CHANGES OVER A SEVENTEEN-YEAR PERIOD TO

SIGNIFICANT HABITATS

In the Town of Rhinebeck, Dutchess County, New York

An addendum to the 2007 report by Reinmann and Stevens

Report to the Town of Rhinebeck

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EXECUTIVE SUMMARY

Hudsonia biologists updated the town-wide mapping of ecologically significant habitats, originally completed in 2007, to reflect both natural and human-caused changes to habitat types. To accomplish this, the most recently available aerial orthophotos (from 2021) were scrutinized and compared against the original mapping and the orthophotos (2004) used for that mapping. Key map figures and the large-scale habitat map were updated to show the near-current conditions in Rhinebeck. We also analyzed habitat changes during the study period and produced a series of maps to display salient changes. Among our major findings were that:

- Ecologically significant habitats covered 84% of the town in 2021, down from 85.5% in 2004.
- Forest (upland and swamp) covered nearly half of the town, down 313 acres since 2004.
- Developed areas increased by 10% (367 acres) and continued to show a pattern of development extending deep into large, interior forests. A total of 206 acres of forest were developed.
- Many large, contiguous blocks of interior forest persisted, but interior forest diminished by 6% (319 acres). One large forest block was dissolved and many others significantly diminished by long driveways and other clearing. One forest block substantially expanded due to forest regrowth.
- Upland shrubland, a declining and important habitat in the Northeast, declined by 15% (133 acres).
- Many large meadows remained: 29 exceeding 25 acres, including 13 of >50 acres and three of >100 acres. Three large meadows had been broken up by development, including one of 85 acres.
- Of non-tidal wetlands, 3.7% (137 acres) were lost to development (23 acres), upland habitats (26 acres), or water habitats (88 acres). It is unclear whether the many instances of filling or draining of wetlands (amounting to 49 acres) were carried out with any required permits.
- The town still harbored 138 intermittent woodland pools and 59 pool-like swamps, a newly mapped type of swamp with properties similar to those of woodland pools. Three pools, and most of a fourth, had been destroyed since 2004, and 137 acres (3.7%) of forest within 750-foot-radius pool conservation zones had been razed.
- Eight kettle shrub pools and 13 buttonbush pools remained. Nearly a quarter of one kettle shrub pool had been either cleared and filled or impounded since 2004, and two buttonbush pools had been flooded to open water, likely by beavers.

- Two percent (511 acres) of the town experienced ecological succession, the tendency of habitats to develop into a new habitat. This includes 245 acres of shrubland to forest and 150 acres of meadow to shrubland.

- Conifer-dominated forests declined dramatically, likely owing in large part to eastern hemlock dieback caused by an invasive insect, the hemlock woolly adelgid.

This habitat map and report, in combination with the original report (Reinmann and Stevens 2007), can help the Town of Rhinebeck identify the areas of greatest ecological significance, develop conservation goals, examine development trends, and establish conservation policies and practices that will help to protect biodiversity resources while serving other needs of the human community. The comparative analysis of habitat changes through time can be used to highlight patterns of development that leave intact priority habitats and ecologically sensitive areas and maintain habitat connectivity; and to avoid the kinds of development and other land use practices that break up habitat complexes and sever habitat connections critical to native plants, wildlife, and ecosystems.

INTRODUCTION

Seventeen years have elapsed since the publication of *Significant Habitats in the Town of Rhinebeck, Dutchess County, NY* by Hudsonia (Reinmann and Stevens 2007). At the request of the Town of Rhinebeck, we revised the town-wide habitat map to reflect changes since 2004 (the year of the most recent aerial orthophotos available in 2007).

Hudsonia originally created a town-wide map of ecologically significant habitats through map analysis, aerial photograph interpretation, and field observations. The original report (Reinmann and Stevens 2007) that accompanied the town-wide map was intended to inform landowners about the habitats on their properties and how they were connected to the greater ecological landscape. Additionally, the report aimed to inspire residents and town officials to approach land development and land management with an eye to the protection of ecosystems and biodiversity. Conservation planning, local legislation, thorough environmental reviews, and thoughtful land management can go a long way to maintaining the natural features of importance to the people of Rhinebeck.

This 2024 report presents results of the habitat map update and discusses possible causes of those changes. Very little ecological information and few conservation recommendations are presented here; therefore we encourage readers to refer frequently to the original report, which is rich in ecological detail, information about species of conservation concern, priority habitats, and threats to biodiversity, and recommendations for best conservation practices.

METHODS

Map updates

We reviewed the 2007 town-wide habitat mapping (which was based largely on 2004 aerial orthophotos) against 2021 orthophotos, obtained from the NYS GIS Clearinghouse, looking for natural and anthropogenic changes to ecologically significant habitats and the previously mapped developed areas. Orthophotos from 2021, while already three years out-of-date, were the most recent high-resolution photographs available at the time of this re-mapping. Online aerial imagery from Google and similar sources, even if more recent, is unsuitable for this purpose because 1) the images are obtained during leaf-on seasons, so conditions beneath the tree canopy are obscured, and 2) the satellite images have inadequate resolution (compared to the orthophoto images obtained from cameras mounted on low-altitude aircraft).

As we reviewed, we simply changed the map to reflect (near-) current conditions. The method we used for making updates allowed us to tally the total extent (in acres) across the town of each type of habitat change or transition: e.g., upland meadow→upland shrubland; upland hardwood forest→developed; marsh→constructed pond.

Map corrections

During the process, we also discovered substantial areas in which the 2007 mapping did not reflect aerial orthophotos of the time or did not conform to our present-day conventions, many of which we had not yet developed in 2007. We made corrections to these areas accordingly, and also to reflect better source data that were unavailable 17 years ago and have made more accurate mapping possible. We did not tally specific changes, though the total acreage of a given habitat or habitat class (e.g., all wetlands) can be compared between the original 2007 mapping and the corrected 2007 mapping. Our analysis of habitat changes over time uses these corrected habitats as a basis for comparison with the updated (2023) habitats. See Figure 1 for a visual representation of these relationships.

Figure 1. Schematic representation of original, corrected, and updated habitats. Analysis in this report is of updated

We made several main types of map corrections as we updated the map:

1. **Wetlands**. We were able to identify and map many additional wetland acres, expand the mapping of some wetlands, and improve the accuracy of some of the previously mapped wetland boundaries.

2. **Upland conifer and upland mixed forests**. Some areas had been mapped as conifer or mixed forest based primarily on the presence of conifers in the *understory*. It is now Hudsonia's convention to only consider *canopy* (or subcanopy) conifers in the mapping of conifer and mixed forests, but this convention had not yet been established in 2007. Thus, for example, we remapped forests with a hemlock understory but few canopy hemlocks as upland hardwood forest.

3. **Shrubland versus forest**. It is sometimes difficult to distinguish shrubland from young forest in the orthophotos and possible to overlook altogether small areas of shrublands surrounded by forest. Also, many densely shrubby areas have scattered trees at varying densities, creating ambiguity of habitat type. Upland shrublands were under-mapped in the original mapping: we reclassified some forest as shrubland in the corrected mapping.

4. **Intermittent woodland pools and pool-like swamps**. Intermittent pools not drawn during the original mapping were discovered, mostly facilitated by additional, and newer, sets of aerial orthophotos. Conversely, some of the originally mapped pools do not qualify as such under our current conventions: for example, pools within much larger hardwood swamps, pools connected to water bodies or other wetlands, and those that appear to hold year-round standing water, even if small.

Some large (and smaller) hardwood swamps *do* qualify as *pool-like-swamps*, a habitat characterization adopted by Hudsonia after 2007. Pool-like swamps have hydrological and ecological properties similar to those of intermittent woodland pools. We indicate pool-like swamps with a star symbol overlaid on a swamp polygon.

5. **Cultural**. We remapped as "developed" some areas that were originally mapped as "cultural," namely smaller lawns around or between buildings that are not large enough to be considered significant habitats under our current conventions.

6. **Tidal habitats**. It is unclear which data source was used to map tidal habitats in 2007. The originally mapped habitats match neither 2004 aerial orthophotos nor the 2007 Hudson River Estuary tidal wetland mapping by the Hudson River National Estuarine Research Reserve (HRNERR) and Cornell Institute for Resource Information Sciences (IRIS) We corrected the 2007 habitats to be based on the 2007 HRNERR and IRIS mapping, along with Hudsonia's field work and remote data interpretation for the 2007 project. We also corrected the original mapping of estuarine rocky shore, which is not covered by the HRNERR and IRIS mapping.

Habitat conventions and boundaries

To maintain consistency within and among habitat mapping projects, we have developed over the years certain mapping conventions that we use to classify habitats and delineate their boundaries. For ease of use, our habitat types are generalized, and therefore do not correspond directly with the habitat types or communities of other systems, such as the "ecological communities" of the New York Natural Heritage Program (NYNHP). For example, where we map upland hardwood forest, NYNHP would map one of approximately 20 different hardwood forest types (e.g., Appalachian oak-hickory forest, successional southern hardwoods), defined by community composition as well as geographic and soil factors. Some of our mapping conventions are described in Appendix A of the original report (Reinmann and Stevens 2007).

It is important to keep in mind that in reality, habitat "boundaries" are usually not discrete lines, but a gradation of physical and biological characteristics between two adjacent habitats. Also, although large amounts of field work were conducted for the 2007 mapping project, much of the town was only mapped remotely, and no new field work was conducted for this update project. Even those habitat boundaries that were field-checked in 2007 were sketched without use of GPS or other land survey equipment. Thus, all of our mapped habitat boundaries should be considered approximations only.

RESULTS

We made a few minor corrections to the habitat types found in the original mapping and then used this set of types in the 2023 habitat map as well. First, we renamed *oak-heath barren* as *rocky barren* in order to encompass a broader array of barrens. We also added crest/ledge/talus as a *non-overlay* habitat category to accommodate a single occurrence of mostly unvegetated ledge below a dam on the Landsman Kill (as opposed to the overlay crest/ledge/talus, which mostly applies to forested rocky habitats). In the tidal zone, we mapped *tidal mudflats*, which had been subsumed under (tidal) open water in the 2007 map, based on the 2018 HRNERR mapping.

We identified 35 types of ecologically significant habitats used in the 2023 map: 13 upland habitat types, 14 non-tidal wetland types, and 8 Hudson River types (tidal and supratidal habitats) (Table 1). We also classified certain swamps as *pool-like swamps* (depicted as points on the habitat map), which did not appear in the original 2007 map.

Upland habitats	Wetland habitats	Hudson River habitats
Calcareous crest/ledge/talus	Buttonbush pool	Estuarine rocky shore
Clay bluff and ravine	Calcareous wet meadow	Freshwater tidal marsh
Crest/ledge/talus	Conifer swamp	Freshwater tidal swamp
Cultural	Constructed pond	Hudson River rocky island
Orchard/plantation	Hardwood & shrub swamp	Supratidal railroad causeway
Red cedar woodland	Intermittent woodland pool	Tidal mudflat
Rocky barren	Kettle shrub pool	Tidal open water
Upland conifer forest	Marsh	Tidal tributary mouth
Upland hardwood forest	Mixed forest swamp	
Upland meadow	Open water	
Upland mixed forest	Spring/seep	
Upland shrubland	Stream	
Waste ground	Wet clay meadow	
	Wet meadow	

Table 1. Ecologically significant habitat types of Rhinebeck.

Overview

The large-format Town of Rhinebeck habitat map illustrates the diversity of habitats that occurs in the town and the complexity of their configuration in the landscape. A reduction of the completed habitat map is shown in Figure 2. Of the town area of 25,321 acres (ac), we mapped 84.2% (21,323 ac) as significant habitats, a decrease from the corrected 2004 value of 85.6% of the town (21,690 ac). An additional 1.4% or 367 acres (ac) of the town were converted from significant habitats to developed uses. In 2004, existing development was dispersed across the town along roads and sometimes lengthy driveways, so that undeveloped land had been fragmented into discontinuous and irregularly shaped patches. This pattern of development, often far from existing roads and deep in forests and other habitats, proceeded between 2004 and 2021. Figure 3 shows blocks of contiguous undeveloped habitat within the town, as of 2021, that are <200, 200-500, 500-1,000, and >1,000 ac.

We discuss causes of changes to individual habitat types in the following account of our findings, but save broader analyses of trends and processes that cover multiple habitat types for the *Discussion* section, below.

