Habitat Use by the Eastern Whip-poor-will (*Antrostomus vociferus*) in New Hampshire

with Recommendations for Management

Report to the New Hampshire Fish and Game Department
Nongame and Endangered Wildlife Program

Pamela Hunt, Ph.D.
New Hampshire Audubon – May 2013

Cover photographs of incubating female Eastern Whip-poor-will and Ossipee Pine Barrens by Pamela Hunt

Cite this publication as:

Hunt, P.D. 2013. Habitat use by the Eastern Whip-poor-will (*Antrostomus vociferus*) in New Hampshire, with recommendations for management. Report to the NH Fish and Game Department, Nongame and Endangered Species Program. New Hampshire Audubon, Concord.

Executive Summary

The Eastern Whip-poor-will (*Antrostomus vociferus*) is a widespread nocturnal bird found in open forests and edge habitats across much of eastern North America. The species has shown strong population declines and range retraction since at least the 1960s, and as a result is a species of conservation interest in most areas where it occurs. Because loss or maturation of early successional habitat is commonly proposed as an important factor behind the declines, this study attempted to relate habitat use to historic management in two areas of New Hampshire where the species remains relatively common.

Whip-poor-will home ranges were mapped using both spot-mapping and radio telemetry, and habitat composition accessed within the resulting polygons. Home ranges averaged approximately 5 ha (12.5 ac), with a range of roughly 1-13 ha (2.5-32.5 ac), and appeared slightly larger in forested situations without significant openings. Collectively, whip-poor-wills tended prefer areas of dense shrubs or heterogeneous young forest and avoid closed-canopy mature forest. Most home ranges included either a significant edge (e.g., wetland, powerline right-of-way, gravel pit) or a large area (at least 3 ha [7.5 ac]) of regeneration or shrubby thicket. In the absence of such features, birds selected areas characterized by open canopy forest that resulted from logging. They rarely use mostly non-vegetated areas except to call or forage from the edges. At a broader scale, whip-poor-wills are more common, and reach higher densities, in pine barrens than in pine/hardwood forests, and are almost entirely absent from hardwood dominated landscapes.

These results suggest that the most appropriate management for the Eastern Whip-poor-will – at least in northern New England – is some combination of forest thinning and shrubland maintenance. The aim should be to create a mosaic of open forest and shrubby openings that provide for nesting, roosting, and foraging. Shrubland habitat may best be enhanced in the short term through overstory removal, since the resulting opening is largely suitable for whip-poor-wills immediately. Prescribed burns also appear beneficial, but are more readily occupied if shrubs and other understory are not removed beforehand (e.g., by mowing). Clear cuts will eventually be used by whip-poor-wills, but perhaps not for 3-5 years, and in many cases may rapidly mature into unsuitable young forest. Such succession may be prolonged if the site is burned within a year of harvest. Right-of-way maintenance through selective tree removal will preserve habitat values indefinitely, but again any wholesale vegetation removal (e.g., mowing) is likely to reduce occupancy. In all cases, the size of a shrubby opening may need to be at least 3-4 ha (7.5-10 ac). Data from other studies indicate that birds are rarely more than 100 m (325 ft) from an edge, suggesting that very large openings are not likely to be proportionally more suitable.

For forest thinning to result in suitable habitat, it may be necessary to remove up to 50% of existing trees (or basal area). Not only does such extensive treatment open up the canopy, but the resulting network of logging and skid roads provides additional edges that are often used by the birds. A less intensive harvest may still be beneficial if combined with some sort of shrubland management as discussed above, or if the treated area is adjacent to an edge such as a field or right-of-way. Forests that are already naturally open may need even less management.

To enhance the chances of success, any management targeted specifically for whip-poor-wills will need to consider limitations of the species range and base habitat preferences in the state. Management directed at predominately hardwood forest is less likely to attract whip-poor-wills unless adjacent to an already occupied area, and even then the appropriate habitat features may not be present. The majority of sites occupied by whip-poor-wills in New Hampshire, and perhaps most of New England, are on well-drained sandy or loamy soils, usually associated with river valleys or in glacial outwash features. The presence of pitch pine is a good indicator of potential suitability, although it is certainly not required. Whip-poor-wills may also be more likely to respond to management if the managed area is in close proximity to existing populations, although data on this are largely anecdotal. The combination of suitable base conditions and existing whip-poor-will concentrations has resulted in two primary and three secondary "focal areas" in the state. The primary focal areas of the Ossipee Pine Barrens and Upper Merrimack Valley probably contain over 75% of the whip-poor-wills in the state, and are thus the most likely areas where management can enhance local populations.

Introduction

The Eastern Whip-poor-will (*Antrostomus vociferus*, hereafter WPW) is a member of the nightjar family (Caprimulgiformes, Caprimulgidae) native to the eastern United States and southern Canada (Cink 1996). Available data suggest that the species requires a mix of both forest for nesting and open habitat for foraging, and thus tends to occur in highly heterogeneous landscapes, including forests with extensive natural openings (Wilson 2003, Hunt 2006, Garlapow 2007). Like many other species typical of early successional and edge habitats, the WPW has been in steady decline over most of its range (Sauer et al. 2011), and there is considerable evidence that its range in the Northeast has retracted by roughly 50% since the early 1980s (e.g., Cadman et al. 2007, McGowan and Corwin 2008, Renfrew 2013, unpublished Breeding Bird Atlas data). As a result, the WPW is listed as a Species of Greatest Conservation Need in most states where it occurs, and considered Threatened in Canada (COSEWIC 2009).

Because of the need for open or edge habitats, WPW declines are often attributed to habitat loss through maturation. The Northeast was historically a heavily forested landscape, with scattered and ephemeral patches of early successional habitat resulting from fire, storms, and clearing by Native Americans. Extensive areas were maintained only in those areas subject to regular fire (e.g., pine barrens – usually on well-drained soils) or in coastal areas subject to wind and salt spray (and also often on poor soils). Following colonization by Europeans, increasing amounts of forest were cleared for agriculture, resulting in over 50% of the southern New England landscape being non-forested by the mid-1800s (Litvaitis 1993). This clearing, and resulting "recalibration" of the early/late successional balance, probably resulted in population increases in bird species requiring edges, shrublands, or young forests. With the decline of agriculture, forests have again become dominant in the non-developed landscape, with grasslands and shrublands becoming smaller and more dispersed. At the same time, increasing development pressure has reduced the overall amount of natural habitat available, especially in coastal and low elevation areas. In such areas, even when habitat has not been directly lost, resistance to management (especially fire) has often precluded the establishment and maintenance of patches of early successional or edge habitat attractive to WPWs and other species.

