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A PRACTICAL GUIDE FOR THE DEVELOPMENT OF A WETLAND ASSESSMENT METHOD: THE CALIFORNIA EXPERIENCE[1]

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ABSTRACT: Wetland rapid assessment methods (RAMs) can provide a cost effective, scientifically defensible estimate of wetland and riparian condition for use in ambient and project monitoring in resource management and regulatory programs. Those who have chosen to develop a RAM to assess wetland and riparian condition are faced with a range of issues and important choices that they must make throughout the development process. This paper is intended as a practical guide to RAM development. Six basic stages in the RAM development process are discussed: (1) organize RAM development by identifying the intended applications, assessment endpoints, and geographic scope of the RAM and forming appropriate teams to advise and review the development process and its products; (2) build a scientific foundation for method development by conducting a literature review, choosing a wetland classification system, building conceptual models, and identifying the major assumptions underlying the model; (3) assemble the method as a system of attributes and metrics that describe a full range of conditions; (4) verify the ability of the method to distinguish between wetlands along a continuum of conditions; (5) calibrate and validate the method against sets of quantitative data representing more intensive measures of wetland condition; and (6) implement the method through outreach and training of the intended users. Important considerations within each of these stages lead to choices in accuracy, precision, robustness, ease of use, and cost. These are identified and the tradeoffs of the various options discussed. Experience with the ongoing development and implementation of the California Rapid Assessment Method (CRAM) is used to illustrate these stages and associated choices in RAM development.
(KEY TERMS: monitoring; rapid assessment; wetlands; riparian habitat; ecological condition; riparian ecology.)

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INTRODUCTION

Over the past century, extensive agricultural development, rapid urbanization, flood control practices, and extraction of physical and biological resources have led to extensive wetland and riparian habitat loss and degradation in the United States (Sandecki, 1989; Ferren *et al.,* 1996). This loss and degradation in habitat are counteracted to some degree by investments of public and private funds in programs to conserve, restore, and manage these important resources. However, the effects of these efforts relative to ongoing wetland loss and degradation cannot be assessed because the ambient condition of wetlands is not routinely monitored. In addition, monitoring methods are often inconsistent from project to project. Consequently, the results of monitoring are not readily useful to analysts and decision makers. This is problematic, particularly in light of a recent study by a National Academy of Sciences Panel on the compensatory mitigation program that found that the federal no-net-loss goal is not being met, in part because of the lack of wetland monitoring (National Research Council, 2001). In order to account for the public investment in wetland protection and restoration and to improve wetland management and regulatory decision making, assessment tools are needed to provide consistent and affordable information about wetland health for all ecoregions and wetland types.

Numerous methods have been developed to assess wetland condition or function at a variety of spatial scales. Methods that are designed to assess large

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areas, such as the Synoptic Approach (Leibowitz *et al.,*1992), typically produce coarser and more general results than site specific methods, such as either the Hydrogeomorphic Method (HGM) (Smith *et al.,* 1995) or the Index of Biotic Integrity (IBI) (Karr, 1981). Existing methods also differ in the amount of effort and expertise they require (Figure 1). Methods such as the Wetland Rapid Assessment Procedure (WRAP) (Miller and Gunsalus, 1999) and the Descriptive Approach (USACE, 1995), are extremely rapid, whereas the Habitat Evaluation Procedure (HEP) (USFWS, 1980), the New Jersey Watershed Method (Zampella *et al.,* 1994), and the Watershed Science Approach (WSA, version 3.0) (Collins *et al.,* 1998) are much more time intensive. However, few existing methods have been broadly applied to all wetland types in states such as California. Even the most widely used methods, such as HGM, IBI, and HEP, have been limited by the up-front time, expense, and effort necessary to develop models applicable to all wetland types in a region.

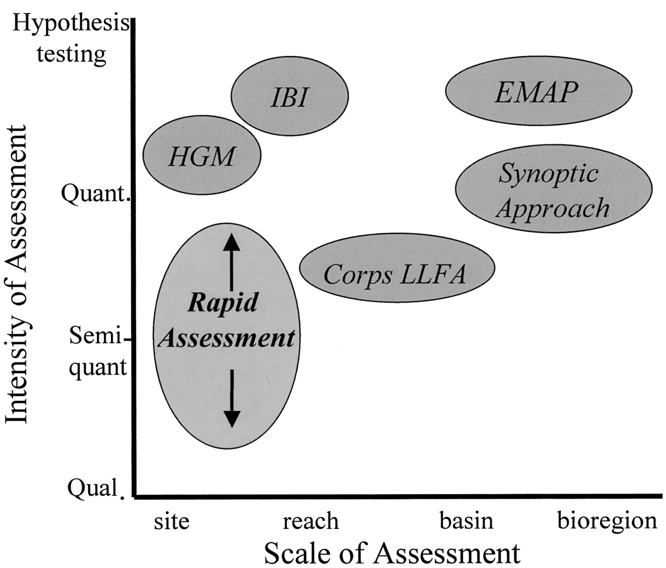

Figure 1. Diagram Depicting the Relationship of Wetland Rapid Assessment Methods to Other Methods, Relative to Scale and Intensity of Assessment (after R. Dan Smith, U.S. Army Corps of Engineers, unpublished).

The intent of all rapid assessment methods is to evaluate the complex ecologic condition of a natural ecosystem using a finite set of observable field indicators and to express the relative condition of a particular site in a manner that informs ecosystem management. It is also important to remember that a RAM is intended to fill a particular niche in the wide range of needs for biological assessments; no one tool is likely to be the silver bullet to address needs for both quick screening and comprehensive evaluation (Smith *et al.,* 1995; Stein and Ambrose, 1998). Rapid assessment methods are best used within a comprehensive program of wetland assessment, including resource inventories, intensive qualitative monitoring, and special studies. They can be used to extend the geographic application of understanding derived from expensive and geographically restrictive special studies and intensive assessments. In this way, RAMs can make comprehensive ambient monitoring and basic assessment of projects affordable.

Rapid assessment methods in general are based on the assumption that the ecological condition of wetlands will vary along a stressor gradient and that the resultant state can be evaluated based on a core set of visible field metrics. The term metric as used here refers to the qualitative measurement of a specific biological or physical attribute that reflects some element of ecological condition. Since these metrics are not quantitative, their use involves a large degree of professional judgment. Development of RAM metrics involves the translation of the thought processes used to make professional judgments into a standard set of diagnostic questions with a set of possible answers that reflect a range in wetland conditions.

Rapid methods generally meet three criteria (Fennessy *et al.,* 2004): the method measures condition as the ability of a wetland to support and maintain its complexity and capacity for self-organization with respect to species composition, physicochemical characteristics, and functional processes, relative to ideal, historical, or existing wetlands of a similar class without human alteration; The method is truly rapid (i.e., it requires two people no more than one-half day of field work plus one-half day of subsequent data analysis); and the method is a site assessment based on expert field observations and not just inferred from surrounding landscape characteristics, existing reports, remote sensing, or other image analysis.

While there is a body of literature summarizing wetland assessment methods (Bartoldus, 1999; Fennessy *et al.,* 2004; and others), there is no comprehensive guide to RAM development that defines the steps, identifies the important issues and considerations in each step, and discusses the tradeoffs of various options or approaches. This paper is intended to provide some guidance for RAM development by outlining the key technical considerations, options, and ramifications that must be considered, based on ongoing work to develop CRAM. A statewide interdisciplinary team of scientists and key state and federal agency staff (the Core Team) led this effort. The Core Team organized the RAM development process into six stages: (1) organize RAM development by identifying the intended applications, assessment endpoints, and geographic scope and forming the RAM development team; (2) build a scientific foundation for the method; (3) assemble the method as a systems of attributes and metrics; (4) verify the method; (5) calibrate and validate the method; and (6) implement the method through outreach and training of intended users. These stages, along with guiding questions common to each, are summarized in Table 1 and discussed in detail in the following sections. As of the publication of this paper, CRAM development was in the calibration phase, with activities planned to eventually implement CRAM through agency outreach, training, and demonstration of CRAM at the watershed scale.

TABLE 1. A Summary of Six Basic Stages and Key Questions in the Development of a Wetland Rapid Assessment Method.

