RESEARCH ARTICLE

Is Information Enough? The Effects of Watershed Approaches and Planning on Targeting Ecosystem Restoration Sites

Sierra C. Woodruff and Todd K. BenDor

ABSTRACT

Since 1996, the watershed approach (i.e., the inclusive use of watershed information) has been a hallmark concept in ecosystem restoration site location. In 2008, federal regulators required use of the watershed approach in siting compensatory mitigation for aquatic impacts regulated under the U.S. Clean Water Act. However, regulations fell short of requiring full watershed plans, which could have required stakeholder involvement and inter-institutional coordination. Little work has evaluated how the watershed approach or planning position mitigation sites in the landscape. Has the watershed approach or watershed planning been successful in targeting restoration sites where they are needed? The North Carolina Division of Mitigation Services (DMS; formerly the NC Ecosystem Enhancement Program), a state agency, has implemented the watershed approach and extensive watershed planning to focus restoration investments. Through a multi-step planning program, the DMS employs a watershed approach to gauge the need of 12-digit watersheds for restoration. In some cases, an intensive local watershed planning process follows this targeting effort. We tested the effect of the program's watershed targeting approach (n = 710) and local watershed planning efforts (n = 147) on increasing the frequency of wetland and stream mitigation projects (n = 480) in each of the state's 1741 12-digit watersheds (1998–2012). We find that while the watershed approach is successful at guiding restoration to targeted watersheds over space and time, the impacts of watershed planning are more nebulous, with important but weaker panel-effects. Our findings highlight the importance of plan quality and data management in using a watershed approach to target restoration sites effectively.

Keywords: ecosystem services, environmental planning, watershed information, watershed planning

Restoration Recap

- The North Carolina Division of Mitigation Services (DMS) has used both the watershed approach and watershed planning to guide wetland and stream mitigation projects for more than a decade, allowing for the analysis of the influence of both approaches on the location of mitigation projects.
- DMS's implementation of the watershed approach has been effective in guiding restoration to targeted areas. The impacts of watershed planning are less clear.
- Using ecological and landscape information to target areas for mitigation projects can help prevent the formation of degradation "hot spots."

Market mechanisms have become an increasingly popular policy instrument for environmental regulation. Market-based approaches have been proposed for air pollution, climate change, water quality, endangered species habitat, impervious surfaces, fisheries, and aquatic resources (Womble and Doyle 2012). Consequently, it is increasingly important to consider ecosystem service markets' benefits and shortcomings and how planning and policy can improve market outcomes (BenDor and Doyle 2009, Judge-Lord and Cochran 2011). As the oldest and most prominent ecosystem service market, markets for wetlands and stream compensatory mitigation may help identify challenges and potential solutions in all ecosystem

Color version of this article is available through online subscription at: http://er.uwpress.org

Supplementary materials are freely available online at: http://uwpress.wisc.edu/journals/journals/er-supplementary.html

Ecological Restoration Vol. 33, No. 4, 2015
ISSN 1522-4740 E-ISSN 1543-4079

service markets (Womble and Doyle 2012, Robertson 2006, Palmer and Filoso 2009). Under Section 404 of the U.S. Clean Water Act (33 USC § 1344 et seq.), many impacts to wetlands and streams can only occur if ecological restoration offsetting these impacts is performed elsewhere. Permitting of wetland impacts and requirements for mitigation have resulted in a market in which restored aquatic ecosystems are commodified and sold as mitigation "credits" (Robertson 2006). Movement of aquatic resources across the landscape is a natural byproduct of the section 404 compensation process: when developers impact wetlands or streams in one location and replace them elsewhere, these ecosystem functions "migrate" to new locations (King and Herbert 1997, BenDor et al. 2007).

Spatial inequalities are a frequent structural concern in the design of ecosystem service markets (Robertson and Hayden 2008, Doyle et al. 2014). Market approaches aim to prevent net loss of ecosystem services, but trading may cause uneven concentration of pollution or degradation in localized areas, "hot spots." Moreover, location is critical to the performance and provision of ecosystem services of mitigation sites (Richardson 1994, NRC 2001, BenDor et al. 2007). This is particularly true for wetlands and streams. The functions of these ecosystems, such as nutrient cycling, water velocity reduction, water storage, and sustenance of fish and wildlife habitat, depend on the landscape position and the composition of the surrounding watershed (Mitsch and Gosselink 2000).

There are multiple approaches to prevent degradation hot spots, including on-site mitigation, limiting the geographic area in which ecosystem service credits can be traded, specifying the type of compensation allowed for impacts, the watershed approach, and watershed planning (Womble and Doyle 2012). Limiting the service area, the area in which credits can be exchanged, limits opportunities for abatement, but decreases the potential for degradation hotspots (Doyle et al. 2014). New Jersey and Minnesota are prominent examples of states using strict trading areas to manage wetland compensatory mitigation (Womble and Doyle 2012). Policies have also attempted to ensure the effectiveness of mitigation by requiring in-kind mitigation, mandating that impacts be offset by mitigation of a similar type of wetland damaged at the impact site or within the same ecoregion (BenDor et al. 2011; Womble and Doyle 2012).

In 2001, the U.S. National Research Council (NRC) recommended that restoration efforts be guided by a "watershed approach," an effort to incorporate information on landscape context, ecological needs of the watershed, and cumulative effects of past impacts into the restoration process (NRC 2001, Davenport et al. 1996). The watershed approach was later integrated into a sweeping regulatory reform of the Section 404 program in 2008 (USACE and EPA 2008). The reforms of the Section 404 program fell short of mandating watershed planning, which typically establishes policies for discouraging resource damage and replaces case-by-case permitting with advance decision making and system management (BenDor and Doyle 2009, BenDor and Stewart 2010). However, the watershed approach improves upon limiting geographic trading areas and in-kind mitigation requirements by recognizing the importance of location within the larger landscape for mitigation success.

