Regional Monitoring Networks (RMNs) **for Lakes**

Jen Stamp

A volunteer, grassroots effort to document current conditions and detect long-term trends at a regional scale

What are RMNs?

The United States Environmental Protection Agency (USEPA) is working with its regional offices, states, tribes and other entities in the Northeast and Midwest to develop Regional Monitoring Networks (RMNs) for freshwater inland lakes. Discussions about forming lake RMNs began in 2015, when participants approached EPA about setting up a network similar to the stream RMNs, which have been successfully implemented in the eastern and midwestern U.S. (USEPA 2016). Participants in the stream RMNs are collecting biological, thermal, hydrologic, water quality and habitat data one or more times a year, for ten or more years, at a set of targeted sites, using regional protocols. The intent is to pool the data at a regional scale, which will enable more robust analyses and allow for detection of widespread patterns that may otherwise be missed at the local level. A lakes RMN would fulfill a similar role. It would help lake programs fill data gaps, achieve greater consistency in the types of data being collected and protocols being used, and build capacity to better utilize emerging technologies like continuous temperature, dissolved oxygen and water level sensors.

Why are RMNs needed?

A major driver behind the RMNs is a lack of long-term data from sites with minimal levels of anthropogenic disturbance (Jackson and Fureder 2006; USEPA 2012). High quality waters are the standard against which other sites are compared. It is critical to document current conditions at these sites and to track whether benchmarks are shifting in response to changing climatic conditions. Changing air temperature and precipitation patterns and extreme weather events are triggering wide-ranging impacts across the U.S. In most U.S. regions, air temperatures are expected to warm, and historically wetter regions (generally the northern and eastern United States) are projected to receive more precipitation with corresponding increases in total runoff/streamflow. The frequency and intensity of heavy precipitation events are also projected to increase (Wuebbles et al. 2017). These changes are occurring at a broad scale that span state and tribal boundaries and affect all lakes, even those in pristine locations. Collecting data to document and better understand how these types of climate-driven changes are affecting waterbodies and interacting with other "traditional" stressors such as land use change will help inform management strategies to enhance the resiliency of aquatic ecosystems to these changes.

Who is driving this effort?

The RMNs are a grassroots effort driven primarily by state and tribal monitoring programs. However, there are participants from other organizations as well. Kellie Merrell from the Vermont Department of Environmental Conservation (VT DEC) has been one of the drivers behind the formation of the Northeast lake RMN. In this era of limited lake monitoring resources, she sees many benefits to working together regionally. "This type of (sentinel) monitoring is a long-term commitment and as such, by collaborating across political boundaries, limnologists are in a position to build more capacity simultaneously while improving their likelihood of detecting trends in time to devise state or region-wide management strategies to restore and maintain the chemical, physical, and biological integrity of lakes. Moreover, a regional lake monitoring network enables one to look for and detect bigger and more widespread patterns related to drivers that would be missed at the local lake management level."

From a tribal perspective, Shane Bowe from the Red Lake Band of Chippewa Indians sees the value in the RMNs as well. "Tribal communities tend to have a closer relationship and higher dependence upon natural resources than neighboring communities and so are disproportionally impacted by changing climatic conditions. This increases our interest in capturing the effects of climate shifts on local resources and implementing adaptation strategies. Tribal resources also have a tendency to be less impacted by anthropogenic influences due to a lower level of development pressure. We feel that tribes are in a unique position to benefit from the increased power of a combined regional data set that would otherwise be impossible to collect on geographically isolated reservations."

Per the request of Merrell, Bowe, and others, Britta Bierwagen from EPA's Office of Research and Development (ORD) has supported development of the RMNs for the last several years. Bierwagen has been able to bring in Tetra Tech's Center for Ecological Sciences to perform analyses that help inform the network design, lead participants through the indicator and protocol selection process, develop guidance and training materials, and assist participants with site selection. EPA regional offices are also an integral part of the RMNs, assisting with coordination, equipment purchase

and development of a Quality Assurance Project Plan (QAPPs).

How are the RMNs structured?

RMNs build on and supplement existing monitoring efforts by state, tribal and volunteer monitoring programs, as well as national programs like the USEPA's National Lakes Assessment (NLA). The lake RMNs also work collaboratively with the Global Lake Ecological Observatory Network (GLEON) to take advantage of GLEON's experience working with continuous sensors and continuous sensor data. What sets the RMNs apart from other lake monitoring efforts is their focus on high frequency data collection over a long duration; collection of thermal and hydrologic data in addition to more "traditional" water quality measures such as water chemistry and biology; and a flexible structure that allows entities to participate at different levels of effort, using regional protocols.

