Towards Creating a National Reference Wetlands Registry

Establishing a national Reference Wetlands Registry would leverage existing programs by providing broad access to information on reference wetlands around the country. A national registry would help to standardize definitions and data formats across programs, thereby facilitating information-sharing for broader assessments. Such data-sharing is critical for evaluating national and regional trends and policies.

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Local and regional reference wetlands networks have proven to be extremely valuable in supporting wetland assessment, planning, and monitoring (Table 1). By establishing a national Reference Wetlands Registry (RWR), we can leverage existing regional and national programs to provide broad access to information on reference wetlands around the country. Such a registry would facilitate data-sharing that is critical for evaluating national trends and policies. Large-scale assessments across broad (continental-scale) gradients are also important to help understand shifts in wetland conditions associated with impacts such as urban and energy development and climate change. Regions looking to develop or expand reference networks will benefit from being able to look at data and distributions from across the country to inform their decisions.

The use of untreated or undisturbed control sites to compare to treated or disturbed sites has long been a foundational approach in scientific studies, so there is strong logic in using the condition of minimally or least-disturbed wetlands as a benchmark to compare how far disturbed wetlands might have deviated from that "reference" condition. The current use of reference wetlands as an accepted practice in scientific and management endeavors has roots in the steps taken by the U.S. Environmental Protection Agency (EPA) to develop and implement a Wetlands Research Program (Zedler & Kentula 1985; Leibowitz et al. 1992) and the launch of the Environmental Management and Assessment Program (EMAP) (Messer et al. 1991; Leibowitz et al. 1991). During this time period, the U.S. Army Corps of Engineers (the Corps) was searching for efficient ways to assess wetlands with an emphasis on hydrogeomorphic (HGM) characteristics and functions. Mark Brinson pioneered the concepts of reference wetlands (1993a), based on his experience with coastal wetlands and riverine ecosystems, and collaborated with the Corps to create a formalized process for classifying reference wetlands and rapidly assessing their functions (Brinson 1993b; Smith et al. 1995).

We find our collective selves, 25-30 years later, with a prodigious and ever-expanding set of data from reference wetlands from across the nation (Table 1). This is fast becoming a fantastic resource for the intended purposes of monitoring and assessment, but important for many other uses, such as condition assessments at multiple geographic scales, large-scale evaluation of management practices, trends analysis related to tracking further degradation or improvements over time, and resampling sites over longer time intervals to follow patterns of invasive colonization or effects of climate change. Major questions loom before us, however, in our attempts to access and use these disparate sets of data, including:

- *How can we find where these data are collected and stored?*
- *How do we access those data to serve our specific needs?*
- *How do we select the reference sites most appropriate for our desired situation or location?*

We believe establishment of a national RWR is needed and can become a valued way to share information among the many potential users. We envision this registry as a clearinghouse with metadata on what resources are available, who distributes and archives data, and how to access these resources. We offer our recommendations on a way forward.

Reasons for Studying Reference Wetlands

The use of reference sites has become increasingly more common as scientists and resource managers search for reasonably efficient and scientifically based methods to mea-

Table 1. Selected examples of datasets for reference wetlands.

Name	Primary Manager	Years/Number of Sites	Data Available
Federal Programs			
National Wetland Condition Assessment (NWCA)	EPA and partners of NWCA	2011: 1,179 2016: 1,000+	Yes; 2016 data available after collection
	• http://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys		
State-Based Programs			
California Wetlands and Watersheds	California Water Resources Control Board	2003-2013: 650 streams and 100+ wetlands	Yes
	• Data available through EcoAtlas and the California Environmental Data Exchange Network		
Washington State Dept. of Natural Resources, Natural Heritage Program	State agency	~1,000	Yes
	• Vegetation composition summaries; FQA scores, ecological integrity scores, mostly reference standard sites; site locations		
Washington State Dept. of Ecology	State agency	~200	Yes
	• Washington Wetland Rating System metric scores/raw data		
West Virginia Dept. of Natural Resources	State agency	~1,700	Yes, with permission
	• http://www.givd.info/db_details.html?choosen_db=243&choose=Load; http://vegbank.org/vegbank/index.jsp		
Regional Workgroups			
Mid-Atlantic Region	Riparia Reference Wetlands Database	1993-2003: 222 now, 1,000+ anticipated (after data from other states added)	Yes, summary data available
	• http://www.wetlands.psu.edu/products/default.asp		
Nongovernmental Organizations			
NatureServe	32 Natual Heritage Programs	2010: >17,000 (wetland communities)	Yes, with permission
	• NatureServe compiled available reference wetlands from across the NatureServe Network in 2010. Of these, over 17,000 were rated A or B across 32 programs that were able to provide the data at that time (see Faber-Langendoen et al. 2016 this issue).		