If WPW declines can be at least partially attributed to reforestation and habitat maturation, it should be possible to stabilize populations through appropriate management. Previous research on this topic has suggested that both burns (Garlapow 2007) and active timber management (Wilson and Watts 2008) may serve to maintain habitat suitable to WPWs, and even then features such as forest edges are preferentially selected over interior forest (Wilson and Watts 2008). Given that WPWs inhabit a broader range of habitats than those in previous studies, one goal of the current research was to determine the characteristics of suitable habitat for WPW in New Hampshire. The results of this study can then be used to inform future management activity and perhaps stabilize state and regional populations.

Study Sites

Whip-poor-will territory mapping was conducted at two New Hampshire sites known to support high densities of the species. The primary study area was the Mast Yard State Forest in Hopkinton and Concord (43.23906, -71.65925). Mast Yard consists of 250 hectares of mature pine-oak forest dominated by white pine (*Pinus strobus*), red pine (*P. resinosa*), and northern red oak (*Quercus rubra*), with lesser amounts of pitch pine (*P. rigida*) and red maple (*Acer rubrum*). The understory is dominated by *Vaccinium* species. Embedded in the forest are several shrubby wetlands and areas of early successional habitat. The latter are the result of previous habitat management and are dominated by seedlings and saplings of the dominant tree species, plus extensive stands of aspen (*Populus* sp.) and birch (*Betula* sp.). Abutting the forest on the north, east, and south are another 200 hectares of both public and private lands of similar habitat that were also included in the study area, for a total area of approximately 450 hectares. A 2 km x 100 m powerline right-of-way passes through the eastern portion of the study site.

Forest management has been taking place at Mast Yard since at least the 1990s, and includes clear cuts, crop tree release cuts, strip cuts, and ongoing management of the powerline right-of-way. During the course of study, two management events occurred in the overall study area. In the late summer of 2009, an abutting private landowner selectively harvested about 20 ha near the northwest corner of Mast Yard (Figure 1 and Table 1, Unit A), leaving a much more open canopy and a network of skid trails. In the winter of 2010-11, the NH Division of Forests and Lands (the managing entity for the forest) selectively harvested another 30 ha in the south-central portion (Units F), and also created two 1.5 ha clear cuts (Units E). An overview of management at Mast Yard is presented in Table 1 and Figure 1.

Based on field observation and management history, six broad habitat types were identified at Mast Yard, as follows:

1) "Mature Pine" includes all untreated areas dominated by mature pines or pine/hardwood mix. It also includes two extensive areas that were strip cut in 2003. These two areas have very narrow canopy openings compared to other thinned areas (see #2, below) and the understory in the harvested portions is dominated by dense low brush rather than the more open understory over most of the study area. Total density reduction in strip cuts was on the order of 30-40% (Table 1).

2) "Thinned Mature Pine" includes areas where at least 50% of available timber or basal area was removed. There were three major blocks of such thinning at Mast Yard: the cut on private land to the north, an area of generally younger habitat in the southwest, and the most recent crop tree release area in the central portion. Although lumped for purposes of habitat analysis, these three areas had very different degrees of WPW use, as will be discussed later.

3) "Young Pine" includes only a 3 ha stand in west-central mast yard that was subject to overstory removal in 1999. Note, however, that there are also smaller stands of young pine within "young hardwood" habitats.

4) "Young Hardwood" is represented by three stands originally clear-cut in the 1990s (Table 1), all of which are now dominated by a mixture of regenerating aspen and white pine, low shrubs, and more barren areas dominated by forbs and grasses. This category also includes shrub-dominated sections of the power-line right-of-way.

5) "Poorly Vegetated" includes primarily the remainder of the power-line right-of-way, which is dominated by grasses, lichens, and low woody shrubs (e.g., sweet fern), but also the two clear cuts created in 2010 and two small log landings.

6) "Shrub Wetland" includes all areas mapped as wetland within the study area. These include both shrubby bogs and alder-dominated areas along streams.

The second site was within the Ossipee Pine Barrens in Tamworth, Madison, Freedom, and Ossipee, an area that supports the highest density whip-poor-will population in New Hampshire (see Hunt 2009a for more detail). This is also the largest remaining area of pitch pine/scrub oak barrens in New Hampshire. Habitat consists of pitch pine and scrub oak (*Q. ilicifolia*) at varying stages of maturity, often depending on recent management. Depending on management history and successional stage, varying amounts of *P. strobus, P. resinosa, Q. rubra, A. rubrum, Populus* and *Betula* are also present, and *Vaccinium* is again a common component of the understory. A significant portion of the area is owned and managed by the New Hampshire Chapter of The Nature Conservancy (TNC), which has been attempting to restore pitch pine habitat through a combination of mowing, harvesting, and burning since 2007. Most field work at Ossipee was concentrated in a roughly 300 ha conserved area along the West Branch in Madison and Freedom (43.83486, -71.17541), although regional WPW surveys were conducted over a larger area as described in the appropriate sections below.

Habitats at the Ossipee Pine Barrens were previously classified into three types by TNC, based on a combination of tree size and density and dominant vegetation. "Thicket" sites were dominated by scrub oak and other shrubs, with trees generally spaced far apart. "Woodland" sites had higher densities of pines and fewer shrubs, although the pines usually did not form a closed canopy. "Forest" sites were dominated by older pines forming a partially closed canopy, with an uneven dispersion of shrubs (and these limited to edges or more open areas). An overview of management in the Ossipee study area is presented in Table 2 and Figure 2.

Methods

From 2008 to 2012, home ranges of Eastern Whip-poor-will were mapped at the Mast Yard State Forest in Hopkinton and Concord, NH. Similar but less intensive efforts occurred in the Ossipee Pine Barrens during the same period.

Home range mapping at both sites was done using a modified spot-mapping technique (Hunt 2009a). Multiple observers stationed themselves at fixed points and took simultaneous compass bearings on calling males, communicating these data via two-way radio. Bearings were plotted on Google Earth and the intersection used as the approximate location of the bird. Data were collected from mid-May through early August, and usually within a two-hour period after

sunset or before sunrise. When possible, individual birds were identified by a combination of location and simultaneous detection of other birds. Precision of all locations was recorded as either "high" or "low," a relative measure reflecting distance to birds, perceived location, and number of observers. Most triangulated locations received a "high" rating, and single observer locations a "low," with exceptions including birds very close to a single observer. When all locations were assigned to individual birds, it was possible to represent each territory with two minimum convex polygons: one using only high confidence locations and one including all locations. Territories were mapped at Mast Yard in 2008-12, and at Ossipee in 2010-11.

