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Vegetation Community Response to Hydrologic and Geomorphic Changes Following Dam Removal in a New England River

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A Scholar of the College Senior Thesis Presented to
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VEGETATION COMMUNITY RESPONSE TO HYDROLOGIC AND GEOMORPHIC CHANGES FOLLOWING DAM REMOVAL IN A NEW ENGLAND RIVER

Dam removal is typically used to restore fish passage, natural flow regimes, and sediment transport in streams. However, dam removal also impacts the riparian vegetation, a change that can have wider effects throughout the ecosystem. Quantifying vegetation change requires a multi-year record to document pre-removal communities and both the immediate and delayed responses. In this study, vegetation change was assessed at the Merrimack Village Dam on the Souhegan River in Merrimack, NH, which was removed in August 2008. The removal caused a ~3 meter drop in water level and rapid erosion of impounded sediment, with ~50% removed in the first three months. The vegetation was sampled using plots at specific intervals along 7 monumented transects that were perpendicular to the channel or adjacent wetland. Tree, shrub, and herbaceous communities were assessed using species percent areal coverage techniques in July 2007, 2009, 2014 and 2015. Change over time was quantified using Analysis of Similarity (ANOSIM) on the Bray-Curtis dissimilarity matrix. As expected, vegetation communities in control plots upstream of the impoundment did not show significant change during the study period. Tree and shrub communities adjacent to the impoundment also did not show significant change. All herbaceous communities adjacent to the impoundment changed significantly ($p < 0.05$). The herbaceous plots closest to the channel changed to bare sand in 2009 due to erosion in the former impoundment, but by 2014 the riparian fringe community seen in 2007 had re-established and expanded in this area, but at a lower elevation. Between 2007 and 2014, the wetland herbaceous community changed from aquatic species to a stable terrestrial community that persisted without significant change in 2015. From 2007 to 2014, the vegetation community on a mid-channel island of impoundment sand changed from a community with ~50% invasive reed canary grass to a ~98% community of invasive black swallowwort, a species not recorded at the site pre-removal. The vegetation response was greatest in areas with largest geomorphic and hydrologic change, such as along the channel margin where erosion and bank slumping created an unstable scarp or on the mid-channel island and off-channel wetland strongly impacted by the lowered water table. However, large unvegetated areas never persisted nor did the areal coverage of invasive species expand: two common concerns of dam removals.

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Table of Contents

Chapter 1 Introduction

Dam removal has been used as a restoration technique to enhance fish passage and is becoming more common as numerous older dams in New England and across the country are more costly to maintain. Removal has numerous repercussions throughout the ecosystem, affecting sediment transport, hydrology, aquatic macroinvertebrates, fish, and vegetation in and surrounding the impoundment. Much of the monitoring associated with dam removals focuses on the changes in sediment transport and hydrology. The monitoring of the biotic effects requires surveys tailored to the communities of interest using assessments that have less overlap with necessary pre-removal project assessments. Compounding this challenge is the long-term nature of complete vegetation response (Elzinga, 1998). In order to capture the response trajectory of different vegetation communities, repeated surveys over multiple years may be necessary to create a record that fully represents the changes.

1.1 Dam Removal and Vegetation Change

Dam removal causes changes in vegetation surrounding the former impoundment, which can have broader impacts on future land use at the site and on important functions of the riparian zone, the interface between land and stream on the extant floodplain. The draining of the impoundment of a dam removal exposes sediment that may then be viewed as an extension of surrounding property. Homeowners of adjacent properties have been known to encroach on vegetated former impoundment (Orr & Stanley, 2006). Likewise, the area could also be used for recreation and parkland. Clearly these possibilities for the former impoundment are dependent on the type of vegetation community that establishes or is cultivated at the dam removal site.

In the more natural functioning of a site, the vegetation is crucial in the effectiveness of the riparian zone as a buffer zone between the terrestrial and aquatic environments. The riparian zone is a key mediator in the exchange of material between the stream and banks or upland area. The vegetative characteristics of the interface affect the movement of sediments eroded from the bank or deposited by the river, and the leaf litter and woody debris flow with contribution from the upland and accumulation on the floodplain fringe (Naiman & Decamps, 1997). The riparian zone also plays a role in nutrient cycling between ecosystems, especially important for aquatic organisms and the underpinnings of the food chain.

The characteristics of the riparian vegetation such as species composition help to determine the dynamics of each of these aspects affecting the overall quality of the stream. Dam removals are a disturbance that reshapes this border, destabilizing the myriad of factors that the ecosystem has developed to accommodate. The vital role that the riparian vegetation plays in the functioning of both the aquatic and terrestrial ecosystems indicates the importance of this zone in the recovery following anthropogenic changes.

1.2 Previous Studies of Vegetation Response to Dam Removal

Despite challenges of monitoring and establishing long-term records of vegetation response, a few studies have identified vegetation response trajectories at dam removal sites. Most focus on transitions in vegetation communities as a result of changes in erosion, deposition, and flow regimes following a dam removal. The fate of riparian fringe communities, both existing on the pre-removal floodplain and on areas exposed post-removal are of particular interest to investigators.

Shafroth (2002) found that the riparian area upstream of small dams is often restricted to a limited area as a result of little flow variation and stage change observed in the reservoir (Figure 1.1). The small areal extent of the riparian fringe occupies the resultant narrow transitional space between the fully-aquatic and fully-upland environments. After the removal, the larger range of vertical water level fluctuation along the channel changes the landscape of the riparian fringe (Figure 1.1). Newly exposed sediment is quickly colonized in the post-removal expansion of the riparian zone, and is hypothesized to follow a classical succession trajectory (Shafroth, 2002). However, the expansion is tempered by the erosion of some of the impounded sediment (Orr Stanley, 2005). In their conceptual model of geomorphic changes after dam removal, Doyle et al. (2003a) suggest that the channel will incise and widen (Figure 1.2). This reshaping of the channel by erosion becomes balanced by aggradation, until the sediment transport of the impoundment reaches a dynamic equilibrium. This combination of dynamic post-removal hydrologic and geomorphology processes influence the evolution of the climax riparian community.

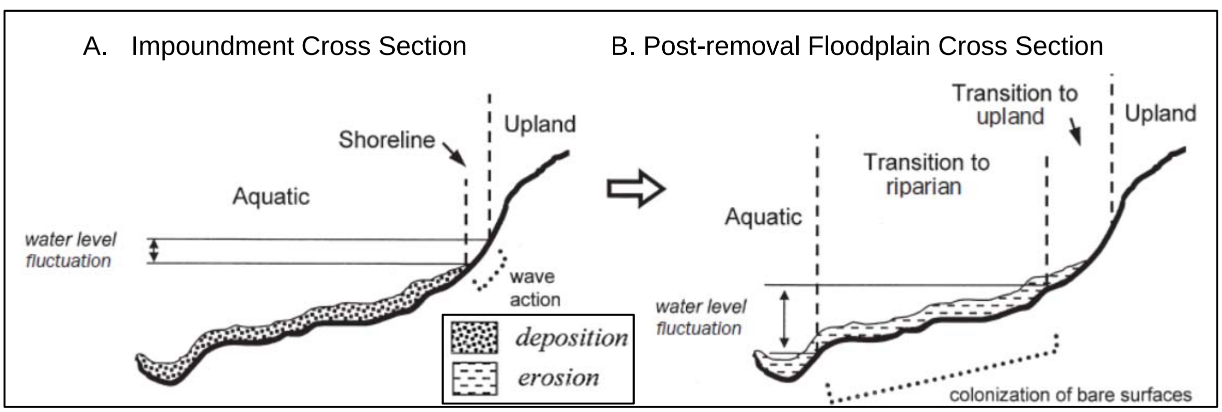

Figure 1.1 A comparison of key physical environmental factors and vegetation adjacent to the impoundment, as shown by a cross section illustration. (A) During the dammed period, vegetation along the reservoir shoreline is often confined to a narrow band, and its composition is driven largely by fluctuations in the reservoir water level and wave action. (B) Following dam removal, large areas of former reservoir bottom are exposed and may be colonized by riparian or upland plants. Trapped sediments behind the dam may be subject to erosion. (Adapted from Shafroth, 2002)

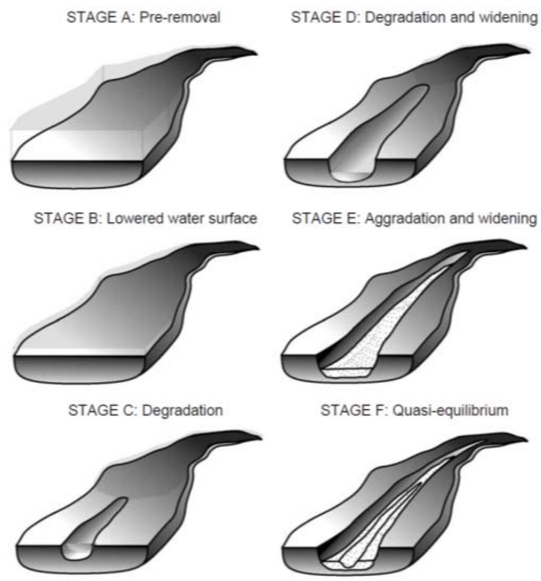

Figure 1.2 Conceptual model of channel changes through time in reservoir following removal of a small dam (Adapted from Orr, Stanley, 2005).

The trajectory of the riparian vegetation response is believed to follow pathways characterized by the resulting community: a return to pre-dam conditions or a novel vegetation state (Shafroth, 2002). These two idealized frameworks were expanded upon by Doyle & Stanley (2005) to encompass other environmental factors and their rates of return to equilibrium or lack thereof. The ecosystem and vegetation are thought to equilibrate either back to a community prior to the dam, or a partial recovery where aspects of the pre-dam community are never reestablished (Figure 1.3). In this expanded example, the timescale is decades for full ecosystem recovery, and at least five years for recovery to a new novel vegetation community. However, the spectrum of recovery structured by these ideas rely on knowledge of pre-dam conditions, which may not be available for sites that have had dams for centuries.

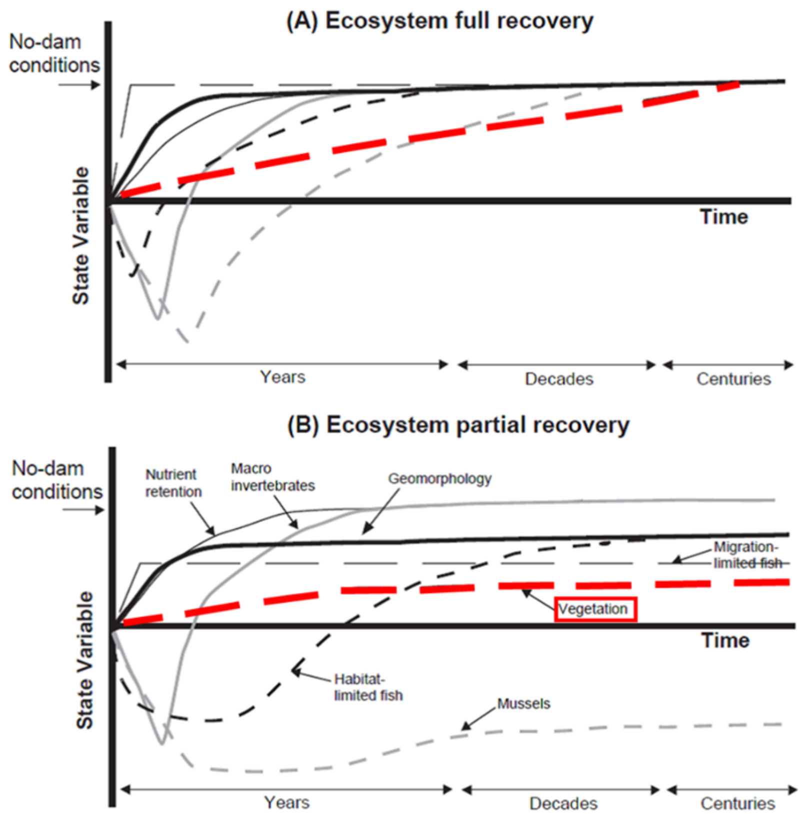

Figure 1.3 Conceptual framework for ecosystem recovery following removal of a small dam. Full ecosystem recovery assumes that all components of the stream ecosystem return to pre-dam conditions, but at variable rates of recovery. Partial ecosystem recover assumes that some components recover to pre-dam conditions, but that others only partially recover while still others are actually damaged by dam removal and not able to recover at all. (Adapted from Doyle, 2003)

These basic ideas of riparian expansion, vegetation colonization, and equilibrium riparian community were built on by the study of a large number of dam removal sites. Orr & Stanley (2006) conducted a retrospective study that surveyed removal sites of 30 small dams (3-16 m high) in the south central and unglaciated region of Wisconsin. Of sites that were allowed to naturally respond, vegetation characteristics were correlated with the time since the dams were removed. The riparian areas surveyed were consistently vegetated, with bare plots only being found as the result of anthropogenic usage. Sites with longer times since removal exhibited higher total numbers of species present, and higher average number of species per plot, though variability in this trend was noted at more recent dam removal sites. On the surveys of impoundment sediment, the vegetation community was commonly composed of only several dominant species, with only a small frequency of additional species (Orr & Stanley, 2006). Aquatic plants were associated with more recent dam removal sites, becoming less common in older sites. Tree species exhibited a higher frequency in communities with longer times since removal. Invasive species were found at every dam removal site, and the frequency of observance was not correlated with time since dam removal. Some invasive species were shown to suppress the native grasses, likely causing arrested development of the vegetation community at sites. The Orr & Stanley (2006) study was limited by the snapshot of a single post-removal survey at each site before attempting to compare the vegetation dynamics of sites across Wisconsin. These arguments can be used as a basis of comparison for single-site studies that monitor vegetation development over time.

1.3 Purpose and Scope

This study investigates short- and long-term vegetation change of plant community changes at the former impoundment of a dam removal site. I used previously collected vegetation species and percent coverage survey data from 2007 and 2009 that were part of the pre- and post-restoration monitoring of the site, based on the methods of Collins et al. (2007). I replicated the original pre-removal survey in July 2014 and 2015 to capture the continuing vegetation response. The tree, shrub, and herbaceous communities documented in the four surveys are analyzed to assess the significance of changes using the statistical methods presented in Roman (2002) and Kent & Coker (2011). Vegetation communities that changed significantly were then analyzed on a species-level to further understand the change over time. Changes in vegetation communities were then related to hydrologic and geomorphic change following the dam removal.

1.4 Study Area

The research for this project was conducted at the former site of the Merrimack Village Dam on the Souhegan River in Merrimack, NH (Figure 1.4). At the dam site, the Souhegan River watershed is 443 km^2 (Pearson, 2010). Approximately 0.5 km downstream of the study, the Souhegan River joins the Merrimack River. The hydrology throughout the study site is monitored using the USGS stream gage number 01094000, located approximately one kilometer upstream of the study reach. No major tributaries enter the river between the gage and study reach.

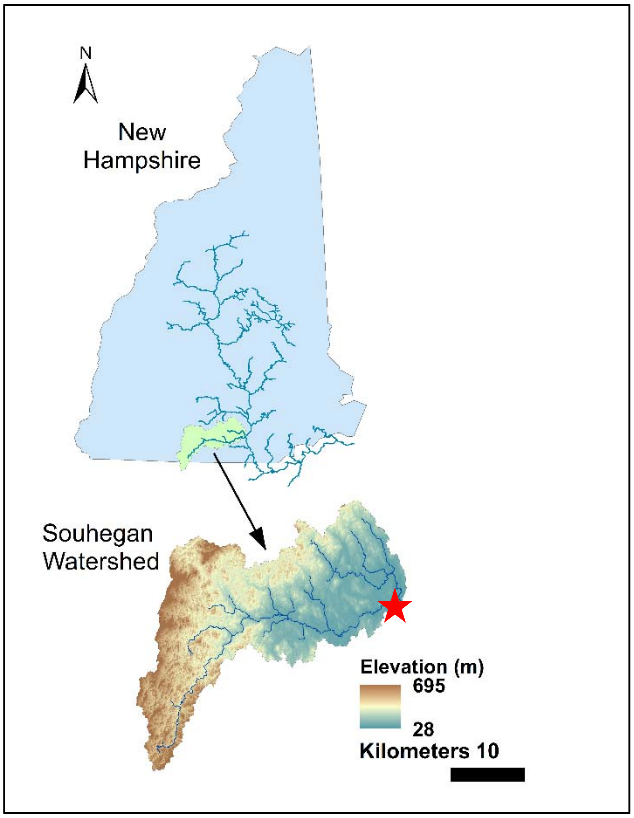

Figure 1.4 Map of New Hampshire showing Merrimack and Souhegan (568 km^2) watersheds, with the study site marked as a star.

The earliest documentation of a dam at this site was a grist and saw mill in 1734. The natural drop created by a steep bedrock falls, when augmented with a dam, created an attractive site to harness hydropower. In 1907, another hydropower dam was constructed directly on top of this older dam (Gomez and Sullivan Engineers, 2004). This dam was a 3.9 meter high run-of-river dam and remained in place until its removal in August 2008. The draining of the impoundment occurred on August 6, 2008, without a gradual lowering of the water level. Deconstruction of the remaining dam structure continued over the following several weeks.

The Merrimack Village Dam removal served as a case study of the sediment dynamics and geomorphology following a dam removal (Pearson 2010, Pearson et al. 2011, Santaniello et al., 2011, Conlon 2013). These multiple studies took advantage of the unmanaged sediment release associated with the removal, since no sediment was dredged prior to the project and no attempts were made to influence or stabilize the rapidly eroding impoundment sediment. Before dam removal, the riverbed upstream of the impoundment was dominated by boulders and cobbles, while the impoundment was composed mainly of unconsolidated sand-sized particles. According to pre-removal estimates, the impoundment had accumulated 66,900 $m^3 \pm 9900$ of mainly sand-sized sediment (Santaniello et al. 2011), calculated using a ground-penetrating radar survey. In the first three months following removal, approximately 50% of the impoundment sediment was eroded in a process-driven phase (Pearson et al., 2011). After this phase of rapid erosion, the sediment transport slowed as it was driven by high flow events. Figure 1.5 shows the geomorphic and hydrologic changes between 2008 and 2014 as erosion of the floodplain, bed, and mid-channel island, and the decrease in water level in both the channel and wetland.

