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Evaluation of Methods for Monitoring Herbaceous Vegetation

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Final Report

Prepared for Ecosystem Management and Restoration Research Program
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Under 2015-ER-13 Setting standards for the detection, and monitoring to improve adaptive management outcomes and ecosystem

Abstract

This special report seeks to advance the field of ecological restoration by reviewing selected reports on the processes, procedures, and protocols associated with monitoring of ecological restoration projects. Specifically, this report identifies selected published herbaceous vegetation monitoring protocols at the national, regional, and local levels and then evaluates the recommended sampling design and methods from these identified protocols. Finally, the report analyzes the sampling designs and methods in the context of monitoring restored herbaceous vegetation at US Army Corps of Engineers (USACE) ecosystem restoration sites. By providing this information and the accompanying analyses in one document, this special report aids the current effort to standardize data-collection methods in monitoring ecosystem restoration projects.

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Preface

This study was conducted for the Ecosystem Management and Restoration Research under 2015-ER-13 “Setting standards for the detection, and monitoring to improve adaptive management outcomes and ecosystem.” The technical monitor was Dr. Christine VanZomeren.

The work was performed by the Wetlands and Coastal Ecology Branch of the Ecosystem Evaluation and Engineering Division, US Army Engineer Research and Development Center–Environmental Laboratory (ERDC-EL). At the time of publication, Ms. Patricia Tolley was branch chief, and Mr. Mark Farr was division chief. The deputy director of ERDC-EL was Dr. Brandon J. Lafferty, and the director was Dr. Edmond J. Russo Jr.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

1 Introduction

1.1 Background

Monitoring the results of ecological restoration projects is critically important to advancing the practice and science of ecological restoration—especially because restoration activities are poised to increase in frequency and magnitude nationally and globally (Suding 2011; Wortley et al. 2013). In the past, restoration projects have been planned and executed with no thought or funding put toward monitoring results postrestoration (Wortley et al. 2013). However, there is a growing acknowledgement that monitoring is a critical component of restoration (Ruiz-Jaen and Aide 2005) and would benefit from the development of standardized data-collection methods (Suding 2011; McDonald et al. 2016).

Generally, monitoring aims to evaluate the effectiveness of actions intended to achieve a specific set of goals and objectives (Thom and Wellman 1996) or testing hypotheses (Herrick et al. 2005), or both. Ecological restoration monitoring focuses on demonstrating success or progress toward specific project goals, providing early warning indicators of deviations from the recovery trajectory and learning from different restoration techniques (McDonald et al. 2016). Monitoring for objective-based management differs from other data-collection activities. Monitoring activities focus on detecting measurable or observable changes in a site or system for the purpose of assessing general trends toward specific restoration or management objectives. Monitoring might require short-term observations, long-term observations, or both, and trends may be positive, negative, or neutral depending on the management objectives.

Current monitoring practice suffers from a lack of consistency between monitoring events as well as between practitioners; trends and the impact of external factors may therefore be difficult to extract from such data, whether comparing sites or comparing data from multiple monitoring events at the same site (Legg and Nagy 2006; Gonzalez et al. 2015). Inability to learn from previous restoration projects potentially reduces the efficiency of future projects and increases the risk of repeated failure. Additionally, data collected during monitoring activities should be standardized in a way that will allow larger trends of ecosystem recovery to emerge and be tracked over time (Suding 2011). Using the results of monitoring activities to communicate the success of restoration projects to partner organizations, constituents, and the broader public is critically important to ensure continued investment and public support of ecological restoration (Jähnig et al. 2011). To advance the science and practice of ecological restoration, concerted efforts must be made to ensure consistent and adequate monitoring of ecological restoration projects.

1.2 Objective

The objectives of this effort are to

- identify published herbaceous vegetation monitoring protocols at the national, regional, and local levels;
- evaluate recommended sampling design and methods from identified protocols; and
- provide an overview of the pros and cons of the identified sampling methods as they relate to monitoring restored herbaceous vegetation at US Army Corps of Engineers (USACE) ecosystem restoration sites.

