Recent and Historic Land Covers of the Big River Management Area

Implications for Early Successional Habitat Management

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Executive Summary

Species that depend on early successional habitat (ESH) are experiencing population declines across the Northeast United States. In order to stabilize and maintain ESH-dependent species populations, active management strategies aimed at increasing the area of ESH through disturbance are thought to be required. In addition, recent studies have stressed the importance of accounting for effects of land use history when forming habitat conservation plans, including plans for ESH management. This study examines the land cover history of the Big River Management Area (BRMA), a 3,500 hectare (8,600 acre) tract of state-owned land currently targeted for ESH management..

The land use history of the BRMA is largely agricultural, although agriculture was relatively unproductive. Since 1939, total transitional forest area has decreased from191 to 113 hectares in 1970 and to 92 hectares in 1997. It is unclear whether the state management goal of 20% seedling-sapling forest cover represents any historical condition on the BRMA. In planning future ESH management of the BRMA, it is important to balance the goal of raising the populations of ESH species with the need to account for land use history. This study illustrates the importance of researching the specific local land cover history of areas targeted for management if informed ESH management decisions are to be made.

Variations in rates and patterns of reforestation on sites targeted for management should also be accounted for in ESH management plans. This study examines reforestation patterns and rates on 19 Big River ESH patches targeted for management by the RI DEM. The results of field sampling provide support for a gradual form of invasion of sample sites by white pines and pitch pines. Yearly mowing would be unnecessary to prevent reforestation by pines after initial management, but could be required every 8-9 years if open habitat maintenance is desired.

Introduction

Early Successional Habitat Declines

Since the first human colonization of the Northeast United States, changes in human population size and land use have caused major shifts in the forest cover of the region. Prior to any anthropogenic interference, natural disturbance regimes including wind, fire, and flooding kept a small percentage of Northeast land in early successional states, though the vast majority remained closed-canopy forest (Lorimer and White, 2003; Brooks 2003). Little is known about the prevalence of open habitat during the height of Indian civilization in the region, but studies suggest that these societies created sizable clearings through firewood harvest and slash-and-burn agriculture, as well as clearing and maintaining grass and shrubland habitat for deer and other game through controlled burning (Askins, 2000). Early European settlers reported that the Indians cleared coastal areas and river valleys for farming and hunting. In 1524, Verrazano wrote that much of the area surrounding Narragansett Bay was open grassland habitat (Day, 1953). Analysis of charcoal deposits reveals that before European colonization fires were relatively rare in inland forest, but quite common in coastal areas (Patterson and Sassaman, 1988). The frequency of coastal fires is likely due to the placement of Indian settlements, but also to the increased vulnerability of low-lying, sandy coastal plains to natural fire following hurricanes (Askins, 2000). One study estimates the pre-colonial early successional habitat (ESH) land area in the Northeast as 3% of total inland forest cover and >15% of coastal forests (Lorimer and White, 2003).

The arrival of European settlers and the transitioning of much of the land in the Northeast to agricultural production resulted in a decline in forested land area by as much as 60% by 1850 (Litvaitis, 1993). In Rhode Island, forest cover decreased to 50 % by 1767, and to 32%

by 1875 (Whitney, 1994). With a shift in the Northeast economy from agriculture to textiles and other factory-based industries however, agricultural lands were abandoned. In the decades immediately following agricultural abandonment, the region was dominated by shrublands and early-successional forests (Oehler, 2003; Litvaitis, 1993). These ecosystems supported a high diversity of mammals, reptiles, birds, insects, and plants, many of whom are obligate users of open habitats (Fuller 2003, Oehler 2003).

Today, the majority of land in the Northeast is again forested. In New Hampshire, forested area has increased to 87%, from a low of 47% in 1880 (Litvaitis, 1993). From a low of 32% in 1875, Rhode Island forest cover had increased to 67% by 1972 (Whitney, 1994). Overall, 67% of the Northeast is currently forested (Trani et al., 2001). Although the amount of forested area has remained relatively constant since 1948, as natural forest succession has progressed, the land cover of ESH has declined (Trani et al., 2001). In New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut combined, "seedling-sapling" land cover has decreased steadily, from 29% in 1950, to 14% in the early 1970s, to 8% in the 1980s (Iseminger, 1997). Along with natural forest succession, the marked decline in ESH area has been attributed to development of open lands and the anthropogenic suppression of natural disturbance regimes such as forest fire and flooding (Lorimer and White 2003).

Although forest ecologists have understood and described the decline in ESH-cover in the Northeast for decades, concern over this trend has grown due to the recent suggestion that ESH habitat loss is closely correlated with observed population declines in wildlife populations in the region. Researchers have observed a significant decline in species that depend on ESH, including many birds, Lepidoptera, and plants, some of which are now described as rare or threatened (Oehler, 2003). Ecologists argue that in order to stabilize and maintain the declining

ESH-dependent species populations, active management strategies aimed at increasing ESH area through disturbance are necessary (eg. Litvaitis,1993).

ESH Management Baselines and Strategies

There are a number of ESH conservation strategies, but debate surrounds the issue of management baselines. Part of the difficulty in defining these baselines exists because management goals vary between agencies; some seek to maximize biodiversity, while others are principally concerned with a few target species, such as songbirds or game fowl. Where biodiversity is concerned, ecologists differ in opinion over whether the observed declines in ESH-dependent species should be cause for alarm, or whether species are simply returning to pre-agricultural equilibrium levels as the Northeast reforests.

Even when a management goal is defined, such as maintaining pre-Columbian population levels of ESH-dependent species, recommendations from ecologists differ. One recommendation is to allow natural disturbance regimes to operate wherever possible, attempting to replicate the conditions predating anthropogenic interference. Most ecologists argue that simply leaving preserves unmanaged however, will fail to replicate pre-Columbian conditions, because disturbances are not frequent enough to recreate on a small protected area the type of ecosystem diversity historically present at a regional level (Askins, 2000). Instead, most ecologists advocate active artificial management. Dettmers, who estimates pre-Columbian ESH cover at 10-15% of the forested landscape within New England, argues that ESH cover should be maintained at this level to support pre-Columbian levels of ESH-dependent species (Dettmers, 2003). According to Litvaitis, however, human development and fragmentation of ESH patches has impaired ESH-dependent species, and a greater overall percentage of ESH land cover will be

required to support pre-Columbian population levels. Instead of providing a single figure for desired levels of ESH land cover across the Northeast, Litvaitis argues that land managers must set levels based on three parameters: dominant forest type, historic land cover, and recent land use history (Litvaitis, 2003).

Along with defining overall baselines, land managers must determine desired patch areas, recognizing that different target species have greatly varying habitat size needs. Managers must also select the most appropriate means of management, whether controlled burning, mechanical cutting and mowing, or some combination. Long-term schemes must also plan for future maintenance of baseline levels, either through routine management of target areas or creation of new clearings as older habitats reforest. Depending on the tree species in question, rates and patterns of reforestation may vary across managed areas, and these variations should be accounted for in maintenance plans. Dovciak et al. reported that white pine invasion into old fields can take at least three forms: gradual reforestation moving out from shady edges, "discrete-step" invasion of specific areas in good recruitment years, or sudden pulses of a large number of seedlings into the field center in particularly favorable recruitment years (Dovciak et al., 2005). The form in which old field reforestation progresses is of particular importance to ESH land managers when planning for future maintenance of managed habitat areas.

Land Use History

In suggesting that land managers consider land use history, Litvaitis contributes to a growing body of ecological literature citing the importance of land use history in shaping modern habitat make-up. Motzkin et al. report that among Massachusetts pitch pine-scrub oak communities, sites with a history of agricultural tilling display dramatically different forest

structure than those that have never been plowed (Motzkin et al. 1999). Bellemare et al. describe land use history as one of the most significant factors affecting secondary forest structure in New England (Bellemare et al. 2002). Flinn and Vellend demonstrate that historical land use can have enduring impacts on species composition, reforestation patterns and other ecosystem processes (Flinn and Vellen 2005). The long term land cover history of an area is a valuable indicator of the historical distribution of ecosystem types, which is a likely indicator of the ecosystem conditions necessary to support the persistence of historically present species (Lorimer, 2001; Thompson and DeGraaf, 2001). Land use history is therefore a critical factor in determining management baselines and habitat restoration or conservation plans.

ESH Management in Rhode Island

In 2004 the Rhode Island Department of Environmental Management Fish and Wildlife Division drafted an 'Upland Habitats Conservation Plan,' with the stated objective to: "restore, enhance, and maintain early successional habitats, concentrating efforts on grasslands, early successional seedling-sapling stage forests and wildlife borders for field edges and woodland margins."[1] The plan cites a number of explanations for the decline of ESH area in Rhode Island, including suppression of natural disturbance regimes, a decline in commercial timber production, and a loss of farmland, particularly historical dairy farms which provided a mixture of ecologically-valuable open and shrub habitats. The plan mentions a number of ESH species that are declining in Rhode Island, including nine species that are currently of particular conservation concern in the state.

[1] RI DEM 'Upland Habitats Conservation Plan,' 2004.

Currently, 6% of Rhode Island forest area is in the seedling-sapling stage.[2] The Upland Habitats Conservation Plan states that in order to maximize wildlife diversity, forest area across the state should be maintained as 60 percent saw timber, 20 percent sapling pole, and 20 percent seedling-sapling.[3] Accomplishing this goal would require conversion of 46,640 acres of forest to seedling-sapling stage, in addition to maintenance of the existing 21,300 acres. According to the Plan: "[a]t a proposed goal of enhancing/creating 500 acres of early successional seedling sapling forest per year, correcting the deficit would take 93 years. We need to begin this process immediately to prevent further declines in species."

In 2005, the RI DEM Fish and Wildlife Division, in cooperation with the Rhode Island Water Resources Board, applied for and received funding for ESH management on the state-owned Big River Management Area. The management plans targeted 19 partially reforested old field habitats for restoration to open conditions (Figure 2). In total, 140 acres of old fields were targeted for management through mechanical mowing and cutting over 5 years. Funding for the project, totaling $271,000 came from the Natural Resources Conservation Service Wildlife Habitat Incentive Program (NRCS WHIP) and from the RI DEM[4]. Mechanical management of targeted areas began in February 2006 and continued through March 2006.