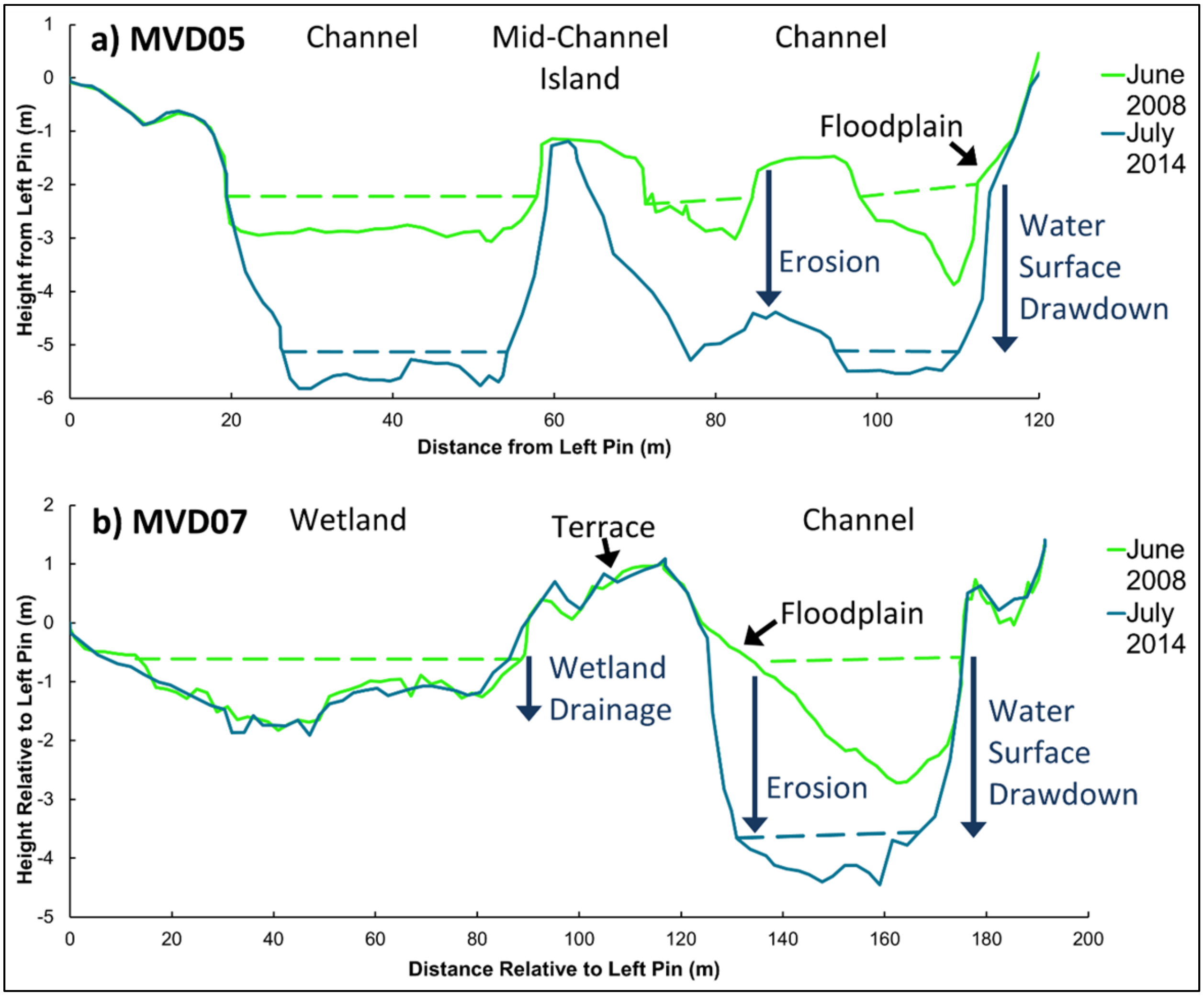

Figure 1.5 Geomorphic cross sections MVD05 (a) and MVD07 (b), showing the water table lowering and erosion across multiple zones of the study site. Cross section locations are noted on Figure 1.6.

Vegetation was studied upstream of the dam, including the wetland, the impoundment and upstream of the Everett Turnpike Bridge (Figure 1.6). Overall, the site vegetation is characterized by a forest dominated by hemlock, oak, and maple. The understory vegetation varies across the site, both with respect to quantity and species composition. Only a limited areal extent of the site has a significant presence of invasive species. On both sides of the channel, the forested area is bordered by urban/suburban development. Throughout the study period, recreational use increased on the network of trails throughout the site.

The V1 and V2 upstream vegetation control transects are characterized by a bedrock channel and steep surrounding banks and valley sides. This area was not impacted by the dam during normal flow conditions. Slightly downstream of the Everett Turnpike Bridge, the channel continues to be dominated by bedrock and large boulders, but with less steep banks, making this area a transition to the study areas in the main body of the impoundment. The treatment vegetation communities of V3 to V6 flank the sand-bedded former impoundment area and extends into the forested area of the site. The well-vegetated mid-channel island (MCI) and wetland created by the impoundment are also included in the survey.

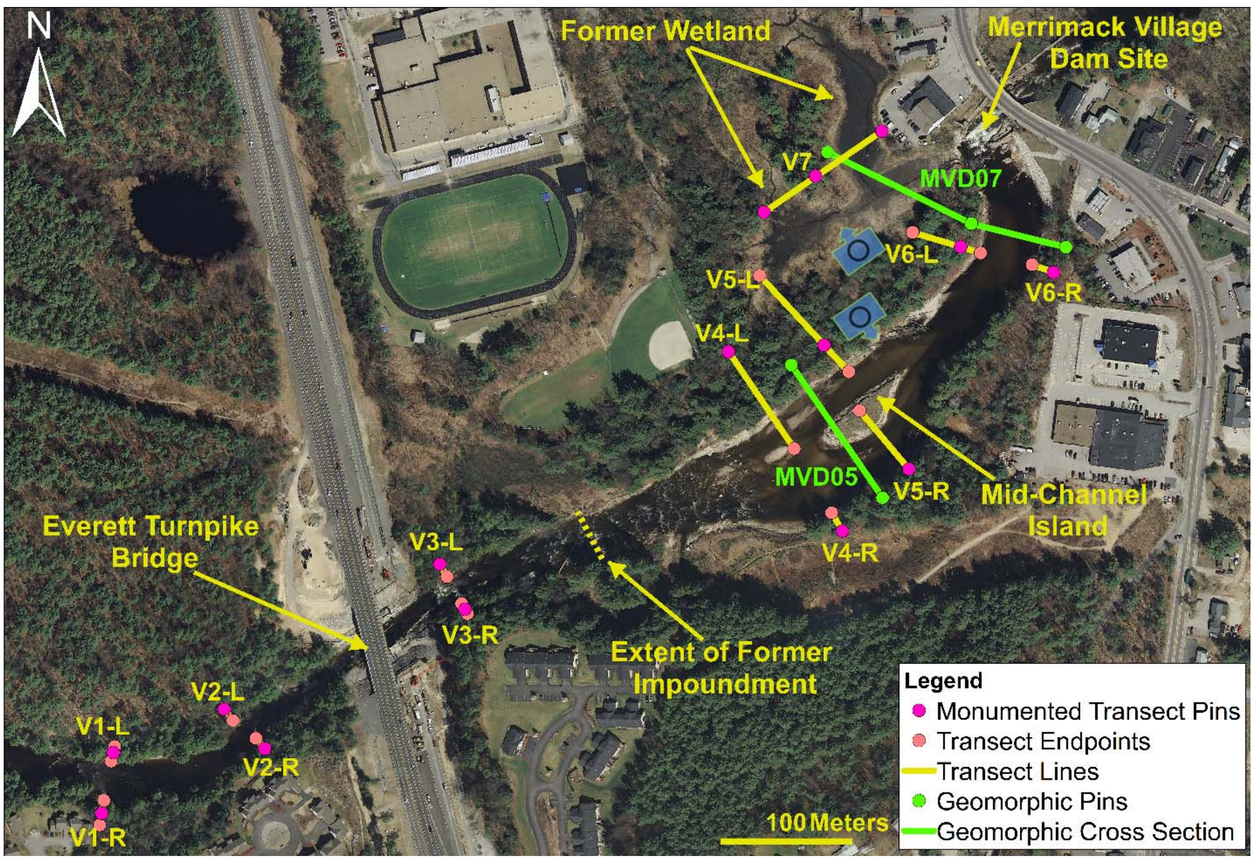

Figure 1.6 Aerial photograph of the former Merrimack Village Dam site, with vegetation monuments, transects, and endpoints marked. Stream flow is to the northeast, and transects are named L or R with respect to river right or river left. The Everett Turnpike Bridge is between V2 and V3. The dam site is seen in the northeast corner. Two of the geomorphic cross sections (Figure 1.5) are noted. Photo stations and their orientations are denoted. Image taken by the state of New Hampshire in 2011.

1.5 Hypotheses

I hypothesized that the most pronounced pre- to post-removal vegetation change would be seen in the most hydrologically and geomorphically impacted areas of the study site (Figures 1.5 & 1.6).

1. The vegetation composition of the control communities upstream of the impoundment will not change over the study period. This area of the site was upstream of the apparent influence of the former impoundment.
2. The tree, shrub, and herbaceous terrace communities adjacent to the former impoundment will not change following removal. These stable communities are likely slower to change, especially in the area of the site not directly affected by the dynamic post-removal environment.
3. The vegetation composition of the floodplain and wetland herbaceous communities will change significantly after the dam removal, following the transformation of the environmental conditions that affect these communities.

Chapter 2 Methods

2.1 Field Methods

2.1.1 Experimental Design

The vegetation monitoring methods employed in this study are detailed in the *Stream Barrier Removal Monitoring Guide* (Collins et al., 2007). The vegetation was surveyed in July or August in years 2007, 2009, 2014 and 2015. The study was designed and implemented in 2007 by NOAA Restoration Center staff and continued in 2009 by State of New Hampshire staff with modified methods (See Section 2.1.3 below). In 2014 and 2015, I replicated the 2007 study methods with guidance from Jim Turek of NOAA Habitat Restoration Division.

To monitor long-term vegetation change, seven monumented transects were installed perpendicular to the channel or wetland area with rebar pins at the upland end, on either side of the channel (Figure 1.6). The vegetation survey transects were offset from the geomorphic cross-sections also located at the site (Pearson et al., 2011), to avoid trampling of the vegetation. Transect placement was directed chiefly by Jim Turek in 2007 before dam removal. The latitude and longitude coordinates of the monuments were recorded by a real-time kinematic global position system (RTK GPS) in December 2015 (Table 2.1).

Table 2.1 Measured RTK GPS point positions corresponding to the vegetation transects. Data obtained from Leica Geo-office, with standard deviations of readings shown. The errors for latitude and longitude are shown in meters, with the coordinate distinctions indicating the direction of the error.

Transect	Latitude	Longitude	Elevation (m)	Std. deviation latitude (m)	Std. deviation longitude (m)	Std. deviation elevation (m)
V1L	42 51 21.618691 N	71 30 4.360972 W	44.0093	0.4007	0.2984	0.9928
V1R	42 51 20.111300 N	71 30 4.690165 W	42.5289	0.3921	0.2971	0.8191
V2L	42 51 22.770190 N	71 30 0.676391 W	50.3694	0.4068	0.2862	1.1013
V2R	42 51 21.830477 N	71 29 59.275617 W	43.6168	0.3684	0.3243	0.9376
V3L	42 51 26.511643 N	71 29 53.579898 W	43.5066	0.3911	0.2921	1.2676
V3R	42 51 25.420085 N	71 29 52.692426 W	46.3001	0.3886	0.3061	0.8494
V4L	42 51 31.974870 N	71 29 44.096494 W	35.3409	0.3855	0.3083	1.3183
V4R	42 51 27.625690 N	71 29 40.092802 W	47.2261	0.2888	0.4000	0.9956
V5L	42 51 32.207843 N	71 29 40.890758 W	43.0964	0.387	0.3039	0.9802
V5R	42 51 29.206229 N	71 29 37.921135 W	40.8571	0.3524	0.3378	0.8811
V6L	42 51 34.736291 N	71 29 36.405152 W	39.3981	0.3732	0.2884	0.8484
V6R	42 51 34.174622 N	71 29 33.259710 W	39.8083	0.0058	0.0049	0.0118
V7-EAST	42 51 37.534799 N	71 29 39.166749 W	38.6336	0.0052	0.0042	0.0104
V7-MID	42 51 36.376198 N	71 29 41.348631 W	43.9782	0.3097	0.2371	1.13
V7-WEST	42 51 35.451376 N	71 29 43.043679 W	40.0064	0.3858	0.3086	1.4891

Two transects, V1 and V2, were placed upstream of the impoundment as control plots, surveying the background vegetation change in vegetation communities adjacent to the channel that was not affected by the dam. The non-impoundment V3 transect flanks a part of channel that is dominated by bedrock and large boulders, but with less steep banks, making this transect a transition to the study areas in the impoundment. The V3 transect is slightly downstream of the Everett Turnpike Bridge, bordering an area affected by bridge construction and installation of riprap in 2009-2011. The V4, V5 and V6 transects flank the sand-bedded former impoundment area and extend into the forested terrace area of the site on both sides of the river. V5 also captures the well-vegetated mid-channel island (MCI) that had developed in the middle of the impoundment pre-removal. The wetland created by the impoundment is surveyed using the northern end portions of the V5 and V6 transects, and V7 transect.

The plots on each transect were positioned by stretching a tape measure between the monumented rebar pin and the edge of the bank, with the zero marker at the pin. Each quadrat was located along the tape at the prescribed distance, typically every five meters for herbaceous plots, 15 meters for shrub plots, and every 30 meters for tree plots. The specific distances were established in the 2007 survey and were kept consistent throughout following surveys. Plots were added as the riparian zone expanded following dam removal as needed at the channel terminus of the transects. The herbaceous plots were defined using a square-meter quadrat placed along the tape, on the downslope and downstream of the specified distance. The quadrat was constructed of PVC pipe frame and increment calibrated so that 25% and 1% areas were marked along the frame. Shrub plots encompassed an area within a five-meter radius centered on the distance marker on the tape. Tree plots encompassed a nine-meter radius.

2.1.2 Sampling Methods

To assess the vegetation communities throughout the site, both the species present and their relative abundances were considered. In each plot, the species were identified using a catalogue of species found at the site, compiled by NOAA Restoration Center staff in 2007. Any unidentified specimens were sampled, pressed, and later identified off-site with plant dichotomous keys (, Newcomb et al. 1977, Gleason et al. 1991). The vegetation was identified to a reasonable specificity, species or genus level. However, for highly diverse groups such as grasses, family categorizations were used.

The percent areal coverage of plant foliage was assessed for each species present. For herbaceous plots, this assessment was done using visual estimation (Figure 2.1). The areal coverage was defined from the perspective of looking directly down at the plot and estimating the percentage of the area covered by leaves of each species present. This method allowed for abundances exceeding 100%, accommodate the leaves of vegetation rooted outside of the plot but projecting into it. For the herbaceous plots, this assessment was aided using the calibrated 1-meter square. The herbaceous plots assessed non-woody vegetation of all heights and woody vegetation shorter than three meters in height. The shrub vegetation abundance was determined visually, calibrated by marking the circular plot and dividing it into quarters. Shrub plots assessed woody vegetation between one and six meters in height, with diameter breast height between one and thirteen centimeters.

Figure 2.1 Surveying herbaceous vegetation using square-meter quadrat aligned on the downslope, downstream side of the tape measure defining the transect. Photo credit: Kaitlin Johnson

Tree species composition was assessed using the field-measured circumference-breast-height of each trunk, taken at 1.5 meters height (Figure 2.3). This measurement was later converted to the diameter-breast height. The total diameter-breast-height for each species of tree present in the plot was calculated and determined as a percentage of the total species' diameter-breast-height, resulting in the percent coverage of each species found. Tree plots assessed woody vegetation greater than six meters in height and thirteen centimeters diameter-breast-height.

Figure 2.2 Tree plot measurement of circumference-breast-height at 1.5 m height. Photo credit: Kaitlin Johnson

2.1.3 Surveying Inconsistencies

The above field methods were developed for the 2007 vegetation survey at the site and were replicated for the 2014 and 2015 surveys. My visual assessment was confirmed by the original researcher to be consistent with his percent areal cover determination. The 2009 surveys were performed by a different researcher who modified the field methods, thus they are potentially less reliable, but likely still are valuable for most communities. The transects and plot distances along the transects were consistent with the original survey. The largest deviation in 2009 plot placement was an inconsistent alignment of plots with the tape. However, since most vegetation variation occurred along the length of the tape, this change in quadrat positioning, resulting in a maximum of a one-meter range, likely did not influence plant community assessment.

The 2009 data was most problematic with the omission of plots that captured the newly forming floodplain or dynamic wetland. In 2009, no plots were added at the end of the transects toward the new post-removal channel location, as prescribed by Collins et al. (2007). Additionally, the V7 transect across the large wetland area was not surveyed, greatly truncating the 2009 assessment of it. Because of these concerns, throughout the analysis if the 2009 data stood out in unexpected ways, these additional confounding factors were strongly considered in determining the validity of the signal.

2.1.4 Aerial and Ground Photographs

Aerial photographs available in Google Earth added an additional resource for change over time assessment at the site. Years available were 1992, 2003, 2007, 2008, 2009, 2011, 2014, and 2015. These images contributed a qualitative overview of reach-scale physical and vegetation changes occurring at the site post-removal, between study years. This additional understanding of the site helped qualify significant vegetation findings. The aerial images can be considered in the context of the mean daily discharges for the dates of the images were obtained from USGS stream gage number 01094000, located approximately one kilometer upstream of the study reach.

Ground photographs were also included, even during years when the vegetation was not surveyed. In the summers of 2008 to 2011, photographs were taken at consistent photograph stations along the channel (Collins et al., 2007), providing observations of the changes in the site between vegetation surveys. The approximate location and direction of the selected photographs used in this study are noted on Figure 1.6. Photographs were taken by former researchers from Boston College as part of the geomorphic monitoring program (Pearson, 2010; Pearson et al., 2011; Conlon, 2013).

2.2 Data Analysis

The following sections describe all processing and analysis of the data after the percent aerial coverage was hand-recorded on field sheets. Each field survey was subject to these methods, 2007 to 2015, since no post-processing had previously been done on the field sheets. The goals of the analysis were to determine which vegetation communities had changed significantly throughout the study period. Any significant community differences were then further investigated using species composition.

Two considerations helped structure the data analysis of this study: the structure of sampling, and the associated biases. The NOAA Restoration Center staff structured the vegetation monitoring protocols in alignment with the methods employed by long-term salt marsh restoration studies. This similarity in experimental procedure enabled a likewise similarity in analysis methods, such as used in Roman et al. (2002), Thom et al. (2002) or Smith et al. (2009). The data analysis must also accommodate the challenge of three different researchers who conducted visual assessment at the site. The validity of repeated studies along permanent transects has been contested by a USDA et al. (2004) study, citing the variation in visual assessment can result in an equally wide variation as the actual vegetation signal. Awareness of this potential confounding factor in the data motivated several of the data analysis methodologies cited below.

2.2.1 Braun-Blanquet Classification

Along with consideration of distinct species, the percent cover was calculated for plant groups of similar morphology (family, genus) (Table 2.2). This combination of areal cover data allowed the analysis to focus on the overall vegetation trends within the community, rather than having the data analysis distracted my uncommon species.

Table 2.2 This vegetation species combination class table describes the scientific and common names of species similar in appearance that were grouped in the analysis.

