Chapter 11
Monitoring and Assessment of Wetlands: Concepts, Case Studies, and Lessons Learned

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Abstract Monitoring and assessment (M&A) have long been considered critical components of any resource management program where there is a need to evaluate progress and performance over time. Understanding the origins of current monitoring and assessment strategies and techniques for wetlands in the United States provides useful perspectives on how wetlands are both similar and different from other waters and allows us to take advantage of the lessons learned across all aquatic resources. We highlight several knowledge threads that significantly influenced how we approach M&A today, including legal mandates, tools developed to improve the management of resources, and scientific evidence of the utility of M&A informa-

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tion. We describe the role of regional forums in the evolution and development of these tools and in the building of support for their programmatic integration in the Mid-Atlantic Region (MAR). We then tell the story of their use and application at a variety of spatial scales, including site-level mitigation applications in Pennsylvania, watershed application in the Upper Juniata Watershed, regional application in the MAR, and, finally, national application in the National Wetland Condition Assessment (NWCA). We document the lessons learned, and present an example of promising future use of M&A data in the construction of Tiered Aquatic Life Use (TALU) Standards for wetlands.

11.1   Introduction

Monitoring and assessment (M&A) have long been considered critical components of any resource management program where there is a need to evaluate progress and performance over time. A number of major US environmental programs are built on a template of ecosystem-based management, which generally emphasizes four main principles: (1) integration of ecosystem components with resource uses and users, (2) focus on sustainable outcomes, (3) avoidance of deleterious outcomes, and (4) use of an adaptive approach wherein experience leads to more effective management. Within the last decade, the adaptive approach has been developed, articulated, and institutionalized to varying degrees (e.g., Thom 1997, 2000; Thom et al. 2005). Monitoring is foundational to adaptive management, providing measures of management performance and ecosystem response and leading to an increased understanding of the ecosystem and effective management mechanisms. The value of M&A information is recognized in the design of major regulatory frameworks. For example, the Federal Water Pollution Control Act of 1972, Public Law 92–500, commonly referred to as the Clean Water Act (CWA), specifies a need to monitor, compile, analyze, and report on water quality data, broadly defined (CWA§106(e)(1)). Wetlands are included because they are "waters of the U.S." Thus, there is both a management imperative and a legal basis to monitor and assess wetlands at a variety of spatial scales, from watershed to nationwide.

Understanding the origins of current monitoring and assessment strategies and techniques for wetlands in the United States provides useful perspectives on how wetlands are both similar and different from other waters and allows us to take advantage of the lessons learned across all aquatic resources. The threads of M&A approaches for wetlands in vogue today can be traced primarily from policies and activities initiated by the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (Corps) in the late 1980s and early 1990s that stimulated a significant record of applied research by agency and academic scientists. It is not our intent to exhaustively list every individual or organization that contributed to the expansion of our knowledge base on wetlands science, management, and monitoring—there were

many, and we benefited from the many publications and conversations that occurred. Rather, our intent is to illustrate the value and utility of wetland M&A by:

1. Highlighting several knowledge threads and efforts that significantly influenced how M&A is typically approached today
2. Telling the story of their use and application at a variety of spatial scales in the Mid-Atlantic Region (MAR)
3. Documenting the lessons learned
4. Presenting some promising future uses of M&A data

11.2   Initial Knowledge Threads: Establishing a Monitoring Framework

The current framework for monitoring wetlands was initiated as a response to legal mandates for the protection of resources and human health, such as the CWA, and the need to manage resources effectively. As monitoring programs and tools were developed to respond to these needs, the scientific evidence that M&A was worth the effort appeared in various forms and the momentum for M&A began to build in earnest.

11.2.1   Legal Mandates for M&A

Monitoring and assessment are essential for any wetland regulatory program to evaluate the performance of permitting, mitigation, and compensation. Although there are legal mandates and guidance for M&A, agency resources are often depleted prior to the M&A phase.

The CWA of 1972 addresses the need for monitoring in §305(b) and §303(d). States are required to report on the status of their water-related activities with information compiled from M&A data. Progress was initially made with streams and rivers with the intention of adding other waters as methods were devised and tested. States are expected to develop and adopt ten elements that comprise an overall water M&A program (USEPA 2003) because, "Broad-based, integrated *monitoring and assessment* programs inform decision makers, target restoration activities, and help us address significant stressors." (USEPA 2006a, p. 102).

11.2.2   M&A in the Management of Resources

Inability to respond to legal mandates often stimulated development of tools for better management of wetlands. Assessment of cumulative impacts is a case in point.

In 1988, the newly formed Wetlands Research Program of the USEPA, convened a workshop to address the ever-elusive topic of how to measure cumulative impacts to wetlands (Preston and Bedford 1988). The workshop initiated discussions and projects concerning how to address cumulative impacts on a watershed basis, how to measure wetland function and condition, and how to develop measures of biological integrity (Preston and Bedford 1988), which eventually led to progress in state M&A programs.

USEPA's Wetlands Division began a concerted effort to build M&A capacity within state wetlands programs in 2000 by establishing two national priorities: (1) assist states and tribes to develop wetland monitoring programs; and (2) improve the success rate of compensatory wetlands mitigation. Between 2003 and 2006, USEPA developed guidance and adopted the three-tiered approach for monitoring wetlands, urging states and tribes to include ten elements in their programs (USEPA 2006a). The three-tiered approach as described by Brooks et al. (2002), and further refined in USEPA's Elements Letter (USEPA 2006a) has the following components:

- *Landscape assessment* (Level 1) uses remote sensing data and field surveys to inventory wetlands and riparian areas
- *Rapid assessment* (Level 2) uses field diagnostics to assess condition of wetland sites
- *Intensive assessment* (Level 3) provides the quantitative data to validate rapid methods, characterize reference condition, and diagnose the causes of wetland condition observed in Levels 1 and 2

More recently, the EPA's guidance called for four core elements in a successful wetlands program (reduced from ten for operational convenience); i.e., M&A, regulatory activities, restoration and protection, and water quality standards (USEPA 2012). M&A is the first core element and is key to tracking performance of any regulatory or management program. Competitive funding through the Wetland Program Development Grants Program provides incentives (CWA; §104(b)(3)). This source of funding has generated dramatic progress within some regions (e.g., Mid-Atlantic and New England), and in some states (e.g., California, Ohio, and Montana), bringing the nation closer to full implementation of wetlands protection programs.

Yet another thread can be traced back to the late 1980s and a goal to restore wetlands. The need for restoration/creation became apparent from three sources: mitigation of impacts or losses related to permitting activities managed by the Corps through §404 of the CWA; restoration of waters designated as impaired from a water quality perspective; and the recognition that the nation needed to curb the extensive losses of wetlands (e.g., Dahl 2011) and restore what had already been lost or degraded. In 1987, the USEPA called for the establishment of a National Wetlands Policy Forum, which was charged with making recommendations for national policy on the protection of wetlands (NRC 1995). The Forum's central recommendation was revolutionary, calling for "no net loss" and "long term gain" in area and function of wetlands (The Conservation Foundation 1988). The first phrase became policy under the administration of President George H. W. Bush, and has continued under every US President since that time.

Even with policy support, efforts to foster long-term gains in wetland area foundered despite scientific evidence that wetlands mitigation was not at all adequate (e.g., Kusler and Kentula 1990; Kentula et al. 1992; Zedler and Callaway 1999; Gwin et al. 1999). Calls for change continued to ring out, beginning with a National Research Council (NRC) report on restoration of all waters (NRC 1992). Again, in a 2001 report, the NRC indicated that the goal of no net loss of wetland function was not being met due to poor mitigation policy and implementation (NRC 2001). In 2002, an interagency National Wetlands Mitigation Action Plan was released, outlining specific tasks needed to improve the integrity of mitigation wetlands (USACE 2002). To help correct this record of poor mitigation performance, the USEPA and the Corps jointly developed and issued the Mitigation Rule of the CWA (33 C.F.R. Parts 325 and 332 and 40 C.F.R. Part 230) (USEPA 2008). The new rule requires mitigation to be carried out in a landscape context using the best available science, to the extent appropriate and practicable. Under the new rule, states must devise measureable and enforceable standards to be used in assessment of mitigation wetland performance during regular monitoring periods. This guidance recommends using many of the approaches and tools described in this chapter.

11.3 Building Support for M&A at Multiple Scales

By the beginning of the new millennium, the mandate for comprehensive wetlands monitoring and assessment had never been stronger, and a number of technical tools had been developed. However, no integrated, transferable, or scalable approach to M&A had emerged. The primary reason for the diverse collection of M&A methods was that the efforts had not occurred through any one model of funding and/or development. Hydrogeomorphic (HGM) classification and functional assessment models had been primarily regional efforts, under the direction and support of the Corps and the USEPA. Development of biological assessment methods had followed suit. They were composed primarily of regional efforts, funded by various sources, and represented to some degree by the USEPA-supported Biological Assessment of Wetlands Working Group (BAWWG). In contrast, assessment of wetlands in a watershed had been mainly represented by projects in the Nanticoke (Whigham et al. 2007) and Upper Juniata (Wardrop et al. 2007a, b) watersheds, funded by USEPA's Environmental Monitoring and Assessment Program (EMAP). Many smaller efforts had taken place across the country, and both the regional/local focus and spectrum of funding sources had made integration of a comprehensive monitoring and assessment program and its technology transfer difficult, if not impossible.

What emerged from these disparate efforts was a clear need for a forum to facilitate the development and implementation of wetland monitoring strategies. Moreover, the forum could not be effective if it chose to tackle specific monitoring issues on a national basis. The range of wetland types and management issues would dilute such an effort past its point of utility. Such a forum, therefore, needed to address issues on a regional basis. Additional reasons for the formation of a regional

wetlands workgroup, most specifically in the MAR, were also in play. Wetland monitoring protocols to meet CWA requirements needed to be developed as a result of lawsuit settlements in Pennsylvania and Delaware. The lawsuits had illuminated the need for an interstate and interagency effort to determine how wetlands monitoring, and restoration could be integrated (e.g., in the development and implementation of Total Maximum Daily Loads, or TMDLs). The growing presence of volunteer monitoring networks, such as the Pennsylvania Organization for Watersheds and Rivers, needed a designated source of technical expertise. Therefore, the overarching goal became the support of a forum to facilitate the development and implementation of wetland monitoring strategies, including elements of a comprehensive wetland monitoring program that met the needs of the Mid-Atlantic States.

Specific models existed for such a forum. The previously mentioned BAWWG, an *ad hoc* national working group formed by USEPA in mid-1990s, had been established for the technical and feasibility review of biological assessment tools, specifically the development of Indices of Biologic Integrity (IBI) (Karr et al. 1986). The BAWWG met periodically during the late 1990s and early 2000s and was led by Susan Jackson and Doreen Vetter of USEPA. Convening this group brought varied scientific and taxonomic experts to the table to develop biological assessment tools to a point where they could be implemented in monitoring programs. The effectiveness of this forum is evidenced by the publication of the Methods for Evaluating Wetland Condition modules (e.g., USEPA 2002), a series of 14 white papers that provide a blueprint and toolbox for the use of biological assessment tools in M&A programs at a variety of scales. Perhaps a more important outcome from the BAWWG was the growth and development of a network of scientists and managers that understood the goals of wetlands M&A and who, collectively, populated the academic, agency, and consulting landscapes with a series of related approaches to M&A.