Stage	Elements	Questions
Organize RAM Development	Assemble RAM Development Team	• What range of expertise is needed, given intended application and geographic scope of RAM? • Who are the targeted users, and how should they be included development process?
	Identify RAM Target Applications	• Are there one or more intended applications of the RAM? • How will intended application influence the type of method and specific metrics selected?
	Identify Assessment Endpoints	• What are the tradeoffs between choosing a single integrative assessment endpoint (i.e., ecological condition) versus several assessment endpoints (i.e., multiple wetland functions)?
	Identify RAM Geographic Scope	• How does broadening the method geographic scope affect method sensitivity and cost of method development?
Build a Scientific Foundation for the RAM Development	Review Existing Methods	• What existing literature, methods, and guidance are useful or relevant for RAM development? • What attributes or metrics are commonly used in RAMs? • What are common pitfalls in RAM development or implementation that can be avoided?
	Identify Wetlands Classes	• Should the RAM have a single method applicable to all wetland types, focus on one wetland class, or customize the method by wetland class? • How does increasing the number of wetland classes affect sensitivity of the RAM versus cost to develop and calibrate method for each class? • If multiple wetlands classes will be used, will attributes and metrics be standardized across wetland classes? • What wetland classification system will be used and are mapping data available to support its use?
	Specify Conceptual Models	• What are the kinds of wetland structure that relate to the assessment endpoint? • Is the relationship between stress and condition or function articulated? • What are the assumptions underlying the use of the conceptual models constructed?
Assemble the Method	Select RAMs Attributes and Metrics	• Should RAM metrics be selected to measure condition, stress, or both? • Should RAM metrics be readily visible or require some degree of quantification? • What is the level of expertise that will be required to use RAM, and what does it imply for the selection of metrics? • What are the tradeoffs in using metrics that are customized for a wetland class or standardized across wetland classes?
	Defining the Reference Network	• How will reference be defined? • What are the tradeoffs of using a culturally unaltered versus best attainable reference standard condition?
	Creating Narrative Ratings and Scales	• What are the implications of using ordinal versus continuous data for aggregating results into a final score?
	Determine How Assessment Area Boundary Will Be Determined	• Can the definition of assessment area be applied with consistency and ease during RAM use? • Given the definition of assessment area, how ecologically meaningful are the results of the assessment? • Given the definition of the assessment area, how will the results contribute to addressing the management information needs?

TABLE 1. A Summary of Six Basic Stages and Key Questions in the Development of a Wetland Rapid Assessment Method (cont'd).

Stage	Elements	Questions
Verification	Verify That RAM Is Measuring Assessment Endpoint As Intended	• Are RAM attributes and metrics comprehensive and appropriate? • Is RAM sensitive to a disturbance gradient? • Does RAM produce repeatable results among different practitioners? • How should sites be selected to so that they represent a range of wetland condition? • What steps can be taken to provide end users with an opportunity for feedback before method calibration?
Calibration and Validation	Determine That Method Is Scientifically Sound Through Calibration and Validation	• Does RAM correlate to more intensive measures of condition? • What metrics and data sources should be used as independent variables for calibration and validation? • What are the tradeoffs of using existing data versus collecting new data for calibration and validation?
Outreach and Implementation	Conduct Outreach	• Has a clear system been established for regular communication, update, and feedback? • Is additional guidance (i.e., beyond user's manual) required for specific applications? • How can pilot projects be used to demonstrate and stimulate interest in RAM applications?
	Manage Information	• How will data collected from different sources be compiled? • What are the tradeoffs of central versus distributed data management? • How can issues of quality control during data collection, management, and delivery be minimized? • How will data be made available to the public?
	Train Users	• Who are the intended users of the RAM, and are they currently involved in its development? • What kinds of materials will be most useful to these groups? • Are there systems in place to assess the repeatability of results among RAM users?

STAGE 1: FORM RAM DEVELOPMENT TEAM AND IDENTIFY INTENDED APPLICATIONS

The first stage in developing a RAM involves forming appropriate teams to advise and review the process and its products, identifying the intended applications and assessment endpoints of the RAM, and defining its geographic scope.

Assembling a RAM Development Team

The primary purpose of the RAM development team is to advise and review the developmental process and its technical products. It is essential that the core of the effort is technical and that technical members take the lead in forming the development team. Care should be taken to choose members who can collectively represent a range of expertise in wetland hydrology, geomorphology, botany, wildlife ecology, and soils of all wetlands within the geographic scope of the method. The team should also be composed of individuals from the targeted end user community who have detailed understanding of the institutional, budgetary, and political issues entailed in implementing the method. This is critical in order to assure that the method meets the needs of these targeted end users.

One important consideration in choosing the development team is balancing the need to encourage broad participation in the development process with promoting an efficient process for RAM development. To address this issue in California, project leads from each region worked together to assemble a statewide CRAM Core Team consisting of experts from key state and federal agencies, universities, and nonprofit research institutes. In addition, Regional Teams were formed that were more broadly inclusive and composed of staff from county, state, and federal agencies, wetland managers, representatives from nonprofit organizations, and biological consultants. The Core Team was primarily responsible for the overall process of RAM development and coordination on issues of implementation. It also served as a mechanism to share technical expertise and experience among the regions. The Regional Teams were responsible for providing perspective on the regional ecology, feedback on initial method development, and to assist in CRAM verification, calibration, and training materials preparation. To streamline CRAM development and assure that it could be vetted within state agencies, the Core Team assumed responsibility for balancing the needs of the various regions versus the entire state and retained the right to make final decisions on all issues affecting method development.

Identifying the Intended Applications of RAM

The breadth of the intended application of a RAM influences development time and effort and the ease of integration into monitoring programs. Some RAMs were initially created for a single purpose; for example, the Ohio Rapid Assessment Method (ORAM) was created to prioritize wetlands for statutory protection (Mack, 2001a). Other methods are developed for multiple applications. Advantages and disadvantages exist with either approach. Methods developed for single applications are, in general, easier to develop because there is no need to balance the assessment approach to fit multiple end users. These methods also tend to be application ready and thus tend to be implemented more quickly. The challenge lies in attempting to adapt the methods for other uses that may require subsequent modifications, thus adding to the cost and time of method development (Fennessy *et al.,* 2004).

Methods developed for multiple applications involve discussions with greater numbers of potential end users, thus increasing the initial development time and cost. In addition, attempting to address the assessment needs of multiple target end users incurs the risk that the RAM that would not perform well for any one use. Despite these shortcomings, the great advantage of creating a method for multiple applications is that a consistent, standardized method used in a variety of applications can enhance the consistency of wetland assessment in wetland management and regulatory programs and projects. Over time, these methods evolve and tend to become more robust because of ample feedback and opportunities for calibration and validation through a larger end user community.

How the RAM will be used also affects the level of precision and hence the stringency of associated quality control procedures. Knowing whether a wetland falls into a category of good, fair, or poor condition requires far less precision than knowing if the wetland meets permit requirements for ecological function – unless crossing the threshold between categories triggers expensive and risky management actions. More precise RAMs require more expertise, time, and cost to develop and implement. As one moves along the continuum of information needs from inexpensive and imprecise to expensive and very precise, RAMs become less appropriate than more intensive, quantitative methods.

The CRAM was developed on behalf of the state of California and several key regional partnerships within the state. These regional partnerships are composed of the major state and federal agencies responsible for wetland and riparian conservation, restoration, and wetland and water quality regulation and management. The primary impetus for CRAM development was the shared need of all these agencies for a cost effective method for ambient wetland monitoring within and among regions. However, it became clear that several key partners needed a RAM to track restoration performance, assess potential project impacts, and evaluate compliance in a regulatory setting. Implementation of CRAM for each of these intended applications (ambient monitoring, potential project impacts, compliance monitoring, etc.) will require more specific guidance on using CRAM; individual applications are not discussed in the present paper. The intended applications of CRAM have been continuously considered throughout method development, verification, and calibration and have greatly influenced the choice of metrics.

Identifying Assessment Endpoints

Wetland RAMs can assess functions, values, stressors, and other drivers of wetland conditions. These are termed assessment endpoints (Hruby, 1999). In developing a RAM, it is important to clearly articulate the assessment endpoint before RAM development begins. This is because ultimately, through the process of initial method development and calibration, the method will be optimized for that endpoint.