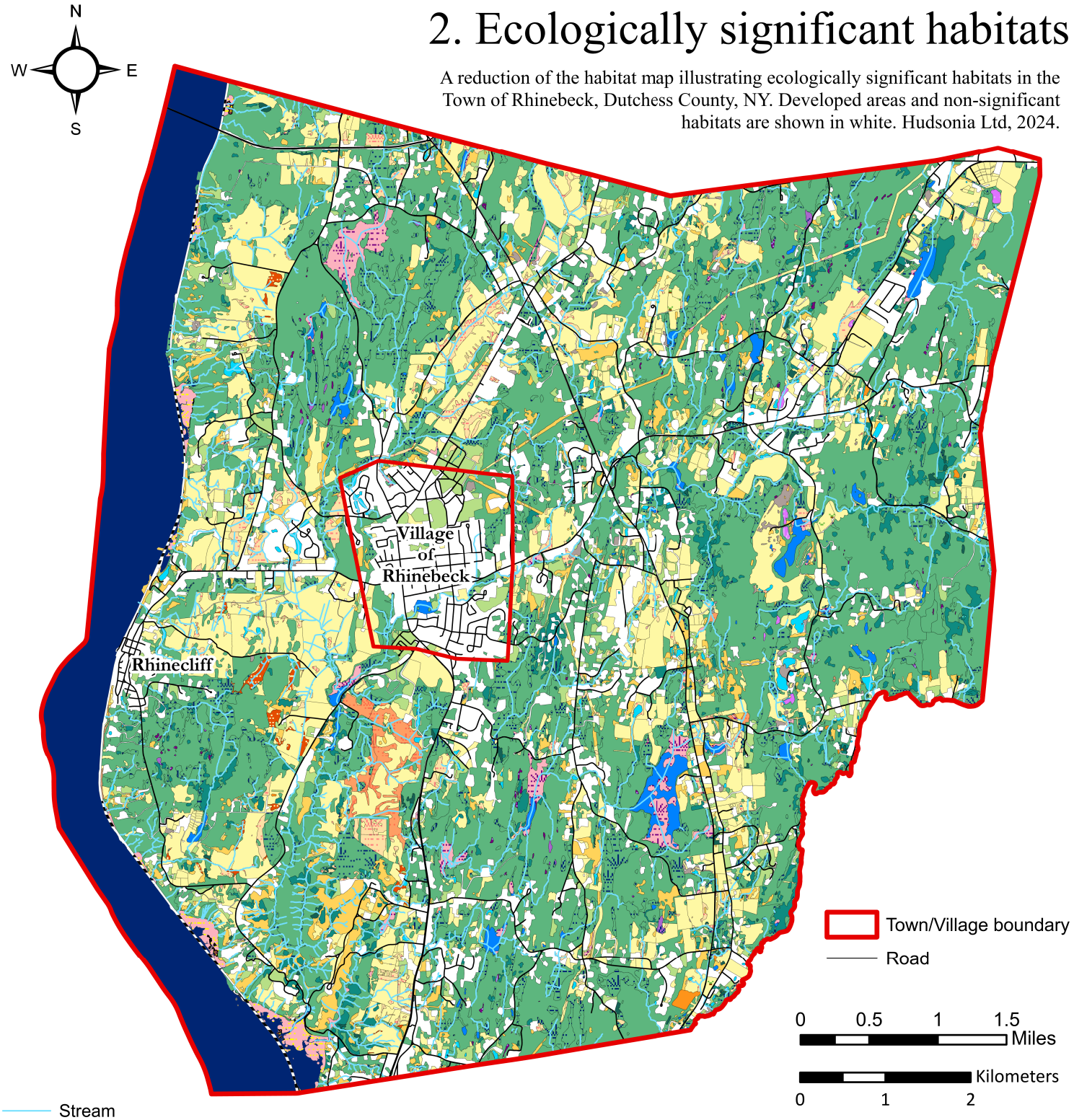
Upland habitats

UPLAND FOREST

Upland forests, including upland hardwood, mixed, and conifer forests, covered around 38% of the town in both 2004 and 2021 but experienced a net loss of 150 ac (1.5%) (Figures 4 and 5).

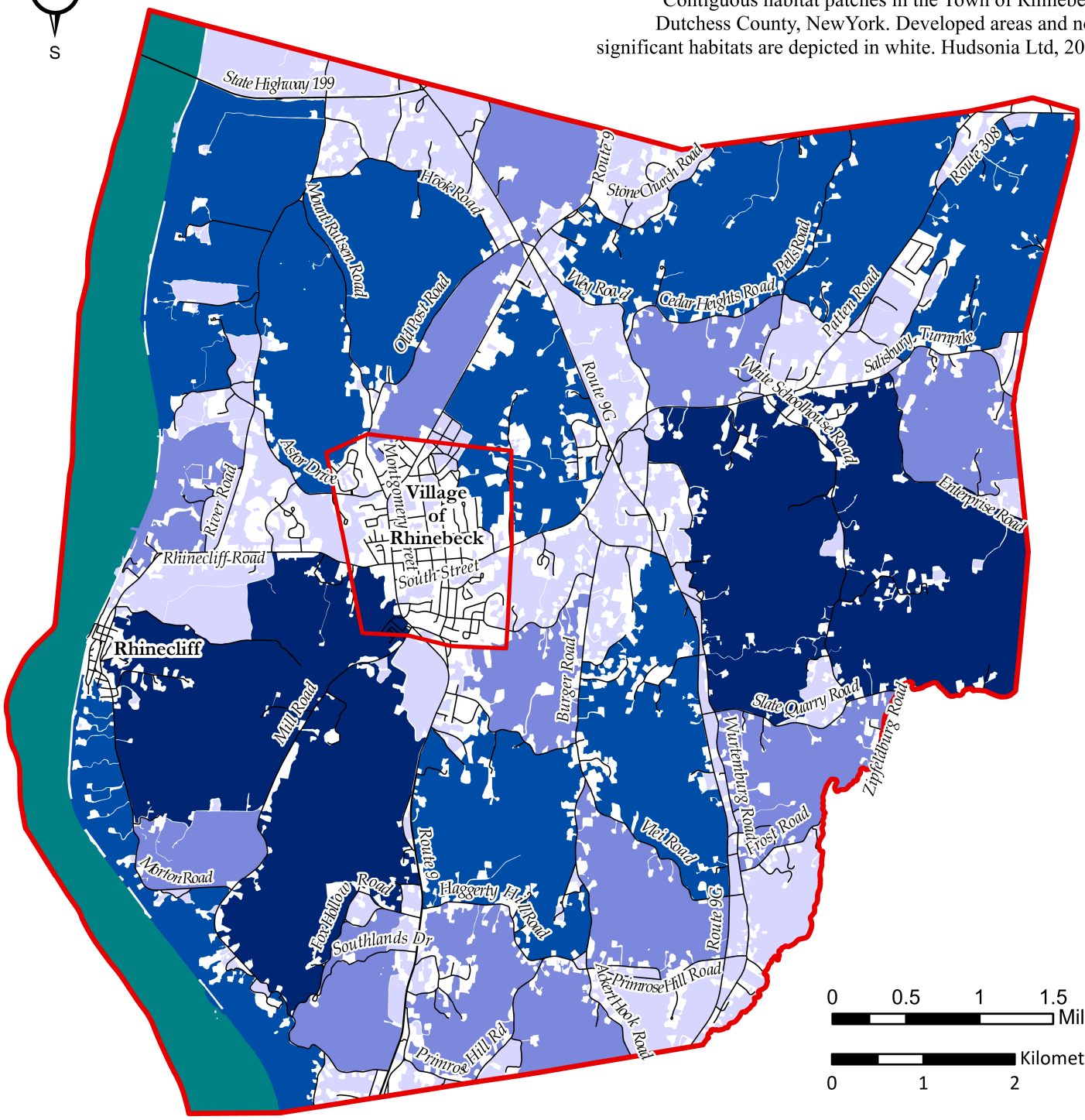
2. Ecologically significant habitats

A reduction of the habitat map illustrating ecologically significant habitats in the Town of Rhinebeck, Dutchess County, NY. Developed areas and non-significant habitats are shown in white. Hudsonia Ltd, 2024.



3. Contiguous habitat

Contiguous habitat patches in the Town of Rhinebeck, Dutchess County, NewYork. Developed areas and non-significant habitats are depicted in white. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Contiguous habitat patch (acres)

< 200

200 - 500

500 - 1000

> 1000

Roughly 456 ac were lost to development and clearing to open habitats, while 268 ac of new forest grew from shrubland and other open habitats. The quality of the gained forest is not known, but all of it is very young, with small trees, and likely has an abundance of invasive plant species, which typically thrive in young, post-agricultural forests. Thus, although 268 ac of new forest replaces some of the *acreage* of the lost forest, it does not replace the ecological function or native biodiversity values of a mature, native-dominated forest.

Upland hardwood forest was the most extensive habitat in Rhinebeck, at 8,971 ac in 2021, representing a 5% (441-ac) net increase from the 2004 coverage of 8,530 ac. While upland hardwood forest was lost to development (172 ac), upland meadow (169 ac) via clearing, and other habitats, more upland hardwood forest was gained by transition from upland mixed forest (540 ac), upland shrubland (227), and other habitats. Upland mixed forest and upland conifer forest both experienced large net losses, of 48% (476 ac) and 66% (114 ac), respectively, leading to the net loss of upland forests. Most of the lost conifer forest became mixed forest, hardwood forest, or shrubland, while most of the lost mixed forest became hardwood forest.

RED CEDAR WOODLAND

The extent of red cedar woodland diminished drastically over the study period, from 48 ac to 16 ac: a 67% reduction. Most became upland mixed forest (11 ac), upland shrubland (10 ac), or upland hardwood forest (6 ac) as the natural process of succession played out, with over-mature cedars dying back and hardwoods or shrubs filling in the meadow-like space between them. Less commonly, more red cedars filled in the gaps, producing upland conifer forest (4 ac).

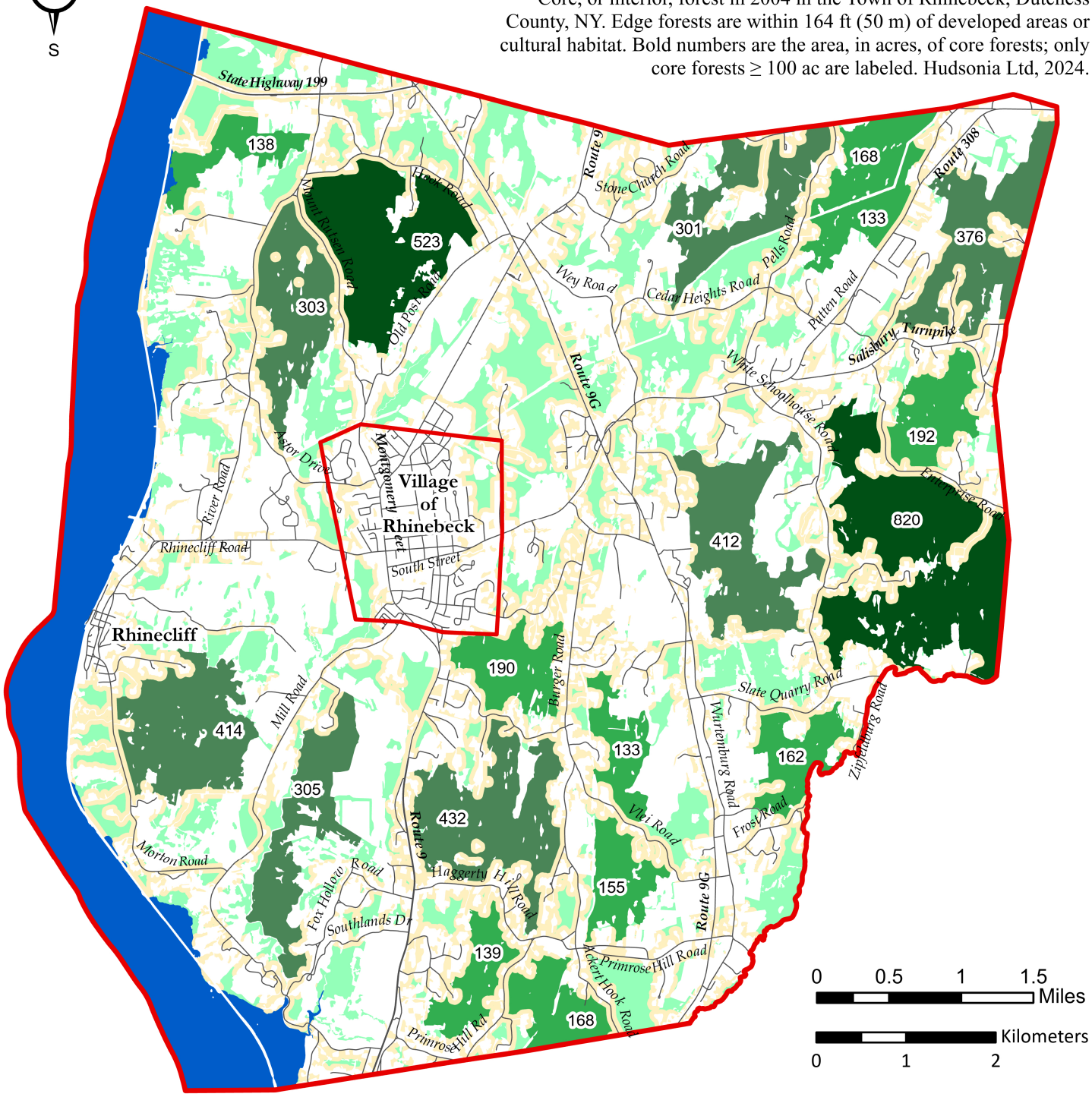
Very little new red cedar woodland was recruited: <1 ac from upland meadow and shrubland. Eastern red cedars are one of our shortest-lived native trees, and a common successional pathway for abandoned agricultural lands is for red cedars to pioneer in "oldfields," grow to maturity in a savanna-like habitat (red cedar woodland), and after a couple decades become shaded out or otherwise outcompeted by other tree species (usually hardwoods). The dearth of new red cedar woodland development is probably indicative of a relative balance between agricultural abandonment and new residential development, wherein many areas freed of agricultural activity are quickly filled by new houses, lawns, and driveways.