Regionalization of the BAWWG approach had been identified as a need by the group. At the first national BAWWG conference held in Orlando, FL, in May of 2001, a consensus was reached as to the need for work in biological assessment to continue, primarily through regionalization of approaches. The reasons stated above spoke to the need for a regional workgroup specifically in the Mid-Atlantic. The New England BAWWG (NEBAWWG) served as an early model for the role of such a group in regional wetland and related aquatic issues.

11.3.1   *Regional Forums for Monitoring and Assessment: The MAWWG Example*

Using the example provided by NEBAWWG, the Mid-Atlantic Wetland Workgroup (MAWWG) was initiated in 2002 with funding provided by USEPA. MAWWG experienced early and immediate success due to a number of factors. Academics and agency personnel from Pennsylvania, Ohio, and Delaware already had strong ties to the national BAWWG and with each other. In addition, EPA-funded M&A projects had already been conducted in Delaware, Maryland, Ohio, Virginia, and Pennsylvania.

The primary objective of the MAWWG was, and still is, to provide a forum to facilitate the development and implementation of wetland monitoring strategies, including elements of a comprehensive wetland monitoring program that met the needs of the Mid-Atlantic States (i.e., wetland monitoring programs to be implemented at the state level). Primary goals for the MAWWG are:

1. Provide the technical support necessary for improved coordination of surface water and wetland monitoring programs, with the eventual long-term incorporation of wetlands into traditional water quality monitoring programs (e.g., CWA § 305(b), 303(d), 319, and 106)
2. Regionalize existing monitoring and assessment tools for wetlands, such as HGM classification and functional assessment and biological assessment
3. Use monitoring and assessment tools to improve restoration and mitigation
4. Provide training for regulatory personnel in monitoring and assessment methods
5. Provide a source of information on monitoring and assessment tools through a workgroup web site

Over its 10 years of existence, the MAWWG membership has been composed of participants from nine states: Delaware, Maryland, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Virginia, and West Virginia. These states represent 9% (~69 million ha) of the nation's contiguous land area and 10% (~4 million ha) of the nation's wetlands (excluding Alaska and Hawaii). The tools and products of both the individual states and the group (MAWWG) are made available through the group's website (http://www.mawwg.psu.edu). The material on the website includes a range of bioassessment and functional assessment tools (including an online calculator for the Floristic Quality Assessment Index (FQAI)), protocols developed at a regional scale for a Mid-Atlantic Wetland Condition Assessment, the results of this assessment, and a reference wetlands database to improve mitigation design and performance. The core states of MAWWG, their representatives, and the various academic and agency partners are presented in Fig. 11.1. The following sections detail how the various tools were developed and successfully deployed at state and regional levels, with the support of MAWWG.

11.3.2   MAWWG and the Implementation of M&A

At its initiation, the MAWWG members had a wide range of experience with incorporation of M&A into regulatory or non-regulatory programs. The motivation for wetland M&A varied across the states. Pennsylvania was anxious to embark on statewide condition assessment monitoring (partially due to a legal mandate discussed previously), while Delaware's approach was directed more towards improving the effectiveness of restoration. Maryland intended to develop water quality standards for wetlands; West Virginia was initiating protection of its highest quality sites; and Virginia's need for support of permitting decisions was becoming critical. Each of these purposes required unique information on the status of the resource
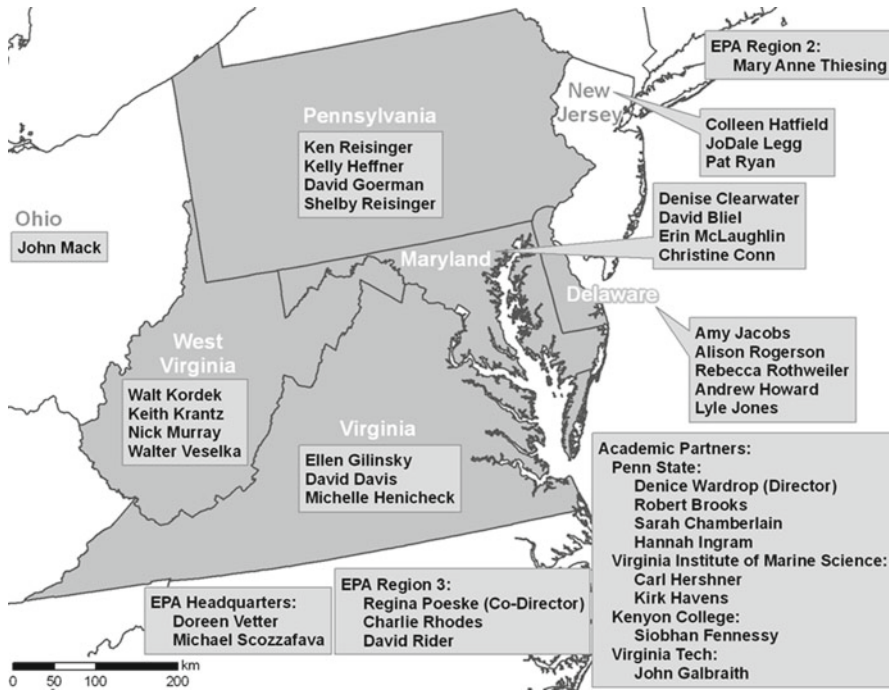
Fig. 11.1 Member states of the Mid-Atlantic Wetland Workgroup (MAWWG) and their representatives

and its primary threats. The collective need was for an approach to appropriately sample the resource, assess its function and/or condition, and report the results in a way that was helpful to the program of interest. A timeline with major milestones in the implementation of M&A by MAWWG, selected state products that were shared within the group, and the major collaborative products that emerged are presented in Fig. 11.2. The following sections detail MAWWG's experience in each of the major areas of M&A.

11.3.2.1 Survey Design

A major impediment in the assessment of wetlands was the lack of a method to obtain a statistically valid sample suitable for making inferences about a population of wetlands at a specified spatial scale. For example, how many wetlands did one need to characterize in a small watershed to make statements about the overall condition of wetlands or the level of function provided? Additionally, the issue of identifying an appropriate survey design was critical to answering the ever-present question on the degree of cumulative impacts due to wetland loss. M&A of wetlands was (and remains) complicated by the fact that, even if resources are available
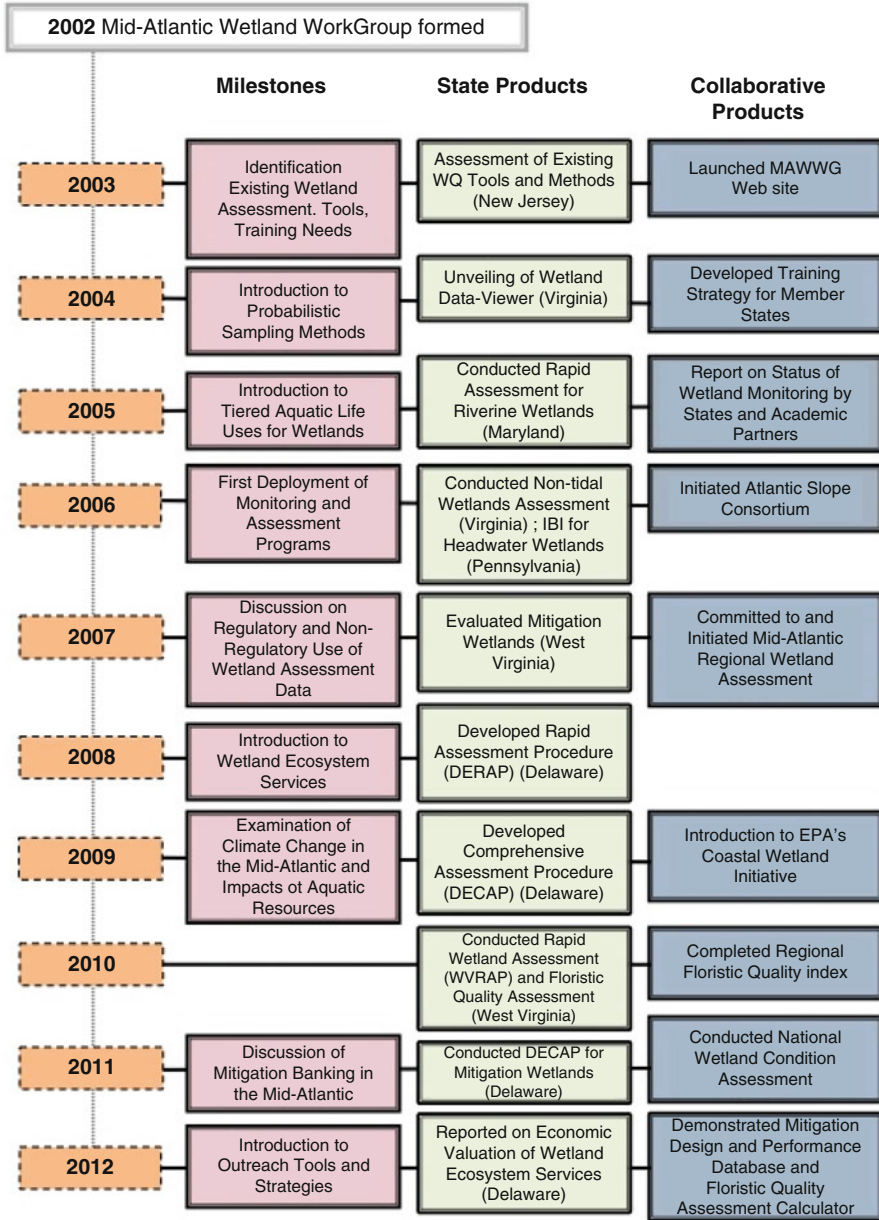
2002 Mid-Atlantic Wetland WorkGroup formed

	Milestones	State Products	Collaborative Products
2003	Identification Existing Wetland Assessment. Tools, Training Needs	Assessment of Existing WQ Tools and Methods (New Jersey)	Launched MAWWG Web site
2004	Introduction to Probabilistic Sampling Methods	Unveiling of Wetland Data-Viewer (Virginia)	Developed Training Strategy for Member States
2005	Introduction to Tiered Aquatic Life Uses for Wetlands	Conducted Rapid Assessment for Riverine Wetlands (Maryland)	Report on Status of Wetland Monitoring by States and Academic Partners
2006	First Deployment of Monitoring and Assessment Programs	Conducted Non-tidal Wetlands Assessment (Virginia) ; IBI for Headwater Wetlands (Pennsylvania)	Initiated Atlantic Slope Consortium
2007	Discussion on Regulatory and Non-Regulatory Use of Wetland Assessment Data	Evaluated Mitigation Wetlands (West Virginia)	Committed to and Initiated Mid-Atlantic Regional Wetland Assessment
2008	Introduction to Wetland Ecosystem Services	Developed Rapid Assessment Procedure (DERAP) (Delaware)	
2009	Examination of Climate Change in the Mid-Atlantic and Impacts ot Aquatic Resources	Developed Comprehensive Assessment Procedure (DECAP) (Delaware)	Introduction to EPA's Coastal Wetland Initiative
2010		Conducted Rapid Wetland Assessment (WVRAP) and Floristic Quality Assessment (West Virginia)	Completed Regional Floristic Quality index
2011	Discussion of Mitigation Banking in the Mid-Atlantic	Conducted DECAP for Mitigation Wetlands (Delaware)	Conducted National Wetland Condition Assessment
2012	Introduction to Outreach Tools and Strategies	Reported on Economic Valuation of Wetland Ecosystem Services (Delaware)	Demonstrated Mitigation Design and Performance Database and Floristic Quality Assessment Calculator

Fig. 11.2 Timeline of major milestones, selected state products, and collaborative products of MAWWG

for all wetlands to be sampled, a high percentage of wetland area nationwide exists on private property, making any approach requiring a complete census nearly impossible due to access considerations. Thus, a survey design for selecting sites to provide valid data for developing accurate estimates for the entire population or area of interest became a priority requirement for the further evolution of M&A.