1.3 Approach

Ecosystem restoration is one of the primary civil-works missions of USACE, which engages in large-scale (for example, Everglades Restoration, Florida) and small-scale (for example, 63rd Street Beach and Dune Restoration, Illinois) restoration projects that often have a vegetation component. However, no accepted standard monitoring protocols or methods for monitoring ecosystem restoration projects currently exists at USACE. Collecting data in an effective and repeatable manner will not only provide robust, evidence-based information to support management decisions, it will also advance our collective understanding of the effects of restoration actions.

To progress the science of restoration ecology, and in support of this mission of ecosystem restoration, the Environmental Laboratory is developing repeatable and consistent methods to monitor herbaceous vegetation for use nationwide. In support of this effort, this special report provides a review of current methods for monitoring herbaceous vegetation and identifies national, regional, and local methodologies. For the purposes of this report, *national level* is defined as methods developed to be used anywhere in the United States, *regional level* to be used at multiple sites within a system, and *local level* to be used at one site. Reviewing methods developed for different spatial resolutions ensures a more robust sample of methodologies.

The review then evaluates published methodologies for the purpose of determining the specificities of the methods used, such as sample plot size, transect- and plot-placement procedures, type of data collected, metrics calculated from the data, frequency of sampling period and type of quality control (QC) or quality assurance (QA). This review is limited to methods for monitoring herbaceous vegetation. Methods for monitoring other vegetation strata (shrubs and trees) require different data-collection techniques and are not included in the current scope for developing methods for monitoring herbaceous vegetation. Note that the term *methods* is used interchangeably with *protocols* for the purposes of this review. Both terms refer to the steps involved in collecting data.

1.4 Vegetation monitoring challenges

Developing methods applicable for monitoring the diversity of USACE's ecosystem restoration sites represents a significant challenge. Restoration projects differ in their overall goals and objectives, size, complexity, and project budget. Trade-offs must occur between the amount of potential data collection and the resources (for example, budget, labor) available for collecting it. Data collection protocols need to generate sufficient data to allow confident management decisions, ensure the success of restoration efforts, and, in so doing, demonstrate the successful investment of federal funds. Because sites have different management objectives and budgets, monitoring methods need to maintain flexibility that will allow them to be tailored for each specific site, while also preserving comparability between sites.

All methods are prone to sampling bias (Vittoz and Gusian 2007), meaning that some plant species abundances will be over- or underestimated. The evaluation of each monitoring methodology in this special report accounts for the potential for sampling bias and includes a determination on whether a particular sampling bias is relevant to monitoring recovering herbaceous vegetation.

2 Methods

2.1 Search terms and search criteria

Terms used to search for published protocols in Google, Google Scholar, and Web of Science include the following: *plants*, *vegetation*, *monitoring*, *protocols*, *methods*, *restoration*, and *success*. Publications were retained for evaluation if they included vegetation monitoring protocols developed for use at the national scale and developed for habitats that have a significant layer of herbaceous vegetation, such as wetlands, grasslands, savannas, and some open canopy woodlands (up to 50% canopy cover). Regional vegetation monitoring protocols were also retained for evaluation if they were developed for multiple sites within a distinct region, such as the Pacific Northwest or Southwest Ponderosa Pine forests. A limited number of local vegetation monitoring protocols that were developed to monitor a single restoration site were retained. Local protocols were limited to those that had been published in peer-reviewed publications or were developed by a USACE district.

2.2 Definitions

The following is a list of the key terms and concepts used in the evaluation of the identified protocols, including definitions and why they are important for this effort.

2.2.1 Methods

The methods used to collect data during a sampling event may include the use of transects and plots. How transects and plots are placed during data collection and the number of sample plots can determine the type of data collected, how labor intensive the protocol is, and the potential for sampling biases. Methods were categorized as *random*, *permanent*, or *mixed*. *Permanent* refers to a sample location that is resampled in the exact same spot, *random* refers to randomly selected sample locations each monitoring event, and *mixed* refers to a combination of the two. Randomly placed plots may have been randomly sampled from a predetermined grid over an area of concern or placed along randomly placed transects. For more information on the differences between these categories, see Kent (2012), Wildi (2013) and Bonham (2013).

