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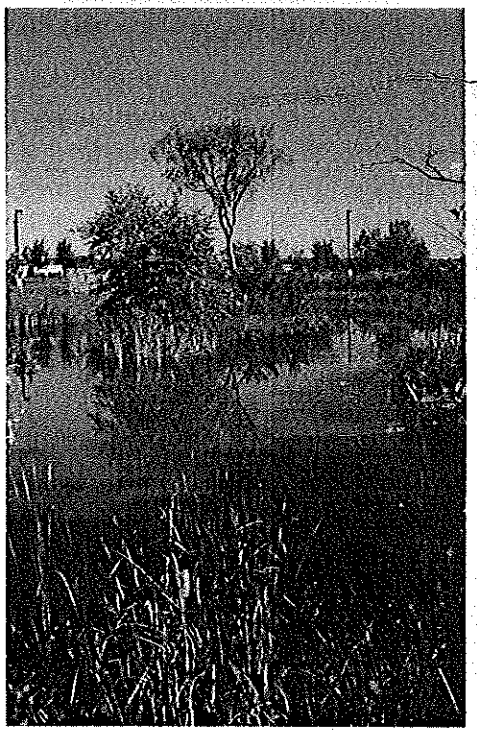
Research Bulletin Number 746 / December 1998

Compensatory Wetland Mitigation in Massachusetts



Stephen Brown and Peter Veneman

Massachusetts Agricultural Experiment Station
College of Food and Natural Resources
University of Massachusetts at Amherst

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Compensatory Wetland Mitigation in Massachusetts

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I. Executive Summary

This study describes the characteristics of a representative sample of wetland replication projects selected from a random sample of 44 towns in Massachusetts. The data describe losses of wetlands that occur from failures of compensatory mitigation at authorized wetland impact sites, but do not address losses from other causes such as Limited Projects and unauthorized fills. The study included analysis of 391 project files identified in the study period between 1983 and 1994, and 114 site visits. Data were collected on project size, location, status, and detailed comparisons of replicated plant communities were made with remnant impacted wetlands when these existed.

Most projects in the study were relatively small, impacting less than 5,000 square feet of wetland. The majority of projects (54.4%) were not in compliance with the requirements of the wetland regulations for a variety of reasons including no attempt to build the project, insufficient size or hydrology, or insufficient cover of wetland plants. Many of the projects that were constructed were smaller than required by their Orders of Conditions (64.9%). The majority of constructed projects involved impacts to forested wetlands (70.1%), but most replication projects were designed to produce scrub/shrub systems (61.4%). Most actually produced either no wetland (38.6%), open wet meadows (36.8%), or some other wetland type. The rates of non-compliance varied among DEP regions, and were highest in the Southeast region.

The plant communities produced at replication sites differed significantly from the wetlands they were designed to replace, in terms of number of species, cover, and species composition. The similarity of the replication site plant communities does not increase between projects that are new and projects up to 12 years old, indicating that similar plant communities may not be replaced at most sites for many years if at all. The completeness of the replication plan and the Order of Conditions affect the likelihood that a project will comply with the regulations, but not the level of similarity between the replicated and impacted plant communities.

Projects constructed under variances from the Wetland Protection Act were much more carefully designed, and were all in compliance with the regulations. However, they had plant communities that were not similar to those of the impacted wetlands they were designed to replace. They generally provided very good replication of water quality and sediment control functions, but not of wildlife habitat functions.

The state's goal of no net loss of wetlands cannot be met unless the regulatory program succeeds in compensating for all authorized wetland impacts, and the program currently allows significant losses to continue. The following recommendations for both local Conservation Commissions and the Commonwealth of Massachusetts address the program limitations discussed here.

Recommendations for Conservation Commissions

1. Increase compliance monitoring.
2. Supervise replication construction.
3. Require completion of the replication before the project starts.
4. Require substantial completion of replication before issuing partial Certificates of Compliance.
5. Do not allow stormwater detention ponds to qualify as wetland replication.
6. Insure that Orders of Conditions have been recorded on project site deeds.
7. Require in-kind replacement whenever possible.
8. Require applicants to support monitoring of the replication project.

Recommendations for the Commonwealth of Massachusetts

1. Develop statewide record-keeping and reporting system.
2. Require in-kind replacement of impacted wetland type.
3. Issue Replication Guidance and provide technical training.
4. Increase pro-active wetland restoration.
5. Promote wetland restoration rather than wetland creation.
6. Require replication for Limited Projects.
7. Fund a comprehensive study of other causes of wetland loss in the Commonwealth.

II. Introduction

Background

The primary purpose of this study is to provide detailed and statistically robust information about the success of current wetlands mitigation practices in Massachusetts. The study was proposed by the Wetlands Restoration & Banking Program to implement recommendations of the Wetlands Banking Advisory Committee. The Committee wanted a detailed and wide-ranging analysis of the current wetland mitigation program to provide background information to support the ongoing discussion of modifications of current mitigation policy and practice. In addition to providing information about the effectiveness of current mitigation practices, this study provides a baseline for comparing the effectiveness of traditional wetland mitigation for comparison with other approaches that may be developed in the future.

Questions Addressed by This Study

This study examines a random sample of sites in the field to provide a statistically valid estimate of compliance across the state with site-specific design criteria and with the performance standards in the Massachusetts wetland regulations. There are six major questions that we address. Each question focuses on a specific area of mitigation success.

1) Design Criteria: What design criteria for wetland replication have been required by Conservation Commissions? Have designs improved over time?

This question was addressed in an earlier study by the U.S. Army Corps of Engineers (USACE 1989), but not among a representative random sample of towns. The study identified a wide range of design standards, and also showed that projects with higher design standards have a higher likelihood of success. Our study aimed to determine if this pattern holds generally for the state as a whole. In addition, we determined whether or not wetland replication designs have improved over time.

2) Compliance: How many of the projects proposed in mitigation plans are actually constructed, and do they follow the design specifications required by the Conservation Commission?

There are few data on the rate of compliance among permits that require wetland mitigation in Massachusetts. The Army Corps study (USACE 1989) identified several projects that were apparently destroyed, and others in which the project failed because design criteria were not followed. Our study provides a statistically valid assessment of the frequency of these failures to adequately replace wetland at project sites. One goal of this study was to determine the size of the problem, and the improvement in mitigation success that may be achieved through greater monitoring of project construction and compliance with approved site design.

3) Effectiveness at meeting performance standards: Are the techniques used sufficient to meet the performance standards in the Regulations?

This is the question that is most frequently associated with the determination of "success" in wetland replacement. It was addressed by the ACOE study, but the estimates of compliance with the performance standards reported cannot be extrapolated beyond the 94 sites visited because site selection was not random. Our sample of the frequency with which the performance standards are met was randomly selected and provides a statistically valid estimate of compliance across the state.

4) Effectiveness at replacing plant communities: Are replication site plant communities similar to those impacted at the same site?

The Wetlands Protection Act is intended to protect the functions of wetlands that are valuable to society, not wetlands per se. Even if replacement projects are successful at establishing some type of wetland vegetation, the replication site may not replace the wetland lost due to the permitted impact. Replacement of function is unlikely when completely different plant communities are created relative to the impacted wetland.

The Wetlands Protection Act Regulations require that replacement wetlands function in a manner "similar" to the wetlands that were impacted, yet no studies have been done in Massachusetts that compare replicated wetlands with natural wetlands. As noted in the preface to the 1983 Regulatory Revisions, "the functions served by bordering vegetated wetlands cannot be replicated in their totality by engineering means" (310 CMR, Preface, V C.). We use the plant community as an indicator of the similarity of function between impacted and replication sites.

5) Project Conditions: What specific requirements are included in the Orders of Conditions for wetland mitigation sites?

The performance standards for wetland replacement (310 CMR 10.55) provide only very general guidelines for the design of a replacement wetland and for the determination of whether the project was successful. Different DEP regions use different standard guidelines, and there is wide variability among Conservation Commissions. The wetlands regulations include the authority to require "any additional, specific conditions the issuing authority deems necessary to ensure that the replacement area will function in a manner similar to the area that will be lost" (310 CMR 10.55 (4) (b)). We analyzed the relationship between project requirements as stated in the Orders of Conditions and the eventual success of the projects to determine if stricter requirements improve success at meeting the performance standards, and if they improve success at replacing wetlands with more similar plant communities.

The Army Corps study identified wide variability in the comprehensiveness of design criteria in Orders of Conditions throughout the state. In addition, there was a tendency for projects with strong Orders of Conditions to be more successful at recreating wetland. This suggests that efforts to improve the comprehensiveness of design criteria and to ensure their widespread use, might improve mitigation success. This study determined if the relationship between design criteria and success is robust throughout the state, or varies among specific project types or regions. In Section IV, we provide recommendations for design criteria that could be adopted by DEP and by Conservation Commissions for wetland replication projects, based on a demonstrated record of their relationship with improved replication success.

6) Are relatively large mitigation projects that are permitted through variances more successful at replacing impacted wetland than small projects?

There is a common assumption that relatively large projects, which involve greater resources in the design, construction, and monitoring phase, will have greater success at reproducing wetlands with high levels of function. This study analyzed all of the freshwater mitigation projects associated with variances under the Wetlands Protection Act that required replication. This group of projects is comparable to pilot wetland mitigation banks or other centralized mitigation approaches, which are likely to involve relatively large wetland restoration or creation projects.

Questions Not Addressed by This Study

This study focuses on the results of wetland replication projects and provides estimates of wetland losses that occur when replication fails. It does not address the other causes of wetland loss in Massachusetts. For example, projects with wetland impacts that require wetland mitigation under the Act but are not mitigated due to decisions by Conservation Commissions are not addressed. The number of such projects is unknown, and would require additional searching of records to enumerate. In addition, unpermitted losses that occur in violation of the Act are not addressed. Future studies should address these causes of wetland loss to assess the magnitude of all Massachusetts wetland losses. The state's goal of no net loss of wetland cannot be achieved without a thorough accounting of all forms of ongoing losses, and a restoration program sufficient to counter those losses.

Analysis of Previous Studies

The Advisory Committee originally proposed a follow-up study to the Army Corps of Engineers report (USACE 1989) to determine the longer term success of the mitigation sites studied then. Based on an analysis of the previous work and the need for statistically valid information about mitigation success in the state, we proposed a new study design as described below.

The Army Corps study (USACE 1989), which was commissioned by DEP, included site visits to a randomly selected subset of mitigation projects. The sites were identified from a database generated through a study at Tufts University. The ACOE study reported a 36% failure rate for wetland replication projects, using a stratified random sampling procedure to represent the population of wetland replication projects in the original database. However, the techniques used to create the database itself did not include a random selection process. The database included only sites reported by Conservation Commissions responding to a mail survey or a notice in the Massachusetts Association of Conservation Commissions newsletter. That survey had only a 25% response rate. There is a clear potential bias in this process. Well-organized, aggressive Commissions were more likely both to respond to the survey and to impose more rigorous design and monitoring criteria, while less aggressive or less well-organized Commissions were under-represented.

The original survey did not follow standard mail survey methodology (e.g. Dillman 1978). In particular, a non-respondent follow-up was not included, which means that the characteristics of the non-respondents could not be analyzed. The study did include several attempts to describe the distribution of the responding towns. They were geographically distributed throughout the state, and composed of roughly the same proportion of Commissions with paid staff as the entire group of towns in the state. However, the non-random selection method has introduced an unknown bias, which is unmeasurable due to the lack of non-respondent follow-up.

In addition, the original study did not record land ownership, and permission is required from current landowners before entering their sites for evaluation. A follow-up study would have required a visit to each town to determine land ownership from tax records. Following up on the existing study would have provided an analysis of wetland development over time. However, given the limitations of the original database design, and the lack of landowner records, the original study records were of limited value and did not provide an adequate basis for determining mitigation success statewide.

III. Methods

Identification of Study Sites

Our goal was to analyze a random sample of at least 10% of the towns in the state, with the number of towns selected in each region weighted by the relative percentage of wetland projects in that region. There were very few data on the distribution of wetland replication projects among regions of the state on which to base a weighted sample. Of the 100 projects in the Army Corps study, the percentages in each region were as follows: North East region 45%; South East region 23%; Central region 22%; Western region 10%. However, the sample was not random, as discussed above, and the study included only projects through 1988. Because shifting economic conditions in the state are likely to have redistributed the relative number of wetland impacts in each region, we used another approach to estimate the total number of projects in each region.

The DEP recorded the total number of Notices of Intent for each region between 1988 and 1995 (Gary Gonyea, personal communication). These include impacts to resources other than Bordering Vegetated Wetlands. We used the total number of NOI's filed in each region between 1988 and 1994, and assumed that the percentage of projects impacting BVW's was equal in each region. In addition, we assumed that the proportion of projects involving

replication was equal among regions. We used these percentages only to weight the number of towns selected for study in each region, as shown in Table 1. The results of this study provide more precise data on the actual distribution of replication projects, as described below.

Table 1: Distribution of towns randomly selected for inclusion in the study based on the goal of at least a 10% sample of 351 towns, weighted by the percentages of all Notices of Intent (NOI's) in each region between 1988 and 1994. Additional towns were added in each region to ensure adequate sample sizes by ecoregion..