Data collected at Mast Yard were further supplemented by radio telemetry in 2010-12. Male WPWs were lured in with a playback of conspecific calls, and captured in standard mist nets (6 m long, 2 m high, 61 mm mesh). Birds were banded with a standard USFWS aluminum band and fitted with radio transmitters (Holohil BD-2: 1.5 g) using a modified harness technique (Hallworth et al. 2009). After a 24 hour waiting period, radioed birds were tracked both systematically and opportunistically until transmitter signals ended. Systematic surveys involved spending 1-2 hours following a single bird and getting its location every 5-10 minutes, depending on extent of movement. Additional locations were collected opportunistically on non-focal birds, for example while traveling to a focal bird, while tracking an adjacent focal bird, or during other activities (e.g., spot mapping, diurnal roost checks). Locations derived from telemetry were similarly categorized as "high" or "low" precision. A clear advantage of data derived through telemetry is that one obtains locations for birds when they are not singing, and home ranges thus derived are thus a more accurate representation of actual habitat use. Home ranges based on telemetry data were derived using the Kernel Density tool in the Spatial Analyst Toolbox Extension of ArcGIS 9.3, as well as through minimum convex polygons, the latter to facilitate direct comparison to spot-mapping data.

In the Ossipee area, spot mapping was supplemented by broader surveys that covered the entire extent of pine barrens habitat. These surveys employed some of the same multi-observer triangulation methods described above, but also used completely independent observers covering non-adjacent sites over a larger study area. These large-scale efforts were focused on estimating the total local population and overall dispersion rather than delineating the territories of individual birds. Such regional mapping efforts occurred primarily in 2011 and 2012, with limited coverage in 2007 and 2008.

Results

Mast Yard

Spot- mapping data were collected for over 50 birds at Mast Yard between 2008 and 2012, 43 of which were used in analysis (Table 3). In 2010-12, 10 radio transmitters were deployed at the site, two of which were placed on birds returning from a previous year (thus 10 transmitters on 8 birds). Because telemetry data do not cover the entire site, or all years of study, it was necessary to first evaluate the telemetry data on their own, and then compare them to the larger spot-mapping data set. The assumption here is that if conclusions based on telemetry data

are similar to those based on spot-mapping for the same birds, it would be acceptable to use the full spot-mapping data set for all further analysis.

Because one transmitter-bearing bird did not maintain a consistent home range (Hunt and Parent, unpubl. data), the effective sample size for telemetry is nine (7 individual birds, with 2 tracked in 2 successive years). While minimum convex polygons based on all telemetry data were always larger than those where low-precision data were excluded, the same was not true for home range kernals (50%, 75%, and 95% probabilities). As a result, all further analysis of telemetry data were based entirely on kernals, including the low-precision locations. Home ranges based on 95% kernals were consistently larger than field observations ever indicated as areas used by WPWs, and the 75% kernals were thus chosen as the most representative of WPW home ranges at the site. To facilitate future comparison with spot-mapped home ranges, 75% kernals were also compared to MCPs based on high-precision telemetry locations, and were not significantly different in size (Wilcoxin Signed-Rank Test: $T=16$, $n=9$, $p>0.10$).

To assess the spot-mapping technique, home range characteristics based on spot-mapping were compared to those based on telemetry for birds with both sets of data (N=8). The 75% kernals from telemetry data were not significantly different from spot-mapped MCPs (Wilcoxin Signed-Rank Test: $T=9$, $n=8$, $p>0.10$), although if an extreme outlier was removed the kernals became significantly larger (75% kernel=7.02 ha, MCP=5.38 ha; Wilcoxin Signed-Rank Test: $T=1$, $n=8$, $p=0.007$). MCPs and 75% kernals were also overlaid onto a rough habitat map (similar to Figure 1) to assess the proportion of each habitat within each bird's home range. For comparison to home range habitat composition, available habitat was calculated for 160 ha of the south-central and southeastern portion of Mast Yard (hereafter the "telemetry study area") that corresponded to all telemetry locations. The resulting home range habitat data were only analyzed for 2012, the only year for which a majority of birds (5 of 7) were mapped with both techniques in the telemetry study area. Although the overall frequency distributions were similar (Figure 3), home ranges based on telemetry tended to contain more forest and less wetland compared to those based on spot-mapping. Home range habitat composition as determined from either method differed significantly from available habitat in the telemetry study area (Chi-squares > 10, $p < 0.05$). However, because both home range sizes and habitat selection patterns were generally similar for both methods, and a much larger sample size was available via spot-mapping, all further analysis and discussion will be based on spot-mapping unless otherwise noted. The minimum convex polygons used to define home ranges were delineated using only the higher-precision spot-mapping locations.

Mast Yard consistently supported between 8 and 11 territorial male WPWs during the study period (Table 3, Figure 4). Home range size (based on high precision MCPs) varied from 0.77 to 12.98 ha across all birds and years, with an overall mean of 4.82 ha (Table 3). If lower precision locations were also used to delineate home ranges, the average size almost doubled. This pattern was most apparent in 2009, when a) there were fewer birds in the right-of-way and b) large home ranges in the north cut (Figure 4c). This estimate compares favorably with other published home range sizes, including 2.8-11.1 ha (Fitch 1958), 5.1 ha (Cink 2002), and 2.3-165.6 ha (mean ≈ 40 ha, Wilson 2003). The extremely large upper limit (and thus mean) in the third study suggests extra-territorial movement (Hunt and Parent, unpubl. data) and is probably not reflective of actual home range size.

As shown in Figure 4, WPWs tended to be concentrated in the eastern (along the powerline ROW) and western portions of the State Forest, with a concentration of variable size (1-3 birds) in the south-central section. In all three areas birds were associated with clearings, edges, or heavily thinned areas of more mature forest. In the summer/fall of 2009, an abutting private landowner conducted an extensive timber harvest on 20 ha near the northwest corner of the State Forest, and WPW occupied this newly opened area for the remaining three years of the study (Fig 4c-e). A similar, albeit less intensive, winter 2010-11 harvest by DRED in the south-central portion of Mast Yard did not have the same effect, although more WPW use in 2012 (Fig. 4e) could have been related.

When habitat within WPW territories is compared to overall habitat available at Mast Yard, WPW clearly prefer thinned areas, young forest, and wetland edges over unmanaged mature forest (Figure 5). These differences were significant in all years (Chi-square = 29-106, $p < 0.001$). Birds were never detected in the largely forested northeastern quadrant of the study area, including the northern half of the right-of way, and were generally rare in the central portion except where adjacent to openings. Consistently used features included the following (see also Table 1 and Figure 1):

a) 2009 harvest to north of Mast Yard
b) Thinned area and adjacent field edge at western end of Mast Yard
c) Two 3-4 hectare regenerating stands in the central portion of Mast Yard
d) A 3 hectare regenerating stand along Broad Cove Road
e) Areas of the powerline right-of-way dominated by taller shrubs (generally on either side of a shrubby wetland)

Telemetry also allowed for characterization of WPW roost sites (N=52) at Mast Yard. Although detailed vegetation data are not currently available, slightly over half of roosts (28) were in clearings dominated by dense shrubs or regenerating pines. The other 24 were in a variety of forested situations, ranging from small openings to denser pine forest. Birds typically roosted from the ground up to 1.5 meters, and above ground substrates included downed woody debris and horizontal branches of shrubs and saplings. In forested situations, at least 7 birds roosted on horizontal branches 3-5 m up in pines.