The elimination of a census as a survey design puts one on a path to a probability survey, defined as a survey in which every element (wetland) has a known probability of being selected for assessment, and the inferences derived from assessing a sampled subpopulation can be applied to the entire population. Because wetlands are distributed across the landscape as discrete elements, linear features, and as a matrix for other systems (e.g., the Everglades), the survey design must include a spatial component. There are a number of approaches to spatial survey design, and the expertise required to choose the one most appropriate for a particular use went beyond the expertise of most state agencies. Fortunately, the answer arose from the efforts of USEPA's Environmental Monitoring and Assessment Program (EMAP), which had long been tasked with developing the science needed to assess the state of the nation's aquatic resources at various spatial scales. EMAP was charged with answering a suite of monitoring questions about the nation's waters: what is the overall quality, to what extent is it changing over time, what is causing the problem, how might we fix it, and how effective are our management techniques? EMAP's approach to answering these questions on a national scale was directly applicable to answering the questions for any individual state.

At the fifth meeting of MAWWG (December 2004), Anthony R. (Tony) Olsen of USEPA Office of Research and Development introduced MAWWG to the Generalized Random Tessellation Stratified (GRTS) design (Stevens and Olsen 1999, 2000, 2004), which was initially developed as a way to sample other aquatic resources, such as streams, rivers, and lakes. Briefly, the GRTS design results in a spatially balanced sample with the points (i.e., locations selected from the sample frame) ordered so that sequential use of the points as study sites maintains spatial balance (i.e., the spatial density pattern of the sample closely mimics that of the resource). In other words, a list of wetland points would be provided to the field crew; the crew would then pursue access to each wetland in the list in order of the draw. Implementing GRTS as a statistical technique requires consideration of a number of factors, and two are of special note: the identification of the sample frame, and the identification of any desirable stratifications of the data. Both are illustrated below with examples of how MAWWG members addressed them.

The sample frame is the digitally mapped representation of the target population (in our case, wetlands of all types in the Mid-Atlantic) that is used to select the sample sites. The National Wetland Inventory (NWI) is a commonly used sample frame for wetlands, because NWI is the most complete digital map of wetland location, type, and extent that is nationally available. However, previous experience in many Mid-Atlantic States, including Pennsylvania, had suggested that NWI missed many small wetlands in forested portions of the landscape, resulting in significant under-coverage (Brooks et al. 1999). Wardrop et al. (2007a) present one approach to supplementing the NWI in an assessment of the condition of wetlands in the Upper Juniata Watershed in south central Pennsylvania.

Geologic structural and stratigraphic information in combination with floodplain maps were used to generate a map of areas with high probability of wetland occurrence, which were screened using recent aerial photography and then ground-truthed. The identification of these additional wetland areas resulted in an estimate of total wetland area in the watershed (2,123 ha) that was almost double that calculated from the NWI map alone (1,144 ha) (Wardrop et al. 2007a).

Another aspect of survey design is the identification of subpopulations of wetlands that may vary in important ecological characteristics, such as size classes, vegetation type, or wetland type and should be included in the reporting on the results of the survey. Stratification, as used in this case, is the process of identifying these relatively homogeneous subgroups and obtaining a representative sample from each. Stratifications can either be an explicit part of the survey design, or can be applied after the sample has been obtained. An example of the former is the approach taken by the Pennsylvania Department of Environmental Protection (PADEP) when planning for their rotating basin assessment of wetland condition in the Commonwealth. PADEP chose surrounding land cover as a criterion for defining four subpopulations of wetlands and utilized the proportion of (or lack of) disturbed cover and natural cover in a 1-km radius circle surrounding each wetland to identify the subpopulations on the sample frame. PADEP's rationale for this approach was that wetlands in similar land cover contexts would be subjected to the same suite of stressors, and these stressors would likely negatively impact condition. The land cover class could be used as an organizing factor around which to prescribe the appropriate family of Best Management Practices (BMPs) that would improve overall wetland condition in the most effective manner. In an example of post-sampling stratification, an assessment of wetlands in the Nanticoke watershed in Delaware by Whigham et al. (2007) encountered a sizable number of privately owned sites for which access permission was denied or was neither explicitly given nor denied, raising concerns about the representativeness of the achieved sample. Because of the possibility of differing management practices between public and privately owned wetlands, and the potential to affect wetland condition, the sample was post-stratified on ownership (methods in Stevens and Jensen 2007).

In summary, the collaborative process between USEPA and MAWWG on survey design had significant implications for both groups that stretched far beyond the technical details of using GRTS to generate a sample. For MAWWG, the consideration of survey design issues forced reflection and discussion on an entire suite of questions that needed to be formulated into monitoring objectives, such as consideration of the amount of riverine wetlands (the most common HGM type) in low condition across an individual state. For USEPA, the demand for technical support for probability-based sampling from MAWWG members reinforced the importance of an effort to make software to create GRTS-based survey designs publicly available (http://www.epa.gov/nheerl/arm/analysispages/software.htm). In addition, questions of how best to report the results of a condition assessment also required the identification of wetland subgroups that may differ in the anthropogenic impacts to which they are subject and in the manner of their response to similar impacts. Thus, a renewed interest in classification followed in the MAWWG.

11.3.2.2   Classification: The Importance of Context

Monitoring information is often utilized in an administrative sense, ignoring its landscape and system context. For example, an inventory of the aquatic macroinvertebrates found in a stream gives few clues about why things are the way they are. Without the accompanying assessment of habitat conditions (e.g., inhospitable benthic conditions or poor water quality) and the human activities that created them, we are without direction in ameliorating a bad condition and restoring valuable function. We must, as Luna Leopold (1977) states, adopt a philosophy of water management that recognizes the hydrologic system as deeply interconnected and placed in the context of geography and climate.

Initial M&A efforts for wetlands provided a way to incorporate the landscape context, as recommended by Leopold (1977), in the design and analysis of M&A efforts. Classification systems were devised that are based on geography and climate, and on hydrogeomorphology. For example, there are the descriptions of ecoregions developed by Omernik (1987) and Bailey (1995) and the HGM classification of wetlands developed by Brinson (1993). Ecoregions exhibit similarities in the mosaic of environmental resources, ecosystems, and the effects of humans (Omernik 1995). They are areas with a relative homogeneity in ecosystems that differ from that of adjacent regions (Omernik and Bailey 1997). Specific to wetlands, Brinson's (1993) HGM classification places emphasis on hydrologic and geomorphic controls that are responsible for determining many of the functional aspects of wetland ecosystems.

Brinson's (1993) HGM classification system looked to properties of geomorphic setting, water source, and hydrodynamics to derive a set of classes of wetlands associated with their ecological functions. Not all wetlands provide the same functions or to the same level (e.g., wetlands in a floodplain setting provide storage of flood waters, while slope wetlands, which by Brinson's definition do not have contours that create a basin, do not). As stated above, HGM classification describes an approach to classifying wetlands that aids in distinguishing the functions that each type can perform and in the identification of the potential effects of anthropogenic disturbance. In contrast, the NWI utilizes a classification of wetlands and deepwater habitats developed by the U.S. Fish and Wildlife Service (USFWS) (Cowardin et al. 1979) wherein wetlands are defined by hydrology, soils, and vegetation in a way that supported the photo interpretation required to create the NWI maps. Therefore, NWI classification does not provide a clear crosswalk between wetland type and the type of function provided, as well as the potential impact by anthropogenic disturbance.

The HGM classification focuses on the drivers of wetland structure and function assures comparisons of "apples to apples," which has clear links to survey design. For example, if flood storage were of interest, only wetlands that were of an HGM type that likely stored floodwaters and were in a landscape position to receive floodwaters would be part of the target population to be assessed. Thus, the associated survey design would assure that only wetlands involved in the function of interest were included.

Whatever the classification scheme, wetland type can be described for an individual site or as a quantitative measure of the abundance of various wetland types at scales from watershed to global. Especially useful are "landscape profiles." These are generally referred to as compilations of the relative abundance of wetland classes defined in terms of the hydrogeologic factors that cause specific wetland types to form and support their functioning in the landscape. The concept of landscape profiles was introduced by Bedford (1996) and then made operational through the use of HGM classification by Gwin et al. (1999). Landscape profiles are critical tools for restoration, management, mitigation, and cumulative impact assessment of naturally occurring wetlands and their utility is widely documented (e.g., Johnson 2005; Wardrop et al. 2007a). For example, in the Upper Juniata watershed, a landscape profile showed that wetlands in the slope class dominated the watershed, followed by riverine types. The profile reflected the physical geography of the region, which has a majority of stream miles in first and second order, and contains abundant toe-of-slope settings with potential groundwater discharge. The profile also highlighted the probable occurrence of significant habitat and biogeochemical functions that are associated with these wetland types.

The reporting requirements of the MAWWG members generally indicated that a HGM approach of classification was necessary because of the reasons stated above. Fortuitously, an additional advantage of HGM classification is its open structure, which allows for regionalization. This is reflected in the abundance of HGM classifications across the country that are generally developed on a regional basis, e.g., the Mid-Atlantic (Brooks et al. 2011) and Oregon (Adamus 2001).

11.3.2.3 The Concept of Reference

Whatever classification is utilized, the next step towards reporting on the condition and/or function of wetlands is setting expectations of condition or function for any specified class and location. For example, what is the difference in likely carbon storage in a depression vs. a riverine wetland? These expectations serve as a benchmark or "reference" for making comparisons and evaluating degradation (e.g., see the discussion of attributable and relative risk in Van Sickle and Paulsen 2008). The concept of reference, as embodied in Brinson's original description of the HGM approach, is often considered one of the most profound legacies of his work (Brinson and Rheinhardt 1996, Chap. 2 of this book). In general, reference denotes a range of wetland conditions that can be correlated with a gradient of anthropogenic impact (Fig. 11.3). Reference standard refers to conditions at the least, or minimally, impacted sites, thereby providing the potential to develop a quantitative description of the best available chemical, physical, and biological conditions in the wetland resource given the current state of the landscape (see Stoddard et al. 2006 for a discussion of various definitions of reference). This conceptual framework and family of definitions is adaptable to any wetland type in any geographic setting.