CREST/LEDGE/TALUS

Because we did no field work for the 2023 map update, we mapped no new crest, ledge, and talus (CLT) habitat. We did remove some rocky habitat in locations where CLT identified in 2007 has since been developed. Thus, we mapped 3,373 ac of CLT in 2023, a slight reduction (1.5%) from the 3,425 ac mapped in 2007. However, it is worth noting here that, except for the

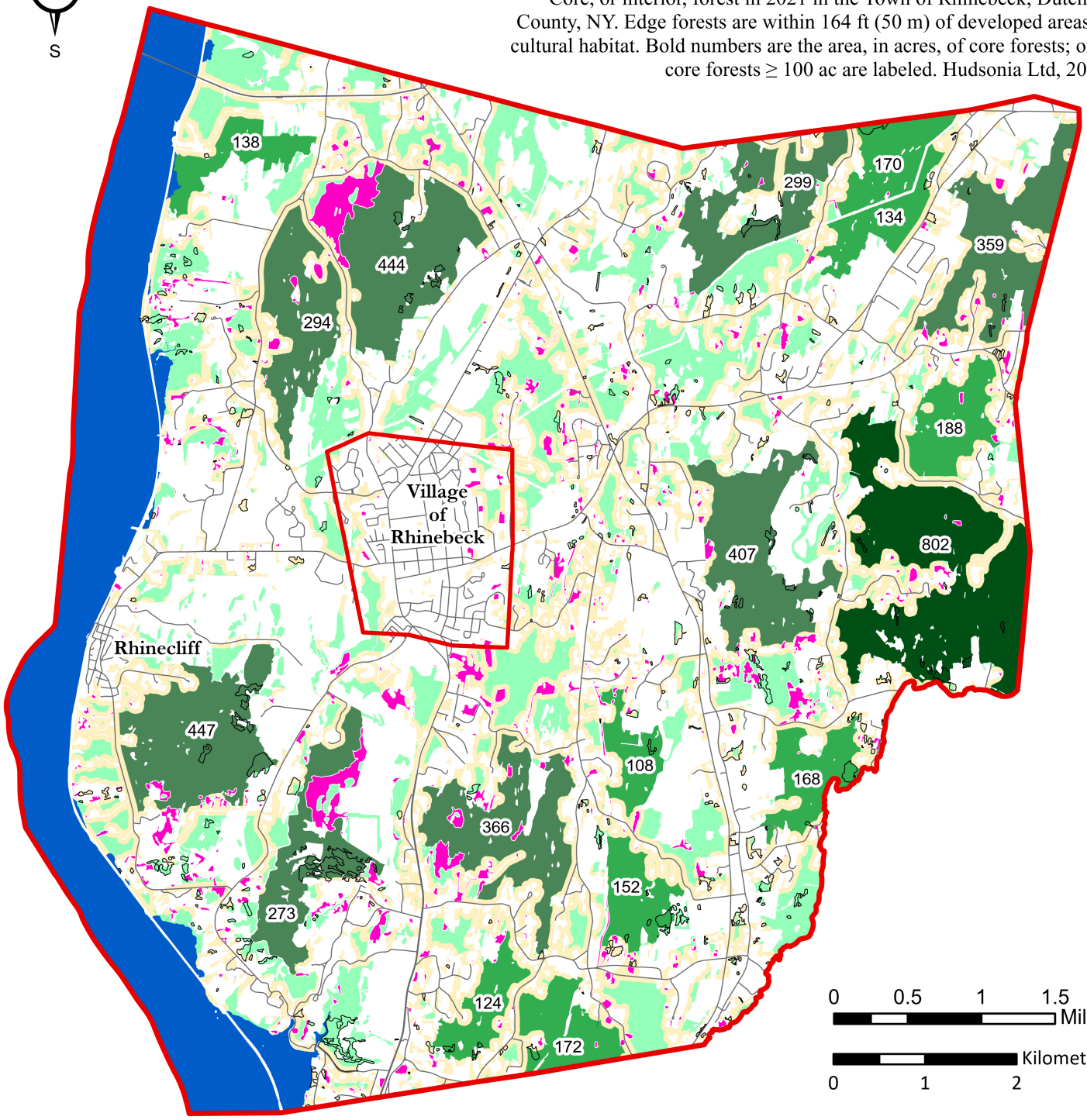
4. Core forest blocks, 2004

Core, or interior, forest in 2004 in the Town of Rhinebeck, Dutchess County, NY. Edge forests are within 164 ft (50 m) of developed areas or cultural habitat. Bold numbers are the area, in acres, of core forests; only core forests ≥ 100 ac are labeled. Hudsonia Ltd, 2024.



5. Core forest blocks, 2021

Core, or interior, forest in 2021 in the Town of Rhinebeck, Dutchess County, NY. Edge forests are within 164 ft (50 m) of developed areas or cultural habitat. Bold numbers are the area, in acres, of core forests; only core forests ≥ 100 ac are labeled. Hudsonia Ltd, 2024.



Town/Village boundary
Road
Hudson River

New forest
Forest loss
Edge forest

Core forest (acres)

< 100
100 - 250
250 - 500
> 500 ac

most exposed ledges, these habitats have no distinct signatures on aerial photographs and were therefore mapped based on a combination of inference based on topographic signature and (2007) field observations. The final overlay of CLT habitats is therefore an approximation. We expect that there are additional bedrock exposures and talus outside the mapped areas, and some areas mapped as CLT are likely not, in fact, rocky.

ROCKY BARREN

Like oak-heath barrens, rocky barrens are exposed, dry areas of sparsely vegetated bedrock. Their vegetation may be dominated by a combination of scrub oak, heath shrubs, and pitch pine (an oak-heath barren), or by herbaceous plants such as Pennsylvania sedge, poverty-grass, common hairgrass, little bluestem, and bracken fern. Alternatively, some rocky barrens have little more than abundant lichens and mosses.

Four rocky barrens were mapped, one of which was labeled as an oak-heath barren in the 2007 map. The other three were added during map correction: one small barren in a utility corridor, and two barrens that consisted of long stretches of sparsely vegetated cliff above the riverside railroad.

CLAY BLUFF AND RAVINE

Because it is mapped as an overlay representing the general extent of this habitat, clay bluff and ravine is not expected to have changed and was therefore not updated.

UPLAND SHRUBLAND

Upland shrubland diminished by 133 ac, or 15%, from 870 ac in 2004 to 737 ac in 2021. In both years, it covered a relatively small proportion of the town, at 3.4% (2004) and 3% (2021). Most of the lost shrubland became either upland hardwood forest (227 ac), through succession, or upland meadow (91 ac), presumably via clearing or brush-hogging by people. Lesser acreages were developed (28 ac) or became upland mixed forest (17 ac) or a variety of other habitats. At the same time, 150 ac of upland meadow grew up into shrubland, and 10-25 ac each of upland hardwood forest and several other habitats also became shrubland. Shrublands, the preferred habitat of several animal species of conservation concern, are a declining habitat in the Northeast as they grow into forest or are converted to developed uses much faster than they are replaced by new shrublands.

UPLAND MEADOW

Upland meadow extent remained fairly stable, with a 2% (77-ac) net increase, from 3,759 ac in 2004 to 3,836 ac in 2021. Three percent (128 ac) of existing upland meadow was developed and 1% (50 ac) converted to cultural habitats (i.e., large mowed lawns), while 4% (150 ac) grew up into upland shrubland. Only 0.8% (29 ac) made it all the way to forest. Another 0.7% (28 ac) was impounded or became one of several other upland habitats.

Conversely, large areas of upland meadow were gained via forest clearing or dieback (185 ac), shrubland clearing (91 ac), and regrowth from cultural areas (76 ac) (but see discussion under *Cultural*) and waste ground (43 ac). Other notable changes included reversion from developed uses (24 ac) and clearing, draining, and/or filling of several types of wetlands, mostly hardwood swamp, to become upland meadow (14 ac). Figure 6 depicts the locations of all meadows (both upland and wet meadows) in Rhinebeck in 2021.

ORCHARD/PLANTATION

Orchards and tree plantations were a minor land use and habitat type in town throughout the study period and saw a net decrease of 46%, from 79 to 42 ac. Most of the loss came as old orchards and plantations were abandoned, becoming shrubland (16 ac), or cleared, becoming upland meadow (28 ac). Across the entire town, 12 ac of new orchard/plantation were created, nearly all from upland meadow.

CULTURAL

The “cultural” habitat type includes areas that are significantly altered and intensively managed (e.g., mowed), but are not otherwise developed with pavement or structures; for example, golf courses, playing fields, riding rings, cemeteries, and large lawns. From a habitat perspective, these are qualitatively different from the areas that we map as “developed,” which often have pavement and/or buildings. The area in cultural habitat—mostly large, mowed and fertilized lawns—remained steady, experiencing only a 2.5% decrease, from 732 ac in 2004 to 714 ac in 2021. Seventy-six ac, or 10% of 2004’s cultural areas, were allowed to become upland meadow, while 32 ac, or 4%, were developed, and smaller areas became other habitats. New cultural areas, including 50 ac from upland meadow, 22 ac from upland hardwood forest, and 12 ac from upland shrubland, did not quite compensate for those subtractions.

However, when cultural areas that were developed are removed from the equation, more new cultural areas (14 ac) were created than were allowed to grow into other habitat types. Furthermore, the “lost” cultural areas, most of which became upland meadows, do not

6. Meadows

Contiguous meadow patches (including upland meadows, wet meadows, wet clay meadows, and calcareous wet meadows) in the Town of Rhinebeck, Dutchess County, NY. (A) Contiguous meadow patches without consideration of hedgerows and fences; (B) contiguous meadow patches shown with hedgerows and fences as fragmenting features. Both maps include active agricultural areas and other managed and unmanaged meadow habitats. Hudsonia Ltd., 2024.

necessarily compensate for the newly created cultural habitat: the created upland meadow cannot soon replace the cleared forest, shrubland, swamp (1 ac), or wet meadow (5 ac) and can easily revert to cultural with a change in management. The cultural/upland meadow relationship is quite fluid, in fact, and the classification of any one field can vary from year to year with management changes. The two habitats can also be difficult to distinguish based solely on aerial orthophotos; thus the number of acres in either habitat is never precise, and values reported for change between the two habitats should be read with caution.