Ossipee Pine Barrens

Because survey effort varied between 2010 and 2011, it is not possible to directly compare WPW habitat use in Ossipee for the two years. The data do show that birds in both years tended to concentrate in the southeastern portion of the study area (immediately north of the extensive non-vegetated area in Figure 6) and were consistently absent in the northern third (not shown on Fig 6). Because there were fewer high precision locations from Ossipee spot-mapping, home ranges were based on all locations. With this method, maximum home range size averaged 5.90 ha in 2010 and 8.05 ha in 2011. The 2011 value is similar to that for Mast Yard using an equivalent data set (Table 3). Although unconfirmed in the absence of radio telemetry, there also appeared to be more extensive home range overlap at Ossipee than at Mast Yard.

Habitat in the southeast of the study area is dominated by a mix of open pitch pine woodland and open shrubby areas, much of the latter a result of burns in 2008 and 2009. Farther west, where WPW activity was generally lower, pines were more spaced and the habitat was dominated by sparse low shrubs regenerating from burns in 2007 and 2009. Habitat to the north fell into two categories, but prior to management was a primarily pitch pine woodland with a variable scrub oak understory. The eastern portion (adjacent to the core WPW area in 2010) was partially harvested and then burned in two phases during 2007 and 2008, resulting in an open savannah-like forest with very limited understory. Similar treatment occurred to the north in 2010. The northwestern part of the site remained untreated pitch pine woodland or forest at the time of study.

This pattern of available vs. used habitat suggests that, within the Ossipee study area, WPW showed preferences similar to those at Mast Yard (Figure 7). The most consistently used areas were either adjacent to an extensive opening or characterized by a heterogeneous mix of open forest, shrubs, and openings. Areas that are either too open or too forested (including hardwood stands) were generally avoided. Delayed use of the area harvested and burned in 2007-08 may be analogous to colonization of thinned forest at Mast Yard. Initial post-treatment conditions may not have been suitable (e.g., limited cover) but over time became more attractive to the birds. Note, however, that detailed data on habitat are less available for Ossipee, and these conclusions are based more on general impressions of vegetation structure.

Data collected during large-scale surveys support the contention that Ossipee supports the highest density of WPW in the state, with roughly 50-60 calling males present in the two surveys (Table 4). Birds are not evenly distributed in this area (Figure 8), and reach exceptionally high densities along an abandoned airstrip in the town of Freedom (Freedom Town Forest). By comparison, WPW density over the entire Mast Yard Study area is approximately 2.0 birds/km^2, or slightly over half that of the core WPW area at Ossipee.

Discussion

Data from this study support the previous observation that WPWs require some kind of open habitat when selecting home ranges. However, openness can be achieved in several different ways as evidenced by individual variation among birds at Mast Yard, and to a lesser extent at Ossipee. Birds at Mast Yard exhibited three broad home range types, as follows:

1) Shrubland-focused. Birds in this category tended to have relatively small home ranges centered on regenerating openings, as typified by WPWs occupying Units C, D, and I on Figure 1. Habitat in these areas was characterized by variable regeneration, resulting in a mix of dense saplings, open gaps, and patches of low shrubs. Birds spent considerable time within the openings, including roosting, and many other locations were still relatively close to the openings. Both Unit D and Unit I had been burned post-harvest, which may have been partially responsible for the heterogeneous vegetation at these two locations. In contrast, the other aspen regeneration stand from 1993 (Figure 1, Unit H) was not burned, and currently contains a denser stand of

taller aspen. WPWs used this area far less intensely than the nearby area that had been burned (Unit I). Examples of birds exhibiting this pattern are show in Figure 9.

2) Edge-focused. Birds in this category had home ranges that included a hard edge, usually along the powerline ROW but also adjacent to the clear cuts in the south-central portion of Mast Yard. Birds adjacent to the mowed field just west of the study site could also fall into this category, although they also show characteristics of the following one. In the case of ROW birds, non-forest habitat comprised up to 50% of home ranges, and birds regularly used both forest and shrubby areas in the ROW (including for roosting). Extensive areas within the ROW with limited woody vegetation ("poorly vegetated" in the habitat classification) were rarely used, and this avoidance may partially explain the absence of WPW from the northern section of the ROW. The WPW whose home range included the 2011 clear cut (Figure 1, Unit E) in 2011 and 2012 followed a similar pattern in that it was almost never recorded within the cut. The absence of a bird in this area prior to cutting suggests that the new edge attracted it to the site, and its home range expansion to the north in 2012 may have been a delayed reaction to the crop tree release of 2011. Examples of birds exhibiting this pattern are shown in Figure 10.

3) Forest-focused. Birds in this category had home ranges that rarely included an obvious open habitat feature like a powerline or clear cut. Instead they tended to occupy areas where mature forest had been thinned to some degree, resulting in a network of skid trails, strip cuts, or both. Home ranges in this category tended to be larger than those in the previous two, suggesting that a larger total area was needed to encompass sufficient open habitat for foraging. Birds that occupied the 2009 harvest north of Mast Yard (Figure 1, Unit A) typify this category. These individuals often sang from slash piles or the edges of skid roads. In all five years of study, a single WPW established a home range at the extreme western end of Mast Yard, in an area that had been thinned in 2003 (Figure 1, Unit B). The strip cuts in this unit were dominated by young pine. This is in contrast to two other portions of Mast Yard that were strip cut in 2003 (visible in Figure 1 but not labeled). The strips in these areas contained more briars, and perhaps the taller trees in the uncut strips lowered the overall areas' suitability for WPW. Examples of birds exhibiting this pattern are show in Figure 11.

Home ranges in the Ossipee Pine Barrens partially fit into the same general categories of habitat, although the more uniform nature of the study area makes the distinctions less clear. Birds are clearly more densely packed into the "thicket" area south of the West Branch. This area has a mix of openings (resulting from fire or harvest) and open forest, and most closely resembles the "shrubland-focused" home range type from Mast Yard. A key difference is that there are not discrete units of early successional habitat embedded in an otherwise mature forest matrix. Birds at the southeast corner of the Ossipee study area are analogous to the "edge-focused" home ranges at Mast Yard in that the forest is largely unmanaged but there is an extensive adjacent open area (a gravel pit) for foraging. Finally, although data are limited, home ranges on the north side of the West Branch are similar to the "forest-focused" home ranges at Mast Yard. This area still contains tall trees, but the understory is more open than analogous

areas at Mast Yard. The greater openness may be partially responsible for lower WPW densities or delayed colonization compared to other habitats at Ossipee. Birds consistently avoided an area dominated by scrub oak in the southwest portion of the study area (Figure 6).