While, in theory, application of the watershed approach directs mitigation projects to areas where they will best preserve and improve watershed functions (ELI and TNC 2014), few empirical studies have evaluated the success of the watershed approach or watershed planning in doing so. Strong competition in land markets (i.e., competition with urban development, a major source of aquatic ecosystem impacts) has long forced restoration away from areas where it is needed (BenDor et al. 2009). Furthermore, although the watershed approach uses ecological and landscape information to guide mitigation projects, it may not go far enough to address issues such as case-by-case decision-making, competition for land from development markets, major future infrastructure decisions, and stakeholder engagement. All of these factors affect the placement of mitigation sites in the landscape and the all-important relationship of aquatic impacts to their restoration offsets (i.e., hot spot mitigation).

The best case study for analyzing the longer-term effects of the watershed approach and planning is the North Carolina Division of Mitigation Services (DMS; formerly known as the NC Ecosystem Enhancement Program), a state agency whose unique role as a mitigation credit clearinghouse and watershed planning organization has been touted as model for other state restoration programs (NCDENR 2013a). Numerous additional state programs aimed at improving wetland mitigation have emerged and could be modeled after the DMS (ASWM 2015). For example, the Minnesota Pollution Control Agency recently adopted a similar process to implementing the watershed approach (Minnesota Pollution Control Agency 2014).

Since its creation in 2003, the DMS has implemented a watershed approach by incorporating extensive information to prioritize watershed needs and identify locations for restoration projects that maximize ecological benefits (BenDor and Stewart 2010). The DMS and its policies evolved from the NC Wetland Restoration Program (WRP) established in 1996, providing over a decade of data. In addition to using a watershed approach, they have implemented local watershed planning in watersheds that are expected to have the most impacts and associated mitigation.

In this paper, we seek to determine the effects of the DMS's use of the watershed approach and watershed planning efforts to guide wetland and stream restoration sites into targeted areas. For the watershed approach, we will rely on the DMS's designation of targeted local watersheds, and for watershed planning we will rely on their creation of local watershed plans, both of which are described in the next section. To what extent has the DMS been successful in placing mitigation sites using the watershed approach? How effective is local watershed planning in promoting mitigation sites in targeted areas? We break these general questions down into four questions that we address through statistical analysis of available data:

1. Are watersheds that are prioritized for mitigation through the targeted watershed approach and watersheds with local watershed plans more likely to contain a mitigation project? (cross-sectional)
2. Do targeted local watersheds and local watershed plans influence the total number of mitigation projects in a watershed? (cross-sectional)
3. How are targeted local watersheds and local watershed plans causally linked to the presence of mitigation projects within watersheds? (time-series)
4. Does the rate of project establishment change for a watershed after becoming a targeted local watershed and undergoing a local watershed plan? (time-series)

It is important to note that our analyses focus on the presence and number of mitigation sites, we do not evaluate if these targeted areas would in fact be the most beneficial ecologically. We also do not evaluate the quality of watershed plans or planning processes; therefore, we do not look directly at the relative success of the planning process in engaging land owners to allow mitigation sites to be established in prime restoration areas. Rather our goal is to assess how effective the watershed approach and planning efforts are in guiding the location of mitigation projects. The results of this study will demonstrate the effectiveness of the DMS's implementation of the watershed approach and provide guidance for other states (see ASWM 2015), such as Minnesota, that have adopted similar processes. In addition, the results may have implications for other ecosystem markets, such as habitat for endangered species, which are impacted by degradation hot spots and where mitigation success is dependent on location within the landscape.

Methods

The North Carolina Division of Mitigation Services (DMS)

By determining priority areas for mitigation sites, the DMS attempts to: 1) concentrate mitigation in areas where it will have the greatest benefit to local watershed function (Dye Management Group 2007, BenDor and Stewart 2010); while 2) establishing restoration in advance of—and of the same type ("in-kind" mitigation) as—project impacts. Projects are sited through a three-step process depicted in Figure 1. First, DMS watershed planners develop River Basin Restoration Priorities reports. These reports use available GIS data, field tours, and input from local resource professionals to identify 12-digit hydrological unit code (HUC) watershed problems (e.g., streams with impaired water quality, degraded habitat) and assets (e.g., rare aquatic species, healthy riparian basins). Based on these problems and assets, 12 HUC watersheds are ranked within each river basin. The DMS designates 12-digit HUCs where restoration, enhancement and preservation projects are expected to achieve the largest functional benefit as targeted local watersheds. Of the 1741 watersheds in our dataset, 710 or 40.8% are targeted local watersheds (Figure 2).

Second, depending on anticipated extent of impacts from permitted project and development, new local watershed planning initiatives are undertaken. Each local watershed planning initiative encompasses one to three existing targeted local watersheds. In our dataset, 147 or 9% of 12 HUC watersheds have a local watershed plan (Figure 2). Factors used to select local watershed plan areas include the abundance of potential project sites, field tours indicating restoration and preservation opportunities, willingness of local resource professionals to participate in the planning process, local funding, and existing DMS mitigation projects. Local watershed plans usually take 24–30 months and includes a watershed assessment, watershed management planning, and creation of a project atlas that provides site-specific information on the most promising mitigation sites.