The choice of assessment endpoint will mainly depend on the purposes of the RAM. Most wetland RAMs are designed to assess condition or function. Condition assessments tend to focus on the integrity or health of the area being assessed (e.g., Ohio Environmental Protection Agency's ORAM) (Mack, 2001a). In contrast, functional assessments such as HGM (Smith *et al.,* 1995) tend to focus on performance of ecological processes or support of societal values (e.g., carbon cycling, surface water storage, food chain support, recreation). Although condition assessments and functional assessments may use similar field indicators, the manner in which they are evaluated and the endpoint of the assessment are obviously quite different. In either case, difficulty exists when a comprehensive set of endpoints is targeted in a single method. Such was the case with the Wetland Evaluation Technique (WET) (Adamus *et al.,* 1987). Although WET represented the critical first steps toward a structured wetland assessment, it was an attempt to evaluate both the capacity and opportunity of any wetland in the United States to perform 11 functions. Because of the breadth, geographic scope, and sheer number of functions targeted, the method was not sensitive to a gradient in function.

In California, the Core and Regional Teams agreed that the method should report on a suite of physical and biological metrics that assessed the overall ecological condition of the wetland. It is assumed that the ecological condition of the wetland relates to its ability to support characteristic flora and fauna (i.e., aquatic life use). The relationship between condition and ability to support aquatic life is an important link for the intended applications of CRAM by state agencies.

Defining the Geographic Scope

Defining the geographical scope of the RAM establishes the range of reference states that will be used for method development and calibration (Smith *et al.*, 1995). In general, multipurpose RAMs and those designed to address broad questions will have greater geographic scopes. Tradeoffs exist in the size of the geographic scope of the RAM, the sensitivity of the method, and the cost of calibrating it. Methods with a more narrowly defined geographic scope are easier and faster to develop, typically incur lower development costs, and are more sensitive in measuring the range of reference states. However, they have limited geographic applicability, so comparisons across regions or watersheds outside of the geographic scope will not be valid. Similar costs must be incurred again if a RAM must be developed for another region. This is a strong disincentive for developing a narrowly focused RAM.

As is the case for RAMs with multiple intended applications, a RAM developed for several ecoregions or an entire state provides a common language for reporting on resource condition, thus enhancing the capacity to report on statewide status and trends and expanding the application to regional/statewide wetland conservation, management, and regulatory efforts. For this reason, a decision was made in California to attempt to create a method that could eventually be applicable to wetlands, streams, and riparian habitats throughout the state. This broad scope presents many technical and institutional challenges. The spatial variability in climate, topography, hydrology, and biotic communities of the state's ecoregions produces a tremendous range in wetland structure and function (Ferren *et al.,* 1996). To address this natural complexity, the general framework of CRAM was developed to be consistent across wetland types and regions yet allow for customization to address special characteristics of some wetland types.

STAGE 2: BUILD A SCIENTIFIC FOUNDATION FOR RAM DEVELOPMENT

As with any scientific assessment method, it is important that a RAM be built through drawing upon the fundamentals of wetland science. Building a scientific foundation for a RAM consists of: reviewing existing methods and published literature; identifying target wetland types or class(es); and drafting conceptual models that describe the scientific foundation for the method, including any assumptions involved.

Review of Existing Methods

The importance of conducting an extensive literature review of existing methods and contacting individuals responsible for the development of rapid methods in other states cannot be overstated. The review of each method should focus on the assessment endpoint and how it relates to the intended geographic scope and application(s) of the method, what assumptions and models underlie the approach, and how metrics were written and assembled into an assessment framework. Such reviews can considerably shorten the time and cost involved in producing a final method. Several recent comprehensive reviews of rapid assessment methods serve as good starting points for this process. A few of these are: Bartoldus (1999), which provides a general review of wetland assessment procedures; Fennessy *et al.* (2004), which provides a comprehensive review of wetland RAMs and a helpful discussion of common pitfalls to avoid; and Danielson and Hoskins (USEPA, 2003), which compiles a series of case studies presenting different approaches to wetland biological assessments in each state along with contact information for each lead investigator. Although the review process is most critical during the early stages of RAM development, it should continue throughout the development process.

In California, CRAM incorporated concepts and approaches from the Washington State Wetland Rating System (WADOE, 1993), the Montana Rapid Assessment Method (Berglund, 1999, unpublished report), ORAM (Mack, 2001), and the Penn State Stressor Checklist (Brooks *et al.,* 2002). The California RAM also draws on concepts from the stream bioassessment and wildlife assessment procedures of the California Department of Fish and Game, the different wetland compliance assessment methods of the State Water Resources Control Board, the Releve Method of the California Native Plant Society (Sawyer and Keeler-Wolf, 1995), and regional HGM guidebooks. The extensive literature review allowed CRAM authors to avoid reinventing the wheel by building on existing assessment approaches and choosing and/or modifying metrics that were appropriate for California wetlands and riparian areas.

Identifying Wetland Classes

An important next step is to identify the target wetland class(es) and determine whether the method under development will be customized to accommodate differences in wetland structure or function by wetland class. Key questions are: Should the RAM focus on a single wetland class, have a single method applicable to all wetland types, or customize the method to accommodate several different wetland classes? How does increasing the number of wetland classes affect sensitivity of the RAM relative to the cost to develop and calibrate method for each class? If multiple wetlands classes will be used, will attributes and metrics be standardized across wetland classes? Will a new wetland classification system will be developed or an existing one be used, and are mapping data available to support its use?

A tendency exists to create a method that is customized for multiple wetland classes for several reasons. Differentiating among multiple classes enhances sensitivity of method to detect a gradient in conditions within each wetland type; different classes may be subject to different stressors or may vary in their susceptibility to stressors; and metrics representing condition may be different by wetland class. Fennessy *et al.* (2004) warn of the pitfall of creating a different version of the method for each wetland class because, they note, each version will have to be separately calibrated. In addition, some wetlands or mosaics of wetlands are not easily classified without making the classification very detailed. They note that single robust methods can accommodate multiple wetland classes if the data are stratified *a posteriori* to establish the range of reference states by wetland class and if metrics are weighted according to wetland type (Fennessy *et al.,* 2004).

Several existing RAMs have different versions of the RAM developed for separate wetland classes (e.g., Washington State Western Rating System and many HGM guidebooks). While recognizing that cost and development time are greatly increased, having multiple RAM versions for separate wetland classes allows a better customization of metrics. Metrics can be worded to cue the practitioner into specific field indicators of condition relevant for that metric for a particular wetland class, thus making the assignment of a score less dependent on the level of expertise of the practitioner. It also increases the objectivity and precision of the method. However, the tradeoffs associated with customization for specific wetland classes must be carefully weighed in light of the management information needs, intended applications, and available funding.

Once target wetland types have been selected, a suitable wetland classification system must be chosen that provides definitions and guidance for its use. The classification system can be entirely created expressly for the new RAM, an existing system can be adopted in its entirety, or a hybrid system can be developed. Rapid assessment methods that are narrowly focused and locally applied may benefit from a unique classification that reflects fine-grained variations among wetlands. This will help increase the precision of the RAM. For example, the National Park Service at Point Reyes National Seashore found that CRAM could not detect differences among very high quality wetlands that corresponded to differences in wetland history or present management actions. The users modified CRAM to reflect these locally important differences. In most cases, however, an existing or hybrid system of classification will be most helpful. Adopting or modifying an existing system will save time in RAM development. Maps or inventories of wetlands based on existing classification systems can serve as sample frames for the RAM. In addition, by adopting an existing classification system, the RAM results are more likely to complement or contribute to existing assessments.

In California, there was a general desire to have a single method that would be ultimately applicable to the entire state, with metrics customized by region and wetland class. The Core Team initially debated using the classification system of either the National Wetlands Inventory (NWI) (Cowardin *et al.,* 1979) or that of the HGM (Brinson, 1993). The HGM classes were chosen based on the rationale that they better separate major differences in wetland structure than the standard Cowardin *et al.* (1979) Systems and Classes do. Recognizing that increasing the number of wetland classes would dramatically increase method development time and cost, the Core Team also considered that aggregating a variety of wetland geomorphic types into a single class would inevitably reduce the sensitivity of the method to detect a gradient in wetland conditions. Given the range in climate, physiographic setting, hydrology, and biotic community types, the Core Team originally decided to group wetlands into six hydrogeomorphic (HGM) classes: estuarine, coastal lagoons, riverine, depressional, seep/spring/slope wetlands, and lacustrine wetlands (Brinson, 1993). The Core Team later decided to split vernal pools out from the depressional wetland class because of the special features of these wetlands, thus resulting in a total of seven classes.