WASTE GROUND

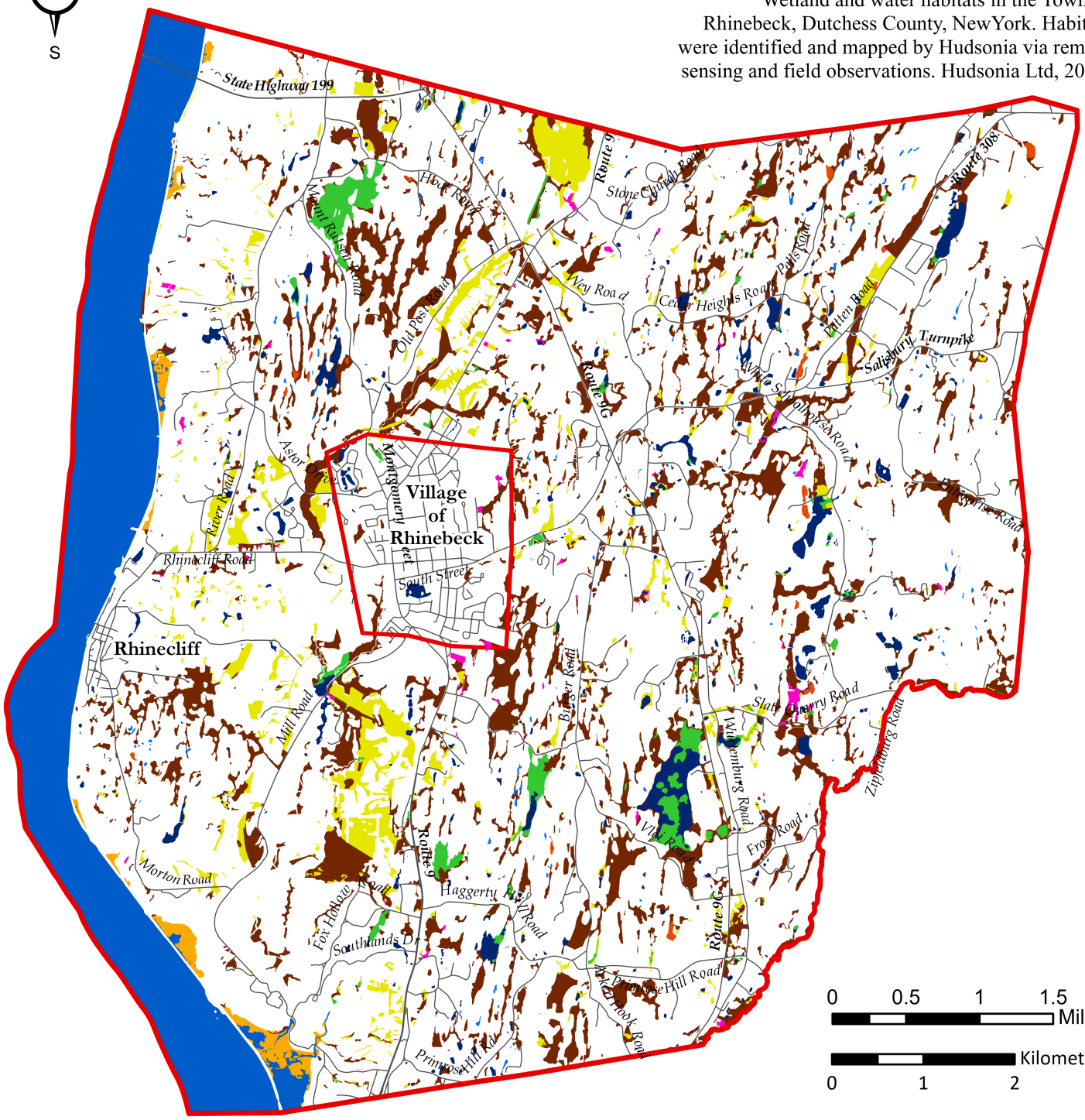
The habitat type that we call "waste ground" includes land that has been severely altered by previous or current human activity but lacks pavement or structures—for example, active and abandoned gravel mines, rock quarries, unvegetated landfill cover, and construction sites. The ecological values of waste ground are described in the 2007 habitat report (Reinmann and Stevens). The study period saw a sharp decline in waste ground—41%—from 101 ac in 2004 to 60 ac in 2021. This occurred as sections of sand and gravel mines were allowed to revegetate with disuse (59 ac), or, to a lesser extent, were developed (11 ac). Most of the revegetating waste ground became upland meadow (43 ac), the first stage in vegetational succession from the "bare slate" of a waste ground. Some new waste ground *was* created during the study period: 12 ac from upland meadow, 6 ac from upland hardwood forest, and 4 ac from hardwood swamp, among other habitats. Most new waste ground occurred in expanding quarries, house sites in the process of development, and temporary piles of gravel and other materials. Waste ground is, in general, a short-lived habitat, and its extent within the town is likely to fluctuate, sometimes greatly, from year to year and decade to decade.

Non-tidal wetland and water habitats

Rhinebeck lost a net 3.7% (137 ac) of its non-tidal wetlands during the study period. Remaining non-tidal wetlands covered 14% of the town in 2021. These values do not include open water habitats (open water, constructed pond, stream), which often are unvegetated and therefore are not, technically, wetlands. Of the 3,660 ac of non-tidal wetlands mapped for 2007, 0.6% (23 ac) were since developed, 0.7% (26 ac) became uplands, and 2.4% (88 ac) became water habitats by 2021. At the same time, small amounts of wetland were gained from developed areas (3 ac), uplands (5 ac), and water (21 ac). Forty-nine acres is a great deal of filled or drained wetlands over the study period, and we do not know whether those alterations were carried out with the required correspondence and permits from local, state, and/or federal authorities. Figure 7 illustrates the locations of all identified wetland and water habitats in Rhinebeck in 2021.

7. Wetlands and water

Wetland and water habitats in the Town of Rhinebeck, Dutchess County, NewYork. Habitats were identified and mapped by Hudsonia via remote sensing and field observations. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Wetland loss, 2004-2021 (to development or uplands)

2021 wetlands and water

Kettle shrub pool/buttonbush pool

Constructed pond/open water

Swamp

Intermittent woodland pool

Marsh

Tidal wetland

Wet meadow/calcareous wet meadow/wet clay meadow

SWAMP

Non-tidal swamps were much more extensive than other wetland types, covering 2,470 ac, or 10% of the town, in 2021. We distinguish three types of non-tidal swamp: hardwood & shrub swamp, mixed forest swamp, and conifer swamp. Hardwood & shrub swamp is a prominent component of the regional landscape and easily the most common type of swamp in Rhinebeck, covering nearly 10% of the town (2,451 ac) in 2021. (The category is a combination of hardwood swamp forest and shrub swamp, two types that can be difficult to distinguish in aerial imagery.) Mixed forest swamp and conifer swamp, which are generally rare in the Hudson Valley, covered much smaller areas, at 18 ac and 1 ac, respectively, in 2021.

All three types diminished in area during the study period, and total swamp acreage fell by 6% (163 ac), from 2,633 to 2,470 ac. Hardwood & shrub swamp was reduced by 5%, or 135 ac (from 2,585 to 2,451 ac). Most of the lost hardwood swamp (119 ac) became marsh and another 25 ac became open water or constructed pond due to water levels raised by humans or beavers. Another 37 ac became one of three types of wet meadows, and 12 ac became upland meadow, mostly due to human forest clearing and (in some cases) filling. Nineteen acres of hardwood swamp were destroyed outright by development. Conversely, 83 ac of new hardwood & shrub swamp developed, mostly by succession from wet meadow (53 ac) and conifer loss from mixed forest swamps (26 ac).

Mixed forest and conifer swamps, while starting from much lower totals than hardwood & shrub swamp in 2004, experienced much higher proportional loss. Of the 44 ac of mixed swamp in 2004, 60% (27 ac) was lost, most of it becoming hardwood swamp. Of 3 ac of conifer swamp in 2004, nearly 2 ac (57%) was lost, mostly by transition to hardwood swamp or mixed forest swamp. All of these transitions reflect a loss of conifers in the swamp canopies. Very little new mixed or conifer swamp developed. One acre of conifer swamp became mixed forest swamp, and about 1 ac of wet meadow became conifer swamp.

In our re-mapping, we marked a special type of swamp called a pool-like swamp. These swamps have hydrological properties similar to those of intermittent woodland pools, in addition to the abundant woody vegetation and hummocks characteristic of swamps. Because of their isolation from streams and waterbodies and their seasonal drying, these swamps may have ecological roles similar to those of intermittent woodland pools—e.g., they may provide a seasonal water source with few aquatic predators, serving as breeding habitat for pool-breeding amphibians, fingernail clams, fairy shrimp, and a host of other invertebrates that depend on these conditions. They may also provide refuge and foraging habitat for turtles, foraging and nursery habitat for some waterfowl, and breeding habitat for certain songbird species. We mapped 59 pool-like swamps, though these should be confirmed in the field, and others likely exist.

INTERMITTENT WOODLAND POOL

We mapped 138 intermittent woodland pools in 2021, down from 141 in 2004. Three pools had been completely destroyed, and 80% of a fourth was destroyed. One pool was replaced by a constructed pond, one filled to create upland meadow, and the third was filled and developed. The fourth pool was converted to waste ground in what looks to be a mining operation.

Figure 8 shows all identified woodlands pools (including intermittent woodland pools and pool-like swamps) in 2021, woodland pools destroyed during the study period, and pool conservation zones for 2004 and 2021. Pool conservations zones constitute the area within 750 feet of pool edges. Forest within that zone serves as critical non-breeding season habitat for pool-breeding amphibians; thus forest loss within the conservation zone is of particular concern. See *Forest Loss* under *Discussion*, below, for more on this.

KETTLE SHRUB POOL/BUTTONBUSH POOL

We mapped 13 buttonbush pools, reduced from 15 in 2007. Both lost pools, one of 1.5 ac and one of nearly 15 ac, were flooded to open water, likely by beaver activity. Of eight kettle shrub pools, only one experienced significant change: namely, a large kettle pool north of Slate Quarry Road was partially impounded and partially cleared and filled, as part of a much larger case of destruction of state-regulated wetlands (see *Discussion*, below). Nearly a quarter of this kettle pool, next to a newly built quarry road, was converted to upland meadow, constructed pond, and wet meadow.

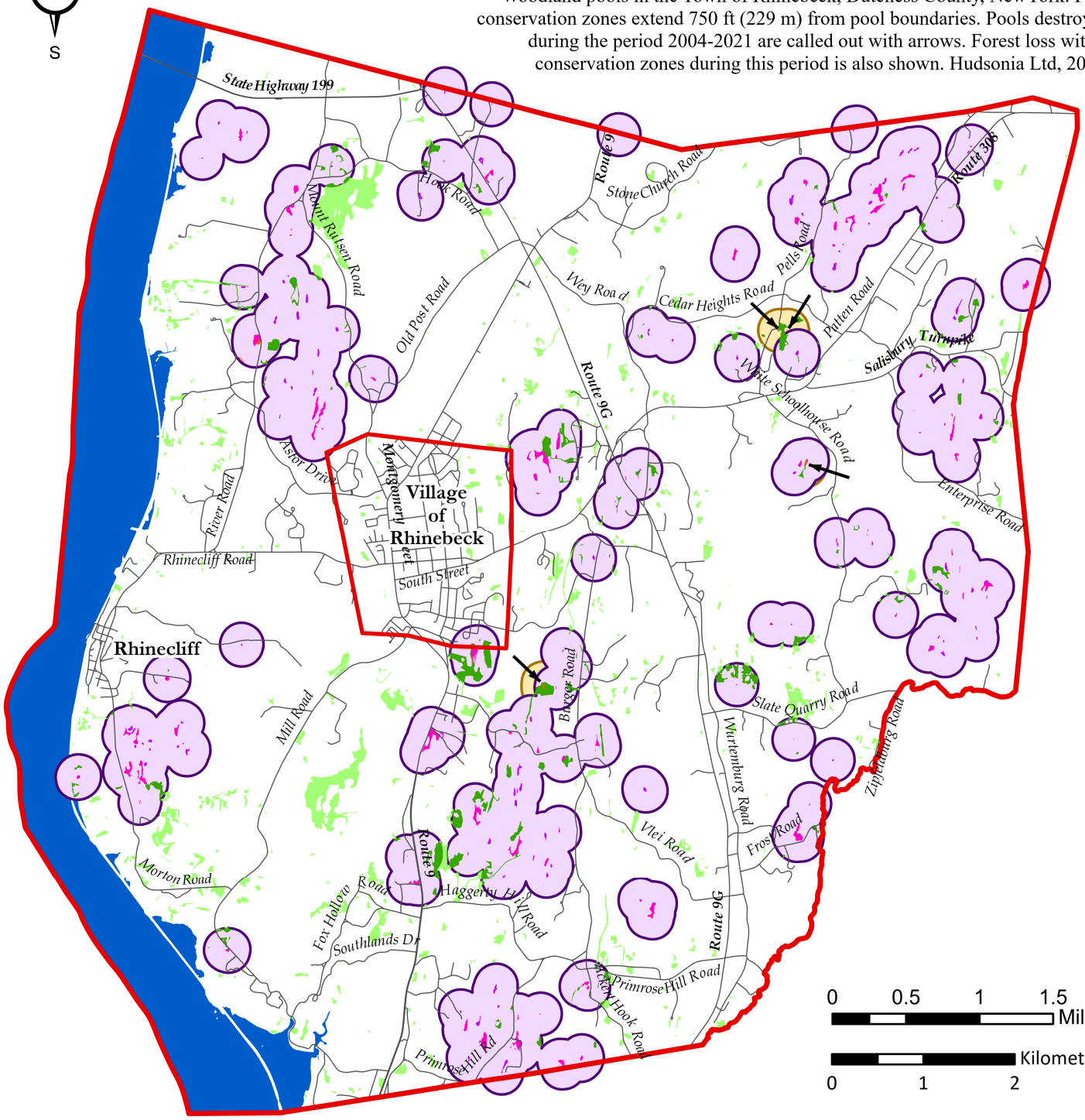
Figure 9 depicts buttonbush pools and kettle shrub pools in Rhinebeck as of 2021, as well as kettle shrub pool destruction since 2004. Conservation zones extending 3,300 feet from pool edges circumscribe an area that should encompass the majority of regular overland movements (to foraging, nesting, overwintering, and refuge habitats) of the State-Threatened Blanding's turtle. Kettle shrub pools, and possibly buttonbush pools, are the core habitat of the turtle, which is known from surrounding towns in Dutchess County.