sure and describe the inherent variability in natural aquatic systems (e.g., Hughes et al. 1986; Kentula et al. 1992). We use the term reference wetlands to connote naturally occurring sites composed of wetland, stream, riparian, lake, and estuarine components that span a gradient of anthropogenic disturbance. Although reference sites often represent areas of minimal human disturbance (i.e., reference standards in HGM parlance (Smith et al. 1995) or conservation of intact or rare natural communities (Stein et al. 2000)), in many instances, it is more useful to represent a range of environmental conditions across natural and anthropogenic gradients (Karr & Chu 1999; Brooks et al. 2006).

Reference sites provide critical anchors for assessment by allowing conditions at sites of interest to be evaluated against both comparable "minimally impacted" sites (i.e., reference standard sites) and sites with variations across known gradients (i.e., reference network sites). Once established, data from reference wetlands can be used to set the standard by which mitigation and management (e.g., restoration, creation, or enhancement) projects can be designed and evaluated. These benchmarks can also represent a starting point in time for trend analyses (e.g., long-term successional studies or impact analysis on a group of wetlands). Reference sites can serve as alternatives to standard experimental controls, which are seldom available in large-scale field studies. Ideally, reference sites should have long-term accessibility, so temporal data can be collected and analyzed.

Reference standard sites form the core of any reference network. Stoddard et al. (2006) suggested that reference standard sites be defined as minimally disturbed, historical, least-disturbed, or best-attainable condition, and that the choice of how you define reference standard is a critical first step in estimating expectations for future comparisons. Some suggest that the primary criterion for selecting reference sites should be sites that represent ideal, relatively natural conditions represented by minimally disturbed sites or, if not available, sites that can achieve relatively natural conditions through restoration (i.e., reasonably achievable improvements), so that the thresholds are not limited to wetland sites that are extant (Brewer & Menzel 2009). Others consider that, given past and current land use practices, the criteria for reference standard sites should be chosen to represent the best-attainable conditions for a particular region even though they may not be, and rarely can be, considered pristine or minimally disturbed (Smith et al. 1995). This approach has been adopted in the Mid-Atlantic region by several states, in part, because there has been an intentional process among those states to use common approaches and methods (Wardrop et al. 2013).

Given limited human and financial resources, creating a pool of reference wetlands that satisfies multiple objectives is desirable. Scientists and managers should decide jointly upon the acceptable level of analytical compromise they can tolerate versus the advantages of shared data and resources (Faber-Langendoen et al. 2016). Most studies will benefit from some overlap in objectives among sets of reference sites. In addition to reference standard sites, the overall reference network should span several gradients. They should include, at a minimum, the full range of common types of wetlands across natural physiographic and climatic gradients, and the range of conditions from minimally disturbed (ecologically intact) to severely disturbed sites (degraded ecological integrity and functions). This will provide the data necessary to assess and rank the condition for the full range of sites that are being assessed (Brooks et al. 2004, 2013; EPA 2015a, b; Serenbetz 2016). Using reference wetlands from a wide variety of vegetation types, disturbance regimes, and landscape positions allows for characterizing this variability. Sampling and monitoring reference wetlands can range from characterizing large extents of a contiguous wetland (i.e., surveying the entire polygon), to choosing an assessment area within a wetland (Faber-Langendoen et al. 2016). For example, when establishing a set of reference wetlands, Riparia at Penn State typically sampled a representative area of about 0.4 hectare (ha) and the California Rapid Assessment Model uses 1 ha (for depressional wetlands) (Brooks et al. 2013). For recommendations on criteria and procedures for establishing a set of reference wetlands, see Smith et al. (1995) and Brooks et al. (2002, 2013).