DEP region Name	Percentage of NOI's	Number of Towns as Proportion of 10% Sample	Number of Towns in Study	Towns Where Data were Collected
Northeast (NE)	27	9.5	11	10
Southeast (SE)	41	14.4	15	14
Central (CE)	22	7.7	9	9
Western (WE)	10	3.5	11	11
Total	100	35.1	46	44

Landscape features such as soil types, vegetation types, and hydrology are known to strongly influence the development of created wetland plant communities (Kusler and Kentula 1989). We designed the sample of towns to detect variation within DEP regions in the success of wetland replication relative to the landscape features of the different sub-ecoregions. For example, landscapes in the Western region differ significantly between the northeastern highlands and the Connecticut river valley. We stratified the sample of towns within DEP regions by sub-ecoregions derived from the EPA classification map for Massachusetts (Griffith *et al.* 1994). We used seven major groups of sub-ecoregions, as described in Appendix 1. These groups were chosen based on their relative homogeneity in soils and major landscape features. Because some town boundaries overlap ecoregions, each town was assigned for purposes of stratification to one ecoregion by determining which ecoregion predominated in that town. However, specific projects in towns with more than one ecoregion were included for analysis in the ecoregion in which they actually occurred.

We selected a random sample of 46 Massachusetts towns, stratified by DEP regions and ecoregions. The location of the selected towns is shown in

Figure 1. Four volunteers assisted in the identification of files and collection of file data. Data were collected for all replication projects in 44 of these towns or 12.5% of the total number of towns in the state. One town was in the process of moving its records, making them inaccessible, and another town was assigned to a volunteer assistant who did not collect the appropriate records. Because the removal of these towns from the study resulted from factors not related to their willingness to provide records, it should not significantly bias the results of the study.

Collection of Replication File Data

We contacted each selected town by mail, and requested assistance from Conservation Commissioners or staff in identifying Notice of Intent numbers for projects that involved mitigation. In towns that were unable to provide this assistance, we examined all files to identify projects involving wetland replication, and collected data on all freshwater wetland mitigation projects that were permitted. Projects involving coastal wetlands were not included in the study.

The study period included all projects in selected towns that involved wetland replication between 1983 and 1994. Replicated wetlands constructed after 1994 did not have two growing seasons for establishment, and therefore compliance with the wetlands regulations could not be determined. For each file, we recorded the information outlined in Appendix 2: Project Data Sheet, including descriptions of the wetland replication plans, the Notice of Intent, the Order of Conditions, and the Certificate of Compliance if one had been issued.

Orders of Conditions and wetland replication plans for each project were analyzed to determine the level of detail of the project design and the requirements placed on the permit holder. Many Orders of Conditions did not explicitly refer to the replication plans, so each was analyzed independently. The completeness of the requirements in both the plan and the Order of Conditions was assessed on the following scale:

Score:	Requirements:
1	No specific conditions regarding construction, only site location
2	Describes site preparation techniques
3	Requires specific construction sequences or techniques
4	Specifies specific soils and/or planting materials
5	Requires monitoring and/or maintenance

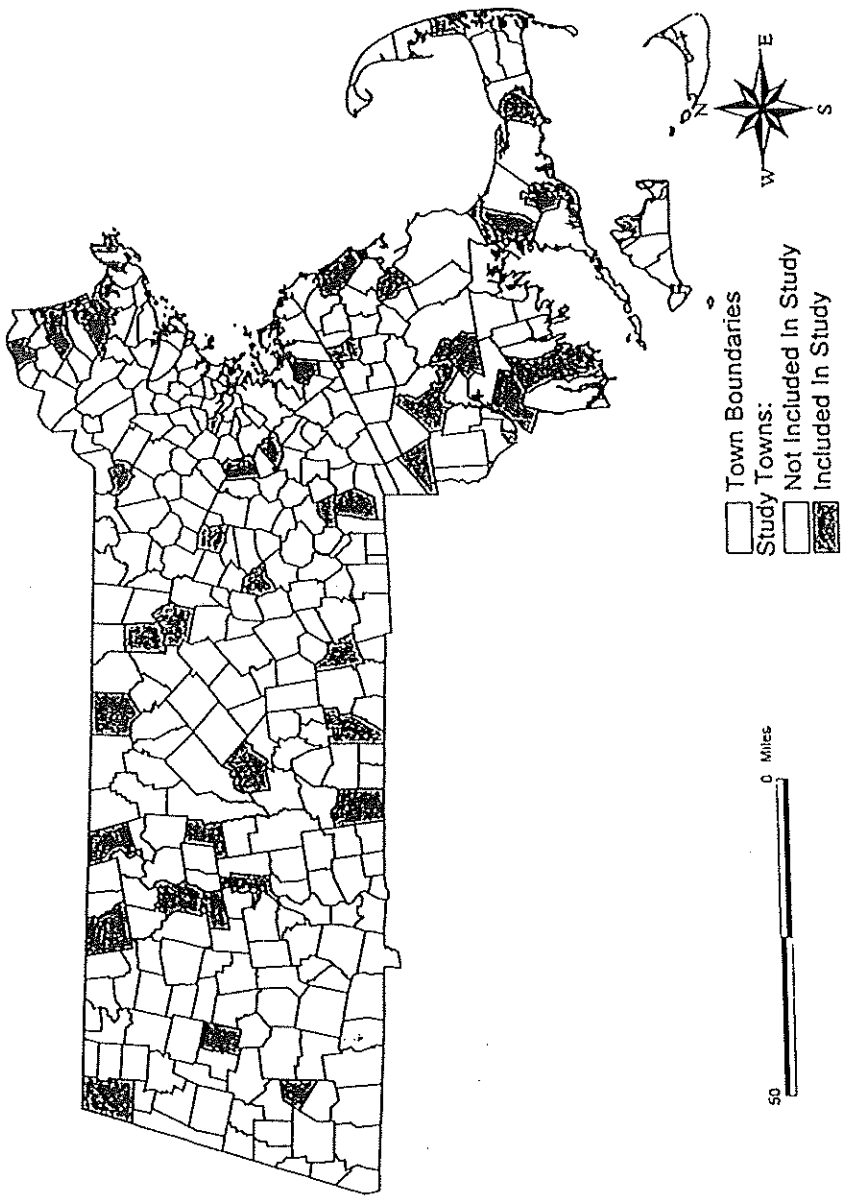

Figure 1. Location of Massachusetts towns included in the study.

Each plan and Order of Conditions was given the highest score corresponding to the specific requirements it included. In almost all cases, a specific plan or Order could be given a unique score on the basis of the requirements included, with all of the less specific requirements included as well. In 11 cases where more specific requirements such as soils types were included without less specific requirements such as a construction sequence, the higher score was given.

Site Visits

Site visits were conducted to a random subset of replication projects to determine if they met the performance standards. Field work began on 5 July 1997, and was completed on 15 October 1997. Our goal was to conduct site visits to as many towns as possible where replication projects had been reported. In the field, each project site was located from design and layout information in the file, and the actual dimensions of the replication site were measured with a meter tape.

Vegetation was analyzed in a representative 50 x 100 foot releve (Kent and Coker 1992). For sites smaller than these dimensions, the entire site was assessed. All plant species with total cover greater than 1% were identified or collected and pressed for later identification. For each plant species, an estimate of the total percent cover was recorded, in one of seven categories following DEP wetland delineation techniques (Jackson 1995), as follows: 1-5%, 6-15%, 16-25%, 26-50%, 51-75%, 76-95%, and 96-100%. For each category, the midpoint of the cover class was used in analyses of the vegetation community (3.0, 10.5, 20.5, 38.0, 63.0, 85.5, and 98.0). Similar techniques were used to sample remnant vegetation if undisturbed portions of the original wetland still existed.

Data Analysis

The wetland indicator status for each plant species was recorded (Reed 1988). The wetland plant indicator list assigns each plant species to a category ranging from obligate wetland to obligate upland. The categories reflect the estimated range of probabilities of a species occurring in wetland areas as defined by Cowardin *et al.* (1979): Obligate Wetland (OBL) = >99%; Facultative Wetland (FACW) = 67-99%; Facultative (FAC) = 34-66%; Facultative Upland (FACU) = 1-33%; Obligate Upland (UPL) = <1%.

We calculated a weighted average wetland indicator value (Wentworth & Johnson 1986) for each vegetation plot based on the percent cover of each species present and its wetland indicator status. Many studies use an index which assigns each class an integer value from 1 for obligate wetland to 5 for obligate upland (Siegelquist *et al.* 1990). Michener (1983) suggested that an index should reflect the fact that the probability classes are not evenly spaced between 1 and 100%. We used the frequency midpoint index value proposed by Eicher (1988) for calculations on wetland indicator status. This index assigns a value to each class designed to reflect the midpoint of its probability range, as follows: OBL = 1.0; FACW = 1.67; FAC = 3.0; FACU = 4.33; UPL = 5.0. Species with index values of 3 or lower are considered wetland species, and lower weighted average index values mean greater dominance by wetland plants.

We calculated the weighted average wetland index (WI) of each plot according to the following formula:

$$WI = \frac{\sum_{i=1}^{n} (IV_i * WIS_i)}{100}$$

where IV_i= importance value (measured by relative cover) of species i in that sample, and WIS_i= wetland indicator status of that species (Eicher 1988). Importance values were calculated by dividing the cover of each species in each plot by the total cover of all plants in that plot.

We compared the species composition of vegetation samples from replication sites and remnant natural wetlands with two common indices, the Jaccard index of similarity for presence-absence data and the Bray-Curtis index of similarity for abundance data (Ludwig and Reynolds 1988). The Jaccard index analyzes the number of species that two sites have in common, using only presence and absence data. The Bray-Curtis index uses the relative abundance of each species in each sample to compare the relative dominance of species between the two samples.

Variance Projects

In addition to sites identified through this random process, we collected information from DEP files on the design of all 12 freshwater mitigation projects associated with variances granted under the Massachusetts Wetlands Protection Act. We visited all of the variance projects that were constructed within the study period, analyzed the vegetation using the techniques described above, and conducted functional assessments at all sites where a remnant wetland existed.

We used the Evaluation for Planned Wetlands (Bartoldus *et al.* 1994) developed by Environmental Concern, to assess water quality, sediment stabilization, and uniqueness/heritage functions. Data were collected according to the protocols defined for each assessment.

For each variance project, we determined if a remnant area of the original wetland remained that could be assessed. We used WEThings (Whitlock *et al.* 1994) and WEThings Birds to assess the potential wildlife habitat value of the variance projects relative to the remnant impacted wetlands. We collected the data required for each assessment in the replication wetland and the remnant natural wetland. WEThings produces a predicted list of amphibian, reptile, and mammal species that could use a particular habitat. We compared the lists with the detailed models for each species and adjusted them as required by the protocol for using the system. We then compared the lists for each pair of replication and natural wetlands using the Jaccard index of similarity. We used similar techniques for birds based on species predictions made using WEThings-Birds.

Statistical Analysis

We used t-tests to compare means of response variables such as the number of species present at replication sites and natural wetlands. We used one-way ANOVA's to compare levels of categorical factors such as the degree of completeness of replication plans. We tested assumptions for data and residuals using normal probability plots. When a factor was significant, we tested pairwise comparisons of means using Tukey's HSD procedure. We performed simple linear regression to explore relationships between factors such as age or a replication project and degree of vegetation similarity. All statistical procedures were performed using SYSTAT (Wilkinson 1992), and a significance level of 5% was used throughout.

We used detrended correspondence analysis, as performed by CANOCO (ter Braak 1992) to analyze the plant species abundances at each restored and natural site during the four years of the study. This technique ordinates the sites according to their species compositions by extracting axes that maximally disperse the species data (Jongman *et al.* 1987). We compared the vegetation communities of the restored and natural sites, and the changes as restoration progressed.

IV. Results

The following sections present the results of the study in each major area. To simplify the presentation of the results, the details of statistical analyses are presented in endnotes compiled in Appendix 3 at the end of the report.

Characteristics of Replication Projects

Of the 44 towns where records were collected, 30 towns reported at least one wetland replication project between the study years of 1983 and 1994. A total of 3,519 files were reviewed to determine if permits included requirements for replication. We identified a total of 319 files requiring a wetland replication project. Of these files, 114 sites were visited to determine the characteristics of the resulting project. Population sizes and areas of the towns in the study are given in Appendix 4.

Certificates of Compliance were on file for 109 of the 319 replication projects identified, or 34%. Of these 109 Certificates, 25 were issued before two growing seasons had elapsed (23%), and 13 were issued within one year of the Order of Conditions (12%).

Twenty projects had Superseding Orders of Conditions. Of these 20 projects, 55% required more replication than the original Order of Conditions, 30% required the same, 15% required more replication but were issued over a town denial, and none were issued with smaller replication requirements than the original order.

The majority of replication projects resulted from impacts to forested wetlands (Fig. 2). Most of the remainder were impacts to scrub/shrub wetlands. The replication projects designed to compensate for these losses were predominantly scrub/shrub systems, with some designed to be forested wetlands. However, most of the actual replication projects where wetland was created were classified as wet meadows, with some marsh and scrub/shrub systems. No forested wetland was successfully created at any replication site during the time period covered by this study.