MARSH

The study period saw a great increase (68%) in the extent of marshes in Rhinebeck, from 142 to 239 ac. Most new marsh (145 ac) came from the flooding of hardwood swamp (119 ac) and the lowering of water levels in open water areas (20 ac). Flooding of hardwood swamps often causes their trees to die, removing the canopy; and open water often fills in with marsh vegetation when water level decreases. Conversely, 45 ac of 2004 marsh was flooded to become open water. Most—35 ac—of the marsh-to-open water transition occurred in one large wetland complex north of Vlei Road, where an artificial or beaver dam at the marsh outlet may have been

8. Woodland pools

Woodland pools in the Town of Rhinebeck, Dutchess County, NewYork. Pool conservation zones extend 750 ft (229 m) from pool boundaries. Pools destroyed during the period 2004-2021 are called out with arrows. Forest loss within conservation zones during this period is also shown. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Woodland pools

Intermittent woodland pool

Pool-like swamp

Woodland pool loss, 2004-2021

Pool conservation zone, 2021

Pool conservation zone, 2004

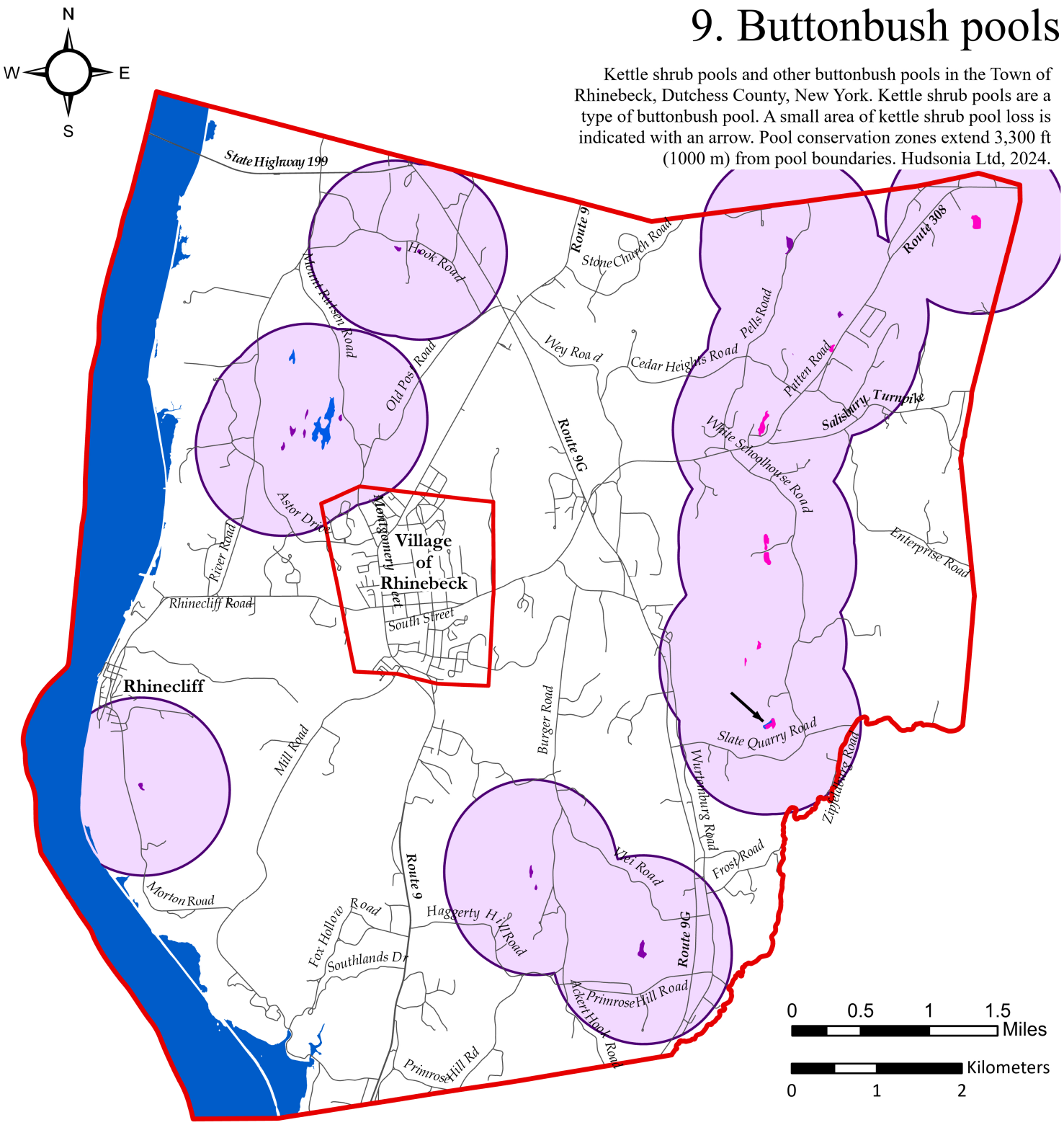
Forest loss

Within conservation zone

Other forest loss

9. Buttonbush pools

Kettle shrub pools and other buttonbush pools in the Town of Rhinebeck, Dutchess County, New York. Kettle shrub pools are a type of buttonbush pool. A small area of kettle shrub pool loss is indicated with an arrow. Pool conservation zones extend 3,300 ft (1000 m) from pool boundaries. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Buttonbush pool

Kettle shrub pool

Kettle shrub/buttonbush pool loss

Conservation zone

reinforced. Most of what appear to be deep-water marshes—or possibly acidic bog mats—remained intact.

WET MEADOWS

Three types of wet meadow—calcareous wet meadow, wet clay meadow, and wet meadow—together covered 787 ac, about 25 ac (3%) less than mapped in 2007. Of this, most (616 ac) was wet meadow, while calcareous wet meadow covered 117 ac and wet clay meadow 54 ac.

There was a net decrease in wet meadow of 41 ac, or 6%. Most of the lost wet meadow became hardwood swamp through ecological succession (53 ac), while 5 ac was converted to cultural habitat and 3 ac developed. New wet meadow came mostly from hardwood swamp that had been cleared (23 ac). Calcareous wet meadow increased by 17 ac (16%), mostly from cleared hardwood swamp. (Very little was lost.) Wet clay meadow extent remained about the same.

OPEN WATER

Open water increased by 31% during the study period, from 195 to 255 ac. Open water gained from flooding of marsh (45 ac), hardwood swamp (19 ac), buttonbush pools (16 ac), and other habitats far exceeded that lost to marsh (20 ac) and other habitats. As mentioned, such changes in water level can be due to human activities or to beavers or other natural causes. In the case of open water, which by our definition is surrounded mostly by unmanaged habitats and is therefore often somewhat removed from direct human impact, much of the newly created open water was likely caused by beaver dam construction.

CONSTRUCTED POND

The study period saw a modest increase, 11%, in constructed pond area, from 131 to 145 ac. Little constructed pond was lost, while new ponds were added mostly from impoundment or excavation of hardwood swamp (6 ac), upland meadow (5 ac), and waste ground (3 ac). The number of constructed ponds increased from 349 to 383. While constructed ponds are popular for ornamental and recreational purposes, they usually support far less biodiversity than the upland or wetland habitats that they replace, owing to the intense management (e.g., herbicides, mowing of perimeter) and other impacts (e.g., nutrient pollution from fertilizer-laden runoff, septic leachate) they usually receive.

STREAMS

Very little remapping of streams was needed as stream courses mostly did not change during the study period. Exceptions included some wetlands where flooding or lowering of water levels caused within-wetland stream courses to shift. We did map streams during map correction that

had gone unmapped in 2007, but these were not new streams. Figure 10 shows all identified streams in Rhinebeck in 2021.

SPRINGS AND SEEPS

We added no new springs or seeps during map updating, as these are unlikely to have changed since 2004. During the map correction phase, however, we did add a few springs and seeps, which had obvious signatures on aerial photographs and/or topographic maps.

Tidal habitats

We updated tidal habitats to reflect the most recent (2018) Hudson River Estuary tidal habitat mapping by HRNERR and IRIS (see large-format map), but no further assessment was made.

DISCUSSION

Overview

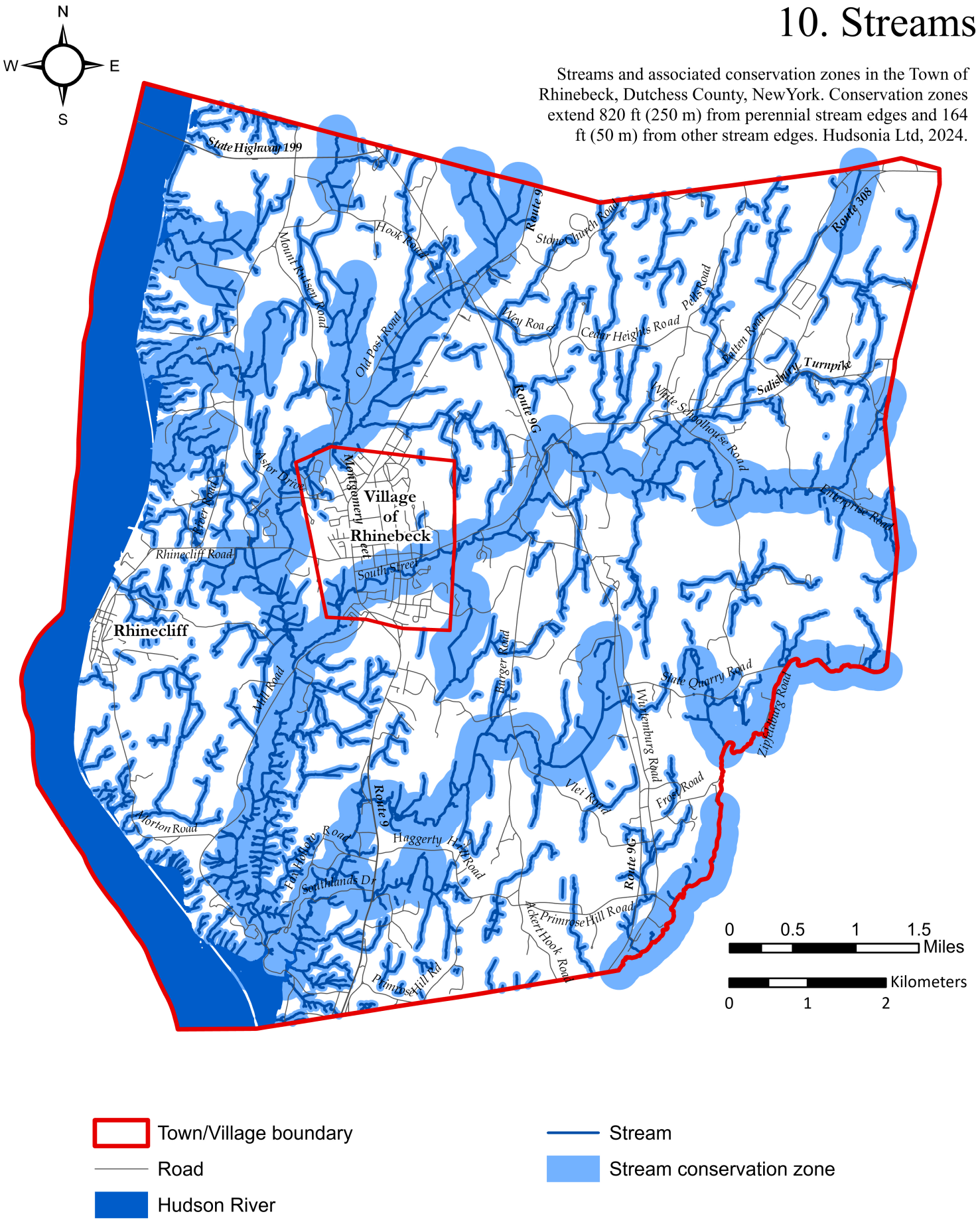
Habitat changes fell into two very broad categories: those which occurred naturally, i.e. not as a result of direct human intervention, and those that were directly human-caused. Some changes were impossible to classify in the absence of field work. Common natural changes included ecological succession, flooding of wetlands by beavers, and changes in tidal habitats caused by major storms, sediment accretion, and other natural drivers. The most prominent human-induced changes to habitats were the conversion of ecologically significant habitats to developed uses (driveways, buildings, paved areas, lawns, etc.) and the clearing and replacement of upland forest or forested swamp by upland meadow, wet meadow, or cultural habitat (large lawns). Other common changes included the conversion of meadow to lawn or vice versa by simple changes in management, clearing of shrubland, and the conversion of meadow and shrubland to waste ground. Many new ponds were also created, impounded either in wetlands or uplands. Figure 11 depicts many of the major types of habitat change that are discussed in some detail below.