Finally, the DMS selects project sites. Project managers use local watershed plan project atlases to pursue agreements with landowners. While local watershed plan project atlases include potential sites with the highest long-term functional benefits, the DMS recognizes it is not always possible to locate projects at these sites. For example, mitigation may be needed in an area where planning has not occurred. In this case managers prioritize sites in targeted local watersheds. Mitigation sites, however, may be located outside local watershed plan and targeted local watershed areas. This allows DMS to meet its mitigation goals in a timely manner if landowner outreach in prioritized areas was unsuccessful. This flexibility also allows DMS to consider local priorities in siting mitigation projects. While the DMS prioritizes mitigation sites in targeted local watersheds, it is unclear to what extent they have been able to achieve this in practice.

Data

Our unit of analysis was the 12-digit watershed (n = 1741), the scale of targeted local watersheds and local watershed plans. To determine the influence of physical, political, and social characteristics on the number of mitigation projects located in a watershed, we built a dataset drawing on multiple secondary sources.

The National Hydrology Dataset (Simley and Carswell 2009) was used to identify watershed boundaries, size,

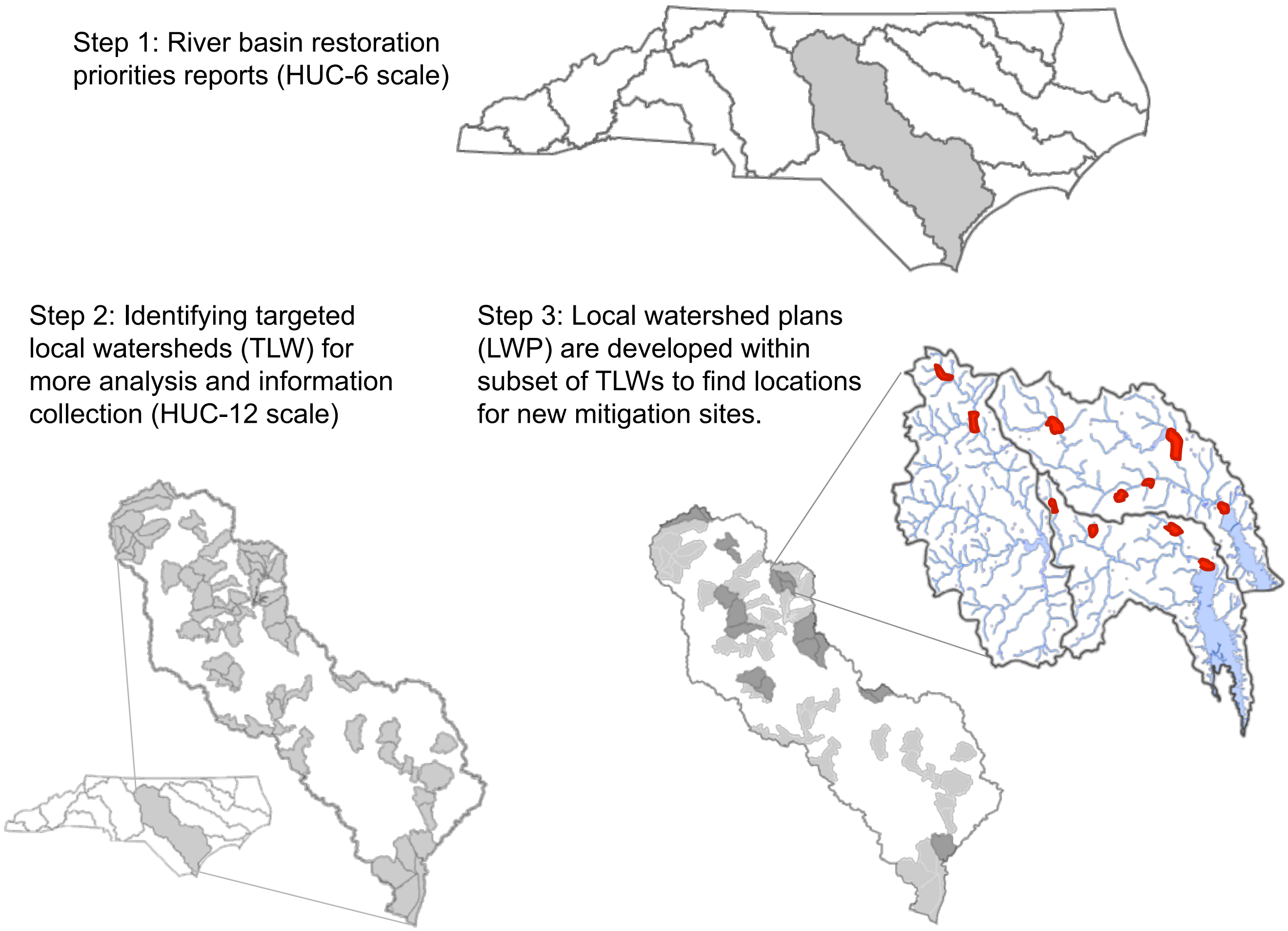

Figure 1. The North Carolina Division of Mitigation Services (DMS) process for implementing the watershed approach and watershed planning.

and modification. Data from the DMS website (NCDENR 2013c) determined if a watershed was designated a targeted local watershed, fell under a local watershed plan, and the number of mitigation projects in the watershed. To control for social factors—change in population, population density, education, income, home value, and rent—that may influence the number of projects in a watershed, data were collected from the 2010 American Community Survey (U.S. Census Bureau 2013). Zoning and tier designation data, a relative measure of economic distress (NC Department of Commerce 2013), were also collected from the UNC School of Government (Owens 2012). Because social characteristics are measured at the block group or county level, the area-weighted-mean of these variables was calculated for each watershed using the Geospatial Modeling Environment (Beyer 2012). These socio-demographic variables were included in our regression models. Preliminary analysis indicated that only tier and population density significantly influenced the number of mitigation sites in a watershed, consequently, only these two socio-demographic variables were included in our final models (see Supplementary Material).