The power of the reference concept in M&A cannot be overstated. It provides the grounding of either end of the condition/disturbance gradient (Fig. 11.3), as well as

Fig. 11.3 Concept of
reference wetlands along a
gradient of anthropogenic
disturbance with reference
standard referring to
conditions at the least, or
minimally impacted sites:
(**a**) linear response of
condition to disturbance;
(**b**) non-linear response of
condition to disturbance;
(**c**) and (**d**) potential envelope
of reference wetland
condition
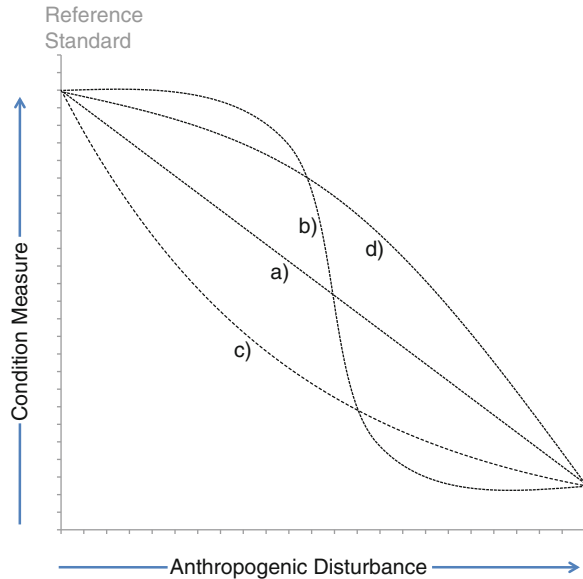
defining the nature of the relationship (e.g., linear, and nonlinear with thresholds) and the variability in condition at any value of the disturbance gradient (e.g., a range of wetland condition exhibited at high levels of disturbance). It also allows establishment of three benchmarks important to the ultimate management of wetlands: minimally disturbed (condition in the absence of significant human disturbance), least disturbed (condition given the best available condition of the landscape, e.g., wetlands in an agricultural setting), and best attainable (the expected ecological condition of least-disturbed sites if BMPs are employed for some period of time) (Stoddard et al. 2006). All of the MAWWG members have invested significantly in the establishment of a collection of reference wetlands. Riparia at Penn State has consistently utilized its reference collection of 222 wetlands in developing monitoring tools such as HGM functional models and IBIs for macroinvertebrates, plant communities, amphibians, and birds.

11.3.2.4 Evolution of Assessment Tools

A family of assessment methods have allowed us to "connect the dots" between land use, stressors, and resulting ecological condition and functions. However, a major obstacle to implementation of M&A is how to balance the value of the information gathered and the cost of collecting it. The obvious limitation to wetland assessment posed by resource constraints has given rise to a multilevel approach, as currently presented by the three-tiered approach (see Sect. M&A in the Management of Resources 11.2.2) and implemented by a number of states. The level of effort

appropriate for a monitoring effort depends on the resources available and the degree of confidence required in the results. As one would expect, the degree of confidence in the data and the reliability of decisions made using the data increase with greater level of effort.

One or more of the three tiers can be employed over a variety of scales (Brooks et al. 2006; Fennessy et al. 2007a; Wardrop et al. 2007a, b; Whigham et al. 2007), and each level can be used to validate and inform the others (Fennessy et al. 2007a). For example, Wardrop et al. (2007a) demonstrated how data from an intensive assessment can be used to evaluate and improve the use of a landscape and a rapid assessment method (RAM). Alternatively, Wardrop et al. (2007b) showed how models of wetland functions that form the components of an intensive assessment can be checked using the results of a landscape and rapid assessment. In another example of how components of the tiered approach work together, Sifneos et al. (2010) used data from an intensive assessment to calibrate a rapid assessment and then employed the resulting correlation between the methods and double sampling (a statistical sampling method) to demonstrate how to make decisions about the number of sites that could be sampled using a combination of both methods for a fixed cost.

Landscape Assessment (Level 1)

A landscape assessment can be accomplished in the office using readily available digital data and a geographic information system (GIS) and requires a low level of effort compared to a site assessment in the field. The most common approach involves the establishment of a reference standard landscape, i.e., the determination of the surrounding land cover that is correlated with a wetland in reference standard condition (see Sect. 11.3.2.3 for a discussion of reference). For example, Wardrop et al. (2007a) chose forested land cover as a reference standard landscape because: (1) it is judged to be the least altered and in the best condition, and (2) non-forested land cover is a surrogate for the stressors that affect wetland condition. Thus, the landscape assessment score measures departure from this reference standard landscape.

Another approach is that developed by Virginia Institute of Marine Sciences (VIMS) in cooperation with the Virginia Department of Environmental Quality (VADEQ). The Virginia Method seeks to utilize the landscape assessment to estimate the level of individual ecosystem services, such as maintenance of water quality and habitat provision, instead of as a general indicator of overall condition. The method assumes that these, individual services (e.g., habitat service or water quality service) are controlled by specific sets of wetland characteristics, and, should not be inferred to be maximized by a wetland in good overall condition. The model construction process is evidence-based and begins by first identifying the ecosystem service of interest; models have been formulated for water quality and habitat. The basic assumption underlying a model is that a wetland's capacity to perform the ecosystem service of interest is greatest when the system is not subject to any stresses that might degrade that performance. A literature search identifies these specific stressors shown to impact the ecosystem service of interest, e.g., modification of hydrology

for water quality improvement. The last step is then the selection of landscape characteristics that are correlated with the occurrence of the identified stressor, e.g., the presence of developed land cover in the buffer surrounding a wetland is highly correlated with hydrologic modification.

This three-step approach (selection of an ecosystem service, determination of the stressors most likely to impact performance, and identification of landscape characteristics that are indicative of stressor occurrence) differs from the more general multi-level approach, as previously discussed, in two primary ways. First, the Level 1 Landscape Analysis provides a relative measure of individual ecosystem service provision instead of general condition. The second is that the VIMS Level 2 rapid assessment and Level 3 intensive assessment do not serve as individual measures of condition, but serve only to inform and validate the Level 1 Landscape Analysis. The result of the VIMS approach, as applied in Virginia, is a census-level assessment of mapped nontidal wetlands (approximately 222,000 wetland units) for water quality and habitat service by watershed, utilizing a GIS-based analysis of remotely sensed information. This information is directly applicable to status and trends reporting under CWA §305(b), and can be utilized in permitting programs to assess cumulative impacts to wetlands within watersheds.

Rapid Assessment (Level 2)

RAMs or Rapid Assessment Protocols (RAPs) are intermediate in intensity between remote, landscape approaches, and intensive site sampling. Rapid assessments are based on easily observable structural indicators at a site, and take, as defined by Fennessy et al. (2007a), less than a 4-h site visit by two people to assess wetland condition. They can be advantageous in implementing M&A programs because they require less time in the field and less taxonomic expertise than do comprehensive assessments, leading to substantial savings in costs and providing the opportunity to increase sample sizes. The structure of RAMs vary, ranging from methods such as the Penn State Rapid Assessment, which is based on stressors and buffer characteristics, to those like the Ohio Rapid Assessment Method (ORAM) that are made up of a combination of indicators based on wetland form and structure and of stressor checklists used to inform the user about causes of degradation. Methods are designed either to provide a single, integrative score to indicate condition or to provide estimates of a suite of wetland functions. The treatment of wetland types varies; many methods are suitable for use in all HGM classes while others have different versions of the method specific to each class. In all cases, RAMs must be calibrated using data collected at a set of reference wetlands, and they must be validated using results of intensive assessments to assure that the results are ecologically robust (Fennessy et al. 2007a).

RAMs have been used effectively in both surveys of ambient condition and as a means to implement regulatory programs. For example, Ohio used an assessment approach combining the GRTS probabilistic sampling design with existing rapid assessment tools, including ORAM and the Penn State Rapid Assessment, to evaluate the ecological condition of wetlands in the 1,300 km² Cuyahoga River watershed.

In an 8-week summer field season, four field crews sampled over 250 sites and generated a "report card" of ambient condition (Fennessy et al. 2007b). Alternatively, ORAM was developed in the first instance as a tool for making regulatory decisions for the purposes of implementing wetland water quality standards and establishing mitigation ratios for wetland impacts. Development of rapid assessment methodologies by a number of states has continued at a rapid pace since Fennessy et al. (2007a, b) provided a review of six individual methods, because they can be modified to suit an individual state's needs (e.g., ORAM for assisting in the establishment of mitigation ratios) and they provide a relatively low cost entry into wetland condition assessment.

Intensive Assessment (Level 3)

Ecological integrity is often assessed by documenting the state or rate of ecological processes such as productivity, respiration and/or the structure of biological communities (Fennessy et al. 2007a; Smith et al. 1995). This can be accomplished by either measuring those processes (such as primary productivity) directly or through the use of indicators (such as the metrics composing IBIs as descriptors of community structure).

Bartoldus (1999) prepared a manual describing and evaluating 40 wetland assessment procedures developed in the United States over the preceding 30 years, and USEPA updated it in a series of documents describing a variety of approaches to assessing the ecological integrity of wetlands (e.g., USEPA 2002). Additionally, methods are further delineated into those that provide one measure of the status of site (i.e., condition assessment) vs. those that may provide function-by-function measures (i.e., functional assessment). Both approaches evaluate the ecological integrity of individual wetlands by comparing the results of the assessment to the values found in an established set of reference wetlands, seek to maintain wetlands in their minimally disturbed conditions, and make only within-type comparisons. A number of assessment methods of either type are available. Biological assessments have been utilized widely as the basis for state assessments of condition (e.g., Ohio, Maine) while functional approaches have been more commonly used at basin scales, perhaps because of their roots as a regulatory approach in Army Corps of Engineers project assessments (e.g., Willamette Valley, Oregon; Columbia Basin, Washington; Wardrop et al. 2007b; Whigham et al. 2007).

Condition Assessment

Condition assessments are rooted in the notion of ecological integrity, which can be estimated using Level 3 approaches such as IBIs as well as Level 2 RAMs. IBIs are multimetric indexes focused on a specific taxonomic group (vascular plant communities, invertebrates, algae) that quantitatively assess change in the structure and composition of those communities that result from anthropogenic disturbance

(Burton et al. 1999; Mack 2007; Miller et al. 2006). Condition describes the extent to which a given site departs from the full measure of ecological integrity that is possible in a region, which is defined by the least-impacted or reference condition. It can be measured in terms of structure (for example, the types and abundance of organisms, which are affected by the ecosystem processes in which they are involved), or form (the arrangement of ecosystem components, which helps define how they interact).

Because the range of possible metric scores and the expectations for condition vary by wetland class, the HGM approach to classification is often used to group sites, making the comparison of scores more equitable (Stevenson and Hauer 2002; Mack 2007). Condition assessments combine multiple metrics into a single score to represent the status of a site, typically by the simple addition of the metric scores, thus providing a measure of where the wetland sits on the scale between full ecological integrity and highly impacted (poor condition). Scores in themselves have no absolute value, but allow comparisons to be made between sites, enable the compilation of the distribution of condition scores by wetland type on a watershed or regional basis, can be combined with the landscape profile for that region to produce a profile of condition (Kentula 2007), and can be used to establish performance standards, for example for mitigation projects. Ultimately, as a site deviates from reference condition, the provision of the ecosystem services that are typical of that HGM class is altered, although methods to quantify the relationships between condition and services are currently lacking.

