoxia. Lists research needed. Made note of a BACI study with dammed lakes going on in Voyagers National Park, MN (C.A. Serieyssol).

Lenssen, J., F. Menting, W. H. van der Putten, and K. Blom. 1999. Control of plant species richness and zonation of functional groups along a freshwater flooding gradient. Oikos 86:523-534. Abstract: We investigated the role of plant interactions in producing the zonation of strong competitors, i.e. clonal dominants, and weak competitors, i.e. interstitials. In addition, it was tested whether the effect of plant interactions on species richness depends on the position on the flooding gradient. During one growing season vegetation canopy was removed at a low elevation, dominated by Phragmites australis and at a high one, dominated by tall forbs, mainly Urtica dioica. The seed bank was examined and in half of the plots seeds of clonal dominants from high elevations and interstitials from low elevations were sown to ensure that seeds of both groups were present at both zones. At both elevations, removal of vegetation canopy resulted in a strong increase of interstitial species, but interstitials from low elevations failed to establish in cleared plots at the tall forb zone. This could not be attributed to the absence of seeds and we concluded that conditions unfavourable for germination, rather than plant interactions determine the zonation of interstitials from the P. australis zone. Many seedlings of tall forb dominants emerged in cleared plots at the low elevation. However, number of seedlings rapidly declined during the first year. Hence, abiotic conditions, most probably flooding, prevented seedling establishment of tall forb dominants at zones dominated by P. australis. Canopy removal increased species richness at the low elevation in the first year only, whereas at the higher elevation species richness in cleared plots remained higher throughout the second year when the canopy was no longer removed. We therefore concluded that species richness of freshwater shorelines is controlled by abiotic factors in the frequently flooded zone and by plant interactions at higher elevations.

Notes: Study in the Netherlands looking at the role of canopy removal on the zonation of interstitials and clonal dominants, and on species richness at two elevations of a freshwater wetland shoreline with a fluctuating water level. The authors showed that elevation plays a role in determining vegetation patterns. At low elevations these interactions only determined the abundance of those species adapted to the prevailing abiotic conditions. At the higher elevation, plant interactions exerted a strong influence on both abundance of species as well as species richness.

Lester, N. P., A. J. Dextrase, R. S. Kushneriuk, M.R. Rawson, and P. A. Ryan. 2004. Light and temperature: key factors affecting walleye abundance and production. Transactions of the American Fisheries Society 133:588-605. Abstract: We used published information to determine optimum light and temperature conditions for walleye Sander vitreus (formerly Stizostedion vitreum) and then applied this simple niche definition to predict how water clarity, temperature, and bathymetry affect walleye habitat availability. Our model calculated thermal-optical habitat area (TOHA), the benthic area of a lake that supplies optimum light, and temperature conditions for walleye during an annual cycle. When water clarity is very low, little walleye habitat exists. As water clarity increases, TOHA for walleye initially increases and then declines exponentially. Optimum water clarity increases with maximum depth of the lake or, in the case of thermally stratified lakes, with thermocline depth. We tested this model by evaluating its ability to account for differences in the sustained yields of walleye fisheries on Ontario lakes. Our results demonstrate that (1) walleye harvest increases in proportion to TOHA times the square root of total dissolved solids, an index of nutrient level, and (2) optimum water clarity for walleye typically exists when Secchi depth is on the order of 2 in. These findings indicate that the increases in water clarity recently observed in the Great Lakes basin (as a result of phosphorus control and dreissenid mussel invasion) have reduced the supply of thermal-optical walleye habitat and, consequently have probably had negative effects on walleye production.
Notes: Optimum light and temperature conditions for walleye were used to develop a model to predict how water clarity, temperature, and bathymetry affect habitat availability in the GL basin. The authors calculated thermal-optical habitat area (TOHA). Findings indicate that increased water clarity in the GL due to zebra mussel invasion have reduced the supply of thermal-optical walleye populations, which probably has negatively affected production.

Abstract: Fifty-four Wisconsin wetlands were surveyed in spring 1996 to determine relationships between macroinvertebrate community structure and a suite of 11 environmental attributes. Canonical correspondence analysis (CCA) showed that, after alkalinity, hydroperiod was the next most significant environmental factor influencing macroinvertebrate community structure within the wetlands sampled. CCA and direct gradient biplots were used to identify indicator taxa characteristic of the spring macroinvertebrate communities in persistent and ephemeral wetlands, and taxa characteristic of semi-terrestrial habitats adjacent to wetlands. Two models were developed to permit the prediction of a wetland's hydroperiod class. One model assigns a range of probabilities that a wetland has a hydroperiod longer or shorter than eight months based on the occurrence or abundance of fairy shrimp, mayflies, scuds, mosquitoes, and phantom midges. A second model predicts that a wetland's hydroperiod is longer or shorter than five months based on the joint occurrences of seven persistent indicator taxa. Data used in both models were derived from a rapid bioassessment of three shoreline D-frame net sweeps. The use of a coarse level taxonomic identification (primarily order and family) allows the approach to be performed in the field or laboratory. The macroinvertebrate models allow a manager to estimate a wetland's hydroperiod when long term water duration records do not exist. This ability is important to water resource managers because hydroperiod classification (i.e., water permanency) is one criterion used in differentiating wetlands from lakes in Wisconsin and because Wisconsin's legal system affords lakes substantially greater protection than wetlands.

Notes: Results of CCA of macroinvertebrate community structure and 11 environmental attributes showed that after alkalinity, hydroperiod was the next most significant factor in 54 surveyed inland wetlands (WI).

Abstract: Abnormally high water levels during spring may have significant effects, such as: (1) shoreline terrestrial vegetation is flooded which initiates drying and decomposition and subsequent release of nutrients, thus increasing the water productivity; (2) fish food organisms such as insects and earthworms are quickly added to the water; (3) new cover and habitat for shoreline fish species is added; and (4) an area of water is created that is sparsely populated with fish, which should stimulate reproduction and growth as fish attempt to fill the ‘void.’ Certain species of fish, especially largemouth bass, do best when water level increases occur immediately before, during, and for a short time following the spawning and nursery period. Though long-term data on standing stocks of fish in relation to changing water levels are rare, especially in the Great Lakes area, some data from reservoirs appear to show direct benefits of high water levels regarding production of young-of-the-year (YOY) fish. Brief, repetitive water level changes in shoreline wetlands near commercial shipping lanes, influenced by passing ships, have been going on for decades. Recent data show that as much as a 70 cm change in wetland water level may be created by passing vessels in channels. Further, larval fishes and drifting invertebrates may be drawn out of the wetlands during drawdown periods. The effects of these frequent alterations of wetlands on fish communities are not well understood. It is hypothesized that not only high, but stable spring/early summer water levels are important to the Pentwater fish community, as studies from reservoirs have indicated that production of YOY sunfish is negatively affected when water levels fluctuate during the
spawning/nursery periods. This should also be true for northern pike, a species spawning in the shallowest, most vegetated portion of the marsh. Unstable, fluctuating water levels may also alter the composition of benthic macroinvertebrates in littoral zones, favoring oligochaetes and chironomids over important prey groups. Such changes may account for some of the lower productivities of sunfishes observed by other authors, and may be attributable to changes in substrate, specifically to the accumulation of silt and loss of vascular macrophytes. Water level fluctuations may also alter temperature regimes in littoral zones, thus influencing fish spawning periods and rates of food production.

Notes: An overview of the relationship between WLF and fish habitat quality and quantity in the GL. At the time, available data were too fragmentary for understanding the complexities on how fish relate to WLF.

Abstract: We collected water quality, land use, and aquatic macrophyte information from 62 coastal and inland wetlands in the Great Lakes basin and found that species richness and community structure of macrophytes were a function of geographic location and water quality. For inland wetlands, the primary source of water quality degradation was inputs of nutrients and sediment associated with altered land use, whereas for coastal wetlands, water quality was also influenced by exposure and mixing with the respective Great Lakes. Wetlands within the subbasins of the less developed, more exposed upper Great Lakes had unique physical and ecological characteristics compared with the more developed, less sheltered wetlands of the lower Great Lakes and those located inland. Turbid, nutrient-rich wetlands were characterized by a fringe of emergent vegetation, with a few sparsely distributed submergent plant species. High-quality wetlands had clearer water and lower nutrient levels and contained a mix of emergent and floating-leaf taxa with a diverse and dense submergent plant community. Certain macrophyte taxa were identified as intolerant of turbid, nutrient-rich conditions (e.g., Pontederia cordata, Najas flaxilis), while others were tolerant of a wide range of conditions (e.g., Typha spp., Potamogeton pectinatus) occurring in both degraded and pristine wetlands.

Notes: A two-year study of the zooplankton community composition and dynamics in Cootes Paradise Marsh (ON) and the factors that structure the community. A forthcoming carp exclusion project is predicted to increase macrophyte growth, which authors predict will increase zooplankton and cause the community to shift to larger forms.

Abstract: We collected water quality, land use, and aquatic macrophyte information from 62 coastal and inland wetlands in the Great Lakes basin and found that species richness and community structure of macrophytes were a function of geographic location and water quality. For inland wetlands, the primary source of water quality degradation was inputs of nutrients and sediment associated with altered land use, whereas for coastal wetlands, water quality was also influenced by exposure and mixing with the respective Great Lakes. Wetlands within the subbasins of the less developed, more exposed upper Great Lakes had unique physical and ecological characteristics compared with the more developed, less sheltered wetlands of the lower Great Lakes and those located inland. Turbid, nutrient-rich wetlands were characterized by a fringe of emergent vegetation, with a few sparsely distributed submergent plant species. High-quality wetlands had clearer water and lower nutrient levels and contained a mix of emergent and floating-leaf taxa with a diverse and dense submergent plant community. Certain macrophyte taxa were identified as intolerant of turbid, nutrient-rich conditions (e.g., Pontederia cordata,
Najas flaxilis), while others were tolerant of a wide range of conditions (e.g., Typha spp., Potamogeton pectinatus) occurring in both degraded and pristine wetlands.

Notes: The authors compared the macrophyte community from 62 coastal and inland wetlands in the Canadian portion of the GL basin to examine how water and sediment quality affect these communities and related these to land use. They identified taxa intolerant of turbid, nutrient-rich conditions, and others that occur in both degraded and pristine wetlands.


Abstract: In the two years that followed the 100-year flood incident of September 1986 in the Saginaw River/Bay ecosystem, the reproduction of Caspian terns collapsed and then slowly recovered. Egg viability and fledging rates of hatched chicks were drastically depressed in 1987 and 1988. Eggs from clutches laid later in the year were less viable and chicks hatched from these eggs displayed wasting syndromes and deformities. The post-flood rate of deformities in hatched chicks in 1987-1989 was 163-fold greater than background rates for this population in 1962-1967. Embryonic abnormalities and deformities were found in many embryos recovered from dead eggs. Recently published data on planar toxic chemicals from samples of forage fish, tern eggs, and chicks from water birds nesting in the bay implicate planar dioxin-like PCBs 77 and 126 as the sources of these severe bioeffects. The planar PCB congeners accounted for >98% of TCDD-EQ toxicity in the tern eggs, and several were present at levels near or at the LD95 levels each for chicken eggs. Actual TCDD was about 1% of the TCDD-EQ toxicity. Very rapid buildup rates of PCBs were measured in tern eggs. The calculated toxic potency of PCB recovered from tern eggs was about 15-fold greater than parent aroclor 1242 PCB. Smaller tern species were projected to be much more at risk than the larger Caspian tern due to greater standard metabolic rates. The study supports the view that sediment disturbance and sediment banks of toxic chemicals are major threats to upper trophic level fish-eating species.

Notes: Presents the findings of field studies (1986-1991) of nesting success and productivity in the Caspian tern colony in a Saginaw Bay (HU) confined disposal facility following a large flood event in 1986. Embryonic abnormalities and deformities were found, as well as high organic contaminant concentrations in tern eggs. The study emphasizes the need to understand how floods and some dredging practices can mobilize toxicants from contaminated sediments into the aquatic food web.


Abstract: 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 (R2 = 0.93) indicated an increase of 1 ft (0.3 m) would result in a decrease of 80 acre (32 ha) or 18% of the 439 acre (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.

Notes: The effects of long-term WLF on extent of MI wetlands and beaches were studied using aerial photos (1938-1980). A linear model relating water level to beach and wetland area was developed.

Abstract: The effects of short-term or summer season water level fluctuations on wetlands were determined from measurements of flooding, relative soil chemistry, and the presence of plants. Analyses demonstrated higher relative concentrations of plant-available soil nutrients and higher density of plants on flooded emergent wetlands as compared to infrequently flooded, unconsolidated shore sites. Flooding resulted in anaerobic soil conditions and increased concentrations of nutrients for wetland plants. The density of emergent wetland plants was highest where the topographic conditions and water level led to duration of flooding between 50 and 85% of the growing season. The effects of long-term water level fluctuations on wetlands were measured from historical aerial photographs of low, average, and high lake level conditions (1938 to 1980). An increase in water levels of 0.3 m reduced the extent of coastal wetlands by 18%. Historical aerial photos demonstrated and a model predicted that 13% of the total wetlands measured at low lake levels remained in the study area at the highest lake level sampled. This result was verified during the high lake levels of May 1985.

Notes: The effects of short-term or summer season and long-term water level fluctuations were determined from measures of flooding, relative soil chemistry, and the plant community. Flooding, with resulting anaerobic soil conditions, increased the availability of nutrients, and flooded emergent wetlands showed higher plant density than those infrequently flooded. Long-term water levels altered total wetland and shoreland area.


Abstract: Benthic macroinvertebrates were sampled in the summer of 1997 using a standard D frame kick net along a transect across the Peshtigo wetland, a river delta wetland on the coast of Green Bay, Lake Michigan, to describe the spatial and temporal dynamics of the invertebrate community. Various abiotic factors, including sedimentation rates determined from Pb-210 and Cs-137 as a proxy for delivery of riverine organic matter, were also measured to determine which factors influenced these dynamics. Significant decreasing gradients in dissolved oxygen and pH with distance from the river, coupled with trends in sedimentation rates, chloride, and sum nitrate (nitrate + nitrite), revealed that riverine water was mixing with wetland water up to 100 ft from the wetland-river interface. Aboveground primary production and total invertebrate densities exhibited Weibull type distributions, with highest rates and numbers occurring 20 to 100 ft in from the Peshtigo River. Invertebrate densities were largely represented by Asellus sp. isopods (12-53%) and exhibited highest numbers in September. Invertebrate diversity at the genus level linearly decreased with distance from the river based on the Simpson's index of diversity (r(2) = 0.60, p < 0.05) and the Shannon-Wiener function (r(2) = 0.73, p < 0.01). Patterns observed suggest that there is an "optimal" zone for benthic invertebrates in the Peshtigo wetland 20 to 60 ft from the Peshtigo River that is protected from high-energy events (e.g., storms, boating) in the Peshtigo wetland by a buffer zone (0 to 20 ft) but is close enough to benefit from replenished levels of dissolved oxygen, nutrients, and organic matter delivered via the Peshtigo River.

Notes: The spatial and temporal dynamics of the benthic macroinvertebrate community in a MI (Green bay) coastal riverine wetland are described. Patterns observed indicated that there is an optimal zone within this wetland where it is protected from high-energy events (e.g. storms, seiches, boating) but is close enough to be replenished with dissolved oxygen, nutrients, and organic matter from the Peshtigo River.


Abstract: Emergence traps were used to sample insects along a transect through a river delta wetland on Green Bay, Lake Michigan in an attempt to document spatial and temporal patterns in insect emergence. Various abiotic factors were also measured to determine which factors influenced these dynamics.
Significant decreasing gradients in dissolved oxygen and pH with distance from the river, coupled with trends in sum nitrate (nitrate + nitrite), revealed that riverine water was mixing with wetland water up to 100 m from the wetland-river interface. Annual emerging insect densities decreased exponentially with distance from the river while emerging insect biomass decreased linearly with distance, both of which were significant. Insects were largely comprised of Chironomidae, which represented 7-88% of the insects emerging. Loss of biomass was largely due to emergence of Aeshnidae (0-34%), Libellulidae (0-69%), Coenagrionidae (0-23%), Siphlonuridae (0-63%), and Chironomidae (1-25%). Major Chironomidae emergence events occurred from early spring until early summer and again from late summer to early fall. These events were likely an important source of energy needed for avian egg production, duckling growth, or migratory flights. Spatial and temporal patterns revealed the importance of wetland areas adjacent to the Peshtigo River to emerging insects, as well as to the transient organisms that use them as a food source.

Notes: Same as MacKenzie, Kaster and Klump (2004) except measured insect emergence in this Green Bay (MI) wetland.

No abstract.
Notes: Forward to special issue of JGLR on Great Lakes nearshore habitat science.

Abstract: The region studied includes the Laurentian Great Lakes and a diversity of smaller glacial lakes, streams and wetlands south of permanent permafrost and towards the southern extent of Wisconsin glaciation. We emphasize lakes and quantitative implications. The region is warmer and wetter than it has been over most of the last 12000 years. Since 1911 observed air temperatures have increased by about 0.11 degrees C per decade in spring and 0.06 degrees C in winter; annual precipitation has increased by about 2.1% per decade. Ice thaw phenologies since the 1850s indicate a late winter warming of about 2.5 degrees C. In future scenarios for a doubled CO2 climate, air temperature increases in summer and winter and precipitation decreases (summer) in western Ontario but increases (winter) in western Ontario, northern Minnesota, Wisconsin and Michigan. Such changes in climate have altered and would further alter hydrological and other physical features of lakes. Warmer climates, i.e. 2 x CO2 climates, would lower net basin water supplies, stream flows and water levels owing to increased evaporation in excess of precipitation. Water levels have been responsive to drought and future scenarios for the Great Lakes simulate levels 0.2 to 2.5 m lower. Human adaptation to such changes is expensive. Warmer climates would decrease the spatial extent of ice cover on the Great Lakes; small lakes, especially to the south, would no longer freeze over every year. Temperature simulations for stratified lakes are 1-7 degrees C warmer for surface waters, and 6 degrees C cooler to 8 degrees C warmer for deep waters. Thermocline depth would change (4 m shallower to 3.5 m deeper) with warmer climates alone; deepening owing to increases in light penetration would occur with reduced input of dissolved organic carbon (DOC) from dryer catchments. Dissolved oxygen would decrease below the thermocline. These physical changes would in turn affect the phytoplankton, zooplankton, benthos and fishes. Annual phytoplankton production may increase but many complex reactions of the phytoplankton community to altered temperatures, thermocline depths, light penetrations and nutrient inputs would be expected. Zooplankton biomass would increase, but, again, many complex interactions are expected. Generally, the thermal habitat for warm-, cool- and even cold-water fishes would increase in size in deep stratified lakes, but would decrease in shallow unstratified lakes and in streams. Less dissolved oxygen below the thermocline of lakes would further degrade stratified lakes for cold water fishes. Growth and production would increase for fishes that are now in thermal environments cooler than their optimum but decrease
for those that are at or above their optimum, provided they cannot move to a deeper or headwater thermal refuge. The zoogeographical boundary for fish species could move north by 500-600 km; invasions of warmer water fishes and extirpations of colder water fishes should increase. Aquatic ecosystems across the region do not necessarily exhibit coherent responses to climate changes and variability, even if they are in close proximity. Lakes, wetlands and streams respond differently, as do fauces of different depth or productivity. Differences in hydrology and the position in the hydrological flow system, in terrestrial vegetation and land use, in base climates and in the aquatic biota can all cause different responses. Climate change effects interact strongly with effects of other human-caused stresses such as eutrophication, acid precipitation, toxic chemicals and the spread of exotic organisms. Aquatic ecological systems in the region are sensitive to climate change and variation. Assessments of these potential effects are in an early stage and contain many uncertainties in the models and properties of aquatic ecological systems and of the climate system.

Notes: Extensive review of potential climate change impacts on the GL and lakes and streams of the Precambrian Shield region.