In addition, we collected data from the DMS mitigation site database and River Basin Restoration Priorities reports across time in attempt to evaluate causal links between targeted local watersheds, local watershed plans, and mitigation projects (NCDENR 2013a, NCDENR 2013d). For each year from 1998–2012 we recorded: 1) the number of projects established in every watershed; 2) whether the watershed was a targeted local watershed; and 3) whether the watershed was included in a local watershed plan. Watersheds that did not have complete time data were excluded from the analysis.

Analysis

We were interested in two independent variables: *targeted local watershed* designation, which describes DMS's use of the watershed approach to prioritize watersheds for mitigation, and *local watershed plan*, which represents watershed planning. We took multiple approaches to evaluate if these variables were important in siting mitigation projects (see the Supplementary Materials for additional details).

To address our first two questions, we triangulated our analysis through three models: a binary logistic, a negative

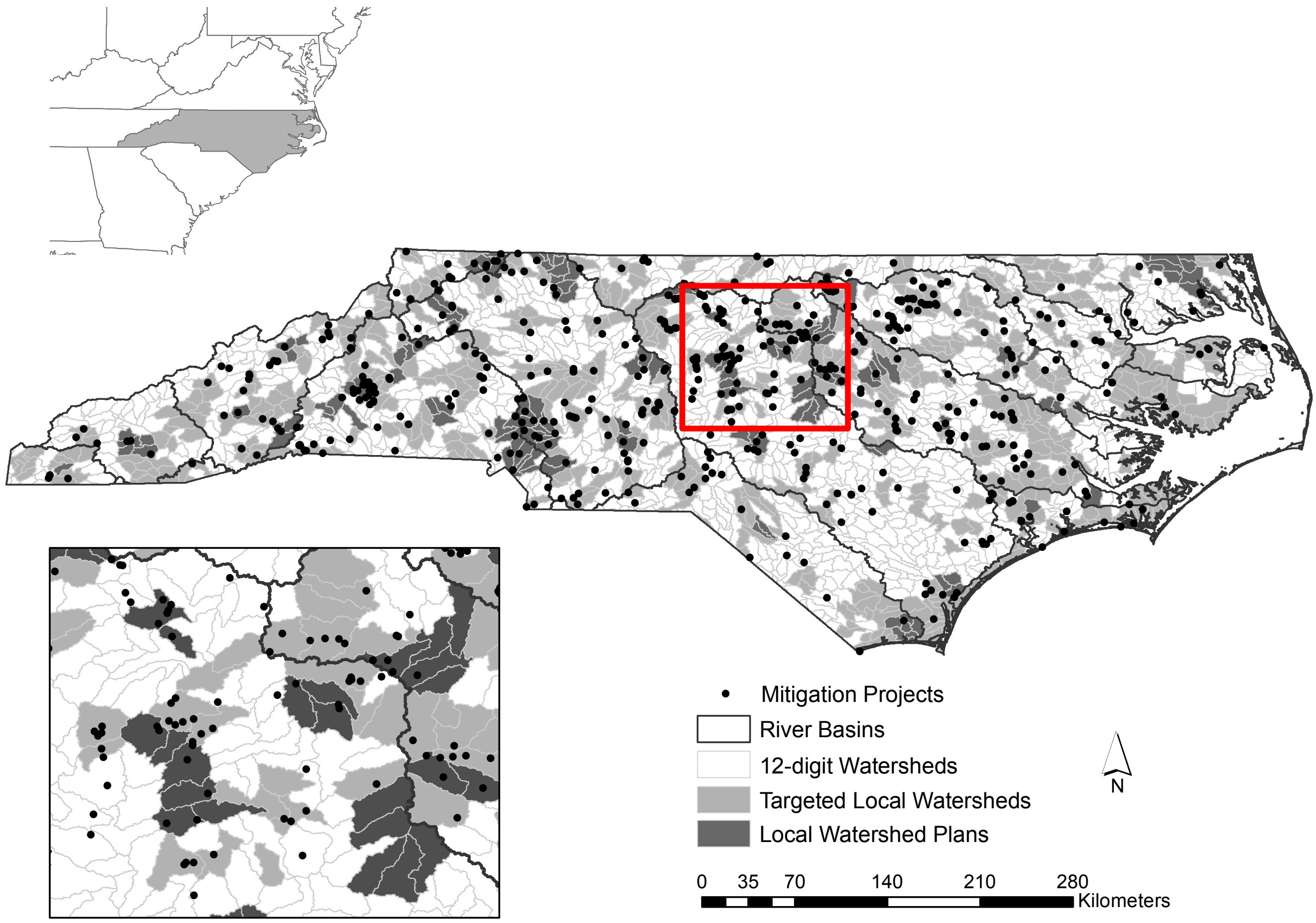

Figure 2. Map of the study area, North Carolina, US, showing the distribution of mitigation projects, targeted local watersheds, and local watershed plans. All areas that have local watershed plans are also targeted local watersheds.

binomial, and a Poisson-'hurdle' model to evaluate the influence of targeted local watersheds and local watershed plans on the number of mitigation projects in a watershed (cross-sectional analysis). Negative binomial models are commonly used with over-dispersed count data and incorporate a dispersion parameter. The hurdle model combines a logistic and Poisson distribution, and assumes that all zero outcomes are 'structural,' or produced through a separate process modeled using a logistic regression. In essence, the hurdle model independently predicts the presence of mitigation sites using a logistic model, while predicting the frequency of mitigation sites using a censored Poisson model.

The structure of this model fits with an important assumption: DMS's decision to establish its first mitigation site in a watershed may be fundamentally different than decisions to add additional mitigation sites in watersheds where they have previously existed. In this case, we assumed that urban development patterns in the region differentiate these 'pioneer' mitigation sites, indicating areas that are becoming newly developed, from areas where large amounts of urban and transportation development have become the norm.

