The Condition of U.S. Lakes and Streams: Findings from the National Aquatic Resource Surveys

Webcast sponsored by EPA’s Watershed Academy

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Instructors:
- Dr. Amina Pollard, Ecologist, Monitoring Branch, U.S. EPA’s Office of Water, Washington, DC
- Dr. John Stoddard, Research Scientist, U.S. EPA’s Office of Research and Development, Corvallis, OR

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Speakers

- **Dr. Amina Pollard**, Ecologist, Monitoring Branch, U.S. EPA’s Office of Water, Washington, DC
- **Dr. John Stoddard**, Research Scientist, U.S. EPA’s Office of Research and Development, Corvallis, OR

Overview of Today’s Webcast

- Overview of the National Aquatic Resource Survey (NARS)
- Key findings of the National Lakes Assessment (NLA) 2012
- Key findings of the National Rivers and Streams Assessment (NRSA) 2008/09
- Findings from a supplemental analysis that found widespread increases in the amount of phosphorus in oligotrophic lakes and streams in the U.S.
The National Aquatic Resource Surveys – An Overview

Presentation Outline

- Background
- NARS Approach
- Accomplishments
- Status
**What is NARS?**

- Series of surveys implemented by EPA and our state and tribal partners addressing 4 waterbody types
- Program to assess all surface waters within the 48 conterminous states
- A cost effective, nationally consistent, regionally relevant means of tracking status and trends
- Program that builds from almost 20 years of research and pilots

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**Purpose of the National Aquatic Resource Surveys**

- Assess biological and recreational condition and change over time
- Document associations between indicators of condition and indicators of stress
- Build/enhance state monitoring and assessment capacity
Why is NARS important?

**Provides national assessments**
- Address gaps in information about the condition of the nation's waters with statistical confidence.
- Reports used as water quality outcome measures of progress tracking protection and restoration nationally.

**Supports national priorities**
- Reports and ancillary analyses support nutrient pollution and habitat protection efforts
- Supplemental analyses show increases in phosphorus in our least impacted rivers/streams and lakes
- Critical data set for identifying and responding to concerns about algal toxins

**Complements state and local monitoring**
- Reports extent of degradation and risk key stressors pose to water quality at national and regional scales.
- State and local monitoring are key to informing local priorities for site specific restoration actions and watershed protection.

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**National Consistency: NARS Approach**

- Randomized design to report on condition of each resource nationally and regionally
  - 1,000 sites in lower 48
- Standard field and lab protocols
- National QA and data management
- Nationally consistent and regionally relevant data interpretation and peer-reviewed reports
Types of Survey Indicators and Measures

**Biological indicators** such as:
- Benthic macroinvertebrates
- Plants
- Fish community

**Public health indicators** such as
- Fish tissue
- Pathogens (e.g., enterococci)
- Microcystins and other algal toxins

Occurrence and extent of key **stressors** such as:
- High levels of nutrients
- Excess sediment
- Physical habitat characteristics (e.g. riparian cover)

May include pertinent **research indicators** such as:
- Sediment enzymes
- Contaminants of emerging concern

Accomplishments

- First ever, nationally consistent assessments of coastal waters, lakes and reservoirs, rivers and streams, and wetlands including information on changes.
- Assessments address ecological and human-health indicators; stressors; and changes over time
- Expanded/strengthened state, tribal and interagency partnerships
Comprehensive, consistent, and statistically-valid assessments

Results:
- Coastal: >35,000 square miles a 40% increase from 2004
- Lakes: >110,000 lakes which substantially increases the assessed acres since 2004
- Rivers/streams: >1.2 million miles more than doubling the assessed miles since 2004
- Wetlands: >60,000,000 acres resulting in a 30 fold increase since 2004

Status

Analysis/Reporting
- NCCA 2015 – Data Analysis getting started

Data Collection/Laboratory Efforts
- NWCA 2016 – Finished field season, samples being processed by labs
- NLA 2017 – Field training is starting in preparation for summer sampling
- NRSA 2018-2019 – Planning and preparations have already begun. Design completed and indicators selected
Acknowledgements

• State and Tribal partners
• Federal partners
  – Fish and Wildlife Service
  – NRCS Soil Survey
  – U.S. Geological Survey
  – National Park Service
  – U.S. Forest Service, Army Corps of Engineers, NOAA
• Academic Institutions
• EPA Office of Research and Development and EPA Regions
Presentation Outline

1. Introduction to the National Lakes Assessment 2012 (NLA)
   - Objectives and design
2. Findings for key indicators
   - Phosphorus, benthic macroinvertebrates, riparian vegetation, microcystin
3. Data and dashboard
National Lakes Assessment 2012

Objectives of the NLA:

– What is the current biological, chemical, physical, and recreational condition of U.S. lakes?