2.2.2 Sample plot

The amount of area covered by the recommended plot shape and size can influence the amount, type, and kind of data collected.

2.2.3 Data type

The type of data collected during sampling can range from a list of species encountered to measuring the percent cover of each species sampled. The type of data collected can also determine how labor intensive the protocol is and how the data can be used to assist with management decisions.

2.2.4 Monitoring results

This review also evaluated how the data are used in reporting monitoring results and calculating vegetation-based metrics. Monitoring results can include species richness, relative dominance of species, coverage of native versus non-native species, relative abundance of certain functional groups (for example, annual, perennial), species turnover, and health of plant community.

2.2.5 Periodicity

How often a protocol is to be conducted (across multiple seasons, annually, etc.) is also important when evaluating how labor-intensive the protocol is and how well the protocol would inform management decisions related to herbaceous vegetation restoration projects.

2.2.6 Objectives

Determining the goals and objectives of a specific project and associated monitoring efforts allows the evaluation of how well the protocol addresses the information needs of managing herbaceous plant restoration projects. This review categorized these monitoring goals and objectives as follows:

- collecting data to inform management decisions
- tracking conditions for general information purposes and for specific management decisions, such as wildlife species or resource production

2.2.7 Quality assurance (QA) and quality control (QC)

QA and QC procedures represent an important and usually overlooked facet of monitoring activities. *QC* refers to the accuracy of data recorded in the field. *QA* refers to the accuracy of reporting the data and managing the data over time. This review combines these activities under the term *QA/QC*.

Although protocols may include data collection methods for other vegetation strata (shrub, tree canopy), this review only evaluates methods describing data collection for herbaceous plant species.

3 Results

This review identified a total of 15 published protocols: 4 national, 9 regional, and 2 local (table 1).

Table 1. List of protocols included in evaluation.

Scope	Organization	Area	Objectives	Documentation
National	Forum for Research and Extension in Natural Resources	Canada	Long-term monitoring of forest herbaceous and shrub understory	Gayton (2013)
National	US Department of Agriculture	United States	Long-term and short-term monitoring of rangelands	Herrick et al. (2005)
National	UK Environmental Change Network	United Kingdom	Long-term monitoring for broad- and fine-grained changes as related to UK National Vegetation Classification habitat types	Sykes and Lane (1996)
National	Environmental Protection Agency (EPA)—National Wetland Condition Assessment	United States	Monitor long-term changes in wetland communities	EPA (2011)
Local	South Slough National Estuarine Research Reserve	Coos Bay South Slough, Oregon	Monitor tidal-marsh restoration	Cornu and Sadro (2002)
Local	Battelle Marine Sciences Laboratory	Elk River Marsh, Washingon	Monitor tidal-marsh restoration	Thom, Zeigler, and Borde (2002)
Regional	National Oceanic and Atmospheric Administration (NOAA)	Lower Columbia River (LCR) and estuary	Monitor habitat-restoration projects	Roegner et al. (2009)
Regional	Lower Columbia River Estuary Partnership	Lower Columbia River and estuary	Monitor impacts of pollutants on salmonid populations and ecosystems of LCR	Lower Columbia River Estuary Partnership (2008)
Regional	Gulf of Maine Tidal Restoration Monitoring	North Atlantic coastal region	Monitor tidal marsh restoration	Neckles et al. (2002)
Regional	Illinois Critical Trends Assessment Program—Illinois Natural History Survey	Illinois	Assess and track condition of major ecosystems in Illinois	Molano-Flores (2002)
Regional	Middle Rio Grande Restoration—USACE–Albuquerque District	Middle Rio Grande	Track non-native and native woody and herbaceous species in restored areas	GeoSystems Analysis (2014)[a]
Regional	Upper Mississippi River Restoration—Habitat Rehabilitation and Enhancement Project	Upper Mississippi River	Assess forest and wetland plant communities for the management of resident and migratory wildlife	McCain (2014)[b]
Regional	University of California Division of Agriculture and Natural Resources	California	Monitor for management and financial accountability	Lewis, Lennox and Nossaman (2009)
Regional	USACE–Chicago District	Lower Lake Michigan Region in Illinois and Indiana	Monitor herbaceous native plant restoration projects	Glennemeier (2015)
Regional	US Geological Survey (USGS)–Western Ecological Research Center	San Francisco Bay estuary	Monitoring restored vegetation over time	Carlisle et al. (2006)