Specify Conceptual Models and Underlying Assumptions

It is essential that the RAM developers share an understanding about why they think the RAM will work and to explicitly state the assumptions that underlie their common thinking. To achieve this understanding, the developmental team should construct one or more conceptual models relating key elements of wetland structure or form to the assessment endpoint. These models will reveal gaps in basic knowledge about wetlands and will highlight the assumptions used to bridge the gaps. The models will also serve as templates for selecting or developing the diagnostic indicators of condition or function that comprise the RAM.

These conceptual models do not need to be exhaustive or complex. However, they should identify the kinds of wetland structure or form that can be described using visible field indicators. It is helpful to start by listing the major structural elements of one type of wetland and then enlarge the list until all types of wetlands for the RAM seem fairly well represented. Most wetlands will share many of the same structural elements. But the forms they take will usually vary among wetland types. The list of structural elements can therefore be annotated with the distinguishing characteristics. For example, vegetation is a common element among most wetlands. But its structure obviously varies in estuarine, depressional, and riverine wetlands. Once the elements and their various forms have been identified, their relationship to the assessment endpoint (i.e., condition or ecological function) can be surmised.

In the development of CRAM conceptual models, the Core Team stated that the ecological integrity or condition of a wetland can be described as the sum of its hydrology, structure of its physical components and biological communities, and landscape context in which the wetland resides. In riverine wetlands and associated riparian habitat, hydrology included the source of water, hydroperiod, and connectivity to the adjacent upstream and downstream areas and the adjacent floodplain. Its physical structure included the diversity and topographic complexity of geomorphic features found in the channel, bank material, and floodplain. Its biological structure includes the diversity of biological communities and the composition, vertical and horizontal structure of vegetation communities, and organic matter composition of the soils. Elements of faunal structure such as riparian birds, amphibians, invertebrates, or mammals were not specifically detailed. Instead, a conceptual link was established between the condition of the fundamental structural elements of the wetland and the support of these communities. Landscape context included elements such as aquatic connectivity and condition and size of the buffer surrounding the wetland. A separate conceptual model was used to explain how a spatial hierarchy of processes, including anthropogenic stress and natural disturbance, are assumed to control the wetland structural elements and impact wetland condition.

From these conceptual models, narrative descriptions of the distinguishing structural elements and forms of different wetland classes were developed. This helped to test the efficacy of the wetland classification and revealed which structural elements and forms were most common. As will be seen in the discussion of Stage 3, many of the CRAM attributes, metrics, and their narrative ratings represent the common structural elements and forms that were revealed by the models. These models were later used to develop a checklist of wetland stressors.

The conceptual models for a RAM will reveal many uncertainties and related assumptions about how wetlands work. These assumptions should be explicitly stated. They indicate the limitations of the RAM and disclose the biases of the development team. The ability of the development team to support the assumptions with data and literature will help defend the RAM. The most important assumptions will be those that cannot be supported or avoided. For example, CRAM assumes that ecological functions follow from physical structure and form, where vegetation is a structural element and hydroperiod contributes to form. This assumption is well supported by existing wetland science. The method also assumes that the condition of a wetland improves as structural complexity and size of wetland increase. These assumptions can be reasonably well supported for some wetlands but not all. The less tenable assumptions should be recast as hypotheses and prioritized for research to strengthen the foundation of the RAM.

STAGE 3: ASSEMBLE THE METHOD

Many RAMs consist of physical and biological features, or attributes, that are common to all wetlands. As the method is assembled, these attributes are selected to be consistent with the conceptual models developed (Stage 2), ensuring that the attributes are common to all wetlands in the geographic scope. Metrics are then developed that represent the major aspects of each attribute. These metrics consist of narrative ratings and associated scores that represent the range of conditions found within the geographic scope. Inherent in this process is the definition of the range of reference states captured by the gradient of conditions within the geographic scope of the method. Assembling the RAM means not only choosing attributes and developing metrics, but also organizing these components into a single assessment framework. It also involves setting rules for defining assessment areas, which determine how the RAM is applied in the field. These issues relevant to Stage 3 are discussed below.

Selecting RAM Attributes and Metrics

Once assessment endpoints are identified, the measures of those endpoints must be selected. In their review of wetland RAMs, Fennessy *et al.* (2004) found that four universal features, or attributes, of wetland condition were commonly chosen: hydrology, soils or substrate, vegetation, and landscape setting. These universal attributes serve as the organizing framework (conceptual model) for metrics that address specific assessment questions. Fennessy *et al.* (2004) summarized the metrics commonly used in RAMs; this list demonstrates a convergence of thought behind the most appropriate metrics that should be included in a RAM and is a good starting point for those embarking on RAM development.

During the development of CRAM, the Core Team used four universal wetland attributes as a foundation for the method that are similar to those identified in Fennessy *et al.* (2004): landscape context, hydrology, physical structure, and biotic structure. Within each attribute, several metrics were defined (Table 2). These attributes and metrics reflect the common, visible characteristics of all wetlands in all regions of California that also directly influence the key wetland functions. For the seven CRAM wetland classes, most metrics were standardized in a manner capable of accommodating all classes. Where necessary, metric descriptions and narrative ratings were tailored to the unique characteristics of each class. One issue of contention within the Core Team was whether metric selection should include direct measures of wildlife use, since wildlife use is generally an excellent indicator of ecological condition. While recognized as an important measure of wetland condition, wildlife use, such as can be measured through direct sightings or sample collection, is difficult to determine reliably in a rapid assessment context. Several rapid methods, such as Florida's WRAP have included metrics to directly assess wildlife use (Miller and Gunsalus, 1999). For CRAM, a decision was made to infer wildlife support from the basic physical and biotic structure of the wetlands.

Key issues concerning the selection of metrics include: whether metrics should be limited to indicators of anthropogenic and natural stressors or wetland condition or both; if metrics should be based on readily visible characteristics or something that must be measured quantitatively; the inherent level of expertise associated with assessing certain metrics in the field; and whether metrics should be sensitive to seasonal or interannual variations in site condition.

TABLE 2. California Rapid Assessment Method Wetland Attributes and Component Metrics and Their Relationship to Assessment Endpoint.

Assessment Endpoint	Attributes	Metrics
Wetland Ecological Condition	Landscape Context	Habitat Connectivity Percent of Wetland With Buffer Average Buffer Width Buffer Condition
	Hydrology	Sources of Water Hydroperiod Hydrologic Connectivity
	Physical Structure	Physical Patch Types Topographic Complexity
	Biotic Structure	Organic Matter Accumulation Biotic Patch Types Vertical Structure Interspersion and Zonation Native Plant Species Richness Percent Invasive Plant Species

Many existing RAMs use metrics that are measures of stress in lieu of, or in combination with, those that measure wetland condition. For example, the Penn State method consists uniquely of a checklist of stressors on wetlands, while the Ohio Environmental Protection Agency's ORAM method combines both metrics of stress and condition (Mack, 2001a; Brooks *et al.,* 2002). While many metrics of stress correlate with condition (i.e., surrounding land use) (Brooks *et al.,* 2004), one difficulty in using them as a proxy for wetland condition is that doing so ignores potential impacts of onsite management of these stressors, such as best management practices. For this reason, the CRAM Core Team elected to remove any metric that was indicative of anthropogenic or natural stressors from those measuring condition. To capture information about stress on the wetland, a separate stressor checklist was developed, bearing a parallel construction with the CRAM condition attributes (i.e., landscape context, hydrology, physical, and biotic structure). Within each stressor attribute category, a checklist of multiple potential stressor types was listed. These are scored independently from the CRAM condition attributes and are only used to suggest possible explanations for the resulting wetland score.