– How is the condition changing over time?

NLA 2012 Assessment Design

• Using a statistically representative process, selects 1,000 lakes, ponds and reservoirs across the conterminous U.S. from the national map of waterbodies (NHDPlusv2)
  ✓ Size: greater than or equal to one hectare
  ✓ Depth: greater than or equal to one meter

• Represents 111,800 lakes across the nation

• Excludes Great Lakes; coastal lakes; treatment, disposal or stock ponds; ephemeral lakes
NLA 2012 Assessment Indicators

- **Water chemistry**
  - Phosphorus, nitrogen, dissolved oxygen, acidification, trophic state

- **Biological assemblages**
  - Benthic macroinvertebrates and zooplankton

- **Physical habitat**
  - Riparian vegetation cover, shallow water habitat, lakeshore disturbance, lake habitat complexity, lake drawdown exposure

- **Recreation**
  - Algal toxins (e.g., microcystin risk and detected), atrazine pesticide screen, chlorophyll a (risk), mercury (methyl and total)
Assessment Benchmarks

Two types of benchmarks were used to determine condition:

1. Nationally-consistent, literature-defined
   Screening benchmarks (WHO for algal toxins)

2. Regionally-relevant, NLA-defined
   Minimally-disturbed condition
   Fixed percentiles define condition designation
   Applied to biological, habitat, and nutrient indicators

Phosphorus (Total)
2012 National Estimates and Change from 2007
Percentage of lakes in each condition category

<table>
<thead>
<tr>
<th>Condition Category</th>
<th>2012 Percentage of Lakes</th>
<th>2007-2012 Change in % Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Disturbed</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Moderately Disturbed</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Least Disturbed</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Not Assessed</td>
<td>No Observed Lakes</td>
<td>N/A</td>
</tr>
</tbody>
</table>

- 40% of the population shows signs of phosphorus pollution; no change in the proportion in most disturbed condition
**Benthic Invertebrates**

*2012 National Estimates and Change from 2007*

**Percentage of lakes in each condition category**

<table>
<thead>
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<th>2012 Percentage of Lakes</th>
<th>2007-2012</th>
<th>Change in % Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Disturbed</td>
<td>31%</td>
<td></td>
<td>-40%</td>
</tr>
<tr>
<td>Moderately Disturbed</td>
<td>26%</td>
<td></td>
<td>-20%</td>
</tr>
<tr>
<td>Least Disturbed</td>
<td>33%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Not Assessed</td>
<td>11%</td>
<td></td>
<td>20%</td>
</tr>
</tbody>
</table>

- 31% of the population is in degraded biological condition; no change in the proportion in most disturbed condition
- Lakes with phosphorus pollution are 2.2 times as likely to have degraded benthic invertebrate communities

**Riparian Vegetation Cover**

*2012 National Estimates and Change from 2007*

**Percentage of lakes in each condition category**

<table>
<thead>
<tr>
<th>Condition Category</th>
<th>2012 Percentage of Lakes</th>
<th>2007-2012</th>
<th>Change in % Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Disturbed</td>
<td>28%</td>
<td></td>
<td>-40%</td>
</tr>
<tr>
<td>Moderately Disturbed</td>
<td>23%</td>
<td></td>
<td>-20%</td>
</tr>
<tr>
<td>Least Disturbed</td>
<td>48%</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Not Assessed*</td>
<td>0%</td>
<td></td>
<td>20%</td>
</tr>
</tbody>
</table>

- 28% of the population is in most disturbed condition; no change in the proportion of the population in most disturbed condition
Microcystin (Detected)
2012 National Estimates and Change from 2007
Percentage of lakes in each condition category

<table>
<thead>
<tr>
<th>Condition Category</th>
<th>2012 Percentage of Lakes</th>
<th>2007-2012 Change in % Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Disturbed*</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Least Disturbed*</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>Not Assessed</td>
<td>1%</td>
<td>N/A</td>
</tr>
</tbody>
</table>

• 39% of the population had detections; statistically-significant increase (+9.5%) in detections
• Although detections are common, concentrations reach WHO risk to recreation levels in 0.7% of the population, which is similar to NLA 2007 findings

Phosphorus (Total)
2012 Estimates and Change from 2007
Percentage of lakes in most disturbed condition – NLA Ecoregions

• Conditions vary across the country
Read, Explore and Analyze

- The NLA report
- Data – including a new file with the “top 50” NLA data elements
- New interactive dashboard for exploring results

For more information on the NLA 2012

National Lakes Assessment:
- https://www.epa.gov/national-aquatic-resource-surveys/nla

Ecoregional Results:

NLA Data Dashboard
- https://nationallakesassessment.epa.gov/
National Rivers and Streams Assessment: 2008/2009 Final Results