Defining Reference Wetlands

Moving toward standardization of nomenclature for reference wetlands, we offer definitions proposed by Brinson (1993b), and used by the Corps (Smith et al. 1995) under his guidance, with minor changes.

- **Reference Wetlands:** Wetland sites that encompass the variability of a *regional wetland type* in a *reference domain*, including representatives of natural or quasi-natural wetlands that either occur presently in the region or occurred there at one time.
- **Reference Standard Wetlands:** The sites within a reference wetland dataset from which reference standards are developed. Among all reference wetlands, reference standard sites are judged by an interdisciplinary team, or other analytical methods, to have the highest level of functioning and/or least-disturbed condition.
- **Reference Domain:** The geographic area from which reference wetlands are selected. A reference domain may or may not include the entire geographic area in which a regional wetland subclass occurs.
- **Regional Wetland Type:** Wetlands within a geographic region that are similar based on hydrogeomorphic, vegetation, or other classification factors, and thus, are likely to provide similar sets of functions, values, and services (e.g., HGM subclass, U.S. National Vegetation Classification groups).

Historic Perspective on Reference Wetlands

In an age when people are bombarded by ever-increasing amounts of information with seemingly less time to reflect on where we are, where we came from, and where we are going, a brief historical synopsis of the concept of reference sites in environmental science and management seems appropriate. Influential environmental thinkers and writers hinted at the reference concept in the past. Henry David Thoreau suggested, ". . . when we experiment in planting forests, we find ourselves at last doing as Nature does. Would it not be well to *consult with Nature in the outset*? (emphasis added) for she is the most extensive and experienced planter of us all. . . ." (Thoreau 1860). Similarly, Aldo Leopold (1934), in discussing prairie restoration near Madison, Wisconsin, stated that, "The time has come for science to busy itself with the earth itself. The first step is to *reconstruct a sample of what we had to begin with* (emphasis added)." Both men sought to examine places deemed to be representative samples of natural ecosystems when seeking to restore or repair damaged environments. In essence, having a place to "reference" brings us to the task of finding, studying, or if necessary, recreating from historical data, a place where natural characteristics and conditions prevail such that we can determine the deviation of damaged sites from reference, or measure the performance of a built or recovering site against the standard of reference.

EPA's first Wetlands Research Plan (Zedler & Kentula 1985) guided the agency's research agenda recommending foci on quantifying water quality functions, assessing cumulative impacts, and evaluating mitigation procedures. The term "reference wetlands" was mentioned only once, with two clear suggestions on how to use them: (1) to compare among least-degraded and severely altered sites (borrowed from concurrent stream studies); and (2) to use natural wetlands as comparators for mitigation projects.

Another EPA initiative, EMAP, was conceived in response to congressional hearings in 1984 on a National Environmental Monitoring and Improvement Act to develop and use indicators to monitor the condition or health of the nation's ecological resources (EPA 1990). Although these concepts were suitable for any ecosystem, EPA's mandate to protect waters based on provisions of the Clean Water Act led them to emphasize aquatic ecosystems. Streams were targeted first (Hughes et al. 1986), although other waters were not far behind (e.g., Brooks & Hughes 1988). A workshop of wetland specialists convened in January 1987 was particularly influential in developing approaches and protocols for understanding and measuring cumulative impacts and wetland condition (Bedford & Preston 1988), also influencing how wetlands would be addressed in EMAP.