Development

In 2004, existing development was dispersed across the town along roads and sometimes lengthy driveways, so that undeveloped land had been fragmented into discontinuous and irregularly shaped patches. This pattern of development, often far from existing roads and deep in forests and other habitats, proceeded throughout the town between 2004 and 2021 (Figure 12), and was responsible for the loss of 319 ac of large core forest and three large meadows for the many

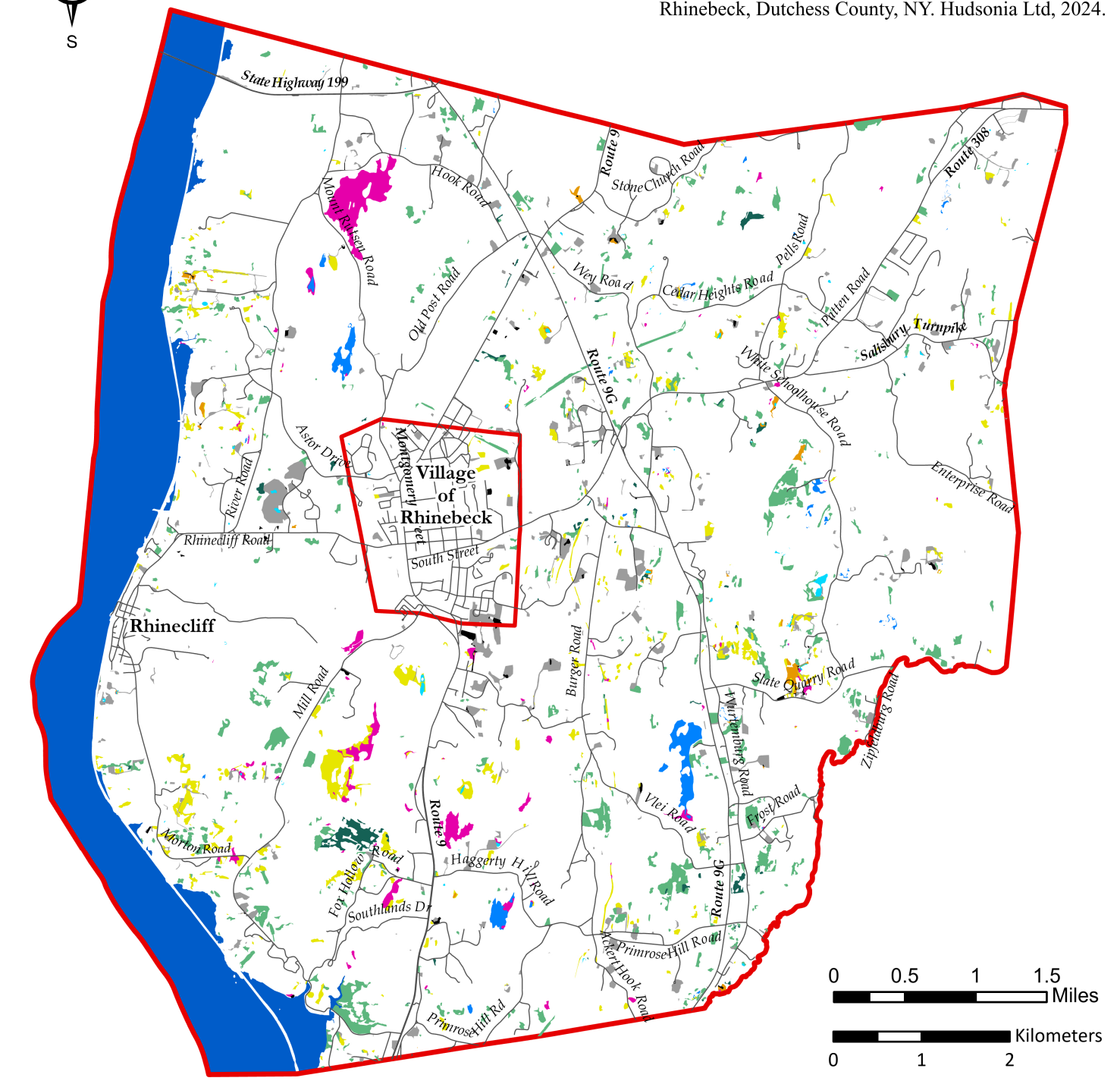
10. Streams

Streams and associated conservation zones in the Town of Rhinebeck, Dutchess County, NewYork. Conservation zones extend 820 ft (250 m) from perennial stream edges and 164 ft (50 m) from other stream edges. Hudsonia Ltd, 2024.



11. Major habitat changes

Major changes in habitats between 2004 and 2021 in the Town of Rhinebeck, Dutchess County, NY. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Changes, 2004 - 2021

Wetland development

Upland development

New open water

New constructed pond

Forested to open wetland

Wetland to upland

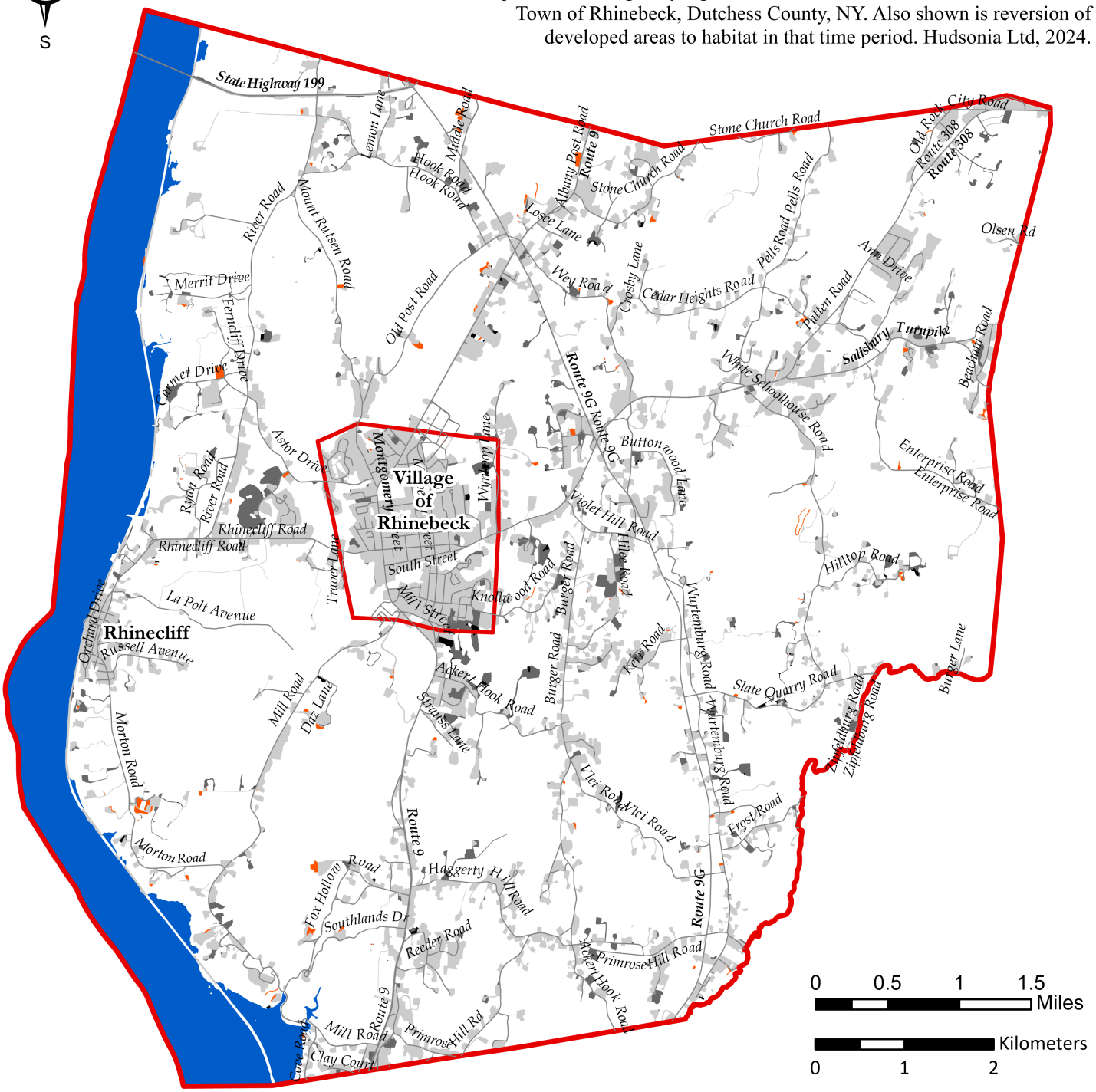
Forest to open upland

Wetland succession

Upland succession

12. Development

Development of ecologically significant habitats between 2004 and 2021 in the Town of Rhinebeck, Dutchess County, NY. Also shown is reversion of developed areas to habitat in that time period. Hudsonia Ltd, 2024.



species of conservation concern that depend on these respective habitats. Nearly all new development was residential, with minor amounts of agricultural (including equestrian) and commercial development. Most new residential development took the form of single dwellings or small clusters of dwellings (≤5 units within a contiguous block of new development), many of which have long driveways. A substantial portion of new development consisted of driveways. We could find only two residential clusters with > 5 units, and these had 26 houses and 38 multi-unit buildings, respectively. (Likely other recent subdivisions have resulted in > 5 dwellings, but they were partially built before 2004 and were thus not fully captured by our analysis.)

Developed acreage increased by 10%, or 367 ac, from 3630 ac in 2004 to 3998 ac in 2021. In other words, an additional 1.5% of the town land area was developed. This value equals the difference between 411 ac of new development and 44 ac of development reversion (to habitats). The most common habitats razed for development were upland hardwood forest and upland meadow, with 172 ac and 128 ac lost, respectively. Overall, 206 ac of forest (including all upland and swamp types) were developed in the study period (Figure 13). Fifteen new development blocks exceeded five acres. The two largest, by far, occupied 28 ac and 25 ac, and the latter was part of an overall 36-ac development on the north side of Rhinecliff Road and west of the village. The 28-ac development straddled the southeastern village boundary. Twenty-three acres of Rhinebeck's wetlands were developed into roads, driveways, buildings, lawn, and other paved areas, including 19 ac of swamp and one intermittent woodland pool. Three instances of wetland development were larger than 1 ac, all on or near the Village boundary, including the largest case, at 2.8 ac.

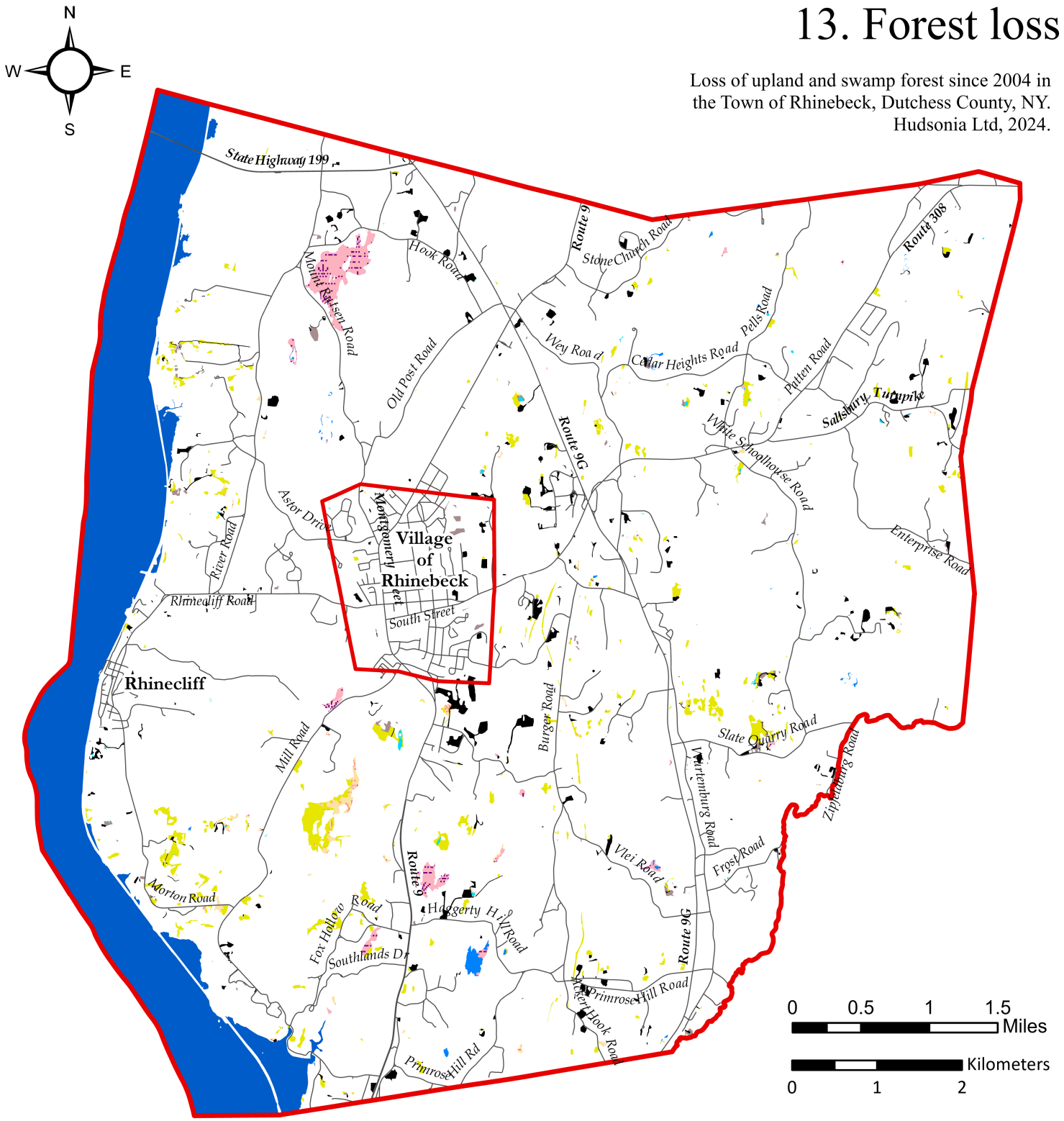
Reversion of developed areas to ecologically significant habitats, while rare, did occur (44 ac). Scattered buildings around the town were torn down; gravel and even pavement were removed. Most of those areas became open (non-forested) habitats. Twenty-four acres became upland meadow—much more than any other habitat. Some of the "new" habitat, it should be pointed out, was "undeveloped" simply by virtue of geometry: a small (<50 m on at least one side) patch of meadow, shrubland, or forest lay between two buildings, for example, and one building was removed, thus connecting the patch to other habitats. Such fragments were examples of "non-significant habitats" that had previously been lumped with developed areas due to their size and isolation.