Our initial analyses established correlations between targeted local watersheds, local watershed plans, and the frequency of mitigation sites, but did not allow us to make causal claims because the temporal precedence of targeted local watersheds and local watershed plans is not established. Therefore, to answer our third question, we re-cast the analysis to temporally evaluate policy and mitigation site data in each watershed from 1998–2012. To account for variability across watersheds and over time, we used a multilevel model that groups outcomes and independent variables by watershed. Using a logistic regression we evaluated the influence of targeted local watersheds and local watershed plans on the odds that a project will be located in a watershed in a given year.

Finally, to answer our fourth question, we took a subset of data that includes only watersheds that are at some point designated a targeted local watershed. We calculated the rate of project establishment before targeted local watershed designation, after targeted local watershed designation, and after local watershed planning. The rate of project establishment during these three periods was compared using the Friedman Rank-Sum Test (Kabacoff 2011). Similar to ANOVA, the Friedman Test can detect differences in different treatments (distributions of rates between treatments) with repeated sampling, but can be applied to non-parametric data. All statistical analyses were performed using the R statistical analysis software (version 3.2).

Results

1) Do targeted local watersheds and local watershed plans influence if a watershed has a mitigation project?

Targeted local watersheds were significantly more likely to have mitigation projects across all models (Wald test; Z = 6.33; $p < 0.001$; Table 1). Holding local watershed planning, economic tier, and population density constant, the odds of a targeted local watershed containing a mitigation project was 135% higher than non-targeted local watersheds. Economic conditions and population density are confounders; controlling for these factors, local watershed plan did not statistically significantly increase the odds that a watershed will have a project (Wald test; Z = 1.59; $p = 0.110$). However, the length of time since planning occurred (second model column in Table 1) was significant (Wald test; Z = 2.06; $p = 0.039$) when it replaces the dummy variable for planning, suggesting that local watershed plans influence the presence of mitigation projects over the long-term. This being said, an additional year since local watershed planning only increased the odds of a mitigation project by 6.2%.

2) Do targeted local watersheds and local watershed plans influence the total number of mitigation projects in a watershed?

In the negative binomial model, targeted local watershed designation significantly increased the number of mitigation projects located in a watershed (Wald test; Z = 8.05; $p < 0.001$), while local watershed plans had no effect (Wald test; Z = 0.87; $p = 0.385$). Targeted local watersheds had a 275% greater rate of project establishment than watersheds that are not targeted. The hurdle model produced similar results: targeted local watersheds had a higher propensity to have a mitigation project (Wald test; Z = 6.33; $p < 0.001$) and were also more likely to have more projects (Wald test; Z = 4.923; $p < 0.001$).

Local watershed plans were found to have no statistically significant effect on the presence of a project or the number of projects established. When we assumed a structural cause of zero mitigation site counts, however, our hurdle model revealed that the longer the watershed had a local watershed plan, the more likely the watershed had a mitigation project (Wald test; Z = 2.06; $p = 0.039$). This matched our findings from the binary logistic model in question 1. We found that the time since local watershed plan creation did not significantly increase the number of projects in the watershed (Wald test; Z = 0.41; $p = 0.679$).

3) How are targeted local watersheds and local watershed plans causally-linked to the presence of mitigation projects within watersheds? (time-series)

Comparing the multilevel model to a null-single level model provided strong evidence that the between-watershed variance was non-zero (Likelihood-ratio test; D = 104.55; $p < 0.001$). Between-watershed variance (*Watershed* variable in Question 3 of Table 1) explained 30% of the remaining, or unexplained, variance for a watershed to have a project. The high proportion of unexplained variance described by between-watershed differences is likely due to the substantial variation in the number of years spent as a targeted local watershed and local watershed plan across watersheds; most watersheds never receive either of these treatments.

Across time, both targeted local watersheds (Wald test; Z = 4.49; $p < 0.001$) and local watershed plans (Wald test; Z = 2.34; $p = 0.019$) significantly increased the probability for a project to be located in a watershed in a given year. When controlling for population density and economic tier, the odds of a project being located in a watershed increased 89% when it is a targeted local watershed, and by 71% when it had a local watershed plan.

4) Does the rate of project establishment change for a watershed after becoming a targeted local watershed and undergoing local watershed planning?

The Friedman Rank-Sum Test accounted for the fact that we were drawing multiple samples from the same watershed, which may be qualitatively unique; the test looked for patterns across watersheds, allowing us to ask, was the rate consistently higher after a targeted local watershed or local watershed plan treatment? On average, the rate of project establishment for a watershed was statistically significantly greater after it becomes a targeted local watershed (Friedman rank sum test; Friedman chi-square = 7.22; $p = 0.007$). The mean rate of project establishment increased from 0.021 projects/year to 0.029 projects/year (Figure 3A). The increase in the rate of project establishment, however, was partially due to the influence of local watershed planning that occurred after watersheds become targeted.

When viewed together, there was a significant difference in the rate of project establishment between the three treatments, before targeted local watershed designation, after targeted local watershed designation, and after local watershed planning (Friedman rank sum test; Friedman chi-squared = 6.45; $p = 0.039$; Figure 3B). The rate of project establishment increased from 0.021 projects/year before targeted local watershed designation, to 0.027 projects/year after targeted local watershed designation, to an average 0.045 projects/year after local watershed planning. However, when viewed separately, there was not a statistically

Table 1. Results from analyses to answer our first three questions: 1) the logistic regression indicates that TLWs influence the propensity of a watershed to have a project; 2) the negative binomial model and hurdle Poisson show targeted local watersheds increase the number of projects in a watershed; 3) the multilevel logistic regression suggests that both targeted local watersheds and local watershed plans are important in establishing mitigation projects in a watershed overtime. Coefficient values are given with standard errors in parentheses. *Tier* was explored as both a linear and set of dummy variables, with minimal changes in coefficients. *Watershed* was a grouping variable that measures how much variance remains between watersheds.