Continuing their work, this ad hoc wetlands planning group recognized the need to use different methods when addressing the issue at multiple geographic scales and levels of sampling intensity, and to do this through the use of reference sites. In the second Wetland Research Plan for EPA, Leibowitz et al. (1991) recommended four sampling tiers:

- **Tier 1:** Landscape Characterization (from existing maps or remote-sensing data)
- **Tier 2:** Assessment of Wetland Condition (remote sensing, field sampling)
- **Tier 3:** Detailed Diagnostics
- **Tier 4:** Process Studies (research projects)

EMAP applied this approach at different scales in various pilot studies for key wetland regions in the United States. Others adopted, modified, and applied the tiered approach over time (e.g., Fennessy et al. 2007; Wardrop et al. 2007; Faber-Langendoen et al. 2008). To move this approach toward implementation, several national (Biological Assessment of Wetland Work Group established in 1997) and regional working groups (New England Biological Assessment of Wetlands Work Group established in 1998; Mid-Atlantic Wetlands Work Group established in 2002; and Southeast Wetlands Work Group established in 2009) were formed, the latter three being still active. All considered or promoted the establishment of reference wetlands.

These concepts and approaches became "institutionalized" by EPA for use by states and tribes as described in "Elements of a State Water Monitoring and Assessment Program for Wetlands" (EPA 2006). Many of these efforts were funded by EPA's Wetland Development Grants program. The most common form of these monitoring and assessment approaches, today, utilizes three, interconnected levels. These three levels largely parallel the first three tiers proposed by Leibowitz et al. (1991):

- **Level 1:** Landscape Assessment (using digital geospatial data)
- **Level 2:** Rapid Field Assessments (basic characterization and stressor data)
- **Level 3:** Intensive Field Assessments (detailed characterization data; typically for vegetation, soils, hydrologic indicators, wildlife habitat, and stressors)

Recommendations for a National Reference Wetlands Registry

A national RWR would serve as a spatially attributed clearinghouse for metadata on available reference wetlands information, and would provide a portal to assist users in accessing these resources. A national RWR would help to standardize definitions and data formats across programs thereby facilitating information-sharing for broader assessments. Such data-sharing is critical for evaluating national and regional trends (e.g., impacts from urban and transportation development and climate change) and policies (Corps-EPA mitigation rule, wetland connectivity to other waters). Moreover, it will allow for continental-scale evaluation of trends in wetland condition and will highlight regions of the country with knowledge gaps about wetland conditions. Large-scale assessments across broad gradients will be particularly important to help understand shifts in species distributions and wetland condition associated with climate impacts. Finally, regions looking to develop or expand reference networks will benefit from being able to look at approaches, data, and distributions from across the country to inform their planning and decisions.

The science of data management no longer requires that data be compiled in a central database. Rather, through use of data standards and application programming interface tools, data can reside on local servers and databases and be dynamically linked to a national registry. This maintains local data stewardship and facilitates ongoing updates to ensure current and accurate data availability. Our vision is for a federal agency or other designated institution with proven capability to archive and manage environmental data to be the manager of the RWR.

Participation in the RWR would be encouraged, but voluntary. A standardized, online form would be completed by those wishing to submit a dataset. Once a dataset was established, updates (e.g., new data, new sites, etc.) could be submitted at the discretion of the holder of the data, or their representative. We realize there may be overlap with environmental data on wetlands stored by other entities (e.g., VegBank and Consortium of Universities for the Advancement of Hydrological Science Water Data Center), but having a multivariate set of data tied to individual sites within a reference network would be most convenient for users focused on wetlands.

We anticipate that the primary users, both for adding a data listing and for locating a relevant listing, will be personnel from federal and state agencies, environmental and natural resource organizations, consulting companies, and research institutions. To keep the metadata reasonably current, we suggest that the RWR "guardians" query contributors annually for any changes in status. The kinds of inquiries of the RWR we expect to see from users are:

- Information on gaps in coverage of reference wetlands for specific wetland types at the national or regional scale.
- Queries of available reference data to inform mitigation designs in a geographic region or for a specific wetland type.
- Investigation of the range of characteristics that are common among wetlands of a specific type (e.g., forested slope sites across a geographic region).

Next Steps

To maximize the RWR's utility and impact, the authors will be conducting a survey of potential generators and users of reference wetlands data. We will summarize the results in a future issue of the *National Wetlands Newsletter* and other outlets for wetlands information. In addition, we will engage potential managers of an RWR and discuss the results with them, so that a national RWR becomes a reality as soon as feasible. ■

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