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Guest editorial

Conceptual assessment framework for forested wetland restoration: the Pen Branch experience

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Abstract

Development of an assessment framework and associated indicators that can be used to evaluate the effectiveness of a wetland restoration is critical to demonstrating the sustainability of restored sites. Current wetland restoration assessment techniques such as the index of biotic integrity (IBI) or the hydrogeomorphic method (HGM) generally focus on either the biotic or abiotic components of wetlands. In addition, current methods generally rely on qualitative or semi-quantitative rankings in the assessment. We propose a quantitative, ecosystem level assessment method similar to that developed by the US EPA's Wetland Research Program (WRP approach) that includes both biotic and abiotic metrics. Similar to the IBI and HGM approaches, biotic and abiotic parameters are compared to those of reference communities, however, the proposed comparisons are quantitative. In developing the assessment method, bottomland reference systems at various stages of succession were compared to a recently restored site in South Carolina (Pen branch). Studies involving hydrology, soil organic matter and nutrient dynamics, vegetation communities, seedling establishment and competition, and avian, small mammal, herpetofauna, fish and macroinvertebrate communities were implemented. In this paper, we discuss the conceptual framework in which we developed our assessment technique.

1. Introduction

Wetland restoration involves the reestablishment of wetland conditions and processes on a site in such way as to provide the basis for a self-sustaining ecosystem (D'Avanzo, 1990; Niering, 1990). Defining what constitutes a self-sustaining ecosystem and the methods used to make that judgement is subject to debate. From a regulatory context, several important constraints are

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placed on wetland restoration assessment techniques, most notably the duration of the assessment and the ease of application. Because of time, resource and technical constraints most assessment techniques are short duration and relatively simple to apply. Determining whether the project is a success with respect to the restoration goal is difficult to determine when the assessment period is short (e.g. 1–3 years) and indicators of desired wetland functions have not been developed (Clewell and Lea, 1990). Short-term prediction of the effectiveness of forested wetland restoration is further complicated by the longevity of trees. Forested wetland restorations take decades if not centuries before one can ultimately judge the recovery of some wetland functions. Most assessment techniques are simple to apply allowing resource professionals to understand and communicate their findings to fellow personnel and regulatory agencies. However, evaluating complex wetland ecosystems with simple methods may not adequately characterize the condition or state of a wetland, especially if fundamental functions such as hydrology or processes such as carbon and nutrient cycling are not fully understood.

2. Evaluation of wetland restoration assessment techniques

A number of approaches have been used to assess wetland restoration effectiveness. Stein and Ambrose (1998) recently presented a summary of impact assessment methodologies including those for wetlands. Generally, approaches attempt to measure or develop indices of wetland function through either abiotic and/or biotic factors. Depending on the original restoration goal under which approaches were developed and the expertise of the researchers, methodologies either focus on the physical sciences of hydrology and soil science (Brinson, 1993) or on biological sciences (Karr, 1991).

A second consideration among assessment techniques is the use of reference systems to compare the effectiveness of a wetland restoration. We believe it is critical that reference systems be integrated into the framework of a scientifically based wetland restoration assessment technique. In most cases, wetland restoration specialists do not have knowledge of the previous unimpacted state of the system because most wetlands were destroyed in late 19th and early to mid 20th centuries. In some circumstances aerial photos may be available but only in rare cases has there been data collected prior to disturbance. As such, the only fair comparison to evaluate restoration effectiveness is with similar, relatively unimpacted wetlands. In many cases, before and after restoration comparisons are used to assess effectiveness (Stein and Ambrose, 1998). Without knowledge of the previous wetland state or use of an analogous reference wetland, before and after techniques are simply assessing the change in the wetland state, not restoration success or failure. We would even argue that before and after techniques are biased toward predicting success. Certainly if one plugs a tile drain and plants hydrophytic vegetation a change has been made that will be discernable through various measurements. From a regulatory view, given that those measurements or indices meet certain criteria, that restoration would be considered a success even though the wetland may have few of the functions once present. In time those functions might recover but not during the short time frame of regulatory assessment. Although, few assessment techniques developed in the past use reference wetlands, the two techniques that have gained the most notoriety and acceptance both utilize reference systems in their analysis. The two most notable are the hydrogeomorphic method (HGM) (Brinson, 1993) and the index of biologic integrity (IBI) (Karr, 1991). A lesser-known method developed by researchers at the US Environmental Protection Agency's Wetland Research Program (WRP approach) also uses reference wetlands in their analysis (Kentula et al., 1992).