Combination Class	**Species Included**	**Common Names**
Arrowhead	*Sagittaria latifolia* *Sagittaria filiformis*	Big-leafed Arrowhead Narrow-leafed Arrowhead
Blueberry	*Vaccinium corymbosum* *Vaccinium angustifolium*	Highbush Blueberry Lowbush Blueberry
Bulrush	*Scirpus atrovirens* *Scirpus vallidus* *Eleocharis palustris*	Bulrush Soft-stemmed Bulrush Common Spike Rush
Dogwood	*Cornus anonum* *Cornus racemosa*	Silky Dogwood Gray Twig Dogwood
Goldenrod	*Solidago rugosa* *Solidago graminifolia* *Solidago speciosa*	Rough Leafed Goldenrod Flat-topped Goldenrod Showy Goldenrod
Grass	*Agrostis sp.* *Digitaria sp.* Unidentified Grass	Hair Grass Crab Grass
No Trees, No Shrubs, No Herbaceous	Barren Dead Detritus	
Oak	*Quercus alba* *Quercus bicolor* *Quercus coccinea* *Quercus rubra* *Quercus velutina*	White Oak Swamp White Oak Scarlet Oak Northern Red Oak Black Oak
Sedge	*Carex sp.* *Sparganium americanum*	Sedge Burreed

The percent coverage data was added so that the analysis remained most representative of the percent coverage observed in the field, as indicated in Collins et al. (2007). Percent cover was classified using Braun-Blanquet cover class scores in order to minimize the variation between researchers (Table 2.3).

Table 2.3 A description of the Braun-Blanquet cover class scores used to categorize the vegetation percent coverage data

Cover Class	Percent Cover Range (%)
T	<1
1	1-5
2	6-15
3	16-25
4	26-50
5	51-75
6	76-95
7	96-100

2.2.2 Classification of Riparian Plant Communities

From the field data, the Braun-Blanquet data of the different plot types remained separated based on the different vegetation characterization techniques used for the herbaceous, shrubs and trees (See Section 2.1.2). The herbaceous plots were further separated based on the geomorphic regions captured: terrace, floodplain, and wetland (Figure 2.3). This distinction along geomorphic distinctions within the site was planned in the original experimental setup, and determined based on the bank top noted in the pre-removal survey (Collins et al., 2007). This analysis organization allowed the vegetation to be considered within the specific riparian zones of the site, as determined by the geomorphology.

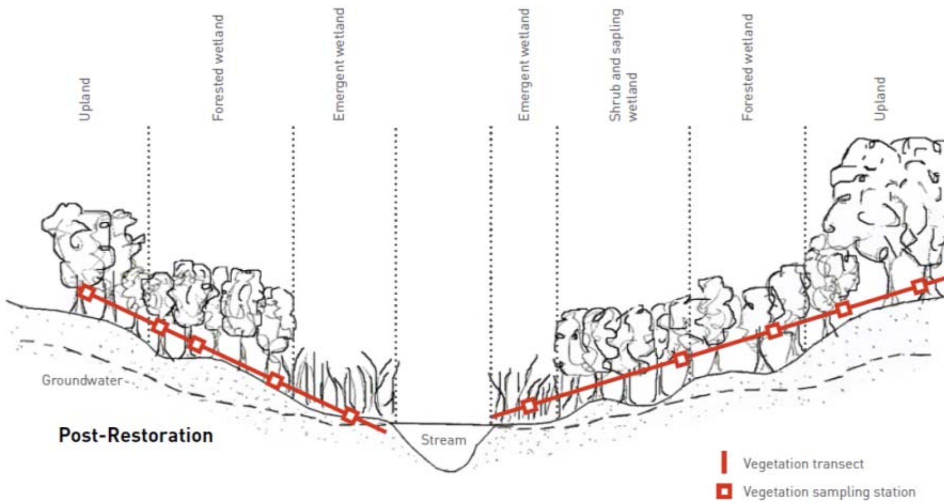

Figure 2.3 A characterization of the post-restoration vegetation progression from the channel. The communities denoted correspond to the progression of the wetland, floodplain, and terrace herbaceous vegetation communities differentiated in this study. Figure not to scale. (Adapted from Collins et al., 2007)

2.2.3 Bray-Curtis Dissimilarity

To determine the change in vegetation community composition assessed between plots from pre-dam removal and post-dam removal, I used the Bray-Curtis Dissimilarity statistic (Kent, 2011). The Bray-Curtis Dissimilarity statistic to determine dissimilarity between plots is as follows: $BC_{ij} = 1 - \frac{2C_{ij}}{S_i + S_j}$ where C_{ij} is the sum of the percent cover data of species shared between plots *i* and *j*, and S_i and S_j are the total percent cover of species found in plots *i* and *j*. Within this method, 0 represents total similarity of species and 1 is total dissimilarity of species between the plots. This analysis was performed twice for each comparison data set, the first including the relative abundance of the species present as described. To consider only the presence or absence of species, C_{ij} is the shared number of species between the plots, and S_i and S_j are the number of species found in plots *i* and *j*. This unweighted computation was performed to see if it yielded different significance results for the plots, possibly indicating a change in abundance of species present, but a consistency in the particular species in the plots. To compare variation in vegetation composition between multiple years, the Bray-Curtis values are computed between each yearly community included in the test.

The Bray-Curtis values are computed between all of the plots from one group against all of the plots of the other comparison group or groups (Oksanen et al., 2013). These computations compare each plot within the community for the considered year against every other plot from a different year. This method yields a holistic comparison of the communities, rather than emphasizing the individual plots that were used to characterize the communities.

To ensure a thorough analysis of the groupings throughout time, the tree, shrub, terrace, floodplain, and wetland communities were compared using data sets from six permutations of years (Table 2.4). With this structure of analysis, the change across a subset of years was considered, enabling short term change between sequential surveys to be assessed without taking into account other change. Additionally, to justify the separation of the herbaceous plots into terrace, floodplain, and wetland, the plots of these communities were compared to one another within a single year, to ascertain that there was indeed a significant difference between these communities.

Table 2.4 Description of the combinations of years compared using Bray-Curtis Dissimilarity matrix.

Years Included in Vegetation Comparison Permutations
2007, 2009, 2014, 2015
2007, 2009
2007, 2014
2007, 2015
2007, 2014, 2015
2014, 2015

The Bray-Curtis dissimilarity matrix was used as the final analysis only for the mid-channel island community. The small amount of yearly plots capturing this community limited the power of additional analysis to accurately characterize the change over time.

The Bray-Curtis dissimilarity matrix was generated using R statistical computing software. Taking advantage of the open-source organization of this programming environment enabled me to utilize pre-written code packages specifically for analysis of vegetation data, using methods outlined by Borcard (2011).

2.2.4 ANOSIM

The Bray-Curtis Dissimilarity matrix was most valuable as the basis for the Analysis of Similarity (ANOSIM) (Kent, 2011). The goal of this analysis was to determine if the vegetation communities sampled displayed significant change throughout the study period. ANOSIM accomplishes this by comparing the dissimilarity values of the plot-to-plot comparisons within a community to the dissimilarity between communities. The generated R statistic indicates the relationship of the intra-community dissimilarity to the inter-community dissimilarity, indicating the degree to which the communities are significantly different (Oksanen, 2013). Based on the mean rank of the Bray-Curtis dissimilarity within and between groups, the R statistic ranges between -1 and +1. A value near 0 indicates completely random grouping with no difference between the groups being compared. Negative R-values are associated with greater dissimilarity within a group than between, and may be associated with the repeated plot structure of the study and communities that span a geomorphic variation. R-values near 1 indicate comparison groups that have a larger difference in dissimilarity values. With this rank-based test, a conventional p-value is generated, indicating the confidence that the groups were dissimilar. The threshold of significance was 0.05. This repeated study of spatially variable communities can bias the R statistic, but the significance value indicates the probability that even within this non-random experimental set-up, the difference between communities is real.

Like the Bray-Curtis, the R analyses were completed twice for each comparison grouping, once with the data including the Braun-Blanquet percent cover scores and the second based solely on the presence or absence of species using binary distinctions 0 and 1.

This analysis was also completed using CRAN R-3.2.1 open source software utilizing the package “vegan” for the analysis.

2.2.5 Pair-wise Analysis

The ANOSIM analysis provided an effective method to compare the vegetation communities sampled but did not determine how specific sampling quadrats changed between the years. To provide this analysis, the Bray-Curtis Dissimilarity analysis was conducted on the plots of years 2007 and 2015. The formula stated above was used, weighted using the percent coverage data of the two years. The result was a percentage change for each sampling plot from 2007 to 2015.

2.2.6 Additional Analyses

In addition to the analyses described above, the vegetation community was considered using percent composition and mean percent cover of each species. Percent composition of the community was characterized based on groupings of species with respect to botanical traits based on stem distinctions of herbaceous, woody, or aquatic, and unvegetated area. For a year of community data, the species were separated based on these distinctions, and the percent cover was summed across the community. The percent composition of each grouping was then determined by dividing by the total percent cover of all groupings. Mean percent cover of each species scaled the total percent cover data of each species by the total number of plots in the community to represent the composition in an “average plot”.

Chapter 3 Results

Photographs allowed a qualitative description of change over time at the site, which are qualified by the mean daily discharge for the day describing water level variation (Table 3.1). The aerial photos indicate the consistent morphology of the site from 1992 to 2008 (Figure 3.1), excepting the slight growth of the mid-channel islands. These older photographs confirm the established pre-removal stable environment present more than 16 years prior to dam removal. After 2008, the former impoundment is drained and more sand is visible within the channel. The mid-channel islands are seen to change shape and erode, with the southwestern island disappearing completely, consistent with the geomorphic cross section data (Figure 1.5). Between 2009 and 2015, the main channel switches from the southern side of the mid-channel island to the northern side. After this switch, the floodplain vegetation is seen to colonize the exposed sediment on the southern channel, no longer having to withstand the higher energy flows within the main channel. With respect to the wetland area north of the channel, the change in vegetation is especially notable in 2011 and after. The area resembles a field or terrestrial environment throughout the year, with no open water as would be visible in a pond area early or late in the growing season. This contrasts to the clearly open water environment seen in April 1992.

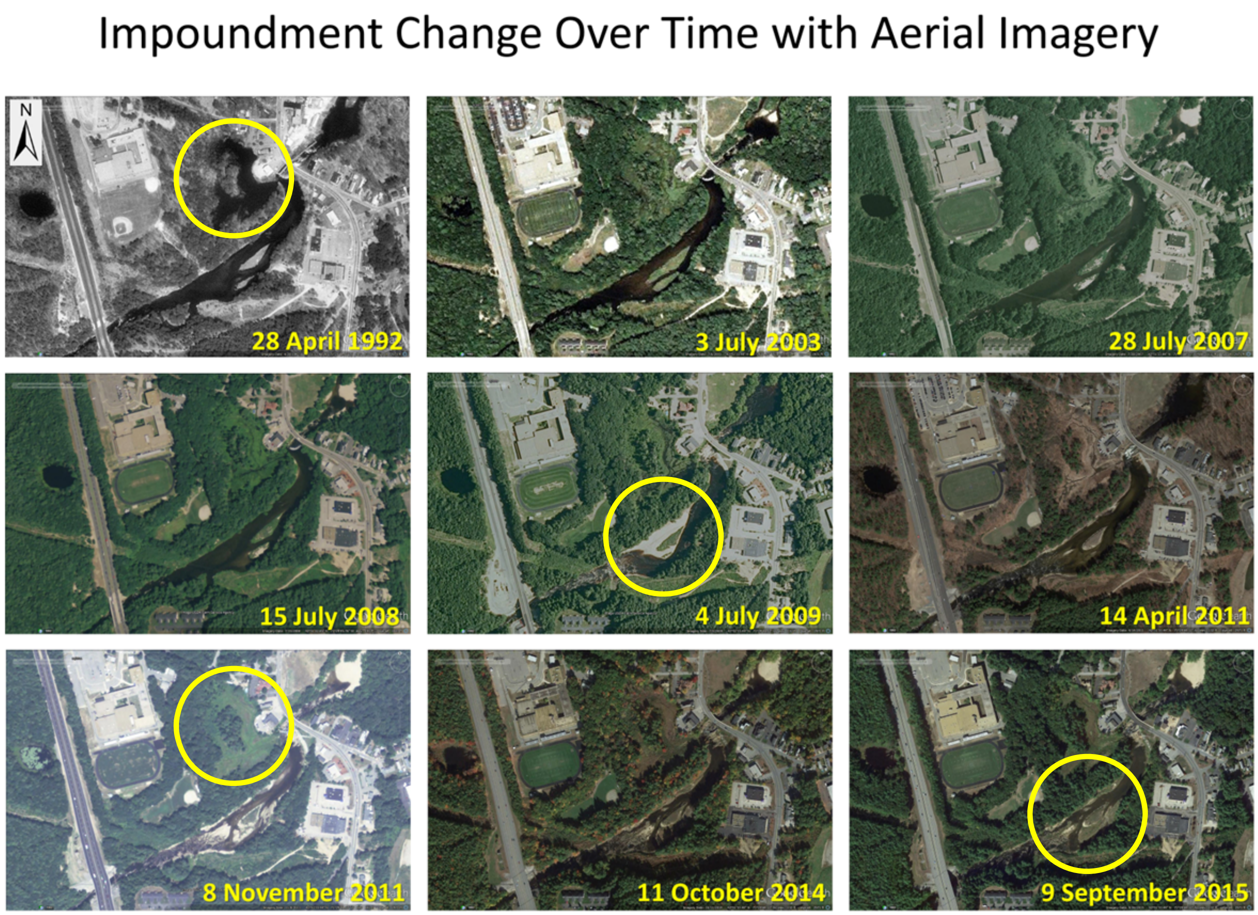

Figure 3.1 Aerial photographs obtained from Google Earth, arranged in a time series. The Everett Turnpike is shown running north-south on the western edge of the image. The dam site is located at the other road crossing in the northeast corner. The circles indicate areas of comparison for change over time.

Table 3.1 The mean daily discharges for the days aerial images. Data was obtained from USGS stream gage number 01094000, located approximately one kilometer upstream of the site. Data was unavailable for April 1992.

Date	Mean Daily Discharge (cfs)	Mean Daily Discharge (m^3/s)
28 April 1992	Not available	Not available
3 July 2003	82	2.3
28 July 2007	66	1.9
15 July 2008	47	1.3
4 July 2009	1380	39.1
14 April 2011	676	19.1
8 November 2011	616	17.4
11 October 2014	46	1.3
9 September 2015	37	1.0

3.1 Overall Vegetation Community Change Analysis

The testing of significance of vegetation change separated the plots into control and treatment groups, then into the separate vegetation communities.

Upstream control plots of herbaceous, shrub and tree vegetation communities did not exhibit significant change in composition or cover for any of the permutations of the analysis (*p* > 0.7) (Table 3.2). Negative R-values are seen in most comparisons, likely reflecting the spatial variation in each community that remained consistent between years. The R-values close to zero indicate little compositional difference between the years. The weighted and unweighted results offered similar significance results.

Table 3.2 The R- and p-value results of the ANOSIM of control communities, both weighted and unweighted by the species percent coverage.

Control Community ANOSIM Results

Tree Control Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	-0.162	0.996	-0.152	0.994
2007, 2009	-0.141	0.939	-0.156	0.999
2007, 2014	-0.156	0.744	-0.188	0.999
2007, 2015	-0.177	0.748	-0.141	0.817
2007, 2014, 2015	-0.189	0.944	-0.170	0.966
2014, 2015	-0.198	0.919	-0.162	0.775

Shrub Control Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	-0.175	0.952	-0.194	0.985
2007, 2009	-0.389	0.999	-0.324	0.935
2007, 2014	-0.083	0.693	-0.167	0.901
2007, 2015	-0.125	0.853	-0.125	0.841
2007, 2014, 2015	-0.097	0.823	-0.137	0.910
2014, 2015	0.062	0.551	-0.130	0.833

Herbaceous Control Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	0.090	0.904	-0.091	0.904
2007, 2009	0.175	0.916	-0.174	0.907
2007, 2014	0.164	0.863	-0.164	0.862
2007, 2015	0.064	0.730	-0.064	0.773
2007, 2014, 2015	0.097	0.882	-0.097	0.859
2014, 2015	0.088	0.779	-0.088	0.756

Tree and shrub communities flanking the former impoundment did not change over the study period ($p > 0.12$), as predicted (Table 3.3). The R-values describe a less than 10% change in the community, indicating little variation between study years.

Table 3.3 The R- and p-value results of the ANOSIM of tree and shrub communities, both weighted and unweighted by the species percent coverage.

Tree and Shrub Community ANOSIM Results

Tree Treatment Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	-0.022	0.813	-0.029	0.919
2007, 2009	0.030	0.233	-0.024	0.626
2007, 2014	0.033	0.172	0.003	0.393
2007, 2015	0.009	0.317	-0.015	0.714
2007, 2014, 2015	0.006	0.509	-0.015	0.696
2014, 2015	0.000	0.422	-0.035	0.879

Shrub Treatment Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	0.011	0.208	0.033	0.055
2007, 2009	0.039	0.115	0.046	0.089
2007, 2014	0.025	0.169	0.023	0.198
2007, 2015	0.020	0.196	0.027	0.159
2007, 2014, 2015	0.014	0.222	0.014	0.221
2014, 2015	0.001	0.451	-0.006	0.519

The herbaceous communities in the area affected by the dam are significantly different between the communities of floodplain, terrace, and wetland ($p < 0.006$) (Table 3.4). These groups were then compared separately.

Table 3.4 The R- and p-value results of the ANOSIM of the comparison of terrace, floodplain, and wetland herbaceous communities, both weighted and unweighted by the species percent coverage.

Herbaceous Community Comparison ANOSIM Results

Terrace, Floodplain, Wetland Herbaceous Community Comparison

	Weighted		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007	0.625	**0.001**	0.619	**0.001**
2009	0.311	**0.006**	0.267	**0.004**
2014	0.2912	**0.001**	0.3037	**0.001**
2015	0.4368	**0.001**	0.4519	**0.001**

The R-values for the floodplain comparison indicate a similar amount of variation present within the yearly communities and between them (Table 3.5). This result may be due to the repeat nature of sampling and wide spatial distribution of floodplain plots from the top of the bank scarp to the dynamic environment at the water's edge.

The R-values have a statistical significance, suggesting that the small changes seen are indeed real. However, this significant result is only evident for permutations including the less-reliable 2009 data (Table 3.5), and at first seem to be inconsistent with the significant change seen in the other comparison years. The distinct 2009 community would indicate that the floodplain community changed from pre-removal conditions that year but equilibrated to a community similar to pre-dam conditions by 2014. A nuance to this picture is the significant result in the unweighted ANOSIM for the same time period, indicating that the species composition likely also changed throughout the period. However, the lack of significant change in the weighted ANOSIM would suggest that minor species at the site increased, a result that was muted in the weighted ANOSIM with the inclusion of the species percent cover data.