Forest loss

In addition to 206 ac of forest (including upland and non-tidal swamp forests) lost to development, 472 ac became open, non-forested habitats, for a total forest loss of 678 ac (Figure 13). Given the 362-ac gain in forest due to succession (see below), the net forest change from 2004 to 2021 was -313 ac, or 313 ac of lost forest. In other words, new forest growth was slightly

13. Forest loss

Loss of upland and swamp forest since 2004 in the Town of Rhinebeck, Dutchess County, NY. Hudsonia Ltd, 2024.



Upland forest or swamp loss to

- Town/Village boundary
- Road
- Hudson River
- Constructed pond
- Open water
- Wet meadows*
- Marsh
- Waste ground or cultural
- Upland meadow or shrubland
- Development

*Wet meadows include wet meadow, calcareous wet meadow, and wet clay meadow habitats.

more than half (53%) of the forest lost during this time period (see discussion, below). However, our analysis considers only *area* of forest, saying nothing about *quality* of forest. In all likelihood, the quality (biodiversity value, native species dominance, ecological function) of the new, young, "scrubby" forest is much lower than that of the pre-existing forest that was cleared (much of which was probably mature, higher-quality forest).

Natural stand-clearing disturbances to hardwood forests, whether due to fire, wind events, or insects/pathogens, are rare in our region, so most of the upland hardwood forest to meadow or shrubland transitions were likely human-caused. However, in this region upland conifer stands commonly *age out* when their constituent trees all die of pathogens, wind disturbance, or competition around the same time as they reach their typical maximum lifespan. In Rhinebeck, numerous old conifer plantations, likely of red pine, eastern white pine, and/or Norway spruce, died off and were replaced by upland shrubland. Thus, much of the turnover of upland conifer and upland mixed forests to upland shrubland appeared to be due to natural ecological processes, while replacement by meadows was more commonly the result of human clearing. On balance, given that upland conifer and mixed forest to upland shrubland and meadow transitions accounted for 50 ac, compared to 191 ac of upland hardwood forest to shrubland and meadow, most forest clearing was likely anthropogenic. The lesser extents of upland forest conversion to cultural habitat (22 ac), waste ground (6 ac), and constructed ponds (1 ac) were all human-caused as well.

Wetland forests, i.e. swamps, experienced similarly mixed fates of human versus natural clearing. Very little mixed or conifer swamp transitioned to open habitats (<2 ac). The most extensive transition was of hardwood swamp to marsh, at 119 ac, a change usually caused by flooding due to damming, either by beavers or humans. Flooding of one swamp—Snyder Swamp—accounted for 65% (77 ac) of the total 119 ac, but it is unclear from orthophotos whether the damming there was beaver-caused or anthropogenic. Another 16-ac swamp north of Haggerty Hill Road also became marsh, this one likely flooded by beavers. Often such determinations require a field visit. The same can be said of the hardwood swamp to open water transition, of which 19 ac occurred in Rhinebeck, most of it—11 ac—at a single flooded swamp west of Haggerty Hill Road (Jobsen Swamp). Numerous human-made constructed ponds were also created out of hardwood swamps, all small. Of the 34 such ponds, only one exceeded 1 ac. In total, 17 ac of hardwood swamp were cleared and became upland meadow, cultural habitat, or waste ground by draining or filling. Thirty-seven acres were cleared to become one of three types of wet meadow, including 17 ac within a wetland complex east of Mill Road. Most of these instances were small, with only two exceeding 1 ac. The largest case comprised 7 ac of swamp that was cleared and evidently filled within a NYSDEC regulatory wetland north of Slate Quarry Road. This property had clearing, filling, developing, and impounding totaling about 12 ac within three DEC regulatory wetlands, including a kettle shrub pool (see below).

Forest near intermittent woodland pools and other woodland pools plays a critical role in the life cycle of pool-breeding amphibians. Hudsonia considers the forest within 750 feet of pool boundaries to be the most critical non-breeding habitat for these amphibians. During the study period, 150 ac of forest within such pool "conservation zones" was cleared, and sometimes developed (Figure 8).

Wetland loss

Wetlands were lost to development, conversion to upland habitats (presumably through draining and/or filling), and impoundment. Rhinebeck lost a net 3.7% (137 ac) of its non-tidal wetlands, not including open-water habitats, during the study period (Figures 7 and 11). Of the 3,660 ac of non-tidal wetlands mapped for 2007, 0.6% (23 ac) were developed, 0.7% (26 ac) became uplands, and 2.4% (88 ac) became water habitats by 2021. Some conversion to water habitats was natural, i.e. beaver-caused.

More marsh (44 ac) was lost (to development, uplands, or water) than any other wetland habitat, though 35 ac of this occurred in a single marsh that became open water. Swamps (all three types) experienced a 62-ac loss, including 19 ac to development, 19 ac to open water, 12 ac to upland meadow, and 6 ac to constructed ponds. Buttonbush pools and kettle shrub pools declined by nearly 17 ac, though 16 ac of this occurred in a single buttonbush pool that was flooded to become open water. About 0.6 ac of kettle shrub pool was destroyed by humans. Twelve ac of wet meadows (three types) were converted to upland habitats, water, or developed land. These values include only losses and do not account for the small amount of new wetlands that developed during the study period.

The largest single case of wetland destruction (not including impoundment or flooding) was 8 ac of one contiguous, NYS-regulated wetland (hardwood swamp and kettle shrub pool), north of Slate Quarry Road, which was cleared, filled, and converted to upland meadow, waste ground, and developed land. Elsewhere, four wetland patches exceeding 2 ac and five patches of between 1 and 2 ac were destroyed.

Large forests

Here we define *core* or *interior* forest as those parts of a forest that are ≥330 ft (50 m) from any development or cultural habitat, which have the most intensive human uses of all mapped land covers. As explained in the original habitat mapping report (Reinmann and Stevens 2007), large, interior forests are critical for many animal species that require the conditions of large interior forests, distant from human noise and visual disturbance and other "edge effects," to maintain successful breeding populations. For simplicity, we show core forest as extending to the boundary of non-forested habitats such as meadows and shrublands. In reality, however, there

are edge effects from such habitats. Therefore, the total area of core forest is less than our maps depict. Additionally, different species (and even individuals) have different sensitivities and tolerances, so the definitions of "large" and "interior" vary depending on the species of concern. We used a minimum core forest width of 25-50 m for determining connectivity between core forest patches because so many animals are sensitive to and avoid edges. When a narrow corridor between two large interior forest areas was less than this threshold, we divided the forest into two separate patches, reflecting the perspective of an edge-wary species that would be averse to using such a narrow corridor. Figures 4 and 5 depict contiguous (connected) forest in Rhinebeck, and classify forest blocks by size: <100 ac, 100-250 ac, 250-500 ac, and >500 ac.

As noted previously, there was a net forest loss (upland and wetland) of 313 ac from 2004 to 2021, comprising 678 ac of forest lost to development and conversion to open habitats and 362 ac gained by succession from shrubland and other habitats. Forest clearing included both interior and edge forest, resulting in a net loss of 319 ac (6%) of large (≥100-ac) interior forest (Figure 5). This decrease, from 5,464 ac to 5,145 ac, is greater than the net town-wide loss of forest, because some previously interior forest became edge forest. The mean large (≥100 ac) core forest size also decreased from 288 to 271 ac.

Comparing Figures 4 and 5, a few changes are especially salient. First, in 2021 there was only one forest block in the largest class (>500 ac), compared with two in 2004: a 523-acre block in the northwestern corner of town lost enough forest to fall below the 500-ac threshold as a result of flooding and marsh growth in a large area of hardwood swamp. Another major change: the construction of a single house and long driveway through the center of a 190-ac core forest block, just off the southeastern corner of the Village, divided the block into two small fragments of <100-ac each. Other, more subtle changes abounded. For example, a 432-ac core forest east of Route 9 was whittled to a 366-ac forest and nearly cut in two by new development, leaving a much narrower connection between the western and eastern sides of the patch. A 133-ac core forest east of Burger and Vlei Roads became a 108-ac forest as another single-lot development project shaved off more than 20 ac of forest from the former core. Many such seemingly small "cuts" to Rhinebeck's large, interior forest blocks occurred throughout the town. Such insidious development is what progressively fracture the forests of the Hudson Valley, indeed the entire Eastern Deciduous Forest, into a fragmentary patchwork of small forests, woodlots, and spiderwebbing development with severely compromised ability to support our native biota.

Large meadows

Certain birds of conservation concern require large, undivided meadows (25 to 500+ ac) to reproduce successfully and maintain local populations (Vickery et al. 1994). Fences, hedgerows, and tree lines through meadows can decrease nesting success for these grassland-breeding birds by providing cover and perching sites for raptors and other species that prey on the birds or their eggs (Wiens 1969). Figure 6 illustrates how meadow patch sizes differ in 2021 when such

dividing features are taken into account. The size thresholds used (25 ac, 50 ac, etc) correspond roughly with minimum areas found by various studies to be preferable to certain birds of conservation concern (see Reinmann and Stevens 2007). Although Rhinebeck's impressive array of meadows covers more than 4,600 ac, only 29 *contiguous* meadows (i.e., with dividing features taken into account) were larger than 25 ac. Of these, 10 exceeded 50 ac and three topped 100 ac. The largest of these, at 194 ac, was west of Route 9 and south of the village of Rhinebeck.

The number of large (>25 ac) meadows remained roughly the same from 2004 to 2021, as several from 2004 were broken up and several new ones created. However, this seeming equivalence may be specious, as two of the four "new" large meadows were created by removal of limited waste ground, development, and a hedgerow and likely had the potential to support certain grassland-breeding birds before these changes (if managed appropriately).

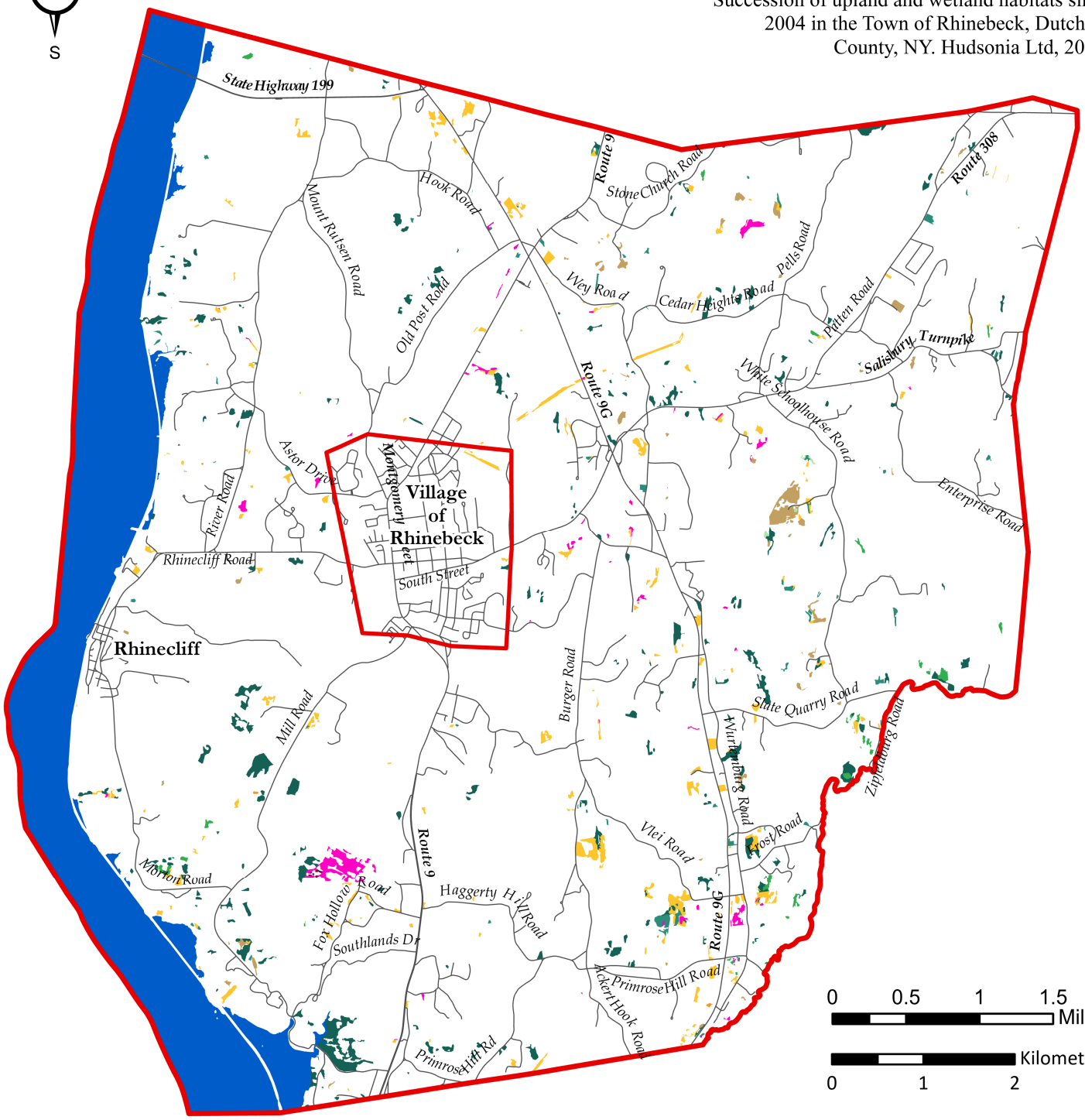
Two meadows of between 25 and 50 ac were broken up into small meadows by development, and one meadow of roughly 85 ac, west of the village off of Rhinecliff Road, was fragmented by development into three smaller meadows of 20 ac or less—a great loss to grassland-breeding birds and other biodiversity. Conversely, four new large meadows were gained, at least on paper, during the study period, all between 25 and 50 ac. Two were created from smaller meadows by the conversion to meadow of waste ground, orchard plantation, and/or development, which had divided the smaller meadows in 2004. A third was similarly created by the merging of two smaller meadows after the removal of a hedgerow. Removal of hedgerows and tree lines is an excellent way to increase the size of contiguous meadows and the suitability for rare grassland breeding birds. A fourth large meadow was created whole-cloth by the clearing of nearly 40 ac of contiguous upland forest and swamp. Given the importance of forests for biodiversity and ecosystem services such as carbon storage and water regulation, in addition to the abundance of pre-existing meadows in our region, the clearing of large areas of forest to create meadows is never a recommended practice.