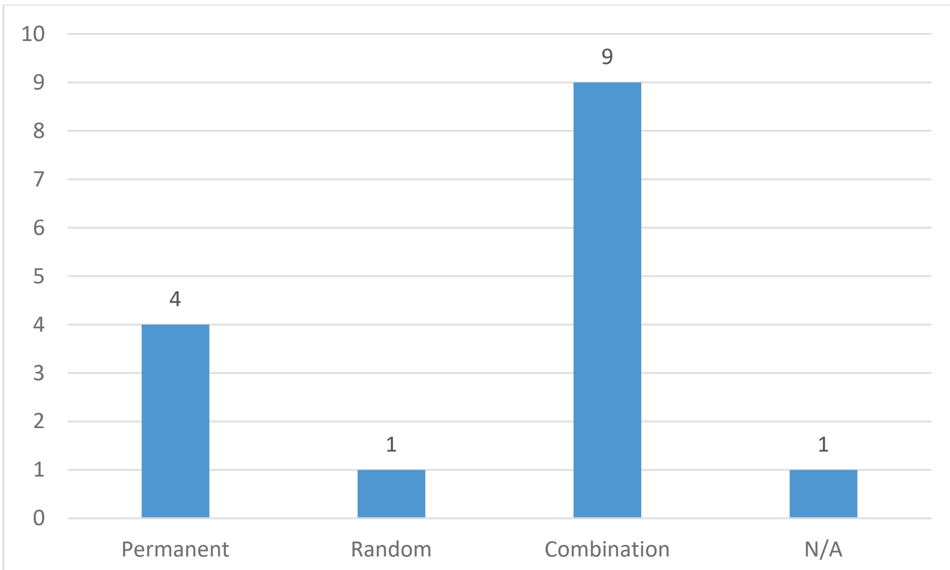
[a] GeoSystems Analysis 2014. “Middle Rio Grande Restoration Project Monitoring and Adaptive Management Plan, Update: April 2014.” Unpublished report prepared for the US Army Corps of Engineers, Albuquerque District. Prepared by GeoSystems Analysis, Inc. Albuquerque, NM. April 2014. URS Contract No. 25008873.

[b] McCain, K.N.S., ed. 2014. “Upper Mississippi River Restoration Monitoring Design Handbook Section 1: Vegetation.” Unpublished report. Rock Island, IL: US Army Corps of Engineers.

3.1 Methods

Out of the 15 published protocols, 14 detailed the data-collection method using transects and plots. Most protocols (9) recommended a combination of both random and permanent methods (figure 1).

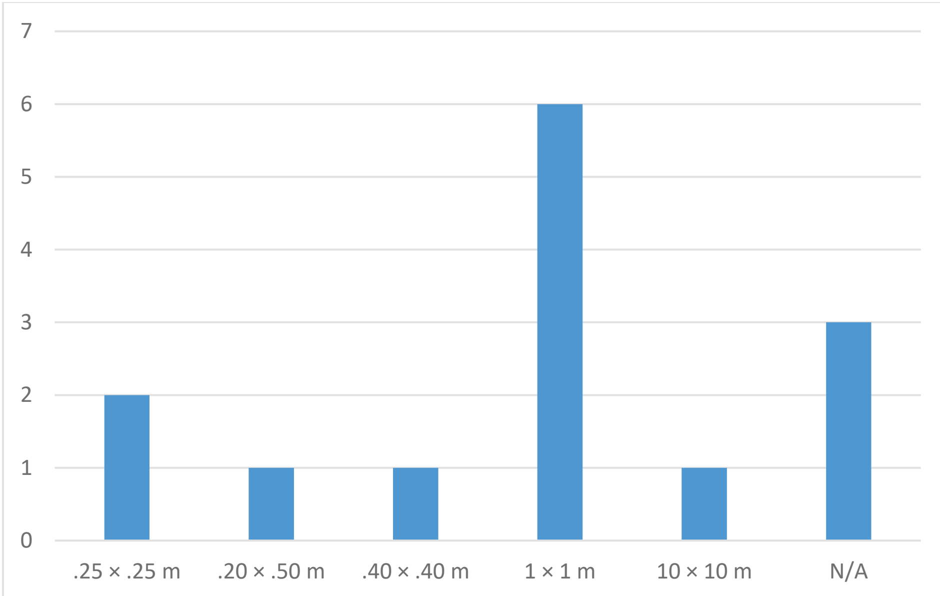
Figure 1. Methods for placement of transects and plots.