The R-values of the terrace community over time indicate little variation within the community ($R < 0.052$) (Table 3.5). However, the comparison yields significant results with the inclusion of the 2015 data. The appearance of change solely in 2015 may be the result of accumulating change post-removal, or have a different cause.

The wetland herbaceous plots show a pattern of delayed response and equilibration. This community displays the highest R-values of any community, in accordance with the vegetation reversal (Table 3.5). The 2007 and 2009 communities are not shown to be statistically different, nor are the 2014 and 2015 communities. However, the 2009 results must be additionally questioned for this community, since the 2009 researcher omitted the V7 wetland transect, which contributed approximately half of the wetland quadrants. The 2007, 2014, and 2015 indicate a clear change from the pre-removal vegetation conditions to post-removal, with the large R value and strong significance.

The large wetland vegetation community appears to stabilize six and seven years after removal, as demonstrated by the non-significant change between the wetland communities of 2014 and 2015 (Table 3.5). The significant unweighted ANOSIM result indicates that this stabilization may continue to evolve with minor species fluctuation in the community.

Table 3.5 The R- and p-value results of the ANOSIM of herbaceous treatment communities, both weighted and unweighted by the species percent coverage.

Herbaceous Community ANOSIM Results

Herbaceous Floodplain Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	0.080	**0.026**	0.124	**0.004**
2007, 2009	0.209	**0.005**	0.212	**0.019**
2007, 2014	-0.007	0.464	0.086	0.135
2007, 2015	0.069	0.162	0.104	0.065
2007, 2014, 2015	0.038	0.163	0.083	**0.037**
2014, 2015	0.044	0.206	0.032	0.247

Herbaceous Terrace Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	0.027	**0.018**	0.044	**0.001**
2007, 2009	-0.002	0.438	0.001	0.369
2007, 2014	0.011	0.185	-0.002	0.444
2007, 2015	0.052	**0.014**	0.094	**0.004**
2007, 2014, 2015	0.024	**0.033**	0.044	**0.010**
2014, 2015	0.009	0.203	0.037	0.054

Herbaceous Wetland Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015*	0.184	**0.001**	0.173	**0.001**
2007, 2009*	0.019	0.345	0.008	0.432
2007, 2014	0.299	**0.001**	0.273	**0.001**
2007, 2015	0.273	**0.001**	0.230	**0.001**
2007, 2014, 2015	0.204	**0.010**	0.182	**0.001**
2014, 2015	0.055	0.062	0.065	**0.034**

The distinct community on the sandy mid-channel islands not shown by ANOSIM to significantly change throughout the study (Table 3.6). The high R value in the 2007 to 2014 comparison indicates that change is evident in the system. However, given the community composed of three plots each year, the power of this test to reject the null hypothesis was greatly reduced. Other methods of describing any change in the mid-channel community were used.

Table 3.6 The R- and p-value results of the ANOSIM of mid-channel island communities, both weighted and unweighted by the species percent coverage.

Mid-Channel Island Community ANOSIM Results

Mid-Channel Island Plots	*Weighted*		*Unweighted*	
Comparison Years	R-value	p-value	R-value	p-value
2007, 2009, 2014, 2015	0.005	0.403	-0.030	0.561
2007, 2009	0.111	0.300	0.074	0.400
2007, 2014	0.352	0.300	0.204	0.200
2007, 2015	0.056	0.349	0.046	0.424
2007, 2014, 2015	-0.018	0.474	0.013	0.438
2014, 2015	-0.250	0.837	-0.250	0.820

3.2 Community and Species-Specific Comparisons

All observations at the Merrimack Village Dam site, both qualitative and quantitative indicate a changing vegetation community, in some zones. Previous studies by Shafroth et al. (2002) and Orr & Stanley (2006) have shown the expansion of the riparian zone following dam removal. This study also shows such a change with the plots added throughout the study to capture the developing floodplain and wetland community (Figure 3.2 and Table 3.7). The necessity of adding plots was itself an indication of the changes found in the vegetation communities at the site.

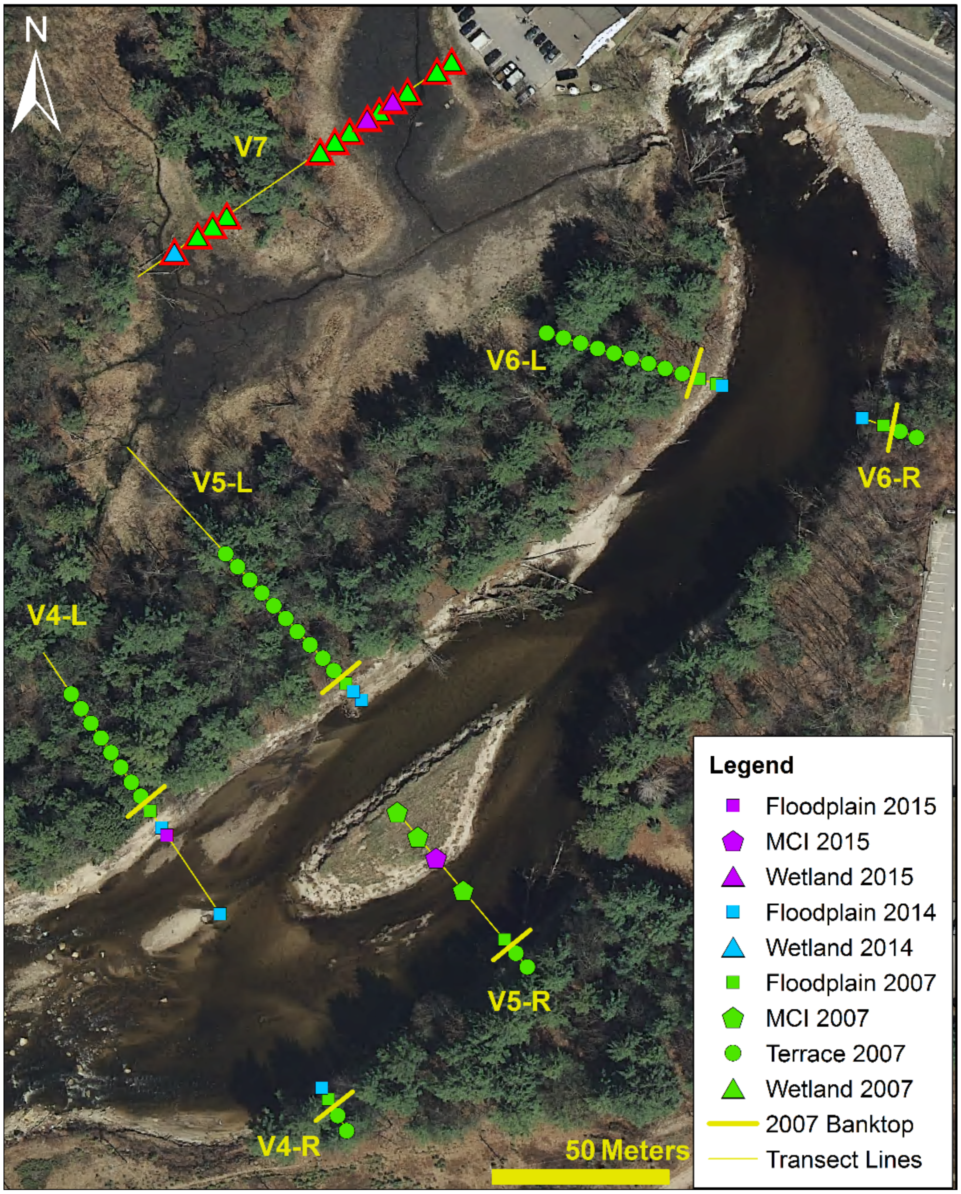

Figure 3.2 Aerial photograph of the former impoundment with transects V3-V7 noted. The floodplain, terrace, and wetland herbaceous community plots and the year they were first included in the study are marked. The 2007 banktop location is also noted. A red outline indicates plots not sampled in 2009. Image taken by the state of New Hampshire in 2011.

Table 3.7 The total number plots included in each yearly surveys

Year	Number of Plots
2007	114
2009	99
2014	128
2015	130

3.2.1 Yearly Species Counts

Following the ANOSIM, the vegetation communities were further scrutinized in order to understand how the plant composition changed. The control communities, and tree and shrub treatment communities, which did not experience significant change, were not further investigated. Only the herbaceous treatment communities were further described.

Beginning the with the most general descriptor of number of species present, the pre- and post-removal terrace and floodplain communities show an increase in species, by 13 and 10 respectively (Figure 3.3). The wetland shows a smaller decrease in species, by 5. The overall species found in the herbaceous plots at the site were both 68 in 2007 and 2015. However, it is important to note that this description only includes the number of species, and years that have the same quantity of species present do not necessarily have the same species composition. Despite the limitation of this depiction of data and the 2009 lack of plot addition, a significant result is the evident decrease in species found in 2009, one year after the dam removal, consistently followed by a rebound.

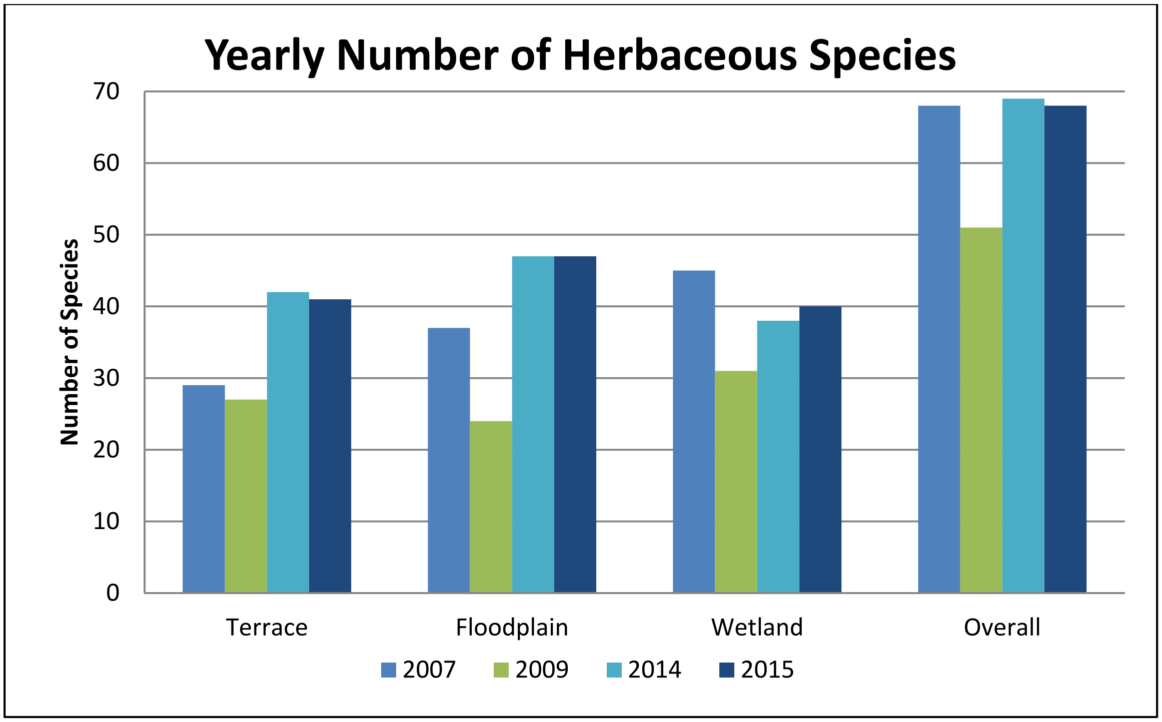

Figure 3.3 The bar graph describes the total number of species found in each vegetation community in each yearly survey. The overall number of species are also denoted yearly, with species included in multiple communities only counted once.

3.2.2 Composition of Herbaceous Communities

Each herbaceous community was then further investigated with the composition and species analysis, in the order of floodplain, terrace, and wetland. For the floodplain community, the 2007, 2014, and 2015 data appear similar (Figure 3.4). The herbaceous floodplain vegetation contributes between 45-60% in these years, with a minor (7-10%) contribution by woody species. In these years, the unvegetated area composed no more than 47% of the total plot area. None of these observations were found to be true in 2009, where only 24% was covered by herbaceous species and 3% by woody species. The remaining 73% of plot area was unvegetated, more than doubling the unvegetated area observed in 2007, qualitatively shown in the 2009 aerial image in Figure 3.1. These observations corroborate the ANOSIM analysis that found 2009 to be statistically different from the other years, and elaborates on the nature of the difference. Following this distinct year, in 2014, the unvegetated area returned to a level similar to pre-removal conditions. 2015 saw a slight increase in the unvegetated area, possibly due to year-to-year weather changes or more erosive events.

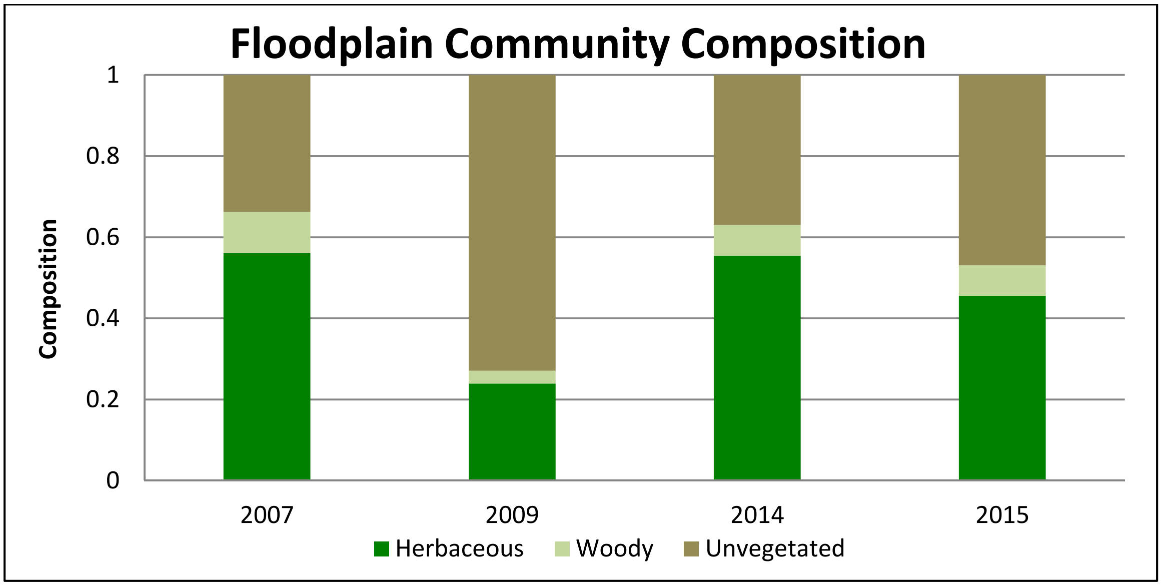

Figure 3.4 The stacked bar graph details the change of floodplain vegetation classes throughout the study period. The percentages of the classes are determined from the summed percent coverage data of the total.

Figure 3.5 allows finer analysis of change over time by considering the fluctuations of selected species over the study period. For many, the mean percent coverage is greatly reduced in 2009. This effect is observed to such an extent that the 2009 floodplain community can be characterized by mainly ground moss (*Bryophyta*), meadow sweet (*Spiraea latifolia*), sedge (See Table 2.2) and poison ivy (*Toxicodendron radicans*). This contrasts to the communities of other study years, where cinnamon fern (*Osmunda cinnamomea*), deer-tongued grass (*Dichanthelium clandestinum*), grass (See Table 2.2), and poison ivy, with contributions made by false nettle (*Boehmeria cylindrica*) and goldenrod (*Solidago sp.*). In these other communities, the contributions increase over the study period, though 2015 sees a slight decrease in the contribution of many characteristic species.

Over the course of the study, species more characteristic of the upland or forest environment decrease in abundance, such as groundnut (*Apias americana*) and wood aster (*Aster divaricatus*). The area is instead being colonized by red maple (*Acer rubrum*) and deer-tongued grass. The species with a smaller root-base pervasive in 2009 are being replaced by these in 2014 and 2015.

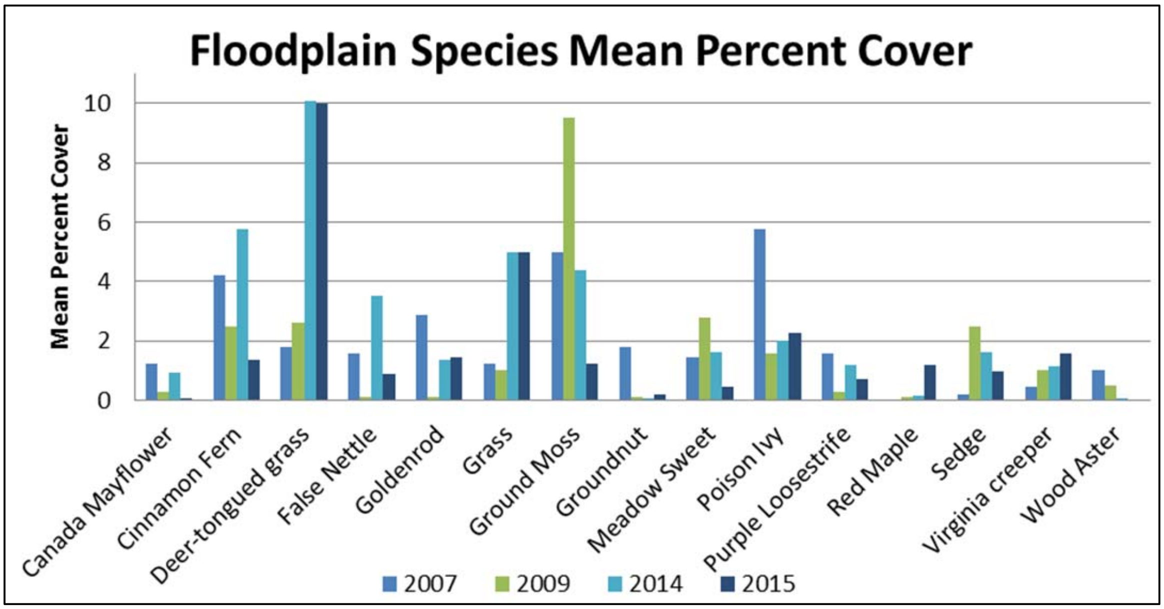

Figure 3.5 Bar graphs indicate the change over time of selected floodplain species, omitting the unvegetated class to enable closer scaling to the other data.

These descriptions of the composition of the floodplain community are enhanced with photographs over time, showing the dam removal effect on both the geomorphic and vegetation characteristics (Figure 3.6). The floodplain images were aligned using the clump of three trees in each image, most prominently in 2008. Viewing the downstream end of the mid-channel island, the erosion of the far river-right (south) bank is clear in the 2009 image and the sandy expanse in the foreground of this image. In 2010 and 2011 the continued erosion of this area is evident by the trees falling down the destabilized bank in on the upstream side of the frame. However, both years show the gradual re-vegetation of the floodplain, most pronounced in 2011. This appears to be aided by the increase in elevation of the floodplain from 2009, associated with greater deposition of sediment, rather than the slumping of bank sediment. The fluvially deposited sediment also has some degree of sorting, as seen in the photographs.