Functional Assessment

The HGM Functional Assessment is a recent advance in wetland assessment protocols, allowing the estimation of ecological functions associated with wetlands of various types on a wetland-by-wetland basis. The method requires three steps: specification of the wetland type (classification), the recognition of the functions associated with the specified wetland type, and the estimation of the level of functioning (functional assessment). HGM functional assessment uses a suite of mathematical models to estimate the magnitude at which a wetland performs a suite of ecological functions associated with a specific wetland subclass (Smith and Wakeley 2001). Assessment at the site level allows for nesting and characterization at larger spatial scales such as a watershed (Wardrop et al. 2007b; Whigham et al. 2007). HGM assessments are developed regionally and require significant field data collection, and so are available for limited areas of the United States (Kentula 2007) and have not been utilized on a widespread basis. It is important to note that the HGM functional assessment method is assumed to provide a reasonable approximation of functional capacity. Functional assessment models rely heavily upon structural measurements, with a sometimes-tenuous connection to real function (Cole 2006). The connection is generally most tenuous for hydrology and biogeochemical functions because they are difficult to validate. The few studies that are available to relate HGM model results to quantitative measurements of function show varying success of the models to estimate function (Jordan et al. 2007).

Riparia at Penn State began efforts to produce a regional HGM classification, reference system, and functional assessment in 1993, following the guidance of Brinson (1993). Over a 10-year period, 222 reference wetlands were characterized, and the data were used in the construction and calibration of a suite of ten functional assessment models (Chap. 2). The use of these functional assessment models has been featured in numerous studies (e.g., Brooks et al. 2006; Miller et al. 2006; Wardrop et al. 2007b, 2011).

11.4   M&A in Action—Examples of Applications in the MAR at Multiple Scales

The ability to assess wetland condition with a range of resource investment has greatly increased the implementation of assessments over a variety of spatial scales. Wetland condition assessments are dependent upon either a complete census or a probability-based sample that allows estimates of the entire population of interest. Techniques such as landscape assessments (Level 1) can allow an estimate of wetland condition at larger scales (e.g., for all wetlands in a watershed or basin), due to the availability of remote sensing data and the ability to perform such desktop analyses. Thus, wetland condition can be expressed at the watershed scale as a distribution of the values for all individual wetlands in the area being assessed (Wardrop et al. 2007a).

RAMs (Level 2) can be similarly used, although the increased effort required for the field work means that, in general, a complete census of all wetlands in a watershed is not feasible. However, use of a probability-based design to select wetlands that can be assessed for a statistically valid estimate of the total population, in conjunction with a rapid technique, has led to widespread use of rapid assessments to provide condition estimates on a watershed or basin scale (Stein and Ambrose 1998). The probability-based design also allows assessment of condition at the national scale; the National Wetlands Condition Assessment in 2011 (http://water.epa.gov/type/wetlands/assessment/survey/index.cfm) assessed condition through intensive assessment at approximately 1,000 sites, providing an expression of wetland condition at regional and national scales.

11.4.1   The Site-Level

Application of M&A at the site level is perhaps the most common, and can provide information relevant to a wide range of site-level decisions including permitting, restoration, mitigation, and protection. One of the most powerful uses has been the ability to assess mitigation sites and natural sites while utilizing the same methods, allowing us to compare the former to the latter. Penn State's efforts to develop M&A tools that were appropriate to this specific task began as early as 1993 with the establishment of a set of reference wetlands that had the primary intent of collecting

the data necessary to improve wetland mitigation design and performance (Brooks et al. 2002, 2004, 2006). Once the commitment was made to establish a reference set, wetlands were added annually for a decade by securing funds from a variety of sources, and were utilized to develop assessment tools for all three levels of effort—Landscape, Rapid, and Intensive (both HGM and IBI approaches). Further discussion and guidance for creating a reference set of wetlands is covered in Chap. 2. By the late 1990s, a full suite of tools was available that could be utilized to compare natural and mitigation sites.

It is critical to use the same methods and protocols to assess mitigated and restored wetlands as those used to characterize naturally occurring reference wetlands; only then can the data be comparative, and useful in advancing the practice of mitigating wetlands. In addition, one needs reference data from an array of wetland types such that an appropriate set of data can be used to compare "apples to apples." Mitigation and restoration projects should be designed to mimic the characteristics of a particular type, presumably the same as the type of wetland being replaced. In some situations, a decision may be made to create a wetland corresponding to another type, perhaps to replenish the excessive loss of that type from a watershed. In either case, the target wetland type should be designated so that any studies of performance will use data from a matching reference type.

By utilizing the same assessment methods and protocols, Gebo and Brooks (2012) were able to show that mitigation and restoration projects in Pennsylvania, even those from mitigation banks, were performing at levels of function significantly below that of natural reference wetlands of the same type. As described in Chap. 12 and in Gebo and Brooks (2012), despite repeated calls over the past two decades to improve the design and performance of mitigation projects, only incremental improvements have occurred. By working with USEPA, PADEP, and agencies of other MAR states, Riparia at Penn State has assembled an interactive database of reference wetlands data, searchable by ecoregion, state, and HGM type (http://www.riparia.psu.edu). The intent is to provide practitioners with essential measurements that will assist in designing mitigation projects that more closely align with reference wetlands of the same type, and to provide suitable benchmarks for evaluating performance and success. Within an M&A program, using data from reference wetlands in the manner described here can bring us much closer to replacing wetland area and function in-kind.

11.4.2 Watershed-Level: The Upper Juniata Watershed

In 1998, USEPA scientists from both Region 3 and the Western Ecology Division collaborated to sponsor the first assessment of wetlands at the watershed scale utilizing an EMAP approach. The work was intended to serve as a scalable and transferable model of wetland assessment that would, hopefully, make wetland monitoring routine (Kentula 2007). Two watersheds in the MAR were selected, the Upper Juniata located in the Ridge and Valley physiographic province, and the

Nanticoke located in the Coastal Plain. A tremendous amount was learned during both assessments, as presented in a special feature of the journal Wetlands in 2007.

While the case for monitoring wetlands on a watershed basis had been strong, attempts to institutionalize it had been almost nonexistent because (1) methods for the assessment of wetland condition that are easily implemented and scientifically defensible had been lacking; (2) it was not clear how to obtain a representative sample of wetlands on a watershed basis, given the heterogeneous distribution of the resource and uncertainties in gaining access; and (3) the cost had been perceived as inordinately high (Wardrop et al. 2007a). The availability of a probability-based survey approach, HGM classification and functional assessment, condition assessment, and a three-tiered approach (all described in previous sections) came together to address these deficiencies. Since these pieces have already been described, the results of their application in the Upper Juniata are of relevance here, as an illustration of what can be learned and gained by their application at the watershed scale (details can be found in Wardrop et al. 2007a, b). Three primary points are discussed: the extent and character of the resource, the use of multiple tiers of assessment to inform one another, and the interplay of landscape and site-specific factors in the interpretation of functional assessment results.

The application of the GRTS design, along with the Landscape and Rapid Assessments, provided the first description of the wetland resource and its ecological condition in the Upper Juniata. One of the first questions regarding the resource was, quite simply, how much wetland acreage was present in the watershed, and of what type. Previous work showed that NWI may miss over half of the smaller wetlands in forested portions of the watershed, resulting in significant under-coverage, and we were interested in testing a method that might supplement the NWI. We utilized geologic structural and stratigraphic information in combination with floodplain maps to generate a map of areas with high probability of wetland occurrence; these high probability areas were sampled in conjunction with the NWI. The result was the first statistically-determined difference in wetland area predicted by the Riparia and NWI maps. Total wetland area in the Upper Juniata watershed was estimated as 2,123 ha (95% c.i. = 1,743, 2,503) using the 81 points from the Riparia map that had wetlands. By comparison, the total wetland area calculated from the NWI map was 1,144 ha. A primary outcome of the assessment was the quantitative confirmation of the under-representation of the resource by the NWI; namely, the addition of the Riparia map to the site selection process increased the estimate of wetland resource in the Upper Juniata almost twofold.

Since the Upper Juniata provided us with the first opportunity to utilize all three tiers of assessment at a significant number of sites (83), we were interested in how results from each tier of assessment could be used to inform the others. Thus, we used one of the components of the intensive assessment to calibrate and refine the landscape and rapid assessments. Specifically, we used the results of the FQAI to illustrate how the evaluation could be done because it had proven to be a reliable measure of wetland condition (the FQAI is described in detail in Chap. 6). Classification and regression tree (CART) analysis was used to evaluate (1) whether the results of the landscape and rapid assessments correspond to those from the

intensive assessment (i.e., do they group sites along a condition gradient supported by ecological data) and (2) whether the categories of condition based on the results of the landscape and rapid assessments (four condition categories had been established) align with categories of condition specified by quantitative ecological data from the intensive assessment. In general, the analysis showed that both the landscape and rapid assessments assign sites to the highest and lowest categories of condition, but sites in the middle have a limited range of FQAI values that do not as clearly define groups. The CART results also indicated that our initial delineation of condition categories for both the landscape and rapid assessments should be more stringent (Table 11.1). For example, our highest condition category from the landscape assessment had been defined as sites with greater than 85% forested cover in a 1-km radius circle surrounding the site, and the CART results indicated that the highest condition was present at sites with greater than 89% forested cover. When both the landscape and rapid assessment scores were used as predictor variables, CART chose the rapid assessment results over the results of the landscape assessment, indicating that the rapid assessment better explained the variation in the response variable (FQAI) than the landscape assessment. This result is notable, since it demonstrates how the level of confidence in the results increases as one changes from a fairly general landscape assessment to more quantitative assessments (i.e., one looks "under the trees").

Finally, we employed the family of HGM functional assessment models (as described in Chap. 2) to provide a measure of the potential functional performance of a single wetland for up to 11 functions, depending on the subclass. Performance of each function is expressed by a Functional Capacity Index (FCI) score ranging between 0 and 1. A score of 1 indicated the site was performing the function at levels comparable to reference standard; a score of 0 indicated the site was not performing the function. We then reported on the distribution of FCI scores across all wetlands in the watershed by constructing cumulative distribution function (CDF) plots for the wetland population (all sampled wetland types), as well as individually for the slope and riverine classes. CDF plots allow estimation of what percent of the wetland area of the population is less than or equal to a particular FCI score. The CDF plots for the entire wetland resource (Fig. 11.4) are fairly linear over most of the distribution for all functions, indicating that the FCI scores are evenly distributed over the population. Several of the plots flatten at the upper and/or lower ends of the curves indicating that a very small proportion of the wetland area had the highest and lowest scores. However, the CDFs can also be utilized to assess whether the results of an individual functional assessment model are in agreement with the results of the landscape and rapid assessments. For example, the range of FCI scores for Characteristic Hydrology in the Upper Juniata wetlands is 50% of reference standard or higher (Fig. 11.4). This result was at odds with the Rapid Assessment findings that hydrologic alteration was a common stressor in the watershed, affecting on average 53% of the resource (Wardrop et al. 2007a, b). Either the hydrologic alterations did not affect the hydrologic functioning of the wetlands or, more likely, the model does not detect the likely effects. Findings such as these indicate that selected functional models require reassessment and revision.