3.2 Plot size

Of the 15 protocols, 6 recommended 1 × 1 m plot size, and 3 recommended 0.25 × 0.25 m plot size (figure 2). Another 3 protocols did not recommend a plot size, instead recommending the line-point method. The line-point intercept method uses a frame with pins that drop to the ground, and data are collected from the plants that intercept the pins.

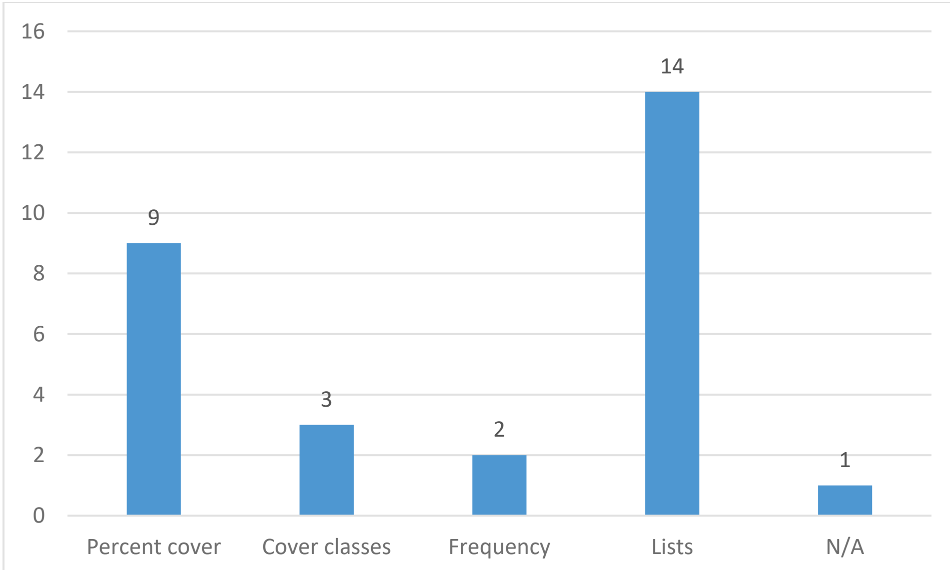
Figure 2. Comparison of plot size.



3.3 Data type

All protocols but one recommended, at a minimum, to record all species encountered during data collection from plots (referred to as *Lists*) (figure 3). Most protocols also recommended recording percent cover of each species from each plot. *Percent cover* refers to how much of the area a plant covers within a defined sample area (for example, 1%–100%). *Cover classes* refers to categories of percent cover, such as 0%–10% (class 1), 11%–25% (class 2), and so on. *Frequency* refers to recording a plant species located within a defined sample area, with no percent cover or class recorded.