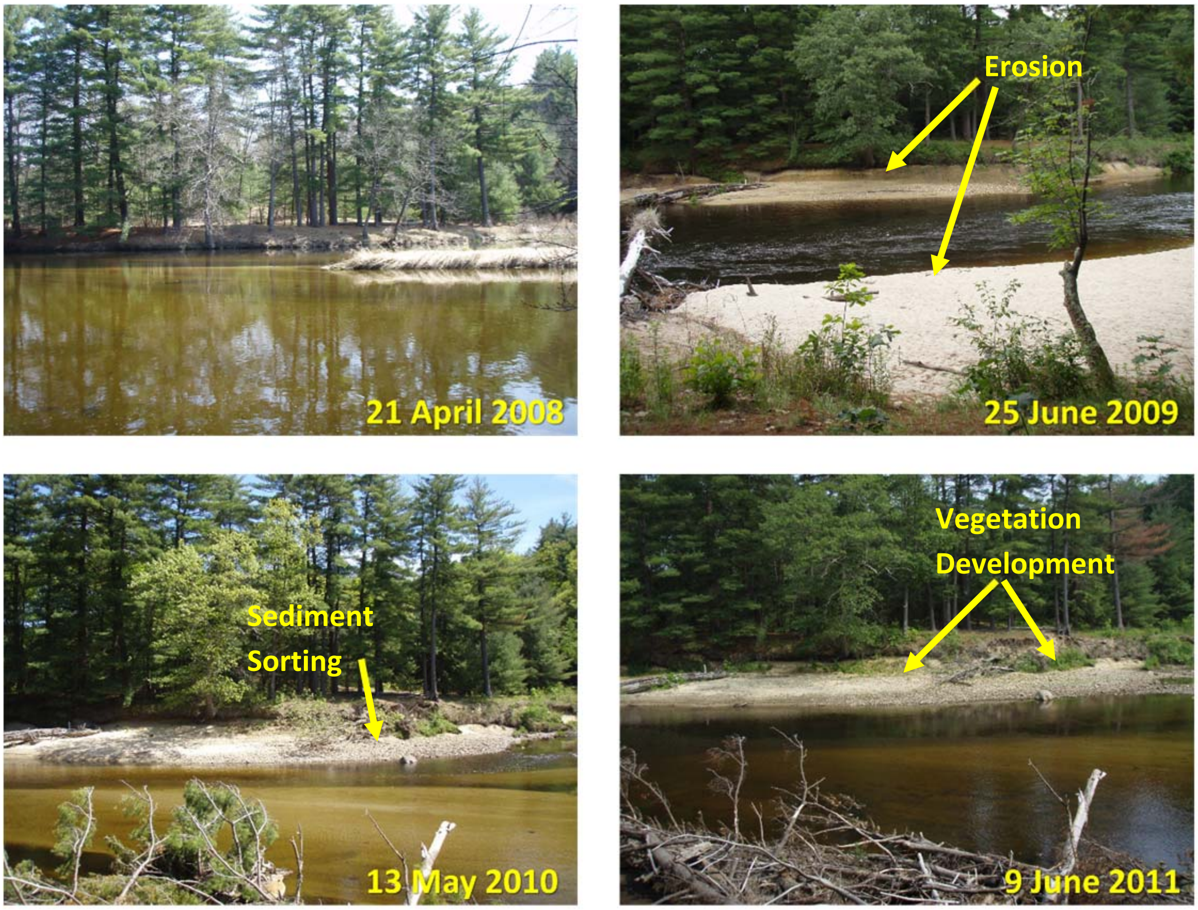

Figure 3.6 A series of photographs taken at a single station from the left bank monument of geomorphic cross section MVD06 overlooking the downstream end of the mid-channel island in the main impoundment. The series details the pre-removal conditions, erosion of the bank and former floodplain zone, and eventual re-establishment of vegetation. See Figure 1.6 for photo station location. Flow is from right to left.

The terrace community displays more similarity throughout the years than either the floodplain or wetland communities. Throughout the years, the contribution of the herbaceous, woody, and unvegetated vary by less than 10% (Figure 3.7). The characteristic composition of the terrace was approximately 15% herbaceous vegetation, 5% woody, and 75% unvegetated, largely pine needle duff of the forest floor. The vegetation class analysis of the terrace community indicate that the significant change noted in ANOSIM may be due to changes in the herbaceous vegetation, which increases from 11% to 18 and 20% in 2014 and 2015 was likely also due to the herbaceous species present, compounding this seemingly narrow change. Conversely, Figure 3.7 displays the very slight variation in unvegetated to vegetated area, which look more significant on the composition analysis and may only be a minor contributor to the significant change.

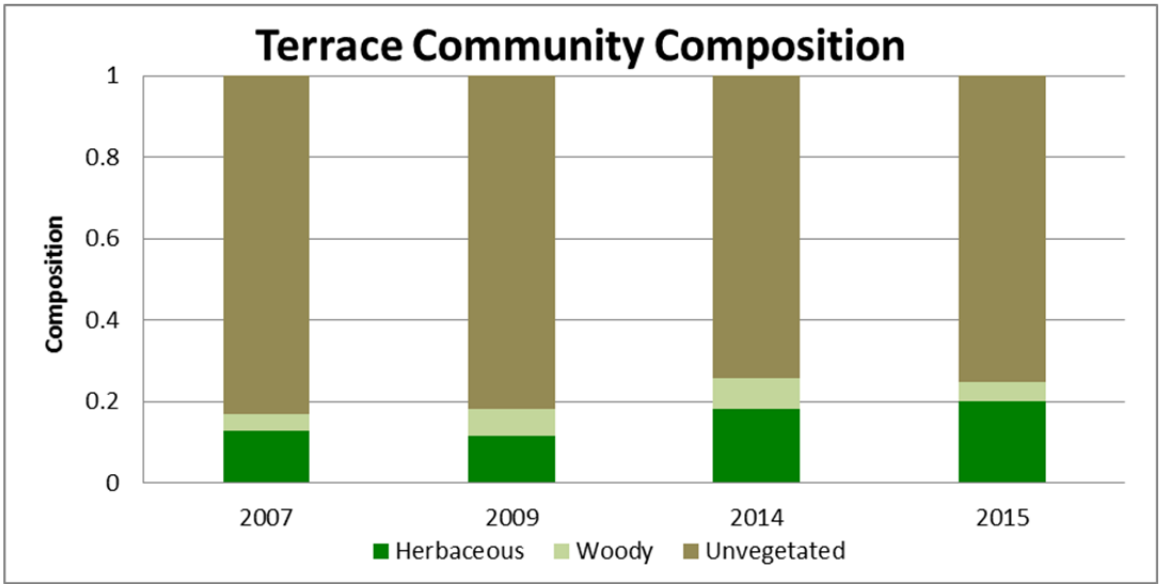

Figure 3.7 The stacked bar graph details the change of terrace vegetation classes throughout the study period. The percentages of the classes are determined from the summed percent coverage data of the total.

As seen in Figure 3.8, Canada mayflower (*Maianthemum virginiana*) was the only species to display a consistent mean percentage across the study period. All other species display a definite increasing or decreasing trend, or at least a year of distinct findings, such as starflower in 2009. Sedges and goldenrods experience the greatest increase throughout the study period, while the woody species like oak (See Table 2.2), red maple, and poison ivy decrease.

Given these data, the significant difference shown by ANOSIM is consistent with the species-findings. The 2015 data appear to be an exaggerated extension of trends in vegetation development. This large difference, especially noticeable with goldenrod, oak, and sedge, contributed to the significant difference in the terrace vegetation community of 2015. These species changes likely compounded the slight changes in unvegetated area to result in an overall significant ANOSIM result.

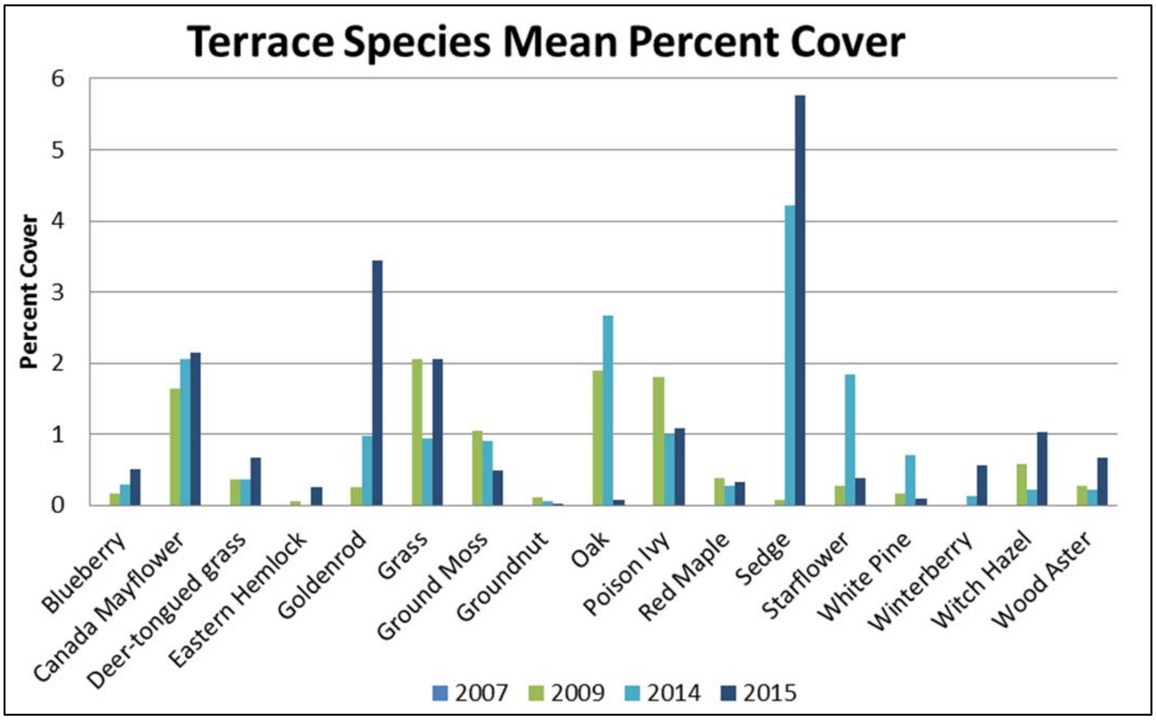

Figure 3.8 Bar graphs indicate the change over time of selected terrace species, omitting the unvegetated class to enable closer scaling of the data.

For the description of the wetland herbaceous community, the 2009 data must again be viewed in the context of surrounding observations since the only sampling that year in the wetland was along the V5-L and V6-L that extend into the wetland, as seen on Figures 1.6 and 3.2. However, the significant difference between the years provides a clear description of the transformation of the wetland vegetation community, not based on subtleties induced with lack of decreased sampling.

The submerged or floating vegetation species present in the 2007 survey disappeared completely in the following surveys, with the exception of one struggling fragrant water lily plant found in the 2014 survey. These submerged or floating species are denoted as the

“Aquatic” classification on Figure 3.9. Another overall change as a result of the draining of the backwater wetland was a great increase in terrestrial soil area available for vegetation, as shown by the increase in vegetation with each survey. Also, the woody vegetation increased in 2014 and 2015, compared to pre-removal conditions, consistent with more complex vegetative development of the community. Compared to the floodplain and terrace herbaceous vegetation communities, the wetland had the least unvegetated area.

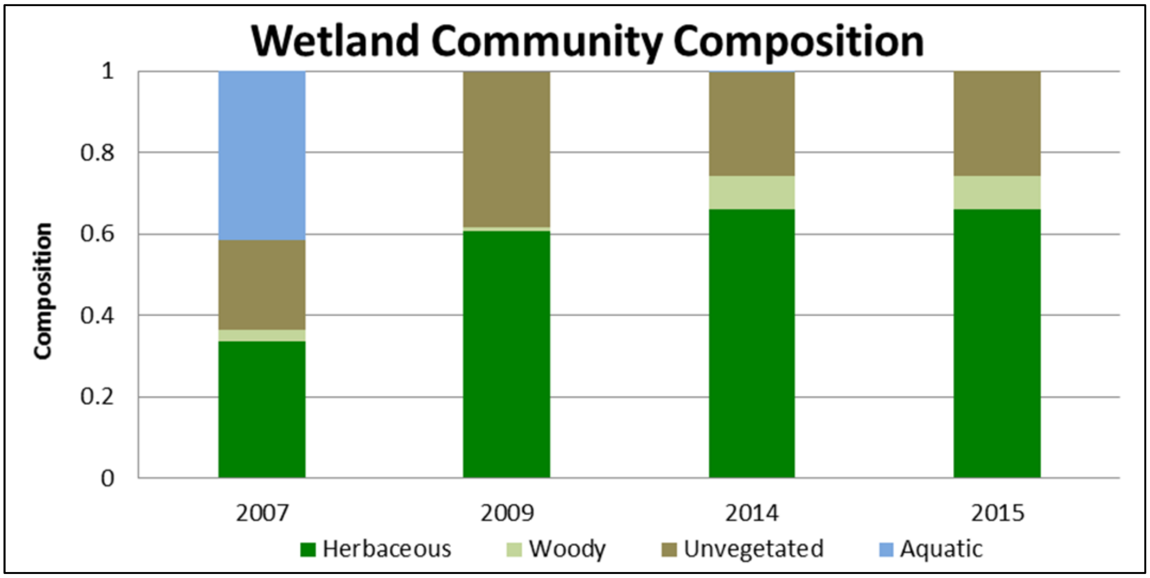

Figure 3.10 The stacked bar graph details the change of wetland vegetation classes throughout the study period. The percentages of the classes are determined from the summed percent coverage data of the total.

Though the broad classification of the wetland herbaceous community shows the clear transition in the community, the change can further be expanded upon with the mean percent coverage analysis of consistent species. The species detailed in Figure 3.11 are arranged from left to right in decreasing water habitat requirements. Such a sorting was used to highlight the disappearance of the aquatic species seen in the first five species. These species are responsible for the aquatic classification in Figure 3.10. Post-removal when the backwater pond-like wetland became an ankle-deep wetland, these submerged and floating species were replaced with emergent species.

The complete transformation of the wetland ecosystem is shown by the decreasing trends in species percent cover data on the left side of the graph and the increasing trends on the right side. As shown by the relatively low prevalence of unvegetated area following the high 2009 occurrence indicates that the transformation was expedient, almost completely replacing the vegetation. The new community development only intensifies over time, shown by the downward trend of unvegetated area, as the wetland dries. However, the unvegetated area post-removal remains slightly more than pre-removal percentages.

Moderately moisture-requiring plants such as jewelweed (*Impatiens capensis*) peak in abundance six years after removal. At this point, there is still sufficient water available, while also not drowning the plant. This effect may have been more extensively described by the data if a complete 2009 survey were conducted. The other species, such as goldenrod and false nettle, show a great increase in abundance in 2014. While invasive species were present in both the pre- and post-removal conditions, as shown by the rice cut grass (*Leersia oryzoides*) and purple loosestrife (*Lythrum salicaria*) data, the invasive species did not dominate the newly formed wetland community.

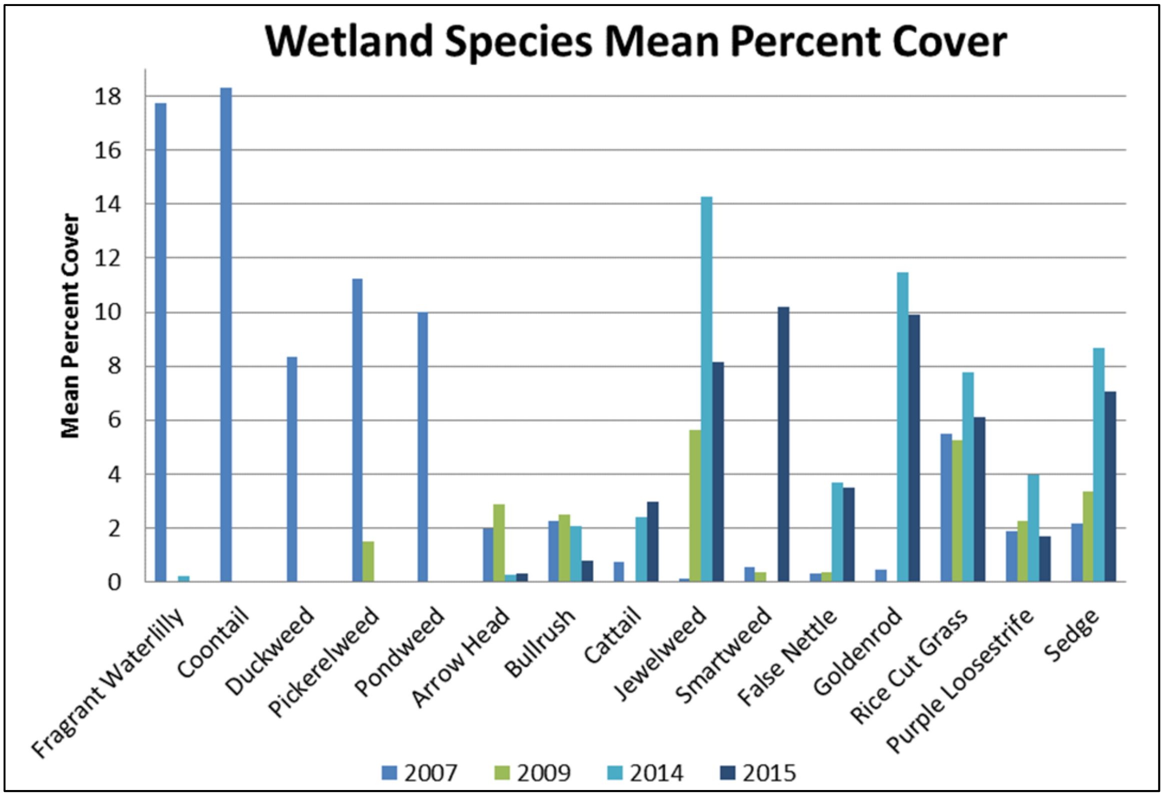

Figure 3.11 Bar graphs indicate the change over time of selected wetland species, omitting the unvegetated class to allow closer scaling of the data.

The wetland photographs (Figure 3.12) qualitatively illustrate the transformation of the wetland. Between the images, the open water pond in 2007 becomes a pond-like area with emergent vegetation in 2008, a drained soil area with the early stages of vegetation colonization in 2010 and finally a heavily vegetated low-lying area in 2011. For size reference, the vegetation in 2011 is approximately shoulder-height.

In comparison to the floodplain images (Figure 3.6), the vegetative development and the sediment and geomorphic processes are different in the wetland. The dark organic-material-enriched wetland sediment is colonized much faster than its sandy floodplain counterpart. In the protected backwater environment, separated from the main channel, the early colonizing plants seen in 2010 are not threatened by floods and erosion in the same manner that the floodplain colonization is.