Away from the core West Branch study area, high density WPW sites at Ossipee corresponded to a combination of edge- and forest-focused landscapes. A loose cluster of birds south and southeast of the study area occupy areas characterized by edges, including an airstrip, recent cut, and open developed area (Camp Calumet). Farther east, the high density cluster of birds along an abandoned airstrip in Freedom (Figure 8) uses both the immediate airstrip edge and a network of old roads through somewhat open forest. Birds in the airstrip area consistently avoid the nearby hardwood-dominated stands to the east and west.

The broad habitat features selected by WPW at Mast Yard and Ossipee conform to those reported by other studies. Garlapow (2007), working in pitch pine habitat on Cape Cod, found that birds preferred pitch pine/oak habitats over pitch pine/scrub oak. The preferred habitat in this case contains a more open understory, similar to the thinned pine habitats used at Mast Yard. Birds on Cape Cod also avoided areas dominated by scrub oak, a result similar to the pattern at Ossipee. In managed forest in North Carolina, there were more detections in regenerating stands than in forest, and all detections tended to be within 100 m of an edge (Wilson and Watts 2008). At the landscape scale, Hunt (2006) found that WPW were more likely to be found in areas with a) relatively high open habitat to forest ratio and b) low percentage of developed land, and that they were strongly associated with pitch pine when the latter was present.

Management Recommendations

Effective management for WPW in New Hampshire (and elsewhere in the Northeast) will depend on two things: appropriate techniques and appropriate landscape focus. Even if particular management practices are known to benefit WPW, they are less likely to have an effect if implemented in areas that are less likely to support suitable habitat or that are not in or near areas known to support the species. There is a wealth of anecdotal evidence that WPWs are absent from locations that appear to contain suitable habitat, but these areas tend to be distant from the species' core distribution in the state. As a result, they are less likely to be discovered and colonized by dispersing birds on a regular basis. To this end, delineation of focal areas is a useful first step in directing future management.

Whip-poor-will Focal Areas

Based on the core distribution of WPW in New Hampshire, two areas have been identified where management is most likely to benefit the species (Figure 12). These areas are characterized by higher densities of WPW, more frequent reports of the species, and a greater extent of apparently suitable habitat. Three secondary focal areas have been identified based on the same general characteristics, although WPW presence in these locations is significantly lower than in the primary focal areas.

It is important to note that not all locations within focal areas are equally suitable for WPWs, and thus amenable to future management. More detailed maps of the two primary focal areas are presented in Figures 13 and 14, with internal priorities as described below. The general habitat and landscape features listed here can also be applied to the secondary focal areas. One of the most prevalent features associated with WPW occurrence in focal areas is the presence of relatively well-drained soils. These sandy or loamy soils tend to occur in river valleys and outwash plains in southern and central New Hampshire, and often support pine forests of some sort. Well-drained soils are likely also of benefit to WPWs because the birds' eggs are laid directly on the ground, and thus highly susceptible to even minor flooding. Well-drained soils were also an important component of the pitch pine distribution model used in the New Hampshire Wildlife Action Plan, and this layer may be a better predictor of WPW presence than soils alone (e.g., Hunt 2006).

If these two layers are superimposed on the focal areas, the result is a clearly defined zone that represents where WPW are most likely to occur within focal towns. For the Ossipee focal area (Figure 13), this zone is centered on an area between Silver Lake and the outlet of Ossipee Lake, with extensions up the Bearcamp and Pine Rivers to the northwest and south. Almost all recent WPW records from this area have been from the modeled pine barrens habitat (Figure 8). An additional area of predicted pine barrens is evident in the town of Conway just to the north, but Conway was not included in the focal area due to a lack of WPW records. However, there is certainly potential for birds to occur in this area given its proximity to the Ossipee Pine Barrens proper.

The Upper Merrimack Valley focal area (Figure 14) is roughly twice the size of Ossipee, and includes portions of the Merrimack River valley and several tributaries (particularly the lower Contoocook, Soucook, Suncook, and Piscataquog). Again, areas modeled as pine barrens tend to have the most records of WPW, although in this case there are also significant numbers in the Piscataquog drainage in Weare. The latter may be partially a result of higher disturbance levels associated with the Hopkinton-Everett Flood Control Area. WPW also occur regularly in the vicinity of the Blackwater River in Webster. Predicted pine barrens in southwestern Belknap County (Tilton and Belmont) and along the Suncook River in Epsom may also be suitable sites for WPW, but the lack of recent records precluded them from being included in the focal area. At the southern end, Manchester has been excluded because most of the suitable habitat there has already been developed.

Focal Habitats

The majority of WPW records in New Hampshire are from habitats dominated by pines, and recent sightings from pure hardwoods are exceedingly rare. Because of this, management specifically targeted toward WPW should be discouraged at hardwood sites, which instead may be better managed for early successional songbird species. Areas where management is most likely to be successful – even within appropriate habitat in focal areas – are those where there has been some history of WPW use, or which are close to already occupied areas. As noted above, pine or pine/hardwood forests on well-drained soils are more likely to contain suitable habitat, or habitat that can be made more suitable through management. In the absence of a soils

map or other soils data, gravel or sand pits are good indications of appropriate soils in an area. Forests on slopes are generally avoided unless underlain by very rocky substrate.

At a stand scale, more open forests with a variable understory appear more suitable. There are few records from pine plantations, stands with complete canopy closure, or forests with a consistently dense shrub layer. However, there is a point at which a forest becomes too open, presumably because there is reduced cover for nesting. The presence of a nearby opening or disturbance (ROW, field, past timber harvest, gravel pit, etc.) can make a pre-treatment site more suitable to begin with, and subsequent management could build upon such existing landscape features where possible and feasible.

Data on the value of wetlands to WPW are equivocal. Birds appear to select them at Mast Yard, but not at Ossipee, but this difference could be due to a higher incidence of wetlands at the former, or their proximity to other preferred habitat types. And while wetlands fell within WPW home ranges, very few actual spot-mapped or telemetry locations were actually within the wetlands proper. In this context, wetlands probably function as an alternate type of edge, and used primarily for singing locations or open areas over which to forage. It is thus unlikely that wetlands are a significant feature of WPW habitat in their own right.

Management Practices

Probably the most effective way to enhance habitat for WPW is through harvest. Not all harvest techniques are equally effective, and only those that open up relatively large areas of canopy – with resultant regeneration – are considered. The silvicultural practices listed below come from *Good Forestry in the Granite State* (Bennett 2010).