Compliance With the Wetland Regulations

The majority (54%) of replication sites in the study failed to meet regulatory requirements (Fig. 3). The largest single cause of failure was that no replication site had been built. Many sites also failed to meet the requirements

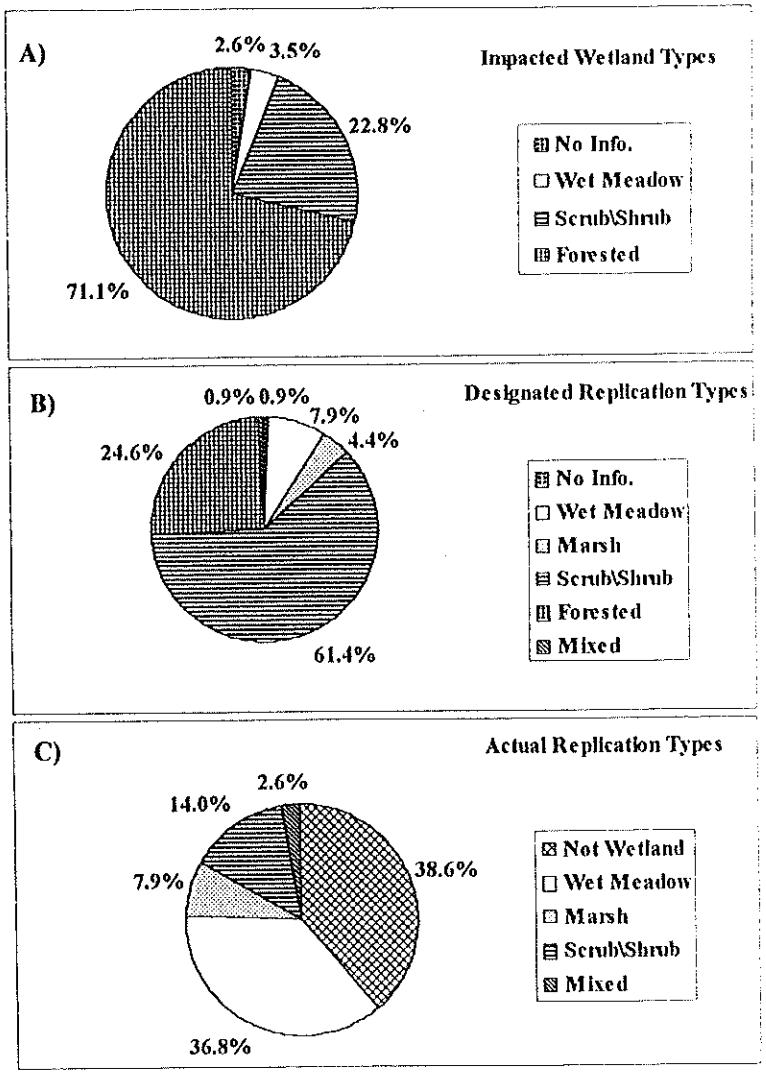

Figure 2. Types of wetlands recorded in this study. A) Wetland types impacted by authorized activities; B) Wetland types proposed in replication plans; C) Actual wetland types created at replication sites ("not wetland" includes projects not built, projects constructed with no wetland hydrology, and projects without wetland vegetation).

because they were too small. Sites were considered smaller than required if they were at least 10% smaller than required in the Order of Conditions. Additional causes of failure included sites that did not support wetland vegetation because they were too dry, sites that were both too small and too dry, and sites where vegetation was sparser than the 75% cover required in the regulations. Sites where the project was never built, so that no impact actually occurred even though a permit had been issued, are reported as a separate category.

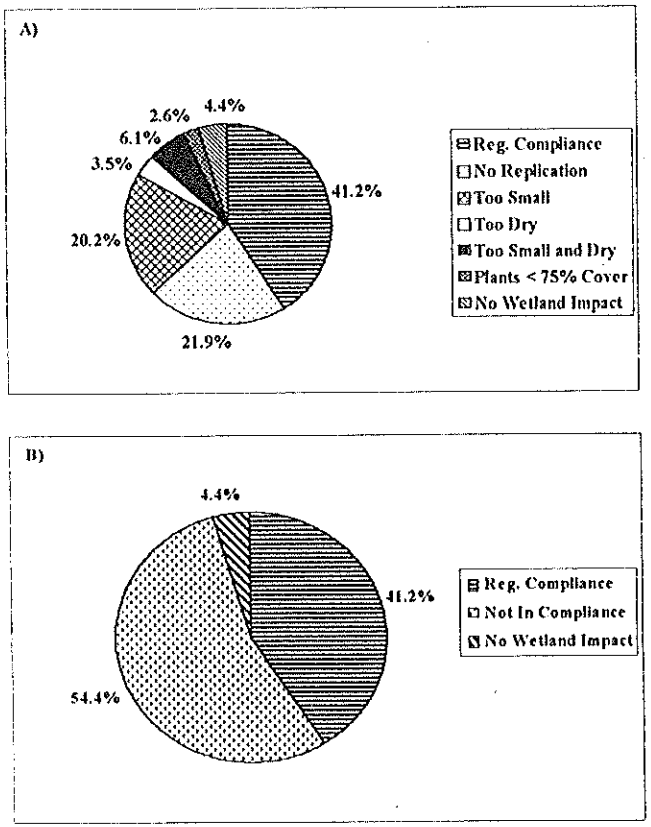

Figure 3. Percentages of projects in compliance with the wetland regulations, showing A) percentages of projects not in compliance by reason of failure, and B) total percentages of projects not in compliance.

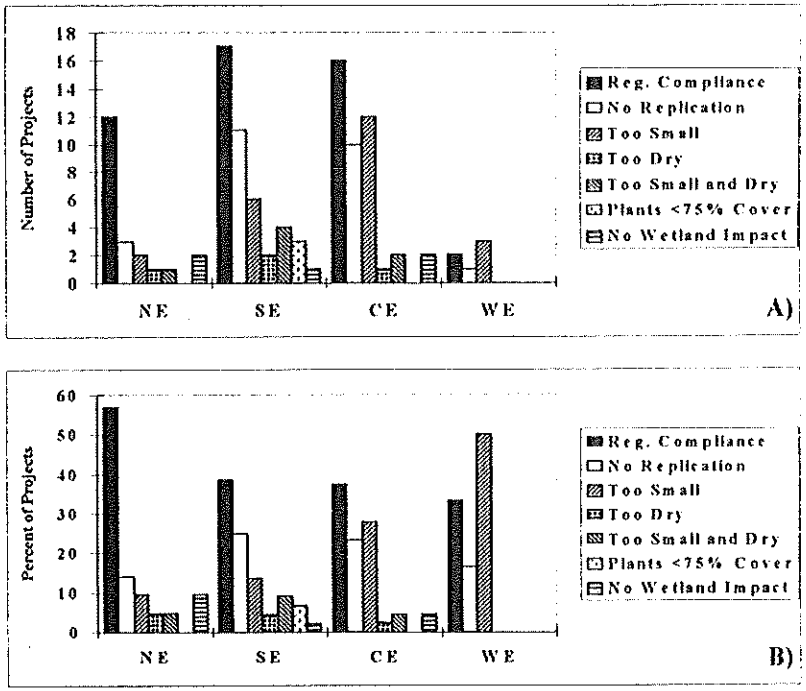

Figure 4. Patterns of non-compliance by DEP Region, including A) number of projects, and B) percentage of projects in each category.

The rates of non-compliance and the causes of site failures varied among DEP regions (Fig. 4). The highest rate of regulatory compliance was in the Northeast region, with the other three regions approximately equal. The percentage of projects that were never built was higher in the Southeast and Central regions than in the Northeast and West. Replication sites that failed to meet the regulatory requirements in the Central and Western regions were most commonly too small. Projects in the Northeast region and the Western region resulted in larger amounts of replication area being constructed, both relative to what was designed and relative to what was impacted, than projects in the other two regions (Fig. 5). In all cases, however, significantly less wetland was

created than what was impacted in the region. The 54% rate of non-compliance with the wetland regulations in this study was higher than the figure of 36% that is generally associated with the ACOE study. However, when the categories of projects are compared directly between the two studies, the rates are much more similar (Table 2). The ACOE report separated categories of projects that did not meet the regulatory requirements, but that might eventually meet the requirements ("conditionally successful"), and projects that were slightly smaller or less vegetated than the requirements but might eventually have the required characteristics ("marginal"). These projects were not in compliance with the regulations, and when the two categories are added with the unsuccessful projects, the overall rate of non-compliance in the ACOE study is 63%. The proportion of unsuccessful projects that failed because no replication was ever built was much higher in this study than the ACOE study (22% vs. 6%), but the overall rate of compliance was also slightly higher in our study.

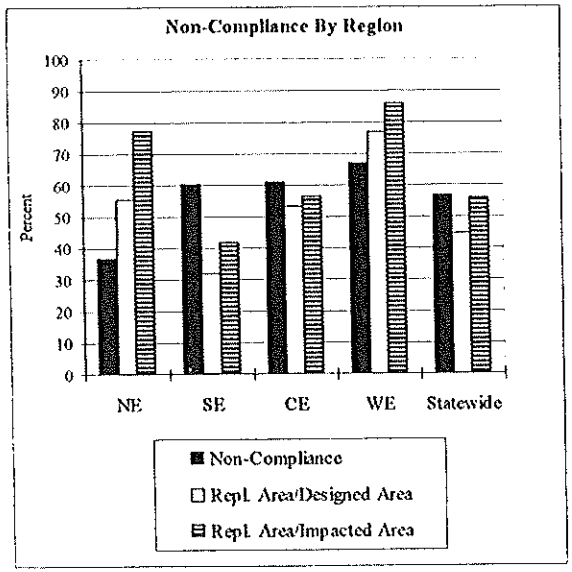

Figure 5. Percent of projects not in compliance by DEP region, and regional percentages of both actual replication area created relative to designated area, and actual replication area constructed relative to impacted natural wetland area.

Table 2. Percentages of projects in compliance with the wetland regu and in each category of reason for non-compliance, compared to th categories from the USACE study of wetland replication in Massachus

ACOE Category	Categories in This Study	ACOE Study No.	ACOE Study %	This Stu No.
Compliance	Compliance	36	33	47
Cond. Successful	Vegetation < 75% Cover	18	17	3
Unsuccessful	Too small, Dry, or both	34	31	34
Marginal	(not Used)	6	6	0
Not Built	Not Built	6	6	25
Destroyed	Destroyed	4	4	0
No Project	No Project	4	4	5
	Total	**108**	**100**	**114**
ACOE Data as Reported		No.	%	
Total Built Projects		94	100	
Compliance		54	57	
"Marginal"		6	6	
Not In Compliance		34	36	

Overall Regulatory Compliance	No.	%	No.
Compliance	36	33	47
Not in Compliance	68	63	62
No Project	4	4	5
Total	**108**	**100**	**114**

Table 2. Continued.

Projects with Wetland Impact	No.	%	No.	%
Compliance	36	35	47	43
Not in Compliance	68	65	62	57
Total	**104**	**100**	**109**	**100**

Towns that responded to an initial contact by letter had higher rates of regulatory compliance than towns that responded after multiple letters and towns that never voluntarily responded (Fig. 6). The lowest rate of regulatory compliance was found among towns that never provided records of replication and where projects were identified by searching through all the existing town files. However, rates of non-compliance varied greatly among towns and the differences among groups of towns with similar levels of contact effort were not statistically significant. In addition, the percentages of projects in compliance with the regulations did not increase over time, and also did not correlate with the total number of projects permitted in each year (Fig. 7).

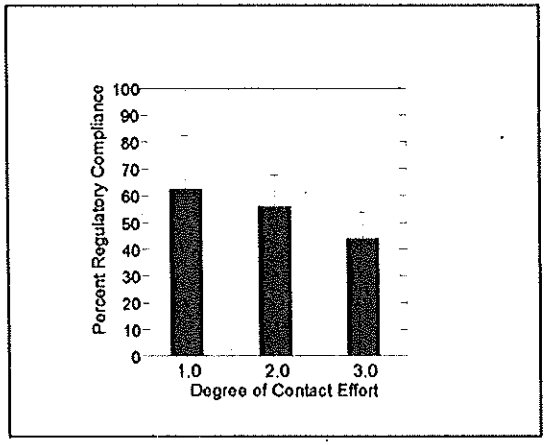

Figure 6. Percentage of projects in compliance with the wetland regulations according to the degree of contact effort required to obtain records from towns. 1 = town responded to an initial contact letter; 2 = town responded to one of four follow-up letters or phone calls; 3 = town never responded, and records were obtained by searching all town files.

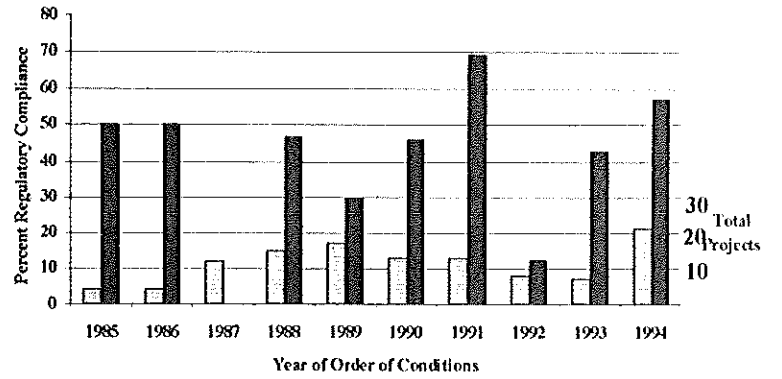

Figure 7. Percent regulatory compliance (black bars) and total number of projects (gray bars) by year that the Order of Conditions was issued.

Replacement of Plant Communities

The plant communities in replicated wetlands differed significantly from those in wetlands they were designed to replace. Compared to the natural wetlands, the replication sites had fewer plant species[1†] (natural 11.4 ± 3.0, replication 9.1 ± 3.5), less total cover of plants[2], fewer wetland plant species with an indicator status of FAC or wetter[3] (natural 10.2 ± 2.7, replication 7.8 ± 3.8), and less total cover of wetland plant species[4]. However, the wetland index values were similar[5] between replication sites and the remnant impacted wetlands (replication sites 2.276 ± 0.328, natural sites 2.251± 0.675).

There is a weak but significant relationship between wetland index values at replication sites and the age of the project (Fig. 8). Older projects have higher wetland index values, indicating a greater predominance of upland vegetation. However, the relationship is very weak, and there is a great deal of variability in index values across the entire range of project ages.