Table 11.1 Ecological condition of the wetland resource in the Upper Juniata watershed based on the landscape assessment ($n=463$) and on the rapid assessment ($n=80$) and using the condition category definitions generated by the CART analysis

| Condition category	Landscape assessment score	Percent of resource	Area of wetland (ha)	Rapid assessment score	Percent of resource	Area of wetland (ha)
Highest	≥89% FLC	3.6 (2.4, 4.8)	76 (51, 101)	≥87	2.9 (0, 5.8)	62 (0, 124)
High	≥82% and <89% FLC	4.0 (2.6, 5.4)	85 (55, 115)	≥58 and <87	28.8 (17.9, 39.7)	611 (380, 842)
Medium	≥74% and <82% FLC	12.5 (9.6, 15.4)	265 (203, 327)	≥42 and <58	14.3 (7.0, 21.6)	304 (149, 459)
Low	≥47% and <74% FLC	36.5 (32.8, 40.2)	775 (696, 854)	<42	54.0 (42.9, 65.1)	1,146 (910, 1,382)
Lowest	<47% FLC	43.4 (39.3, 47.5)	922 (835, 1,079)			

Values are means followed by the 95% confidence interval in parentheses. *FLC* Forested Land Cover. From Wardrop et al. (2007a)
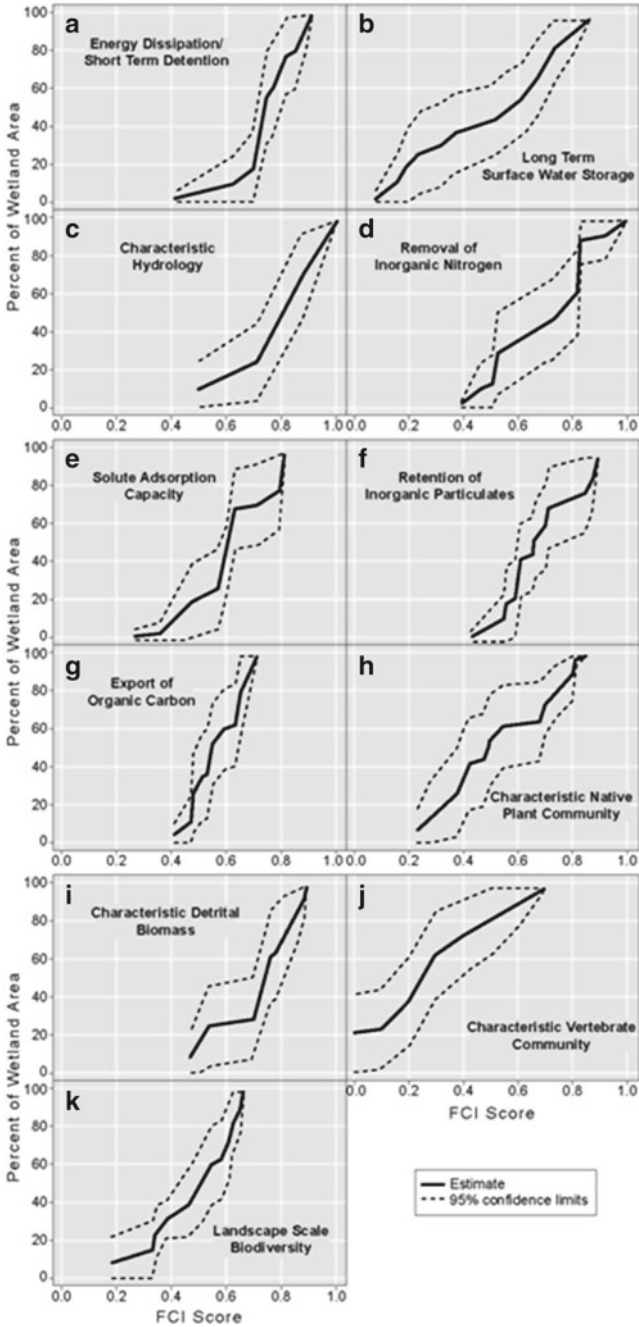
Fig. 11.4 Distribution of hydrogeomorphic (HGM) Functional Capacity Index (FCI) scores across all wetlands in the Upper Juniata watershed using cumulative distribution function (CDF) plots (Wardrop et al. 2007b)
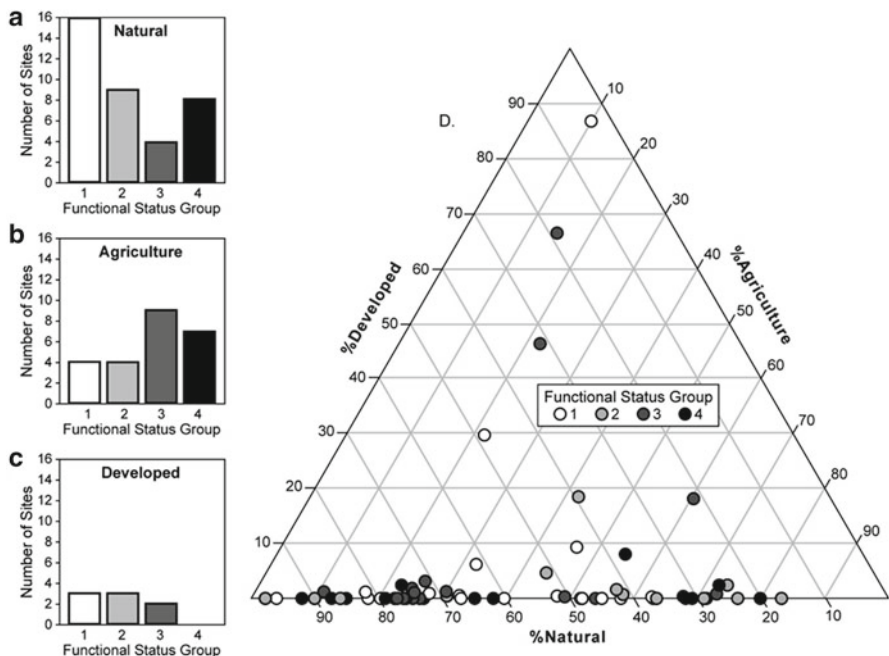
Fig. 11.5 Distribution of the 69 riverine and slope sites in the Upper Juniata watershed by Functional Status Group (FSG) within the (**a**) natural, (**b**) agriculture, and (**c**) developed reference domains. (**d**) Shows the relationship between FSG and percent land cover. Each circle represents one site. Reproduced from Wardrop et al. (2007b)

Finally, we were interested in whether clear groupings of sites with similar functional score profiles were present (e.g., a group of sites exhibiting high FCI scores across all functions), and if these groups were correlated with surrounding land cover classes. The FCI scores for the Characteristic Plant Community, Detrital Biomass, and Vertebrate Community Functions were chosen for the analysis because they either represented functions that were measured directly or had been validated. Clustering of the 69 riverine and slope sites for these three functions resulted in the formation of four Functional Status Groups (FSG) representing combinations of high, medium, and low mean FCI values for the three functions. Groups 1 and 2 represented a relatively high-functioning group of sites, but were differentiated by an exceptionally high Plant Community Function in Group 1 that differs significantly from the low value for the same function in Group 2. FSGs 3 and 4, with a combined total of 30 sites, represented a relatively low functioning group of sites and were differentiated by a significantly high Vertebrate Community Function in Group 3.

We used a ternary plot to visually represent the sites relative to their land cover setting (Fig. 11.5); these diagrams have three axes, one each for the percentage of agriculture, developed, or natural land cover surrounding the site. The figure clearly shows that sites of any given FSG are distributed across a variety of land cover compositions. We took a closer look at sites within a given category of surrounding

land cover by establishing land cover-based reference domains, *sensu* Brinson and Rheinhardt (1996). Sites with surrounding land cover of >50% natural cover are termed "Natural," sites with >50% surrounding agricultural cover are termed "Agricultural," and all remaining sites are termed "Developed."

Sites of all FSGs appear in each reference domain, with some notable differences in distribution (Fig. 11.5). Sites in the Natural Domain are much more likely to be in the higher functioning FSGs, while sites in the Agricultural Domain are dominated by sites in FSGs 3 and 4, with an overall low level of functioning. Sites in the Developed Domain are equally distributed across FSGs 1, 2, and 3. What is surprising about this result is the realization that surrounding land cover does not completely control functional performance. The information obtained during the rapid assessment proved to be a valuable diagnostic tool because of the inclusion of information on the quality of the buffer associated with the sites as well as the stressors present. For example, what distinguishes a site in FSG 1 (highest level of functioning) and in developed land cover is the fact that it has an intact buffer. This type of information has potentially significant utility in restoration and management, since it provides a template of a high-functioning site that does so in spite of its context.

11.4.3   Regional-Level: The Mid-Atlantic Regional Wetland Assessment

As per Fig. 11.2, MAWWG decided to embark on a regional condition assessment in 2007, with funding from USEPA. The decision was a result of a number of factors, including: (1) the desire to be a regional pilot for the National Wetland Condition Assessment (NWCA) (described in the following section), (2) the management utility of a landscape and stressor profile for the entire region, as well as each individual state, (3) the opportunity to build state capacity in the various M&A tools, and (4) the construction of an assessment protocol that could be applied across the region and subsequently adopted by states, if appropriate. This project, which is in the final stages of analysis, used a combination of tools that had been developed by a number of the states and academic partners. The VIMS Landscape Assessment, which results in an estimate of potential water quality and habitat ecosystem service and was described above, was performed on all NWI polygons for freshwater wetlands in the MAR (about two million sample points). A RAP that could be applied across the entire MAR was developed using a synthesis of the Delaware, Penn State, and VIMS approaches and was applied at approximately 400 points obtained using the GRTS design (Fig. 11.6). The MAR rapid assessment was designed to provide a regional landscape profile, various stressor profiles, and an assessment of condition.

Following a training session to help standardize field methods, two field teams of two or three persons per team, one from Riparia and one from VIMS, conducted the sampling. Field sampling was conducted throughout the region during two summers, 2008 and 2009. Each of the field sites consisted of a wetland assessment area with a 40-m radius circle, surrounded by a 100-m buffer. Our goal was to have a
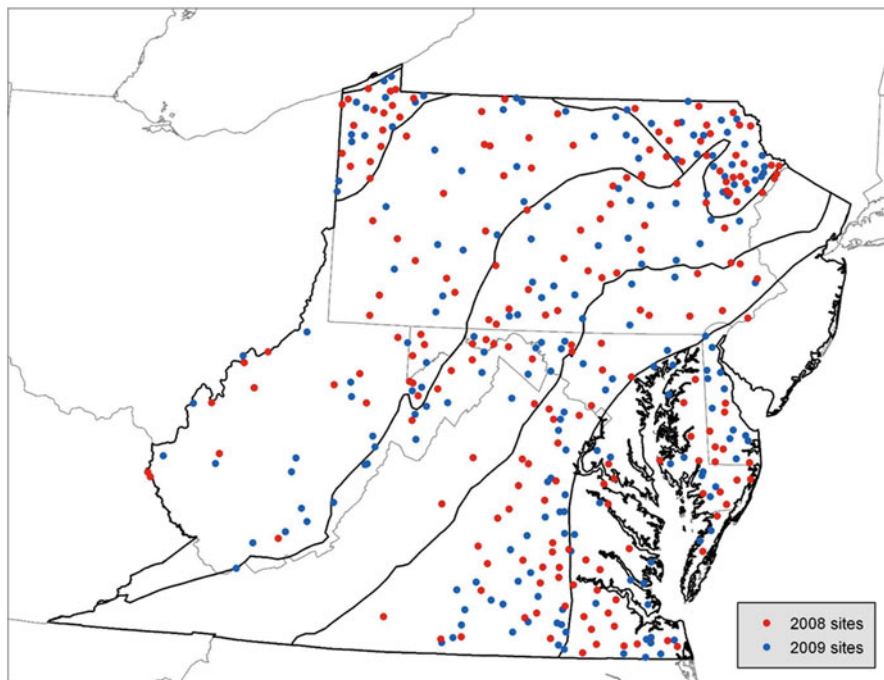
Fig. 11.6 Spatially balanced sample across the Mid-Atlantic Region for a condition assessment of wetlands conducted in 2008–2009 using the Unified Mid-Atlantic Rapid Assessment Protocol (Brooks et al. unpublished)

sufficient number of assessed sites in each of the five major ecoregions (80 sites in each ecoregion), and where possible, make comparisons across the more common wetlands types (e.g., riverine). The landscape profile (Fig. 11.7) shows that riverine wetlands dominate HGM types across the MAR. A simple tally of stressors recorded from the wetland assessment area shows that ecoregions are being affected differentially (Fig. 11.8). Results of this study will be posted at http://www.riparia.psu.edu/MARbook when available.