Finally, most techniques ultimately develop indices so that scores across functions can be accumulated and a single decision can be made as to the effectiveness of a restoration. Some techniques use simple categories such as high–medium–low while others scale real measurements. Comparisons are then made between before and after conditions or to reference wetlands. Inherent to these comparisons is the assumption that functions change linearly over time. If ten hydrophytic herbaceous plant species occur in the reference wetland and the restored wetland has five species, an index 0.5 would be calculated signifying that the restored wetland has 50% recovery for that index. However, if the natural dispersion of hydrophytic herbaceous plant species follows a logarithmic relationship over time, we may only be at 10% recovery. The WRP approach uses field data from reference wetlands and wetlands that have been restored at various time intervals to quantitatively develop response surfaces (Fig. 1) to more fully characterize the temporal recovery of a wetland function or indicator of that function (Kentula et al., 1992). Of course this type of characterization to determine the response surface of important functional metrics entails long-term monitoring. Kentula et al. (1992) also suggests using statistical tests to detect differences among reference wetlands and restored wetlands at various stages of recovery.

3. Pen branch assessment approach

Our objective is to evaluate if the restored system, Pen branch, is on the planned trajectory toward a recovering forested wetland (Fig. 1). In this issue of Ecological Engineering, studies are

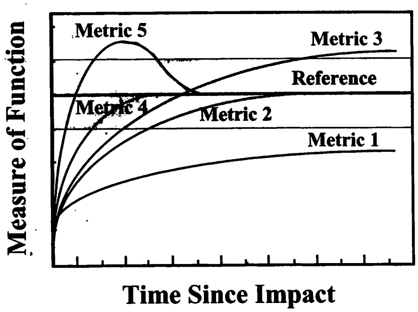

Fig. 1. Theoretical response surface of wetland functions or indicators of wetland function (after Kentula et al., 1992). Shaded zone indicates the possible variability in reference conditions over time.

presented measuring what we consider important metrics that will be influenced by restoration. In most of these studies, measurements have been made in both the restored system (Pen branch) and in one if not more reference systems (Meyers branch, Upper Three Runs creek, and Tinker creek). In addition, some studies have included systems that have been hydrologically restored at various time intervals but have not had vegetation manipulation (unplanted areas of Pen branch, Fourmile creek and Steel creek). During the development of the Pen branch restoration, we understood very early that we had a unique opportunity for the development of an assessment framework. With a thermally impacted restored wetland, thermally impacted unrestored wetlands and unimpacted reference wetlands all in close proximity, the successional gradient design developed, attracting researchers from multiple disciplines.

The focus of our assessment is on ecosystem processes or functions that change as succession proceeds (Fig. 1). Comparisons of populations and processes across successional gradients allow the effect of disturbance and restoration activities to be evaluated. The approach measures conditions over time (stage of development) and is used to assess the effectiveness of attaining the desired wetland conditions (e.g. restoration objective). As proposed by the EPA (Kentula et al., 1992), we are developing response curves of specific metrics that are indicative of wetland function. Individual metrics will be variable depending the parameter and the magnitude of the impact (Fig. 1). Although considerable spatial variability exists among reference systems, and temporal variability within a single reference system, in the long-term, reference systems have relatively constant rates of providing specific functions over time unless naturally disturbed (reference in Fig. 1). If an inherent property of the ecosystem is not restored to its previous state, such as hydrology, we might expect to find some functions to never fully recover (metric 1 in Fig. 1). Alternatively, other inherent ecosystem properties may be restored to a higher state than in the original ecosystem and may provide more or greater function after the impact (metric 3 in Fig. 1). Some metrics, such as species richness or diversity of faunal communities, may experience an initial rise above the reference state and decrease as time proceeds, ultimately leveling off at the reference state (metric 5, Fig. 1). Although there are a multitude of response surfaces that different functions can exhibit over time, theoretically we expect functions to recover over time and, at some point, approach that of the previous unimpacted reference system (metrics 2 and 4 in Fig. 1). By using active intervention strategies such as planting, we expect to accelerate the recovery of wetland functions (metric 4 in Fig. 1) when compared to a naturally recovering system (metric 2 in Fig. 1).