Abstract: The first reported in situ measurements of benthic primary production in Lake Erie were made on rocky substrata using oxygen and dissolved inorganic carbon change in 1997 and 1998. The productivity quotient for net benthic algal growth was determined to be 1.1 based on contemporaneous measurement of oxygen production and carbon uptake. Highest rates of gross photosynthesis were > 300 mg O2/m2/h on rocky substrata with mixed stands of Cladophora and dreissenid mussels. These stands also exhibited the greatest rates of oxygen consumption in the dark. Bare rock substrata had lower rates of gross photosynthesis than rock occupied by mussels or Cladophora, but even these habitats had rates that would place them among the highest rates measured in fresh water. Areal benthic photosynthetic rates would greatly exceed areal pelagic photosynthesis in depths shallower than 5 m depth in the eastern basin; and, at greater depths, the importance of declining benthic areal photosynthesis relative to generally increasing integral pelagic production with depth would depend on substratum type and water clarity. Dreissenid mussels had a positive effect on benthic photosynthesis that was especially evident in stimulating Cladophora growth over the course of the 1998 season.

Notes: The authors measured nearshore benthic photosynthesis and respiration in ER during 1997 and 1998. A shift in primary production from pelagic to benthic may be out of proportion to the shifts in energy flow because benthic food webs may be more efficient than pelagic in supporting secondary production. The zebra mussel invasion may have profoundly changed the energy dynamics of the nearshore.


No abstract.

Notes: Presents a boreal bird conservation plan for the region that extends across the northern states of MN, WI, and MI, including the Upper Penninsula. Lists priority bird populations and habitats in the region including forests, grassland and savannas, urban areas, and wetlands. Identifies specific conservation needs for bird species and their respective habitats requirements. Wetland birds discussed include Belted Kingfisher, Willow Flycatcher, N. Rough-winged Swallow, Bank Swallow, Common Yellowthroat, Swamp Sparrow, and Rusty Blackbird. Wetland-specific conservation recommendations include removing unneeded dams, dikes, and levees to reestablish hydrological connections, and to work to limit development along shorelines.
No abstract.

Notes: SOLEC 1996 background paper (114 pp) contains extensive information on GL coastal wetland ecological functions and values, stressors, and indicators of wetland health. Also includes a lake-by-lake discussion of the status of coastal wetlands (circa 1996). Water level change, both seasonal and long-term, is listed as the major natural stressor of GL coastal wetlands. WLF is also discussed in the context of climate change.

Abstract: Along with clean air and drinkable water, abundant natural resources are the foundation of a healthy society and a sound and sustainable development. As one of the six major Great Lakes ecosystems, coastal wetlands and their health is fundamentally important to assure the biological diversity of the Great Lakes basin (Edsall, 1998). Coastal wetlands are not only important habitats for diverse plant and animal communities, they also provide coastal protection, water purification and perform other essential functions with direct and indirect human benefits. In spite of their benefits, anthropogenic activities have had a profound impact on these ecosystems. Coastal areas around the Great Lakes became focal points for human settlement, industry and recreation, and therefore due to their proximity, coastal wetlands have felt the stress from these impacts. Coastal wetlands have been one of the most impacted of all Great Lakes ecosystems. Maintaining their key functions and structural integrity is a formidable challenge, particularly in the face of many rapidly urbanizing watersheds. A critical stage in conserving and restoring wetlands is understanding their capacity to support various biological communities in relation to what would be expected of healthy wetlands in the same region (Grabas, 2003). For this reason, a major initiative is underway to develop procedures that could be used for basin-wide assessment of wetlands ecosystem health. Considerable effort has gone into the development of an indicator-based system to partition natural and anthropogenic disturbances. While there is much current work on Great Lakes wetlands, there has not been a journal issue devoted exclusively to these ecosystems since the special issue of the Journal of Great Lakes Research in 1992. The present issue has evolved from the special symposium entitled "Coastal Wetlands of the Great Lakes" organized at the 23rd Annual Meeting of the Society of Wetland Scientists held on June 2-7, 2002 in Lake Placid, NY, USA. The major objective of the special issue is to provide a general reference on the state of knowledge of the Laurentian Great Lakes wetlands. This was accomplished by assembling the collection of ten papers covering a variety of wetland topics.

Notes: An overview of natural and anthropogenic factors important in GL coastal wetland development. Includes a discussion of geology, climate, land use, wetlands classification, and problems and issues that need to be addressed in wetland research.

Abstract: Early life stage survival often determines fish cohort strength and that survival is affected by habitat conditions. The structure and dynamics of ichthyoplankton assemblages can tell us much about biodiversity and fish population dynamics, but are poorly understood in nearshore areas of the Great Lakes, where most spawning and nursery habitats exist. Ichthyoplankton samples were collected with a neuston net in waters 2–13 m deep weekly or biweekly from mid-April through August, during 3 years (2000–2002) as part of a study of fish assemblages in west-central Lake Erie. A suite of abiotic variables was simultaneously measured to characterize habitat. Cluster and ordination analyses revealed several distinct ichthyoplankton assemblages that changed seasonally. A lake whitefish (Coregonus clupeaformis) dominated assemblage appeared first in April. In May, assemblages were dominated by several percid
species. Summer assemblages were overwhelmingly dominated by emerald shiner (Notropis atherinoides), with large gizzard shad (Dorosoma cepedianum) and alewife (Alosa pseudoharengus) components. This seasonal trend in species assemblages was also associated with increasing temperature and water clarity. Water depth and drift processes may also play a role in structuring these assemblages. The most common and widely distributed assemblages were not associated with substratum type, which we characterized as either hard or soft. The timing of hatch and larval growth separated the major groups in time and may have adaptive significance for the members of each major assemblage. The quality and locations (with reference to lake circulation) of spawning and nursery grounds may determine larval success and affect year class strength.

Notes: Ichthyoplankton composition, abundance, and distribution were examined near major river mouths within the west-central basin, ER. The authors’ goals were to determine spatial and temporal structure, describe any observed structure using ecological community attributes, and to quantify the relationship of that structure to habitat conditions. Water temperature and clarity both showed a strong correlate with fish assemblage structure. WL is not discussed directly, but some results do indicate that as coastal conditions change and sediment input to the lake changes in quality and volume, the nearshore zone remains a viable and important habitat for ER fishes.


Abstract: We quantified the chlorophyll a content of planktonic algae and benthic algae in periphyton on acrylic rods and in epiphyton growing on macrophytes in 24 coastal wetlands in all five Laurentian Great Lakes. Sites were selected to represent a wide range of environmental conditions ranging from nutrient-poor, clear-water marshes with abundant macrophytes to nutrient-enriched, turbid systems devoid of aquatic vegetation. Water quality and species and percent cover of submergent macrophytes were measured in each wetland. Principal components analysis (PCA) showed that total phosphorus, turbidity, and suspended solids, variables associated with human-induced degradation, were most strongly correlated with PC axis 1 (PC1), accounting for 69% of the total variation. The PC1 site score was significantly related to both periphyton and phytoplankton biomass, respectively accounting for 54 and 70% of the total variation in periphyton and phytoplankton data, whereas PC1 only accounted for 18% of the variation in epiphyton biomass. Periphytic and epiphytic biomass were negatively correlated with percent cover and species richness of submergent macrophytes, but phytoplankton biomass was not. We conclude that periphytic and planktonic chlorophyll a biomass are good indicators of human-induced water-quality degradation and recommend that both benthic and planktonic algal biomass should be routinely monitored as part of an effective wetland management program.

Notes: The authors measured periphyton, epiphyton, and phytoplankton biomass (as chlorophyll-a) in 24 GL coastal wetlands across a range of environmental conditions from extremely nutrient-poor to nutrient-rich systems lacking submerged plants. The study took place across all five GL in the summers of 2000-2001. Although the study was not directly WLF related, the authors developed a standardized protocol to assess wetland quality.


No abstract.

Notes: A review of the direct and indirect effects of WLF on seasonal habitat functions of birds in the GL basin. WLF can affect nesting habitat stability, with species nesting in unstable sites showing a lower degree of site tenacity. WLF can affect migrating bird feeding and stop-over sites, and wintering birds by
primarily altering feeding areas. This paper contains numerous citations on GL birds published prior to 1985.


Abstract: We combine information on the influence of temperature on the physiology and ecology of fishes with information on the interrelationships between climate and physical limnology for an initial assessment of the impact of future climate warming on fishes and their habitats in the Great Lakes basin. The predicted increase in mean annual air temperature of 3.2-4.8 °C is not expected to extirpate fish taxa in the basin. Habitat warming in streams and lakes will likely shrink extant populations of salmonines and coregonines through reductions in preferred thermal habitat and allow range extensions of cyprinids, esocids, centrarchids, and ictalurids. Competition for optimal thermal space within thermal niches will increase, resulting in changes in community composition. Relatively rapid changes in water level would adversely affect the structure of wetlands and littoral areas, reducing their efficacy as spawning and nursery areas. Changes in fisheries yields of preferred species are expected.

Notes: Review paper that brings together information on zoogeography, past climate-related changes in fish distribution, and temperature effects to provide a basis for forecasting some impacts of climate warming on fish and fish habitat in the GL basin. Focus is primarily on the potential effects due to increased water temperature, but the authors state that rapid changes in water level will adversely affect the structure of wetlands and littoral areas, reducing their value as spawning and nursery areas.


Abstract: Fish community data were collected to investigate the role of wetlands in supporting fish communities of protected embayments in Lake Ontario. Wetland and deeper, more open, littoral sites were sampled in five protected embayments using gill nets, fyke nets, minnow traps, and electrofishing gear during the summers of 2001 and 2002. Pooled gear data were used to analyze community composition, size frequency, and species richness. We found that even within protected embayments where community composition of both habitats is similar, wetlands support a community of fish different in species dominance and size structure than littoral embayment habitats. The abundance of young-of-year fish suggests that wetlands support fish populations by providing important nursery habitat. The similarity in fish community composition between wetland and littoral habitats indicates that wetlands remain important in supporting a subset of the embayment fish community. These results demonstrate that both wetlands and littoral areas in embayments are valuable and intensively utilized fish habitats that should receive special consideration in ecosystem management plans for the Great Lakes.

Notes: Fish community data were collected to investigate the role of wetlands in supporting fish communities of protected ON embayments. Does not deal with WLF directly, but does emphasize the importance of coastal wetlands as fish nursery habitats.


Abstract: Upland breeding bird communities were sampled from 225 points in 15 survey routes in the coastal region of western Lake Superior to examine relationships to human land use. Eighty-four species were detected and 50 were abundant enough to be included in data analysis. Monotonic quadratic regression models were constructed for these 50 species by using species counts as the dependent variable and the proportion of human conversion of the landscape (residential, agriculture, and commercial/ industrial land uses) within each study area as the independent variable. Twenty-seven bird species had significant regressions (P < 0.05), 18 of which generally avoided areas developed by humans
and 9 of which were attracted to development. Detrended correspondence analysis using counts of these 27 bird species was used to investigate multivariate, community responses to development. The first DCA axis was interpreted as a gradient from urban avoiding to urban exploiting bird species and was strongly correlated with land cover variables related to human development. Our results advance the idea that breeding bird communities can be used as indicators of ecological condition and can diagnose potential causes for changes in these conditions. Further, our study points out the usefulness of bird monitoring data in regional planning efforts that incorporate goals for maintaining native biological diversity.

Notes: Upland breeding bird communities were assessed in western SU. Breeding bird communities can be used as indicators of ecological condition in GL wetlands.

Abstract: The relationships among environmental conditions and phytoplankton assemblages were characterized during late summer (2003-2005) in Saginaw Bay, Lake Huron. Differences among sampling stations, arising primarily from spatial disparities in water-column optical properties and nutrient availability, were evident. Cyanobacteria and diatoms dominated phytoplankton assemblages, with the greatest total chlorophyll a concentrations occurring at the innermost portions of the Bay. Microcystis abundance was greatest in the Bay’s upper reaches and decreased with increasing distance from the mouth of the Saginaw River. A suite of variables, indicative of annually-distinct meteorological and hydrological conditions and phosphorus-laden inflows, were identified to (collectively) best 'group' stations in a manner consistent with that of phylogenetic-group chlorophyll a concentrations and cyanobacterial biovolumes. However, a great deal of variability between abiotic and biotic patterns remained unexplained and several abiotic variables singularly corresponded with Microcystis abundance. Taken together, it appears that multiple environmental conditions (including annual/episodic meteorological patterns, seasonal/intermittent riverine inflows, annual phosphorus loading, etc.) interact with taxon-specific physiological traits to holistically influence late-summer phytoplankton abundance throughout inner Saginaw Bay.

Notes: The authors investigated the relationship between phytoplankton communities and environmental conditions in Saginaw Bay, HU. Not directly WLF related, but they do mention that meteorological/hydrological patterns appear to interact with taxon-specific physiological traits to regulate abundance and blooms throughout the inner bay.

Abstract: Great Lakes coastal wetlands occur along the Great Lakes shoreline proper and in portions of tributary rivers and streams that are directly affected by Great Lakes water regimes. These wetlands form a transition between the Great Lakes and adjacent terrestrial uplands, and are influenced by both. Over the past two decades, a wealth of detailed information has been generated on these systems, ranging from a comprehensive inventory of wetlands along the U.S. Great Lakes shoreline (Herdendorf et al. 1981a-1981f), to detailed studies on the hydrology, sediment history, water chemistry, and flora of one or a few sites (e.g. Krieger 1989). To date, however, there has been little emphasis on regional variability within these wetlands and how that variability relates to environmental parameters.

This study addresses that gap, by providing a regional perspective on the abiotic variability and associated vegetation characteristics of herbaceous coastal wetlands of the Great Lakes shoreline. This study is based on field sampling conducted in over 110 coastal wetlands in Minnesota, Wisconsin, Michigan, Ohio, Pennsylvania, and New York by Michigan Natural Features Inventory (MNFI) between 1987 and 1994 (Albert et al. 1987, 1988, 1989; Minc 1996a, 1996b, 1997a, 1997b, 1997c). The goal of
MNFI's project was to identify vegetatively distinct wetland types, and to develop a wetland classification for the Great Lakes coastline that links floristic variability to controlling abiotic factors.

Notes: A U.S. EPA on-line report that summarizes the abiotic variability and associated vegetation characteristics of herbaceous GL coastal wetlands. Three temporal scales of WLF (short-term, seasonal and interannual) contribute to the dynamic nature of coastal wetlands, though interannual fluctuations impose the greatest stress. As water levels rise and fall the vegetation communities experience locational shifts, and aquatic plants are also subject to a broad range of stressors including changes in wave action, water currents, turbidity, nutrient availability, alkalinity, and temperature as well as ice scour and sediment displacement. Conversely, the dampening or absence of WLF alters species composition.


Abstract: Karr's index of biotic integrity (IBI) approach provides a biological measure of ecosystem health using a wide spectrum of metrics which can be extracted from fish catch data obtained using standardized methods. Extensive electrofishing surveys of littoral fish assemblages, conducted in three Great Lakes' areas of concern, provided the basis for developing a lacustrine IBI that was 12 metrics of three broad types: (i) species composition, (ii) trophic composition, and (iii) abundance and condition. In contrast with lotic IBIs where diversity and abundance metrics have mostly been used, several biomass metrics were adopted to accommodate the large size range of lentic fishes. The variability of repeated measures was low enough to allow valid testing of intertransect differences with three to five samples per transect. Comparisons among survey areas showed significant differences consistent with the varying levels of ecosystem degradation. Analyses of mean IBI values with measures of submerged vegetation density and cover by transect produced significant positive correlations. This IBI developed for the Great Lakes' littoral zone, both by design and by demonstrated correlations, integrates the effects of four main factors influencing fish assemblages and hence revealing ecosystem health: exotic fishes, water quality, physical habitat supply, and piscivore abundance.

Notes: Assesses the performance and value of a fish IBI derived for the GL littoral zone that integrates the four main factors influencing fish assemblages: water quality, physical habitat supply, exotic fishes, and piscivore abundance.


No abstract.

Notes: Introduction to this special issue.


Abstract: Great Lakes wetlands can be studied systematically and for their importance in the landscape at different scales. A systems-oriented study of the wetlands of southwestern Lake Erie along Ohio's shoreline has been organized at two levels of hierarchy. At the ecosystem level, a specific wetland model was developed from data collected on hydrology, nutrient budgets, and aquatic metabolism. The model, calibrated from the field data, was used to predict phosphorus retention rates and to compare them with results from empirical models and field studies. At the landscape scale, synoptic surveys of diked (hydrologically isolated with impoundments) and undiked (natural hydrology) wetlands for hydroperiods, water quality, sediment chemistry, and vegetation biomass and species illustrated several differences between these two types of wetlands. Combining data collected from these surveys with data collected from remote platforms will lead to the development of spatial dynamic models for the shoreline to deal with landscape-level questions on the management of these shoreline wetlands.
Notes: This paper summarizes a study of ER southern shore wetlands using two levels of models and field measurements from an ecosystem to a landscape approach. WLF are discussed; in pre-settlement times, high water levels would send wetlands inland, while during low water levels the wetlands would extend lakeward. At any given wetland location, the wetland will vary from emergent vegetation dominated (shallow water) to planktonic or floating-leaved vegetation during high water.

Abstract: A simulation model is developed for a coastal wetland of Lake Erie, one of the North American Laurentian Great Lakes, to determine the fate and retention of phosphorus in the wetland as water flows from an agricultural watershed through the wetland and into Lake Erie. Phosphorus retention in the wetland is a desirable to prevent eutrophication of Lake Erie. The model is developed with sub-models for hydrology, productivity, and phosphorus and a simulated barrier beach that can be opened or closed to Lake Erie. A simulation based on 1988 data is calibrated in step-wise fashion. Resuspension is a necessary inclusion in the model to predict phosphorus concentrations in the wetland's water column. Subsequent simulations are made for various combinations of increased flow from the watershed and changing Lake Erie water levels. Phosphorus retention varies from 17 to 52% with highest retention when high inflows are coupled with high lake levels.

Notes: Introduces a wetland model used to estimate the role of ecosystem metabolism, sedimentation, resuspension, and lake hydrodynamics in the cycling and retention of phosphorus in Old Woman Creek Estuary, ER. The model allows estimates of P retention and cycling rates under low and high water levels.

Abstract: A coastal wetland along Lake Erie (Ohio, U.S.A.) was studied to determine hydrologic and phosphorus budgets and spatial and temporal variation of phosphorus and related chemical parameters. The wetland was influenced by changing Lake Erie water levels, seiches, shifting shoreline sediments, and watershed inflow during a year of severe drought. The water budget for a 7-month period (March – September, 1988) had average inflow of 15 200 m3 day–1 from the watershed and 3.5 m3 day–1 from Lake Erie. The wetland increased in volume by 700 m3 day–1 despite a drought that resulted in 80% more evapotranspiration than rainfall as a barrier beach isolated the wetland from Lake Erie for 77% of the study period. Conductivity decreased by 34% as water flowed through the wetland and turbidity and total suspended solids were variable and statistically similar at inflow and outflow. Average total phosphorus concentrations in the inflow and outflow were also similar (247 and 248 µg P l–1 respectively) although total soluble phosphorus and soluble reactive phosphorus decreased significantly (agr=0.05) from inflow to outflow (averages 94 to 45 µg P l–1 and 7.5 to 4.0 µg P l–1 respectively). Nutrient budgets from field data estimate a retention of 36% of the phosphorus, presumably in the sediments (0.8 mg P m–2 day–1). A general nutrient retention model, an estimated deposition rate from a sediment core and a simulation model predicted higher mass retention of phosphorus but similar percentage retention.

Notes: Hydrologic and phosphorus budgets for an ER coastal wetland were studied in 1988, a major drought year. The researchers’ goal was to determine whether this wetland was serving as a chemical and hydrologic buffer between the upland and ER. A conceptual phosphorus retention model is presented.