The 19 areas selected for management by the RI DEM can all be classified broadly as early successional habitats, but each area has a unique appearance and land use history. Very little has been published about the land use and land cover history of the Big River Management Area.

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[2] Ibid.
[3] Ibid.
[4] RI DEM 'NCRS WHIP Project Proposal – Concept Plan' December 2004

Research Objectives

This study employs what Motzkin et al. term a "regional-historical" approach to analyze the management of early successional habitat in Rhode Island's Big River Management Area. I set out to create a land cover history for the Big River Management Area using aerial photographs from 1939-1997, historical maps of the area, and the 1870 West Greenwich Agricultural Census. Through the creation of a land cover history, I hoped to analyze patterns of land cover change. I also attempted to quantify and characterize rates and patterns of reforestation on areas targeted for management, thereby evaluating plans for future maintenance of the managed areas. Overall, the study addresses the question: how does (or should) historical land cover guide current wildlife management plans?

Methods

Site Description

The Big River Management Area (BRMA) is located in West Greenwich and Coventry, R.I. at approximately 41° 39' N and 71° 33' W, approximately 15 km west of Narragansett Bay (Figure 1). Elevation ranges from 75-110 m. The area has a climate typical of coastal Southern New England, with four distinct seasons, January being the coldest month (mean temperature = 1.8 °C) and July and August being the warmest (mean temperature = 22.8 °C). Annual precipitation for the area is approximately 120 cm, and is evenly distributed throughout the year.

The BRMA consists of approximately 3,500 ha (8,600 acres) of state-owned land in central Rhode Island condemned in the 1960s by the R.I. Water Resources Board for the purpose of constructing a new reservoir. The reservoir was never built, but the Water Resources Board continues to manage the land, which was designated as open space and a future public water supply by the RI General Assembly. The BRMA is used by a number of different stakeholders, including farmers, the military, mountain and dirt bikers, gravel miners, and residents. State agencies conduct limited forestry and wildlife management in the area.[5] The area has recently been targeted by the Rhode Island Water Resources Board and the Kent Country Water Authority as a new source of groundwater, and numerous USGS test wells are being evaluated as possible sites for high volume groundwater withdrawal.

The bedrock underlying this area, as well as most of the surrounding region, is granite. The Wisconsin glacier last receded from the site around 10,000 years ago. The soils throughout the area are sandy, and generally well-drained and nutrient-limited. Vegetative cover is dominated by white pine and pitch pine.

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[5] *Property Management: Big River Management Area*. State of Rhode Island Water Resources Board. http://www.wrb.state.ri.us/programs/pm/

The land use history of the area is largely agricultural, although agriculture was relatively unproductive on the area's well-drained soils. West Greenwich was incorporated in 1741, and the town's population peaked in 1790 at 2,054 persons. The early nineteenth century saw large-scale abandonment of the area's marginal farmland, and the West Greenwich population decreased by half between 1790 and 1890. Sixty-five farms in total were abandoned during this era, representing 3,580 ha, or one quarter of the town's area.[6] The 1890 Report of the Commissioner of Industrial Statistics described West Greenwich as "the poorest and most desolate town in the state."[7] Those farmers who remained in the area throughout the nineteenth century reported livestock (meat and dairy) and timber as major agricultural products. Although there was little agricultural mechanization in the area, there were three operating sawmills within the bounds of the BRMA in 1870.[8]

Analysis of Land Cover Change/Land Use History

I created maps of the recent land cover history of the BRMA using aerial photographs from 1939, 1970, and 1997 (Figures 4-6). I interpreted the photographs to classify each area within the BRMA as forested, cleared, transitional or water. The 'forested' classification was used to describe closed canopy forest stands. 'Cleared' described developed areas; gravel pits, or actively farmed and managed fields with no evidence of sapling or shrub intrusion. The 'transitional' classification denoted land that was not actively managed and showed signs of reforestation. From these maps I generated rasters displaying and classifying land cover change

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[6] *West Greenwich Preliminary Report.* Rhode Island Historical Preservation Commission, October 1978.
[7] Ibid.
[8] West Greenwich map, 1870 Rhode Island Atlas

over the periods 1939-1970 and 1970-1997 (Figures 7-8). All photographs were provided by the Rhode Island Geographic Information System Database.[9]

I also created a map of estimated 1870 West Greenwich BRMA land cover (Figure 3). Using a West Greenwich map from the 1870 Rhode Island atlas, I recorded landowner names within the BRMA bounds and matched those owners to land use records available in the 1870 Federal Agricultural Census. From there, I classified areas as either improved, woodland, other unimproved (the three census land classifications). Additionally, I estimated the areas of forest and gravel pits shown on the 1870 atlas map. All analyses were performed using Arc GIS 9.1.

Field Sampling

I examined reforestation patterns and rates through field sampling in three of the 19 Big River ESH patches targeted by the DEM for management. The three focal sites range in time since abandonment from less than 10 years to approximately 30 years. Two of the sites were once used for intensive agriculture (Sites B and C), while one was cleared for unknown purposes (Site A). On each site, I surveyed the species, age, and height of trees across reforesting areas to reveal successional patterns.

Using a transect-based systematic random sampling scheme, transects were placed 20 m apart, running perpendicular to the edge of the dominant forest stand. Sampling points were set out at randomly generated distances, at either a 20 m or 10 m spatial resolution, depending on the density of reforestation on the site (the younger sites were sampled at finer resolution). Each sampling plot was a two-meter radius circle centered at each point, within which the species and height of each tree was recorded. I determined the age of each tree using cores and cross-sections. I calculated vertical growth rate (meters/year) for each tree by dividing height by age.

[9] Accessed at RI GIS Data Distribution Website. http://www.edc.uri.edu/rigis/

To determine whether some recruitment years had seedling recruitment further from parent stands than other recruitment years I used a Student's T-test comparing mean seedling distance from parent stand across all years to mean seedling distance from parent stand within each separate year. I also conducted a regression comparing seedling distance from parent stand to seedling growth rate to determine whether seedlings are advantaged by establishing further from a parent stand. Statistical analyses were conducted using Microsoft Excel and JMP 3.2.2.[10,11]

[10] Microsoft Corporation, 2002. Microsoft Excel 2002.
[11] SAS Institute, 1997. JMP 3.2.2.

Results

Land Cover History of Big River

Using the 1870 atlas map and the 1870 agricultural census I was able to classify or estimate the cover of 57% of the land area of the West Greenwich portion of the BRMA. Land cover classifications were based on census information found for 21 of the 31 land owners listed in the 1870 Rhode Island Atlas, representing 68% of land owners.

In 1870, 15% of the study area was 'improved,' or cleared (representing 26% of known/estimated cover.) Six percent of area was classified as 'other unimproved' (3% of known/estimated area). Thirty-three percent was classified as 'woodland' (19% of known/estimated), while an additional 31% was estimated to be forested (18% of known/estimated). An estimated 2% of cover was gravel quarries (4% of known/estimated area.)

In 1939, 89% of the BRMA land area was forested (closed-canopy), 5% was cleared and 4% was transitional. In 1970, forested area remained at 89%, while cleared area had increased to 7% and transitional area had decreased to 4%. In 1997, forested area had increased to 92%, cleared area had decreased to 5% and transitional to 3% (Figure 9). Total transitional area decreased from 191 ha in 1939 to 114 ha in 1970 to 92 ha in 1997. Mean transitional patch size decreased from 1.3 ha (±1.7 ha) in 1939 to 0.6 ha (±0.8 ha) in 1970, before increasing slightly to 0.8 ha (±1.1 ha) in 1997. Changes in mean transitional patch size were not significant because of large standard deviations.

Of the 192 ha that were transitional in 1939, only 25 remained transitional in 1997. Over that period 88 ha were converted to transitional from another land cover and 163 ha of transitional area were lost. An even smaller area remained transitional from 1970 to 1997: 13 ha

in total. Over that period 78 ha converted to transitional from another land cover, and 100 ha of transitional area were lost (Figure 10).

Over the 1939-1970 period, approximately 2/3 of new transitional area was converted from forest, while from 1970 to 1997, 3/4 of transitional area gain came from previously cleared areas (Figure 11). From 1939 to 1970, almost 80% of transitional area lost was converted to forest. From 1970 to 1997, more than 90% of transitional area loss was to forest (Figure 11).

Of 2,892 total West Greenwich BRMA land hectares, land cover was determined or estimated for 1,657 ha, or 57%. Of those 1,614 ha, 33% was 'known woodland,' 31% was 'estimated woodland,' 26% was 'improved,' 6% was 'other unimproved,' and 4% was 'estimated granite quarry'.

Reforestation Patterns and Rates

Across the three sampling sites, 605 trees were sampled. Seventy-two of these were sampled at site A, 70 at site B, and 460 at site C. Recruitment years of sampled trees varied from 1984-2005 on site A, 1995-2005 on site B, and 1999-2005 on site C (Figures 12 and 13).

Mean growth rate of all trees sampled was equal to 64 mm/year ± 73 mm/year. Mean distance from parent stand for all trees sampled was 21.1 m. Seedling distance from parent stand and seedling growth rate were significantly correlated, with a weak negative relationship ($F=16.6729$; $p<0.0001$; $r^2=0.0271$; $y= -0.0012x + 0.1259$) (Figure 15).

Discussion

Land Cover History and Management Baselines

In describing the motivation for undertaking the BRMA Old Fields Restoration project, Brian Tefft, of the RI DEM Fish and Wildlife Division, cited a desire to maximize biodiversity and protect threatened ESH species, but also stressed the importance of protecting pieces of Rhode Island's 'cultural past.' Tefft noted that ESH species are valuable because they provide a link to the historical landscape of Rhode Island, a landscape in which human manipulation of the land produced the open habitat patches ESH species depend on. Tefft's comments highlight one fundamental philosophical debate around setting ESH management baselines: should managers seek to replicate pre-human conditions, or aim for landscapes similar to those created by the land managers who came before? And if a baseline from within human history is desired, what point in history is most appropriate?