The RMN design was informed by power analyses (USEPA 2016), literature searches and expert elicitation. It calls for sampling at least 30 sites with similar environmental and biological characteristics in each region on an annual basis for 10 or more years, using comparable methods. The number of sites sampled by each participating entity varies (e.g., for stream RMNs, it ranges from 1 to 15). The use of consistent and comparable methods is very important, as different methodologies may introduce biases in analyses and contribute to variability, which reduces the sensitivity of indicators and increases trend detection times. The goal is to maximize the likelihood of detecting changes over as short a time period as possible, while staying within the resource constraints of participating organizations. Another goal is to collect high frequency thermal and hydrologic data (e.g., recorded at 60-minute intervals, year-round) to provide a better understanding of temporal patterns and episodic events that may otherwise be missed with limited numbers of discrete measurements.

What is the status of the Northeast and Midwest lake RMNs?

Implementation is expected to begin over the coming year at limited levels. Participants from both regions are currently working together to finalize selection of indicators, protocols and sites (Figure 1). Proposed "phase one" indicators include water clarity, vertical profile data (temperature and dissolved oxygen), water chemistry, ice cover, and water level. Table 1 contains proposed protocols, which allow for different levels of effort to maximize participation. Protocol documents are currently being written for each indicator. A lake RMN QAPP that encompasses these indicators and protocols is being written as well.

RMN participants can pick and choose the options that fit within their resource constraints and best fit their priorities, as well as the priorities of the larger RMN working groups. Efforts are made to collect as many of the recommended data as possible, using the RMN protocols. The higher the level of effort an entity is able to contribute, the more ways the data can be used. However, only the minimum level of effort is required for participation.

RMN participants have identified total phosphorus (TP) as a top "phase one" priority indicator. A recent analysis of TP data from EPA's National Aquatic Resource Surveys (NARS) showed patterns of increasing TP in streams and lakes nationwide, including oligotrophic lakes in relatively undisturbed catchments (Stoddard et al. 2016). Nutrient data from the RMNs will help lake monitoring programs track and better understand this pattern. Another top "phase one" priority is vertical profile data, which will provide important information about stratification (mixing) patterns. Where feasible, moored arrays of continuous sensors that record temperature and dissolved oxygen data year-round at 60-minute intervals will be deployed at RMN lakes, using guidance from Minnesota's Sentinel Lakes program, the National Park Service Great Lakes Inventory and Monitoring Network (GLKN), and the Red Lake Band of Chippewa Indians. Vertical profile data are high priority because warming