Abstract: Our objective was to evaluate the status of lake trout Salvelinus namaycush rehabilitation in South Bay, Lake Huron. Standardized surveys were conducted to quantify natural recruitment, annual
mortality, and the contribution of wild- versus hatchery-origin lake trout. Some indicators suggest a high level of natural recruitment. The spawning population was comprised of multiple ages, and the mean age of spawners (8.4 years for females, 7.9 years for males) was at least 1 year older than the age at 50% maturity (5.8 years). Estimated annual total mortality rates (0.20-0.25) and sea-lamprey induced mortality rates (0.02) were less than maximum allowable values. The proportion of wild-origin fish captured was high among spawners but varied among sampling programs (42% in fall trap nets, 70% in fall gill nets, and 88% in summer gill nets). A strong year class (1997) could be tracked from 2001 to 2005. Few fish were captured from early (< 1996) or later (1999-2002) year classes. Possible explanations for low natural recruitment during these later years include declining spawning habitat quality caused by low water levels and/or invasion of non-native mussels (Dreissena spp.) and/or direct or indirect effects of alewife (Alosa pseudoharengus).

Notes: The authors evaluated the status of lake trout rehabilitation in South Bay, HU. Recruitment declined in the later year classes (1999-2002). Possible explanations for the lower natural recruitment included declining spawning habitat due to low water levels as well as zebra mussels and alewife. Low water levels in HU since 1999 had dewatered high-quality near-shore spawning habitat. WLF of 1-2 m seen in HU has maximum impact in South Bay where lake trout spawn in shallow (1-4 m) nearshore waters.


Abstract: The Canadian Wildlife Service and the Adaptation and Impacts Research Division of Environment Canada secured funding in 2003 for a two-year project on Great Lakes Coastal Wetland Communities. In partnership with Fisheries and Oceans Canada and the University of Waterloo, the project examined the vulnerability of coastal wetland plant, bird and fish communities to climate variability and change, and explored adaptation strategies to maintain ecosystem function and values.

Notes: Extensive report produced from a collaborative research project to assess the vulnerability of selected GL wetlands to climate change. Utilized literature reviews, field surveys, stakeholder engagement, and modeling to explore (1) the response of GL coastal wetland communities to hydrologic and thermal changes, and (2) human-directed adaptations to WLF. Vulnerability indices were developed for wetland vegetation, wetland-dependent breeding birds, and fishes for changes in temperature and water level regimes.


Abstract: Significant change in global climate could occur due to human-induced changes in the chemistry of the atmosphere. We provide a basis for the continuing assessment of potential impacts of climate change on aquatic ecosystems. A series of climate change scenarios have been developed for the Great Lakes basin using general circulation models (GCMs), climate spatial transpositions, and historical climate analogs. The direct impacts of climate change on the Great Lakes ecosystem would occur through higher air and water temperatures. Indirect climate change impacts include both positive and negative changes in precipitation, decreases riverine runoff, less snowfall and snowpack accumulation, higher evapotranspiration, and a reduction in lake levels and connecting channel flows. These climate and hydrologic changes affect the quantity and quality of wetland and aquatic habitats, alter the frequency and timing of lake turnover, and change dissolved oxygen, and alter fish community composition and dynamics. We provide an integration of Great Lakes climate scenarios. We also illustrate, for the first time, the spatial variability of the climate change scenarios on a tributary river-basin scale.
Notes: An integration of GL basin climate scenarios. The hydrological and ecological impacts of the different GCM climate change scenarios are discussed. In the 4x CO$_2$ scenarios the supply of water to the GL decreases although precipitation increases in large portions of the basin. Warmer air temperatures will cause lake level declines from increased evaporation and evapotranspiration resulting in increased moisture loss and less runoff. Changes in ice cover extent and duration will also increase water loss. In 2x CO$_2$ scenarios the decreases in lake level are significant, with MI-HU and ER dropping > 1m. Water level drops of this magnitude will have important impacts on wetlands, fisheries, and shoreline habitat.

Abstract: Historical changes in wetland classes in three shoreline fens, Baie du Dore, Oliphant, and Howdenvale, along the eastern shoreline of Lake Huron were analyzed to determine responses to fluctuating water levels. Wetland classes (lake, floating emergent, emergent marsh, meadow marsh, fen, and exposed substrate) were delineated through interpretation of aerial photographs for the period 1938 to 1995. Scan vectorization was used to develop a digital database of wetland classes. Spatial and temporal analyses, conducted in a geographic information system (GIS), allowed comparison of trends among and within wetland classes which were linked to water level conditions. In periods with low water levels, overall wetland area increased primarily through expansion of the exposed substrate class lakeward; although meadow marsh also contributed to the increase. While wetland area increased during low water levels, exposed substrate did not markedly add to wetland habitat value but represents potential new wetland area that can be recolonized from seed banks. During high water levels, wetland area decreased as the lake class expanded inland and exposed substrate contracted or disappeared. Fen remained consistent in areal extent and location for most years at Howdenvale, but fen at Baie du Dore expanded with lower water levels, and contracted and became more fragmented with higher levels. At Oliphant, during low water levels fen area did not change, and with high levels the lake flooded the fen. With high water levels, lake area and wetter classes dominated and migrated inland. Under low water level conditions, lake was replaced by exposed substrate and drier wetland classes expanded, but did not necessarily colonize exposed substrate.

Notes: The authors used 1938-1995 air photo interpretation and spatial analysis to document and assess wetland areal changes to WLF in three HU fens. With high water levels, lake area and wetter classes dominated and migrated inland. Under low water level conditions, lake was replaced by exposed substrate and drier wetland classes expanded, but did not necessarily colonize exposed substrate. A table summarizes wetland class responses to high and low water levels for the three HU fens.

Abstract: Pythium species are economically significant soilborne plant pathogens with worldwide distribution, causing seedling damping-off or root rot diseases. Pythium phragmitis is a newly described pathogen of common reed (Phragmites australis), widespread in the reed-belt of Lake Constance, Germany. It is highly aggressive towards reed leaves and seedlings, but obviously does not affect roots. In the context of 'reed decline' phenomena, P. phragmitis infection of reed inundated during flooding events may be of particular significance. We could show that flooding itself is not necessarily detrimental for reed plants. In the presence of the pathogen, however, most submerged leaves and plants were killed within several weeks. Clipped plants did not show regrowth in the Pythium infested treatments. Significant losses in assimilating leaf area of reeds could, thus, be the result of Pythium infection rather than of flooding alone. Therefore, we suggest that the combination of extended flooding and the presence of P. phragmitis might considerably contribute to 'reed decline' at Lake Constance. In parallel, we could show that pathogenicity and spread of this species are considerably favoured by rising temperatures.
Since an increase in average water temperature has been found for Lake Constance, we propose that *P. phragmitis* could be an important factor in the dieback of reed stands likely to be promoted by predicted climate change phenomena.

Notes: From Lake Constance (Central Europe), the author presents results of artificial flooding experiments to determine the infection rate of a soilborne pathogen, *Pythium*, on young *Phragmites australis* plants. Results show that extended flooding plus the presence of the pathogen contribute to reed decline in the lake.

Abstract: Freshwater unionid clams in North America have been virtually eliminated from waters that are colonized by zebra mussels. Near total mortality has been reported in western Lake Erie but we have now discovered a large population of native clams in a Lake Erie wetland that shows little sign of infestation. Field observations and laboratory experiments show that warm summer water temperatures and soft, silt-clay sediments trigger burrowing by clams. This discourages infestation and physically removes any attached zebra mussels.  
Notes: Surveys of the unionid community in Metzger Marsh, a western ER coastal wetland that was undergoing a dewatering, showed a native clam population that had survived the zebra mussel invasion. Field observations and lab experiments showed warm temperatures and soft sediments trigger burrowing by clams. As the clams burrowed into soft sediment they were able to remove attached zebra mussels. Wetlands may provide a place for intensive management of native clam stocks, ensuring their survival in zebra mussel infested waters.

Abstract: Our overall goal was to develop indicators that both estimate ecological condition and suggest plausible causes of ecosystem degradation across the U.S. Great Lakes coastal region. Here we summarize data gathered along the U.S. Lake Huron coastline for breeding bird, diatom, fish, invertebrate, and wetland plant communities. We sampled these biotic communities on 88 sites in Lake Huron coastal wetlands, uplands, estuaries/bays, and high-energy shorelines. The sites were selected as part of a larger, stratified random design for the entire U.S. Great Lakes coastal region using gradients of anthropogenic stress that incorporated over 200 stressor variables (e.g. agriculture, land cover, human populations, and point source pollution). The U.S. Lake Huron coastal region exemplified wide variation in human-related stress relative to the entire U.S. Great Lakes coast. In general, levels of stress decreased from south to north partly reflecting the change in climate and physiography, but also due to the greater human influences in the southern region as compared with the north. The primary stressors in the southern region are due to agriculture and human development, while the northern region has substantially less agriculture and less human population. The biotic communities sampled were strongly related to the environmental stress gradients, especially agriculture and urbanization. The following indicators were developed based on responses to stress: 1) an index of biological condition for breeding bird communities corresponding to land use, 2) a diatom-inferred total phosphorus indicator corresponding to water quality, 3) exotic fish (carp [*Cyprinus carpio*] and goldfish [*Carassius auratus*]) corresponding to agriculture, and 4) a multi-taxa index for wetland plants corresponding to a cumulative stress index. These communities can all serve as useful indicators of the ecological condition of the Lake Huron coast. The ecological indicators provide a baseline selected conditions for the U.S. Lake Huron coastal region and a means to detect change over time.
Notes: Reports on a project in which the biotic communities of 88 HU coastal wetland sites were sampled to develop indicators to estimate ecological condition and causes of ecosystem degradation. Several indicators were developed and are provided.


Abstract: The post-glacial history of the Great Lakes has involved several changes in lake levels throughout the latest Pleistocene and Holocene, resulting from the changing position of the retreating Laurentide ice sheet, outlet incision and isostatic rebound. The final lowering of lake levels occurred at approximately 7600 C-14 yr BP, after which lake levels began to rise again to the Nipissing highstand at approximately 4700 C-14 yr BP. During this time of rising lake levels, black bands of iron sulfide were being formed in the sediments of all five of the Great Lakes. These bands signify suboxic to anoxic conditions, at least within the sediments and possibly at the sediment-water interface, during the middle Holocene warm interval. During this interval, the climate was warmer and drier than present, possibly resulting in the occasional absence of seasonal turnover in the lakes. We examined a series of piston cores from northern Lakes Michigan and Huron and found that the black bands are correlatable among cores taken from within the same basin. The observation that the banding can be correlated suggests a basin-wide cause, near-bottom or sub-bottom anoxia in the northern Michigan and northern Huron sediments during the mid-Holocene warm period. The sedimentary and geochemical processes in the Great Lakes during the middle Holocene warm interval are good indicators of possible future scenarios for the lakes as a result of global warming, as 21st-century temperatures are predicted to reach similar levels due to increased concentrations of greenhouse gases.

Notes: Sediment piston cores from northern MI and HU show black banding that indicates Mid-Holocene bottom anoxia. The sediment and geochemical processes during this period are good indicators of possible future basin-wide suboxic to anoxic conditions in the GL as a result of global warming.


Abstract: No abstract.

Notes: Review of literature available in 1985 on anthropogenic interferences with natural water level regimes in the context of other stresses on GL coastal wetlands.


Abstract: Inundations of lakeshores are classical examples of how disturbance can influence community diversity and composition. As the occurrence and intensity of flooding are predicted to change dramatically as a result of climate change, predicting the consequences of such changes has become a major task for community ecology. Here we present abundance data of five species that comprise a species-poor community of high conservation value at lakeshores of Lake Constance over 17 years, during which one of the longest flood periods and the lowest water levels since 1890 occurred. We used simple regression models and increasingly sophisticated Markov chain models plus non-linear parameter estimation to put down abundance changes to direct effects of flooding on population-dynamic parameters and to indirect effects of flooding through modification of interspecific competition. We found a negative effect of flood duration on abundance changes for the non-specialist species Agrostis stolonifera and Phalaris arundinacea, but no effect on Carex acuta. The specialist species, Ranunculus...
but not Littorella uniflora showed a positive effect of flooding. Data analysis revealed an unambiguous competitive hierarchy with the two graminoid species (C acuta, P. arundinacea) being superior, and the habitat specialists being most sensitive to interspecific competition. We used estimated parameters to project the community dynamics under different flooding regimes. Long-term projection showed that the original community is threatened by two non-specialist species (C acuta and P. arundinacea). Even if this forecast was influenced by various model limitations, it may indicate irreversible changes in soil fertility during the phase of high eutrophication between 1950 and 1980. Our study demonstrated that long-term abundance relies combined with Markov modelling and predictive simulations are an important counterpart to detailed short-term studies. The combination of empirical and theoretical methods elucidates the interaction of biotic and abiotic factors in community change.


Abstract: Natural recruitment from hatchery-origin lake trout in the Great Lakes has been minimal, except in Lake Superior and a few limited areas in Lake Huron. Quantitative studies of survival between egg deposition and fry emergence were conducted on a spawning reef in the eastern basin of Lake Ontario to determine variables associated with poor reproduction of hatchery-origin lake trout. Thirty to 90 mesh bags were buried in the substrate of Stony Island Reef in 1990, 1991, and 1992 to collect eggs and fry. Bags were retrieved on three dates over the six month period between the end of spawning and fry emergence. Mean egg abundance in the substrate increased significantly (P < 0.01) from 700 m(-2) in 1990 to 3,572 m(-2) in 1991 and 3,355 m(-2) in 1992. Change in egg abundance probably resulted from an increase in the proportion of Seneca strain spawners, rather than an increase in the total number of admits in the eastern basin. Mean embryo survival from spawning to late November or early December was 45% (range, 27-57%), approximately 7.5% (range, 7.4-7.5%) to mid-April, and about 3% (range, 1.8-3.9%) to the time of emergence in mid-May. Much of the early mortality of fertilized eggs was probably due to physical shock caused by water currents during storms. Mortality later in development was caused by predation and possibly poor incubation quality of substrate along the base of the reef due to sedimentation. A life history model for lake trout in Lake Ontario was developed and parameters set with the levels of fertilization and egg-to-fry survival rate estimated in this study. Other parameters were estimated from stocking rates and previous studies. Model output indicated that the current lake trout population has the potential to produce over 1.2 million age-1 fish annually. No evidence exists for this level of recruitment in Lake Ontario. Natural recruitment may be limited by a low proportion of eggs incubating in suitable substrate and/or low survival of fry to age-1. These problems could be due to a combination of 1) a limited amount of spawning habitat, 2) ineptitude of some strains to locate or recognize spawning habitat, 3) disease-related mortality during the swim-up life stage, and 4) mortality from fish predation shortly after swim-up. Managers need to reconsider current strategies and time requirements necessary to achieve restoration goals and objectives for lake trout in Lake Ontario.

Notes: This paper describes research on the dynamics of hatchery-origin lake trout natural recruitment on an ON spawning reef. Mortality of fertilized eggs was determined to be from physical shock from storm-related water currents, and later mortality caused by predation and sedimentation along the reef. A life history model was developed.


Abstract: We tested a hypothesis that the high densities of some passerines breeding in North American marshes result from greater safety of this habitat from predators as compared to upland habitats. We examined the relative importance of water depth and distance from the marsh edge in lowering predation
rates on experimental nests with Blue-breasted Quail (Coturnix chinensis) eggs. In addition, using cameras we studied the role of water depth in determining the predator community. Our results showed that: (1) predation was lower in the marsh than in the adjacent upland; (2) predation rates decreased with increasing water depth in the marsh; (3) for the marsh nests, the distance to the marsh edge was relatively unimportant; (4) the diversity of nest predators decreased with increasing water depth; and (5) in the deep marsh areas, there was only one major predator, the Marsh Wren (Cistothorus palustris). We propose that the greater safety of deep-water marsh areas, the reduced complexity of the predator community, and the type of predators allowing effective nest defense by nest owners have played the key role in the evolution of reproductive strategies of marsh-nesting passerines.

Notes: The authors tested the hypothesis that high densities of birds breeding in marshes are due to decreased predation rates. They examined the relative importance of water depth and distance from the marsh edge in reducing predation on eggs. Observations were that predation was lower in the marsh than the adjacent upland and decreased with increasing water depth. The study was conducted in an inland marsh in Ontario.

Abstract: The importance of detritus varies greatly among shore zones of lakes, but in a large majority of these regions detrital pathways prevail. Aside from a great spatial and seasonal variability, macrophytes and bottom sediments appear to be dominant stores of nutrients in these habitats. Macrophytes hold a central position in nutrient cycling in the shore-littoral lake zones. They are the main source of autochthonous detritus as they prevail in the total biomass of littoral organisms, and they are only rarely available as direct food of consumers. Various processes and interactions determine the role of macrophytes in nutrients dynamics. These are: the intensity of nutrient uptake and translocation, release of nutrients by healthy plants and from decomposing plants, exchange of elements between macrophytes and their periphyton, as well as interception of seston by macrophyte stands. Particular plant species differ in their time of dying and susceptibility to decomposition. The changes in decomposing material (size structure of particles and nutrient content) mean that detritus in various stages of decomposition differs in its role in trophic dynamics of shore-littoral lake zones. Several types of shore regions as regards detritus sources and retention level are discussed.

Notes: A review of nutrient dynamics in littoral zones. Macrophytes and bottom sediments appear to be the dominant stores of nutrients in these habitats. Not GL or WLF specific.

Abstract: A Typha-dominated marsh bordering Lake Ontario had a strong hydraulic connection with the lake during spring 1991, when the water level was more than 10-20 cm above the marsh surface. During this period, water-level changes were dominated by the general decline of Lake Ontario, by short-term fluctuations caused by seiche activity (1.7 h periodicity) and by setup (diurnal). These were transmitted into the marsh at 65-135 m h-1. The water surface profile was generally flat over the marsh during this period but water depth was uneven owing to peat surface adjustment. High buoyancy of the surface in the 30 m margin adjacent to the lake minimized water depth there. By 21 June, water depth at the margin was essentially zero, but elsewhere was 0.07-0.1 m; all water exchanges between the marsh and lake were thereafter constrained to relatively slow subsurface flow (approximately 10(-3)-10(-4) m h-1). Short-term fluctuations caused by lake-level variability were then restricted to the margin. The Lake Ontario water level then dropped faster than that on the marsh, as did the water table on the adjacent mineral terrain, resulting in an upwardly convex water surface profile on the marsh, where water flow was away from the marsh. Between 14 June and 6 August, 116 mm of rain and 264 mm of evapotranspiration resulted in 30
mm of lateral water loss from the marsh centre; only 1 mm was lost at the marsh margin, reflecting the frequent reversals of hydraulic gradient there.

Notes: The author examined the spatial and temporal water level variations in an extensive Typha-dominated ON coastal marsh to better understand water exchange between the marsh and lake and adjacent uplands. A water balance was performed for both the marsh interior and the marginal zone. The marsh hydrological regime was intimately linked to the lake but also distinct from it. At times lake level fell faster than the water level at the marsh interior. The marginal marsh areas, however, maintained a good two-way hydraulic connection with the lake.


Abstract: Distributions of pond-breeding amphibians may be influenced by habitat factors at different spatial scales. We used anuran calling surveys to investigate the association between 5 anuran species and habitat variables measured within 100, 500, 1,000, and 3,000 m of sampling points at 63 coastal wetlands along the U.S. shores of Lake Michigan and Lake Huron. Stepwise logistic regression was used to create predictive models for each species at each spatial scale. Our results confirm the view that habitat variables at multiple scales influence frog distributions, but the strength of predictive models was significantly affected by the spatial scale at which habitat variables were derived. Remotely sensed habitat variables within a 3000 m radius were among the most effective predictors of occurrence for American toad (Bufo americanus), eastern gray treefrog (Hyla versicolor), spring peeper (Pseudacris crucifer), and green frog (Rana clamitans melanota). The western chorus frog (Pseudacris triseriata) was predicted most effectively by variables derived within a 500 m radius. For the most part, these anurans exhibited species-specific responses to habitat variables; however the suite of landscape-scale variables associated with urban land use appeared in all species' regression models. Associations with landscape-scale variables coupled with well-documented habitat needs at local breeding sites suggest that conservation and assessment of frogs and toads in coastal wetlands should consider the influence of habitat variables at multiple spatial scales.