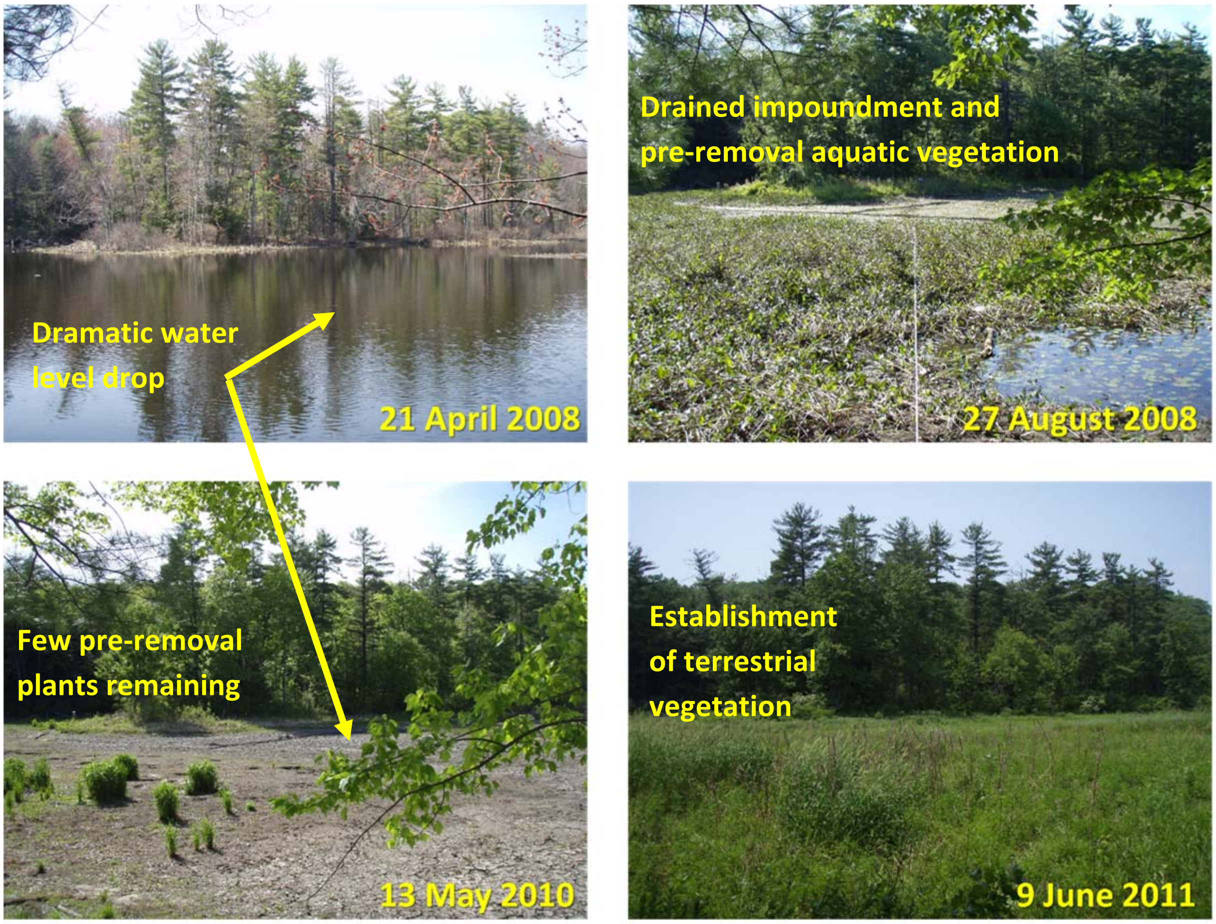

Figure 3.12 A series of photographs taken at a single station overlooking the middle area of the wetland, detailing the pre-removal conditions, slow draining of the wetland, and colonization of bare surfaces by vegetation over multiple years. See Figure 1.6 for photo station location. Flow is from left to right.

3.3 MCI Dissimilarity and Qualitative Analysis

The mid-channel island (MCI) plots established in 2007 have been kept separate throughout this analysis due to their geomorphic and hydraulic conditions different from the other regions of the site. Overall, the mid-channel island of vegetated impoundment sediment was characterized by three plots, until 2015 when an additional plot was added (Figure 3.2). As a result of this very small sample size, there was not a significant difference between years, according to ANOSIM (Table 3.6). However, the Bray-Curtis statistics highlight, some of the differences in the MCI plant community over the course of the study period (Table 3.8).

The change in the MCI plots can be quantified using the Bray-Curtis Dissimilarity matrix where all MCI plots of each year are compared to all plots of each of the other years. The full table of the comparison results is available in Appendix 1, but the average dissimilarities are described in Table 3.8. As shown in the first column of the results, the composition of the MCI vegetation community is least dissimilar between 2007 and 2009, indicating a delayed vegetation response. The dissimilarity increases to exceed 76% difference for 2014 and 2015 in comparison to pre-removal conditions. For all other comparisons, the steady ~60% change indicates a species composition that transforms differently each year.

Table 3.8 The Bray-Curtis dissimilarity matrix describes the average changes found between the MCI plots for each comparison of years.

MCI Average Dissimilarity of Yearly Comparison

	2007	2009	2014	2015
2007				
2009	0.519			
2014	0.787	0.640		
2015	0.763	0.652	0.667	

Following this Bray-Curtis description of the MCI vegetation community, the community can be described by the classification of the major species components each year (Figure 3.13). As shown, the invasive reed canary grass decreases from a 44% contribution to only 8% over the course of the study. In 2014, the community appeared to have traded one invasive species (reed canary grass) for another (black swallowwort) that may have been better suited to the drier post-removal mid-channel island conditions. However, the 2015 data indicate a more balanced vegetation community of invasive species, unvegetated area, and the other herbaceous species than detected in any of the previous samplings. This observation may suggest the potential for recovery in the ecosystem, rather than a state of invasive-species-induced arrested development where the monoculture becomes established, preventing the development of a climax community.

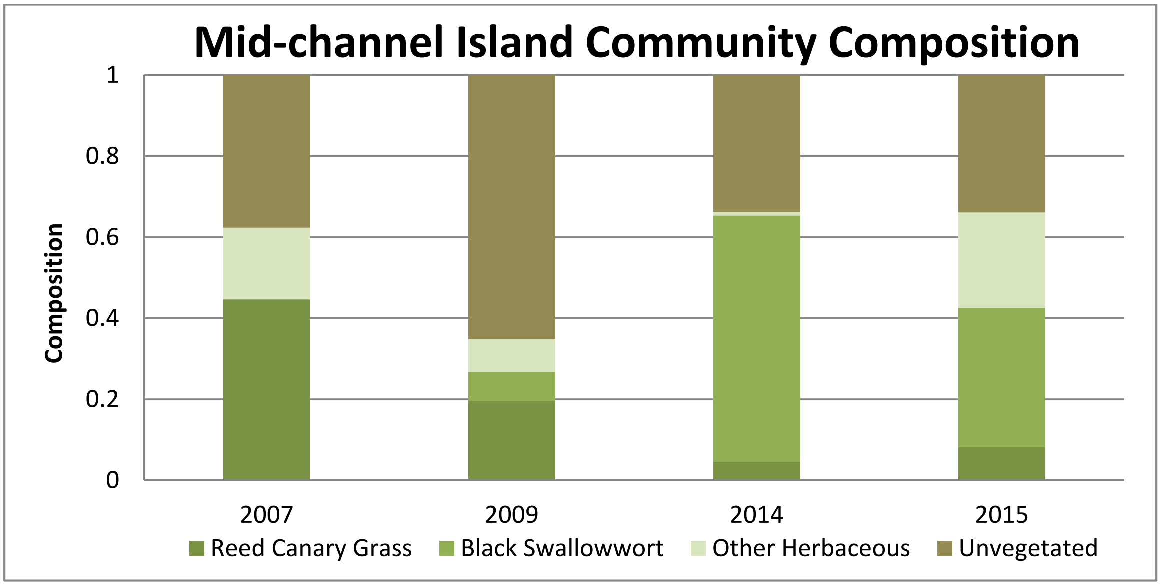

Figure 3.13 The stacked bar graph details the change of MCI vegetation species and classes throughout the study period. The percentages of the classes are determined from the summed percent coverage data of the total. Reed canary grass and black swallowwort are *Phalaris arundinacea* and *Cynanchum louiseae*, respectively.

3.4 Pairwise Analysis Results

Previously, the surveys of vegetation sampling plots can be looked at from the perspective of the communities that the plots represent. However, the plots can also be considered as discrete units that change over time, with all change considered with respect to the single plot's initial and final conditions. A description of the change of each individual plot can describe the pattern of change within that of the overall community. The goal of the pairwise analysis of the plots was to reiterate the change occurring at the site, but with the individual plot-points of change that could be used to speak to both the geographic distribution of community change.

The pairwise analysis identifies the areas of the site that underwent the most change of herbaceous plots from 2007 to 2015 (Figure 3.14). The herbaceous plots that were added throughout the duration of the study are still included within the figure, counting as 100% dissimilarity. These additions are appropriate in the figure because what was in 2007 the open water of the impoundment would not have been sampled for vegetation. When this area becomes exposed sediment and vegetated by 2015, the change would still be 100%.

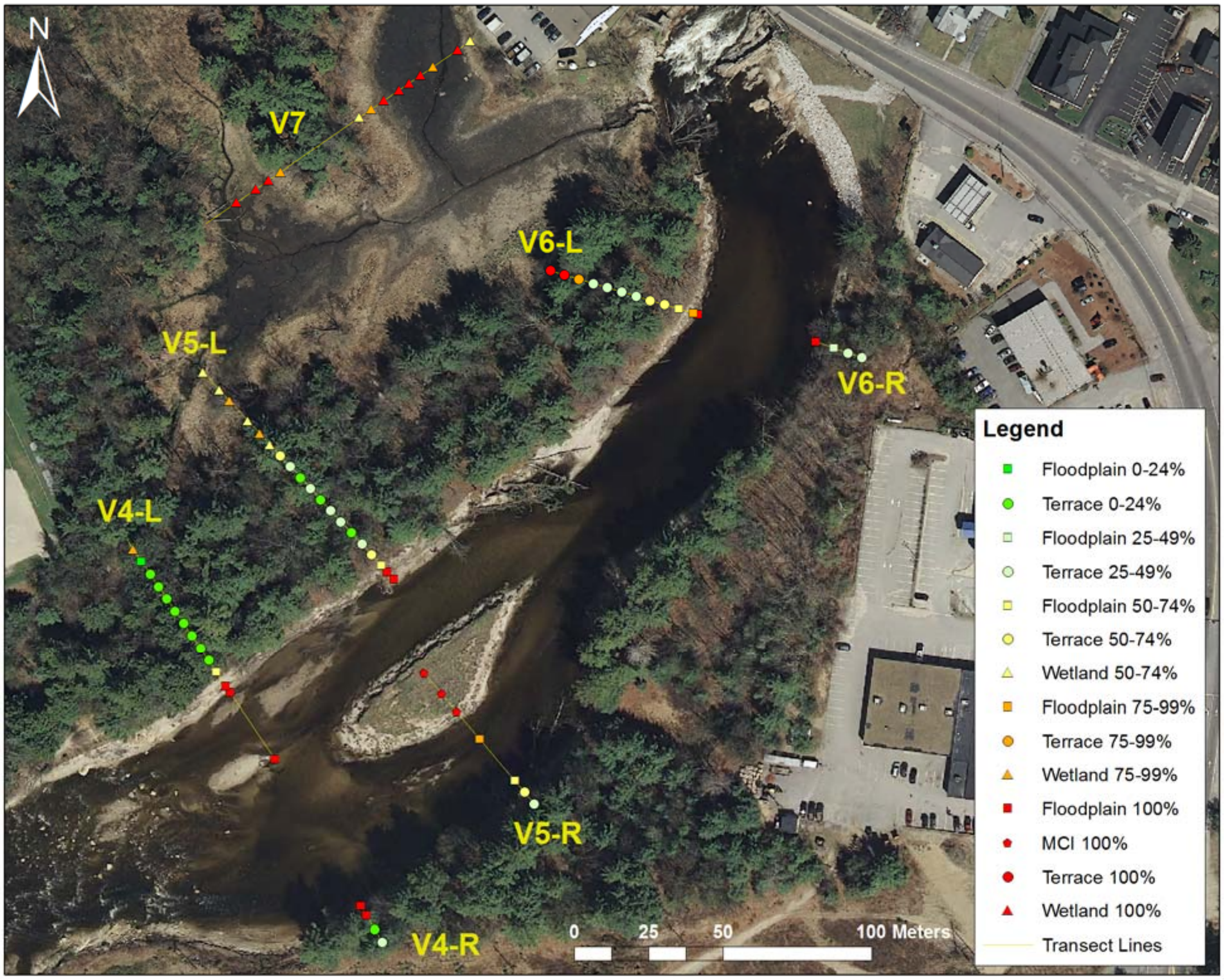

Figure 3.14 Aerial photograph of the former Merrimack Village Dam site, with transects noted. Herbaceous plots are marked along transects at appropriate distances and color-coded based on the calculated Bray-Curtis dissimilarity for species composition between 2007 and 2015. The shape of the symbols denotes the vegetation community of the plot. Image taken by the state of New Hampshire in 2011.

As seen on Figure 3.14, the most vegetation change was observed on the wetland transect and on the channel ends of impoundment transects. Both of these areas were in close proximity to the water level prior to the removal of the dam. These areas were seen to change to the greatest extent and with the greatest consistency throughout the geographic extent of the vegetation surveys. Conversely, the areas of the study area further removed from the channel are shown to have less dissimilarity in vegetation between 2007 and 2015.

These geographic distinctions throughout the site also correspond to the different herbaceous communities. When the dissimilarities of the plots are grouped according to the communities and the communities are described in terms of these plots (Figure 3.15), familiar patterns emerge. The highest dissimilarity is found in the floodplain, wetland, and MCI communities. The main community contributing to the smaller change values is the terrace community. However, a notable portion of the floodplain plots were less than 25% changed between 2007 and 2015.

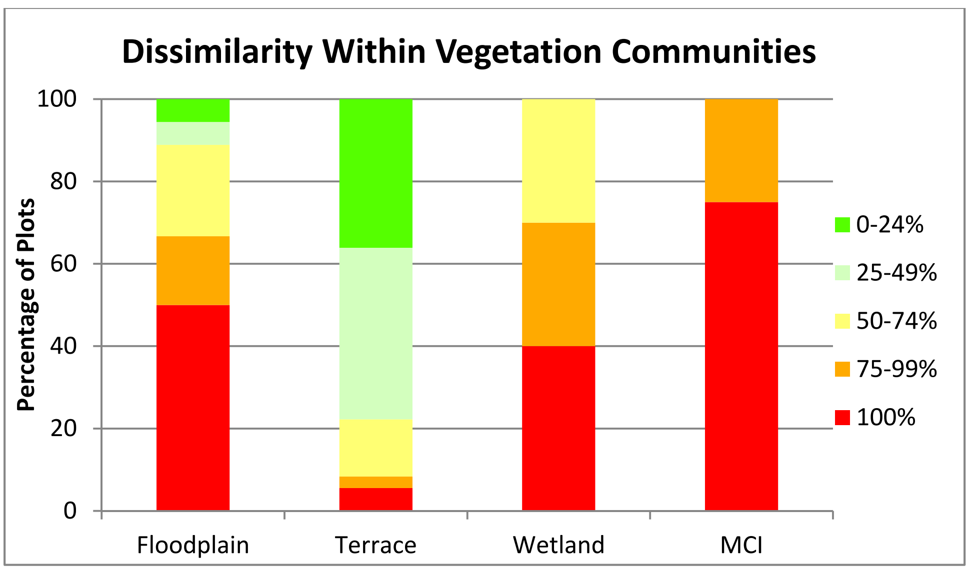

Figure 3.15 The stacked bar graph details the pairwise Bray-Curtis dissimilarity of the herbaceous vegetation communities between 2007 and 2015. The plots were sorted by dissimilarity, the percent dissimilarities were grouped, and the number of plots in each dissimilarity category were described as a percent of the total plots in the community.

Overall, the pairwise analysis enabled a description of the spatial distribution of the herbaceous vegetation change. When the community distinctions were applied to the data, the distribution of change across and within communities also became evident. The value of this pairwise analysis was in bringing these two factors, spatial and geomorphic, as they are reflected in change over time in vegetation communities after the dam removal.

Chapter 4 Discussion

The investigation of how the vegetation at the Merrimack Village Dam site changed following the dam removal motivated each of the qualitative and quantitative observations. Each community of vegetation highlighted in the hypothesis can now be evaluated within the entirety of the study results.

4.1 Communities Hypothesized to Not Change

4.1.1 Control Communities

The tree, shrub, and herbaceous vegetation communities in the control reach were expected to be similar throughout the study period. This original hypothesis was supported by both qualitative field observations and the ANOSIM analysis (Table 3.2). The vegetation change at the site was shown to be non-significant throughout the study period in areas of the site not directly affected by the dam removal, only subject to the background geomorphic, hydrologic, and climatic variation. These results indicate that in an area unaffected by the dam removal, the established vegetation community is stable. The absence of a significant change in the control communities enables closer scrutiny of communities that did experience a significant change throughout the study period, namely those flanking the former impoundment. This consistent similarity in the control reach also lends credibility to the 2009 surveys because all aspects of this control dataset are consistent with the control data from every other survey year.

4.1.2 Tree and Shrub Treatment Communities

The tree and shrub communities surrounding the former impoundment were also hypothesized to be similar throughout the study period. Like the results in the control communities, the data also supported this hypothesis (Table 3.3). The tree and shrub communities were set back from the actively changing floodplain area and were thus not affected by the changing fluvial geomorphology in the sense that the major areal extent of the communities were challenged with erosion or inundation, though the trees at the very edge of the pre-removal bank scarp fell into the floodplain as a result of erosion (Figure 3.6).

The geomorphic cross section data reports the water surface, indicating an approximately 3-meter drop in water table (Figure 1.5). The similarity of the tree and shrub communities throughout the study period may indicate that this drop did not significantly impact these communities, or the vegetation response has yet to be observed. This difference depends on the depth of the tree and shrub root systems and ability to grow downward into the lower water table. The vegetation is already adjusted to the fast-draining sandy soil, which would not have stored a great amount of water pre-removal, compared to other soil types. Once the dam was removed, the tree and shrub communities may have already been accustomed to a well-drained environment and were not significantly impacted. Conversely, the trees and shrubs may not have the root systems to accommodate the drop in water table. Throughout the seven-year study period, they may have been able to compensate but compositional changes may occur in the future if these trees and shrubs are unable to survive with the decreased water availability.