Succession

"Ecological succession" refers to the transition in species composition and structure of a community of organisms (e.g., plants, intertidal invertebrate animals) over time as the result of competition and facilitation, nutrient and carbons flows, microclimatic changes, and other ecological processes. Ecological succession is a long-studied and foundational theory in community ecology that has in recent decades come under scrutiny and been found to be much more complicated, less predictable, and less universal than previously held. For our purposes, however, it is meaningful and sufficient to refer to a set of generalized and well-defined transitions as succession: primarily meadow to shrubland, shrubland to forest, and wet meadow to forested and shrub swamps (Figure 14). Other, less common successional transitions in

14. Ecological succession

Succession of upland and wetland habitats since 2004 in the Town of Rhinebeck, Dutchess County, NY. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Wetland succession, 2004-2021

Wet meadows* or marsh to hardwood & shrub swamp

Wet meadow to conifer swamp

*Wet meadows include wet meadow, calcareous wet meadow, and wet clay meadow habitats.

Upland succession, 2004-2021

Cultural, meadow, or orchard/plantation to forest

Cultural, meadow, or orchard/plantation to shrubland

Red cedar woodland to forest

Meadow or shrubland to red cedar woodland

Shrubland to forest

Waste ground to cultural, meadow, or shrubland

Waste ground to forest

Rhinebeck included orchard/plantation to forest, red cedar woodland to forest, and waste ground to upland meadow. Overall, some 511 ac of upland habitat, amounting to 2% of the town, underwent succession to a different habitat type during the study period. The most common transition was of upland shrubland to upland hardwood forest: more than a quarter—26% (227 ac)—of the shrubland in 2004 had become hardwood forest by 2021. Another 17 ac of shrubland became upland mixed forest, and 1 ac became upland conifer forest, totaling 245 ac of upland shrubland to upland forest. At the same time, 150 ac (4%) of 2004's upland meadow grew up into upland shrubland. Most of this succession occurred in small patches scattered across the town. Of 230 patches of new forest from shrubland, the largest were of 26 ac and 10 ac, and the vast majority were of <1 ac. Of 74 patches of upland meadow (29 ac) that transitioned all the way to young forest, only one exceeded 5 ac, and the rest were of <2 ac. Similarly, of 181 patches of new shrubland from meadow, only two were between 10 and 12 ac, and the rest smaller than 4 ac. Thus abandonment of agricultural land (e.g., hayfield, pasture) seems to have been piecemeal and at small scale over the last two decades. Another somewhat common transition was that of waste ground to upland meadow, at 43 ac (43%) of the waste ground in 2004. As mentioned previously, waste ground tends to have a high turnover rate, and, once abandoned, sometimes develops substantial herbaceous vegetation in a matter of years rather than decades. (Further successional changes may take much longer.) Most other upland successional pathways (e.g., red cedar woodland to forest, cultural to shrubland and forest) had very limited extents across Rhinebeck.

Wetland succession was much less common. The only transition of significance was from wet meadow to hardwood & shrub swamp, which occurred across 53 ac, or 8%, of 2004's wet meadow. Most became shrub swamp, though some developed into a young hardwood swamp, including parts of the largest single patch, at 23 ac. Most other wet meadow-to-hardwood swamp transitions were of <1 ac.

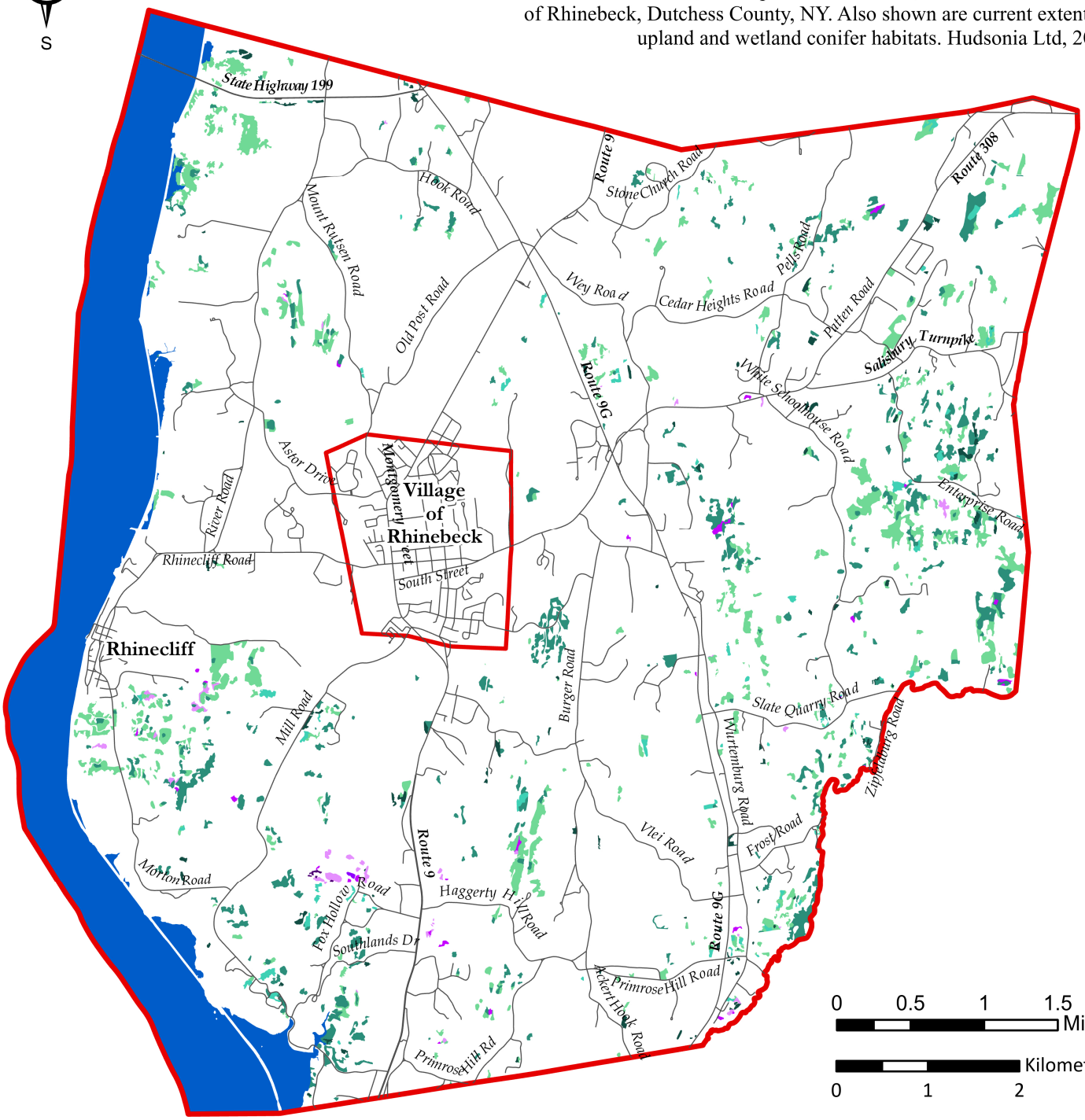
Conifer loss

Large areas of forest canopy dominated or co-dominated by conifers (eastern white pine, eastern hemlock, eastern red cedar) in 2004 lost many or most of their conifers during the study period. Upland conifer forests and swamps became mixed and hardwood forests and swamps; mixed forests and swamps became hardwood forests and swamps (Figure 15). Lack of field work notwithstanding, we attribute this rampant conifer loss to natural[1] tree deaths rather than any direct human intervention. Two widespread sources of mortality are likely to explain most of the conifer deaths and conifer forest loss: hemlock deaths from hemlock woolly adelgid (HWA) (along with co-morbidities such as hemlock scale insect), and age-related red cedar deaths from competition or natural disturbances. The latter is a normal part of the succession of a post-

[1]although HWA was introduced to the eastern U.S. by humans and first discovered here in the mid-20th century.

15. Conifer forests

Loss of conifer habitats, both upland and wetland, since 2004 in the Town of Rhinebeck, Dutchess County, NY. Also shown are current extents of upland and wetland conifer habitats. Hudsonia Ltd, 2024.



Town/Village boundary

Road

Hudson River

Conifer loss, 2004 - 2021

- upland conifer forest (no change)
- upland mixed forest (no change)
- upland conifer to upland mixed forest
- upland conifer or mixed forest to upland hardwood forest
- conifer swamp (no change)
- mixed forest swamp (no change)
- conifer to mixed forest swamp
- conifer or mixed forest swamp to hardwood swamp

agricultural landscape and explains much of the loss of conifer dominance in Rhinebeck in current and recent agricultural areas. Probably most conifer loss, however, has derived from the succumbing of hemlocks to the woolly adelgid, a non-native insect that weakens and ultimately kills infested trees, over a period of a few years to a decade, as the tiny insects suck sap from the tree (NYS DEC 2024). It is a widespread scourge that has affected eastern hemlocks across 90% of their range and dramatically altered the ecology and ecosystem function of many thousands of acres of formerly hemlock-dominated forests.

The declines have been dramatic, as is evident in Figure 15. Of 172 ac of upland conifer forest in 2004, 36% (62 ac) became upland mixed forest and 18% (31 ac) became upland hardwood forest by 2021. (Given losses due to forest clearing, only 28% remained). Equally pronounced was the decline in upland mixed forest: of 996 ac in 2004, more than half (54%) transitioned to upland hardwood forest with the death of all or most of its canopy conifers. (With other changes, only 42% of 2004's mixed forests remained.) Conifer swamp, always a rare habitat in Rhinebeck, declined by 85%, from 3 ac to about 0.5 ac, during the study interval. Finally, of 44 ac of mixed forest swamp in 2004, 60% (26 ac) transitioned to hardwood swamp. Overall, by 2021, only 16 ac of mixed forest swamp remained, 37% of the 2004 coverage.

CONCLUSIONS

Much of Rhinebeck—approximately 2,581 ac or 10% of the town—experienced some type of change in habitat. The most extensive types of change were ecological succession (of several types), conversion of forest, meadows, and other habitats to developed uses, forest clearing (to meadow, etc.), conifer loss from upland mixed and conifer forests, and flooding of swamps to marsh or open water. Habitats changed from well under 1 ac to 77 ac at a time. Large flooded wetlands (e.g., of 77, 35, and 17 ac), development projects (36 ac), wet meadow succession (23 ac), conifer loss (19, 17, and 15 ac), and removal of orchards (17, 14 ac) constituted the largest single habitat changes.

The information in this addendum should help the citizens and municipal agencies of the Town of Rhinebeck engage in proactive land-use and conservation planning to ensure that future land development occurs in locations, quantities, and configurations that best protect the town's significant remaining biological resources. Many kinds of plants, animals, and other organisms, some of them rare, still thrive in the town, and riches of extensive, mature, interior forest, large meadows, deep glacial pools, teeming vernal pools embedded gem-like in enshrouding forest, and other habitats still grace the town; but this is not by guarantee, and these finite populations and habitats will endure only with foresight and careful stewardship by the town's planners, decision-makers, and landowners.

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