11.4.4   National-Level: The National Wetland Condition Assessment

The NWCA is part of the USEPA's National Aquatic Resource Surveys (NARS). The 2011 NWCA is the first national assessment of wetlands and the fifth in a series of NARS assessments, after streams, rivers, lakes, and coastal systems. The assessments will be conducted every 5 years, resources permitting, to report to Congress and the nation on trends in the condition of the nation's aquatic resources.
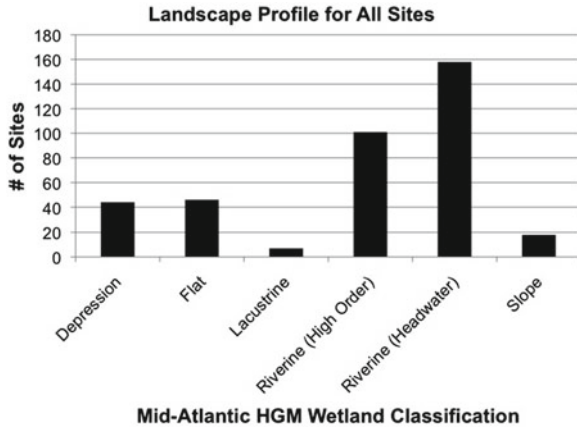
Fig. 11.7 Landscape profile of HGM wetland types provides a representative distribution of freshwater wetlands for the MAR
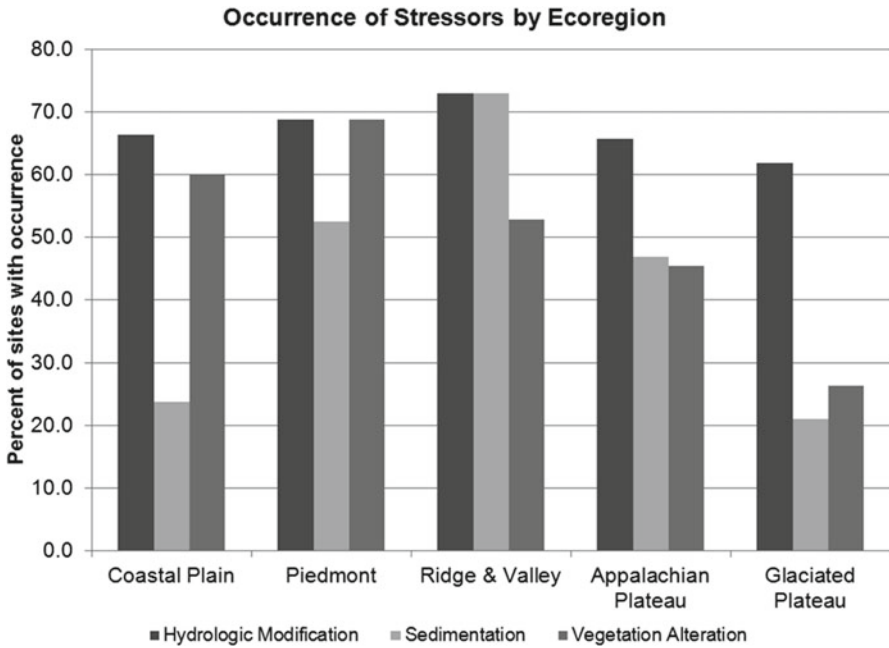

Fig. 11.8 Percent of sites with occurrence of stressors (hydrologic modification, sedimentation, vegetation alteration) by ecoregion in the MAR

The NWCA was designed to build on and augment the achievements of the USFWS's status and trends (S&T) reporting which characterizes changes in wetland acreage across the conterminous United States (e.g., Dahl 2011). Paired together, the NWCA and S&T reporting will provide the public and government agencies tasked with the management of natural resources with comparable, national information on wetland quantity and quality (Scozzafava et al. 2011). The NWCA is designed to produce detailed information on wetland quality by wetland type and region of the United States, providing insight into the implications of the changes in area reported by the USFWS S&T program. An overview of the NWCA and a presentation of frameworks for reporting the results in the context of the other NARS assessments are found in Kentula et al. (2011).

The fact that wetlands were added to the NARS is due in no small part to M&A efforts in the Mid-Atlantic as described in the sections above. In particular, it's interesting to note that the relationship between USEPA's Mid-Atlantic Regional Office in Philadelphia, Pennsylvania, and the wetland programs of the Mid-Atlantic States that led to the formation of the MAWWG also was instrumental to developing the science needed for implementation of the NWCA. Art Spingarn of USEPA's Regional Office was the person who made the assessments of the Upper Juniata and Nanticoke watersheds happen. Spingarn built support with the wetland managers from the states of Delaware and Pennsylvania, interacted with the scientists who would conduct the studies, protected the funding from attempted cuts, provided technical review, and did everything that needed his skills and attention to assure that the assessments were done. The assessments of the wetland resources in the Upper Juniata and Nanticoke watersheds and the subsequent assessment of the MAR convincingly demonstrated that the wetland scientific and management communities could cooperate to conduct an assessment of wetland condition at large scales and were ready to take on the challenges of planning and implementing the first NWCA.

Components of the NWCA were the same as tools developed for MAWWG and being used by the state wetland programs in the MAR. The following brief description of the NWCA details how those tools were used in the 2011 assessment.

The 2011 NWCA sample design was linked to the design used for the S&T reporting to assure that comparable information on wetland quantity and quality is produced. Both efforts used an ecological definition of wetlands, specifically:

*Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have **one or more** of the following three attributes:*

- *at least periodically, the land supports predominantly hydrophytes;*
- *the substrate is predominantly undrained hydric soil; and*
- *the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year (Dahl 2006).*

The target population was defined as: Tidal and nontidal wetlands of the conterminous United States, including certain farmed wetlands not currently in crop production. The wetlands have rooted vegetation and, when present, open water less
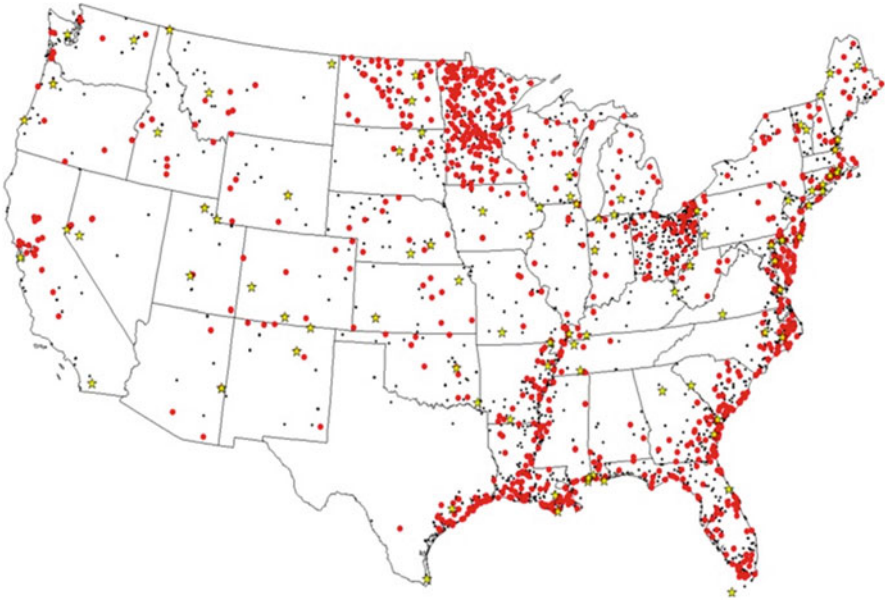
Fig. 11.9 Map of the conterminous United States showing all the points from the NWCA sample draw. • = the primary sample points; • = oversample points (for use if the primary points are not sampleable) ☆= revisit sites (primary sites that are resampled for quality assurance purposes)

than 1 m deep (USEPA 2011a). The Target Population is composed of seven of the wetland classes used in the S&T reporting, i.e., Estuarine Intertidal Emergent, Estuarine Intertidal Forested/Shrub, Palustrine Forested, Palustrine Shrub, Palustrine Emergent, Palustrine Unconsolidated Bottom/Aquatic Bed and Palustrine Farmed. The classes are a modification of the system developed by Cowardin et al. (1979).

A spatially balanced probability survey design was used (Stevens and Olsen 1999, 2000, 2004) to generate enough sample locations (hereafter points) to assure a target sample size of 900 (Fig. 11.9). The 2005 USFWS S&T sample plots augmented for better coverage on the Pacific Coast were used as the sample frame. Specifically, the frame was composed of 4-m^2 plots containing mapped wetlands, deepwater habitat, and uplands. Points were drawn from the wetland areas.

The NWCA was designed so that wetland condition could be reported by wetland type for the nation and by aggregated ecoregions based on the Omernik Level III Ecoregions (Omernik 1987; USEPA 2011b). USEPA Regions and major river basins are among the additional reporting units being considered. The ability to report on additional geographic units will depend on the number of sites sampled per unit.

A definition of reference condition is used to quantitatively describe the standard or benchmark against which to compare the current condition measured in the assessment (Stoddard et al. 2006). The NWCA, as done in previous NARS assessments, has defined reference as least disturbed and good condition as greater than or
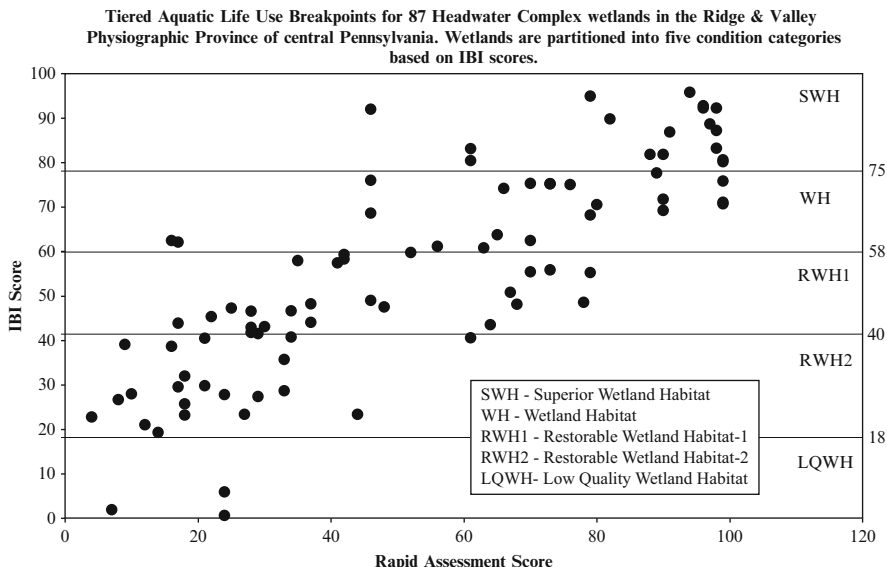
Fig. 11.10 Potential future use of M&A data in the construction of Tiered Aquatic Life Uses (TALUs)

equal to the 25th percentile of values observed in the reference population (USEPA 2006b, 2009). Candidate reference sites were recommended to the NWCA by the States, the National Estuarine Research Reserve System, the National Park Service, the USFWS National Wildlife Refuge System and the US Forest Service. The 1,141 candidate sites were evaluated using a series of screens that used aerial photography and digital land cover data to identify sites that were part of the target population, able to be sampled, and likely to be least disturbed. This resulted in 150 recommended reference sites distributed across ecoregions and wetland classes targeted for sampling in the 2011 NWCA. Identical field sampling and laboratory protocols were used for the recommended reference sites and 900 probability sample points. Additional screening will be performed post field sampling to assure that the field data collected support the pre-sampling evaluation of least disturbed and to identify any sites from the probability sample meeting the definition of reference (e.g., see the screening process described in Herlihy et al. 2008).