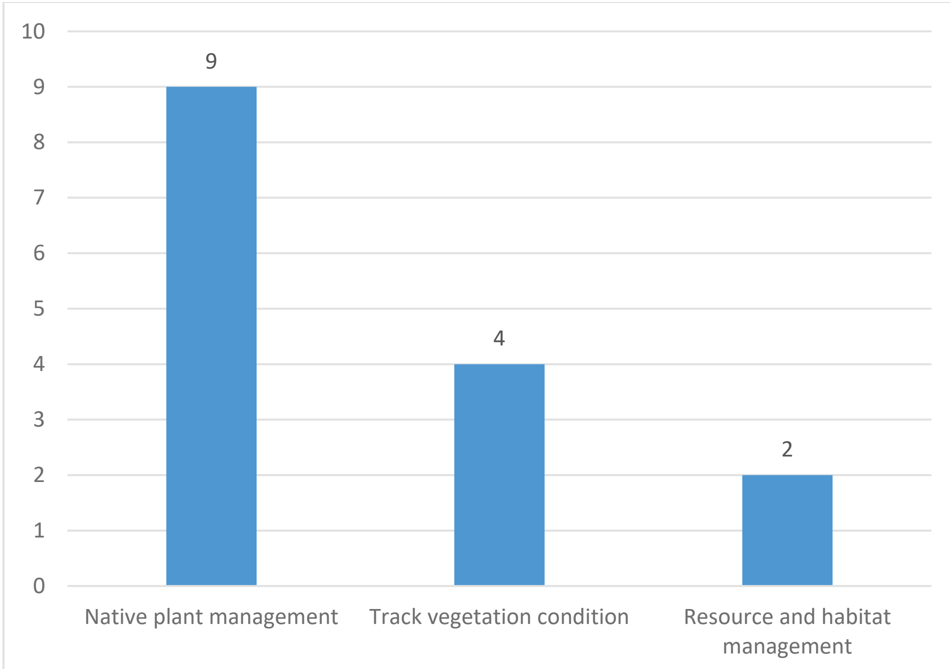
Figure 3. Comparison of data collected.



3.4 Monitoring objectives

Most protocols (9) sought data that would inform native plant management, followed by tracking passive changes to vegetation condition (4) (figure 4). *Native plant management* refers to maintaining an assemblage of native plants characteristic of a region, where monitoring informs the management of that native plant community. *Track vegetation condition* refers to assessing how plant communities change over time irrespective of management efforts. *Resource and habitat management* refers to a monitoring objective focused on attributes of a system or habitat of interest that is not plant-community specific, such as the recovery of threatened and endangered species that rely on certain vegetation characteristics, and so includes vegetation as part of a larger monitoring plan.

Figure 4. Comparison of monitoring objectives.



3.5 Calculations and metrics

Table 2 presents a brief list of the calculations and subsequent metrics that can be derived from the data collected from the reviewed protocols. Most protocols recommended metrics related to species composition, such as a list of species, species richness, or relative dominance of species.

Table 2. List of metrics that can be calculated using the data collected from protocols.

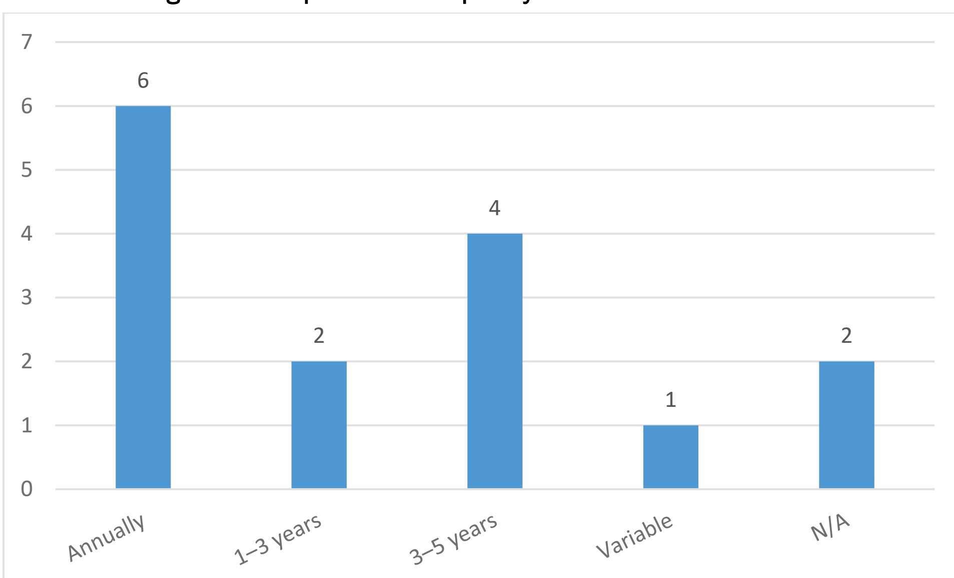
Metric	Description
Species richness	Number of species
Species diversity	Number and evenness of species
Species composition	List of species
Dominance	Relative cover or relative importance
Shoot and stem density	Measure of abundance
Quality, floristics	Floristic quality assessment index and proportion of non-native to native species
Quality, habitat	Food value
Invasive species	Percent cover, relative importance, relative abundance and others that estimate cover or dominance
Similarity index	Percent shared species or species abundance
Compare to reference	Reference condition or restoration target condition
Compare to control	Control condition or without restoration