The number of species that are shared between replication sites and the impacted natural wetlands is very low (Fig. 9). There is no significant trend toward increasing similarity values with time. The results are similar for the Bray-Curtis

† Numbers refer to the results of statistical analysis reported in Appendix 3.

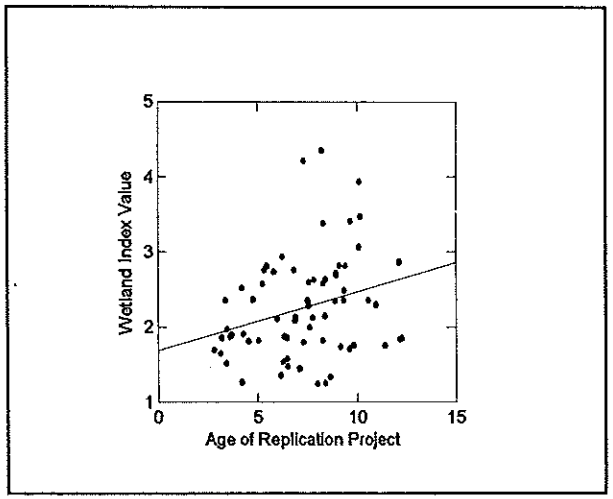

Figure 8. Weighted average wetland index value as a function of age of wetland replication project in years. $R^2 = 0.079$, $F = 5.72$, $df = 1,67$, $p = 0.020$

index of similarity, which incorporates both species presence and relative abundance (Fig. 10). Several sites had unusually high similarity values for both indices, and these were in-kind replacements of scrub-shrub wetlands with replication sites dominated by shrubs, or of marshes with replication sites dominated by marsh species. When the impacted wetland types were separated, there were higher similarity values between impacted wet meadows and their replication sites for both Jaccard similarity (Fig. 11) and Bray-Curtis similarity (Fig. 12). However, the differences were not significant for either index.

The ordinations of sites by species composition confirm that replication sites differed substantially from the natural wetlands. Figure 13 is a biplot showing both site scores and species scores for a detrended correspondence analysis of replication and natural wetland sites. The natural wetlands are dominated by forested wetland species and scrub-shrub wetland species. There are two main groups of replication sites, one dominated by drier-end open meadow species such as *Daucus carota*, *Phleum pratense*, *Aster novae-angliae*, and *Solidago canadensis*, which were occasionally too dry to be classified as wetland, and another dominated by wet-meadow species such as *Carex tribuloides*, *Leersia oryzoides*, *Bidens spp.*, and *Juncus effusus*. Some replication sites are similar in species composition to the natural wetlands, and these generally are dominated by

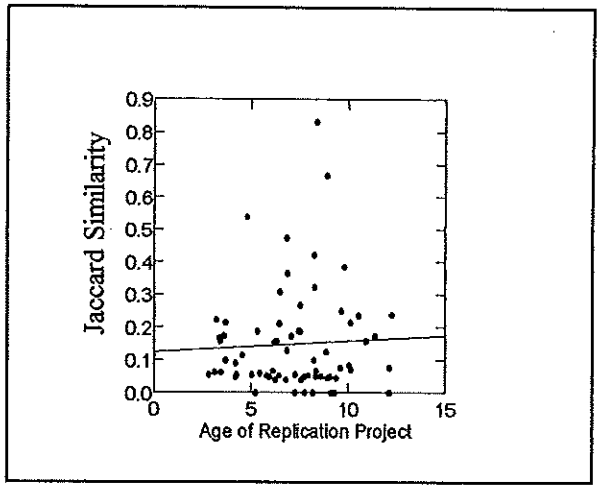

Figure 9. Jaccard similarity of replication plant community with remnant natural wetland plant community at impacted sites, as a function of the age of the replication project in years. $R^2 = 0.003$, $F = 0.17$, $df = 1, 67$, $p = 0.679$.

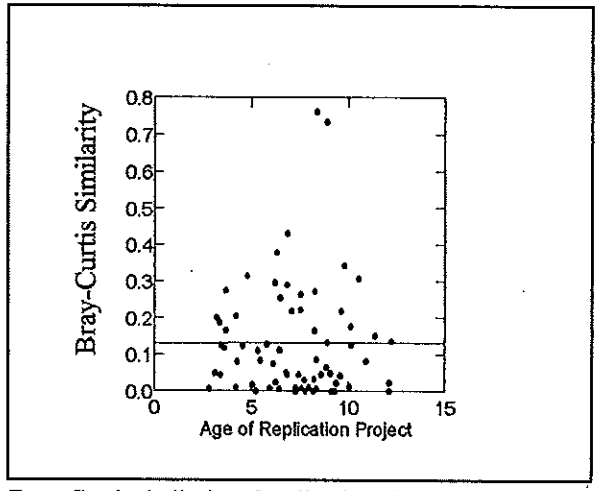

Figure 10. Bray-Curtis similarity of replication plant communities with remnant natural wetland plant community at impacted sites, as a function of the age of the replication project in years. $R^2 = 0.001$, $F = 0.01$, $df = 1,67$, $p = 0.945$.

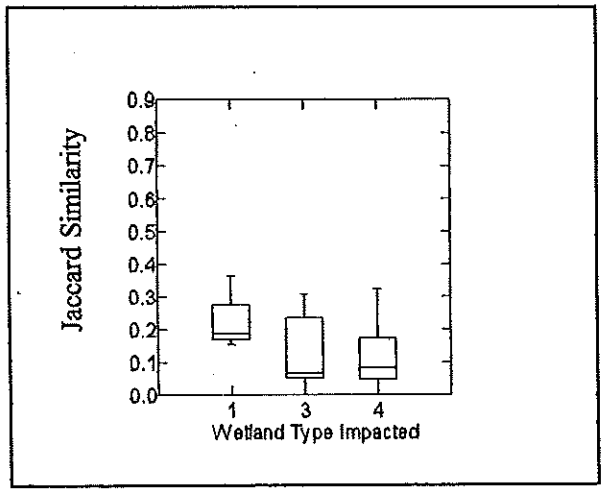

Figure 11. Jaccard similarity of replication plant community with remnant natural wetland plant community at impacted sites, as a function of the type of wetland impacted. 1 = wet meadow, 3 = scrub/shrub, 4 = forested. $R^2 = 0.003$, $F = 0.17$, df = 2,66, $p = 0.679$

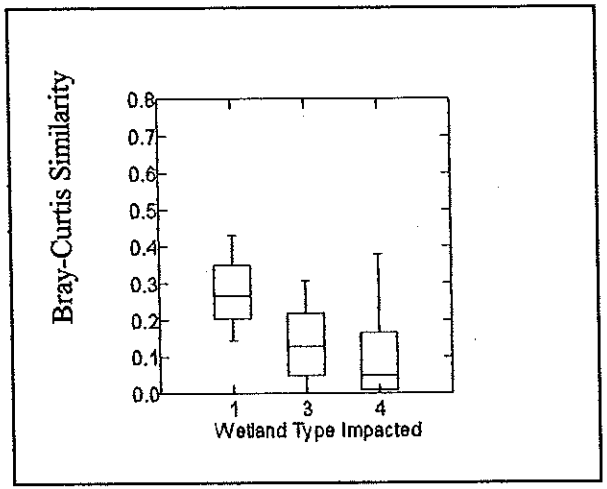

Figure 12. Bray-Curtis similarity of replication plant communities with remnant natural wetland plant community at impacted sites, as a function of the type of wetland impacted. 1= wet meadow, 3 = scrub/shrub, 4 =forested. $R^2 = 0.073$, $F = 2.583$, df = 2,66, $p = 0.083$.

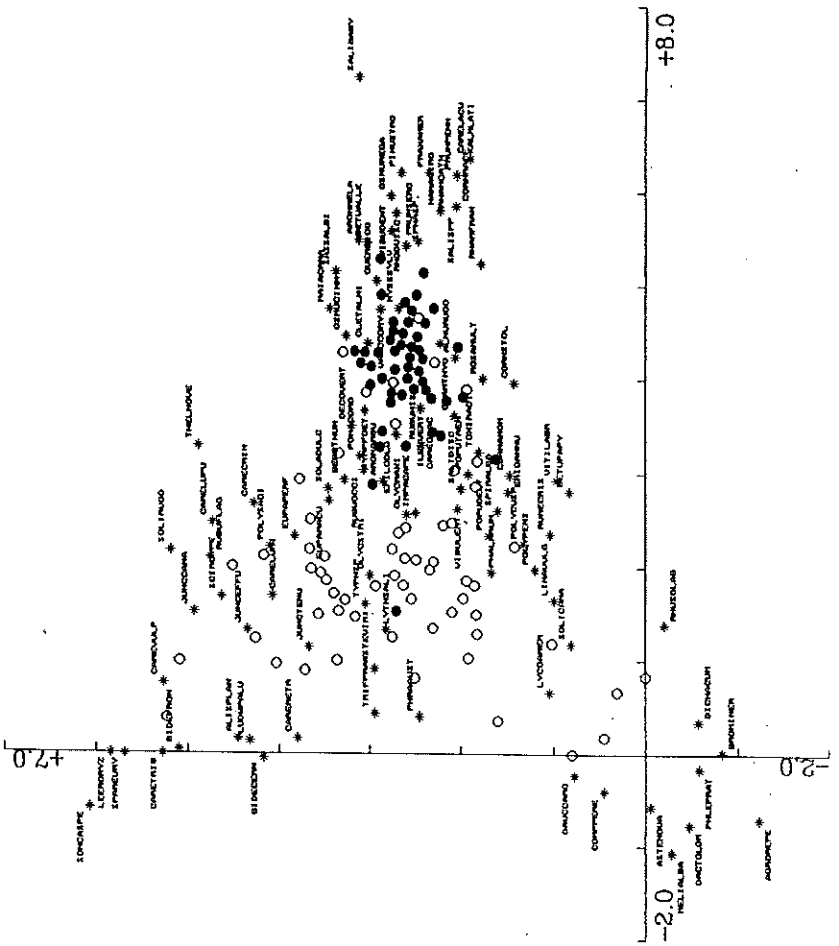

Figure 13. Detrended correspondence analysis of plant communities at replication sites (filled circles) and natural wetlands (open circles). Species scores are plotted with asterisks, and species are indicated with the first four letters of the genus followed by the first four letters of the species.

the scrub-shrub species common at natural wetlands such as *Alnus rugosa*, *Cornus spp.*, *Salix spp.*, and *Clethra alnifolia*. In addition, the older replication sites generally do not have plant communities more similar to the natural wetlands (Fig. 14). In a comparison of the 13 replication sites with the highest similarity in the ordination with the other 56 sites in the analysis, the average age did not differ[6] (similar sites mean age 7.319 ± 2.546, dissimilar sites mean age 7.241 ± 2.424). The more similar replication sites also did not differ from the less similar replication sites with respect to either wetland index value[7] or size[8].

The ordination results differ significantly from similar work conducted in upstate New York on restored wetlands (Brown 1995). In restored wetlands, there is generally a systematic recovery of the wetland plant community following restoration of hydrology. Figure 15 shows detrended correspondence analysis results for 14 restored wetlands, and the increase in similarity that occurred during the first three years following restoration. These results suggest that wetland restoration may be more effective at replacing wetland plant communities than wetland creation, as discussed below.

Analysis of the Regulatory Process

Most wetland replication projects resulted from relatively small impacts authorized under the 5,000 square foot provisions of the regulations (Fig. 16). Of the 319 files reviewed in this study, 255 (79.9%) were for impacts less than 5,000 square feet. The remainder were authorized as "limited projects". Most replication sites were designed to be slightly larger than the impact to existing wetlands (Fig. 17). Among the 319 files reviewed the ratio of designed size to impact size was 1.27 ± 0.699 (mean ± standard deviation). The ratio of designed replication size to impact size among the 114 sites visited in this study was 1.23 ± 0.567. Compared to all the files identified in the study, a slightly smaller proportion of replication designs among the sites visited were smaller than 5,000 square feet (76 projects, or 66.6%). However, 85% of the replication projects actually constructed were smaller than 5,000 square feet (Fig. 18). The average ratio between replication size and wetland impact for these projects was 0.66 ± 0.610. Of the projects visited in this study 74 (64.9%) were smaller than required by their Orders of Conditions.