Researchers and land managers recognize that there are a number of value judgments contained in the process of setting ESH management baselines, and determining which habitat conditions are "natural." It is also generally understood that ESH management planning must operate on a number of spatial scales, and that the baselines set for an entire region should not necessarily be applied unilaterally across ecosystems (eg. Thompson and DeGraaf, 2001). Thompson and DeGraaf suggest a process by which land managers first set regional-scale management goals, and then determine subregional and landscape level management plans by balancing regional goals with site-specific local conservation requirements and social costs and benefits (Thompson and DeGraaf, 2001). According to Thompson and DeGraaf, regional goals need not be represented by a single baseline figure (i.e. % forest cover in ESH), but can instead be stated in terms of a "historic range of variability" (HRV). The HRV concept acknowledges

“that a range of historic conditions was likely suitable for species persistence,” and that species will likely be supported by habitat conditions that approximate that historic range. The HRV strategy leaves room for variation in management plans at the subregional and landscape level based on local considerations (Thompson and DeGraaf, 2001).

The Rhode Island DEM has prioritized ESH species conservation in part because it views ESH species a valuable part of Rhode Island’s history. Although the DEM has not defined a particular historical baseline as a guide to management, the agency has set a goal of returning 20% of the state’s forest to seedling-sapling stage. This regional goal is based on a United States Fish and Wildlife Service estimate of the percentage of ESH cover required to support “sustainable populations” of the American Woodcock, an ESH-dependent species that has experienced marked population declines (Brian Tefft, personal communication). In setting the regional 20% ESH goal, the RI DEM has adopted a primarily biodiversity-focused strategy for determining their management baseline, as opposed to a land use history-based strategy.

Although the RI DEM has not defined a particular historical baseline as a guide to management, the stated regional goal of returning 20% of the state’s forested land area to seedling-sapling stage implies a desire to replicate conditions last seen across New England in the mid-twentieth century (according to Askins and Iseminger). It is important to note, however, that these regional habitat conditions (and corresponding levels of biodiversity) were not uniform across the region, and varied widely at a subregional landscape scale (Lorimer, 2001; Thompson and Askins, 2001). The land cover history generated for this study suggests that whether or not the 20% ESH cover conditions ever existed in the BRMA, they have not existed there within the last sixty years, nor, most likely, in the last 130.

It is possible that ESH species were populous in Rhode Island before European colonization as a result of Indian land management practices. The BRMA, as a low-lying, sandy, semi-coastal plain, would have been a prime area for controlled burning to create open habitat for game. Indian land management practices most likely have created the open habitat required to support significant populations of ESH-dependent birds (Askins, 2000). Any area maintained as clear by Indians would have reforested with European colonization, as disease shrunk Indian populations and colonizers dislocated native communities. Following European colonization however, the Big River area was not deforested as rapidly or completely as other parts of the state because of its marginal value as agricultural land.

The town of West Greenwich experienced a relatively short period of agricultural clearing (approximately 50 years, 1741-1790). The years following 1790 were characterized by continuous agricultural abandonment.[12] According to my 1870 classifications, forested area in that year comprised 64% of known and estimated land cover, significantly higher than Whitney's 32% figure for forested area of Rhode Island in 1875 (Whitney, 1994). My 1870 land classifications do not describe the entire extent of West Greenwich BRMA land cover because 1870 agricultural census information did not exist for 32% of land owners listed in the 1870 atlas. This discrepancy may be due to inconsistencies in state and federal record keeping, or to the fact that some West Greenwich farmers were land renters, meaning that agricultural census information recorded for these farms did not match the land owner names listed in the atlas. It would be logical to assume however, that the land use patterns of the 10 unknown land owners would have been similar to those of the 21 known land owners. The mean land holding among the 21 known owners was 48 ha, with 19 ha 'improved,' 24 ha 'woodland,' and 5 ha 'other unimproved.' Assuming that these means hold for the unknown 10 land holders, the unknown

[12] *West Greenwich Preliminary Report*. Rhode Island Historical Preservation Commission, October 1978.

holdings would add an additional 240 non-woodland hectares, meaning that the remaining 995 ha would likely have been forested. Overall, forest would have covered 2060 ha, or 71% of the West Greenwich BRMA land area. This high percentage of forest cover suggests that by 1870, significant reforestation had already occurred across the Big River Area. ESH cover in the BRMA was probably greatest in the 1790-1890 period, as abandoned farmland was gradually reforested.

By 1939, 89% of the BRMA was forested, and only 5% was in transition. Although parts of the area were still being actively farmed, transitional and cleared land together covered an area similar to 10-15% estimate of pre-Columbian New England ESH cover. Parts of the cleared dairy farmland in the area might have provided habitat for ESH species, but it is likely that ESH species levels in the BRMA in 1939 were lower than estimated pre-Columbian levels for the area. As total transitional cover of the area declined by more than half from 1939-1997, ESH species levels likely declined correspondingly.

Drivers of Land Cover Change

Throughout the periods from 1939-1970 and 1970-1997, very little land remained in transitional cover from one aerial photo to the next. Although the BRMA displayed a net loss of transitional area over both periods, transitional areas were in flux across the landscape, with gains in some areas and losses in others. These patterns demonstrate the ephemeral nature of transitional habitat, even when the forces driving habitat creation and destruction are anthropogenic and not natural disturbance regimes. From 1939-1970, the majority of new transitional gain came from land that had previously been forested, suggesting that some sort of disturbance (natural or anthropogenic) cleared those forested areas after 1939, and natural

reforestation transformed them to ESH. Over the same period, the majority of transitional loss was to forest (presumably through natural reforestation), although a significant portion also became cleared (through human action). In contrast, after the BRMA came under state management, human activities became a much weaker driver of land cover change. From 1970-1997, 3/4 of new transitional area came from cleared land, due to the progression of natural reforestation. Over that same period, only 4 ha of transitional area were lost to cleared land, while around 100 ha naturally reforested into closed-canopy forest. State ownership of the BRMA means that the major pressure threatening ESH areas is the progression of natural reforestation, instead of the pressure of human development facing most other areas in the state and region.

One management question is whether ESH areas should be greatly increased on state lands like the BRMA because these lands provide an opportunity to compensate for lost ESH in other parts of the state. There are distinct advantages to directing conservation resources towards increased ESH management on state lands instead of programs to encourage ESH creation on private lands. One advantage is that areas like the BRMA provide opportunities for the creation of large, contiguous ESH patches, which support a different suite of species than small patches like those likely to be maintained on private land. Additionally, ESH patches on state lands are not threatened by development pressures like those facing privately-owned habitat. It is unclear however, whether concentrating ESH habitat in state preserves will be as ecologically effective as scattering ESH patches across the landscape.

Reforestation Patterns and Rates – Management Implications

Recruitment density varied across study sites, and only Site C contained a sample size large enough to support definitive conclusions about rates and patterns of reforestation. Site C, where white pine was the dominant reforesting species, displays a trend increased mean seedling distance from parent stand with each passing year (Figure 14). This pattern could be taken to suggest a gradual invasion by white pine, where established seedlings and saplings along parent stand edges facilitate gradual continued intrusion towards the old field center. Site C does not display evidence of "step-wise" or "pulse" recruitment patterns, where seedlings from a single recruitment year display higher recruitment and significantly further mean distance from parent stand. Because Site C was so recently abandoned however, and sampled seedlings were so young (1-6 years old), continued monitoring will be required to definitively determine reforestation patterns.

A somewhat surprising result was that establishing further from parent stands did not appear to advantage a seedling, as seedlings that established further from parents actually displayed slightly lower growth rates. This phenomenon may be explained by the fact that my sampling sites were all in relatively early stages of reforestation, where density-dependent fitness reduction and mortality may not yet be a significant factor.

The DEM has expressed an interest in maintaining managed ESH patches in the BRMA at different stages of succession, in order to provide a diversity of ESH habitats. In the areas to be maintained as grassland, Tefft plans to perform annual mowing, as well as application of herbicides to control invasive shrubs. Although this type of active management may be necessary to prevent growth of some shrubs, my findings indicate that yearly mowing would be unnecessary to prevent reforestation by pines. Even in years where seedlings establish relatively

far from parents stands, growth rates remain low. A mean growth rate of 64 mm/year across sites suggests that mowing might be necessary every 8-9 years, allowing trees to reach heights of about a half meter.

ESH Management in Rhode Island and Beyond

The primary responsibility of the RI DEM Fish and Wildlife Division is to serve a guardian of the state's most threatened species. The Upland Habitats Conservation Plan was created in response to precipitous declines in a number of ESH-dependent species across the state and the region. The RI DEM used a biodiversity-based strategy in determining its management baseline of 20% ESH forest cover because this strategy most directly addresses concerns over declines in species of regional conservation concern. There is substantial evidence however, that ecologically viable conservation of ESH-dependent species must also take land cover history into account. I would argue that land use history is one of the "local considerations" which must be balanced with regional goals in the creation of subregional and landscape management plans.

The February-March 2006 BRMA old field restoration project created approximately 57 additional hectares of ESH in the area. Added to the 91 transitional hectares present in 1997, this additional ESH area brings total transitional cover to 148 ha, or approximately 5% of land cover (and forest cover) of the BRMA, between the 6% cover seen in 1939 and the 4% cover seen in 1970. This level, while replicating mid-twentieth century conditions for the BRMA, still falls well short of the RI DEM's stated goal of 20% of statewide forest cover in seedling-sapling stage.

In planning future ESH management of the BRMA and the rest of the state, the Rhode Island DEM must weigh and balance the goal of raising the populations of ESH species with the goal of replicating conditions of the historic landscape or historic range of variability. In the case of the BRMA, it is unclear whether 20% seedling-sapling cover and the corresponding levels of ESH-dependent species ever existed on the landscape.

This study illustrates the importance of researching the specific land cover history of areas targeted for management. Because Big River's ecology is unique, its land use and land cover history are also distinct from the environmental history of other parts of the state. Even in a state as small as Rhode Island, state-wide generalization about land use history is impossible. Land managers across the Northeast who seek to make informed ESH management decisions would be well served to research land use history on a local scale.