Metrics based on qualitative, visual observation were selected whenever possible to enhance the rapid nature of the method. Some metrics, such as Interspersion and Zonation of vegetation, lend themselves to visual observation and a graphical representation of the gradient in conditions such that no textual rating was necessary (Figure 2). For many metrics, however, a text-based narrative rating was necessary (i.e., the Topographic Complexity metric) (Table 3). Other metrics such as Biotic Patch Richness, Native Plant Species Richness, and Percent Invasive Plant Species required a more quantitative method of observation because of the complexity of what was being observed as well as potential problems with observer bias (e.g., Biotic Patch Richness) (Figure 3). Also important in the selection of the metrics were implications about the level of expertise required to conduct a CRAM assessment. The tradeoffs are clear: metrics that require greater expertise tend to perform better and produce more reproducible scores. However, requiring a higher skill level could eliminate some potential RAM applications. For CRAM, the Core Team decided that as a general rule of thumb, the end-user would be required to possess at a minimum the skills and knowledge equivalent to that required to perform a U.S. Army Corps of Engineers wetland delineation.

In general, it is recommended that metrics that are sensitive to seasonal or interannual variation be avoided whenever possible. However, given the highly variable nature of wetland physical and biological structure, this is extremely difficult. To address this issue, guidance for CRAM implementation stresses that CRAM is best conducted within an established temporal window. In some cases, experts may use field observations from outside the window to infer what the wetland would be like within the window.

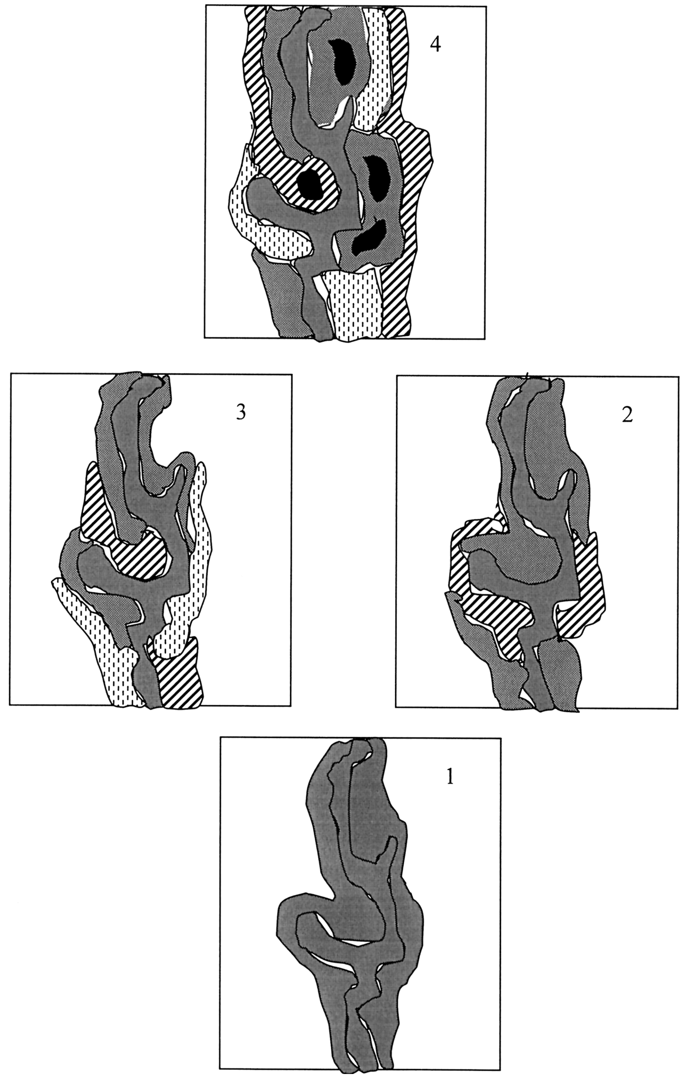

Figure 2. CRAM Metric Interpersion and Zonation, Adapted From Western Washington State Rating System (WADOE, 1993) and ORAM Version 5.0 (Mack, 2001a), Uses a Graphical Depiction to Illustrate a Gradient in Habitat Interspersion. Each pattern represents a different plant zone; numbers represent numerical score.

TABLE 3. California Rapid Assessment Method Narrative Rating and Scores for Topographic Complexity.

Rating	Alternative States
4	Assessment area (AA) as viewed along cross sections has a variety of slopes or elevations that are characterized by different moisture gradients. Each subslope contains physical patch types or features that contribute to irregularity in height, edges, or surface of the AA and to complex topography overall.
3	AA has a variety of slopes or elevations that are characterized by different moisture gradients; however, each subslope lacks many physical patch types such that the slopes or elevation zones tend to be regular and uniform.
2	AA has a single, uniform slope or elevation. However, that slope or elevation has a variety of physical patch types.
1	AA has a single, uniform slope or elevation with few physical patch types.

Biotic Patch Type (check for presence)	**Check if Present**	**Low-Gradient Riverine**	**High-Gradient Riverine**	**Estuarine**	**Lagoon**	**Depressional**	**Seep or Spring,**	**Lacustrine**
Fully submerged aquatic bed (e.g., *Vallisneria, Hydrilla, Zostera*)		1	1	1	1	1	0	1
Diatom felt or mat		1	1	1	1	1	1	1
Emergent dicot beds (e.g., *Polygonum, Plantago, Plagiobothrys*)		1	1	1	1	1	1	1
Free-floating bed (e.g., *Lemna, Azolla*)		1	0	0	0	(1)	0	1
Ground cover herbs and forbs (e.g., *Ranunculus, Potentilla, Trifolium, Sagittaria* (< 10 cm tall)		1	1	1	1	1	1	1
Macroalgal Mat/Periphyton		1	1	1	1	1	1	1
Medium emergent monocot beds (e.g. *Sparganium, Phalaris*, medium-size *Scirpus*) (35 cm to 1.5 m tall)		1	1	1	1	1	1	1
Moss bed		1	1	1	1	1	1	1
Rooted-floating bed (e.g., *Ruppia, Hydrocotyle, Nymphaea*)		1	0	1	1	1	0	1
Shellfish bed		0	0	1	1	0	0	1
Short deciduous trees (e.g., *Sambucus, Salix, Cornus,* young *Alnus*, young *Plantanus,* young *Acer* (< 6 m tall)		1	1	1	1	1	1	1
Short nondeciduous trees (e.g., *Tamarix*, young *Picea*, young *Pinus* (< 6 m tall)		1	1	1	1	1	1	1
Short emergent monocot beds (e.g., *Distichlis, Eleocharis, short Juncus*) (< 35 cm tall)		1	1	1	1	1	1	1
Shrubs (e.g., *Baccharis, Grindelia, Ribes, Rubus*)		1	1	1	1	1	1	1
Standing tree snags		1	1	1	1	1	1	1
Submergent bed (e.g., *Potamogeton, Myriophyllum)*		1	0	1	1	1	0	1
Tall deciduous trees (e.g., old *Acer*, old *Plantanus*, old *Alnus* (> 6 m tall)		1	1	0	1	1	1	1
Tall herbs and forbs and ferns (e.g., *Lythrum, Conium, Berula, Delphinium, Woodwardia* (> 10 cm tall)		1	1	1	1	1	1	1
Tall emergent monocot beds (e.g., *Typha, Arundo,* tall *Scirpus*) (> 1.5 m tall)		1	1	1	1	1	1	1
Tall nondeciduous trees (e.g., old *Picea*, old *Pinus* (> 6 m tall)		1	1	0	1	1	1	1
Number of Patch Types Observed								
Number of Expected Patch Types per Wetland Class		19	16	17	19	19 (18)	15	20
Percent of Expected Patch Types Observed in AA: ________								

Score	**High-gradient Riverine**	**Depressional**	**Seep and Spring**	**All Other Wetland Classes**
4	> 75%	> 56%	> 60%	> 60%
3	67 - 75%	48 - 56%	58 - 60%	51 - 60%
2	57 - 66%	22 - 47%	54 - 57%	38 - 50%
1	< 56%	< 21%	< 53%	< 37%

Figure 3. Rating System for Biotic Patch Richness Metric Including a Checklist of Biotic Patch Types by Wetland Class and a Rating Table for Determination of Metric Score Based on Percentage of Expected Patch Types.

Having this ability means that an assessor can infer the status of wetlands for the past growing season based on its appearance at other times of the same or subsequent year. This ability can only be gained though abundant experience.

Metric Development: Defining the Reference Network

One important element of metric development is definition of the standard of comparison that defines the highest and lowest levels of potential or expected wetland condition. This standard of comparison is commonly referred to as a reference, however, the concept of reference is more accurately defined as a range of conditions that can be correlated with a known set of stressors. The highest point on this reference continuum is then termed reference standard condition. The collection of sites or theoretical states that represent a gradient in conditions is referred to as the reference network. To the extent possible, the reference conditions should be represented by actual wetlands.