1) Clearcutting. Clear cuts in and of themselves are not necessarily attractive to WPWs for a few years (e.g., 3-5) following harvest. This may be because they lack any significant vegetative features such as patchy shrubs. However, if a clear cut is adjacent to otherwise suitable forest (e.g. an open canopy achieved through natural or silvicultural means), it may be used by WPWs for foraging from its edge. Once a clear cut starts exhibiting a more varied regenerative structure (5-8 years post harvest) it is more likely to be attractive. Some evidence from Mast Yard suggests that a post-harvest burn may result in more heterogeneous regeneration and make such cuts even more suitable to WPWs. There are no data that allow for rigorous evaluation of the effects of cut size on WPW, but anecdotal information suggest that smaller cuts are less likely to be occupied. At Mast Yard, two small (<1 ha) log landings were rarely used by WPW, but this could also be because of limited regeneration. However, such cuts can provide an attractive edge if surrounding forest is suitable for the species' needs. A similar practice - Group Selection – is included here because the ultimate result is the same: trees are completely removed from an area of forest. However, group cuts tend to be relatively small (< 1 ha) and in this context may not be large enough to be used by WPW on a regular basis. At the opposite extreme, other studies have shown that WPW are usually within 100 m of an edge (Wilson and Watts 2008), suggesting that clear cuts larger than 5-6 ha could have unused interiors and thus not be fully used.

2) Overstory Removal. This practice removes larger trees while leaving the understory of saplings and shrubs relatively unaltered. The result can be a dense area of young growth interspersed with openings resulting from both skid roads and the overstory removal itself. A 3 ha patch treated this way at Mast Yard was regularly used by WPWs for both foraging and roosting. A benefit over clearcutting is that the relatively unimpacted shrub layer is probably more attractive to WPW in the short term.

3) Crop Tree Release. In a crop tree release (CTR), some percentage of trees is removed to enhance growing conditions for pre-identified dominant or co-dominant trees. The result is a variable degree of opening in both the canopy and understory that may be attractive to WPWs. However, limited data from Mast Yard suggest that such a forest is less attractive to WPWs than one with more extensive cutting, and in this regard a CTR may be more similar to a shelterwood cut (below). Areas of open understory resulting from CTR may be used as part of a WPW home range if other suitable habitat features (e.g., clear cuts) are adjacent or nearby.

4) Shelterwood and strip cuts. These two common forestry techniques can also result in a mosaic of forest types, but may not result in habitat configurations attractive to WPWs. This may be because the openings that are generated are relatively narrow, in which case a more extensive shelterwood cut may be more effective. But in either case, available data suggest that more extensive harvesting as discussed above is more likely to generate the appropriate early successional structure.

Comparison of CTR and other partial cuts at Mast Yard with the private cut to the north (Figures 1 and 11) suggests that heavier thinning is more likely to provide suitable habitat for WPW in the short term. In this particular case, relatively heavy cutting combined with an extensive network of roads and skid trails resulted in perhaps 50% or more of the site being open. As such a harvested site ages, however, it may become unsuitable more quickly as herbaceous growth and regeneration fill in the relatively narrow gaps. This successional process may be one reason that the fairly narrow 2003 strip cuts at Mast Yard are not used by WPW, and the thinned area of Unit B (Figure 1) only supported 1-3 birds during this study, as compared to 3-5 in the similarly-sized Unit A. Detailed data are currently unavailable to assess how long birds will use such thinned stands, although anecdotal information suggests it may be a little as 15-20 years. Another option is to combine thinning with complete harvests (either clear cuts or overstory removal) on smaller parcels. The latter areas will persist as suitable WPW habitat for a longer period (especially if periodically maintained), and perhaps serve as foci for WPW activity (as they appear to have done at Mast Yard).

Powerline rights-of-way are something of a unique situation. Ideally, these can be maintained as shrublands adjacent to forest indefinitely through selective harvest of taller trees (e.g., those that a growing into the zone where they are more likely to interfere with transmission lines). Selective harvesting of this sort allows the shrubby or open understory to persist, whereas more broad-based approaches such as mowing (and some herbicide treatments) would eliminate all ROW vegetation to the likely detriment of WPW use (as per clear cuts). Forest landowners

who abut ROWs and who are interested in enhancing habitat for WPW might consider implementing forestry on areas adjacent to the ROW. This may be of particular benefit if the adjacent forest is dense or overly shrubby, in which case a small group cut could improve nesting habitat while the ROW continues to provide foraging habitat.

Prescribed Burns are a special case of WPW habitat management. Burns are the preferred method of maintaining or restoring pine barrens habitat, in part because pitch pine germination is facilitated by fire. In most NH barrens, fire is combined with some other management technique (usually mowing and/or tree harvest) that first opens up the understory. This combination serves the dual purpose of removing potentially competing species and reducing fuel loads and the risk of wildfire. The extent of pre-burn treatment may be important in determining the future suitability of a site for WPW. Based on observations at Ossipee, extensive areas of shrub mowing combined with tree removal result in sites characterized by widely scattered trees. After a burn, and the elimination of remaining woody debris and herbaceous vegetation, such sites resemble savannah, and are rarely occupied by WPW. After a few years however, as regenerating shrubs become larger, the birds are more likely to use the site, but even then appear to occur at lower densities or be concentrated at the edges of the treated area. Burning in the absence of mowing or burning, or more selective tree/shrub removal, seems to result in habitat patches more attractive to WPW. As in traditional harvest-only management, proximity to otherwise suitable habitat will increase the chances of WPW using sites that would otherwise be too open.

As noted above, a prescribed burn post-cut may result in suitable habitat for WPW even if pine barrens vegetation is not the management objective. Of the three Mast Yard clear cuts dating to the 1990s at Mast Yard, WPW activity was far more consistent at the two that were subsequently burned. These sites also differed by being more open, with highly variable regeneration, while the unburned site was dominated by denser and taller aspen. Presumably, burning had some uneven effect on aspen regeneration that resulted in more heterogenous site conditions in subsequent years.

Because WPWs nest directly on the ground, management operations should not occur during the peak breeding season (mid-May through late July) if birds are present on a site. If needed, the presence of birds can be determined by conducting 2-3 evening surveys during peak lunar conditions during this period (half hour after sunset on clear nights during the week preceding a full moon, Hunt and Gallo 2007). Limited evidence from Mast Yard State Forest suggests that harvests in unoccupied areas *adjacent* to occupied ones may facilitate more rapid colonization during subsequent breeding seasons.