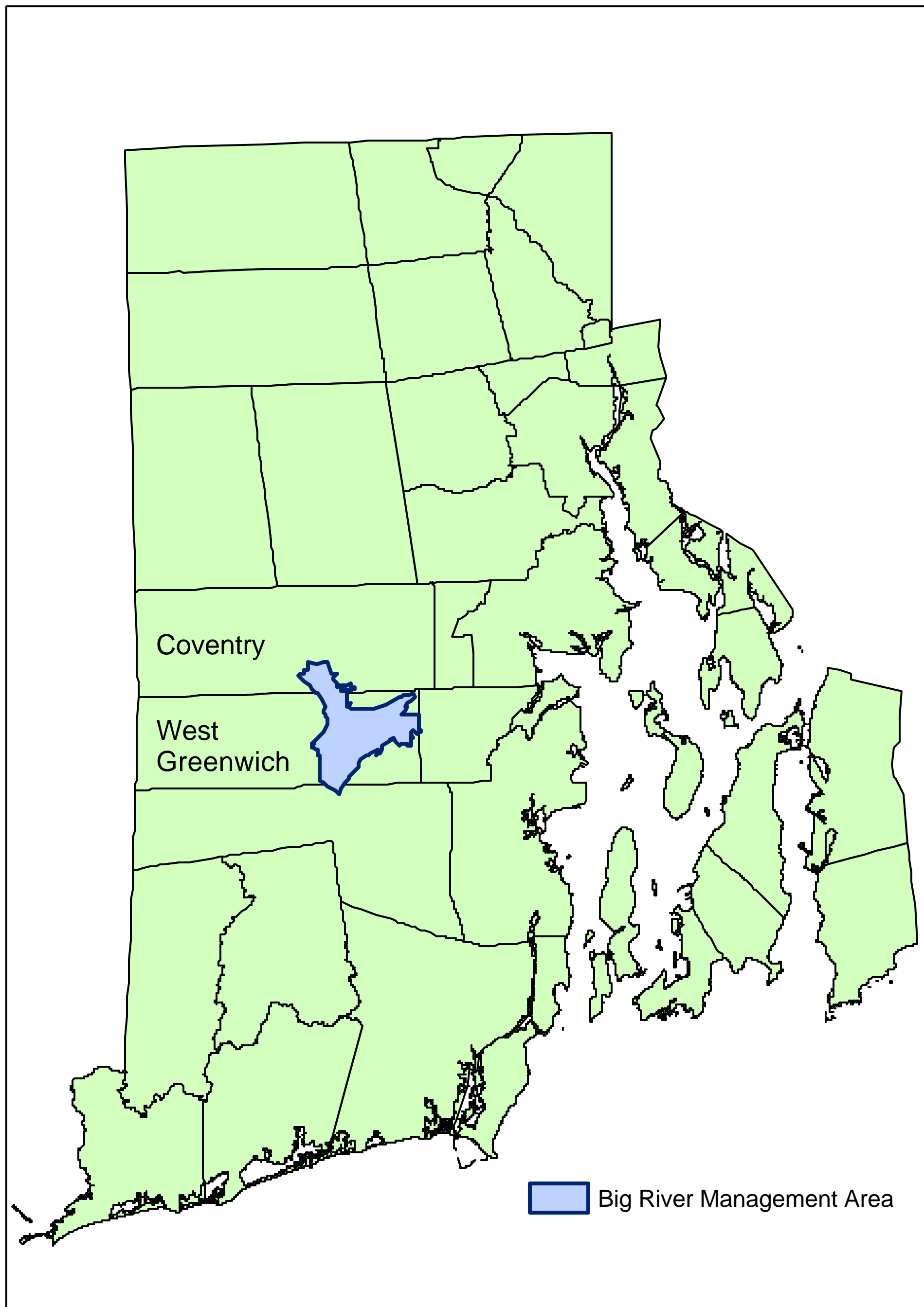

Figure 1. Location of Big River Management Area within Rhode Island

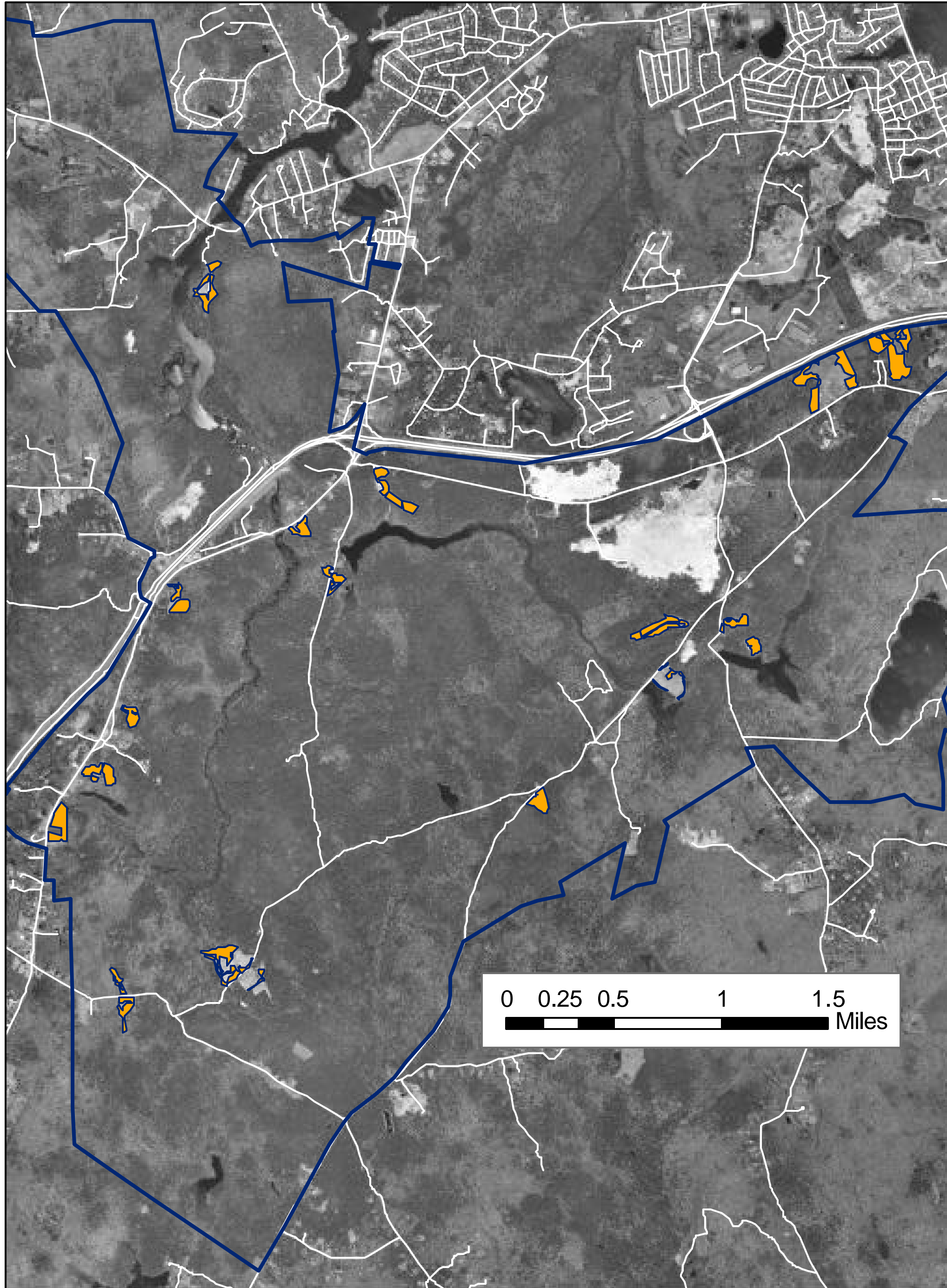

Figure 2. Nineteen areas with the Big River Management Area (Central Rhode Island) targeted for ESH management by the Rhode Island DEM

(Aerial photo courtesy of RI GIS)