4.1.3 Terrace Herbaceous Communities

The herbaceous vegetation on the terrace flanking the impoundment was also initially hypothesized to be similar throughout the study period. The terrace area of the site was thought to be far enough removed from the geomorphic changes at the site to be insulated from the effects of the dam removal (Figure 3.2). The main factor from these geomorphic changes would have been the erosion and removal of trees rooted on the bank edge, increasing the light available to the herbaceous plants and decreasing competition for water and nutrients (Figure 3.6).

Unlike the tree and shrub communities, with the smaller water demands of the individual herbaceous terrace plants, the sandy soil and shallow root systems of the herbaceous plants may already make the vegetation dependent on moisture from precipitation, separating the community from the changes in water table. The ANOSIM results supported this reasoning for all comparisons of years, except those including the 2015 study year (Table 3.5).

Two possible explanations for the significant change of the terrace community may be the result of a drastic change between years, or the result of gradual change across the study period. The explanation of a drastic change in 2015 seemed plausible initially. Based on climatic data from West Hampstead, NH, in winter of 2015 the Merrimack region received 0.64 meters more snowfall than average and several months were ten degrees Fahrenheit colder according to mean monthly temperatures (NCDC, 2014). However, these variations are within normal expectations. The non-significant change between 2014 and 2015 does not support the explanation based on seasonal variation, which would have predicted change in this comparison. Similarly, the explanation fails with the lack of any drastic change in vegetation class or species composition (Table 3.5, Figures 3.7 and 3.8).

The data supports the explanation of gradual change, exhibiting a classic sensitivity to record length. First, the increase in number of species occurred throughout the study period (Figure 3.7), with a great change observed after 2009, but no great difference was observed in 2015. Also, the changing species composition appears to occur as an outgrowth of trends that span the study period with most species displaying increasing or decreasing trends (Figure 3.8).

The change in vegetation composition in Figure 3.14 is regionalized, more prevalent in transects V5 and V6, indicating a potentially regionalized effect causing the change. Figure 3.15, though noting the subtleness of the change, indicates that approximately 1 of every 4 terrace plots experienced a change of at least half of the plant composition.

In comparison to the complete vegetation reversal of the wetland, this slight difference is not that apparent. The ANOSIM will also be more sensitive to slight change in the terrace community comparison since the community is more homogenous than other vegetation communities. As a result, the magnitude of change required to elicit a significant determination will be smaller. However, even though the descriptive data of the terrace vegetation community does not indicate a drastic change in species composition, the data still support the ANOSIM result as a valid signal of change (Table 3.5). The signal may be a combination of the effects of a harsher preceding winter, compounded with the post-removal changes. A possible cause for the post-removal change in terrace composition may be that as the water table dropped, the root networks of the trees and shrubs became more competitive for the surface water, prompting a change in the herbaceous community as water becomes more competitive. This explanation is supported by the delay in the signal, and similarity of tree and shrub communities throughout the study period. An additional year of data would indicate whether the 2015 signal was the result of a yearly variation or the manifestation of a long-term post-removal change.

4.2 Communities Hypothesized to Change

The floodplain, wetland, and MCI herbaceous vegetation communities displayed the most consistent change throughout the study period. This supports the overarching hypothesis that the most drastic vegetation change would be seen in areas where the post-removal impact on geomorphology and hydrology was greatest (Figures 1.5 and 3.5). The regionalization of high rates of dissimilarity displayed in Figure 3.15 display this effect, without exception. The pre-removal vegetation communities had established themselves in an equilibrium that was ecologically accustomed to the gradual hydrology and geomorphology variations associated with the impoundment and wetland fringe. When this environment became destabilized with the dam removal, the vegetation species that had become established were no longer suited to the early post-removal conditions and the communities changed to accommodate this.

4.2.1 Floodplain Community

The floodplain community displayed the surprising result of only changing significantly when the 2009 survey was included (Table 3.5). Though this 2009 signal was initially suspect, every other description of the floodplain vegetation indicates that the change was real. The pre-removal floodplain fringe underwent great geomorphic change early after removal with the erosion of the unconsolidated sand, and any vegetation that had established itself (Pearson et al., 2011). In 2009, the survey of the community showed a much greater amount of bare sand in previously vegetated plots (Figures 3.4 and 3.6). These plots were then found to be vegetated in later surveys as well.

Comparing the results of the pairwise analysis with the ANOSIM results (Figure 3.15 and Table 3.5), the similarity of the 2007 and 2015 surveys would seem to be called into question, especially in comparison to the terrace results. However, the test is based on comparing the total intra-group variation with the inter-group variation for each year. The more diverse and spatially variable floodplain would have an ANOSIM that was less sensitive to change between years.

The notable aspect of the floodplain herbaceous assessment was the return of the vegetation community to pre-removal conditions in the survey six years (Table 3.5 and Figure 3.5). This post-removal community expanded spatially and is present at a lower elevation along the channel. This re-establishment was likely facilitated with stored seeds in the surrounding sand. Though the pairwise analysis indicates a high dissimilarity along the channel edge, the change indicates the spatial expansion of the floodplain community, rather than the transition of a pre-established vegetation community.

This re-equilibration of an existing community following a disruption is ecologically significant, illustrating the disruption as not an inherently negative event. The floodplain development may have been the result of the run-of-the-river dam, which would have accustomed the vegetation to a natural level of flow variation in the flowing reservoir environment. This run-of-river dam site exhibited a more dynamic setting than may be found behind a dam that was actively used to control the upstream water level. This initial condition likely enabled the floodplain riparian fringe to better respond to the dam removal with re-establishment rather than the complete reversal found in the wetland environment. The floodplain data suggest that the increase in disturbance within the ecosystem has a less significant effect on the vegetation community. A greater impact was caused by the drop in water level, erosion of impoundment sand, and the overall increase in area available for vegetation.

4.2.2 Wetland Community

The wetland herbaceous community underwent the most dramatic transition of any region of the study site (Table 3.5, Figures 3.10, 3.11, and 3.12). The ecosystem went from being navigable in a canoe to being walkable, with hardly getting one’s shoes wet. The increasing prevalence of terrestrial herbaceous and woody species follows the traditional successional trajectory of vegetation development. This complete transformation of the vegetation community was predicted. The area only served to manifest the long-standing ecological observations.

However, this drastic transformation did not occur within the first year post-removal, due to the magnitude of the reversal and the slower nature of the hydrologic and geomorphic change acting on the wetland. The wetland area had been accumulating a thick organic layer during lineage of dams at the site, and likely before as a smaller, possibly ephemeral, wetland area. The deposition of the finer sediment would have been enhanced during flood events, when the river would be carrying an increased sediment load. The finer particles would have stayed in transport throughout the river environment, to be deposited more readily in the lower energy backwater pond environment. This accumulated finer sediment has a lesser permeability which, when combined with the porosity induced by organic matter accumulation from many growing seasons, resulted in a much longer time period for the drying of the wetland depression.

Along with these cohesive characteristics of the soil, the smaller flow through the wetland greatly retarded the regression of the knickpoint that formed following removal. Several years post-removal, this erosion resulted in the formation of a narrow trenched drainage network within the wetland, evidence of the retreating knickpoint. The water base level drop caused by the removal did not fully affect the wetland until this network formed. The delayed hydrologic and geomorphic impact of the removal due to the specific soil and discharge characteristics of the wetland was reflected in the vegetation observations.

Since the pre-removal vegetation was not stripped by erosion, as occurred along the river channel and bank edge, the wetland transition was also delayed. Some species of the floating plants were able to survive for several seasons following removal, with the last vestiges of the community seen in 2014. Following this longer physical transition and slower evolution of the terrestrial vegetation community, by 2014 and 2015 a stable dynamic equilibrium was observed in the vegetation.

These interpretations of the specific vegetation communities are evaluated in light of the known information. The study would be benefited by continuation of monitoring to capture long-term vegetation response. The available data is limited by the truncated surveying in 2009 and the large gap between 2009 and 2014.

4.3 Common Concerns of Vegetation Following Dam Removal

The results of vegetation change observed in the study site address questions posed by previous research. The consistent vegetation of exposed surfaces, and invasive species are a prevalent topic surrounding dam removals, raised in both Shafroth (2002) and Orr & Stanley (2006). Both studies express concern regarding the susceptibility of bare surfaces to colonization by invasive species, following changes in disturbance regimes following the construction or removal of a dam. The Wisconsin surveys observe arrested vegetation development as a result of invasive species following a dam removal, on a site-by-site basis. The observations at the Merrimack Village Dam site can further elucidate each facet of these concerns.

The results of this study support the findings of Orr & Stanley (2002). Following the dam removal, no area of the site had unvegetated sediment that persisted throughout the study period. The floodplain areas of the site experienced several years of sparser vegetation, however the community was reestablished by the 2014 survey (Figure 3.6). The terrace herbaceous vegetation community does not demonstrate a similar effect because its largely unvegetated characteristic is due to the forested vegetation structure of the site. The sparse vegetation is observed consistently throughout the study period, including the pre-removal survey, making it not a result of the removal.

Invasive species were present intermittently throughout the different vegetation communities at the site, but in these instances were not dominating the community and creating a monoculture. On the sediments exposed by the removal, a balanced vegetation community developed in all instances. The main theatre for invasive species development was the mid-channel island (MCI). At the time of the pre-removal studies, this ecosystem was dominated by the invasive species reed canary grass (Figure 3.13), mirroring Shafroth's (2002) findings. Following removal, this invasive species was replaced by another, black swallowwort, which had completely taken over the island by 2014. At this point in the study period, the data would indicate the arrested development of the MCI community, where the dynamic equilibrium of a climax community would not become established. However, in 2015, the community shows evidence for another transition, with a decrease in black swallowwort and increase in other native herbaceous species. These data contrast Orr & Stanley's (2002) observations of arrested vegetation development, possibly illuminating an observation that was a result of the single-survey at each site. In this study, though invasive takeover was observed at a small fraction of the site, the data suggest that the community was still in the process of equilibrating. Also, at this site, the areal extent of the invasive species did not increase as a result of the removal.

Both Shafroth (2002) and Orr & Stanley (2006) refer to the development of the post-removal restoration with respect to the pre-dam conditions. This is a theoretical concept that is difficult to apply in the field, because the pre-dam conditions are rarely known, as is the case at the Merrimack Village Dam site. The lineage of dams extends more than 300 years, making the determination of pre-dam vegetation conditions difficult, compounded by the difference in geomorphology, climatic, land use, and invasive species conditions. Control reaches that have never had dams constructed on them could be used to further the understanding of long-term impacts of dams and the post-removal trajectories, but also subject to variation. Alongside this, the more feasible comparison the post-removal vegetation community would be with respect to the pre-removal community, which is more commonly and accurately described in vegetation surveys. The comparison of the pre- and post-removal conditions would detail how the vegetation communities respond to a disturbance within a more consistent set of surrounding environmental conditions.

Chapter 5 Conclusion and Recommendation

The results of the vegetation analysis supported the original hypothesis. The greatest effect was observed in communities subjected to the largest degree of hydrologic and geomorphic change. Some vegetation communities showed a return to pre-removal community compositions within the post-dam conditions, while others transformed into an entirely new community.

This study describes several vegetation response trajectories, explored within the pre-removal and physical conditions of the site. This framework understanding of factors that predispose communities towards a particular developmental path can be built on by further vegetation studies and sites. The burgeoning understanding would be a tool for dam removal planners, enabling better understanding of post-removal vegetation management. Most importantly, this study builds confidence that natural revegetation following a dam removal can result in the establishment of a diverse, dynamic vegetation community.

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Appendix 1 Mid-channel Island Bray-Curtis Dissimilarity Matrix

MCI Bray-Curtis Yearly Dissimilarity

		2007			2009			2014			2015			
		5R-29m	5R-49m	5R-59m	5R-29m	5R-49m	5R-59	5R-29m	5R-49m	5R-59mH	5R-29m	5R-41m	5R-49m	5R-59m
2007	5R-29m													
	5R-49m	0.676												
	5R-59m	0.214	0.568											
2009	5R-29m	0.524	0.800	0.429										
	5R-49m	0.250	0.636	0.250	0.412									
	5R-59	0.556	0.667	0.556	0.600	0.391								
2014	5R-29m	0.455	0.742	0.364	0.067	0.333	0.524							
	5R-49m	0.826	0.875	0.826	1.000	0.684	0.545	0.882						
	5R-59mH	1.000	1.000	1.000	1.000	0.889	0.714	1.000	0.176					
2015	5R-29m	0.524	0.800	0.429	0.000	0.412	0.600	0.067	1.000	1.000				
	5R-41m	0.733	0.641	0.733	1.000	0.692	0.862	0.917	0.840	1.000	1.000			
	5R-49m	0.739	0.813	0.739	0.625	0.579	0.455	0.647	0.333	0.294	0.625	1.000		
	5R-59m	1.000	1.000	1.000	1.000	0.889	0.714	1.000	0.529	0.375	1.000	1.000	0.529	

Appendix 2 Herbaceous Species Mean Percent Cover Table

		Floodplain							
Species	**Category**	**Mean Percent Coverage**				**Frequency**			
		2007	2009	2014	2015	2007	2009	2014	2015
Pondweed	AQUATIC	0.000	0.000	0.000	0.882	0.000	0.000	0.000	0.059
Arrow Arum	HERBACEOUS	0.000	0.000	0.000	0.412	0.000	0.000	0.000	0.059
Arrow-leaved Tearthumb	HERBACEOUS	0.000	0.000	0.000	0.294	0.000	0.000	0.000	0.118
Aster	HERBACEOUS	0.000	0.000	1.050	0.206	0.000	0.000	0.563	0.118
Bedstraw	HERBACEOUS	0.222	0.000	0.244	0.059	0.222	0.000	0.125	0.059
Blue Flag Iris	HERBACEOUS	1.333	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Blue Joint	HERBACEOUS	0.000	0.100	0.000	0.000	0.000	0.100	0.000	0.000
Brown Nut	HERBACEOUS	1.556	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Bugle Weed	HERBACEOUS	0.111	0.000	0.500	0.000	0.222	0.000	0.063	0.000
Bullrush	HERBACEOUS	0.000	0.000	1.994	3.912	0.000	0.000	0.375	0.294
Canada Mana Grass	HERBACEOUS	0.000	0.000	0.438	0.029	0.000	0.000	0.063	0.059
Canada Mayflower	HERBACEOUS	1.222	0.300	0.925	0.059	0.444	0.200	0.250	0.059
Cinnamon Fern	HERBACEOUS	4.222	2.500	5.750	1.353	0.222	0.100	0.063	0.059
Clearweed	HERBACEOUS	0.000	0.000	0.063	0.059	0.000	0.000	0.063	0.059
Climbing Dogbane	HERBACEOUS	0.000	0.000	0.375	0.000	0.000	0.000	0.125	0.000
Clover	HERBACEOUS	0.000	0.000	0.175	0.000	0.000	0.000	0.188	0.000
Club moss	HERBACEOUS	6.889	0.000	0.125	0.000	0.333	0.000	0.063	0.000
Dandelion	HERBACEOUS	0.000	0.000	0.000	0.029	0.000	0.000	0.000	0.059
Deer-tongued Grass	HERBACEOUS	1.778	2.600	10.056	10.000	0.444	0.300	0.563	0.471
Eastern Black Nightshade	HERBACEOUS	0.000	0.000	0.000	0.118	0.000	0.000	0.000	0.059
False Nettle	HERBACEOUS	1.556	0.100	3.500	0.882	0.333	0.100	0.188	0.118
False Solomon's Seal	HERBACEOUS	0.000	0.000	0.125	0.000	0.000	0.000	0.063	0.000
Goldenrod	HERBACEOUS	2.889	0.100	1.375	1.471	0.778	0.100	0.313	0.353
Grass	HERBACEOUS	1.222	1.000	4.981	5.000	0.444	0.400	0.438	0.412
Ground Moss	HERBACEOUS	5.000	9.500	4.375	1.235	0.222	0.200	0.125	0.294
Groundnut	HERBACEOUS	1.778	0.100	0.063	0.176	0.444	0.100	0.063	0.118
Jewelweed	HERBACEOUS	0.111	0.000	0.563	0.029	0.222	0.000	0.125	0.059
Joe Pye-weed	HERBACEOUS	0.222	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Mint	HERBACEOUS	0.000	0.000	0.375	0.059	0.000	0.000	0.063	0.059
Morning Glory	HERBACEOUS	0.000	0.000	6.063	0.000	0.000	0.000	0.125	0.000
Mullen	HERBACEOUS	0.000	0.000	0.113	0.000	0.000	0.000	0.125	0.000
New York Fern	HERBACEOUS	0.000	0.300	0.188	0.000	0.000	0.200	0.063	0.000
Nightshade	HERBACEOUS	1.778	0.000	0.125	0.235	0.333	0.000	0.063	0.059
Pearly Everlasting	HERBACEOUS	0.000	0.500	0.000	0.000	0.000	0.100	0.000	0.000
Pennywort	HERBACEOUS	0.000	0.000	0.250	0.706	0.000	0.000	0.063	0.118
Pokeweed	HERBACEOUS	0.000	0.500	0.000	0.000	0.000	0.100	0.000	0.000
Purple Loosestrife	HERBACEOUS	1.556	0.300	1.188	0.706	0.444	0.100	0.250	0.294
Reed Canary Grass	HERBACEOUS	5.000	0.000	3.938	0.000	0.556	0.000	0.250	0.000