Reference standard condition can be defined in one of two ways. The first is often termed culturally unaltered and implies a state that existed prior to grazing, agriculture, fire suppression, land development, water resource management, flood control, or other human management activities. An alternative approach to defining reference standard condition is termed best attainable condition. It refers to highest possible state that may exist given permanent or semipermanent constraints on the landscape, such as major dams, urban centers, or flood control facilities.

The manner in which reference standard condition is defined greatly impacts the structure and development of a RAM. Use of the absolute culturally unaltered condition allows for a consistent reference standard over a large, diverse geographic area. However, direct measurement of reference standard conditions are typically not possible and must be inferred. The relative standard obtained via use of best attainable conditions allows direct measurement of reference standard condition but typically does not produce consistently scaled metrics across broad areas.

Because the goal of CRAM was to have a consistent method for all wetlands and riparian areas in California, the culturally unaltered condition was chosen as the approach to defining reference standard condition. Use of this approach necessitates that assessment metrics are developed and scaled relative to theoretically optimum states that would have occurred in the absence of substantial human influence. The preliminary scaling must then be calibrated by comparing metric scores at a range of sites subject to various amounts of disturbance (i.e., natural or anthropogenic stressors) to direct measures of the assessment endpoint. In the case of CRAM, this assessment endpoint is the capacity to support wetland dependent species. A RAM developed in this manner cannot be used with confidence until calibration occurs. However, the resulting method can be made more robust because the narrative ratings and scales can be refined iteratively with additional data over multiple years (Mack, 2001a). This approach is fundamentally different from the approach used for the HGM, in which ratings are developed based on data collected at a range of reference sites subject to varying degrees of disturbance. In the HGM approach, the reference standard condition is defined as the best attainable condition based on data collected from the most pristine reference sites in the study area (Smith *et al.,* 1995). This approach reduces the amount of effort necessary for calibration but may limit the geographic applicability of the assessment tool.

Metric Development: Creating Narrative Ratings and Scales

The basic concept supporting the creation of narrative ratings and scores is that each metric is scaled along a gradient reflecting the condition of the wetland relative to a variety of stressors acting at different spatial scales within the wetland and the surrounding landscape. Two key concepts must be addressed at this step in the process: the development of clear and mutually exclusive descriptions for metric narrative ratings; and whether the metric scaling will be ordinal or interval and the implications of this choice for aggregating (i.e., adding, subtracting, multiplying, or dividing) the results into a final condition score.

Clear and mutually exclusive descriptions for the narrative ratings of a metric are important to ensure method sensitivity and repeatability and to minimize observer error. The descriptions of these narrative ratings can be narratives, diagrams and schematics, or combinations of these. Ample field experience is required to envision the possible states for each metric. This is easier if different narrative ratings are envisioned for different wetlands classes. Developing descriptions of ratings that apply equally well to multiple classes of wetlands can be very challenging and perhaps not useful. Having developed one set of attributes and metrics for almost all wetland classes in California, the CRAM development team attempted to develop a similarly universal set of descriptions of alternative states. Through many iterations involving field tests by the Regional Teams and review by the Core Team, a mixture of universal and class-specific narrative ratings for each metric was developed.

For any given metric, the appropriate number of descriptions of intermediate states will depend on many factors. A larger number of intermediate states tends to be apparent in the field for metrics that have a broader overall range of states. Experts tend to see more intermediate states for the wetlands they know best. However, as alternative states are added to a set, the differences among them decrease, and the repeatability or consistency of the method among users also tends to decrease. For CRAM, the number of intermediate states was reduced to one or two for each metric. Thus, each metric is represented by only three or four narrative rating categories.

After choosing either the culturally unaltered or best attainable reference standard condition (see above), narrative ratings are developed for each metric. For CRAM, which is based on a culturally unaltered reference, it was helpful to start the descriptions for each metric by describing a well-known intermediate condition and adding descriptions for increasingly extreme states until the full range of conditions was well represented. How to know and describe the best possible narrative rating for each metric was a special concern. In California, a great loss of wetlands has occurred for every wetland class, and essentially all of the remaining wetlands are stressed to some degree. Reference sites for nearly pristine conditions only exist for a few wetland classes in a few ecoregions. Most of these are montane or alpine and do not pertain to the rest of the state. It was therefore not feasible to find examples of the best possible wetlands. The Core and Regional Teams developed descriptions of what they surmised was the best achievable state for each metric based on historical conditions and professional judgment about how wetlands would appear if stressors were removed. For any wetland class, a compilation of the descriptions of the highest quality states for all the metrics thus represents an ideal wetland. Use of highly experienced wetland experts was critical in this process.

A variety of techniques has been employed to help CRAM users rapidly choose among the narrative ratings for each metric. For metrics that focus on the qualitative forms of wetlands, such as the Interspersion/Zonation metric of the Biotic Structure attribute, the narrative ratings were replaced or augmented with simple schematics (Figure 2). For the semiquantitative metrics that focus on structure, such as Biotic Patch Type and Vertical Biotic Structure, the categories are represented by mutually exclusive numerical ranges. For the metrics that are purely qualitative and cannot be illustrated, such as Water Source and Biotic Matter Accumulation, parallel construction of the narrative descriptions enhances their readability as mutually exclusive categories.

Once narrative ratings for each metric have been established, decisions must be made regarding how to assign numerical scores to each category. There are essentially two main approaches: ordinal or interval scales. Ordinal scales rank objects (categories of condition, in the case of a RAM) in order, such as highest, next highest, and lowest condition. Interval scales provide additional information by rating the magnitude of the differences between adjacent categories, such as 100 m, 50 m, and 10 m. Although numbers can be used to represent different levels on either of these scales, the scales differ in the way that the numbers correspond to the underlying wetland condition (Westman, 1985). Mathematical operations that are appropriate for one type of scale may not be appropriate for the other. Conversely, the precision of underlying ecological knowledge or assumption associated with each scale differs.

Ordinal scales provide less resolution and ability to combine metrics but are more easily justified ecologically and mathematically. With an ordinal scale, arithmetic relativity is implied between adjacent ratings within a metric. For example, a rating of A is assumed to be better than a rating of B; however, the magnitude of the difference between the two is not specified. Since the exact mathematical distribution of ratings along an evaluation scale is not defined, the values cannot meaningfully be added, subtracted, multiplied, or divided (Margules and Usher, 1981). Similarly, multiple ordinal metrics should not be aggregated into a grand index (Westman, 1985). The lack of defined proportionality also precludes the use of measures of central tendency, such as means and variances, or the use of traditional statistical methods, such as analysis of variance and t-tests (Goodchild, 1986). However, ordinal scales require only the ability to rank wetlands based on their relative similarity to the desired assessment endpoint without knowing precisely how close the condition is to that endpoint or to the next highest rating category.

Interval scales provide greater resolution than ordinal scales and allow combinations of metrics into overall scores, subject to certain assumptions and verifications. Appropriate use of an interval scale requires either sufficient understanding of the quantitative relationship between different alternative states or the use of a continuous variable that is directly measured (e.g., percent cover by invasive plant species) as the assessment metric. For example, assigning an interval scale to different degrees of stream entrenchment would require knowledge of whether the adverse effects associated with degradation increase in a linear, logarithmic, exponential, or other scale. If an assessment of equivalency is conducted (typically as part of the calibration process), interval scales allow aggregation of individual metrics into an overall score. In other words, in order for metric scores to be meaningfully combined, the ecological difference between a high and low score should be relatively consistent between metrics. Generation of overall indices has the advantage of summarizing large amounts of information about wetland condition into a single index to aid in decision making. The disadvantage of aggregation is that the relative contribution of individual aspects of wetland condition may be obscured.

If one chooses to aggregate, metrics may be aggregated in several ways. The simplest and most common approach is to calculate an arithmetic mean, which assumes that all metrics have an equal weight and contribution to overall wetland condition. In some cases, certain metrics can be given a higher total proportion of the total points to reflect their relative importance in the overall assessment. This approach is not intended to embody underlying ecological processes. Another approach is to construct a set of combination rules that are based on the best available knowledge of ecological relationships and account for synergistic, multiplicative, or offsetting influences of different elements of wetland condition. While this approach is used in many of the HGM guidebooks that have been developed across the United States (Hauer *et al.,* 2002), one could also argue that the notion that metrics should be put through multiplicative or other kinds of combination rules is not merited because the ecological understanding of the relationship between metrics and condition is insufficient.