Question 1. Logistic Regressions (n = 1741)			
		Dummy Variables	**Time**
Intercept		–2.368 (0.181)*	–2.255 (0.176)*
Targeted Local Watershed		0.856 (0.135)*	
Years as Targeted Local Watershed			0.091 (0.016)*
Local Watershed Planning		0.322 (0.201)	
Years with Local Watershed Plan			0.061 (0.029)*
Population Density		0.0004 (0.0002)*	0.0004 (0.0002)*
Tier		0.193 (0.087)*	0.198 (0.087)*
AIC		1606.9	1611.1
BIC		1634.2	1638.4
Question 2. Negative Binomial Models (n = 1741)			
		Dummy Variables	**Time**
Intercept		–2.321 (0.169)*	–2.153 (0.164)
Targeted Local Watershed		1.010 (0.125)*	
Years as Targeted Local Watershed			0.095 (0.014)*
Local Watershed Plan		0.158 (0.182)	
Years with Local Watershed Plan			0.042 (0.027)
Population Density		0.0002 (0.000)	0.0001 (0.000)
Tier		0.216 (0.080)*	0.238 (0.080)*
Question 2. Hurdle Poisson Models (n = 1741)			
		Dummy Variables	**Time**
Censored Poisson	Intercept	–1.191 (0.277)*	–0.716 (0.238)*
	Targeted Local Watershed	1.037 (0.211)*	
	Years as Targeted Local Watershed		0.056 (0.019)*
	Local Watershed Planning	–0.129 (0.205)	
	Years with Local Watershed Planning		0.012 (0.028)
	Population Density	–0.0001 (0.000)	–0.0002 (0.000)
	Tier	0.142 (0.103)	0.133 (0.103)
Logistic	Intercept	–2.368 (0.181) *	–2.255 (0.176)*
	Targeted Local Watershed	0.856 (0.135)*	
	Years as Targeted Local Watershed		0.091 (0.016)*
	Local Watershed Planning	0.322 (0.201)	
	Years with Local Watershed Planning		0.061 (0.029)*
	Population Density	0.0004 (0.000)*	0.0004 (0.000)*
	Tier	0.193 (0.087)*	0.198 (0.087)*
Question 3. Multilevel Logistic Models (n = 25860)			
		Model 1	**Model 2**
Intercept		–5.021 (0.084)*	–5.984 (0.281)*
Targeted Local Watershed		0.718 (0.140)*	0.636 (0.141)*
Local Watershed Plan		0.625 (0.230)*	0.539 (0.229)*
Population Density			0.139 (0.062)*
Tier			0.201 (0.099)*
Watershed*		1.498 (1.224)	1.428 (1.195)
AIC		4138.31	4120.59
BIC		4170.97	4169.55

* Indicates significance $p = 0.05$ level or lower

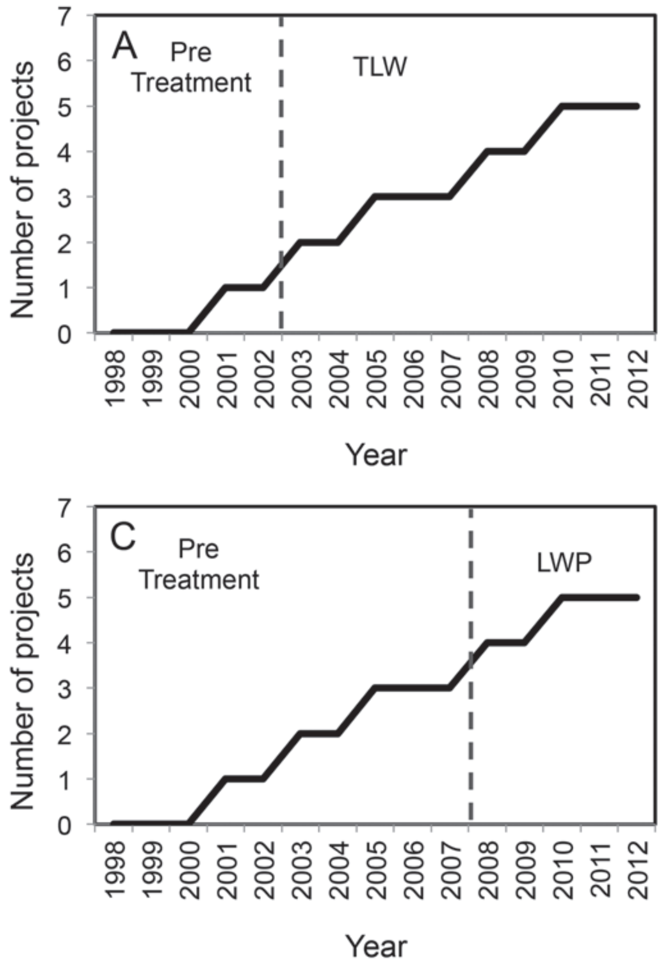

Figure 3. The Hypothetical development of mitigation sites in a watershed visually representing the analysis conducted to answer our fourth question; does the rate of project establishment differ between treatments? A) The rate of projects establishment before and after targeted local watershed designation stratified by watershed is statistically significant (Friedman rank sum test; Friedman chi-square = 7.22; $p = 0.007$). B) The rate of project establishment between pretreatment, targeted local watershed designation, and local watershed planning (when both targeted local watershed designation and local watershed plans are in place) stratified by watershed is statistically significant (Friedman rank sum test; Friedman chi-square = 6.45; $p = 0.039$), driven by the difference between pretreatment and local watershed planning (Friedman rank sum test; Friedman chi-square = 11.31; $p < 0.001$). C) The rate of projects establishment before and after local watershed planning stratified by watershed is not statistically significant (Friedman rank sum test; Friedman chi-square = 3.45; $p = 0.063$; Figure 3 C).

significant difference between the rates before targeted local watershed designation and after (Friedman rank sum test; Friedman chi-square = 2.14; $p = 0.125$), nor after targeted local watershed designation and after local watershed planning (Friedman rank sum test; Friedman chi-square = 1.2; $p = 0.273$). Only the individual difference between before targeted local watershed designation and after local watershed planning was significantly different (Friedman rank sum test; Friedman chi-square = 11.31; $p < 0.001$).