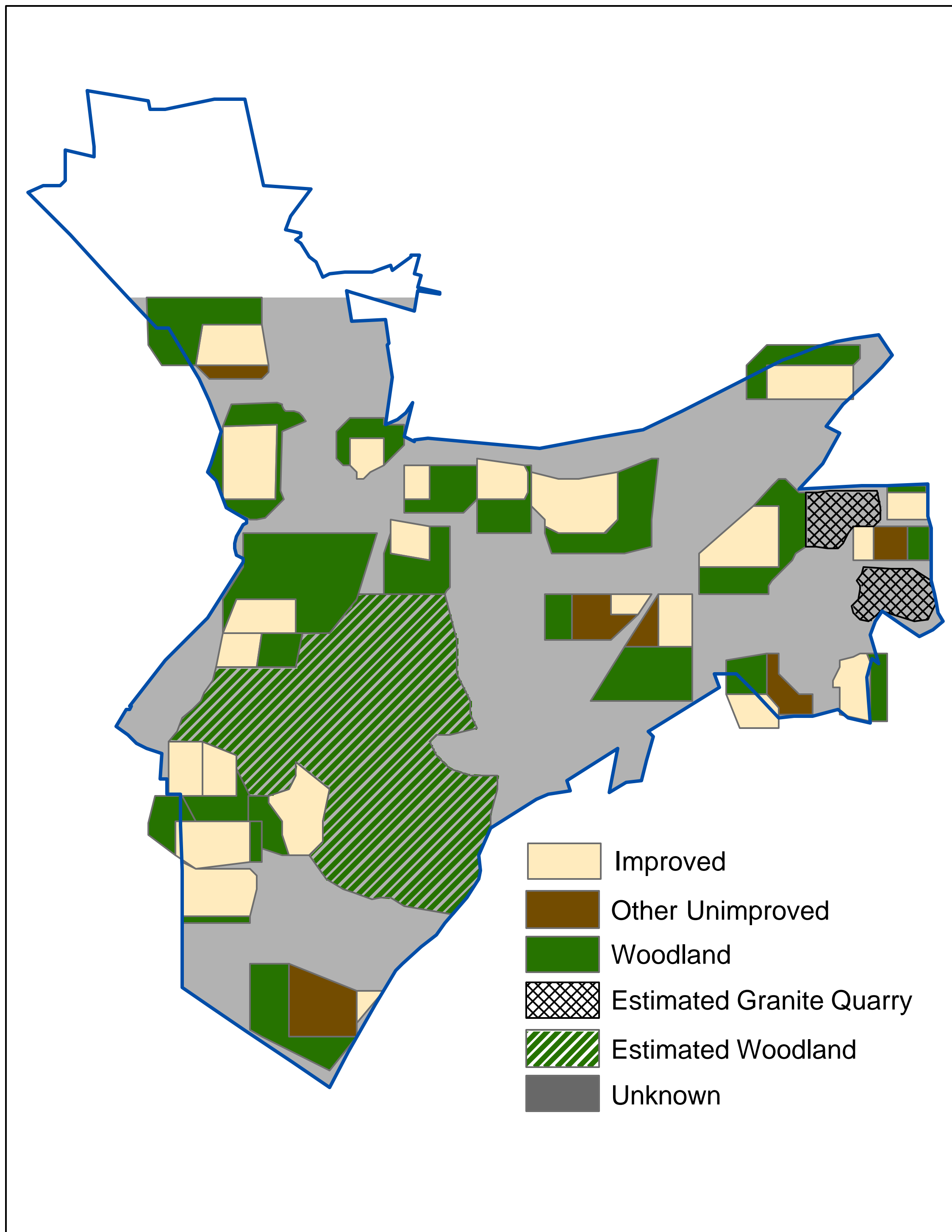

Figure 3. Land cover of the Big River Management Area, central Rhode Island (1870) (West Greenwich Portion)

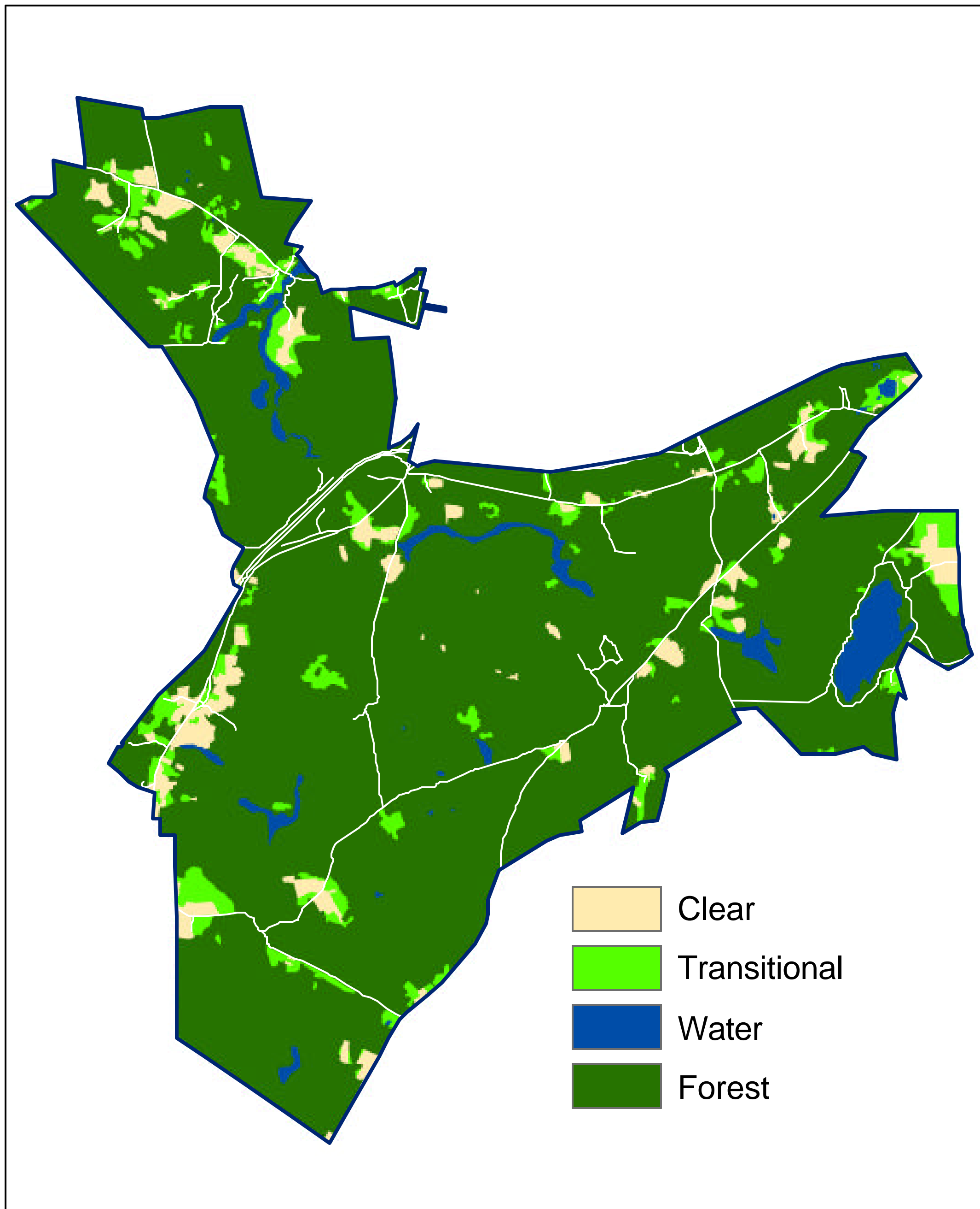

Figure 4. Land cover of the Big River Management Area, central Rhode Island (1939)

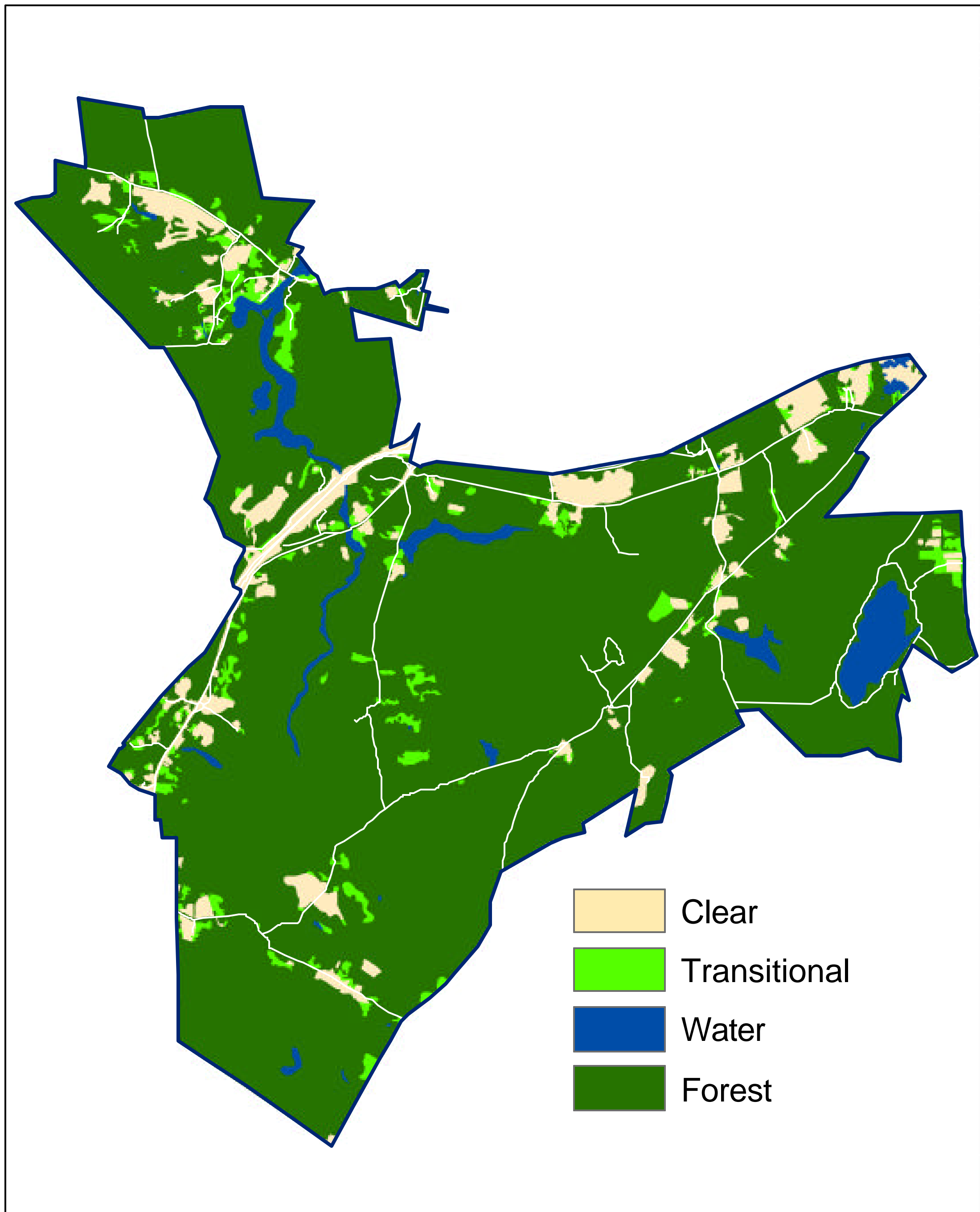

Figure 5. Land cover of the Big River Management Area, central Rhode Island (1970)