Dr. Richard Mitchell
Biologist, Monitoring Branch, U.S. EPA Office of Water
Presentation Outline

• Overview of NRSA 2008/09

• Summary of key findings
  – National and ecoregional results: benthic macroinvertebrates, total nitrogen, total phosphorus
  – Change analysis
  – Relative/Attributable risk

NRSA 2008/2009 Results

• Indicators
  – Biological
    • Benthic macroinvertebrates
    • Fish
  – Chemical
    • Nutrients (total nitrogen and phosphorus)
    • Acidification
    • Salinity
  – Physical Habitat
    • Excess streambed sediments
    • In-stream fish habitat
    • Riparian vegetation cover
    • Riparian disturbance
  – Enterococci
  – Mercury in fish tissue
Sites Sampled for the NRSA 2008/09

Benthic Macroinvertebrates MMI

- 46% of river/stream miles are rated poor for biology
- Similar results in the Eastern Highlands and Plains
- Only 27% of river/stream miles are rated poor for biology in the West
Nationally, 41% of river/stream miles are rated poor for total nitrogen

- Similar results in the Eastern Highlands and Plains
- Only 20% of river/stream miles are rated poor for total nitrogen in the West
• Nationally, 46% of river/stream miles are rated poor for total phosphorus
• Eastern Highlands had the highest percentage (58%) of miles in poor condition, and the West had the lowest percentage (33%)
Ecoregion Total Phosphorus

Comparing Ecoregions by Concentrations (Nitrogen and Phosphorus)

- Total Phosphorus Concentration Distribution (µg/L)
  - Coastal Plains
  - Northern Appalachians
  - Southern Appalachians
  - Northern Plains
  - Southern Plains
  - Temperate Plains
  - Upper Midwest
  - Western Mountains
  - Xeric

- Total Nitrogen Concentration Distribution (µg/L)
  - Coastal Plains
  - Northern Appalachians
  - Southern Appalachians
  - Northern Plains
  - Southern Plains
  - Temperate Plains
  - Upper Midwest
  - Western Mountains
  - Xeric
- Biology showed significant decreases in stream miles rated as good between 2004 and 2008/2009.
- Total phosphorus showed a significant decrease in stream miles rated as good between 2004 and 2008/2009.
- Total nitrogen showed no significant change between 2004 and 2008/2009, either nationally or regionally.

*Statistically significant*
What You Need to Know about Phosphorus

- Phosphorus is a required nutrient for life
- It is generally considered THE limiting nutrient in freshwaters
- Common element in soils and bedrocks, particularly those derived from marine sediments
- It tends to stay put, unless mined (source of most P for fertilizers and industrial use) or eroded
- Movement of phosphorus through the environment is mostly as particulates
- Common anthropogenic sources of phosphorus to freshwaters:
  - Agricultural runoff
  - Stormwater runoff
  - Wastewater runoff

Why do we care? Phosphorus limits algal growth in most freshwaters
Why do we care? Phosphorus limits algal growth in most freshwaters

Lake 226, Experimental Lakes Area – Whole Lake Phosphorus Addition

Lake Erie, 2011
Total Phosphorus in NARS Stream Surveys

2004 median = 26 µg/L

Total Phosphorus (µg/L)

Cumulative Proportion of Stream Length

2000-2004

Total Phosphorus in NARS Stream Surveys

2009 median = 48 µg/L

2004 median = 26 µg/L

Total Phosphorus (µg/L)

Cumulative Proportion of Stream Length

2000-2004

2008-2009
Total Phosphorus in NARS Stream Surveys

- 2004 median = 26 µg/L
- 2009 median = 48 µg/L
- 2014 median = 56 µg/L

Total Phosphorus in NARS Lake Surveys

- 2007 median = 20 µg/L
Total Phosphorus in NARS Lake Surveys

- 2007 median = 20 µg/L
- 2012 median = 37 µg/L

Oligotrophic Systems – Population Estimates
Creation of Reference Site Dataset

Least-Disturbed catchments from each survey:
• < 5% agricultural land use
• < 1.5% urban land use
• < 2 km km⁻² road density
• riparian disturbance index values < 1.25

Focused analysis on re-surveyed (overlap) sites located in catchments that pass all of these criteria

Reference Site Comparisons

Median change = +2.2 µg L⁻¹ yr⁻¹
Reference Site Comparisons

(c) Streams (2008/09 - 2013/14)

Median change = +2.9 µg L⁻¹ yr⁻¹

(b) Lakes (2007 - 2012)