Notes: Distributions of pond-breeding amphibians may be influenced by habitat factors at different spatial scales. Uses data from 63 GL coastal wetlands in MI and HU.


Abstract: Frogs and toads (anurans) are sensitive to a variety of anthropogenic stressors and are widely suggested as indicators of ecological condition. We surveyed 220 coastal wetlands along the U.S. shores of the Laurentian Great Lakes and quantified relationships between presence of anuran species and degree of anthropogenic disturbance. Results were used to derive explicit, functional relationships between environmental condition and anuran occurrences. These functions were subsequently used to calculate a multi-species indicator of ecological condition at other (novel) wetlands. Of 14 anuran species observed, spring peeper (Pseudacris crucifer) exhibited the strongest and most consistent relationship with environmental condition across the entire study area. Other species exhibited significant relationships with the environmental gradient, but the direction of association varied geographically or the overall species abundance was very low (e.g., mink frog, Rana septentrionalis). Even if applied to separate ecological provinces (Laurentian Mixed Forest or Eastern Deciduous Forest), multi-species estimates of wetland condition based on anurans are not much better indicators of environmental condition based on human disturbance than are indices based solely on occurrence of spring peeper. Nevertheless, indicators grounded in explicit relationships with environmental stress are superior to traditional measures (e.g., species richness) that combine species with different responses to
the stress gradient. At least one anuran species (spring peeper) can contribute meaningfully to the assessment of ecological condition in Great Lakes coastal wetlands; its value as an indicator will be improved if it can be combined with information from other wetland species such as birds, fishes, and vascular plants.

Notes: The authors tested whether amphibians can serve as effective indicators of overall ecological condition. Field data from 220 GL coastal wetlands (all five GL) were used to evaluate the relationship between anuran species presence and anthropogenic disturbance. Spring peepers were found to be useful indicators of human disturbance. WLF were not included.

No abstract.

Notes: Nesting birds in four wetland study areas, two with dikes controlling water levels, and two experiencing natural water level fluctuations, were monitored over a four-year period. Density and number of species increased as the amount of open water decreased in the wetlands. Those wetlands with poorly developed areas of submerged plants did not contain as many species.

Abstract: Literature on habitat and limiting factors of waterfowl in Great Lakes wetlands and deep water habitats is reviewed; more than 30 species of waterfowl use coastal habitats at some time during the year. Waterfowl use of the Great Lakes has declined dramatically from pre-settlement times; the obvious cause is human encroachment on coastal wetlands and destruction of river delta and embayed wetland complexes. Loss of wetland habitats from diking and filling above the average water level constitutes a permanent habitat loss, especially during high water cycles. The greatest number of species and individuals use 15 concentration areas during the spring and fall migratory periods when use by diving ducks, sea and stiff tailed ducks, and swans and geese predominates. Lesser numbers of species use the coastal wetlands for breeding. Large concentrations of dabbling ducks, primarily mallards (Anas platyrhynchos) and American black ducks (A. rubripes), and mergansers (Mergus spp.) are found on ice-free areas during winter. Wetland habitats have become more favorable, due to human modifications, to dabbling duck species found in the prairie habitats of North America. Mallards have become the most numerous species breeding in coastal wetlands along with a concomitant decline in black ducks, which may be a consequence of introgression. Habitat modifications, degradation, and loss have great potential to affect existing waterfowl populations negatively and to point the way toward future research.

Notes: A review of the literature on habitat and limiting factors for waterfowl in GL wetlands and deepwater habitats. Includes a discussion of the impact of lake level on habitats used by waterfowl, with a discussion of the Edsall (1988) plant community displacement model.

Abstract: The loss of polychlorinated biphenyls (PCBs) from sediment by volatilization is currently under scrutiny by polluters, regulators, and researchers. In this research, a one-dimensional mathematical model for the volatilization of PCBs from sediment was developed. The model considers a system with three phases: A water-saturated PCB contaminated sediment, the overlying water, and air above the water. A simple microcosm consisting of sediment, water and air that allows for (pseudo)onedimensional transport of PCB from the sediment to the gas phase was utilized to perform PCB transport studies using two PCB congeners: 4,4-dichlorobiphenyl (DCB) and 2, 2',4,4',5,5'-hexachlorobiphenyl
(HCB). The experimental data on DCB were used to calibrate and validate the mathematical model. The calibrated model was then used to simulate the effect of sediment layer thickness, depth of the overlying water, and the level of contamination on the rate of DCB volatilization.

Notes: The study’s primary objective was to determine the rate and extent of PCB volatilization from sediment. The authors developed models to predict the PCB transport process, which were used to simulate the effect of sediment layer thickness, depth of overlying water, and the level of PCB contamination on the rate of DCB (a PCB congener) volatilization.


Abstract: Throughout the world, diverse avian populations continuously utilize wetlands. The abundance of the resources, including shoreline habitat and food, has resulted in bird species that are adapted exclusively to this habitat and others that use this habitat only during portions of their life cycle or during migration. Today, we witness many adaptations which maximize benefit from this semi-aquatic life style, including: anatomical and morphological adaptations (including rear leg placement for swimming, bone and lung modifications for diving, water resistant plumage), adapted feeding tactics, modified migratory flight paths, and life history adaptations (Weller). These adaptations have created a dependency upon wetland habitat availability for sustained population levels. The effect of birds on wetland habitat is critical for the ecosystem. They are responsible for seed dispersal of many plants, and also for the dispersal of many invertebrates. In addition to the transfer of seeds and organisms, the birds have an effect on many wetland soils through their waste products, which can serve as nutrient deposits (WB). Birds are also critical to wetlands because they draw the attention of humans to the environment. Many critical pieces of wetland legislation have resulted from the pressure of waterfowl hunters who are concerned with the decline in habitat and the potential ramifications on their recreation. They are also critical to local economies, and then residents may choose to maintain wetlands for their recreational value rather than convert them for another use. Groups such as Ducks Unlimited and Audubon are able to work on a national level to preserve wetlands. In northern Michigan, coastal marshes nurture a diversity of plants and animals. The variance in perennial Great Lakes’ water levels has sustained a myriad of plant species. With the long-term cycling of low and high water levels, many changes in micro-habitat occur which result in a shift of the entire biotic community. Plants are directly affected by nutrient availability and water saturation, thus becoming good indicators of many chemical and geophysical properties of the soil in the immediate area surrounding them. Bird populations are directly affected by plant presence and by the availability of insects, invertebrates, small mammals and other birds, which makes them an indicator of the entire productivity of an ecosystem (Weller). The cycling of water levels also has effects on the macro-habitat by significantly affecting the amount of shoreline which is nesting and foraging habitat for birds and therefore the bird populations. This effect was studied through the observation of bird species diversity and abundance at several northern Michigan coastal marsh sites and was compared to historical records to determine if Great Lakes’ water levels had an effect on bird species diversity and abundance.

Unable to obtain reprint.


Abstract: Toxic sediments remediation represents a potentially long-term environmental programme in the Great Lakes basin. The prospect of declining lake levels due to global climate change in coming decades presents challenges to environmental policy makers concerned with choosing appropriate toxics clean-up methods and timing. It is important to integrate the possibility of declining lake levels into Great
Lakes toxic sediments remediation in order to ensure that long-term environmental policy is not in conflict with the potential regional hydrological impacts of climate change.

Notes: This paper is primarily a discussion on the policy of toxic site remediation and the potential for reduced water levels in the GL from climate change. The authors stress the importance of integrating declining lake level into GL toxic sediment remediation plans, and in particular to choose appropriate toxic clean-up methods and timing. Two options are available: either accelerate clean-up projects to reduce future atmospheric exposure, or take advantage of lower lake levels and the increased access to toxic sites they provide.

Abstract: Although relationships of birds to patch area and habitat characteristics have been dominant themes in avian ecology over the past few decades, relatively little is known about these relationships in wetland-dominated landscapes of the Great Lakes coastline. During 1997 and 1998, we surveyed birds and measured habitat characteristics along transects in wet meadows associated with the northern Lake Huron shoreline (NLHS) in the Upper Peninsula of Michigan. Using a suite of multivariate techniques, we related abundance and presence/absence of individual species to wet meadow area and habitat characteristics. Nine species were positively associated with increasing wet meadow area, which underscores the importance of large wetlands to avian conservation in the region. Bird variables also were related to habitat characteristics. Higher values of bird variables were generally associated with a suite of characteristics: more robust and dense grass/sedge vegetation, structural diversity in the horizontal and vertical planes, and increased frequency of willow shrubs. Individual species that require particular aspects of these characteristics for nesting or foraging were associated with principal components containing those aspects. In the NLHS, large wet meadows that possess these characteristics would support the greatest diversity and benefit the majority of species. However, conservation efforts that focus only on these traits will not be sufficient for all species because habitat requirements for some species are very specific (e.g., open water for mallard), and for others, habitat preferences may change from year to year in response to lake-level changes. While our results provide important insights, continued research is needed to further the successful conservation and management of birds in Great Lakes coastal wetlands.

Notes: The relationship of birds to area and habitat characteristics in GL coastal wetlands is discussed. Surveys took place in 1997-1998 in wet meadows associated with the northern HU shoreline. Bird-habitat relationships (positive and negative associations) for both years are shown graphically. Based on their observations, conservation efforts should focus on large wet meadows. Not directly WLF related but does discuss habitat for wetland birds.

Abstract: Landscape context can influence species richness, abundance, or probability of patch-use by birds. Little is known, however, about the effects of landscape context on birds in wetland-dominated landscapes. This lack of knowledge is alarming because many wetlands are threatened by development and other human impacts, while serving critical functions as migratory, breeding and foraging habitat. To address this lack of knowledge, we censused birds in North American Great Lakes coastal wet meadows located along the northern Lake Huron shoreline in Michigan (USA) during 1997 and 1998. Using a suite of multivariate techniques, we first accounted for effects of area and within-patch habitat characteristics before testing for effects of landscape context. Most bird variables were significantly related to landscape context, and two major patterns were apparent. First, avian species richness, abundance, and probability of patch-use by some species were higher for wet meadows located in complex contexts (adjacent to many patch types) compared to simpler contexts (adjacent to only one
patch type). Second, these variables were higher for wet meadows located in wetland contexts compared to contexts that were terrestrial and road-impacted, dominated by open water habitats, or dominated by forested wetland habitats. Conservation plans for wetlands have focused on saving large wetlands and creating the vegetative habitat structure required by birds, but they should go further and explicitly consider the landscape context of wetlands as well. Specifically, wetlands located in complex and/or wetland contexts should have a higher conservation value than similar wetlands located in simpler, more terrestrial contexts.

Notes: Birds in 40 northern HU coastal wet meadows were censused to investigate the effects of landscape context on avian species richness and patch-use. The authors identified several specific landscape contexts which are important predictors of species richness and probability of patch-use. Variables assessed included water depth, plant density, and cover type. Results provide guidelines for wetland protection which, in general, should strive to protect entire wetland complexes or preserve connections between wetland types rather than just focus on one wetland or individual wetland types.


Abstract: The objective of this research was to compare and contrast C dynamics within plots occupied by Phragmites australis, Typha spp., and Sagittaria latifolia in a Lake Erie coastal wetland (Ohio, USA). The effect of each species on above- and belowground biomass, soil C pools, soil labile C, litter decomposition rates, and microbial catabolic response profiles were analyzed. Phragmites australis and Typha spp. produced significantly more aboveground biomass (1,522 +/- 464 and 1,177 +/- 164 g DM m^{-2}, respectively) than S. latifolia (500 +/- 80 g DM m^{-2}), although no difference was observed in terms of belowground biomass. After 208 days in the field, litter of S. latifolia had lost 72% of its initial mass while only 47% of the litter of Typha spp. and P. australis had decomposed. This coupled process of high primary production and slow litter decomposition within P. australis and Typha spp. communities did not translate into greater accumulation of C in the soil. In fact, we observed lower rates of C mineralization and greater biomass of methanogens in the S. latifolia plots. Despite similar water level, soil conditions in the S. latifolia community was more saturated, which might have limited availability of C for microbial consumption in these plots. Microbial catabolic responses to 24 substrates demonstrated distinct differences in the respiration responses of the soil microbial communities of the three macrophyte species. The microbial community found in the rhizosphere of P. australis was particularly responsive to phenolic acids. Few differences in C fluxes and pools were observed between plots occupied by P. australis and Typha spp., but the replacement of S. latifolia by one of the two other species could have a significant effect on the C cycle in the Great Lakes coastal wetlands.

Notes: The study’s objective was to compare and contrast carbon dynamics in plots occupied by emergent vegetation in an ER coastal wetland. Few differences in C fluxes were seen between plots of P. australis and Typha spp., but replacing S. latifolia by one of the other species could have a significant effect on C cycling in GL coastal wetlands. Not directly related to WLF but is relevant with regard to species shifts and invasives.


Abstract: Introduction-The Lake Erie Committee (LEC), representing five fisheries-management agencies comprised of New York, Pennsylvania, Ohio, Michigan, Ontario have developed a set of fish-community goals and objectives for Lake Erie in accordance with the Joint Strategic Plan for Management of Great Lakes Fisheries (Great Lakes Fishery Commission 1997). Agencies recognized nine guiding principles during development related to self-sustaining stocks, the stock concept, indigenous species, aversion to introductions, preservation and restoration of habitat, preservation of rare and endangered species, recognition of naturalized species, requirement to harvest on a sustainable basis, and recognition of the
limit on productivity. Lake Erie has had a long history of fish-community instability and subsequent change in its fisheries. Restoration of fish-community stability can be best achieved through management to promote healthy stocks of top predators, reduction in and/or prevention of the establishment of aquatic nuisance species, and protection and/or restoration of important coastal nearshore and tributary habitats. The LEC endorsed two goals. The first is to secure a balanced, predominantly cool-water fish community characterized by self-sustaining indigenous and naturalized species that occupy diverse habitats, provide valuable fisheries, and reflect a healthy ecosystem. Walleye (Stizostedion vitreum) would be a key predator in the western basin, central basin, and the nearshore waters of the eastern basin. The second goal is to secure a predominantly cold-water fish community in the deep, offshore waters of the eastern basin with lake trout (Salvelinus namaycush), and burbot (Lota lota) as key predators. Further, the LEC has endorsed additional objectives concerning desired ecosystem conditions; the composition of fisheries and their link to supporting habitat; contaminants in fish; conservation of genetic diversity and of rare, threatened and endangered species; and the ecology of fish production. The committee strongly endorses the cooperative, inter-jurisdictional approach to fisheries management, as facilitated through the Great Lakes Fishery Commission.

Notes: Great Lakes Fishery Commission report on fish-community goals and objectives for ER. No discussion of WLF.

Abstract: In this study, we investigated the impact of carp and turbidity on the growth of macrophytes from propagules in four Lake Ontario marshes with low submersed macrophyte abundance. A healthy propagule bank was transplanted into 4 m(2) carp exclosures (5-cm-mesh cages), turbidity exclosures (enclosed in plastic), and open control sites, with four replicates per treatment used in each marsh. Carp exclosures were intended to protect the transplanted propagule banks from carp and other large aquatic organisms; turbidity exclosures were intended to also reduce wind exposure and inflowing suspended sediments, thus increasing the amount of light reaching bottom sediments. The mean density of shoots produced in the turbidity exclosures (256 +/- 46 shoots m(-2)) was significantly higher than that produced in carp enclosures (20 +/- 7 shoots m(-2)) and open controls (10 +/- 5 shoots m(-2)); above-ground biomass (AGB) was also significantly greater in turbidity exclosures. The difference in protection afforded the developing submersed macrophyte shoots can be attributed to the lower concentration of total suspended solids and greater level of light penetration in the turbidity exclosures. There was a strong linear relationship between photosynthetically active radiation (PAR) reaching the substrate surface and shoot growth in terms of both shoot density and AGB. The growth response was more sensitive to PAR in the field than it was in a growth chamber, suggesting that light levels are more critical to shoot development when multiple stressors are involved. The two marshes exposed to high wave energy had very high levels of suspended solids, and the introduced propagule bank was eroded away in controls and carp exclosures. In such marshes, both turbidity and exposure would have to be addressed for macrophyte recovery.

Notes: Results from exclosure experiments to assess the effect of turbidity and carp on submersed macrophyte growth in four ON coastal wetlands. Light levels are critical to macrophyte growth, and both carp and exposure of the wetland affect turbidity. WLF not mentioned but has been mentioned by others as affecting wetland turbidity.

Abstract: The present study was conducted to determine impacts of zebra mussel (Dreissena polymorpha [Pallas, 1771]; Dreissenidae) infestation on unionids in firm substrata in western Lake Erie. Unionid
mollusks were collected at a total of 15 stations on three offshore depth contours (2, 3, and 4 m) in 1983 (before zebra mussel infestation), in 1990 and 1993 (after zebra mussel infestation), and at one station on a nearshore 2-m depth contour and along one transect on a nearshore 1-m depth contour in 1993. Numbers of living unionids on substrata along offshore contours remained similar between 1983 and 1990 and then decreased from 97 individuals in 1990 to only five individuals in 1993. In addition, the number of species decreased from nine to four between 1990 and 1993. In contrast, on nearshore contours 85 living individuals representing nine species were found in 1993. About 48% of the living and 79% of the dead unionids at the two nearshore locations were covered by byssal threads of dreissenid mussels, but were not actively infested by mussels. The presence of living unionids on nearshore contours of western Lake Erie in 1993 indicates that survival of unionids in the presence of abundant zebra mussel populations can be possible in firm substrata and that these habitats can provide natural "refugia" for unionid populations. At present, we do not know what allows unionids to survive in the presence of zebra mussel colonization, but believe that water-level fluctuations and waves could contribute to the removal of mussels from unionids. This information could be of major concern in the mitigation of impacts of infestation on unionids in waters throughout North America.

Notes: Zebra mussel effect on unionid survival in ER. Not directly WLF related.

Abstract: Recent research that couples climate change scenarios based on general circulation models (GCM) with Great Lakes hydrologic models has indicated that average water levels are projected to decline in the future. This paper outlines a methodology to assess the potential impact of declining water levels on Great Lakes waterfront communities, using the Lake Huron shoreline at Goderich, Ontario, as an example. The methodology utilizes a geographic information system (GIS) to combine topographic and bathymetric datasets. A digital elevation surface is used to model projected shoreline change for 2050 using water level scenarios. An arbitrary scenario, based on a 1 m decline from February 2001 lake levels, is also modeled. By creating a series of shoreline scenarios, a range of impact and cost scenarios are generated for the Goderich Harbor and adjacent marinas. Additional harbor and marina dredging could cost as much as CDN $7.6 million. Lake freighters may experience a 30 percent loss in vessel capacity. The methodology is used to provide initial estimates of the potential impacts of climate change that can be readily updated as more robust climate change scenarios become available and is adaptable for use in other Great Lakes coastal communities.

Notes: Uses a hydrologic model to predict effects of GL WLF on human communities.