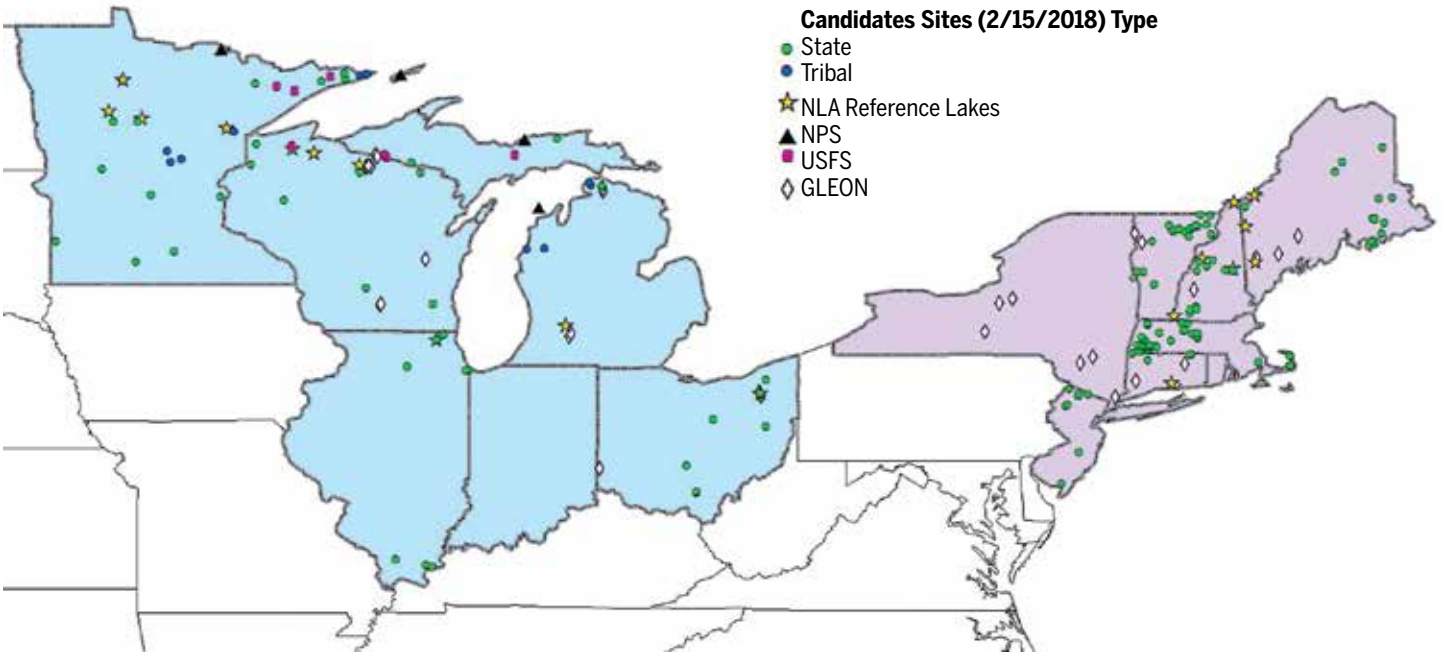

Figure 1. Candidate sites currently being considered for the Northeast and Midwest lake RMNs.

temperatures and earlier ice-out could contribute to an increase in the strength and duration of summer stratification, which would have wide-reaching, cascading effects on lake ecosystems. For example, these changes could contribute to lengthened periods of oxygen depletion in deep water lake habitats, which would negatively affect cold water fisheries (Jacobson et al. 2008). Another potential implication is that bloom-forming cyanobacteria may gain a competitive advantage over other phytoplankton groups, which could contribute to increases in harmful algal blooms (HABs) (Jöhnk et al. 2008; Paerl and Paul 2012).

Biological data are also of high importance to RMN participants but are considered a longer-term ("phase two") pursuit. For many programs, biological protocols for lakes are still in a formative stage, and more work needs to be done to achieve consensus on which are most suitable for this regional effort. The eventual goal is for biological RMN data to contribute to lake biocriteria development, which has lagged behind stream biocriteria in many places in part due to the loss of the Federal Clean Lakes Program (Sec. 314).

What do I do if I want to participate in the RMNs?

RMNs are open to anyone who wants to join. Simply email Britta Bierwagen (Bierwagen.Britta@epa.gov) and she will add you to the contact list and connect you with the RMN lead in your region. If you have candidate lakes in mind, please send those to her as well (with coordinates) so that they can be screened for disturbance and classification purposes.

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Table 1. "Menu" of Options for the Lake RMNs.*

Sampling location	Parameter	Level of participation		
		Minimum	Target	Better
Deep point	Secchi depth	1X/year during late summer (July 24-August 7)	Spring turnover + 3X/year during summer (July 15-Sept 15); one of the 3 visits should occur during the July 24-Aug 7 time period	Monthly during open water season
	Total phosphorus (TP)			Spring turnover + monthly during open water season
	Vertical profile – temperature			Continuous sensors recording year-round at 60-minute intervals
	Vertical profile – DO**			
	Vertical profile – conductivity**			
	Vertical profile – pH**			Monthly during open water season
	Chlorophyll-*a*	1X/year during late summer (July 24-August 7)	3X/year during summer (July 15-Sept 15)	Monthly during open water season
	Other core water chemistry		1X/year during late summer (July 24-August 7)	3X during open water season (one during July 24-August 7)
	Water level (deep water vs. shoreline – see below)***	--	Continuous sensor recording year-round at 60-minute intervals	
Rapid visual lakewide surveys	User perception	1X/year during late summer (July 24-August 7)		
	Shoreline disturbance			
	Aquatic invasives			

Sampling location	Parameter	Level of effort		
		Minimum	Target	Better
Shoreline (at specific location)	Ice cover	Ice out date (within 1 week)	Duration of ice cover (days ice on to ice off)	Daily percent ice cover
	Water level (shoreline)***	Discrete visual reading from staff gage once per month	Discrete visual reading once per week on the same day and at approximately the same time, plus readings within 12 hours to 24 hours of substantive rainfall events	Continuous sensors recording year-round at 30-minute intervals during the open water season
	Photos	1X/year during late summer (July 24-August 7) from the exact same location(s)	Daily (1-2x/day) photos taken year-round from exact same location(s), using time-lapse cameras	Photos taken at higher frequency (more than 1-2x/day), year-round from exact same location(s)

* RMN participants can pick and choose the options that fit within their resource constraints and best fit their priorities, as well as the priorities of the larger RMN working groups. Efforts are made to collect as many of the recommended data as possible, using the RMN protocols. The higher the level of effort an entity is able to contribute, the more ways the data can be used. However, only the minimum level of effort is required for participation.

** Optional – order of priority: DO, conductivity, pH

*** Some entities are obtaining water level measurements from non-vented pressure transducers attached to fixed, moored arrays at the deep point in the lake (in combination with a non-vented pressure transducer installed on land that measure barometric pressure and air temperature). Others obtain them from discrete visual readings from staff gages or reference points along the shoreline, or from continuous sensors installed at or near the shoreline. Either method is acceptable. It is up to the discretion of the participating entity.