Lake Level Fluctuations in Wisconsin

Catherine Hein
The Natural Flow Regime

A paradigm for river conservation and restoration

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1997 BioScience
Lake Levels Fluctuate Too

Robertson et al. 2009 USGS Report 2009–5077
Natural Lake Level Regime

modified from McGrail et al. 1998
Lake Ecology & Management

- Recreation
- Navigation
- Water quality
- Habitat
- Biological Community
- Fisheries
Long-term lake level records are sparse compared to streams.

Lake Staff Gauge

Daily Streamflow Data

Stream Gauging Station
Future for Lake Level Research & Management

- Expand Lake Level Monitoring
- Develop Lake Level Models
- Define Natural Lake Level Regime

Impacts:
- Physical
- Chemical
- Biological

Set Management Targets

Regulatory policies for water quantity
Volunteer Lake Level Monitoring
Future for Lake Level Research & Management

Expand Lake Level Monitoring

Develop Lake Level Models

Define Natural Lake Level Regime

Impacts:
- Physical
- Chemical
- Biological

Set Management Targets

Regulatory policies for water quantity
Understand how groundwater and climate influence water level fluctuations in Wisconsin’s seepage lakes

Collaborators:
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Bob Smail, Matt Diebel, Andrew Rypel (WDNR)
Paul Juckem, Jordan Read (USGS)

Funding: State of Wisconsin Joint Solicitation for Groundwater Research
Coherent, near decadal cycle in lake and groundwater levels

Watras et al. 2014 Geophysical Research Letters
Groundwater and Lake Level Database

- ~1000 lakes and ~1000 wells from 1900-2015
- Data published on Environmental Data Initiative
- Eight agencies

![Map of Wisconsin with data points for lakes and wells](image)
Regional patterns in groundwater and lake level coherence
Precipitation best explains north-south divide in water levels

WI Cumulative Deviation from Monthly Mean Precipitation
Prism Data 1895 - 2017
10 yr rolling mean

2010-05

Courtesy of Bob Smail
But regional precipitation patterns change over time.
Empirical Bayesian Hierarchical Model

Lake Level = $\alpha + \beta \cdot \text{Cumulative Deviation from 8-year Rolling Mean Precipitation}$

Seepage lakes with:
- 8+ years of data
- Groundwater withdrawals < 10,000,000 gals/year
- Observed precipitation range $\geq q_{85}-q_{15}$

Discarded seepage lakes with:
- Negative slopes
- Suspect data

Bob Smail, WDNR
State & local empirical models perform well

Long Lake - Waushara

- Local Slope: 2.284

North Lake - Walworth

- Local Slope: 1.849

Cumulative Deviation Precipitation (mm)

Year
Predicting and Understanding Lake Levels

• Precipitation drives seepage lake level fluctuations
• Lake levels can successfully be predicted using the 8-year cumulative deviation in precipitation
• Statewide model approximates lake level fluctuations, but may need to collect lake level data to parameterize local model
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Effects:
- Physical
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Regulatory policies for water quantity
Ecosystem Effects of Lake Level Fluctuations

Water Clarity

Mercury Bioaccumulation

Woody Habitat & Fisheries

Cobble & Rusty Crayfish
Lake levels influence water clarity
Lake levels influence water clarity

Eutrophic: water is more clear at high lake levels
Oligotrophic: water is more clear at low lake levels

Lisi & Hein 2019 L&O
Influence of drought on water clarity

More Clear
- Reduced phosphorus loads
- Reduced shoreline erosion
- Ultraviolet bleaching
- Dimictic, Oligotrophic lake
- Ex. Silver Lake

Less Clear
- Warmer surface water
- Internal nutrient loading
- Concentration of nutrients
- Polymictic, eutrophic lakes
- Ex. Shell Lake, Anvil Lake

Juckem & Robertson 2013 USGS 2013-5181
Mosley 2015 Earth Science Reviews
Lake water sulfate (and pH) now track the water cycle rather than atmospheric deposition.
Higher mercury concentrations in walleye in high water years

Low lake levels decrease available coarse woody habitat and impact fisheries

Lake levels in Little Rock Lake declined by >1.1 m and 76% of coarse woody habitat became inaccessible to fish.
Reduced perch abundance and largemouth bass growth rates

Yellow Perch Abundance

Largemouth Bass Growth

High wood density

Minimum length limit

Low wood density

Gaeta et al. 2014 CJFAS v.71
Recruitment of invasive rusty crayfish reduced when cobble exposed

Sparkling Lake, Vilas County

Courtesy of Tim Kratz
UW North Temperate Lakes
Long Term Ecological Research

3 year lag
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- Impacts: Physical, Chemical, Biological
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- Regulatory policies for water quantity
Example Management Targets

• Species Richness: <15% areal loss in lake area at Historic P50
• Lake Mixing
• Basin Connectivity
• Max vertical extension of Carex: P10 – P75
• Min water depth in Carex during spawning of pike
• Aesthetic: Historic P90
• Water skiing: minimum area > 5 feet deep
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