Abstract: Beach closings are a growing concern in coastal regions because of serious public health and economic ramifications. Two beach sites separated by 150 m of shoreline on Lake Michigan were monitored in the summer of 2003 and 2004 for E. coli densities to evaluate the potential outcome of relocating an existing beach to a site immediately to the south. Under identical weather conditions, there was a large disparity between the two sites for 25 of the 39 days tested, where E. coli levels at the existing beach were at least twice as high as those at the proposed beach. Following rainfall, E. coli levels at the existing beach increased up to 100-fold to levels as high as 4,500 CFU/100 mL, whereas only a 10-fold increase in levels was observed at the proposed beach site. Water exchange in the beach areas was predominantly from wind driven currents rather than dilution, and longshore current speed at the proposed beach was calculated to be twice that of the existing beach. Stormwater and combined sewer overflow (CSO) discharged from two closely spaced outfalls approximately 0.5 km north of the existing
beach was found to have E. coli levels above the EPA recommended limit of 235 CFU/100 mL for recreational waters. However, this input did not appear to be a major influence on beach monitoring results. In some cases, E. coli levels at the beach did not exceed 235 E. coli/100 mL during a CSO. Defining the sources and spatial range of pollution inputs would allow beach monitoring results to be interpreted in a more meaningful context, which may lead to the formation of effective management strategies.

Notes: Investigated sources of fecal pollution at two MI south shore beaches. Nearshore water dynamics do play a role in water exchange and subsequent dilution of E. coli levels.


Abstract: We use fish and environmental data from 40 wetlands of the Laurentian Great Lakes to develop the wetland fish index (WFI), a tool that can be used to assess the quality of coastal marshes. A partial canonical correspondence analysis was used to ordinate fish species along multidimensional environmental axes that accounted for anthropogenic disturbance based on temperature, conductivity, and the presence of pollutants (e.g., suspended solids and primary nutrients). Compared with other measures of fish habitat quality (e.g., Shannon–Wiener diversity index and species richness), the WFI was the only index that was significantly related to the degree of water quality degradation and wetlands condition, as indicated by an independent index of wetland quality, the water quality index (WQI). WQI ranks sites according to deterioration in water quality and is statistically related to the degree of land-use alteration in wetland watersheds. We demonstrate the usefulness of the WFI for detecting intrawetland variation between two sites in a degraded urban wetland, Frenchman's Bay, Lake Ontario, and to distinguish the heavily impacted wetlands in lower Green Bay from the less-impacted marshes in middle and upper Green Bay, Lake Michigan. This was accomplished by using only published fish data without corresponding environmental variables.

Notes: The authors used a wetland fish IBI to distinguish the heavily impacted wetlands in lower Green Bay from the less-impacted marshes in middle and upper Green Bay, Lake Michigan.


Abstract: The wetland fish index (WFI), a published indicator of wetland condition that ranks wetlands based on tolerance of fish species to degraded water-quality conditions, had been developed with data from 40 wetlands located exclusively in the southern portion of the Great Lakes basin (Erie, Ontario, and Michigan). No data had been included from wetlands of the northern Great Lakes (Superior and Huron) and especially those of eastern and northern Georgian Bay, where many wetlands are still unaffected by human activities. We demonstrate why application of the WFI for the lower lakes (WFILower) can yield biased scores when applied to data for upper lakes wetlands. We then develop a basin-wide index to include data from 60 other coastal wetlands located in the northern portion of the basin, including 32 from Georgian Bay. Inclusion of northern sites in development of a basin-wide WFI (WFIBasin) still produced index scores that were positively correlated with water-quality conditions as indicated by water quality index scores. We explain why use of the basin-wide WFI is better than one developed specifically for upper lakes (WFIUpper). Overall, WFIBasin scores were higher in the northern lakes (Superior 3.49, Georgian Bay 3.67, Huron 3.62) than in the southern lakes (Michigan 3.33, Erie 3.12, Ontario 3.09). WFI scores are only minimally affected by inter-annual variation, which allows for its use for long-term monitoring. We recommend that the WFIBasin be used when managers need to manage at a scale across the entire Great Lakes basin.
The authors demonstrate why application of the wetland fish index for the lower lakes can yield biased scores when applied to data for upper lakes wetlands. They then develop a basin-wide index to include data from 60 other coastal wetlands located in the northern portion of the basin, including 32 from Georgian Bay. Inclusion of northern sites in development of a basin-wide WFI still produced index scores that were positively correlated with water-quality conditions as indicated by water quality index scores.


Abstract: Wetlands between, and within, dune-beach complexes along the south shore of Lake Michigan are strongly affected by ground water. The hydrogeology of the glacial drift aquifer system in a 26 km2 area was investigated to determine the effects of ground water on the hydrology and hydrochemistry of Cowles Bog and its adjacent wetlands. The investigation showed that ground water from intermediate- and regional-scale flow systems discharges to Cowles Bog from confined aquifers that underlie the wetland. These flow systems are recharged in moraines south of the dune-beach complexes. Water from the confined aquifers discharges into the surficial aquifer mainly by upward leakage through a buried till sheet that serves as the confining layer. However, the till sheet is breached below a raised peat mound in Cowles Bog, allowing direct upward discharge from the confined aquifer into the surficial sand, marl, and peat. The shallow ground and wetland water in the area influenced by this leakage is a calcium magnesium bicarbonate type, with low tritium concentrations consistent with mixing of older ground water and more recent precipitation. Ground water and wetland water from surrounding areas are less mineralized and have higher tritium concentrations characteristic of precipitation in the late 1970s. The results of this study suggest that wetlands in complex hydrogeologic settings may be influenced by multiple ground-water flow systems that are affected by geomorphic features, stratigraphic discontinuities, and changes in sediment types. Discharge and recharge zones may both occur in the same wetland. Multidisciplinary studies incorporating hydrological, hydrochemical, geophysical, and sedimentological data are necessary to identify such complexities in wetland hydrology.

Notes: Hydrology of ground water flow in an interdunal wetland in southern MI. Not directly WLF related.


Abstract: Undiked wetlands in Lake Erie experience fluctuating water levels, and diked wetlands are isolated from these natural hydrologic events. Growth and survival of vegetation within the two wetland types is influenced by different water level regimes. Our objective was to report the occurrence and abundance of flora in a 100 ha diked wetland (DW) and an adjacent 100 ha undiked wetland (UW) at Winous Point Shooting Club in southwestern Lake Erie (SWLE) during September 1991. Randomly sampled aquatic macrophytes were identified to species and number of stems was recorded. Water depth and land elevation readings were also made. Forty-six species of aquatic macrophytes were identified in the DW while no plants were found in the UW. The controlled water depth of the DW (28.40 +/- 2.39 [SE] cm) was significantly lower (P < 0.0001, t = 11.95) than the uncontrolled depth in the UW (95.41 +/- 5.07 cm). Although the basin elevation of the DW was higher (P = 0.01) than the elevation of the UW, the mean difference in water depth between the two wetlands was much greater (p < 0.0001) than the mean elevation differences. Thus, higher water levels were primarily responsible for floristic differences between the two wetlands. Because most ecological functions of wetlands are derived from processes requiring aquatic macrophytes, we suggest that unvegetated wetlands, such as undiked wetlands in SWLE, provide few of their potential ecological benefits. We propose that the relative ability of a SWLE wetland to advance landward is the most important factor in determining the need to construct dikes and control water levels for aquatic plant restoration. We generally recommend that dike systems should only be constructed on SWLE wetlands with restricted upland borders.
Notes: Reports the occurrence and abundance of flora between an undiked and a diked wetlands in southwestern ER. Water depth and land elevations were measured. Higher water levels of the late 1980s were primarily responsible for floristic differences between the two wetlands, with eradication of vegetation in the undiked wetland. Water level management in the diked wetland resulted in a diverse and dense flora. The authors propose that the relative ability of a wetland to advance landward is the most important factor in determining the need to construct dikes and control water level for aquatic plant restoration. They generally recommend that dikes should only be used on wetlands with restricted upland borders.

Abstract: We observed extensive mortality (eggs and chicks) of the endangered interior population of the least tern (Sterna antillarum) and threatened piping plover (Charadrius melodus) caused by natural flooding during the 1990 breeding season along the Platte River, Nebraska. Aerial videography of the Platte River before and after the flood revealed a 78% reduction of perennial vegetation on sandbars. The flood scoured vegetation from sandbars and greatly increased the amount of barren sandbar habitat that nesting least terns and piping plovers use. A review of river gauging station data indicated that flooding of the 1990 magnitude or greater can be expected to occur about once every nine years. We recommend a review of the annual operating plans of managed rivers to account for the effects of dam discharges on least terns and piping plovers.

Notes: The authors observed extensive mortality of eggs and chicks of the least tern and piping plover caused by natural flooding along the Platte River, NE. Flooding scoured vegetation from the sand bars that were used as nesting habitat. Not GL related but provides information on frequency and timing of high water events and effects on nesting terns and plovers.

Abstract: The flow between Hamilton Harbour and Cootes Paradise was monitored from April until December 1997 to provide background information for the operation of a fishway in the connecting channel. The flow was highly variable, and changed direction several times each day. Comparison with local meteorological and water level data revealed several interesting features. Outflow events of four hours or greater in duration were typically preceded by winds from the east usually lasting at least six hours. Similarly inflow events longer than 4 hours were typically preceded by westerly winds for at least six hours. There was evidence of diurnal and semi-diurnal flow reversals and of free surface oscillations of Lake Ontario, but not of Helmholtz resonance between Hamilton Harbour and the lake nor of exchange flow resonance between the harbor and Cootes Paradise.

Notes: The author measured flow in a fishway connecting Hamilton Harbor and Cootes Paradise Marsh, ON from April to December 1997. Flow was predominantly bidirectional and characterized by many reversals throughout each day. Flow direction was effected by rainfall events, wind direction, and water levels. There were diurnal and semi-diurnal lake oscillations. Strong, persistent winds are necessary to overcome these oscillations.

No abstract.
Notes: This report focuses on the ecological assessment of European lakes using benthic invertebrates. Includes assessing effects of hydromorphological alterations.


Abstract: A three-year (2001-2003) monitoring effort of 14 northeastern Minnesota lakes was conducted to document relationships between water-level fluctuations and mercury bioaccumulation in young-of-the-year (YOY) yellow perch (*Perca flavescens*) collected in the fall of each year at fixed locations. Six of those lakes are located within or adjacent to Voyageurs National Park and are influenced by dams on the outlets of Rainy and Namakan lakes. One site on Sand Point Lake coincides with a location that has nine years of previous monitoring suitable for addressing the same issue over a longer time frame. Mean mercury concentrations in YOY yellow perch at each sampling location varied significantly from year to year. For the 12-year monitoring site on Sand Point Lake, values ranged from 38 ng gww-1 in 1998 to 200 ng gww-1 in 2001. For the 14-lake study, annual mean concentrations ranged by nearly a factor of 2, on average, for each lake over the three years of record. One likely factor responsible for these wide variations is that annual water-level fluctuations are strongly correlated with mercury levels in YOY perch for both data sets.

Notes: Results are reported from a three-year monitoring effort to document relationships between WLF and Hg bioaccumulation in YOY yellow perch in 14 northeastern MN lakes (inland). Annual WLF are strongly correlated with Hg levels in YOY perch. The mechanisms for this are not entirely understood and the authors encourage further study.


Abstract: Uncertainty about the effects of ongoing natural and anthropogenic changes to Great Lakes ecosystems, such as managed stabilized water levels, coupled with widespread public interest regarding status of wetland birds prompted us to evaluate sensitivity of regional wetland birds to hydrologic changes. We reviewed published literature to determine preferred habitat of 30 wetland birds in the region, emphasizing vegetation required for foraging and nesting during the breeding season. Species were subsequently assigned to one of three risk categories based on association with vegetation types sensitive to water-level stabilization, as well as nesting height above water. Notably, of the bird species designated as low, moderate, and high risk, 25%, 33%, and 63%, respectively, have been regionally declining based on Bird Studies Canada’s Marsh Monitoring Program. This evaluation may be useful to regional biologists, planners, and managers concerned with predicting how particular species might be affected by future hydrologic changes in this and related systems.

Notes: The authors evaluated the sensitivity of eastern GL wetland birds to hydrologic changes, with particular emphasis on managed stabilized water levels. They reviewed published literature to determine habitat preferences of 30 wetland birds. The paper includes a table of foraging and nesting habitats and nest heights of ON wetland birds. Also includes a classification of these species into risk categories, and notes population trends.


Abstract: Stable carbon and nitrogen isotope ratio analyses were used to characterize the primary energy sources and trophic positions of 16 common Lake Superior wave zone invertebrate species. Isotope data from six tributary species that were taxonomically and ecologically matched with common wave zone species revealed broad energetic separation between these similarly structured benthic food webs. Previously published stable isotope data for Lake Superior wetland and pelagic food webs were used to
assess the relative importance of inter-habitat energy flow within the Lake Superior ecosystem. The results of these comparisons indicate that the Lake Superior wave zone is energetically distinct from its tributaries, wetlands, and to a lesser extent from its vast pelagic realm. This information and approach should prove useful in future studies on the bioenergetics of inter-zonal migrants and other species that forage in multiple habitats within the lake and also in revealing energetic connections among terrestrial, riverine, littoral, and pelagic food webs in the coastal ecosystems of Lake Superior.

Notes: The objective of this study was to characterize the primary energy sources and trophic positions of representative benthic invertebrate species from wave zone sites along south-central shoreline of SU. The littoral zone, though small in area, is an important foraging zone for lake trout and whitefish, and many other invertebrate, fish and bird species derive energy from shallow water food webs.


Abstract: The fish community in the littoral areas of eight regulated lakes and five reference lakes in Finland was sampled by electrofishing. No significant effect of winter drawdown on species richness was recorded across lakes. Total fish density for stony bottoms of the regulated and reference lakes averaged 19.3 and 32.7 individuals per 100 m2, respectively, but this difference was not statistically significant. The combined proportion of littoral fish species, including minnow (Phoxinus phoxinus), bullhead (Cottus gobio), alpine bullhead (Cottus poecilopus), nine-spined stickleback (Pungitius pungitius), and stone loach (Barbatula barbatula), supplemented with zoobenthos feeders ruffe (Gymnocephalus cernuus) and young burbot (Lota lota), was much lower in the regulated lakes than in the reference lakes. Besides winter drawdown, other variables, such as nutrient level and lake size, affected the fish community.

Notes: This study sampled the littoral fish community in eight regulated and five reference lakes in Finland. The authors conclude that besides winter drawdown, other variables, such as nutrient level and lake size, affected the fish community. Species richness or total fish density did not show a clear response to winter drawdown WLF. The fish community may not highly vulnerable to winter drawdown.


Abstract: We evaluated the potential of vegetation and sediment habitats in wetlands of the St. Lawrence River for developing a macroinvertebrate bioassessment program with reference conditions. During September 2004, we collected macroinvertebrates in emergent vegetation and sediment in both fluvial sites (reference) and tributary-plume sites (impacted) in waters of the north and south shores of Lake Saint-Pierre (St. Lawrence River). In each habitat, we compared taxa richness, abundance, and community structure of macroinvertebrates between reference and impacted sites, and used multivariate models to relate macroinvertebrate community to environmental conditions. Each habitat was suitable for discriminating reference fluvial sites from impacted tributary-plume sites based on macroinvertebrate communities. In emergent vegetation, macroinvertebrates were dominated by epibenthic fauna such as crustaceans (Gammaridae, Asellidae) and molluscs (Valvatidae) at fluvial sites, and insect larvae (Chironomidae, Caenidae) at tributary-plume sites. In sediment, macroinvertebrates comprised a greater proportion of endobenthic fauna such as Oligochaeta and Sphaeridae. Crustaceans and molluscs were still dominant at fluvial sites and Oligochaeta and Chironomidae at tributary-plume sites. No strong difference was depicted in macroinvertebrate composition between north and south shore water masses. Environmental variables explained a higher proportion of variance in macroinvertebrate community composition in emergent vegetation than in sediment (68% versus 44%). Macroinvertebrate composition in sediment was more related to metal contamination, whereas macroinvertebrate composition in emergent vegetation was related primarily to vegetation type and water quality. Relevance of the study
for bioassessment of macroinvertebrates in the St. Lawrence River using the reference condition approach is discussed.

Notes: The authors evaluated vegetation and sediment habitats in SLR wetlands for developing a macroinvertebrate bioassessment program using reference conditions. Macroinvertebrate composition in sediment was more related to metal contamination, whereas in emergent vegetation it was related to vegetation type and water quality. Not directly related to WLF.

Abstract: The effect of high water on floristic composition and diversity was compared at a diked, managed marsh, and an undiked, unmanaged marsh. Species richness and alpha diversity were determined for Cells A through D at Pipe Creek Wetland (PCW), a restored, managed marsh, and MHD Wetland, an undiked, unmanaged marsh. Both wetlands are located on Sandusky Bay in the western basin in Lake Erie, Ohio. Water levels were unusually high during 1997 when this study was conducted. Thus, the flora of Cells C and D at PCW in 1997 were compared to results from a vegetation survey of these cells conducted in 1994, a low-water year. Values for species richness in 1997 ranged from 25 (Cell A) to 42 (Cell D). Pipe Creek Wetland, and Cell D in particular, had higher species richness than MHD Wetland. Average alpha diversity values in 1997 ranged from 0.95 to 1.34; Cell D had significantly higher alpha diversity than Cell C at PCW and MHD Wetland. Species richness of Cells C and D at PCW declined substantially between 1994 and 1997 and species composition changed considerably. These findings reflect the combined effects of the very different marsh surfaces, hydrologic regimes, and human influences at Pipe Creek and MHD Wetlands. It is suggested that species richness and alpha diversity at Pipe Creek Wetland would be even higher in a low-water year. However, MHD Wetland would not become more diverse if water levels dropped due to the extreme dominance of stress-tolerant, aggressive plant species at MHD.

Notes: A study of floristic composition and diversity under high water conditions in an undiked, unmanaged ER coastal wetland and a diked, biennially drawn-down marsh. Discusses the interaction of invasive species and drawdowns.

No abstract.

Notes: Marsh Monitoring Program (MMP) basin-wide and within-basin summaries for birds and amphibians. Comparisons of coastal and inland bird indices and amphibian indices to mean annual GL water levels are presented.

Abstract: We used Great Lakes hydrologic data and bird monitoring data from the Great Lakes Marsh Monitoring Program from 1995-2002 to: 1) evaluate trends and patterns of annual change in May-July water levels for Lakes Ontario, Erie, and Huron-Michigan, 2) report on trends of relative abundance for birds breeding in Great Lakes coastal marshes, and 3) correlate basin-wide and lake-specific annual indices of bird abundance with Great Lakes water levels. From 1995-2002, average May, June, and July water levels in all lake basins showed some annual variation, but Lakes Erie and Huron-Michigan had identical annual fluctuation patterns and general water level declines. No trend was observed in Lake Ontario water levels over this period. Abundance for five of seven marsh birds in Lake Ontario wetlands showed no temporal trends, whereas abundance of black tern (Chlidonias niger) declined and that of
swamp sparrow (Melospiza georgiana) increased from 1995-2002. In contrast, abundances of American coot (Fulica americana), black tern, common moorhen (Gallinula chloropus), least bittern (Ixobrychus exilis), marsh wren (Cistothorus palustris), pied-billed grebe (Podilymbus podiceps), sora (Porzana carolina), swamp sparrow, and Virginia rail (Rallus limicola) declined within marshes at Lakes Erie and Huron/Michigan from 1995-2002. Annual abundances of several birds we examined showed positive correlations with annual lake level changes in non-regulated Lakes Erie and Huron/Michigan, whereas most birds we examined in Lake Ontario coastal wetlands were not correlated with suppressed water level changes of this lake. Overall, our results suggest that long-term changes and annual water level fluctuations are important abiotic factors affecting abundance of some marsh-dependent birds in Great Lakes coastal marshes. For this reason, wetland bird population monitoring initiatives should consider using methods in sampling protocols, or during data analyses, to account for temporal and spatial components of hydrologic variability that affect wetlands and their avifauna.

Notes: WLF in wetlands maintains diversity and constantly changes plant communities. This study used GL hydrologic data and MMP data to assess trends and annual patterns in coastal marsh breeding birds. Results did not show direct evidence of an effect but do suggest WLF affects distribution of birds if not abundance. Authors emphasize the importance of considering hydrologic conditions when assessing marsh bird communities.