The completeness of the Orders of Conditions issued for replication projects did not improve significantly between 1983 and 1994 (Fig. 19). The average age of Orders with no requirements was slightly but not significantly

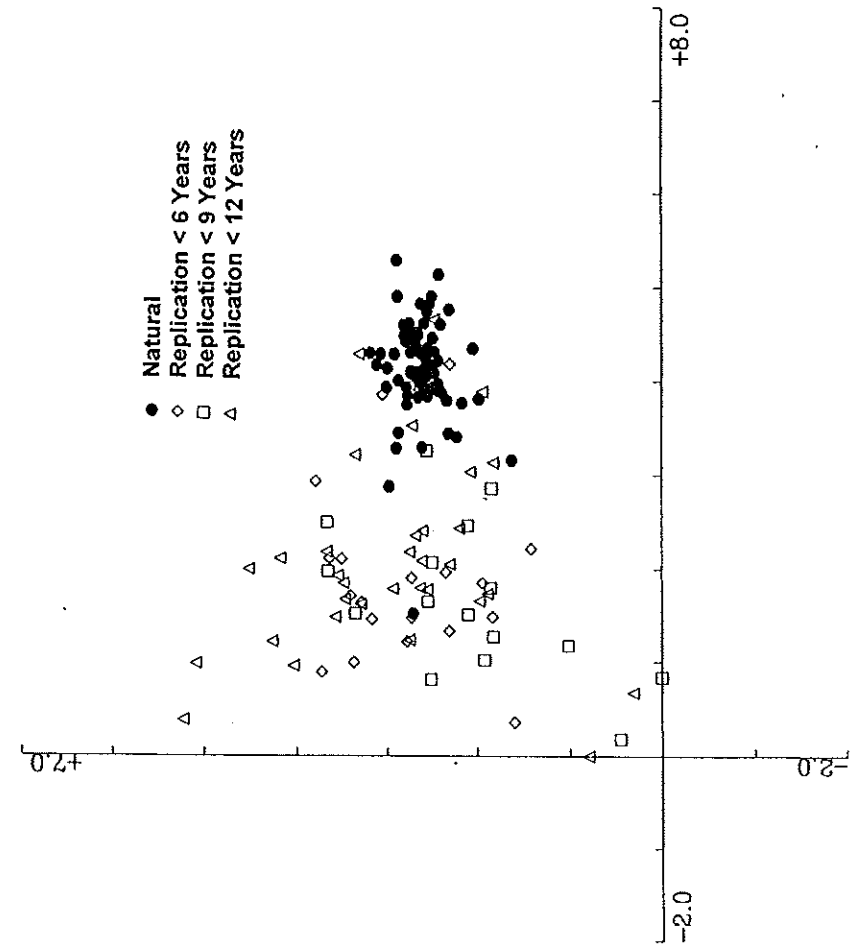

Figure 14. Detrended correspondence analysis of plant communities at replication sites (open symbols) and natural wetlands (filled symbols). Replication sites less than 6 years old are indicated with diamonds, between 6 and 9 years old with triangles, and between 9 and 12 years old with squares.

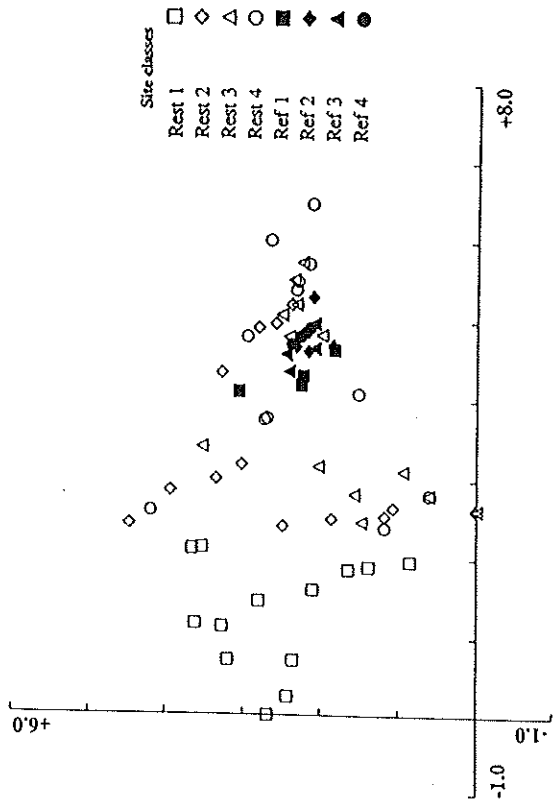

Figure 15. Detrended correspondence analysis of plant communities at wetland restoration sites (open symbols) and natural reference wetlands (filled symbols) in northern New York. 1 = before restoration, 2 = 1 year after restoration, 3 = 2 years after restoration, 4 = 3 years after restoration.

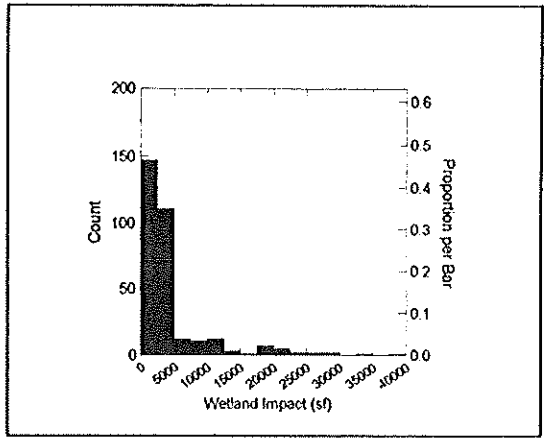

Figure 16. Histogram of sizes of wetland impacts in 319 replication site files, in square feet.

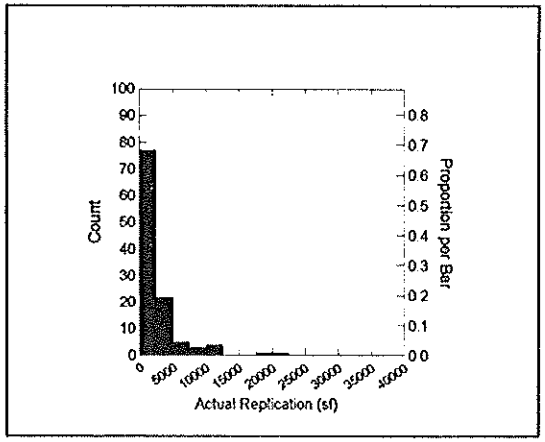

Figure 17. Histogram of sizes of designated wetland replication sites in 319 site files, in square feet.

higher than that of Orders requiring monitoring ($p = 0.052$), indicating that some improvement may be occurring. In contrast, the completeness of replication plans submitted by the applicants did improve significantly during the study period[9] (Fig. 20). Orders requiring specific soils and/or planting materials

(Category 4) and Orders requiring monitoring (Category 5) were on average significantly more recent than the other three categories[10]. In addition, replication plans on file were significantly more complete than the Orders of Conditions issued for the same project[11].

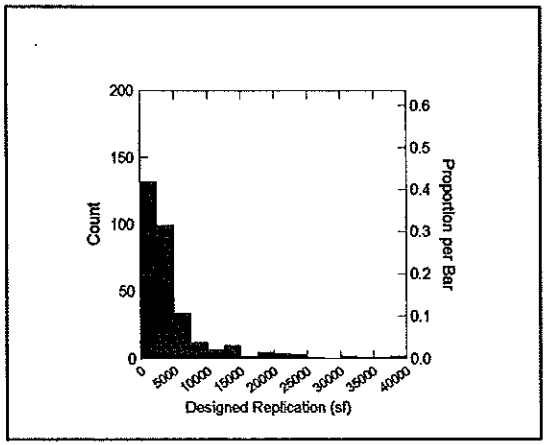

Figure 18. Histogram of actual constructed wetland replication project sizes at the 114 sites visited in this study, in square feet.

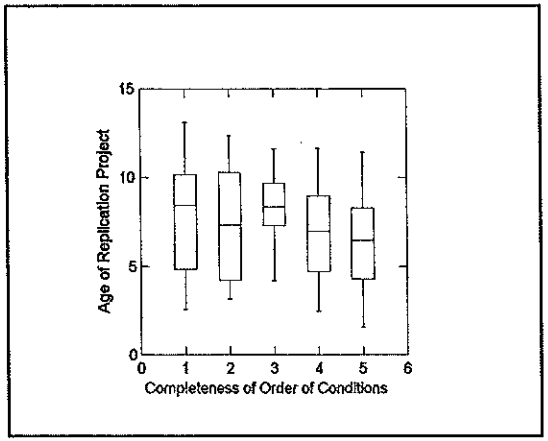

Figure 19. Box plot of median ages of replication projects plotted by completeness of the Order of Conditions for the project. Categories are defined in Appendix 2.

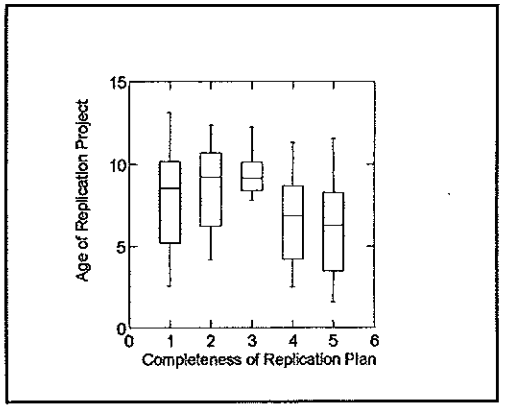

Figure 20. Box plot of median ages of replication projects plotted by completeness of the replication plan for the project. Categories are defined in Appendix 2.

The completeness of the replication plan was significantly related to the likelihood that a specific replication project would be in compliance with the wetland regulations[12]. Similar results were found for more complete Orders of Conditions[13]. However, there was no evidence that more complete Orders of Conditions correlated with significantly higher Jaccard similarity[14] (Fig. 21) or significantly higher Bray-Curtis similarity[15] (Fig. 22) between the resulting replication site plant communities and the impacted wetlands. Similarly, the completeness of the replication plan did not correlate with either Bray-Curtis[16] or Jaccard[17] similarity between impacted and created wetland vegetation. The types of wetlands impacted, designed for replication, and actually built included wet meadow, marsh, scrub/shrub, forested, and mixtures of these. The type of wetland impacted did not significantly influence the likelihood of a replication project being in compliance with the regulations[18]. However, the type of wetland designed did affect compliance rates[19], with more designed scrub/shrub sites in compliance (although not necessarily actually producing successful scrub/shrub wetlands). For wetlands actually constructed, the type of wetland created affected the likelihood of being in compliance[20], with scrub/shrub wetlands and scrub/shrub wetlands mixed with either marsh or wet meadow more likely to be in compliance. No forested systems were successfully created at any replication site, even though 28 project plans (24.6%) indicated that forested wetland was the restoration goal.

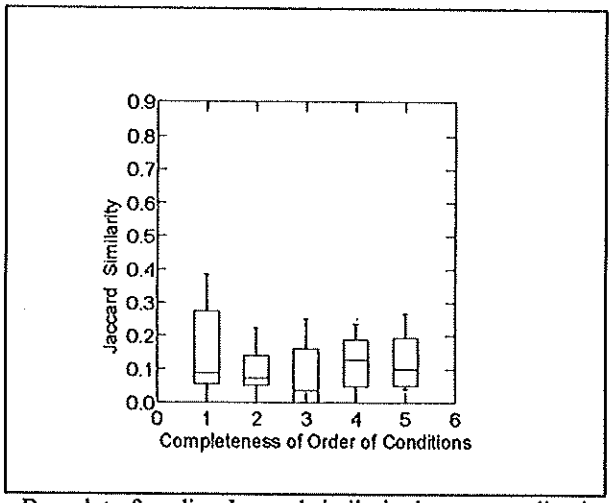

Figure 21. Box plot of median Jaccard similarity between replication site plant communities and remnant natural wetland plant communities plotted by completeness of the Order of Conditions for the project. Categories are defined in Appendix 2.

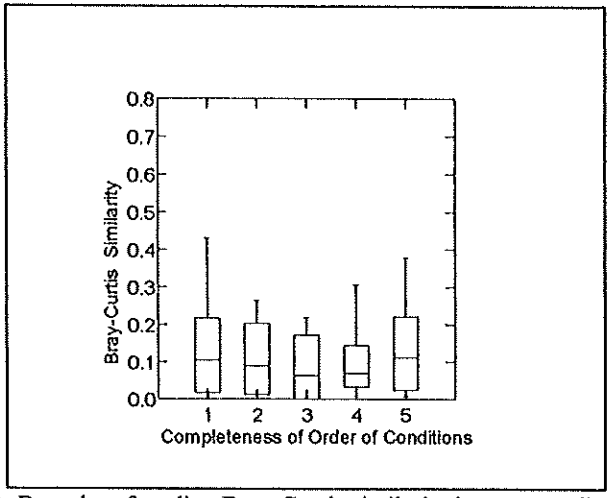

Figure 22. Box plot of median Bray-Curtis similarity between replication plant communities and remnant natural wetland plant communities plotted by completeness of the Order of Conditions for the project. Categories are defined in Appendix 2.

The proportion of projects in regulatory compliance varied within DEP regions according to the ecoregion in which the project was constructed (Table 3). In the Southern New England Coastal Plains, projects were less likely to be in compliance than for the Southeast region as a whole. However, this pattern did not occur for the other two regions in which this ecoregion occurs. In the Narragansset/Bristol Lowlands, projects in both the Central region and the Southeast region were more likely to be in compliance than for these regions as a whole. There were too few projects in the other ecoregions for the analysis to be meaningful.

Statewide Extrapolation of Results

The results from this study can be extrapolated to the state as a whole because the sample of towns was random within each region. However, there were no measured characteristics of the towns in the study that correlated well with the number of projects that occurred in each town. For example, the population of each town is only weakly related to the number of projects that occurred (Fig. 23)[21], and the correlation does not adequately predict the occurrence of towns with no projects. The number of projects therefore varies unpredictably among towns, and any predictions about towns not in the study should be analyzed with caution.

If we assume that the rates of non-compliance found for the 114 projects visited apply to all 319 projects identified for the 44 towns in the study, then the loss of wetlands between 1983 and 1994 in these 44 towns is estimated to be 18.18 acres (Table 4A). If the regional loss rates from this study are applied to all of the towns in each region that were not studied, the total loss for the state is 120.7 acres (Table 4B). These losses would have occurred from an estimated impact of 245.3 acres statewide during this period (Table 4C). The largest amount of wetland losses occurred from projects with impacts between 2,500 square feet and 12,500 square feet (Fig. 24), with both the largest and smallest size categories showing small net gains in wetland area. These loss estimates should be considered minimum estimates of losses that occurred from projects fully documented in Conservation Commission files, and do not include losses from undocumented authorized projects (missing files), authorized Limited Projects that did not require mitigation, or unauthorized filling activities, which probably represent the majority of wetland losses.

Table 3. Percentage of 114 replication projects in compliance with the wetland regulations by the ecoregion in which the project occurred, and compared to total rates for the DEP region in which the ecoregion occurs.