There was also no significant difference in the rate of project establishment before (0.028 projects/year) and after local watershed planning (0.048 projects/year; Friedman rank sum test; Friedman chi-square = 3.45; $p = 0.063$; Figure 3 C). As with the first test, this was likely due to the fact that the pre-condition includes time when the watershed is targeted.

Discussion

Targeting local watersheds for further planning and mitigation was found to significantly increase placement rates of mitigation sites throughout our analysis. Not only are targeted local watersheds more likely to have mitigation projects than other watersheds, but across time projects are also more likely to become established in a watershed after it has become a targeted local watershed. These results provide strong evidence that the DMS's implementation of the watershed approach (using watershed information to target specific areas for restoration) has been effective in guiding restoration to targeted areas.

Although finding that restoration sites are located in areas targeted for restoration may appear to be tautological, previous findings have shown that strong competition for land markets has long forced restoration away from areas where it is needed (BenDor et al. 2009). It is encouraging to see that targeted local watershed designation appears to be effective in guiding mitigation sites into areas needing ecological restoration. This is an important policy tool for reducing spatial hot spots of aquatic ecosystem degradation.

We expected local watershed plans to have a similar effect, however, the results for local watershed planning were mixed. Across the state (i.e., across space), local watershed plans do not significantly influence the siting of mitigation projects. This may, in part, be due to the relatively short tenure of local watershed plans. The oldest plans in our dataset were 9 years old. Although most plans, 64%, were over 5 years old, nearly 22% had been established in the last two years. This may be too short of a time frame for plans to influence the total number of projects in a watershed.

Across time, local watershed plans were found to significantly increase the likelihood of a project being established in a watershed in any given year, providing evidence that planning is important in siting mitigation projects. The rate of project establishment, however, is not significantly different between before- and after- planning. Our rate analysis identifies a second challenge in measuring the effect of local watershed plans, it is difficult to differentiate the effect of the targeted local watershed treatment and planning. The rate analysis indicated that only when watersheds had both treatments was the rate of project establishment significantly greater than no treatment; to what extent is this due to planning and to what extent is it due to targeted local watersheds? Our inability to partition the signals of the two treatments is a barrier to our analysis; yet, the mixed results suggest that planning may not be as important as previously expected in determining the placement of mitigation sites into areas that the DMS previously believed were in need or restoration.

Conclusions

The NC DMS implementation of the watershed approach demonstrates that institutional systems can be created to overcome challenges of geographic shifts in ecosystem services resulting from markets. In light of strong development pressure, the DMS's process of targeting specific watersheds that have high need and mitigation potential appears to be effective at clustering mitigation in desired locations. This is important for avoiding hot spots of aquatic ecosystem degradation that could lead to major ecosystem service deficits (see discussion of this dynamic in the rapidly developing Lake Michigan watershed in Chicago, BenDor et al. 2007).

However, the role of watershed planning—a more in-depth, secondary treatment—was not consistently found to be as statistically motivating for mitigation site location. While planning was hypothesized to enable the creation of more projects in targeted local watersheds, it was not consistently found to be a significant factor in the placement of restoration sites. This is surprising as the focus of local watershed plan efforts is to direct resources, assessments, and community involvement to address watershed issues in areas that have already been deemed critical (NCDENR 2013b). This result may stem from the fledgling nature of most plans and the difficulty of partitioning the effect of planning from targeted local watersheds.

It is important to note that our analysis focuses exclusively on the number of projects sited in a watershed and may not capture many of the benefits of planning. For example, planning may increase the success and quality of mitigation projects, and may be important over the long term in convincing landowners of prime restoration sites to allow mitigation sites to be placed on their properties. Future work should expand on this analysis to consider distributions of mitigation site costs, as well as focus on the use of operations research models to cast this problem as a site location issue, whereby sites can be optimally located to maximize water quality and other ecosystem services (e.g., Polasky et al. 2008). While our results may be applicable to other markets (i.e., different types of ecosystem service markets; markets in other states [ASWM 2015]), this area is in strong need of additional research to fully explore the role of mitigation-centered watershed planning.

References

Association of State Wetland Managers (ASWM). 2015. In Lieu Fee Programs Approved under the 2008 Mitigation Rule. aswm.org/wetland-programs/in-lieu-fee/1043-in-lieu-fee-programs-approved-under-the-2006-mitigation-rule.

BenDor, T., N. Brozovic and V.G. Pallathucheril. 2007. Assessing the socioeconomic impacts of wetland mitigation in the Chicago region. *Journal of the American Planning Association* 73:263–282.

BenDor, T. and M.W. Doyle. 2009. Planning for ecosystem service markets. *Journal of the American Planning Association* 76:59–72.

BenDor, T., J. Sholtes and M.W. Doyle. 2009. Landscape characteristics of a stream and wetland mitigation banking program. *Ecological Applications* 19:2078–92.

BenDor, T. and A. Stewart. 2010. Land use planning and social equity in North Carolina's compensatory wetland and stream mitigation programs. *Environmental Management* 47:239–53.