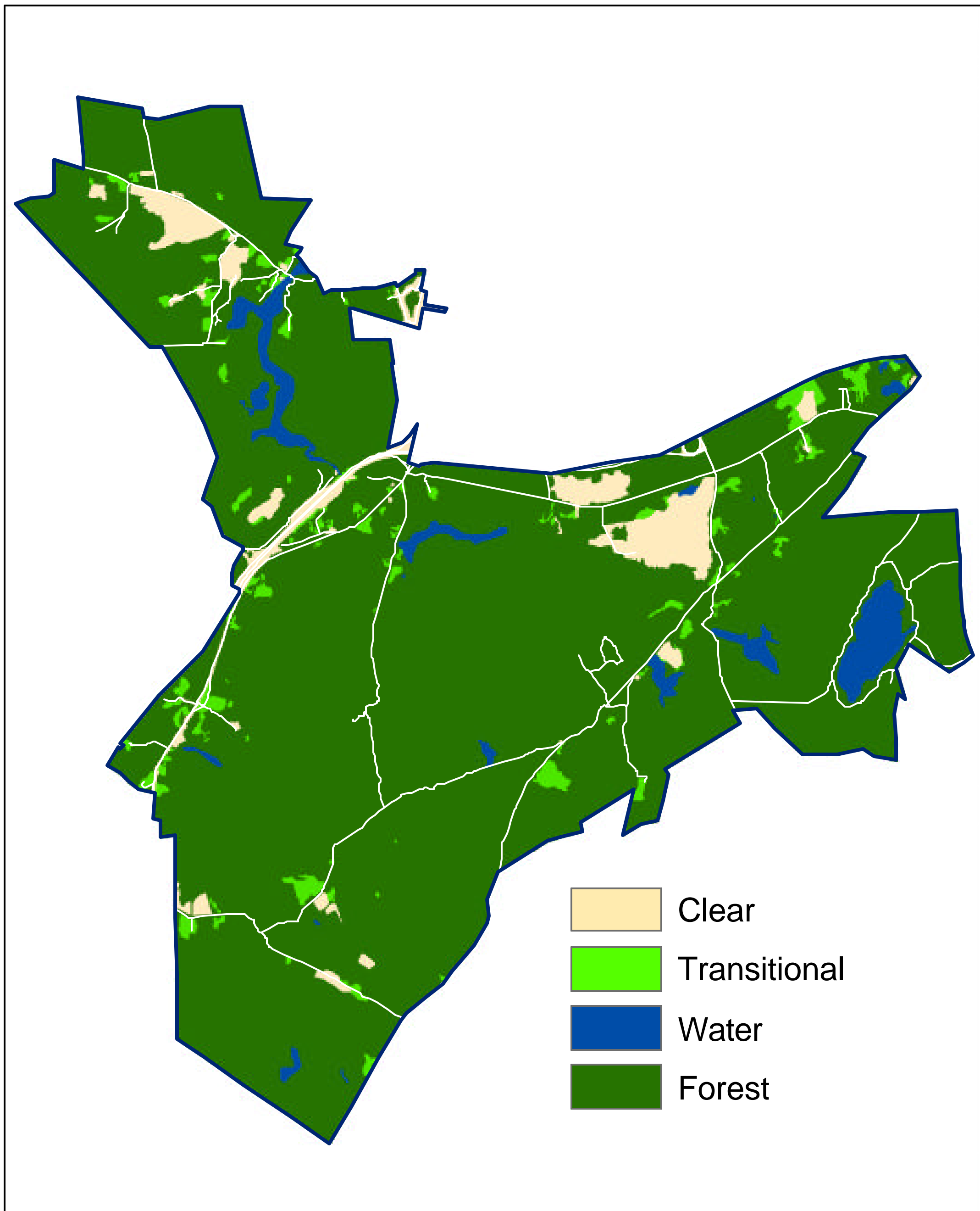

Figure 6. Land cover of the Big River Management Area, central Rhode Island (1997)

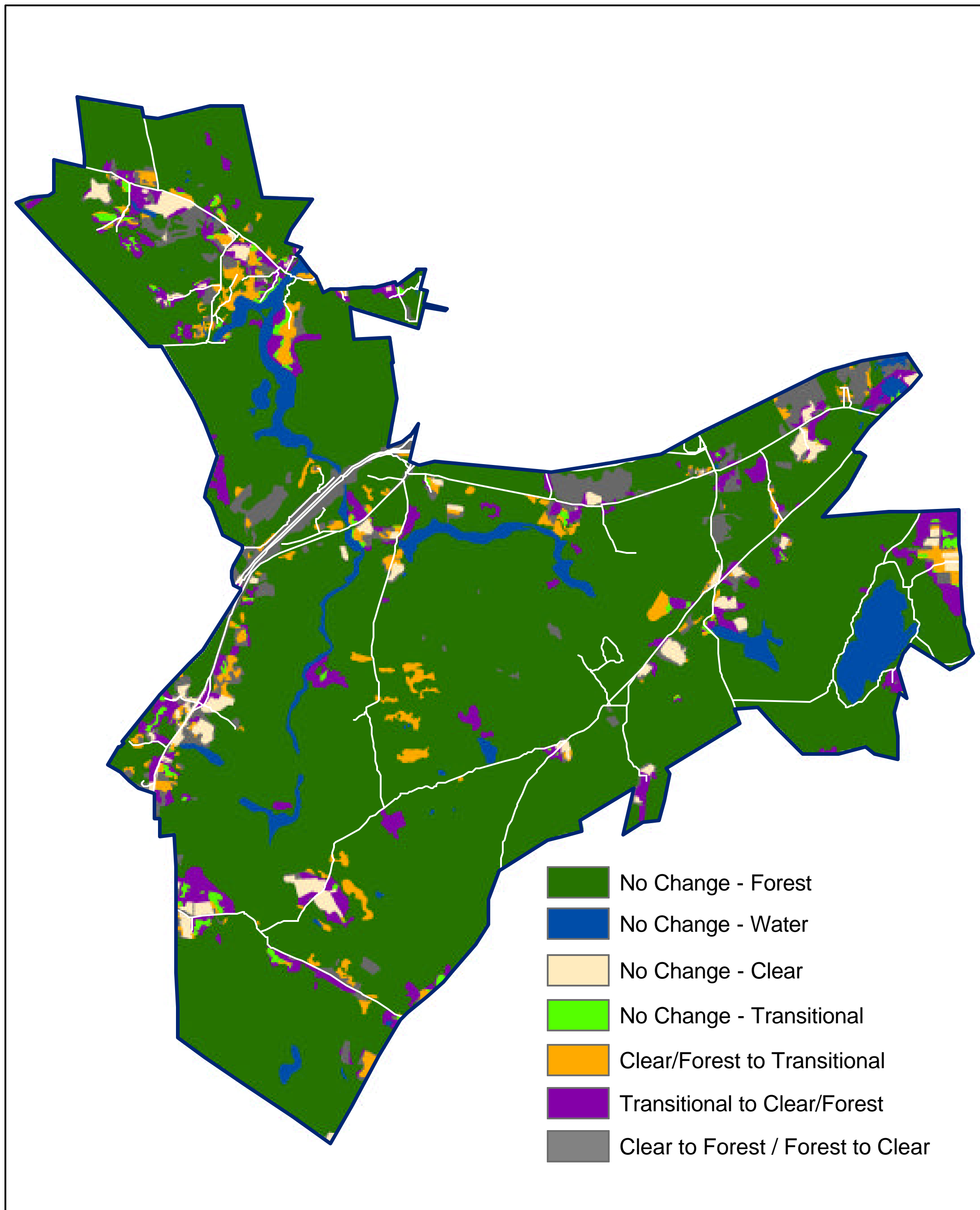

Figure 7. Land cover change of the Big River Management Area, central Rhode Island (1939-1970)

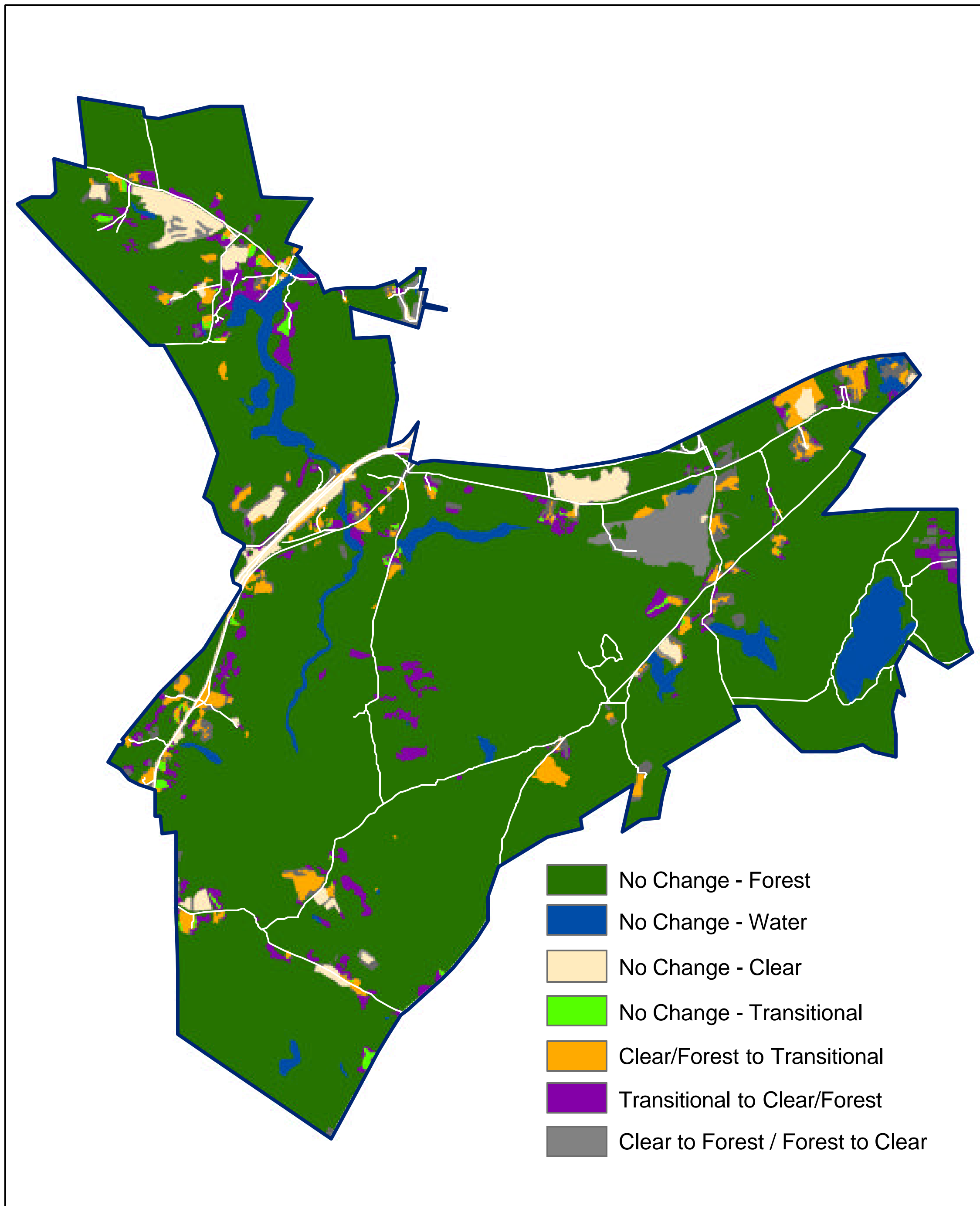

Figure 8. Land Cover Change of the Big River Management Area, central Rhode Island (1970-1997)