The NWCA used all components of the three-tiered approach. As described above, a landscape assessment was employed to screen potential reference sites and to evaluate points as to suitability for sampling (e.g., was the wetland part of the target population) (USEPA 2011a). A rapid assessment was developed for national application and used in 2011 to provide data for an initial evaluation of its performance. The primary data set for the NWCA was generated using an intensive assessment. NWCA protocols were designed to be completed by a four-person field crew during one day in the field. The field crew sampled a 0.5-ha assessment area (AA) and an area immediately adjacent to the AA (i.e., the buffer). The indicators

used and a brief description of the sampling approach is presented below; the detailed protocols used in the 2011 NWCA are found in the Field Operations Manual (USEPA 2011c).

- *Vegetation* was characterized by collecting plant data in plots systematically placed across the AA
- *Soils* data were collected in four soil pits and include an on-site description of the soil profile and collection of four types of soil samples (chemistry, bulk density, stable isotope, and soil enzymes) for laboratory analysis
- *Hydrologic* data included an assessment of hydrologic sources and connectivity, indirect evidence of hydroperiod, estimates of hydrologic fluctuations, and documentation of hydrology alterations or stressors
- When standing water was present in the AA, *water chemistry* samples were taken and analyzed for general surface water conditions, various chemical analytes, and evidence of disturbance
- *Algae* samples were collected from sediments (benthic samples) and from the surface of vegetation stems and leaves (epiphytic samples)
- The presence of *stressors* was measured in the AA and buffer

Reporting on the 2011 NWCA will follow the format established in the NARS Wadeable Streams and Lake Assessment reports (USEPA 2006b, 2009). The results of the assessments are presented in four categories. First, the extent of the wetland resource will be described in ways that will inform and augment the USFWS S&T reporting, in particular, the report for 2004–2009 (Dahl 2011). For example, the NWCA will document the frequency and location of S&T mapping errors. In addition, the NWCA will provide information on the occurrence and condition of various wetland types in the Palustrine Unconsolidated Bottom Class, especially those commonly known as freshwater ponds. Freshwater ponds had the largest percent increase in area nationally of any wetland type between 1998 and 2004 (Dahl 2006) and increased 3.2% between 2004 and 2009 (Dahl 2011). The resulting shift in wetland types from vegetated wetland to those dominated by open water can involve changes in ecological structure and function in the affected landscape (e.g., see Gwin et al. 1999; Magee et al. 1999; Shaffer and Ernst 1999; Shaffer et al. 1999; Magee and Kentula 2005). To better capture the nature of the of any changes associated with increase in area of ponds, S&T added descriptive categories to the 2004–2009 report (Dahl 2011), which were also tracked in the 2011 NWCA.

Second, the NWCA will report on the ecological condition of the nation's wetland resource. Vegetation is the NWCA's primary indicator of condition with algae and soil providing additional information. The vegetation data collected are suitable for the development of various condition indices, especially IBIs (e.g., Miller et al. 2006), an Observed vs. Expected index (e.g., Carlisle and Hawkins 2008; Van Sickle 2008), and a Floristic Quality Index (FQI) (e.g., Lopez and Fennessy 2002; Rooney and Rogers 2002; Mathews 2003; Bourdaghs et al. 2006; Miller and Wardrop 2006). Although Vegetation IBIs and FQIs have been developed for a number of states and regions and for a number of wetland types (see Mack and Kentula 2010 for a review); they are not available for the nation or for all states or regions and will require additional information and research for use in NWCA reporting.

Third, the NWCA will report on the area of the target population affected by biological, chemical, and physical stressors, thus recognizing the connection between the presence of stressors and wetland condition. The use of stressor data are consistent with current approaches to assessment. For example, some RAMs use only stressors as indicators of wetland condition (e.g., the Delaware RAM Jacobs 2007), the Penn State Stressor Checklist (Wardrop et al. 2007a) and models comprising an HGM intensive assessment use stressors as variables (e.g., Wardrop et al. 2007b; Whigham et al. 2007). The estimates of the relative extent of stressors generated from the NWCA are a measure of how common a stressor is and can be reported for the nation and ecoregions and by wetland class.

Finally, the NWCA will explore the relationship between stressors and ecological condition through the concepts of relative and attributable risk. Relative risk is an expression of the likelihood of having poor ecological condition when the magnitude of a stressor is high vs. low (Van Sickle and Paulsen 2008). Attributable risk provides an estimate of the proportion of the population in poor condition that could be reduced if the effects of a particular stressor were eliminated (Van Sickle and Paulsen 2008). An example from the Wadeable Streams Assessment (USEPA 2006a) illustrates how these measures of risk can illuminate subtleties in the M&A data. The relative risks for all stressors in the West region are consistently larger than for the nation and other regions while the extent of streams in poor condition are consistently lower. This suggests that although the stressors are less widespread in the West, the region's streams are particularly sensitive to the stressors detected.

The above description of the reporting anticipated from the 2011 NWCA demonstrates the comprehensive nature of the data that can be generated from M&A and suggests uses in resource management. Reporting on the extent and condition of the resource can be used to track effectiveness of regulation and management practices by geographic region and/or wetland type. Alternatively, the estimates of the extent of stressors can identify the emergence of new threats to wetland condition, while the use of relative and attributable risk helps to prioritize management actions by stressor, geographic region, and/or wetland type. The number of examples above coming from work done in the Mid-Atlantic is notable and the potential uses for NWCA data echo the objectives of the MAWWG.

11.5 Lessons Learned

The success of M&A in the Mid-Atlantic required innovations in three areas: technical tools, programmatic opportunities and applications, and partnerships. Lessons learned for each are:

Tools

- It would be difficult to imagine M&A without all of the technical advances of the last 20 years, most notably Mark Brinson's contribution of the HGM Classification. However, the point to be made is that no one tool was the basis for rapid progress in M&A; it was that the field allowed one tool to inform the

development of another. For example, IBI and HGM functional assessment each had dedicated proponents, but clearly profited by the cross-pollination of concepts. The concept of reference substantially informed the construction of the stress gradient used in the development of IBIs; in turn, many of the condition assessment indicators (such as plant-based IBIs) became critical variables in functional assessment models

- The development of a robust collection of condition assessment tools, representing a range of resource requirements (e.g., three tiers of assessment) was critical for use and application. Users varied widely in both the resources available for assessment and the requirements for the precision of the resulting data, and the availability of tools to inform a myriad of decisions hastened the refinement of the entire toolbox. In addition, tools from each level could be used to refine each other, as has been evident in a number of efforts and discussed in this chapter

Programmatic applications

- The realization that condition assessment data could be broadly utilized across both wetland regulatory and/or non-regulatory programs led to a blossoming of uses. Mid-Atlantic States used condition assessment data for assessment of mitigation programs (Pennsylvania), permitting and cumulative impact decisions (Virginia), water quality standards (Maryland), restoration performance and design standards (Delaware), and protection (West Virginia). The willingness of the leadership of various state programs to utilize these tools played a key role in their use, which led to tool refinement, which led to broader usage
- Consistent use of the same M&A methods in various parts of a wetlands program leveraged the value of the information. For example, a landscape profile of wetland types obtained during condition assessment could be utilized as a template for wetland creation; assessment of mitigation wetlands utilizing the same protocol as that used for condition assessment of natural wetlands provided a fair assessment of the success of the mitigation projects

Partnerships

- Regional forums such as MAWWG allowed state programs to stand upon one another's shoulders, and allowed the development of both tools and their applications to proceed in a cost-effective manner. As evidence, many of the state's condition assessment tools resembled one another, and provided a regional consistency that ultimately led to the Mid-Atlantic Regional Wetland Assessment. Successes, as well as challenges, were freely shared, and states that had not developed certain tools could gain them rapidly since they could pick and choose parts of existing methods or adopt them in their entirety. In another dimension, the academic/regulatory partnership of Riparia and USEPA Region 3 (via the leadership of Regina Poeske) was reflected in the agenda of MAWWG meetings, which split meeting time almost equivalently between technical issues and programmatic ones
- Partnerships between MAWWG and external groups, such as USEPA's EMAP, were invaluable in providing a level of technical assistance that had been previously unavailable to state programs. For example, the investment of time

and expertise by both Mary Kentula and Anthony Olsen of USEPA resulted in numerous applications of the GRTS protocol to large, probability-based surveys in a number of states, as well as region-wide in the Mid-Atlantic Regional Wetland Assessment.

11.6   Future Uses of M&A

Most states in the MAR have begun moving away from program development into implementation of statewide monitoring and assessment programs. The focus for state wetland monitoring programs, therefore, has shifted from the development of tools to estimate wetland condition to integrating ecologically meaningful data into water quality standards. This translation of data into standards is the final step in institutionalizing state monitoring and assessment programs for wetlands.

Davies and Jackson (2006) developed a framework for interpreting the ecological condition of wetlands and other habitats from empirical data termed the Biological Condition Gradient (BCG). The BCG provides a common foundation for states to develop water quality standards for wetlands in the form of tiered aquatic life uses (TALUs) (US Code title 33, section 1,251 (b), 1,313) with each tier corresponding to a different level of ecological integrity.

In cooperation with the PADEP, Riparia developed a prototype of a BCG for Headwater Complex Wetlands in the Ridge and Valley Physiographic Province. Using vegetation data collected from 87 wetlands, five tiers of habitat condition were described: SWH, WH, RWH1, RWH2, LQWH (see below). CART analysis of IBI scores (Miller et al. 2006) for each wetland was used to derive breakpoints, thus providing a quantitative basis for each tier. Once tiers are established and codified, prescriptive measures can be promulgated to protect the highest tiered wetlands, prevent further degradation of wetlands in the middle tier, and restore the functions and values of those in the lowest tiers.

Thus, the knowledge treads and efforts of the past three decades have coalesced into a varied tapestry composed of a plethora of assessment tools, programmatic applications, and partnerships generated from a common objective to improve protection and management of the wetland resource based on sound science. The anticipated future of the monitoring and assessment of wetlands promises a rich and exciting design to come.

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