Our assessment focused on five components of the wetland ecosystem; hydrology, soils, vegetation, carbon and nutrient cycling, and faunal communities. Hydrological studies focused on the upland–wetland interface and wetland–stream interface, assessing the hydrologic budgets of wetlands at various stages of succession (Kolka et al., 2000) and the influence of upstream modifications on the Savannah river to SRS swamp hydrology (Chen, unpublished data). Soil studies investigated soil carbon storage (Giese et al., 2000) and organic matter quality (Wigginton et al., 2000). Vegetation studies centered on both current and potential terrestrial vegetation (Giese et al., 2000; Landman, 2000) and aquatic vegetation (Fletcher et al., 2000; Giese, unpublished data). Carbon and nutrient cycling studies will integrate soil, vegetation and hydrological data to describe change in energy and nutrient budgets across the successional and recovery gradients (Kolka, Giese, others, unpublished data). Faunal community studies assessed stream invertebrates (Lakly and McArthur, 2000; Parker, unpublished data), fish (Fletcher, unpublished data), herpetological communities (Hanlin et al., 2000), birds (Buffington et al., 2000), and small mammals (Fliermans, unpublished data; Wike and Martin, 2000).

The Pen branch restoration assessment will not attempt to develop indices that summarize or combine various metrics. We recognize that the recovery of wetland functions or indicators of functions is time dependent. It is not ecologically justifiable to develop one qualitative number that defines the status of our wetland restoration. Simply stating that some functions have recovered and that others are or are not on their planned trajectory is a rational scientific approach. We see nothing inappropriate about saying habitat and populations have recovered for herpetofauna but we are decades if not centuries from developing a similar understory vegetation community. The Pen branch approach is both quantitative and descriptive. From the studies and associated measurements contained in this issue and in subsequent publications, we will prioritize a set of easily measurable parameters that are indicative of wetland function recovery over time. We will continue to measure these selected metrics over the long-term to develop response surfaces which will allow us to describe the state of recovery of various wetland functions. Although we are assessing the success/failure of the Pen branch restoration, this is a scientific endeavor. We understand that regulatory agencies or private firms cannot afford the time or expense of the comprehensive approach we developed. However, once response surfaces of indicators of wetland function have been developed, others will be able to utilize that information and quantitatively assess the stage of recovery of their wetland restoration.

4. Conclusion

Expanding upon the EPA's WRP approach (Kentula et al., 1992), we believe we have comprehensively collected the breadth of information needed to characterize the early status of the Pen branch restoration. For restoration to be considered effective, wetland functions need to be restored or at least on a trajectory where restoration of those functions is probable (Fig. 1). The problem arises when predicting the effectiveness of restoration efforts in forested systems because of their longevity. Methods need to be developed to predict the effectiveness of restoration efforts within the first few years after restoration. Only through long-term studies, we will be able to characterize response surfaces of functional indicators so that short-term data can be used to predict future wetland conditions. Through long-term monitoring and the use of a restored system, naturally recovering systems and reference systems we expect to develop wetland function response curves such as those shown in Fig. 1. Once the results of past, ongoing and planned research are integrated, we will have a holistic view of the biotic and abiotic parameters that have the most promise as wetland function indicators.

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