Metric ratings in CRAM were divided into three or four discrete categories. An effort was made to construct narrative ratings that were unambiguous, mutually exclusive, and equally distributed along the disturbance continuum in order to approximate a linear relationship. To aid in scoring, each metric category was accompanied with a narrative description of wetland condition (an example is provided in Table 2). Within each discrete category, the user will be able to assign an ordinal score from a range of available points, thus allowing the aggregation of metric scores into a final result.

Due to the lack of independent data sources available for calibration of all CRAM metrics, there is a limit to the extent to which scientifically defensible intervals can be established between adjacent ratings for several of the metrics. As such, some metrics have ordinal scaling while others have interval scaling. Although not ideal from a mathematical standpoint, it is a common practice to aggregate scores from metrics based on ordinal scaling (e.g., ORAM, Florida Water Quality Index, Maryland Department of the Environment Method, and others). This is necessary to allow managers to distill the large amounts of information associated with individual metric scores into overall assessments of condition. In generating the CRAM attributes, interval scaling is developed where possible; however, for management purposes, metrics are aggregated to attributes, and attribute to overall scores, regardless of the scaling. The Core Team acknowledges that allowing aggregation of these ordinal scores violates strict mathematic principals underlying the metric scaling, and a caveat is placed in the user's manual cautioning users about the limitations in the use of the aggregate scores. Furthermore, users are advised to retain individual metric scores to allow more refined interpretation of the CRAM output.

Delineating the Assessment Area Boundary

A key consideration in developing a RAM is how to determine the boundary of the wetland area to be assessed, that is, the assessment area (AA). There must be a standard rule set for AA delineation for each wetland class of the RAM. The rule set should be developed for easy and unambiguous application in the field. The AAs should also provide results that pertain directly to intended application(s) of the RAM.

Fennessy *et al.* (2004) provide a detailed discussion of the issues surrounding delineation of the AA, and their observations are summarized here. They note that delineation of the AA is critical because it determines how the data are collected and influences the results of the assessment. Definition of the AA should be considered in light of several questions: Can the definition of the AA be applied with consistency and ease during RAM use? Given the definition of the AA, how ecologically meaningful are the results of the assessment? How will the results contribute to addressing the management information needs (Fennessy *et al.,* 2004)? In light of these considerations, several approaches to delineating the assessment boundary can be illustrated. The New Hampshire Coastal Method samples the entire wetland, but this approach can be difficult when very large wetlands are to be assessed or when the wetland is a complex mosaic of wetland classes (Cook *et al.,* 1993). The draft Delaware Method (Fennessy *et al.,* 2004) uses a 0.5 ha area surrounding a point, an approach that lends itself to the use of this method in probabilistic surveys. Assessments that are based on delineation of jurisdictional wetlands might not be entirely ecologically meaningful or adequate in semiarid or arid areas where many seasonal wetlands and riparian areas fall outside the jurisdictional boundary. These approaches and considerations for final application of the method should be carefully considered in determining how the AA will be delineated.

The rule set to delineate AAs for CRAM was adapted from ORAM (Mack, 2001a). It emphasizes two interrelated factors, homogeneity of hydrological processes and size (Collins *et al.,* 2004). For example, the AAs for riverine and estuarine wetlands are delineated by features in the field that cause significant changes in the quantity, quality, or rate of transport of water or sediment. Such features can include grade control structures, tributaries, dams, levees, weirs, and natural waterfowl. Once a riverine or estuarine AA is delineated, it is assessed as completely as possible within the time constraints. In all cases, there is only one wetland class per AA.

STAGE 4: METHOD VERIFICATION

The goal of verification is to provide a general assessment of whether the draft attributes and metrics established during initial method development are: comprehensive and appropriate; sensitive to a gradient in conditions; able to separate between wetlands at different ends of the reference network (i.e., high condition wetlands from low condition wetlands); and able to foster repeatable results among different practitioners.

To verify CRAM, the three Regional Teams selected 118 wetlands representing high quality and low quality conditions for each of the wetland classes. The *a priori* classification of condition was based on consensus of the experts following their review of pertinent site-specific reports and field visits. Verification was conducted through the Regional Teams, and the regional results were complied into one verification dataset.

Results of the CRAM verification indicated that the choice and general structure of the CRAM metrics were relevant for assessing wetland condition. In addition, the method provided a spread of scores across sites for the various CRAM metrics, and these scores correlated well with general knowledge about the site, including the number of stressors observed. This provided preliminary assurances that the draft metrics were able to distinguish among wetlands of varying condition. Rapidity of the method was also verified: the mean time per site spent conducting CRAM in the field was 2.1 h (S.D. = 0.9), based on field teams of at least two people.

The verification process was most useful because it highlighted areas in which CRAM required refinement. It revealed that some metrics did not perform as well as needed, usually because the narrative statements of alternative conditions were not mutually exclusive, confused stressors with response indicators, or were simply unclear to some users. These shortcomings fostered too much variability in the interpretation of the narrative statements, which in turn led to less consistency among users than needed. Several metrics were therefore substantially revised and subjected to further verification. For each metric, a set of field indicators was added to the user's manual to help the users identify the most suitable rating category. The guidance for delineating the AAs was refined for some wetland classes, mainly to reduce the influence of user bias. The verification process continued for more than a year, with multiple revisions to some metrics and the user's manual, until the development team was satisfied that the metrics were performing as needed. Verification also provided the raw data to start testing the various approaches for scaling the narrative ratings of some metrics. For example, for each wetland class, the verification data were used to determine the number of biotic patch types that should be expected in high quality versus low quality wetlands.

STAGE 5: METHOD CALIBRATION AND VALIDATION

As of the writing of this paper, CRAM was being calibrated for estuarine and riverine wetlands. The following section provides preliminary thoughts on the calibration and validation phases, without the benefit of experiencing them in their entirety.

The goals of RAM calibration and validation are different, and as such, they represent distinct phases in RAM development. In both calibration and validation, the concept is to determine whether RAM metric, attribute, and overall index scores are good predictors of wetland condition, as measured against the results of more intensive measures of wetland condition. These more intensive measures can include, for example, bird diversity and abundance and wetland plant or benthic macroinvertebrate community composition.

The purpose of calibration is to optimize the correlations between RAM results and quantitative data for wetlands representing a gradient of conditions within the reference network. The RAM is conducted at these same sites where intensive data exist or new data are being collected. Calibration data are then used to develop a system for weighting the various scores based on their relative contributions to wetland condition. Sensitivity analyses are used to weight each metric and attribute, as needed, to produce RAM metric and attribute scores that are consistent with the more intensive measures of condition.

Validation is needed to assure that the calibration holds for wetlands outside of the network. The efficacy of the calibrated CRAM is tested and revised, as needed, to continue optimizing the method. Thus, validation is a long term, ongoing process that results in a more robust method over time. In true validation studies, test sites for each kind of wetland are randomly selected along known stressor gradients.

Given the cost of collecting intensive data, very few assessment methods are calibrated, and those that are often are calibrated to other indices of wetland condition. Even fewer RAMs are validated, although excellent examples do exist (e.g., ORAM validation with bird, amphibian, and vascular plant diversity data) (Mack, 2001b; Micacchion, 2002; Staphanian *et al.,* 2004). Obviously, newly collected data for use in calibration would be most desirable but may be cost-prohibitive in view of the funding available and geographic scope targeted for the calibration effort. For this reason, relying on existing data sources is attractive. However, several difficulties are associated with the use of existing data for this purpose. These include: If existing data are used, potential implications exist in the event of a temporal offset between when data were collected and the period of calibration; and when calibrating over a large geographic area, it is difficult to locate datasets that are collected using standardized methods at sites representing a gradient in disturbance. These issues must be carefully weighed in determining whether to employ existing data or collect new data to calibrate or validate the RAM.