No	Ecoregion Name	Region	Projects in Compliance	Total Projects	Ecoregional Compliance (%)	Regional Compliance (%)
1	Northeastern Highlands	WE	0	4	0	
2	Connecticut Valley	WE	2	2	100	33
3	Central Plateau	CE	3	13	23	
4	SNE Coastal Plains	CE	10	25	40	
4	SNE Coastal Plains	NE	12	21	57	57
4	SNE Coastal Plains	SE	3	16	19	
6	Narr./Bristol Lowlands	CE	3	5	60	37
6	Narr./Bristol Lowlands	SE	14	28	50	39
	Total		47	114	41	41

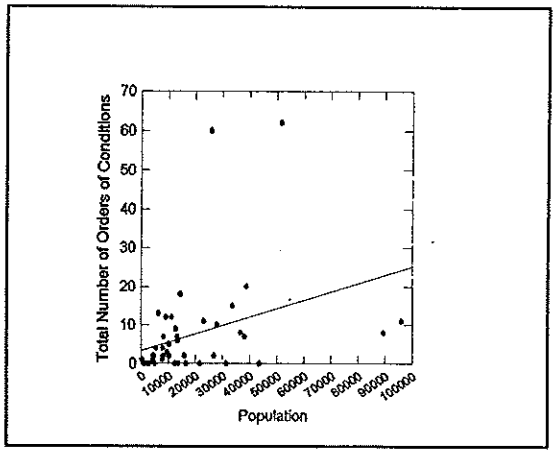

Figure 23. Total number of wetland fill authorizations for the 44 towns in the study where records were collected, plotted as a function of the population size of the town in which the impact occurred. $R^2 = 0.121$, $F = 5.78$, $df = 1, 42$, $p = 0.021$

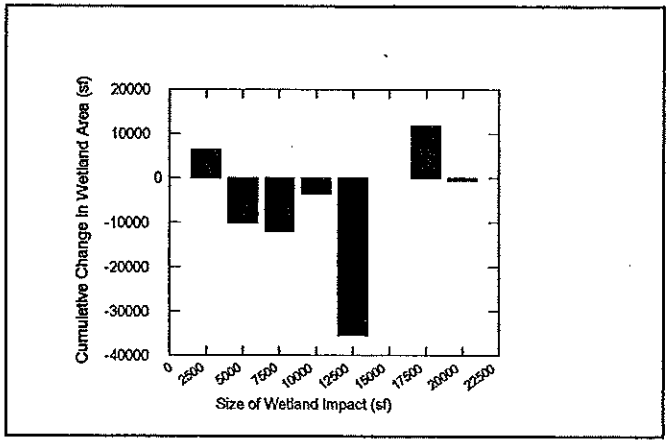

Figure 24. Cumulative wetland loss or gain from all 114 projects where site visits were conducted, by size of wetland impact.

Variance Projects

There were 12 variances issued for impacts to freshwater wetlands under the Act. Because these projects were generally much larger and involved much greater planning and oversight, they were analyzed separately. Of the 12 variances

issued, seven had been constructed long enough ago that two growing seasons had passed. We conducted site visits to all seven of these sites. At five of the sites a remnant wetland was present that could be studied for comparison with the created site, but at two the original wetland was completely destroyed. At one of the variance sites, two separate replication projects had been created, and these were analyzed separately but compared to the same original wetland at that project site.

Table 4. Statewide estimates of wetland loss from failures of replication at authorized wetland impact sites, extrapolated from the data in this study: A) total losses estimated for the 44 towns in the study from the losses measured at 114 site visits; B) total statewide losses estimated from the losses in each DEP region; C) total statewide wetland impacts estimated from the impacts in each DEP region.

A. Wetland losses estimated for towns in this study.

Reg	Total Impact (sf)	Designated Replication (sf)	Failure Rate (%)	Est. Failed Area (sf)	Est. Area Successful (sf)	Estimated Loss (sf)	Est. Loss (Acres)
NE	232,838	304,176	37	112,065	192,111	40,727	0.9
SE	968,631	1,150,908	66	695,898	455,010	513,621	11.8
CE	321,679	284,794	61	173,627	111.122	210,557	4.8
WE	46,297	58,036	67	38,691	19,345	26,952	0.6
Total sf Acres	**1,569,445 36**	**1,797,869 41.3**	**57**	**1,022,641 23.5**	**775,228 17.8**	**791,857 18.2**	**18.2**

B. Statewide loss extrapolation.

Region	Estimated Loss (sf)	Towns in Study	Towns in Region	Statewide Est. Loss (sf)	Statewide Est. Loss (Acres)
NE	40,727	10	95	386,905	8.9
SE	513,621	14	75	2,751,540	63.1
CE	210,557	9	80	1,871,622	43.0
WE	26,952	11	101	247,465	5.7
Total	**791,857**	**44**	**351**	**5,257,532**	**120.7**

Table 4. Continued.

C. Statewide impact extrapolation.

Region	Estimated Loss (sf)	Towns in Study	Towns in Region	Statewide Est. Loss (sf)	Statewid Loss (Ac
NE	232,838	10	95	2,211,961	50.8
SE	968,631	14	75	5.189.095	119.1
CE	321,679	9	80	2,859,369	65.6
WE	46,297	11	101	425,091	9.8
Total	**1.569,445**	**44**	**351**	**10,685,515**	**245**

All of the variance projects had fully complete replication p authorizing orders. They varied from 2.9 to 13.5 years old, and were c compensate for impacts ranging from 1,800 square feet (the varia necessary due to the large amount of temporary impact) to 82,764 sq (1.9 acres). Most impacted forested or scrub/shrub systems, and were to replace the same type impacted, but all of the replication projects we wet meadow or marsh communities, generally with small amounts of co sparsely planted trees or shrubs. All were in compliance with the re requirements.

Unlike the plant communities at the smaller replication sites, communities at the variance replication projects had comparable total of plant species[22] (natural 15.5 ± 3.4, replication 17.3 ± 2.4), total plants[23], and comparable numbers of wetland plant species[24] (natural 13 replication 14.7 ± 7.5) to the impacted wetlands. However, the amount of wetland plants was significantly lower at the replication sites[25]. The index values did not differ between the variance replication sites and the i wetlands[26] (natural 2.1 ± 0.7, replication 2.0 ± 0.4).

The plant communities at the variance replication projects similar in terms of species composition to the impacted wetlands. The Jaccard similarity was 0.119 ± 0.098, and the average Bray-Curtis simil 0.046 ± 0.046. Therefore, the variance plant communities are generally similar to the impacted wetlands than the smaller replication projects.

The functional assessment results comparing the variance re sites indicated that they were successful in providing water quality and

stabilization functions. The average water quality function values for replication sites (0.950 ± 0.032) were significantly higher[27] than for the impacted wetlands (0.856 ± 0.079). The values for sediment stabilization at the replication sites (0.863 ± 0.073) were higher than those at the impacted wetlands (0.856 ± 0.051), but the difference was not significant[28]. Neither the replication sites nor the impacted wetlands had uniqueness/heritage values as defined by the Evaluation for Planned Wetlands.

The variance projects differed substantially from the impacted natural wetlands in terms of predicted wildlife utilization (Table 5). The created wetland sites supported fewer predicted species of amphibians[29], mammals[30], and birds[31] than the natural sites. The differences between numbers of predicted reptile species were not significant[32]. Similarity values were consistently very low for all wildlife species groups, indicating that the proportion of species shared by the two types of sites was low for all variance sites.

Table 5. Jaccard similarity between predicted species lists for amphibians, mammals, and reptiles at replication sites constructed under variances and remnant natural wetlands.

Site No.	Amphibians	Mammals	Reptiles	Birds
1	0.000	0.500	0.000	0.087
2	0.455	0.286	0.667	0.125
3	0.000	0.188	0.000	0.133
4	0.182	0.294	0.000	0.200
5	0.636	0.385	0.000	0.182
6	0.455	0.357	0.000	0.200
Mean	**0.288**	**0.355**	**0.111**	**0.155**
SD	0.266	0.106	0.272	0.046

V. Discussion

Regulatory Compliance

The majority (65.8%) of replication projects did not have a Certificate of Compliance, despite the fact that adequate time had passed for the project to be completed and to have two growing seasons necessary to determine compliance. Many (22.9%) Certificates of Compliance were issued before adequate time had elapsed in which to determine the long-term success of the project. The lack of a Certificate indicates that Conservation Commissions either have not inspected the project to determine if it met the requirements in the Order of Conditions, or that the project was inspected and found not to meet the requirements in the Order of Conditions. However, only one file contained a record of a site being inspected and not meeting the requirements. This suggests that most projects have not been inspected by the Commission, or that inadequate records of inspections are being kept. Without systematic inspection, Commissions cannot determine if replication efforts are successful at meeting the regulatory requirements.

Most replication sites, if successful at creating wetland at all, do not replace the type of wetland that was impacted. Impacts to forested wetlands were never compensated with created forested wetlands, although some sites may ultimately develop into forested systems given adequate time. However, only 14% of the replication sites, which are currently scrub/shrub systems, show any potential for developing into forested systems on the basis of their current vegetation. This means that most wetland impacts occurring in Massachusetts cannot be replicated in-kind in the short term. The wetlands that are being created differ substantially in terms of type from the impacted sites, and the ongoing exchange of wetland types has cumulative effects that should be analyzed to determine the effect on wetland functions.

Most replication sites fail to meet the compliance requirements in the wetland regulations, which require only that some form of wetland be constructed, that it have at least 75% cover of some wetland plant species, and that it be the same size as the impact. A substantial improvement could be achieved simply by ensuring that replication sites were actually built whenever they were permitted, and that they were built as large as proposed. Removing these two causes of failure would increase compliance rates from 41.2% to 83.3%. However, many sites failed after being constructed at an appropriate size because they were designed too shallow to have appropriate wetland hydrology, or failed to support adequate cover of wetland vegetation. These sites would require design

improvements, or supervision during construction so that adequate designs were actually implemented, in order to ensure that they were successful.

The largest number of failed replication projects occurred in the Southeast, suggesting that the need for improvement is particularly great in this region. However, the rate of non-compliance is approximately equal in all regions except the Northeast, and the large number of failed projects in the southeast results in part from the greater number of permit applications. The largest causes of failure in the Southeast were from projects not being built, or being built too small, both of which could be addressed with increased site inspections by Conservation Commissions..

Comparing the results of this study with the earlier study by the ACOE shows that a higher percentage of projects is in compliance now than was found earlier. This may suggest that there has been some improvement in the application of the wetland regulations by Conservation Commissions, because the ACOE study included only projects through 1989, while this study includes projects through 1994. However, our analysis of the percentage of projects in compliance during each year of the study indicates no trend toward higher compliance rates in later years. Also, it is difficult to compare the results directly due to the different techniques used to determine the sample of towns. The ACOE study has a very low rate of projects that were never built, which probably results from the inclusion only of towns that responded to the initial mailing. Our results show that these towns are likely to have higher rates of compliance. From either study, it is clear that many replication projects fail to replace the type, area, and quality of wetland that was impacted, and this situation must be changed if the state's goal of no net loss of wetland is to be achieved.

Plant Communities

The replicated plant communities differed from the natural wetlands with respect to most of the variables measured. The only exception was the wetland index value. Most of the impacted areas were at the upslope borders of the natural wetlands, so that the driest portion of the wetland was affected. Conservation Commissions routinely attempt to limit encroachment of projects into wetlands, resulting in lessened impacts. In addition, attempts to limit impact often restrict filling activity to the borders of existing wetlands, where the vegetation is more transitional in character.

The increase in wetland index value toward upland values among projects may indicate that replicated wetlands are becoming drier over Possible explanations for this include the increased evapo-transpiratio occurs with the establishment of more mature plant communities, or the ev failure of planted wetland vegetation. However, it is important to note th data are from different projects established at different times, so the cha index values cannot be strictly interpreted as a trend line. An alter explanation may be that projects constructed more recently are designe deeper excavation, resulting in wetter conditions, or are located so as to in wetland hydrology. Detailed hydrological analysis would be necessa distinguish among these possibilities.

The regulations require that replication sites should function in a m similar to that of the impacted wetland. The recreation of a similar vege community is a clear pre-requisite to replacement of wildlife habitat val wetlands. In addition, reestablishment of a diverse wetland vege community may serve as an indicator that appropriate wetland hydrolog other functions have been created. However, virtually all of the replicatio that were constructed fail to provide similar wetland plant communities. of these failures can be described as designed failures, because the community proposed for the replication site was dramatically different fro impacted site, or because the appropriate vegetation community was pro but the site was not designed correctly to support it. Many replication site excavated as little as possible to create a marginal wetland plant communit were dominated by wet meadow species such as *Juncus effusus* and *Sol. graminifolia*. These systems cannot replace the functions of scrub-shr forested systems because they lack the cover and structure used by many w species.

The plant community ordinations confirm that the replication sit significantly different from the natural sites with respect to species compos Moreover, there is no evidence that the replication sites are developing g similarity to the impacted natural wetlands over time. The common assur that, given adequate time, replication sites will eventually develop into si wetland plant communities does not appear to be supported over the time of this study. This means that, at best, there is a significant temporal l wetland function for at least 12-15 years following creation of a replicatio and this loss may possibly last much longer. At worst, the replication site never provide similar plant communities, as there is no evidence that a

toward increasing similarity with time is found among the sites in this study. Long term differences in plant communities probably result from the different hydrology and soil characteristics compared to the natural wetlands, which were generally observed to have longer hydroperiods and greater development of organic soils.