One other factor to consider when contemplating WPW habitat management is the effects of various practices on Lepidoptera communities. Moths comprise a significant portion of WPW diets (Cink 2002), and there has been speculation that population declines could in part be the result of historic declines in large moth species (e.g., Sphingidae, Saturniidae). These declines may in turn be due to historic chemical and biological control of gypsy moths (*Lymantria dispar*) (Schweitzer 2004). Given potentially reduced abundance of large moths, any additional impacts on WPW prey availability could have cumulative impacts on foraging success and productivity. While data on the effects of forestry on moths are limited, there is some evidence that diversity is

more strongly reduced in stands subject to clearcutting when compared to more selective harvest techniques (Summerville and Crist 2002, Summerville 2011). How this might apply to WPW habitat is unknown, but is presented here for potential consideration.

Acknowledgements

Funding for research on Eastern Whip-poor-wills in New Hampshire since 2003 has come from a wide variety of sources, including the Piscataquog Watershed Association, Russell Piscataquog Watershed Foundation, Nuttall Ornithological Club (Charles Blake Fund), Northeast Coordinated Bird Monitoring Partnership (through a USFWS Multistate Conservation Grant to the American Bird Conservancy), Norcross Wildlife Foundation, N.H. Fish and Game Department (through State Wildlife Grants), and multiple private donations. Permission to conduct research at Mast Yard and Ossipee was granted by the N.H. Division of Forests and Lands and N.H. Chapter of The Nature Conservancy, respectively. Additional permissions were granted by Dennis Barnard and Dennis Travers, owners of private land abutting the Mast Yard State Forest. Inge Seboyer and Jeff Lougee provided critical information on past management history at Mast Yard and Ossipee. Vanessa Jones did all the GIS work. The results reported here would not have been possible without the assistance of several paid and volunteer field technicians, in particular Kyle Parent, Kathy Gunther, Rob Woodward, Steve Manifold, Chele Miller, Robert Quinn, Rebecca Webster, Jennifer Salchunas, and Nate Handwerker.

Table 1. Overview of management at Mast Yard State Forest and vicinity since 1993. See Figure 1 for locations of stands and other features.

Fig. 1 Code	Stand *	Area (ha)	Management	Year	Current Habitat
A	North Cut	20	Partial harvest (details unavailable, but ≥50%)	2009	Thinned Pine
B	Stand 18 (approx)	20	1/3 cut in 33' strips	2003	Thinned Pine
C	Stand 17	3.2	Overstory removal (shrubs/seedlings retained)	1999	Young Pine
D	Stand 16 (Bean Lot)	3	Clear cut 1996, brush saw 2000, burn 2001	1996+	Young Hardwood
E	Stands 7 and 14 (in part)	3	Clear cuts	2011	Poorly Vegetated
F	Stands 2 and 7 (in part)	30+	Crop tree release (30-40% density reduction)	2011	Thinned Pine
G	Powerline right-of-way	13	Occasional mowing	Var.	Poorly Vegetated
H	Stand 9	5	Clear cut	1993	Young Hardwood
I	Stand 28	3.5	Clear cut, spring burn 1994	1993+	Young Hardwood

* Based on N.H. Division of Forests and Lands maps.

Table 2. Overview of management at the West Branch portion of the Ossipee Pine Barrens 2007-2011. See Figure 2 for locations of management units and other features.

Fig. 2 Code	TNC Management Unit(s)	Area (ha)	Management	Year	Original Habitat
A	West Branch 4 and 8	26.5	Harvest and Burn	2010	Forest/Woodland
B	West Branch 5 and 9	15	Burn	2008	Forest
C	West Branch 1 and 2	7.6	Mow and Burn	2007	Woodland/Thicket
D	Thicket 1 and 2	9	Mow and Burn	2009*	Thicket
E	Thicket 3 and 4	6	Mow and Burn	2007	Thicket †
F	Thicket 7	14	Mow and Burn	2010	Woodland/Thicket
G	Thicket 8	9.2	Burn	2009	Woodland
H	S Jackman Ridge 1	2	Burn	2008	Thicket

* Area D was burned again in 2011, after the field season.
† Area E includes 2 small pine plantations that have not been treated to date.

Table 3. Overview of territory characteristics for WPW at Mast Yard State Forest, 2008-2012. Values are based on minimum convex polygons using only high-precision locations collected through spot-mapping. See text for details.

Year	# territories	Territory Size (hectares)			
		Min	Mean	Max	Expanded*
2008	9	2.29	3.75	6.74	6.79
2009	8	2.69	4.94	7.73	6.56
2010	7	1.49	6.42	12.98	13.61
2011	8	0.77	4.50	10.42	7.91
2012	11	1.18	5.01	9.66	8.80
Overall	43	0.77	4.82	12.98	8.45

* Mean home range size based on all spot-mapped locations for comparison

Table 4. Abundance and distribution of WPW in the Ossipee Pine Barrens during two coordinated multi-observer surveys. See also Figure 8.

Survey Section	**Number of Birds**		**Approx. Area (km^2)**	**Density (per km^2)**
	2011	**2012**		
Airstrip *	20	27	2.0	~10
West Branch/Windsock	22	27	5.7	~4
Camp Calumet	4	3	0.8	~4
Tamworth	3	2	2.7	~1
Total	49	59	15.0 †	3.6

* 19 birds were also estimated along the airstrip in 2008

† This total does NOT include the Tamworth survey section, but does include areas of unsuitable/unused habitat between the three other sections.

Figure 1. 2011 aerial photograph of Mast Yard State Forest (red outline) and vicinity, showing areas subject to management since 1993 and discussed in this report. See text and Table 1 for further details.