Metric	Description
Species accumulation	Accumulation of number of species encountered over number of plots sampled

3.6 Periodicity

Most protocols (6) recommended annual data collection, particularly for sites targeted for active vegetation management (Cornu and Sardo 2002). Four (4) protocols recommended every three to five years, and two (2) protocols recommended one-to-three-year data-collection increments, especially for passive monitoring (EPA 2011). One (1) method recommended changeable or variable increments (according to management response), and two (2) protocols did not recommend any specific time between monitoring events (figure 5).

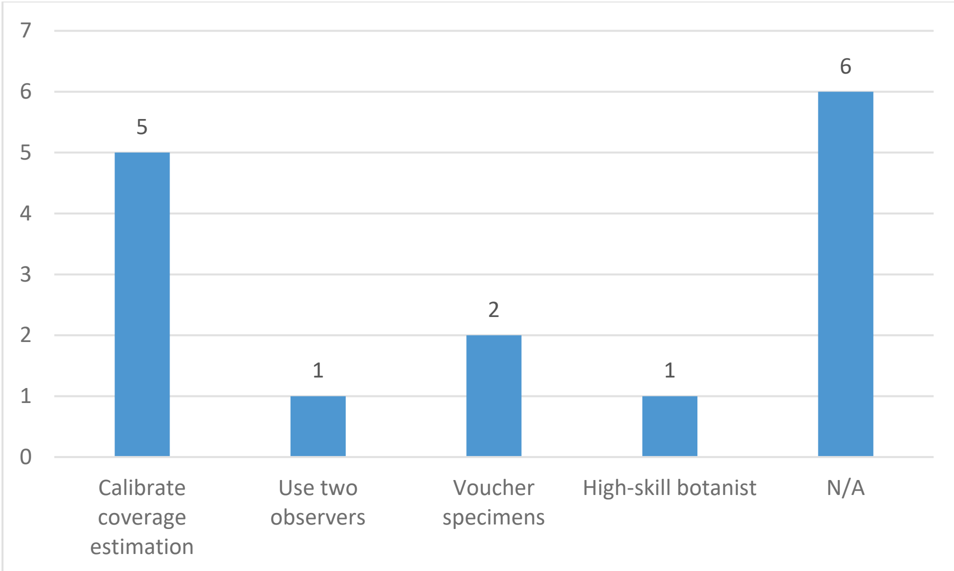
Figure 5. Comparison of frequency of data collection efforts.



3.7 QA/QC

Most methods (6) did not report QA/QC protocols; however, five (5) did report recommendations for observers to train on or calibrate their estimation of plant species coverage. A few protocols (2) recommended that voucher specimens (individual plants taken from the field and preserved for verification) be taken of plant species encountered and used as confirmation of plant species identification. Only one (1) protocol recommended the use of two observers and an average of their coverage estimation per plant species to reduce any potential observer bias.

Figure 6. Comparison of quality-assurance (QA) and quality-control (QC) protocols.



4 Discussion and Conclusion

The evaluation revealed that not many methods developed for the national level currently exist (4); most were either regional or local in scope. The methods developed at the national level were all developed by federal agencies (for example, US Department of Agriculture). The scarcity of national-level protocols and the need for large organizations to develop them illustrates the challenges of developing standard methods at the national level. Challenges also include the inherent variability of vegetation restoration projects, which naturally have different management needs that then dictate data-collection needs. In addition, every project has its own budget, which dictates the resources available for monitoring activities. Although these challenges are real, they can and should be overcome to advance the science and practice of ecological restoration.