Notes: Marsh Monitoring Program (MMP) amphibian monitoring results. The authors examined amphibian community attribute response to both high water (1995-1998) and low water (1999-2003) periods. Two of the community metrics responded significantly to WL disturbance. The response of the amphibian IBI will be stronger in high water years. Additional analysis to quantify the effect of changing water levels on the coastal wetland amphibian community is recommended.


Notes: Winter muskrat house surveys were used to estimate their abundance in eight tributary wetlands in Upper SLR.

Trebitz, A. S. 2006. Characterizing seiche and tide-driven daily water level fluctuations affecting coastal ecosystems of the Great Lakes. Journal of Great Lakes Research 32:102-116. Abstract: Seiches in the Great Lakes probably play a role similar to that of tides in estuaries in organizing the structure and function of coastal wetlands and embayments, but information needed to test this idea is lacking. Past Great Lakes work has focused on enumerating frequencies of oscillation but without addressing their combined influence. Information on seiche magnitude is sparse and focused on extremes rather than typical levels, and tools that integrate magnitude and frequency components to derive net day-scale effects are lacking. This study uses water level time series to characterize daily fluctuation regimes for 51 stations around the Great Lakes. Distributions of fluctuation magnitude typically had long upper tails, with some level of activity always present. Logarithmic mean daily water level range varied from similar to 4 cm in Lake Ontario to > 20 cm in Lake Erie, with largest values at the ends of lakes and in large bays. Oscillation frequency patterns were spatially variable and had both seiche and tide components. One-half the daily sum of water level increments is a computationally tractable metric of fluctuation intensity that integrates magnitude and frequency. This metric is directly
interpretable as the column of water moved by all seiche and tide modes combined, which when multiplied by an area of interest yields the volume of water involved. Logarithmic mean values for this metric ranged from similar to 10 cm in Lake Ontario to > 50 cm in Lake Erie. Data and tools provided will support future efforts to establish seiche and tide influences on Great Lakes wetlands and embayments.

Notes: This study uses water level time series to characterize daily WLF regimes for 51 stations in coastal wetlands and embayments around the GL. Logarithmic mean daily water level ranged from ~ 4 cm in ON to > 20 cm in ER. Oscillation frequency patterns were spatially variable and had seiche and tide components. The tools and data presented could assist in establishing amounts of seiche- and tide-driven water mixing affecting coastal systems.


Abstract: We present water quality data from 58 coastal wetlands, sampled as part of a larger effort investigating effects of nutrient enrichment and habitat disruption in the Laurentian Great Lakes. Our sampling design selected sites from across a gradient of agricultural intensity within combinations of biogeographic ecoprovince and wetland hydromorphic type and captured a large range in water quality. Levels of total nutrients (N and P), and various measures of particulate concentration, water clarity, and ionic strength were strongly associated with agricultural intensity in the watershed, and could be effectively aggregated into an overall principal component-based water quality descriptor. Lake Erie wetlands had the highest nutrient levels and lowest water clarity, while wetlands in Lakes Superior and Huron had the lowest nutrient levels and clearest water. Lake Ontario wetlands had clearer water than would be expected from their nutrient levels and position on the agricultural intensity gradient. Dissolved oxygen, silica, pH, and dissolved organic carbon (DOC) were independent of agricultural intensity but DOC was responsible for low water clarity in some Lake Superior wetlands. Simple classification by hydromorphic type (riverine or protected) did not explain water quality differences among wetlands exposed to similar agricultural intensity levels, so finer hydrologic classification may be desirable. Results are used as a basis for discussing research and information needs underlying development of water quality criteria and monitoring programs for coastal wetlands of the Great Lakes.

Notes: Water quality data from GL coastal wetlands were compared with hydrogeomorphic type, biogeographic province, and a wide range of water quality parameters. This paper relates to WLF somewhat in that hydrogeomorphic type did not explain differences seen in water quality among wetlands experiencing the same agricultural stressors. The authors suggest that a finer hydrologic classification may be desirable.


Abstract: Despite the documented importance of hydrodynamics in influencing the structure and function of Great Lakes coastal wetlands, systematic assessments of coastal wetland hydrology are lacking. This paper addresses this gap by describing patterns in lake and tributary inputs, water residence times, and mixing regimes for a suite of western Lake Superior wetlands that differ in the amount of tributary and seiche flow they receive. We show that variability in tributary flows among wetlands and over time is far greater than variability in seiche-driven water movements, and that the amount of tributary flow strongly influences wetland hydrology via effects on water mixing and residence times, seiche size, mouth closures, and relative amounts of main and off-channel areas. Wetland seiche amplitudes were reduced in systems with small mouth openings and wetland mouth size was correlated with tributary flow. All wetlands experienced seiche-driven water level oscillations, but there was lake water intrusion only into
those wetlands where tributary outflow was small relative to the seiche-driven inflow. Wetlands in settings exposed to long-shore sediment transport exhibited periodic mouth closures when stream flows were low. The absolute and relative size of lake and tributary inputs must be explicitly considered in addition to wetland morphology and landscape setting in studies seeking to understand determinants of coastal wetland structure, function, and response to anthropogenic stressors.

Notes: This paper characterizes the hydrodynamics of a suite of river-influenced SU coastal wetlands. Data are presented describing typical patterns in lake and tributary inputs and showing how they interact with wetland morphology and landscape setting to determine water movements, mixing, and residence times. In addition, the relationship between wetland hydrology and coastal wetland classification schemes across the entire GL basin is discussed. Substantial hydrologic variability exists even among wetlands of the same type on the same lake. Their results establish the strong role of tributary flow in determining wetland hydrology not only by influencing flushing rates and water quality but also by influencing the size, opening/closing of the wetland mouth, the location of the lake-wetland mixing zone, and the relative abundance of on and off-channel habitats. The absolute and relative size of lake and stream inputs determines the role wetlands play at the biogeochemical interface between the GL and their watershed.


Abstract: Despite the recognized importance of wetlands as habitat for fishes and the growing need to assess and manage human impacts on that habitat, there is little information on patterns and variability of habitat within Great Lakes coastal wetlands. Our goal was to describe wetland aquatic habitat patterns and the natural factors that organize them as a step towards developing habitat assessment schemes and identifying experimental design elements for future synoptic surveys. We analyzed data on aquatic vegetation structure, water chemistry, and water movement (inferred from gypsum plug dissolution) in relation to hydrology and morphology in inundated segments of ten relatively un-impacted coastal marshes of western Lake Superior. Spatial differences in aquatic habitat within wetlands were as large or larger than differences among wetlands, and habitat patterns were strongly associated with morphology and hydrology. Back-bay segments tended to have greater vegetation cover and structural complexity and lower levels of water movement, and they were prone to high water temperatures and low dissolved oxygen levels in wetlands having little seiche activity. Increasing seiche inputs tended to homogenize habitat elements among wetland segments, while increasing tributary inputs tended to increase spatial variability. Patterns in emergent vegetation differed from patterns in submerged/floatig vegetation, and different assessment metrics may be needed for different plant zones. Segment-scale sampling schemes like those used in this study have the potential to elucidate habitat patterns within inundated portions of wetlands with a reasonable level of effort. Human impacts on coastal wetland fish habitat must be interpreted in the context of natural spatial heterogeneity as structured by wetland morphology and magnitude of seiche and tributary inputs.

Notes: This paper describes wetland aquatic habitat patterns and the natural factors that organize them as a step towards developing habitat assessments and surveys. They analyze data on aquatic vegetation structure, water chemistry, and movement in relation to hydrology and morphology in 10 SU coastal wetlands, focusing on the inundated, herbaceous vegetation that provide habitat for GL fishes. Within- and among-wetland patterns and variability in water depth, movement and chemistry, and aquatic plant structure are strongly related to water inputs (seiches and tributaries) and morphology.


Abstract: We use data from inundated-area surveys of 58 coastal wetlands spanning a gradient of
anthropogenic impacts across all five Laurentian Great Lakes to describe the distribution of nine exotic and invasive taxa of aquatic plants. We found plants that were exotic or have invasive strains to be substantially more prevalent in wetlands in Lakes Erie and Ontario than in Lakes Superior and Huron, with Lake Michigan wetlands intermediate. Najas minor (slender naiad), Butomus umbellatus (flowering rush), and Hydrocharis morsus-ranae (European frogbit) were restricted to the lower lakes and rarely dominant. Myriophyllum spicatum (Eurasian milfoil), Potamogeton crispus (curly pondweed), Lythrum salicaria (purple loosestrife), Phalaris arundinacea (reed canary grass), Phragmites australis (common reed), and Typha sp. (cattail) were more widespread and except for P. crispus, often among the dominant taxa. None of the submerged or floating-leaf exotic taxa were associated with altered total plant cover or richness, although M. spicatum, P. crispus, and native Stuckenia pectinatus (sago pondweed) were positively associated with agricultural intensity in the watershed (a surrogate for nutrient loading). Emergent P. australis, L. salicaria, and Typha were more likely to be present and dominant as agricultural intensity increased, and were associated with elevated emergent cover and decreased emergent genera richness. Effects of dominant taxa on plant cover and richness were readily detected using ordinal data from 100 m inundated segments but were harder to discern with data aggregated to the wetland scale. The sum of shoreline-wide abundance scores for four easily identified taxa (S. pectinata, P. australis, Typha, and L. salicaria) is proposed as a rapidly-measured indicator of anthropogenic disturbance across the Great Lakes.

Notes: The authors used data from 58 coastal wetland surveys spanning a range of anthropogenic disturbance across all GL to describe the distribution of exotic and invasive aquatic plants. Not directly related to WLF.


Abstract: Great Lakes coastal wetlands are subject to water level fluctuations that promote the maintenance of coastal wetlands. Point an Sauble, a Green Bay coastal wetland, was an open water lagoon as of 1999, but became entirely vegetated as Lake Michigan experienced a prolonged period of below-average water levels. Repeat visits in 2001 and 2004 documented a dramatic change in emergent wetland vegetation communities. In 2001 non-native Phragmites and Typha were present but their cover was sparse; in 2004 half of the transect was covered by a 3 m tall, invasive Phragmites and non-native Typha community. Percent similarity between plant species present in 2001 versus 2004 was approximately 19% (Jaccard's coefficient), indicating dramatic changes in species composition that took place in only 3 years. The height of the dominant herbaceous plants and coverage by invasive species were significantly higher in 2004 than they were in 2001. However, floristic quality index and coefficient of conservatism were greater in 2004 than 2001. Cover by plant litter did not differ between 2001 and 2004. The prolonged period of below-average water levels between 1999 and early 2004 exposed unvegetated lagoon bottoms as mud flats, which provided substrate for new plant colonization and created conditions conducive to colonization by invasive taxa. PCR/RFLP analysis revealed that Phragmites from Point au Sauble belongs to the more aggressive, introduced genotype. It displaces native vegetation and is tolerant of a wide range of water depth. Therefore it may disrupt the natural cycles of vegetation replacement that occur under native plant communities in healthy Great Lakes coastal wetlands.

Notes: Documents the rapid change in wetland vegetation of a Green Bay (MI) lagoon over a 3-year period of low water, and the subsequent rapid invasion of Phragmites. The authors compare the vegetation structure and community composition before and after the invasion. Other wetlands within the MI-HU system did not experience such an extensive Phragmites invasion, and the authors suggest this may be because the Au Sable wetland is a lagoon and not subject to wave action. Au Sable also has more silty substrates where other wetlands have organic substrates.

Abstract: The relative importance of Great Lake, ecoregion, wetland type, and plant zonation in structuring fish community composition was determined for 61 Great Lakes coastal wetlands sampled in 2002. These wetlands, from all five Great Lakes, spanned nine ecoregions and four wetland types (open lacustrine, protected lacustrine, barrier-beach, and drowned river mouth). Fish were sampled with fyke nets, and physical and chemical parameters were determined for inundated plant zones in each wetland. Land use/cover was calculated for 1- and 20-km buffers from digitized imagery. Fish community composition within and among wetlands was compared using correspondence analyses, detrended correspondence analyses, and non-metric multidimensional scaling. Within-site plant zonation was the single most important variable structuring fish communities regardless of lake, ecoregion, or wetland type. Fish community composition correlated with chemical/physical and land use/cover variables. Fish community composition shifted with nutrients and adjacent agriculture within vegetation zone. Fish community composition was ordinated from Scirpus, Eleocharis, and Zizania, to Nuphar/Nymphaea, and Pontederia/Sagittaria/Peltandra to Spargainium to Typha. Once the underlying driver in fish community composition was determined to be plant zonation, data were stratified by vegetation type and an IBI was developed for coastal wetlands of the entire Great Lakes basin.

Notes: The authors’ primary objective was to explore relationships of fish populations among GL coastal wetlands. Their secondary goal was to develop a fish-based IBI for wetland ecological health. Not directly related to WLF, but contains information on fish habitat within coastal wetlands.


Abstract: Development of indicators of 'ecosystem health' for the Great Lakes was identified as a major need at the State-of-the-Lakes Ecosystem Conference in 1998, 2000, and 2002. Our goal was to develop an invertebrate-based index of biotic integrity that was robust to water level fluctuations and applied to broad classes of lacustrine wetlands across wave-exposure gradients. Our objectives were to evaluate the performance and test the robustness of our preliminary index (e.g., Burton et al., 1999) at a range of water levels, eliminate any problems with the index of biotic integrity, remove the preliminary status, test the index on similar wetlands of Lake Michigan, and establish stressor:ecological-response relationships. Twenty-two sites, both open- and protected-fringing lacustrine marshes of Lake Huron and Michigan were selected for study. Correspondence analysis and Mann-Whitney U tests were used to test the robustness of existing metrics and search for additional metrics. Wilcoxon Signed Rank tests were used to determine if metrics were responding to inter-annual water level fluctuation. Principal components analysis and Pearson correlations were used to establish stressor:ecological response relationships. Analyses confirmed the utility of most of the metrics suggested in our preliminary index, but we recommended several improvements. With improvements, the index was able to place all sites in a comparable order of disturbance that we placed them a priori based on adjacent landuse/landcover, limnological parameters and observed disturbances. The improved index worked very well from 1998 through 2001 despite the substantial decreases in lake level over this time-period. Analyses of 2001 data collected from similar fringing wetlands along the northern shore of Lake Michigan suggested that the index could also be used for fringing wetlands of northern Lake Michigan. We are confident that our index is ready for implementation as a tool for agencies to use in assessing wetland condition for Lakes Huron and Michigan fringing wetlands.

Notes: The authors evaluated the performance of their macroinvertebrate IBI during WLF and across different classes of lacustrine wetlands across wave exposure gradients in HU and MI coastal wetlands.

Abstract: Many Great Lakes coastal wetlands that remain today have been heavily fragmented by anthropogenic activities. The rate of fragmentation tends to increase during periods of low lake levels, especially in areas of low-gradient bathymetry where wetland area expands substantially and prompts the desire to dredge channels and groom shorelines. We sampled fish and invertebrates, using fyke nets and dipnets respectively, from wetland fragments paired with either areas where wetland vegetation was moved or removed completely. Our concurrent studies showed that removal of vegetation by beach grooming and channel dredging created conduits for pelagic water to infiltrate the marsh and disrupt the ambient chemical/physical conditions. Alterations to both fish and macroinvertebrate communities were also evident where a significant amount of vegetation was removed. However, where only enough vegetation was removed to allow for boat access, impacts on fish communities were generally non-detectable. Mowing seemed to impact fish, but not invertebrates. Our data suggest that wetland fragmentation may have substantial and long lasting effects on wetland biota, but the magnitude of the impact is likely associated with the area of vegetation removed coupled with the potential for pelagic water to penetrate remaining fragments.

Notes: Documents the effect of fragmentation and mowing on invertebrates, fish, and chemical and physical conditions in fringing wetlands of MI and HU. Mowing had little effect on water quality but major impacts on invertebrate density and richness and on fish communities were seen. WLF related in that lower and more stable water levels encourage land owners to mow closer to the water’s edge.


Abstract: We compared the performance of various approaches to determine the distribution and biomass of submerged and emergent aquatic plants in a large fluvial lake. Three empirical models linking local macrophyte biomass to single and multiple environmental variables were applied in a GIS-framework to estimate the spatial distribution and biomass of aquatic macrophytes in Lake St. Pierre, a large (300 km$^2$), shallow (mean depth: 3 m) and complex widening of the St. Lawrence River (Quebec, Canada). The resulting maps and emergent and submerged macrophyte distributions obtained independently by remote sensing and echo sounding techniques were compared to field data collected in 2000. Maps derived from echo sounding, from a biomass versus depth regression and from a four-variable model (i.e. exposure to wind and waves, plant growth form, water depth and transparency) were the most accurate (55-63% overall agreement with field data). Remote sensing techniques were the least accurate for determining underwater macrophyte distribution in Lake St. Pierre due to the limitations of image-based methods for detecting submerged aquatic vegetation in coloured, turbid waters. This study demonstrates that environmental models in combination with GIS can be used to estimate aquatic macrophyte distribution over larger spatial scales and to examine potential change in macrophyte growth form assemblages arising from different environmental conditions.

Notes: The authors used field data to assess the performance of remote sensing, echo sounder data, and three environmental models applied in a GIS-framework to predict the distribution of emergent and submerged macrophytes in a large fluvial lake (SLR).


No abstract.

Notes: Introduction to special issue on WLF in inland lakes.

Abstract: Changes in water levels and development of shorelines are expected to negatively affect coastal marshes. The small-bodied fish assemblage was sampled in the inner marsh vegetation zone in five Les Cheneaux bays with differing levels of development. Observations were made from 1996 to 2004 during which time summer water levels varied from 177.2 m to 176.0 m (chart datum = 176.0 m). Each marsh was sampled for 10 consecutive days in July and August using gangs of five baited commercial minnow traps. Assemblage composition was assayed by species richness, the number of native minnow species, the percentage of selected tolerant fishes (bowfin, Amia calva, mudminnow, Umbra limi, common carp, Cyprinus carpio, and brown bullhead, Amiurus nebulosus), and catch-per-unit-effort (CPUE). There were no consistent relationships between fish assemblage measures and year, water level, annual change in water level, exposure, and water temperature. Fish assemblage measures except CPUE were impacted by the density of building along the shoreline, a measure of development. Impervious surface area was < 4.5% and was not consistently related to fish assemblage measures.

Notes: This study sought to determine if HU WLF and human development affect forage fish assemblages in coastal wetlands. There were no consistent relationships between fish measures and year, water level, exposure, or temperature for all five marshes. However, there were consistent differences among marshes primarily due to the degree of human shoreline development.


Abstract: An approach based on a digital elevation model (DEM) was used to untangle the confounding effects of long-term water-level fluctuations and increasing human population on the cover of emergent vegetation in Cootes Paradise Marsh, a degraded coastal wetland in Lake Ontario, Canada. Data for 20 observations between 1934 and 1993 were used in the analysis. First, we calculated the inundated area based on the DEM, a derived measurement that reflected the bathymetry of the marsh and the mean water level for a particular year. Then Mantel correlations and regression analyses were used to analyze the relationships between emergent cover and corresponding water level, inundated area, and human population, respectively. Results of the simple and partial correlations indicated that areal change of emergent plants was significantly correlated with inundated area after controlling for the effect of water level fluctuation; however, there was no significant correlation between emergent cover and water level after controlling for inundated area. This is an important consideration when multiple sites from the same Great Lake are compared since the same water level may correspond to vastly different inundated areas for different marshes. Changes in emergent cover were also significantly correlated with human population after controlling for water level effects. Altogether, inundated area explained 83.1% of the variation, human population explained 4.2%, and the interaction between population and inundated area explained an additional 4.3% of the remaining variation in areal emergent cover. This indicates that the synergistic effect of high water level (expressed as inundated area) and increased human population induced greater detrimental impact on the emergent plants than did either stressor alone.