Median change = +1.6 µg L⁻¹ yr⁻¹
Oligotrophic Systems – Detectable Phosphorus

<table>
<thead>
<tr>
<th>Years</th>
<th>Method Detection Limit (MDL) (µg L⁻¹)</th>
<th>% of population&lt;MDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-2004</td>
<td>3.1</td>
<td>10.8%</td>
</tr>
<tr>
<td>2008-2009</td>
<td>5.5</td>
<td>0.4%</td>
</tr>
<tr>
<td>2013-2014</td>
<td>4.0</td>
<td>0.3%</td>
</tr>
<tr>
<td>Lakes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>3.9</td>
<td>7.1%</td>
</tr>
<tr>
<td>2012</td>
<td>2.9</td>
<td>0%</td>
</tr>
</tbody>
</table>

Potential Mechanisms

Possible reasons for phosphorus changes:

- Data Quality
  - One lab analyzed all samples
  - No methods changes in lab or field
  - Quality assurance is extensive and thorough
Potential Mechanisms

Results of Blind Audit Analyses, 2000-2014

Possible reasons for phosphorus changes:

- **Data Quality**
  - One lab analyzed all samples
  - No methods changes in lab or field
  - Quality assurance is extensive and thorough

- **Increases from agricultural/wastewater/stormflow runoff (the classics)**
  - Not consistent with notable increases in reference sites
  - Should increase both N and P (but doesn’t)
Potential Mechanisms

N and P usually very correlated with one another:
Potential Mechanisms

Possible reasons for phosphorus changes:

- **Data Quality**
  - One lab analyzed all samples
  - No methods changes
  - Quality assurance is extensive and thorough

- Increases from agricultural/wastewater/stormflow runoff (the classics)
  - Not consistent with notable increases in reference sites
  - Should increase both N and P (but doesn’t)

- Changes in hydrology
  - Because Total P is associated with particulates, increased flow might explain differences between N and P
  - But . . .
• Quarterly runoff for each HUC8
  Modeled by USGS
• Years, Seasons matched to sampling dates for each overlap sample
• No significant changes in streams
• Small, but significant increase in lakes

Potential Mechanisms

Possible reasons for phosphorus changes:

• Data Quality
  • One lab analyzed all samples
  • No methods changes
  • Quality assurance is extensive and thorough
• Increases from agricultural/wastewater/stormflow runoff (the classics)
  • Not consistent with notable increases in reference sites
  • Should increase both N and P (but doesn’t)
• Changes in hydrology
  • Because Total P is associated with particulates, increased flow might explain differences between N and P
• Forest Dieback, Migratory Birds, Recovery from Acidification
  • All operate at small scales (if at all), not continentally
• Atmospheric Deposition
  • Wet Deposition data very problematic
  • Dry Deposition more likely source of Phosphorus
  • Dust??
Atmospheric deposition of Phosphorus

- Roughly 200 NADP sites collect long-term data on phosphorus in rain
- NADP does not measure Total Phosphorus
- 95% of the 100,000 observations are below detection

Atmospheric deposition of Phosphorus

KS32 (strongest trend)
Atmospheric deposition of Phosphorus

98% of sites had upward slopes
67% of sites had trends with p<0.10 (all positive)
Mean trend = +5.8 µg/L/yr
Median trend = +3.1 µg/L/yr
Translates to ca. 15-30 µg/L over 5 years
Phosphorus deposition in dust?

- Ca\textsuperscript{2+} deposition increasing in the West
- A surrogate for dust deposition?

(from Brahney et al. 2013, Aeolian Research)
• Trends in “low visibility events” in the West
• A surrogate for dust storms?

Conclusions

• Strong evidence that Total P is increasing nationally in both lentic and lotic systems
• Especially evident in reference sites
• Streams with TP < 10µg/L:
  • 25% in 2004
  • 10% in 2009
  • 2% in 2014
• Lakes with TP < 10µg/L:
  • 25% in 2007
  • 7% in 2012
• Likely cause needs to be:
  • Very large in scale (continental)
  • Operating in remote, undeveloped areas (as well as everywhere else)
• Potential mechanisms driven by climate change?:
  • Extreme hydrologic events
  • Atmospheric Deposition (dust?)
Questions?

Speaker Contact Information

**Sarah Lehmann**, Team Leader for NARS, Monitoring Branch, U.S.EPA's Office of Water, Washington, DC
[Lehmann.Sarah@epa.gov](mailto:Lehmann.Sarah@epa.gov)

**Dr. Amina Pollard**, Ecologist, Monitoring Branch, U.S.EPA's Office of Water, Washington, DC
[Pollard.Amina@epa.gov](mailto:Pollard.Amina@epa.gov)

[Mitchell.Richard@epa.gov](mailto:Mitchell.Richard@epa.gov)

**Dr. John Stoddard**, Research Scientist, U.S. EPA's Office of Research and Development, Corvallis, OR
[Stoddard.john@epa.gov](mailto:Stoddard.john@epa.gov)

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You can type each of the attendees names into the PDF and print the certificates.
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