Rice Cut Grass	HERBACEOUS	0.000	0.000	0.250	1.294	0.000	0.000	0.063	0.059
Royal Fern	HERBACEOUS	9.778	0.000	3.250	0.000	0.222	0.000	0.125	0.000
Sedge	HERBACEOUS	0.222	2.500	1.619	0.971	0.222	0.100	0.188	0.235
Sensitive Fern	HERBACEOUS	0.222	0.000	0.500	1.765	0.333	0.000	0.063	0.235
Skurpis sp.	HERBACEOUS	0.111	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Smartweed	HERBACEOUS	0.000	0.000	0.000	9.441	0.000	0.000	0.000	0.294
St. John's Wart	HERBACEOUS	0.000	0.100	0.000	0.000	0.000	0.100	0.000	0.000
Sticktight	HERBACEOUS	0.333	0.000	0.000	0.118	0.333	0.000	0.000	0.059
Tall Meadow Rue	HERBACEOUS	0.111	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Unknown	HERBACEOUS	0.000	0.500	0.000	0.059	0.000	0.200	0.000	0.059
Vinca	HERBACEOUS	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059
Water Hemlock	HERBACEOUS	0.000	0.000	0.313	0.294	0.000	0.000	0.125	0.353
water plantain	HERBACEOUS	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.059
Whorled loosestrife	HERBACEOUS	0.000	0.000	0.000	0.588	0.000	0.000	0.000	0.059
Wood Aster	HERBACEOUS	1.000	0.500	0.063	0.029	0.333	0.100	0.063	0.059
No Herbs	NO HERBS	34.778	74.300	38.806	46.294	1.000	0.900	0.875	0.824
Arrow wood	WOODY	0.000	0.000	0.000	0.235	0.000	0.000	0.000	0.059
Black Birch	WOODY	3.889	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Blueberry	WOODY	2.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Buttonbush	WOODY	0.000	0.000	0.063	0.000	0.000	0.000	0.063	0.000
Climb Bittersweet	WOODY	0.000	0.200	0.000	1.588	0.000	0.100	0.000	0.118
Dogwood	WOODY	0.333	0.000	1.313	1.941	0.222	0.000	0.063	0.059
Eastern Hemlock	WOODY	1.333	0.300	0.000	0.000	0.222	0.100	0.000	0.000
Japanese Barberry	WOODY	0.000	0.000	0.500	0.000	0.000	0.000	0.063	0.000
Meadow Sweet	WOODY	1.444	2.800	1.625	0.471	0.222	0.200	0.188	0.118
Oak	WOODY	1.222	0.000	3.625	0.059	0.333	0.000	0.188	0.059
Partridgeberry	WOODY	0.111	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Pepperbush	WOODY	0.000	0.000	0.063	0.000	0.000	0.000	0.063	0.000
Poison Ivy	WOODY	5.778	1.600	2.000	2.294	0.444	0.200	0.188	0.235
Raspberry	WOODY	0.667	0.000	0.125	0.176	0.333	0.000	0.063	0.059
Red Maple	WOODY	0.000	0.100	0.169	1.176	0.000	0.100	0.188	0.412
Sassafrass	WOODY	0.000	0.000	0.056	0.000	0.000	0.000	0.063	0.000
Virginia Creeper	WOODY	0.444	1.000	1.125	1.588	0.333	0.100	0.188	0.353
White Pine	WOODY	0.000	0.000	0.056	0.029	0.000	0.000	0.063	0.059
Winterberry	WOODY	0.778	0.000	0.563	0.412	0.333	0.000	0.125	0.059
Yellow Birch	WOODY	0.000	0.000	0.000	1.588	0.000	0.000	0.000	0.176

Terrace

Species	**Category**	**Mean Percent Coverage**				**Frequency**			
		2007	2009	2014	2015	2007	2009	2014	2015

Arrow Wood	HERBACEOUS	0.000	0.000	0.000	0.028	0.000	0.000	0.000	0.028
Aster	HERBACEOUS	0.000	0.000	0.167	0.056	0.000	0.000	0.083	0.056
Bracken Fern	HERBACEOUS	0.000	0.000	0.000	1.167	0.000	0.000	0.000	0.056
Bugle Weed	HERBACEOUS	0.028	0.000	0.000	0.000	0.028	0.000	0.000	0.000
Bullrush	HERBACEOUS	0.000	0.000	0.361	0.056	0.000	0.000	0.028	0.028
Canada Mana Grass	HERBACEOUS	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.056
Canada Mayflower	HERBACEOUS	2.222	1.639	2.050	2.153	0.583	0.472	0.583	0.611
Cinnamon Fern	HERBACEOUS	0.611	0.833	1.944	0.972	0.028	0.028	0.028	0.028
Club moss	HERBACEOUS	0.333	0.000	0.136	0.153	0.083	0.000	0.111	0.111
Deer-tongued Grass	HERBACEOUS	0.028	0.361	0.358	0.667	0.028	0.167	0.139	0.083
False Nettle	HERBACEOUS	0.000	0.000	0.083	0.028	0.000	0.000	0.028	0.028
False Solomon’s Seal	HERBACEOUS	0.000	0.000	0.222	0.333	0.000	0.000	0.028	0.028
Goldenrod	HERBACEOUS	0.278	0.250	0.969	3.444	0.111	0.083	0.167	0.167
Grass	HERBACEOUS	4.056	2.056	0.942	2.056	0.306	0.417	0.306	0.111
Ground Moss	HERBACEOUS	0.972	1.056	0.911	0.486	0.028	0.083	0.167	0.111
Groundnut	HERBACEOUS	0.250	0.111	0.056	0.028	0.083	0.028	0.028	0.028
Hog Peanut	HERBACEOUS	0.083	0.000	0.000	0.000	0.028	0.000	0.000	0.000
Male-berry	HERBACEOUS	0.000	0.278	0.000	0.000	0.000	0.028	0.000	0.000
New York Fern	HERBACEOUS	0.000	0.000	0.361	0.167	0.000	0.000	0.028	0.028
Nightshade	HERBACEOUS	0.083	0.000	0.000	0.000	0.028	0.000	0.000	0.000
Partridgeberry	HERBACEOUS	0.000	0.000	0.278	0.000	0.000	0.000	0.028	0.000
Reed Canary Grass	HERBACEOUS	0.000	0.278	0.472	0.000	0.000	0.028	0.083	0.000
Sedge	HERBACEOUS	0.028	0.083	4.222	5.764	0.028	0.028	0.111	0.250
Sensitive Fern	HERBACEOUS	0.000	0.139	0.025	0.000	0.000	0.028	0.028	0.000
Smartweed	HERBACEOUS	0.056	0.000	0.000	0.139	0.028	0.000	0.000	0.028
Starflower	HERBACEOUS	0.361	0.278	1.833	0.375	0.222	0.167	0.139	0.278
Sticktight	HERBACEOUS	0.000	0.000	0.000	0.028	0.000	0.000	0.000	0.028
Unknown	HERBACEOUS	0.000	0.194	0.025	0.042	0.000	0.111	0.028	0.083
Violet	HERBACEOUS	0.000	0.000	0.025	0.000	0.000	0.000	0.028	0.000
Water Hemlock	HERBACEOUS	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.028
Water Pimpernel	HERBACEOUS	0.000	0.000	0.083	0.000	0.000	0.000	0.028	0.000
Whorled Loosestrife	HERBACEOUS	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.028
Wild Sasparilla	HERBACEOUS	0.083	0.000	1.889	0.028	0.028	0.000	0.111	0.028
Wintergreen	HERBACEOUS	0.028	0.000	0.028	0.014	0.028	0.000	0.028	0.028
Wood Aster	HERBACEOUS	0.889	0.278	0.219	0.681	0.111	0.083	0.139	0.139
No Herbs	NO HERBS	83.111	83.444	74.050	75.542	1.000	1.000	0.944	0.944
American Hophornbeam	WOODY	0.000	0.000	0.028	0.000	0.000	0.000	0.028	0.000
Black Birch	WOODY	0.194	2.389	0.000	0.000	0.028	0.139	0.000	0.000
Black cherry	WOODY	0.194	0.000	0.000	0.000	0.083	0.000	0.000	0.000
Blueberry	WOODY	0.722	0.167	0.300	0.514	0.139	0.056	0.111	0.056
Choke Cherry	WOODY	0.000	0.000	0.056	0.403	0.000	0.000	0.028	0.139
Climb Bittersweet	WOODY	0.000	0.139	0.000	0.000	0.000	0.083	0.000	0.000

Dogwood	WOODY	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.028
Eastern Hemlock	WOODY	0.333	0.056	0.000	0.264	0.111	0.028	0.000	0.111
Fox Grape	WOODY	0.000	0.000	0.025	0.111	0.000	0.000	0.028	0.028
Grey Birch	WOODY	0.000	0.000	0.025	0.000	0.000	0.000	0.028	0.000
Japanese Barberry	WOODY	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.028
Meadow Sweet	WOODY	0.333	0.833	0.194	0.000	0.028	0.028	0.028	0.000
Oak	WOODY	0.833	1.889	2.667	0.069	0.139	0.167	0.194	0.056
Paper Birch	WOODY	0.000	0.000	0.111	0.000	0.000	0.000	0.028	0.000
Poison Ivy	WOODY	2.583	1.806	1.000	1.083	0.139	0.056	0.083	0.056
Princess Pine	WOODY	0.000	0.139	0.000	0.000	0.000	0.056	0.000	0.000
Raspberry	WOODY	0.000	0.000	2.667	0.000	0.000	0.000	0.056	0.000
Red Maple	WOODY	0.500	0.389	0.283	0.333	0.111	0.194	0.278	0.611
Rosa sp.	WOODY	0.000	0.000	0.111	0.167	0.000	0.000	0.028	0.028
Shagbark Hickory	WOODY	0.000	0.000	0.056	0.000	0.000	0.000	0.028	0.000
Virginia Creeper	WOODY	0.000	0.167	0.108	0.000	0.000	0.028	0.056	0.000
White Pine	WOODY	0.139	0.167	0.711	0.097	0.083	0.111	0.194	0.167
Winterberry	WOODY	0.167	0.000	0.131	0.556	0.056	0.000	0.111	0.056
Witch Hazel	WOODY	0.500	0.583	0.222	1.028	0.083	0.083	0.056	0.056
Yellow birch	WOODY	0.000	0.000	0.000	0.944	0.000	0.000	0.000	0.083

Wetland

Species	**Category**	**Mean Percent Coverage**				**Frequency**			
		2007	2009	2014	2015	2007	2009	2014	2015
Coontail	AQUATIC	18.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Duckweed	AQUATIC	8.333	0.000	0.000	0.000	0.167	0.000	0.000	0.000
Fragrant Waterlilly	AQUATIC	17.722	0.000	0.200	0.000	0.278	0.000	0.100	0.000
Pondweed	AQUATIC	10.000	0.000	0.000	0.000	0.222	0.000	0.000	0.000
Arrow head	HERBACEOUS	2.000	2.875	0.250	0.333	0.278	0.375	0.050	0.048
Arrow-leaved Tearthumb	HERBACEOUS	0.000	0.000	0.000	1.857	0.000	0.000	0.000	0.286
Aster	HERBACEOUS	0.000	0.000	0.050	0.000	0.000	0.000	0.050	0.000
Bedstraw	HERBACEOUS	0.111	0.000	1.145	3.048	0.111	0.000	0.200	0.333
Blue Vervain	HERBACEOUS	0.000	0.000	0.000	0.952	0.000	0.000	0.000	0.143
Bugle Weed	HERBACEOUS	0.500	0.000	0.000	0.000	0.167	0.000	0.000	0.000
Bullrush	HERBACEOUS	2.278	2.500	2.050	0.810	0.167	0.125	0.350	0.143
Canada Mana Grass	HERBACEOUS	0.167	17.500	0.000	0.000	0.056	0.500	0.000	0.000
Canada Mayflower	HERBACEOUS	0.056	0.250	0.350	0.405	0.056	0.125	0.100	0.095
Cattail	HERBACEOUS	0.722	0.000	2.400	2.952	0.111	0.000	0.200	0.333
Cinnamon Fern	HERBACEOUS	5.222	5.000	3.145	1.381	0.167	0.125	0.150	0.095
Clearweed	HERBACEOUS	0.111	0.000	0.000	0.000	0.056	0.000	0.000	0.000
Cleavers	HERBACEOUS	0.000	0.250	0.000	0.000	0.000	0.250	0.000	0.000

Climbing Dogbane	HERBACEOUS	0.000	0.000	0.200	0.000	0.000	0.000	0.050	0.000
Clover	HERBACEOUS	0.000	0.250	0.000	0.000	0.000	0.250	0.000	0.000
Club Moss	HERBACEOUS	0.667	0.000	0.000	0.000	0.111	0.000	0.000	0.000
Deer-tongued Grass	HERBACEOUS	0.500	1.000	0.450	1.429	0.167	0.500	0.200	0.048
Dogwood	HERBACEOUS	0.778	0.000	0.550	0.643	0.167	0.000	0.100	0.190
Eastern Black Nightshade	HERBACEOUS	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.048
False Nettle	HERBACEOUS	0.333	0.375	3.700	3.476	0.222	0.250	0.350	0.238
False Solomon's Seal	HERBACEOUS	0.000	0.250	0.000	0.000	0.000	0.125	0.000	0.000
Fox Grape	HERBACEOUS	0.000	0.000	2.950	4.286	0.000	0.000	0.100	0.048
Goldenrod	HERBACEOUS	0.444	0.000	11.490	9.905	0.056	0.000	0.450	0.381
Grass	HERBACEOUS	0.056	3.125	1.495	0.952	0.056	0.500	0.300	0.048
Ground Moss	HERBACEOUS	0.000	0.000	0.245	0.429	0.000	0.000	0.100	0.143
Groundnut	HERBACEOUS	0.278	0.125	0.200	0.333	0.056	0.125	0.050	0.048
Hog Peanut	HERBACEOUS	0.000	0.000	0.000	0.095	0.000	0.000	0.000	0.048
Jewelweed	HERBACEOUS	0.111	5.625	14.300	8.143	0.056	0.250	0.650	0.381
Marsh Fern	HERBACEOUS	1.000	1.500	0.000	0.000	0.111	0.250	0.000	0.000
Mock Bishopweed	HERBACEOUS	0.000	0.125	0.000	0.000	0.000	0.125	0.000	0.000
Morning Glory	HERBACEOUS	0.000	0.000	0.295	0.024	0.000	0.000	0.150	0.048
New York Fern	HERBACEOUS	0.667	3.750	0.500	0.238	0.167	0.125	0.150	0.095
Nightshade	HERBACEOUS	0.000	0.000	0.400	0.048	0.000	0.000	0.200	0.048
Pearly Everlasting	HERBACEOUS	0.056	0.000	0.000	0.000	0.056	0.000	0.000	0.000
Pennywort	HERBACEOUS	0.056	0.000	0.050	0.000	0.056	0.000	0.050	0.000
Pickerelweed	HERBACEOUS	11.222	1.500	0.000	0.000	0.333	0.375	0.000	0.000
Pink Ladyslipper	HERBACEOUS	0.056	0.000	0.000	0.000	0.056	0.000	0.000	0.000
Purple Loosestrife	HERBACEOUS	1.889	2.250	3.950	1.714	0.278	0.625	0.450	0.381
Reed Canary Grass	HERBACEOUS	0.000	0.000	7.750	0.000	0.000	0.000	0.200	0.000
Rice Cut Grass	HERBACEOUS	5.500	5.250	0.000	6.095	0.333	0.375	0.000	0.095
Royal Fern	HERBACEOUS	0.722	0.125	0.000	0.571	0.056	0.125	0.000	0.048
Rumex sp.	HERBACEOUS	0.056	0.000	0.000	0.000	0.056	0.000	0.000	0.000
Sedge	HERBACEOUS	2.167	3.375	8.650	7.048	0.389	0.375	0.450	0.476
Sensitive Fern	HERBACEOUS	2.000	0.625	2.750	0.024	0.278	0.250	0.100	0.048
Smartweed	HERBACEOUS	0.556	0.375	0.050	10.190	0.278	0.250	0.050	0.476
Sphagnum Moss	HERBACEOUS	0.111	0.000	0.000	0.000	0.111	0.000	0.000	0.000
St. John's Wart	HERBACEOUS	0.389	0.750	0.000	0.000	0.056	0.250	0.000	0.000
Sticktight	HERBACEOUS	1.056	0.000	0.000	0.048	0.278	0.000	0.000	0.048
Swampcandles	HERBACEOUS	0.000	1.250	0.000	0.000	0.000	0.125	0.000	0.000
Unknown	HERBACEOUS	0.000	0.375	1.050	0.095	0.000	0.125	0.150	0.048
Water Hemlock	HERBACEOUS	0.167	0.000	0.200	0.000	0.111	0.000	0.050	0.000
Water Pimpernel	HERBACEOUS	0.167	0.000	0.000	0.000	0.056	0.000	0.000	0.000
Whorled Loosestrife	HERBACEOUS	0.000	0.000	0.000	3.238	0.000	0.000	0.000	0.143
Wood Sorrel	HERBACEOUS	0.000	0.125	0.000	0.000	0.000	0.125	0.000	0.000
No Herbs	NO HERBS	29.833	39.375	26.620	25.643	0.556	0.750	0.700	0.762
Arrow Wood	WOODY	0.000	1.125	0.550	0.024	0.000	0.250	0.050	0.048

Buttonbush	WOODY	2.389	1.250	0.000	0.000	0.167	0.125	0.000	0.000
Climb Bittersweet	WOODY	0.000	0.000	0.000	0.286	0.000	0.000	0.000	0.048
Meadow Sweet	WOODY	0.000	0.000	0.200	0.571	0.000	0.000	0.050	0.048
Poison Ivy	WOODY	1.389	0.625	1.450	0.333	0.111	0.125	0.100	0.048
Raspberry	WOODY	0.000	0.000	0.145	0.095	0.000	0.000	0.100	0.048
Red Maple	WOODY	0.167	0.000	0.045	0.048	0.167	0.000	0.050	0.095
Virginia Creeper	WOODY	1.389	0.000	0.045	0.000	0.056	0.000	0.050	0.000
Winterberry	WOODY	0.389	0.000	2.200	0.667	0.056	0.000	0.200	0.095
Yellow Birch	WOODY	0.000	0.000	1.550	1.429	0.000	0.000	0.100	0.048

Mid-Channel Island

Species		**Mean Percent Coverage**				**Frequency**			
		2007	2009	2014	2015	2007	2009	2014	2015
Aster	HERBACEOUS	0.000	0.000	1.000	12.500	0.000	0.000	0.333	0.250
Black Swallowwort	HERBACEOUS	0.000	7.333	66.000	31.500	0.000	0.667	0.667	0.500
Bugle Weed	HERBACEOUS	1.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Bullrush	HERBACEOUS	5.667	0.000	0.000	0.000	0.667	0.000	0.000	0.000
Clover	HERBACEOUS	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.250
Deer-tongued Grass	HERBACEOUS	4.333	0.000	0.000	0.750	0.333	0.000	0.000	0.250
Dodder	HERBACEOUS	0.667	0.000	0.000	0.000	0.333	0.000	0.000	0.000
False Nettle	HERBACEOUS	2.000	0.000	0.000	0.500	0.333	0.000	0.000	0.250
Goldenrod	HERBACEOUS	0.000	0.000	0.000	4.000	0.000	0.000	0.000	0.250
Grass	HERBACEOUS	2.333	1.667	0.000	0.000	0.333	0.333	0.000	0.000
Greenbriar	HERBACEOUS	0.000	6.667	0.000	0.000	0.000	0.333	0.000	0.000
Joe Pye-weed	HERBACEOUS	5.000	0.000	0.000	0.500	0.333	0.000	0.000	0.250
Morning Glory	HERBACEOUS	0.000	0.000	0.000	1.500	0.000	0.000	0.000	0.250
Purple Loosestrife	HERBACEOUS	1.000	0.000	0.000	1.250	0.333	0.000	0.000	0.250
Reed Canary Grass	HERBACEOUS	70.000	20.000	5.000	7.500	1.000	0.667	0.667	0.250
Sedge	HERBACEOUS	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.250
Sensitive Fern	HERBACEOUS	1.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Smartweed	HERBACEOUS	0.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
St. John's Wart	HERBACEOUS	1.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Sticktight	HERBACEOUS	0.333	0.000	0.000	0.000	0.333	0.000	0.000	0.000
Wood Aster	HERBACEOUS	2.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000
No Herbs	NO HERBS	59.000	66.667	36.667	31.000	1.000	1.000	0.333	0.500
Red Maple	WOODY	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.250