Most protocols recommended using a mix of random and permanent methods for the placement of transects and plots. This trend reflects research into the trade-offs between statistical power (random) and interpreting changes in vegetation in a management context (permanent) (Herrick et al. 2005). Most protocols recommend defining a sampling area that represents a consistent type of plant community with specific management questions (for example, low tidal marsh versus high tidal marsh) then randomly determining either the start of the transect or the placement of the first plot followed by either systematically or randomly placing plots along the transect. The mix of random and permanent has been referred to as *stratified random* (Herrick et al. 2005; Vittoz and Gusian 2007) and allows a bit of flexibility between sites and years while still maintaining comparability.

Most protocols (9) recommended a 1 × 1 m plot size. This plot size was described by Kent (2012) as being the recommendation because of previous research looking at species and area curves when sampling herbaceous vegetation using differently sized and shaped plots. However, in habitat types with an even distribution of vegetation coverage (versus sparsely vegetated) in which multiple species may exist in one plot (for example, Tallgrass prairies), the 1 × 1 m plot becomes harder to accurately and quickly estimate plant species coverage. In areas that have more evenly distributed coverage of plant species, the 0.25 × 0.25 m plot has become popular (for example, Chicago region). An observer may visually assess the whole of the plot at one vantage point without having to move around the plot to make confident visual estimates of plant species coverage. The drawback with the smaller-sized plot is the need to take more samples within an area of concern to make up for the smaller area sampled in any one plot.

Almost all the protocols recommended taking at least an inventory of plant species present within the sample area. The next most frequent recommendation was to estimate the percent cover of each species. Collecting data on the relative abundance of each species meets an important need in native plant management decisions (Kent 2012; Vittoz and Gusian 2007). However, previous research has shown that visually estimating species coverage has the potential for observer bias (Godinez-Alvarez et al. 2009; Milberg et al. 2008; Morrison 2016). Observer bias can be mitigated through training observers in a standard method of estimation and then having the observers calibrate their estimations as a group prior to monitoring (Scott and Hallam 2002). And although 6 out of the 15 protocols evaluated did not recommend any QA/QC protocols, the most popular QA/QC protocol recommended in those that did was to calibrate or train observers on species-coverage estimations.

The evaluated protocols often recommended annual monitoring. Annual monitoring of restored herbaceous vegetation makes practical sense in the first 5–10 years of restoration, because herbaceous plants' presence and coverage can change significantly from one year to the next. However, after 10 years, the frequency of monitoring may be reduced (Glennemeier 2015; McCain 2014)* depending on management needs and overall trends from the last 10 years, if they indicate a more stable plant community has emerged.

This review of published protocols indicates the need to incorporate a mixed (permanent and random) approach to the placement of transects and plots, to take into consideration the potential variety of restored plant community types that may exhibit different coverage (evenly or patchily dispersed vegetation), to incorporate measures of species coverage, to develop a set of QA/QC protocols that cover visual estimation techniques, and to conduct annual monitoring for at least the first 5–10 years. Additionally, this evaluation highlighted a variety of ways to monitor plant

* McCain, K.N.S., ed. 2014. "Upper Mississippi River Restoration Monitoring Design Handbook Section 1: Vegetation." Unpublished report. Rock Island, IL: US Army Corps of Engineers.

restoration projects and that there is a lack of standardized methods across most agencies and organizations. Whichever monitoring method is chosen that method must be flexible to meet the needs of different USACE projects while still maintaining a rigorous data-collection methodology to ensure comparability between project sites and years.

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14. ABSTRACT
This special report seeks to advance the field of ecological restoration by reviewing selected reports on the processes, procedures, and protocols associated with monitoring of ecological restoration projects. Specifically, this report identifies selected published herbaceous vegetation monitoring protocols at the national, regional, and local levels and then evaluates the recommended sampling design and methods from these identified protocols. Finally, the report analyzes the sampling designs and methods in the context of monitoring restored herbaceous vegetation at US Army Corps of Engineers (USACE) ecosystem restoration sites. By providing this information and the accompanying analyses in one document, this special report aids the current effort to standardize data-collection methods in monitoring ecosystem restoration projects.

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