The comparison with ordination results from restoration sites in New York emphasizes the difference between creating and restoring wetlands. Restored sites have the advantage of existing topography and remnant wetland soils. The convergence of the restored wetland plant communities with those at reference wetlands happened much sooner, and will apparently lead to high levels of similarity over time at the restored sites. Opportunities for wetland restoration should be pursued vigorously in Massachusetts, both as compensation for authorized impacts and as pro-active restoration to offset ongoing losses.

Analysis of the Regulatory Process

Although the management of wetland replication projects through the Orders of Conditions being issued by Conservation Commissions did not improve significantly between 1983 and 1994, the replication plans being submitted by applicants did improve. This suggests that a straightforward and relatively simple improvement in the process could be achieved if Commissions simply required in the Order of Conditions that all of the specifications in the replication plans be followed. While some towns included this requirement routinely, a large number did not.

Most towns are not systematically tracking the progress of replication projects and determining if they are in compliance with the regulations. The majority of projects studied did not have Certificates of Compliance. Some projects that were clearly not in compliance, including two that were never built, had been issued Certificates. Many of the issued Certificates were dated less than two years following the issuance of the Order of Conditions for the project. While there is no specific requirement that a Commission wait the entire two-year period before determining compliance, doing so raises the risk that unforseen difficulties will arise later in the life of the project, but the Commission will no longer have jurisdiction. Commissions should routinely inspect permitted replication projects, determine if they are in compliance, and issue Certificates of Compliance to those that are.

Projects with more complete replication plans and Orders of Cond were more likely to be in compliance with the wetland regulations. How there was no increase in the similarity of the created wetland vegetation more complete plans or Orders. Therefore, Commissions should strive to re complete plans and produce complete Orders, but should also require in replacement of the impacted wetland wherever possible. If this is not fea particularly in the case of forested wetlands, the Commission should at make an informed decision about what type of wetland would provide the benefits to the local area, and require that type be replicated. The author require replacement of specific wetland types is already provided by regulations, which specify that the Commission may require whatever addit specifications are necessary to protect the interests of the Act. The protecti wildlife habitat value would provide ample rationale for requiring spe wetland types to be replicated.

There is some evidence that more complete designs, which were more likely to include proposed scrub/shrub systems, were more oft compliance with the regulations. It is impossible to determine from the whether the increase in compliance is associated with the greater succe scrub/shrub systems, or whether the greater success resulted from other ef or site conditions that occurred more often at sites where scrub/shrub sys were designed. Although many of these projects did not successfully c scrub/shrub systems, they apparently included greater efforts to d functioning wetland systems, and some were actually successful at creating s swamps. Commissions should encourage applicants to design and cons scrub/shrub systems when these are being impacted, and not to allow the cre of open wet meadows in compensation for impacts to scrub/shrub wetland

Variance Projects

Projects constructed under variances from the Wetland Protectior were much better planned and designed, and much more likely to b compliance with the Act than the smaller projects in this study. This is surprising given the relatively large amount of investment in project desigr regulatory review, and the greater monitoring effort these projects receive.

However, the variance replication projects were no more successf replacing the plant communities that were impacted, and many smaller replic projects had higher similarity values. Again, this is not surprising becaus

regulations require only that some form of wetland be created, with the added provision that it function in a "similar manner" to the impacted site. Since the degree of similarity is not defined in the regulations, the requirement that the replicated site function similarly appears to be poorly understood both by Conservation Commissions and by permit recipients, and approval is routinely given for wetland replication projects that are designed to be dissimilar from the impacted wetlands in both structure and function.

The variance projects adequately replaced the sediment stabilization functions of the impacted wetlands, and had significantly higher levels of water quality function. This results from the construction of the replication projects in closed basins, which are rated highly by the functional assessment procedure used for water quality function. However, the replication projects did not adequately replace the wildlife functions of the impacted sites. This is primarily due to the lack of vegetation, the physical structure, and the soil characteristics compared to the natural wetlands. It is not likely that these structural features will develop at the replication sites in the foreseeable future.

Comparison With Other Studies

The wetland protection program in Massachusetts differs considerably from that of other states. Nevertheless, some comparisons can be made to results from studies of other state and federal wetland mitigation programs. The total wetland losses from permitted replication failures in Massachusetts are small compared to the losses routinely permitted in other regions. For example, federal wetland mitigation under the USACE Section 404 Program in the Great Lakes Basin resulted in a net loss of 159 acres between 1986 and 1989 (Lake Michigan Federation 1991).

The high rate of non-compliance with the Massachusetts wetland regulations is not unique. There was a high rate of non-compliance with state regulations in a Florida study covering a comparable time period, with 34% of required mitigation projects not constructed, and only four of the 63 permits reviewed in full compliance (Florida Department of Environmental Regulation 1991). Only 12% of freshwater projects were "ecologically successful", defined as having produced a functional wetland of the intended type. Loss rates were much higher than in Massachusetts, with a total of 3,305.42 acres impacted between 1985 and 1990. A similar study in Texas found that permits issued under the federal Section 404 Program administered by the USACE required

compensatory wetland construction generally equal to that impacted, but did not determine compliance rates in the field (Sifneos *et al.* 1992).

The failure to implement specific provisions of the regulatory process that was found in this study is not a new phenomenon. The history of problems with the results of wetland replication projects has been noted in many of the studies cited above. In an earlier study of five towns, few Certificates of Compliance were issued, and 5 of the 9 were issued before two full growing seasons (Clark 1990). The study also mentioned similar problems with impacts from nearby homeowners, such as mowing, filling, etc.

Earlier studies estimating losses from replication may have underestimated the rates of failures from projects not being built. This was discussed above for the ACOE study on replication in Massachusetts. Actual field conditions are generally significantly worse than what is described in the files. For example, a 1994 DEP study estimated that the Northeast region had a net gain of wetlands, with 66.7 acres filled, 68.8 acres replicated, and a net gain of 1.75 acres between 1988 and 1992 (MADEP 1994). However, the actual amount replicated was not determined for these projects. Our data suggest that statewide less than half of the designed replication area is actually constructed in compliance with the regulations.

The general problems with wetland construction have been noted in several earlier studies. One study suggested that restoration of degraded systems should be preferred over replication because of poor success rates, and because creation of wetlands trades one habitat type for another (Reimold and Cobler 1986). Another study recommended that wetland replication not be used based on the poor track record of project success, and expressed concern that the 75% cover criteria was insufficient because it does not translate into wetland function (Drainville and Whelan 1990). The results of the current study support the argument that more detailed regulatory criteria are needed to ensure replication success.

VI. Recommendations

The following recommendations are intended to improve the success of wetland replication in the Commonwealth. One apparently helpful recommendation that is often discussed as an approach to improving wetland mitigation is to increase the mitigation ratio required for particular projects. The reasoning is that while some projects will fail, others will succeed, and if the successful projects are larger than their associated wetland impacts, they will contribute

toward offsetting the losses that occur from the projects with replication failures. However, this recommendation is limited in its effectiveness. If the larger replication sites continue to have high rates of failure, then wetland losses will continue, and their location and magnitude will be unpredictable. The recommendations presented below should result in fewer project failures. The common requirement that replication sites be larger than the specific impact at each project site undoubtedly contributes toward the goal of lowering wetland loss. However, only by ensuring that all required replication sites are constructed so as to offset the actual environmental impacts associated with each project will the overall loss of wetland be controlled.

Recommendations for Conservation Commissions

Conservation Commissions have the authority to require any specific site construction techniques or other measures necessary to satisfy the interests of the Act (310 CMR 10.55 (4) (b)). However, simply ensuring that projects follow the requirements that are routinely included in Orders of Conditions is the most important improvement that could be made.

The following recommendations would significantly improve the success of wetland replication in most towns. Many of these recommendations must be implemented together for the improvement in replication results to occur. For example, if Commissions require better replication plans but do not follow up with monitoring to determine if the Order of Conditions was followed, there may be much less effect on the outcome.

1. Increase compliance monitoring.

The largest single increase in the success of wetland replication in Massachusetts would be achieved simply by ensuring that permitted projects are 1) actually built and 2) built according to designed specifications. This can only be accomplished through systematic and regular monitoring of replication sites to determine if they have been built according to the requirements in the Order of Conditions, and if they have achieved the minimum requirements for cover of wetland plants specified in the regulations.

2. Supervise replication construction.

Although time-consuming, supervision of construction provides an important opportunity to observe projects that are being incorrectly built and correct the problem. Once construction equipment has left the

site, the additional cost of repairing or redoing part of the replicati becomes much higher. Some town staff indicated a reluctance to requ repair of inadequately constructed sites for this reason. Observing t construction while underway also provides an opportunity to adjust pla as site-specific circumstances require.

3. Require completion of the replication before the project starts.

The major incentive for completing a replication site is the abil to go ahead with the permitted project itself. Once the project has be built, this incentive is lost. Many replication projects were left until afi the project had been completed, and were eventually construct inadequately or not at all. For this recommendation to be effective, pri completion of the replication project must be required, and monitori must be adequate to determine if it has been carried out. In cases whe a project is permitted to proceed before the replication site is establishe a performance bond should be required to ensure that the applicant w successfully perform the construction and monitoring activities requir in the Order of Conditions.

4. Require substantial completion of replication before issuing part Certificates of Compliance.

Many partial Orders of Conditions were issued by Commissio before the replication project had been inspected. This was particula common in the case of residential subdivision developments, where t replication provided mitigation for impacts during the construction access roadways. Individual lots in a multiple-lot development should r be allowed to be developed until the requirements for the wetla replication have been met. This will provide an incentive to the develop to complete the project in compliance with the Order of Conditions. Tl requirement would not be unnecessarily onerous if the Commissi simply required substantially complete construction of the replication s before further development was permitted, or before Certificates Compliance were issued for individual lot developments.

5. Do not allow stormwater detention ponds to qualify as wetla replication.

Many failed wetland replication projects were actua

stormwater detention basins. These routinely fail to create wetland, either because they are too dry or too wet. Dry detention basins cannot support wetland vegetation. Flooded detention basins may provide some aquatic habitat, but not wetland habitat. If the design of the development requires stormwater detention in addition to what can be provided by the replication wetland, it should be designed separately. Consideration should be given to providing an adequate water supply for the replication sites, while protecting it from contaminated runoff. In general, detention basins designed to retard stormwater cannot replace lost wetland function and Conservation Commissions need to recognize this in the development of appropriate replication plans.

6. Ensure that Orders of Conditions have been recorded on project site deeds.

Orders are currently required to be recorded, but many towns are leaving this responsibility to the applicant without any systematic follow-up to determine if it has been carried out. Several towns in the study routinely follow the practice of recording Orders on the property deed on behalf of the applicant. Properly recorded orders indicate the need for a Certificate of Compliance if the property is sold. This provides an incentive to the landowner to comply with the regulations. If the Orders are not recorded, as was apparently the case in a many of the towns studied, this important incentive is lost

7. Require in-kind replacement whenever possible.

Replication plans that do not specify the type of wetland that is proposed, or that specify a particular type of wetland but are insufficiently detailed to bring about successful construction of that type, are likely to lead to wetlands that are different from the type impacted. Towns should require in-kind replacement, and ensure that the Orders of Conditions make this a requirement of success, unless they have local environmental goals that can be better served through creation or restoration of some other specific wetland type.

8. Require applicants to support monitoring of the replication project.

Commissions should require applicants to retain environmental consultants on behalf of the Conservation Commission to monitor results

of wetland replication. Most towns do not have the human resources t monitor all permitted projects. Consultants hired by the applicant t construct and monitor the same project have a clear self-interest presenting favorable results. Independently hired consultants whose ta was only monitoring would provide unbiased analysis of replicatic results without putting an undue burden on the Commission staff.

Recommendations for the Commonwealth of Massachusetts

1. Develop statewide record-keeping and reporting system.

The poor quality of records currently kept by many towns mal a full accounting of the impacts of wetland replication impossible. Mar projects have incomplete files, and in some cases the requirement for replication project cannot be confirmed. In addition, the copies of recor kept by the Department of Environmental Protection usually reflect tl initial design, and may not include subsequent modifications made by tl Conservation Commissions.

Massachusetts should develop a statewide reporting and recor keeping system that would provide data on all wetland impacts and tl replication designed to mitigate for them. This system should inclu yearly Conservation Commission reports of the total number of projec impacting wetlands, the size of each project, the size of the propos replication, and the results of compliance monitoring. This data is critic to ongoing measurement of compliance with the regulations.

2. Require in-kind replacement of impacted wetland type.

The vast majority of wetland impacts are to forested and scrul shrub wetlands. Because the regulations require only that some type wetland be created, and because it is far less expensive to repla herbaceous systems, most replication projects make only a poor attem to replace woody vegetation. The result is a systematic exchange habitat type. The regulations should require that impacts to one type wetland be mitigated with in-kind replacement. The replacement forested systems is extremely difficult and in many areas forest wetlands are very common. Therefore, it may be appropriate for DEP develop a system that allows out-of-kind replacement with wetland typ that are locally or regionally rare. Intentional out-of-kind replaceme

may be justified in some cases by local conditions. Some forested wetlands, such as cedar swamps, spruce bogs, and *Nyssa* swamps are not common in Massachusetts, and in-kind replacement should generally be required. Decisions about replacement types should be based on some form of landscape analysis to determine what types of wetlands exist, and what wetland functions are most in need of improvement. In any case, the state should be making considered decisions about the type of habitat to replace, rather than allowing any type of wetland to suffice.