BenDor, T., J.A. Riggsbee and M.W. Doyle. 2011. Risk and ecosystem service markets. *Environmental Science and Technology* 45:10322–10330.

Beyer, H. 2012. *Geospatial Modeling Environment*. Brisbane, Australia: Spatial Ecology, LLC.

USACE and EPA. 2008. Compensatory mitigation for losses of aquatic resources. *Final Rule, Federal Register* 73:19593–19705.

Environmental Law Institute (ELI) and the Nature Conservancy (TNC). 2014. Watershed approach handbook: Improving outcomes and increasing benefits associated with wetland and stream restoration and protection projects. www.eli.org/sites/default/files/eli-pubs/watershed-approach-handbook-improving-outcomes-and-increasing-benefits-associated-wetland-and-stream_0.pdf.

Davenport, T.E., N.J. Phillips, B.A. Kirschner and L.T. Kirschner. 1996. The watershed protection approach: A framework for ecosystem protection. *Water Science and Technology* 33:23–26.

Doyle, M.W., L.A. Patterson, Y. Chen, K.E. Schnier and A.J. Yates. 2014. Optimizing the scale of markets for water quality trading. *Water Resources Research* 50:7231–7244.

Dye Management Group. 2007. Study of the merger of ecosystem enhancement program & clean water management trust fund: Final report of findings and recommendations. North Carolina General Assembly: Raleigh, NC. www.nceep.net/pages/DYE_2007_EEP_CWMTF_Study_Final_Report.pdf.

Judge-Lord, D. and B. Cochran. 2011. Putting ecosystem services to work: Institutional changes needed to implement an ecosystem-based plan. *Oregon Planners' Journal* January–Feburary:7–12.

Kabacoff, R. 2011. *R in Action: Data Analysis and Graphics with R*. Shelter Island, NY; London: Manning.

King, D.M. and L.W. Herbert. 1997. The fungibility of wetlands. *National Wetlands Newsletter* 19:10–13.

King, G. and L. Zeng. 2001. Logistic regression in rare events data. *Political Analysis* 9:137–63.

Klimek, Suzanne. 2010. Deficiencies documented in spatial analysis of the ecosystem enhancement program. *National Wetlands Newsletter* 32:18.

Minnesota Pollution Control Agency. 2014. Watershed approach to restoring and protecting water quality. www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/watershed-approach/index.html.

Mitsch, W.J. and J.G. Gosselink. 2000. The value of wetlands: importance of scale and landscape setting. *Ecological Economics* 35: 25–33.

National Research Council. 2001. *Compensating for Wetland Losses Under the Clean Water Act*. Washington, D.C.: The National Academies Press. www.nap.edu/catalog.php?record_id =10134.

NC Department of Commerce. 2013. 2013 County tier designations. www.nccommerce.com/research-publications/incentive-reports/2013–county-tier-designations.

NCDENR. 2013a. Awards and recognition. *N.C.* Ecosystem Enhancement Program. portal.ncdenr.org/web/eep/awards.

NCDENR. 2013b. Watershed planning. N.C. Ecosystem Enhancement Program. portal.ncdenr.org/web/eep/watershed-planning-home.

NCDENR. 2013c. EEP library: Research & data. N.C. Ecosystem Enhancement Program. portal.ncdenr.org/web/eep/research-and-data.

NCDENR. 2013d. Watershed planning documents: River basin restoration priority plans. N.C. Ecosystem Enhancement Program. portal.ncdenr.org/web/eep/rbrps.

NRC. 2001. *Compensating for Wetland Losses Under the Clean Water Act*. National Academy Press, Washington, D.C.

Owens, D.W. 2012. County zoning. UNC School of Government: Planning and Development Regulations. www.sog.unc.edu/node/943.

Palmer, M.A. and S. Filoso. 2009. Restoration of ecosystem services for environmental markets. *Science* 325:575–76. doi:10.1126/science.1172976.

Polasky, S., E. Nelson, J. Camm, B. Csuti, P. Fackler, E. Lonsdorf, C. Montgomery, D. White, J. Arthur, B. Garber-Yonts, R. Haight, J. Kagan, A. Starfield and C. Tobalske. 2008. Where to put things? Spatial land management to sustain biodiversity and economic returns. *Biological Conservation* 141:1505–1524.

Richardson, C.J. 1994. Ecological functions and human values in wetlands: A framework for assessing forestry impacts. *Wetlands* 14:1–9.

Robertson, M.M. 2006. Emerging ecosystem service markets: Trends in a decade of entrepreneurial wetland banking. *Frontiers in Ecology and the Environment* 6:297–302.

Robertson, M.M. and N. Hayden. 2008. Evaluation of a market in wetland credits: Entrepreneurial wetland banking in Chicago. *Conservation Biology* 22:636–646.

Simley, J.D., Jr. and W.J. Carswell. 2009. The national map—Hydrography. U.S. Geological Survey. nhdftp.usgs.gov/DataSets/Staged/States/.

U.S. Census Bureau. 2013. American community survey, 2007–2011 American Community Survey 5–Year Estimates, Report R10492640. Generated using Social Explorer. www.socialexplorer.com.

Womble, P. and M. Doyle. 2012. The geography of trading ecosystem services: A case study of wetland and stream compensatory mitigation markets. *Harvard Environmental Law Review* 36:229–94.

Sierra C. Woodruff (corresponding author), Curriculum for the Environment and Ecology, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, sscheleg@live.unc.edu.

Todd K. BenDor, Department of City and Regional Planning and UNC Institute for the Environment, University of North Carolina at Chapel Hill, New East Building, Campus Box #3140, Chapel Hill, NC 27599-3140.