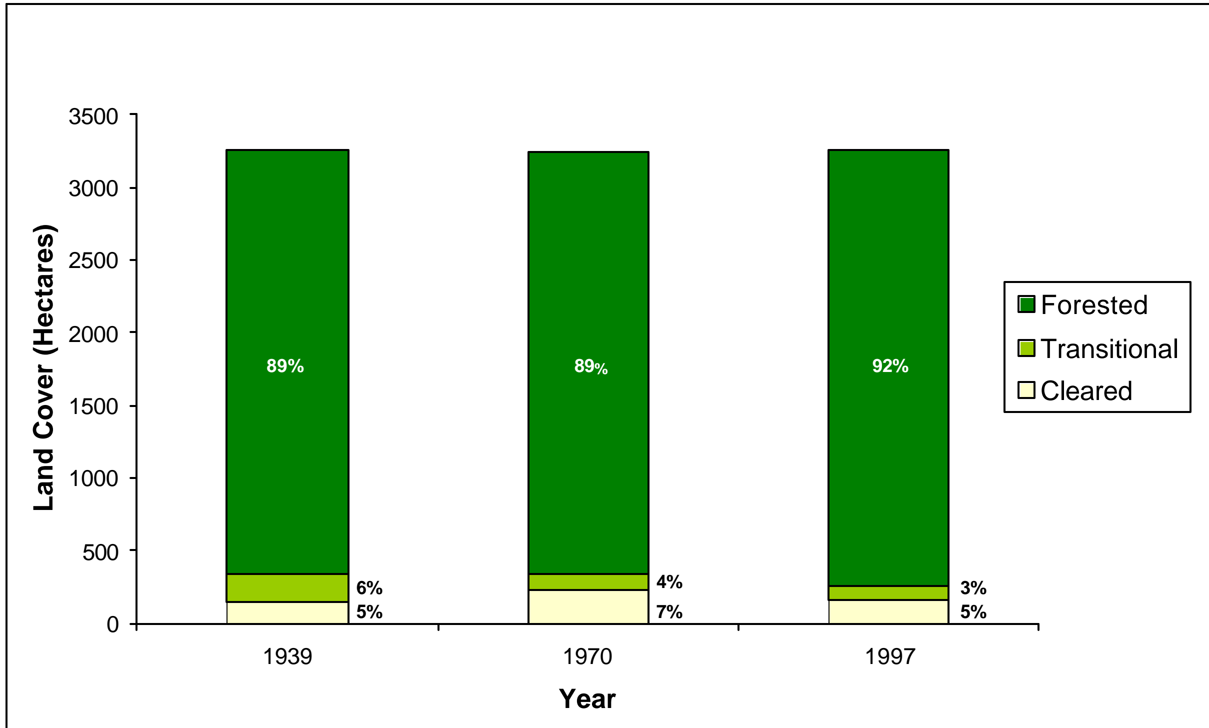

Figure 9. Land cover of Big River Management Area, central Rhode Island (1939-1997)

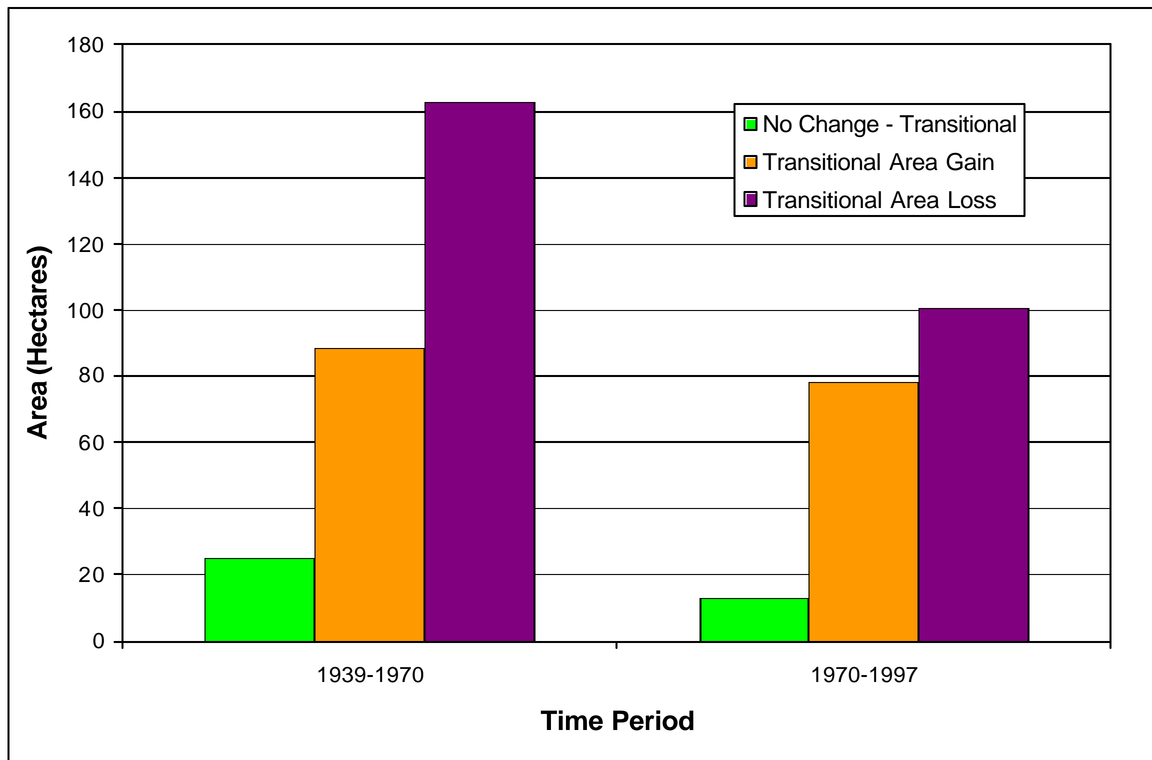

Figure 10. Transitional area land cover change in Big River Management Area, central Rhode Island (1939-1997)

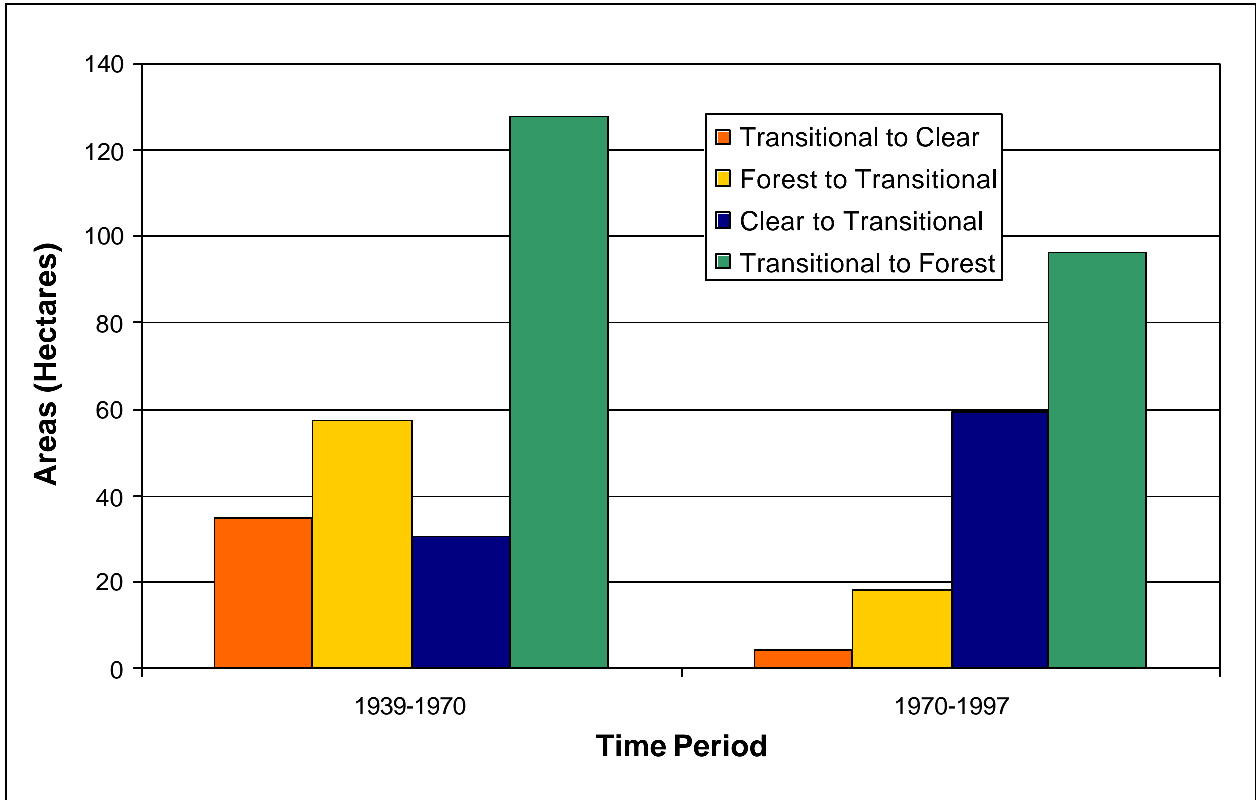

Figure 11. Land cover changes in Big River Management Area, central Rhode Island (1939-1997)