3. Issue Replication Guidance and provide technical training.

The records of many towns suggest confusion about basic aspects of the wetland regulations. In addition, many Commission staff people expressed an interest in guidance from the state. In the absence of systematic guidance, many towns are turning to outdated reports on wetland creation for some help in choosing design parameters. The state should issue uniform guidance specifying the conditions under which wetland impacts require mitigation, appropriate construction techniques, guidelines for reviewing replication plans, requirements for adequate Orders of Conditions, monitoring requirements, and general information about common mistakes in the construction of wetland replication projects. This Guidance should be supplemented with a technical manual presenting design issues for wetland replication. Finally, DEP should provide for training of Conservation Commissioners on how to use the Guidance and apply the manual.

4. Increase pro-active wetland restoration.

The state has a goal of achieving no net loss of wetland. For this goal to be realized, the ongoing impacts to wetlands must be offset by the replication of impacted wetlands, and the restoration of formerly existing or degraded wetlands. It is clear from the results of this study that the authorized impacts to wetlands in the Commonwealth significantly exceed the amount of wetland created by replication. There are many other sources of impacts to wetlands, such as unauthorized impacts in violation of the Act and exempt activities, that further reduce or degrade the State's wetland resources. The current administration and enforcement of wetland replication regulations is not adequate even to replace permitted losses. While this performance can be improved, it is likely that

significant wetland losses will continue. The state should therefore dramatically increase current efforts to restore former wetlands if the goal of no net loss is to be achieved.

5. Promote wetland restoration rather than wetland creation.

Wetland restoration is generally more successful than wetland creation at providing wetland functions (Kusler and Kentula 1989; Brown 1995). Wherever possible, restoration should be encouraged as an alternative to wetland creation. The completion of Watershed Wetland Restoration Plans, which are currently being conducted in several Massachusetts Watersheds and will eventually be competed statewide, will help Commissions identify potential restoration sites that would be alternatives to creation.

6. Require replication for Limited Projects.

Limited projects by definition involve larger impacts to existing wetlands than projects permitted under the 5,000 square foot regulations. Some of the largest losses recorded in this study are from Limited Projects, which require mitigation only at the Conservation Commission's discretion. The largest project filled 81,000 square feet (1.85 acres), and provided only 40,000 square feet (0.92 acres) of designed replication. Allowing the larger projects to proceed without mitigation reduces the Commonwealth's overall wetland resource base.

7. Fund a study of other causes of wetland loss in the Commonwealth.

This study documented only losses occurring as a result of failed replication projects. Many other sources of wetland loss exist, and these have not been adequately studied. Existing information about loss rates of wetlands in the Commonwealth should be updated. In addition, further study should be conducted to determine the causes of ongoing wetland loss. This information is critical to determining the extent of wetland restoration programs needed to achieve no net loss of wetlands.

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Appendix 1: Mitigation Study Ecoregions

1) Northeastern Highlands (58)
    - Taconic Mountains (58a)
    - Western New England Marble Valleys (58b)
    - Green Mountains/Berkshire Highlands (58c)
    - Lower Berkshire Hills (58d)
    - Berkshire Transition (58e)
    - Vermont Piedmont (58f)
2) Connecticut Valley (59a)
3) Central Plateau
    - Worcester/Monadnock Plateau (58g)
    - Lower Worcester Plateau/Eastern Connecticut Upland (59b)
4) Northeastern Coastal Zone
    - Southern New England Coastal Plains and Hills (Part of 59c)
5) Boston Basin (59d)
6) Southeastern Coastal Zone
    - Southern New England Coastal Plains and Hills (Part of 59c)
    - Narraganset/Bristol Lowland (59e)
7) Cape Cod/Long Island (59f)

Note: Ecoregions and subregions followed by numbers in parentheses are based on Griffith *et al.* (1994). The seven numbered areas are the ecological regions proposed for stratifying wetland mitigation sites in this study.

Appendix 2: Project Data Sheet

File Information **NOI Number** ☐

Project Location Data: **Landowner Name and Address:**
Town:

Parcel Book & Page Number

Project Size Data: **Wetland Type Impacted**
Size of Project Impact: ☐ Notes:
Size of Replacement Wetland: ☐
Design Ratio: ☐

Project History: **Notes**
Dates of: Det. Of Applic. ☐
NOI ☐
Order of Cond. ☐
Project Built ☐
Sup. Order of C.? ☐
Cert. Of Compliance ☐

Wetland Replication Plans:
☐ 1 No information about construction, site location only
☐ 2 Describes site preparation
☐ 3 Construction techniques described
☐ 4 Includes monitoring and/or planting materials
☐ 5 Monitoring and/or maintenance specified

Order of Conditions:
☐ 1 No specific conditions about replication
☐ 2 Requires specific site preparation
☐ 3 Requires specific construction techniques
☐ 4 Requires specific soils and/or planting materials
☐ 5 Requires monitoring and/or maintenance

Consulting Firm: Name, Address, Phone

Details of Design Specifications: **Notes:**
Proposed Soils:
Transplanted hydric Imported hydric
Mineral only

Designed Wetland Type:

Proposed Vegetation:
Planted Natural colonization

Proposed Monitoring:
Period planned:
Who conducts:
What will be measured:

Comments:
Describe any information from the project file that affects the assessment of success. (i.e. was there an enforcement action, records of monitoring site visits, etc.?)

Checklist:
☐ Site location map
☐ Data sheet completed
☐ Site plan completed
☐ Copy of any detailed information not recorded above

Data Collection:
Collected by:
Date:

Appendix 3: Results of Statistical Tests

1. t=4.148, df=136, p<0.001
2. t=4.537, df=136, p<0.001
3. t=4.225, df=136, p<0.001
4. t=5.326, df=136, p<0.001
5. t=0.284, df=136, p=0.777
6. t=0.013, df=67, p=0.918
7. t=1.259, df=67, p=0.224
8. t=1.414, df=67, p=0.178
9. F=7.32, df=4,286, p<0.001
10. (Tukey's HSD, Category 4 relative to Categories 1-3: p=0.002, p=0.002, p=0.038 respectively; Category 5 relative to Categories 1-3 p=0.009, p=0.007, p=0.028, respectively).
11. Z=-2.635, p=0.008
12. X^2=10.08, df=4, p=0.039
13. X^2=10.45, df=4, p=0.034
14. r=0.002
15. r=0.042
16. r=0.158
17. r=0.191
18. X^2=5.57, df=2, p=0.062
19. X^2=11.18, df=3, p=0.011
20. X^2=10.21, df=4, p=0.037
21. R^2=0.121, F=5.78, df=1,42, p=0.021
22. t=-0.449, df=10, p=0.663
23. t=1.875, df=10, p=0.090
24. t=-0.307, df=10, p=0.765
25. t=2.373, df=10, p=0.039
26. t=0.540, df=10, p=0.601
27. t=2.71, df=10, p=0.022
28. t=0.183, df=10, p=0.859
29. t=2.570, df=10, p=0.028
30. t=4.189, df=10, p=0.002
31 t=-6.228, df=10, p<0.001
32. t=1.861, df=10, p=0.092

Appendix 4: Population Sizes of Towns Included in the Study

Towns included in the study, by ecoregion, with DEP region, population size in 1990, total area in square miles, and population density per square mile.

Town	Region	Ecoregion	Pop.	Area	Density
NECoastal Zone					
AMESBURY	NE	4	15,980	12.65	1263
BRAINTREE	NE	4	33,798	13.70	2467
IPSWICH	NE	4	12,421	33.21	374
LOWELL	NE	4	96,054	13.38	7179
NEWBURY	NE	4	6,384	23.97	266
ROCKPORT	NE	4	7,854	7.02	1119
WESTON	NE	4	10,301	17.17	600
Boston Basin					
ARLINGTON	NE	5	43,624	5.18	8422
NEEDHAM	NE	5	28,080	12.50	2246
SWAMPSCOTT	NE	5	13,743	3.08	4462
WATERTOWN	NE	5	31,437	4.06	7743
So.New England Coastal Plains and Hills					
FRANKLIN	SE	4	25,818	26.80	963
ABINGTON	SE	4	14,467	9.97	1451
MARSHFIELD	SE	4	23,133	28.35	816
Narraganset/Bristol Lowlands					
ATTLEBORO	SE	6	38,863	27.51	1413
DARTMOUTH	SE	6	27,868	60.91	458
WHITMAN	SE	6	13,439	6.70	2006
FALL RIVER	SE	6	89,425	32.89	2719
TAUNTON	SE	6	51,624	47.29	1092
LAKEVILLE	SE	6	8,816	29.54	298
KINGSTON	SE	6	10,256	18.55	553

Cape Cod/Islands					
EASTHAM	SE	7	4,639	14.25	326
MASHPEE	SE	7	9,540	23.86	400
YARMOUTH	SE	7	21,727	24.13	900
BUZZARDS BAY	SE	7	16,646	41.02	406
OAK BLUFFS	SE	7	2,996	7.14	420
Central Plateau					
WINCHENDON	CE	3	9,248	42.53	217
HARDWICK	CE	3	2,453	38.40	64
STURBRIDGE	CE	3	8,046	37.39	215
So.New England Coastal Plains and Hills					
NORTHBOROUGH	CE	4	12,752	18.47	690
FITCHBURG	CE	4	36,726	27.47	1337
OXFORD	CE	4	13,298	26.71	498
STOW	CE	4	5,535	17.68	313
MEDWAY	CE	4	11,232	11.60	968
LEOMINSTER	CE	4	38,240	28.81	1327
NE Highlands					
WHATELY	WE	1	1,298	20.46	63
TYRINGHAM	WE	1	368	18.77	20
WILLIAMSTOWN	WE	1	7,907	46.73	169
COLRAIN	WE	1	1,817	43.21	42
PERU	WE	1	863	26.05	33
Connecticut Valley					
HADLEY	WE	2	4,327	23.16	187
DEERFIELD	WE	2	5,158	32.57	158
W. SPRINGFIELD	WE	2	26,786	16.75	1599
Central Plateau					
NORTHFIELD	WE	3	3,115	34.18	91
SHUTESBURY	WE	3	1,695	26.68	64
MONSON	WE	3	8,242	44.84	184

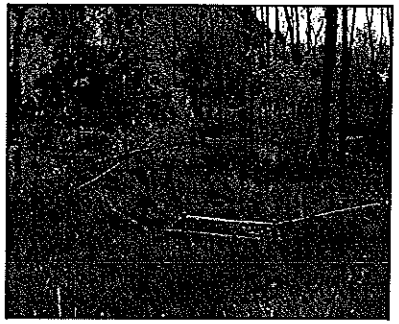

Plate 1. Most impacts occurred in forested wetlands filled for residential housing development (background), while successful replication sites were most commonly herbaceous wetlands (foreground).

Plate 2. Many replicated sites lacked strong hydrology and were only marginal wetlands with very low plant diversity.

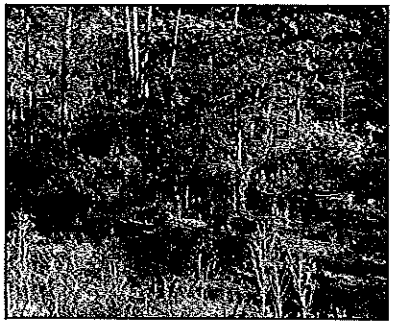

Plate 3. A common problem was that wetland soils were not moved from the impact area to the replication area, as was usually required in the Order of Conditions.

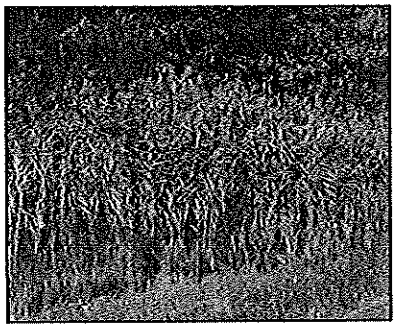

Plate 4. *Pragmites australis* was a common dominant at replication sites, resulting in very low plant diversity and low wildlife habitat value.

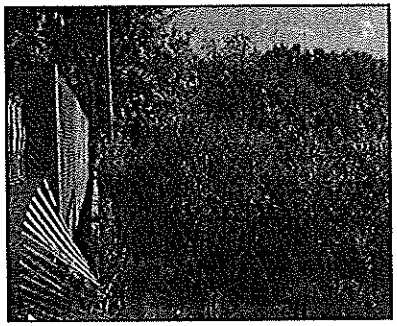

Plate 5. Some replication sites successfully created shrub swamps.

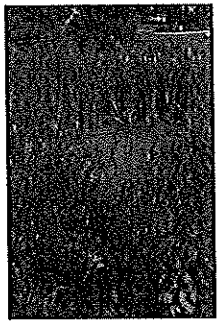

Plate 6. Most wetter replication sites were dominated by cattail (*Typha spp.*).

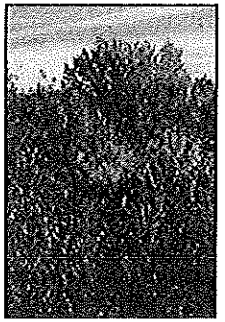

Plate 7. Two of the replicated shrub wetlands were as high in plant diversity as the natural wetlands that were impacted.

Plate 8. Forested wetlands were the common type of wetland impacted.

Plate 9. No forested wetlands were successfully created, and attempts to create forested wetlands are unlikely to develop into forested wetlands in the foreseeable future.

Plate 10. Forested wetlands (background) were generally replaced by herbaceous wetlands (foreground) even under the stricter provisions of wetlands variances.

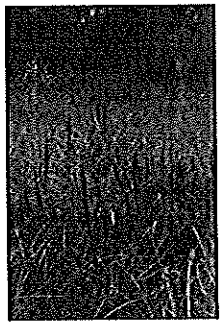

Plate 11. Purple loosestrife (*Lythrum salicaria*) occurred on a small number of replication sites, but was often more common on the impacted natural wetlands.

Plate 12. Surrounding land uses often had significant impacts on the replicated sites.