For the calibration of CRAM, a decision was made to use existing data because of the lack of sufficient funding to collect new intensive data for the state of California. Furthermore, a decision was made to focus on calibrating the riverine and estuarine wetland classes. Calibration of other wetland classes will take place as data or funding become available. For the estuarine or riverine wetland classes, existing data are available that were considered to adequately represent a gradient in disturbance across sites, had an adequate geographic representation of the study area, and were collected within one to three years of the CRAM calibration assessment. Because of the temporal offset (two years for riverine data and three years for estuarine), a decision was made to eliminate from the calibration dataset those sites that had appeared to have undergone substantial disturbance or recovery from stressors (e.g., flood, fire, or land use change), since the data of intensive data collection would likely no longer reflect current site conditions.

Another important consideration in the calibration and validation phase is the selection of intensive measures of wetland condition. Conceptual models developed in Stage 2 were used to identify the kinds of data that would be most appropriate for calibrating each attribute for each wetland class. As would be expected, no single integrated measure of wetland condition exists that can be used as a gold standard against which to compare a RAM index, attribute, or metric score. A reasonable approach may be to choose several intensive measures of condition against which to calibrate the RAM overall index or attribute score. Decisions on weighting RAM metrics and attributes to optimize correlation between RAM attribute or index scores and these more intensive measures should be based on a weight of evidence approach involving all datasets. If choices must be made to optimize the RAM for one intensive measure over the other, it is important to consider the assessment endpoint, level of confidence in quality of the intensive datasets, and factors such as temporal offsets between the datasets in making such decisions.

For the calibration of CRAM, three principal intensive measures are being used for the riverine wetland class: riparian bird diversity, abundance, and number of breeding species; benthic macroinvertebrate species diversity and an associated index of biotic integrity; and indices of landscape context or condition, such as population data, impervious cover, road density, and the Landscape Development Intensity Index (Brown and Vivas, 2005) now under development for California. These data provide a measure of overall wetland condition against which to compare CRAM scores. Indicators of landscape condition can be used to assess performance of the overall CRAM index score. Intensive measures of bird and benthic macroinvertebrate community composition, which are considered robust indices of community structure and high order functioning of the ecosystem, can be used to evaluate CRAM performance at the attribute level.

The CRAM calibration effort will proceed by exploring correlations between the calibration data and overall CRAM scores, attributes, and metrics. The efficacy of calibrating overall scores by weighting or scaling attributes will be determined first, since this is the easiest calibration step. Attributes or metrics will not be weighted or scaled unless the calibration of overall scores fails to provide the desired degree of correlation to the calibration data.

STAGE 6: METHOD OUTREACH AND IMPLEMENTATION

While the outreach and implementation step is presented here as the final step in the process of method development, in reality this work is integrated throughout the entire process of RAM development. Important components of outreach and implementation include: establishing a mechanism for regular communication, update, and feedback from end-users; developing implementation modules and/or guidance for specific applications of RAM; information management; and training.

Outreach

Outreach consists of establishing a mechanism for regular communication, update, and feedback among RAM developers and users. Establishing a clear system for regular communication, update, and feedback is critical to ensuring that the RAM is useful and relevant.

Fostering communication about CRAM has been challenging because of the large number of governmental policies, programs, and projects that could be benefited. The most effective component of the communication strategy has been to use the Core Team and Regional Teams for method development and review as well as to conduct ongoing discussions of implementation issues. A small statewide Core Team with three larger Regional Teams helped balance the need to keep the development process efficient with the need to have an open process with ample opportunity for input by a great variety of stakeholders.

Rapid assessment methods will tend to have multiple user groups. For example, CRAM is designed to be used by regional wetland management partnership for regional ambient monitoring, state and regional water quality agencies, and U.S. Army Corps of Engineers Wetland Regulatory programs. Because of the difference in culture and mission among these intended user groups, there are implementations issues unique to each. The Core Team therefore decided that the best approach was to create a core method that fit the basic needs of all groups, but then create add-on modules that would customize the core method to meet specific needs of different groups. In the case of regional ambient monitoring, where CRAM implementation would be used in tandem with a variety of other tools to assess condition, the module would essentially amount to a guidance document for the core method. In the case of compliance monitoring, CRAM scores would be augmented with assessments of project performance relative to site specific performance criteria (Ambrose and Lee, 2004, unpublished report).

Demonstration projects can be especially helpful for users and other interested parties to see RAM in use, understand its information content, and assess possible applications. For CRAM, various demonstrations are being conducted at the scale of individual projects and whole watersheds. The watershed demonstration projects are especially useful to show the value of RAMs for large scale ambient assessment. Demonstration projects are also helpful for troubleshooting RAMs before they are committed to full scale applications (Ambrose and Lee, 2004, unpublished report).

Information Management

Information management should be addressed throughout the course of RAM development process. Specific decisions include: How will data be collected, processed, and distributed? How will quality assurance and control be incorporated into the information management process? The answers to these questions are dependent, in part, on the context in which the RAM is implemented. In California, the Core Team recognized early on the importance of maintaining a database of CRAM scores throughout the verification and calibration phases in order to refine metric scaling and build a regional picture of reference. During the verification phase, a relational database was built to house CRAM scores and any ancillary data collected. This database has been modified and expanded to accommodate calibration data and will be used throughout the CRAM development process.

The Core Team is also considering how to streamline CRAM data collection so that potential errors associated with transcription of field data are minimized. Personal data assistants (PDAs) are particularly well suited for menu driven collection of field data. The Core Team will be developing an information management system that links PDAs with Web-based applications to upload field data from PDA to regional master relational database for data entry, archiving, and sharing. Additional issues yet to be addressed include whether to have central or distributed data management systems, the process by which CRAM data can be made available to the public, and who will be responsible for CRAM information management. The answers to these questions and the particular details of quality assurance and quality control depend, in part, on the specific application of CRAM and are still under consideration.

Training

Training is an important component of RAM implementation, particularly because the method is based on visual observation and is therefore subject to some degree of observer bias (Metzeling *et al.,* 2003). The creation and use of Regional Teams in CRAM development have helped to identify the kinds of training materials that are most helpful. For example, each version of CRAM has been packaged for Regional Team use, and the feedback from the Regional Teams about the content and organization of the packages has helped the Core Team understand how CRAM manuals might be improved.

Part of the training and user support material being developed for CRAM includes open source software for using CRAM on a CRAM user's manual with data sheets packaged online and within PDAs, with links to a the master relational database and imaging through the Internet. The software version of CRAM includes access to the full user's manual and converts the method into a series of multiple choices for each metric, with pull down schematics and photos to clarify the choices. The Core Team envisions that attendance in a multiple day CRAM training session will be a basic requirement for all CRAM users. For some applications, the Core Team has suggested that practitioners should be required to participate in occasional efforts to assess the repeatability and precision of the method. It is suggested that there be some system of regular checks to make sure the users get repeatable and comparable results. This can be especially important for practitioners who use CRAM to assess restoration or mitigation projects. It is also important when regional or watershed scale ambient survey assessments involve multiple teams contributing to a single overall assessment of a large number of sites and collecting data that will be used as a unit. (M. Kentula, USEPA, personal communication, March 2003).

CONCLUSIONS

The intent of all RAMs is to evaluate the complex ecologic condition of a natural ecosystem using a finite set of observable field indicators and to express the relative condition of a particular site in a reasonably straightforward and simple manner. Achieving this objective requires many assumptions based on existing knowledge, prior experience, and previous wetlands research. The successful development and implementation of a wetland RAM depends on input from a broad range of expertise, including that of managers, scientists, and users. This collaboration ensures that the assumptions used in the method are transparent and acceptable to as many of the potentially affected parties as possible and are grounded in the best available science. The time and effort expended during method development to build broad participation and consensus is critical to the ultimate confidence and reliability of the method. It is also important to remember that a RAM is intended to fill a particular niche in the wide range of needs for biological assessments; no one tool is likely to be the silver bullet to address needs for both quick screening and comprehensive evaluation (Smith *et al.,* 1995; Stein and Ambrose, 1998).

The CRAM is being developed to quickly assess the condition of a broad range of wetland types throughout most of California's diverse landscape. The diversity range of wetland expertise represented by the Core and Regional Team members involved in CRAM's initial development and verification resulted in feedback from multiple perspectives, including that of state and federal agency representatives, wetland scientists and managers, and biological consultants. Numerous potential users have contributed to CRAM's development. As a result, the ultimate product should be a user friendly and scientifically sound method that is responsive to a range of wetland assessment needs.

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