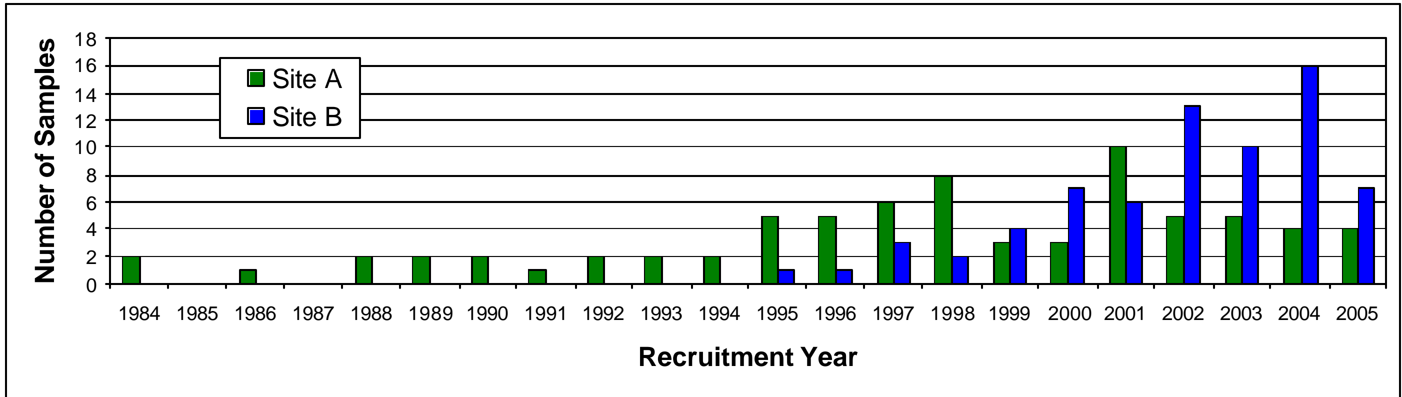

Figure 12. Age distribution of tree samples across Sites A and B

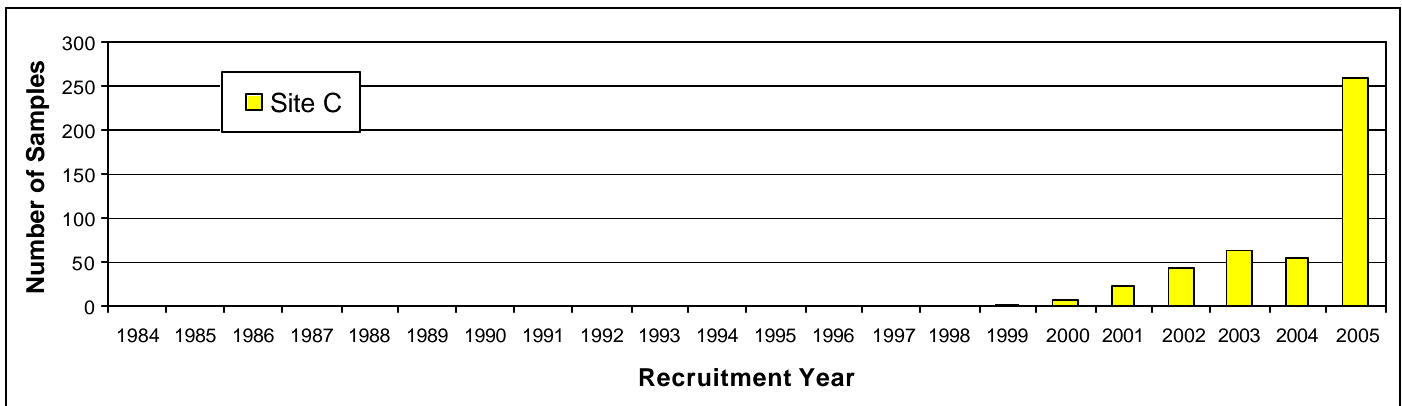

Figure 13. Age distribution of tree samples across Site C

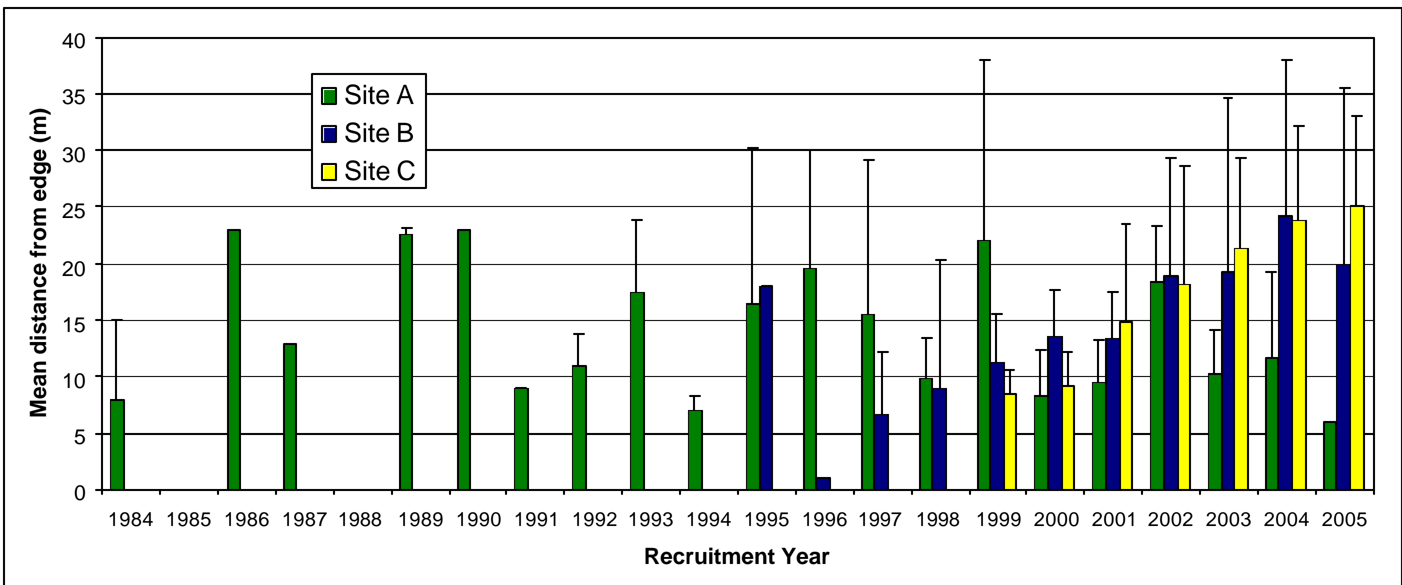

Figure 14. Mean seedling distance from parent stand by recruitment year (+1 SD)

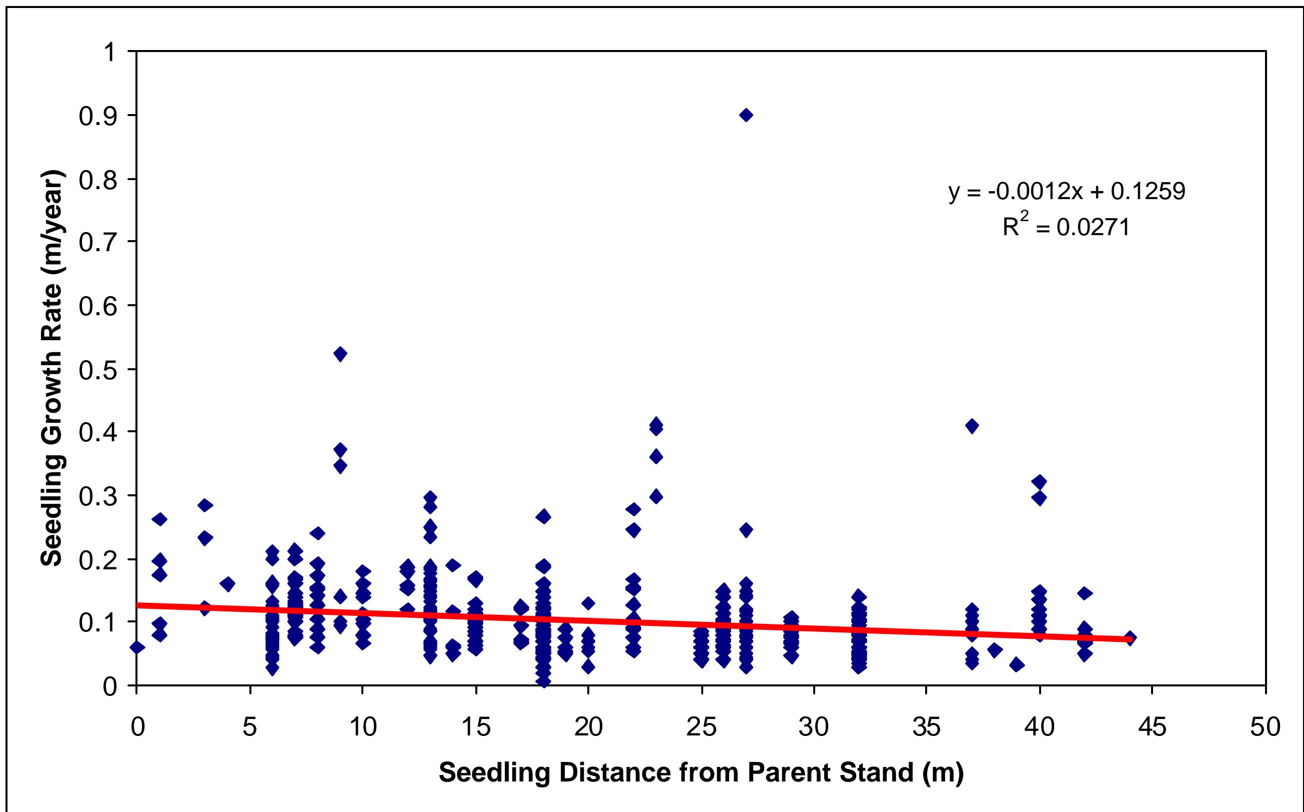

Figure 15. Seedling distance from parent stand (in meters) compared to seedling growth rate (in meters/year)

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