Notes: The authors use a DEM approach to untangle the confounding effects of long-term WLF and increasing human populations on emergent vegetation in Cootes Paradise Marsh, ON. The stressors have a synergistic effect on plant distribution. They show that both inundated area and human population size in the region are significant predictors of percent cover of emergent vegetation.

Wei, A., and P. V. Chow-Fraser. 2006. Synergistic impact of water level fluctuation and invasion of Glyceria on Typha in a freshwater marsh of Lake Ontario. Aquatic Botany

Abstract: The effects of multiple stressors on the native Typha marsh community (mainly Typha latifolia) were examined using historical records of water levels, human census population, and field vegetation
maps. Percent cover of the major plant species was estimated in a GIS, and the percent cover of Typha was related to changes in water level, human population growth, and percent cover of exotic Glyceria maxima and invasive Phragmites australis. Water level fluctuation was the major natural disturbance and it alone accounted for 88% of the variation in Typha. After partitioning out the effect of water level, both human population growth and the presence of exotic species were still significantly related to the decline of native Typha. We suggest that multiple stressors interact with each other to influence changes in native Typha community and cause greater detrimental impact. An important implication of our results is that projected water level decline due to climate change may not necessarily favor the restoration of a desirable native marsh because of the presence of other disturbances such as exotic and invasive species and altered nutrient regime.

Notes: The authors examined the effects of multiple stressors on the native Typha community using historical water level data, human population density, and field vegetation maps in Cootes Paradise Marsh, ON. An important implication of their results is that projected water level decline due to climate change may not necessarily favor the restoration of a desirable native marsh because of the presence of other disturbances such as exotic and invasive species and altered nutrient regimes.

Abstract: Wetlands throughout North America have been diminished in quantity and quality because of human activities, and it is therefore important that fishery managers monitor changes in supply of this critical fish habitat. Use of traditional field-based methods to detect and record the change in aquatic vegetation in Great Lakes wetlands is a daunting task because wetlands are extensive and widely distributed along the Great Lakes shoreline. Mapping wetlands for such a large geographic area necessitates the use of remote sensing technology to obtain an accurate inventory of these ecosystems. The objective of this study was to explore the capabilities of using IKONOS satellite imagery to map different types of aquatic vegetation and habitat features in Great Lakes wetlands. We acquired imageries for Fathom Five National Marine Park in Lake Huron and an area of eastern Georgian Bay in 2002 and chose 11 wetlands for habitat mapping with remote sensing software. The comparison of results of the image analysis with reference data indicated that the overall accuracy of mapping was approximately 90%. This suggests that high resolution IKONOS imagery can be used effectively to monitor the change in aquatic vegetation and thus track alterations in fish habitat in Great Lakes coastal marshes.

Notes: The authors’ objective was to explore the capabilities of using IKONOS satellite imagery to map aquatic vegetation types and habitat features in GL wetlands. They chose 11 HU and Georgian Bay wetlands for habitat mapping with remote sensing software. The results show that the overall accuracy of mapping using IKONOS imagery was about 90%. The authors conclude that this method can be used effectively to monitor changes in GL aquatic vegetation.

Abstract: The effect of water-level (WL) fluctuations on both the structure and functioning of coastal marshes is well documented, and in the past, scientists have demonstrated this by relating historical changes in the areal cover of emergent vegetation (EM) of a particular site to corresponding WL data. This approach of relating areal cover to WL cannot be applied to multiple sites from a region experiencing the same WL because in that instance, WL would be a constant and cannot be used as an explanatory variable for emergent cover. In a previous study of Cootes Paradise Marsh, we proposed the use of a digital elevation model (DEM) to examine the effect of WL fluctuations on emergent plant cover over a 60-year period (1934-1993), and found that the inundated area (IA) was a better predictor of emergent cover than WL. However, the transferability of the marsh-inundation model and the related uncertainty has not yet been tested in a distinct geographic region. In the present article, we test the
transferability of the model and develop a regional model of vegetation response to validate the DEM-based method. We confirm the existence of a highly significant relationship between percent IA and percent emergent cover over a large spatial scale in eastern Lake Ontario. Additionally, we showed that this general relationship might be modified by the degree of urbanization in wetland watersheds. Our results suggest that this DEM-based approach is useful for predicting the aggregate response of EM to annual WL fluctuations and is transferable from local to regional scales.

Notes: The authors developed a regional model (Cootes Paradise Marsh, ON) of vegetation response to validate the DEM-based method of examining the effect of WLF on emergent plant cover over a 60 yr period. They found that the inundated area was a better predictor of emergent cover than WL. Their results suggest the DEM-based approach will be useful in predicting the response of emergent vegetation to annual WLF.


Abstract: In this paper, we used assembled fish distributions (over 9500 field observations) and correlated them with 11 categories of the Great Lakes shoreline (i.e., bedrock, bluff, coarse beach, sandy beach - dune, sandy-silty bank, clay bank, low riverine - coastal plain, composite, wetland, artificial, and unclassified) to validate the appropriateness of classifying Great Lakes fishes into three species complexes (taxocenes) that account for differences in their dependence on shoreline features. A chi² goodness-of-fit test with Bonferroni correction indicated a significant positive association between the presence of fish and three shoreline classes: wetland, sandy beach - dune, and bluff. The Dutilleul modified t test was used to quantify the correlation between wetlands and distribution of the 25 most abundant species and those of different functional groupings. Our results confirm that (i) the Great Lakes fish community utilizes certain shoreline features (especially wetlands) disproportionately to their availability, (ii) the distribution of wetland-associated taxa is influenced by wetland type (i.e., protected embayment versus open-shoreline wetland), and (iii) the preferred utilization of coastal wetlands by a majority of the fish community is consistent across geographical scales, from the local site to the entire Great Lakes shoreline.

Notes: The authors validate the appropriateness of the fish distribution scheme of Jude and Pappas (1992) using an independent data set that includes information from all five GL. They determined whether or not fish of different species or taxocenes use wetlands in proportion to the availability of other shoreline features in order to provide guidance to managers on which shoreline features to restore, preserve, or conserve. The GL fish community utilizes wetlands disproportionally to their availability. Not directly WLF related but does emphasize the importance of coastal wetlands to GL fish communities.


Abstract: The ability to predict the composition of communities from environmental factors is a central goal of community ecology. We carefully selected a pool of species and subjected it to a range of environmental factors to determine which factors were able to filter out subsets of species. We began with a pool of 20 species and sowed them into 120 wetland microcosms representing 24 different habitat treatments and monitored them for 5 yrs. The treatments were fertility, water depth, fluctuations in water depth, soil texture, leaf litter, length of the initial growing season, and invasion by Typha. After 5 yrs 14 species persisted; no rare species survived. The experimental communities differed from random expectation and were assembled by rules that constrained their organization. There were strong and consistent effects of fertility, water level and leaf litter on community composition. Community assembly was modeled as a series of environmental filters. Some aspects of assembly were deterministic; trajectories were constrained within two ‘pathway basins’ and species rank abundances were
significantly concordant within treatments. Other factors indicated that assembly has a strong stochastic component: 50% of species were present only occasionally and we cannot accurately predict species ranks. Community stochasticity did not show any clear patterns among treatments.

Notes: The authors present result from a five-year long wetland microcosm experiment. They began with a pool of 20 wetland plant species and sowed them into 120 microcosms representing 24 habitat treatments: fertility, water depth, fluctuations in water depth, soil texture, leaf litter, growing season length, and Typha invasion. The strongest community composition effects observed were for fertility, water depth, and leaf litter. A community assembly conceptual model based on the microcosm experiments is shown.


Abstract: Elevation, standing crop, disturbance and soil fertility often emerge from studies of freshwater plant communities as the dominant environmental factors determining both species richness and species composition. Few studies in North America have investigated the relationship between these factors and species abundance (standing crop) and species composition in the context of invasion by Phragmites australis. This study explores the influence of key abiotic and biotic variables on species abundance and composition across three Lake Erie wetlands differing in hydrology and Phragmites abundance in East Harbor, Ohio, USA. Standing crop for 92 species was related to standard sediment analyses, wave exposure, distance to shoreline, elevation, light interference, species density, and Phragmites standing crop in each of 95 1 × 1 m quadrats by using canonical correspondence analysis (CCA). Elevation (Axis I) and Phragmites standing crop-soil fertility (Axis II) explained 35.7 and 26.2%, respectively, of the variation in the species–environment relationships. Wave exposure was not a primary component of the first four canonical axes. Axis I was instrumental in describing species composition, separating wet meadow species from marsh species. Axis II was inversely related to species density for both wet meadow and marsh species. These findings generally support prevailing models describing the distribution of wetland plants along environmental gradients. Two discrepancies were noted, however: (1) species density was highest in the most sheltered sites and (2) wave exposure was directly associated with Phragmites standing crop-soil fertility gradient. The structural integrity of Phragmites stems, topographic heterogeneity and differential responses to anthropogenic disturbance may contribute to departure from prevailing multivariate models. This information has direct implications for local and regional wetland managers.

Notes: This is a descriptive study of three ER wetlands to characterize key abiotic and biotic variables associated with plant species richness and composition, to identify maximum species richness along the dominant environmental and biotic gradients, and to determine the relationship between Phragmites abundance and the dominant gradients. WL and wave exposure were important factors.


Abstract: We created a stochastic habitat-based population model to compare the relative effectiveness of potential conservation strategies to increase the endangered Great Lakes population of piping plovers. Initial model parameters were based on an extensive 14-year dataset obtained by annual studies of breeding pairs in Michigan and 6 years of observations of color-marked individuals. Cumulative persistence probability curves and population trends were compared for scenarios with all possible combinations of the following: (1) empirical, medium and high site specific probabilities of reproductive success and (2) empirical, medium and high numbers of available breeding territories. Sites were also categorized according to land ownership to determine if long-term preservation of publicly owned lands
is sufficient for population recovery under any of the scenarios. Only scenarios in which both reproduction and habitat availability were high and all ownership classes were included resulted in a model population that persisted for 100 years and was likely to reach the US Fish and Wildlife Service current population recovery goal (100 breeding pairs) for Michigan. The model was most sensitive to survival rates of adults and more sensitive to changes in reproductive parameters than to number of breeding sites or territories. Model results suggest that intensive measures to increase productivity alone are not sufficient for population recovery; increases in nesting densities or total number of available territories are also likely necessary. Given uncertainties about nesting densities possible at specific breeding sites, preservation of presently unoccupied habitat throughout the Great Lakes region and management of this habitat to encourage breeding by plovers are recommended. Use of techniques to augment the breeding, population in conjunction with protection of habitat and reproduction may be warranted.

Notes: Using data on GL piping plover populations, the authors created a habitat-based population model to assess the ability of existing breeding habitat to support a viable plover population in Michigan. They also used the model to compare the effectiveness of two potential management strategies: increasing reproductive success and acquiring and restoring habitat. No direct discussion of WLF.


Abstract: The Asian clam Corbicula fluminea, originating from Southeast Asia, was first recorded in Lake Constance in 2003 and developed local mass occurrences afterwards. Effects of harsh winter conditions in 2005/2006 associated with a strongly decreasing water level were studied at three different depths at and below the mean low water level (MLL, MLL - 1 m and MLL - 3 m). Low winter temperatures produced a massive die-off of the C. fluminea population. The mortality of the clams was size class and depth dependent. At the mean low water level (MLL), all clams died because of lying dry. However, at MLL -1 m and at MLL -3 m, mortality was a consequence of water temperatures around 2°C for nearly 3 months. At MLL -3 m, clams >5 mm died later than young clams <5 mm and later than clams of all sizes at MLL -1 m. But in late spring even the clams >5 mm at MLL -3 m were dead and only about 1% of the overall population of C. fluminea survived the winter conditions until spring 2006. Lethal effects of low water temperatures on C. fluminea, which may become effective only after a time lag, were corroborated in an outdoor mesocosm experiment with constant water level and without predation.

Notes: A Lake Constance (Central Europe) study to determine how non-native clam densities are affected by low water temperatures combined with low water levels during winter.


Abstract: Long-term (similar to 20-year) data on water level, water quality and aquatic biota from four remote research areas in the Laurentian Great Lakes region were compiled to reveal patterns of natural water-level fluctuation (WLF) and associated effects on water quality and aquatic communities. Of the 16 natural lakes (no dam impoundment and lowest possible anthropogenic disturbance) yearly amplitude in water level did not exceed 1.27 m (x = 0.26 +/- 0.15 m) and yearly average water levels did not deviate greater than 0.75 m (x = 0.10 +/- 0.11 m) from the long-term mean. Linear and waveform regression analyses revealed a significant (P <= 0.05) decreasing trend in water levels and a 10-year oscillation in WLFs. Similarly, linear regression analysis demonstrated a significant reduction in yearly amplitude WLF over time. Correlation analyses revealed significant correlations with water quality parameters (DOC, Ca2+, Conductivity, pH, SO42-) and WLFs in Boreal Shield research areas. Of the long-term biotic information available (periphyton, macrophytes, macroinvertebrates and fish) only
macròinvertebrates demonstrated a significant relationship with natural WLFs. Species richness followed a unimodal response (P = 0.002, r(2) = 0.66) with richness decreasing in years when water levels were either higher or lower than the long-term mean. The novel results of this study demonstrate patterns in natural WLF and associated correlations with water quality and biota across multiple lakes within the Laurentian Great Lakes region. The results are congruent with the intermediate disturbance hypothesis and have direct implications for reservoir management and climate change modeling.

Notes: The authors compiled long-term (~20 year) data on water levels, water quality, and aquatic biota from small, inland Boreal Shield lakes to reveal patterns of natural WLF and effects on water quality and biota. Only macroinvertebrates showed a significant relationship with natural WLF. Species richness decreased in years when water levels were either higher or lower than the long-term mean. Emphasizes the need for long-term studies across a range of WLF.


Abstract: The areal distribution of the floating-leaf macrophyte *Nelumbo lutea* was mapped for 10 of 18 years between 1977 and 1994 in the Old Woman Creek National Estuarine Research Reserve, a coastal wetland located in Lake Erie's western basin. The areal extent of *N. lutea* in the wetland increased from 2.84 hectares (3%) in 1977 to 19.24 hectares (36%) in 1993. Despite an overall increase in the distribution and abundance of *N. lutea*, individual beds show annual variations in bed coverage and production. Few studies to date have examined the Various factors regulating annual macrophyte population dynamics in Great Lakes coastal wetlands. Water-level fluctuations are generally considered the principal factor affecting change in these plant communities; however, we suggest that specific plant growth characteristics such as bed age and reproduction may play a significant role in explaining the observed changes in *N. lutea* distribution and abundance.

Notes: They use the areal distribution of *Nelumbo lutea* to illustrate the dynamic nature of GL wetland vegetation. They challenge the perception that WLF are the only factor affecting vegetation change. The magnitude of WLF seen during the period of their study did not appear sufficient to account for a decline in bed coverage, nor do WLF coincide with the cyclical pattern of growth. They suggest more quantitative study of the composition and distribution of wetland plant species, as well as analysis of specific factors that regulate growth are needed.


Abstract: Hydrologic disturbance can affect wetland and aquatic macrophyte communities by creating temporal changes in soil moisture or water depth. Such disturbances are natural and help maintain wetland diversity; however, anthropogenic changes in wetland hydrology may have negative effects on wetlands. Since plant communities respond to habitat alterations, observations of plant-community changes may be used to recognize effects of hydrologic disturbances that are otherwise not well understood. A number of plants, including *Typha angustifolia* (narrow-leaf cattail) and *Lythrum salicaria* (purple loosestrife), are recognized as disturbance species; they are often found in roadside ditches, in wetlands that have been partially drained, or in low areas that have been flooded. Other species commonly occur on mudflats exposed by lowering of water levels. In addition, wetland shrubs and trees invade or die as a result of draining or flooding. In more subtle terms, the relative composition of plant communities can change without the addition or loss of species, and zonation patterns may develop or change as a result of altered hydrology. Remote sensing (photointerpretation) and field vegetation studies, coupled with monitoring of water levels, are recommended for gaining an understanding of hydrologic disturbances in wetlands.
Notes: This paper presents site specific examples from the GL of macrophyte changes to identify potential clues for use in investigating anthropogenic hydrologic changes in natural areas. Remote sensing techniques such as photointerpretation, field vegetation studies, and water level monitoring are all important tools needed to monitor effects of anthropogenic hydrologic disturbances.

Abstract: Primary succession of plant communities directed toward a climax is not a typical occurrence in wetlands because these ecological systems are inherently dependent on hydrology, and temporal hydrologic variability often causes reversals or setbacks in succession. Wetlands of the Great Lakes provide good examples for demonstrating the implications of hydrology in driving successional processes and for illustrating potential misinterpretations of apparent successional sequences. Most Great Lakes coastal wetlands follow cyclic patterns in which emergent communities are reduced in area or eliminated by high lake levels and then regenerated from the seed bank during low lake levels. Thus, succession never proceeds for long. Wetlands also develop in ridge and swale terrains in many large embayments of the Great Lakes. These formations contain sequences of wetlands of similar origin but different age that can be several thousand years old, with older wetlands always further from the lake. Analyses of plant communities across a sequence of wetlands at the south end of Lake Michigan showed an apparent successional pattern from submerged to floating to emergent plants as water depth decreased with wetland age. However, paleoecological analyses showed that the observed vegetation changes were driven largely by disturbances associated with increased human settlement in the area. Climate-induced hydrologic changes were also shown to have greater effects on plant-community change than autogenic processes. Other terms, such as zonation, maturation, fluctuations, continuum concept, functional guilds, centrifugal organization, pulse stability, and hump-back models provide additional means of describing organization and changes in vegetation; some of them overlap with succession in describing vegetation processes in Great Lakes wetlands, but each must be used in the proper context with regard to short- and long-term hydrologic variability.

Notes: This paper addresses the applicability of hydrarch succession in GL wetlands with an emphasis on the implications of hydrologic variability. Strongly WLF related.

Abstract: Photointerpretation studies were conducted to evaluate vegetation changes in wetlands of Lake Ontario and the upper St. Lawrence River associated with regulation of water levels since about 1960. The studies used photographs from 16 sites (four each from drowned river mouth, barrier beach, open embayment, and protected embayment wetlands) and spanned a period from the 1950s to 2001 at roughly decadal intervals. Meadow marsh was the most prominent vegetation type in most wetlands in the late 1950s when water levels had declined following high lake levels in the early 1950s. Meadow marsh increased at some sites in the mid-1960s in response to low lake levels and decreased at all sites in the late 1970s following a period of high lake levels. Typha increased at nearly all sites, except wave, exposed open embayments, in the 1970s. Meadow marsh continued to decrease and Typha to increase at most sites during sustained higher take levels through the 1980s, 1990s, and into 2001. Most vegetation changes could be correlated with lake-level changes and with life-history strategies and physiological tolerances to water depth of prominent taxa. Analyses of GIS coverages demonstrated that much of the Typha invasion was landward into meadow marsh, largely by Typha x glauca. Lesser expansion toward open water included both T. x glauca and T. angustifolia. Although many models focus on the seed bank as a key component of vegetative change in wetlands, our results suggest that canopy-dominating, moisture-requiring Typha was able to invade meadow marsh at higher elevations because sustained
higher lake levels allowed it to survive and overtake sedges and grasses that can tolerate periods of drier sod conditions.

Notes: The authors used photo interpretation of images from 16 ON wetland sites that spanned five decades (1950s – 2001) to evaluate vegetation changes. Most vegetation changes could be correlated with lake levels and with life-history strategies and physiological tolerances to water depth. Typha was able to invade meadow marsh at higher elevations because sustained higher lake levels allowed it to survive since it is a better competitor under wetter conditions.


Abstract: Interest by land-management and regulatory agencies in using biological indicators to detect wetland degradation, coupled with ongoing use of this approach to assess water quality in streams, led to the desire to develop and evaluate an index of biotic integrity (IBI) for wetlands that could be used to categorize the level of degradation. We undertook this challenge with data from coastal wetlands of the Great Lakes, which have been degraded by a variety of human disturbances. We studied six barrier beach wetlands in western Lake Superior, six drowned-river-mouth wetlands along the eastern shore of Lake Michigan, and six open shoreline wetlands in Saginaw Bay of Lake Huron. Plant, fish, and invertebrate communities were sampled in each wetland. The resulting data were assessed in various forms against gradients of human disturbance to identify potential metrics that could be used in IBI development. Our results suggested that the metrics proposed as potential components of an IBI for barrier beach wetlands of Lake Superior held promise. The metrics for Lake Michigan drowned-river-mouth wetlands were inconsistent in identifying gradients of disturbance; those for Lake Huron open embayment wetlands were yet more inconsistent. Despite the potential displayed by the Lake Superior results within the year sampled, we concluded that an IBI for use in Great Lakes wetlands would not be valid unless separate scoring ranges were derived for each of several sequences of water-level histories. Variability in lake levels from year to year can produce variability in data and affect the reproducibility of data collected, primarily due to extreme changes in plant communities and the faunal habitat they provide. Substantially different results could be obtained in the same wetland in different years as a result of the response to lake-level change, with no change in the level of human disturbance. Additional problems included limited numbers of comparable sites, potential lack of undisturbed reference sites, and variable effects of different disturbance types. We also evaluated our conclusions with respect to hydrologic variability and other major natural disturbances affecting wetlands in other regions. We concluded that after segregation of wetland types by geographic, geomorphic, and hydrologic features, a functional IBI may be possible for wetlands with relatively stable hydrology. However, an IBI for wetlands with unpredictable yet recurring influences of climate-induced, long-term high water periods, droughts, or drought-related fires or weather-related catastrophic floods or high winds (hurricanes) would also require differing scales of measurement for years that differ in the length of time since the last major natural disturbance. A site-specific, detailed ecological analysis of biological indicators may indeed be of value in determining the quality or status of wetlands, but we recommend that IBI scores not be used unless the scoring ranges are calibrated for the specific hydrologic history pre-dating any sampling year.

Notes: The authors collected data to evaluate the potential success of a GL wetland IBI. After segregation by geographic, geomorphic, and hydrologic features, they concluded that a functional IBI is attainable for wetlands with relatively stable hydrology. The index worked best for identifying a human disturbance gradient in barrier beach wetlands of SU. Results for other wetland types were inconsistent. Wetlands with unpredictable WLF will require differing scales of measurement for years that differ in the length of time since the last major natural disturbance. IBIs should be calibrated for the specific hydrologic history pre-dating any sampling year.

Abstract: The diversity and resultant habitat value of wetland plant communities in the Laurentian Great Lakes are dependent on water-level fluctuations of varying frequency and amplitude. Conceptual models have described the response of vegetation to alternating high and low lake levels, but few quantitative studies have documented the changes that occur. In response to recent concerns over shoreline management activities during an ongoing period of low lake levels in lakes Superior, Michigan, and Huron that began in 1999, we analyzed a quantitative data set from Saginaw Bay of Lake Huron collected from 1988 to 1993 during a previous lake-level decline to provide the needed information on vegetation responses. Transects were established that followed topographic contours with water-level histories that differed across a six-year period, ranging from barely flooded to dewatered for varying numbers of years to never dewatered. Percent cover data from randomly placed quadrats along those transects were analyzed to assess floristic changes over time, document development of distinct plant assemblages, and relate the results to lake-level changes. Ordinations showed that plant assemblages sorted out by transects that reflect differing water-level histories. Distinction of assemblages was maintained for at least three years, although the composition and positioning of those assemblages changed as lake levels changed. We present a model that uses orthogonal axes to plot transects by years out of water against distance above water and sorted those transects in a manner that matched ordination results. The model suggests that vegetation response following dewatering is dependent on both position along the water level/soil moisture gradient and length of time since dewatering. This study provided quantitative evidence that lake-level fluctuations drive vegetative change in Great Lakes wetlands, and it may assist in making decisions regarding shoreline management in areas that historically supported wetlands.

Notes: The authors analyzed a quantitative dataset collected from Saginaw Bay, MI from 1988-1993. Percent cover data ordinations showed that plant assemblages sorted out by transects that reflect differing WL histories. They present a model that sorts by years dewatered against distance above water. The model suggests that vegetation response is dependent on both position along the water level/soil moisture gradient and length of time since dewatering.


Abstract: Summary-In this report, we present recorded and reconstructed (pre-historical) changes in water levels in the Great Lakes, relate them to climate changes of the past, and highlight major water-availability implications for storage, coastal ecosystems, and human activities. 'Water availability,' as conceptualized herein, includes a recognition that water must be available for human and natural uses, but the balancing of how much should be set aside for which use is not discussed. The Great Lakes basin covers a large area of North America. The lakes capture and store great volumes of water that are critical in maintaining human activities and natural ecosystems. Water enters the lakes mostly in the form of precipitation and streamflow. Although flow through the connecting channels is a primary output from the lakes, evaporation is also a major output. Water levels in the lakes vary naturally on timescales that range from hours to millennia; storage of water in the lakes changes at the seasonal to millennial scales in response to lake-level changes. Short-term changes result from storm surges and seiches and do not affect storage. Seasonal changes are driven by differences in net basin supply during the year related to snowmelt, precipitation, and evaporation. Annual to millennial changes are driven by subtle to major climatic changes affecting both precipitation (and resulting streamflow) and evaporation. Rebounding of the Earth's surface in response to loss of the weight of melted glaciers has differentially affected water levels. Rebound rates have not been uniform across the basin, causing the hydrologic outlet of each lake to rise in elevation more rapidly than some parts of the coastlines. The result is a long-term change in lake level with respect to shoreline features that differs from site to site. The reconstructed water-level history of Lake Michigan-Huron over the past 4,700 years shows three major high phases from 2,300 to
Within that record is a quasi-periodic rise and fall of about 160; 40 years in duration and a shorter fluctuation of 32; 6 years that is superimposed on the 160-year fluctuation. Recorded lake-level history from 1860 to the present falls within the longer-term pattern and appears to be a single 160-year quasi-periodic fluctuation. Independent investigations of past climate change in the basin over the long-term period of record confirm that most of these changes in lake level were responses to climatically driven changes in water balance, including lake-level highstands commonly associated with cooler climatic conditions and lows with warm climate periods. The mechanisms underlying these large hydroclimatic anomalies are not clear, but they may be related to internal dynamics of the ocean-atmosphere system or dynamical responses of the ocean-atmosphere system to variability in solar radiation or volcanic activity. The large capacities of the Great Lakes allow them to store great volumes of water. As calculated at chart datum, Lake Superior stores more water (2,900 mi³) than all the other lakes combined (2,539 mi³). Lake Michigan’s storage is 1,180 mi³; Lake Huron’s, 850 mi³; Lake Ontario’s, 393 mi³; and Lake Erie’s, 116 mi³. Seasonal lake-level changes alter storage by as much as 6 mi³ in Lake Superior and as little as 2.1 mi³ in Lake Erie. The extreme high and low lake levels measured in recorded lake-level history have altered storage by as much as 31 mi³ in Lake Michigan-Huron and as little as 9 mi³ in Lake Ontario. Diversions of water into and out of the lakes are very small compared to the total volume of water stored in the lakes. The water level of Lake Superior has been regulated since about 1914 and levels of Lake Ontario since about 1960. The range of Lake Superior water-level fluctuations and storage has not been altered greatly by regulation. However, fluctuations on Lake Ontario have been reduced from 6.6 ft preregulation to 4.3 ft over the past three decades postregulation, and storage changes have been reduced from 9 mi³ to 6 mi³. Regulation affects shoreline property owners and industries that have structures in the flood-hazard zone; they generally desire lower lake levels. Higher lake levels are preferred by recreational boaters and marinas concerned about lake access in shallow areas, as well as by municipal and industrial water-supply facilities concerned about water-intake structures. The shipping industry and hydropower industry prefer increased flow through the connecting channels and lower St. Lawrence River. Regulation of lake levels has created problems for wetlands of Lakes Superior and Ontario. Periodic high lake levels are needed to kill trees, shrubs, and canopy-dominating emergent plants in Great Lakes wetlands, and low water levels following the highs are needed to promote seed germination and growth of a multitude of species. Occasional low water levels are also needed to restrict growth of plants that require very wet conditions, such as cattails, at higher elevations in wetlands that are typically colonized by sedges and grasses. The diversity of wetland plant communities and the habitats they provide for fish and wildlife in Great Lakes wetlands are dependent on water-level fluctuations. The effects of regulation have been most severe in Lake Ontario, where the natural pattern of high and low lake levels has largely been eliminated. As a result, extensive stands of cattails have become established in nearly all wetlands in Lake Ontario, mostly at the expense of the sedge/grass community, and diversity of habitats has been reduced substantially.

Notes: USGS report that presents recorded and reconstructed (pre-historical) changes in water level in the GL, relates them to climate changes of the past, and highlights major water availability implications for storage, coastal ecosystems, and human activities. Summarizes what is currently known about coastal ecosystem responses to WLF.


Abstract: Integrated, GIS-based, wetland predictive models were constructed to assist in predicting 14 the responses of wetland plant communities to proposed new water-level regulation plans for Lake Ontario. The modeling exercise consisted of four major components: 1) building individual site wetland geometric models; 2) constructing generalized wetland geometric models representing specific types of wetlands (rectangle model for drowned river mouth wetlands, half ring model for open embayment wetlands, half ellipse model for protected embayment wetlands, and ellipse model for barrier beach
wetlands); 3) assigning wetland plant profiles to the generalized wetland geometric models that identify associations between past flooding / dewatering events and the regulated water-level changes of a proposed water-level-regulation plan; and 4) predicting relevant proportions of wetland plant communities and the time durations during which they would be affected under proposed regulation plans. Based on this conceptual foundation, the predictive models were constructed using bathymetric and topographic wetland models and technical procedures operating on the platform of ArcGIS. An example of the model processes and outputs for the drowned river mouth wetland model using a test regulation plan illustrates the four components and, when. Compared against other test regulation plans, provided results that met ecological expectations. The model results were also compared to independent data collected by photointerpretation. Although data collections were not directly comparable, the predicted extent of meadow marsh in, years in which photographs were taken was significantly correlated with extent of mapped meadow marsh in all bat barrier beach wetlands. The predictive model for wetland plant communities provided valuable input into International Joint Commission deliberations on new regulation plans and was also incorporated into faunal predictive models used for that purpose.

Notes: The authors constructed integrated, GIS-based wetland predictive models to assist in predicting the responses of wetland plant communities to proposed water-level regulation plans for ON. They present the general approach to the modeling effort, including the input data required, model design, and the process involved in building individual wetland geometric models based on geomorphic type. The development of quantitative relationships between water levels and wetland plant communities, generalized geometric wetland elevation models, and estimates of wetland area provides predictive tools to evaluate water level regulation plans in ON.

Abstract: Previously described models for predicting the percent of Lake Ontario wetlands that would be occupied by sedge/grass-dominated meadow marsh were used to test four proposed new plans for regulation of lake levels and to make comparisons with the current plan and unregulated conditions. The models for drowned river mouth, barrier beach, open embayment, and protected embayment wetlands assessed responses to lake levels that would be generated by each plan under net total supplies modified from those that occurred from1900 to 2000. In years when reduced supplies would allow meadow marsh regeneration, simulated unregulated lake levels produced the most meadow marsh in all wetland geomorphic types; current Plan 1958DD produced the least. Overall predicted percent meadow marsh under the test plans decreased in the order B+, 2007, D+, and A+, and the latter three plans produced rather similar results in many cases. Lower percentages of meadow marsh under some plans were due to insufficient low lake levels that could allow soils to dry and restrict invasion by cattails, as well as lack of periodic high lake levels that could kill invading upland plants. An assessment of seasonal lake level characteristics demonstrated that Plan 2007 would reduce mean winter lake levels by 13 cm or more than Plan B+ and springtime lake levels by more than 10 cm. These seasonal differences could result in less winter habitat for muskrats and reduced access to spring spawning habitats for fish such as northern pike. Our model results provide important information for use in the process of selecting a new regulation plan for Lake Ontario.

Notes: The authors used models for predicting the percent of ON wetlands that would be occupied by sedge/grass-dominated meadow marsh to test four new water-level regulation plans for ON. Their evaluations of model results showed that increases in meadow marsh require periodic high WL followed by a period of several years with low lake levels.

Abstract: Recent expansion of *Phragmites australis* throughout many Great Lakes wetlands has caused concern among resource managers because it is thought to degrade waterfowl habitat and reduce biodiversity. Wetlands at Long Point, Lake Erie, have some of the most important habitats for staging waterfowl and anecdotal evidence suggests that *Phragmites* has been expanding rapidly in some of these wetlands. To make informed management decisions, a better understanding of historical changes in distribution and abundance of this species is needed, as well as the ability to identify which plant species/communities *Phragmites* is replacing. Long Point's wetland communities were digitally mapped from aerial photographs from 1945 to 1999. The aerial extent of *Phragmites* stands was measured by digitizing vegetation boundaries, ground-truthing, and analyzing the data using a GIS. A geometric growth formula was used to determine the intrinsic rate of change of *Phragmites* over time. *Phragmites* abundance fluctuated throughout the period (1945: 4 ha; 1955: 7.7 ha; 1964: 69 ha; 1968: 3.6 ha; 1972: 15.1 ha; 1978: 17.7 ha; 1985: < 4 ha; 1995: 18 ha; 1999: 137 ha), but its abundance increased exponentially between 1995 and 1999 (137 ha; intrinsic rate of growth in area = +0.50/yr). The species/communities that were most often replaced by *Phragmites* between 1995 and 1999 were *Typha* spp. (33.8%), marsh meadow (31%), sedge/grass hummock (10.8%), and other mixed emergents (9.6%). Of 31 stands analyzed within the study area, 28 (90%) were of a non-native strain of *Phragmites australis* (haplotype M) that has been rapidly expanding throughout the Atlantic region of the United States. We suggest that the recent rapid expansion of *Phragmites* at Long Point is the direct result of this exotic invasion, and that it has been facilitated by both declines in Great Lakes water levels and increases in ambient air temperatures; anthropogenic and natural disturbances have possibly also contributed. Given the invasive nature of the exotic genotype, combined with future global warming predictions, *Phragmites* probably will continue to rapidly expand throughout lower Great Lakes coastal wetlands.

Notes: The authors assessed the recent expansion of *Phragmites australis* in ER wetlands. They suggest the recent expansion is the direct result of exotic invasion facilitated by declining WL, increases in air temperatures, and human and natural disturbances. They predict this invasive will continue to expand throughout the lower GL coastal wetlands.


Abstract: The water levels of the Great Lakes fluctuate as much as +/- 1 m from their respective long-range mean elevations in response to changes in climatic conditions. Coastal wetland areas on each Great Lake expand or contract in response to the long-term water level fluctuations. The water level of the St. Marys River, a connecting channel between Lakes Superior and Huron, is largely controlled by the level of Lake Huron. The St. Marys River wetlands expand and contract in a fashion similar to wetlands on the lakes. Data on St. Marys River wetland areas were derived from historical aerial photographs and placed in a geographic information system (GIS) to analyze the effects of water level fluctuations. The GIS was used to measure wetland area changes between the years for which photographic data were available. Use of GIS allowed quantification of wetland area changes, estimation of response rates and description of inter-class transfer dynamics, for five coastal wetland classes influenced by long-term water level fluctuations.

Notes: The authors used GIS to analyze WLF effects along the St Marys River, connecting SU and HU. This allowed quantification of wetland area changes, estimation of response rates, and a description of inter-class transfer dynamics for five coastal wetland classes.


Abstract: This article provides an overview on the status of remote sensing and geographical information system (GIS) applications in developing landscape-level environmental indicators for estuarine
ecosystem assessment. These broadscape indicators are related to near-shore water quality, submergent aquatic vegetation, coastal wetlands, as well as watershed landscape structure and pattern. Slightly different from other general reviews, this paper focuses more on the contributions included in this Special Issue that highlight the remote sensing and GIS research conducted by scientists from the US EPA EaGLe (Estuarine and Great Lakes) program. Following on from the content of this special issue, some future research priorities are identified which may be particularly useful to meet the needs of estuarine researchers and resource managers. Finally, the research needs and major challenges for integrated assessment of an estuarine ecosystem by using remote sensing and GIS are discussed.

Notes: The author provides an overview of recent GIS and remote sensing developments for estuarine ecosystem analysis. The primary focus of this work is on the U.S. EPA Estuarine and Great Lakes indicators program, which developed landscape-level ecosystem indicators for estuaries. The author discusses the use of remote sensing data to assess estuarine water quality, SAV mapping, coastal wetland mapping, and landscape structure and pattern characterization.


Abstract: Diatom assemblages in surface sediment samples in depth profiles from Lake Ontario and from East Lake, a shoreline lake, were analyzed for the purpose of describing the relationship between species distribution and water depth. At both sites species composition varied markedly with sample depth. In East Lake a multiple regression of four habitat groups: benthic, epiphytic, tychoplanktonic, and euplanktonic, against water depth (30 cm-8 m) produced a relationship with a standard error (SE) of 1.5 m. An analysis of the ratio of euplanktonic diatoms to periphytic diatoms over a transect from 3 m to 150 m in Lake Ontario produced a multiple regression with an SE of 11.8 m. In another approach, water depth optima for 91 diatom taxa were developed using a weighted averaging (WA) technique. A good correlation (r² > 0.9) was found between measured and inferred water depth over the range 3 m to 30 m using a unimodal WA regression model. The transfer functions offer the possibility of inferring Holocene water level changes in Lake Ontario from fossil diatom assemblages in sediment cores.

Notes: Diatom assemblages in surface sediment samples in depth profiles from ON were analyzed to describe the relationship between species distribution and water depth. Species composition varied markedly with water depth. The transfer functions developed here offer the possibility of inferring Holocene ELF in ON from fossil diatom assemblages in sediment cores.


Abstract: Submerged aquatic vegetation (SAV) distribution and coverage were quantified in two bays of Lake Ontario in 1972, 1980 (1982), and 1999–2002, using a combination of aerial photograph interpretation (API), hydroacoustics, and rake sampling. The three methods gave similar estimates of SAV presence in 2002, supporting our use of API for quantifying SAV changes across decades in bays of a large lake. The SAV coverage in Sodus Bay increased by 5% between 1972 and 1980 and by 35% between 1980 and 1999–2002 whereas the maximum depth of SAV colonization extended from 5.5 to 6.4 m during this period. In Chaumont Bay, the SAV coverage tripled while its maximum depth of occurrence increased from 5.1 to 6.1 m from 1982 to 2002. Although the difference in SAV coverage between 1972 and 1980 was not larger than the difference between consecutive years in the 2000s, the large increase in SAV coverage between the 1980s and 2000s represents a major ecosystem change in these bays. This change was likely caused by increased water clarity in Lake Ontario, which could be associated with the implementation of the Great Lakes Water Quality Agreement (GLWQA) and the dreissenid mussel
invasion. Although other factors such as water level, wave exposure, bottom slope, and sediment nutrients may be important, they have not changed in a fashion that would predict local increases of SAV coverage.

Notes: SAV distribution and coverage were quantified in two ON bays in 1972, 1980, and 1999-2002, using aerial photographs, hydroacoustics, and rake sampling. The three methods gave similar results in 2002, which supported the authors’ use of photo interpretation to quantifying changes across decades in bays of a large lake. The large increase in SAV coverage between 1980 and 2000 was likely caused by an increase in water clarity due to zebra mussel invasion. Though changes in water level, wave exposure, bottom slope, and sediment nutrients may have also occurred, the authors conclude these had not changed in ways conducive to the increase in SAV coverage observed.