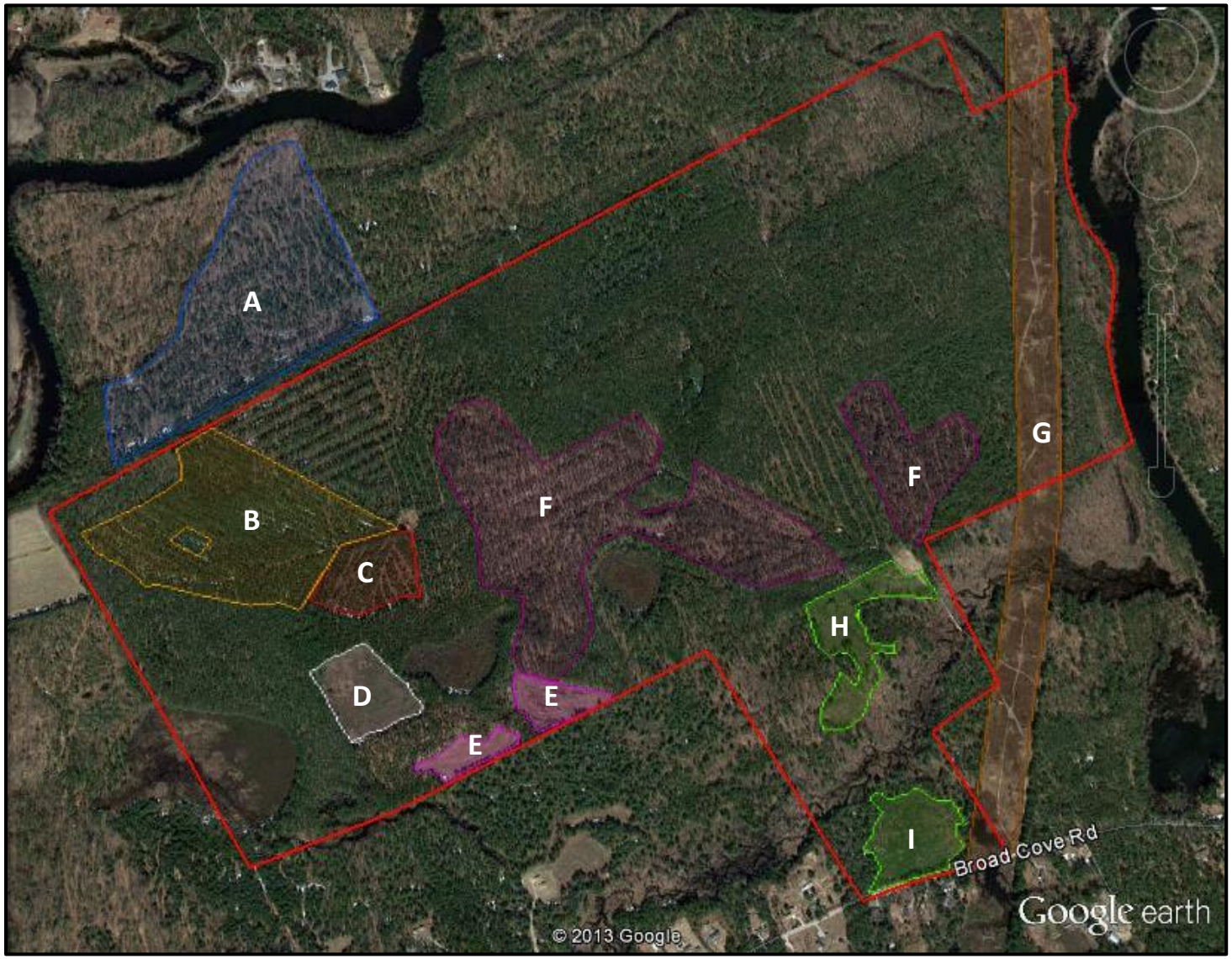


Figure 2. 2011 aerial photograph of West Branch area of Ossipee Pine Barrens and vicinity, showing areas subject to management since 2007. Colors indicate year in which units were burned. See text for and Table 2 for further details.

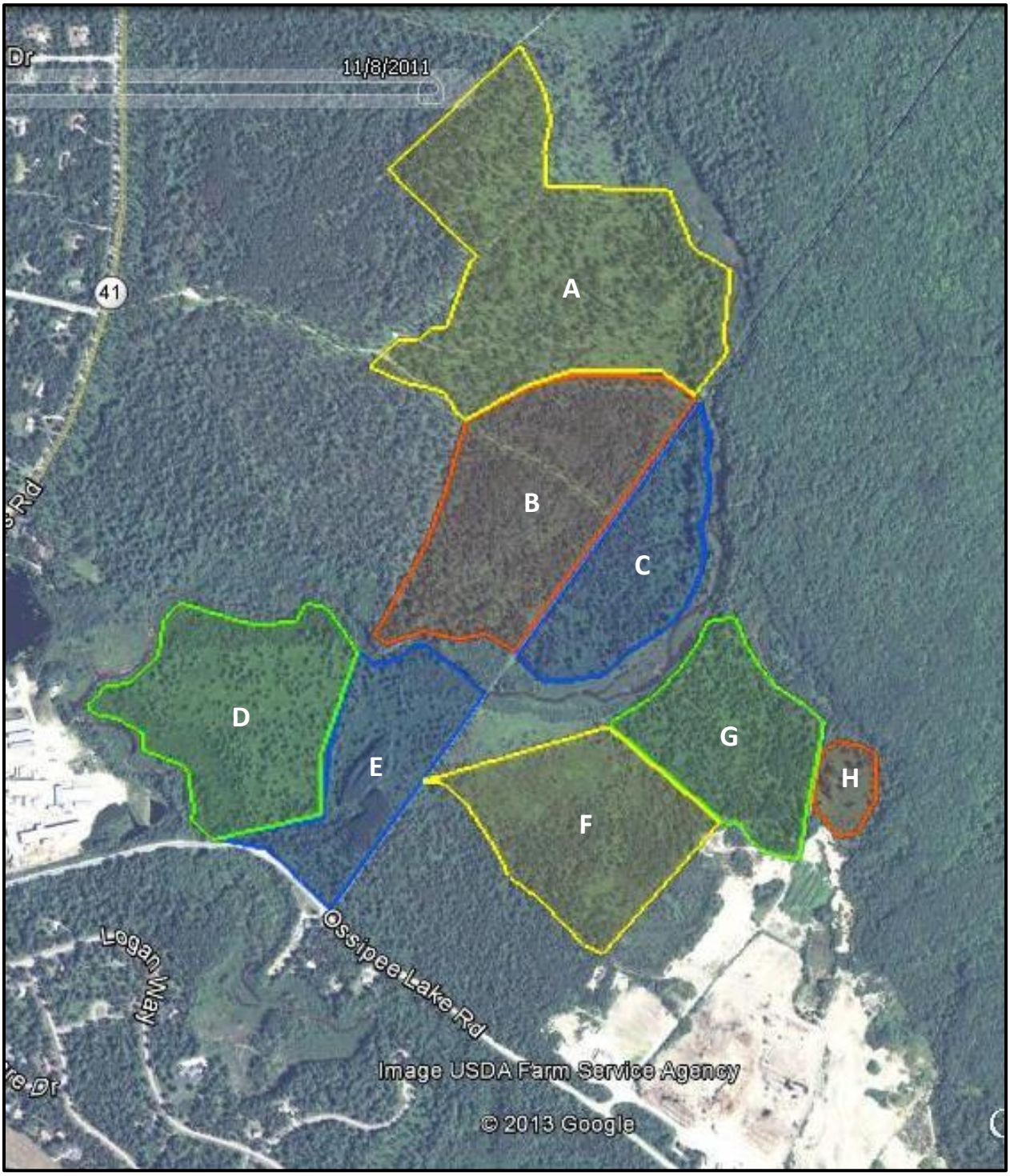


Figure 3. Comparison of home range composition based on spot-mapping and radio telemetry. Data are from five birds with extensive data from both methods in the south-central and southeastern portion of the study area in 2012. Habitat categories lumped from those in Figure 5 because of small sample sizes: 1) forest includes thinned pine and 2) shrub/sapling includes young pine, young hardwood, and poorly vegetated.

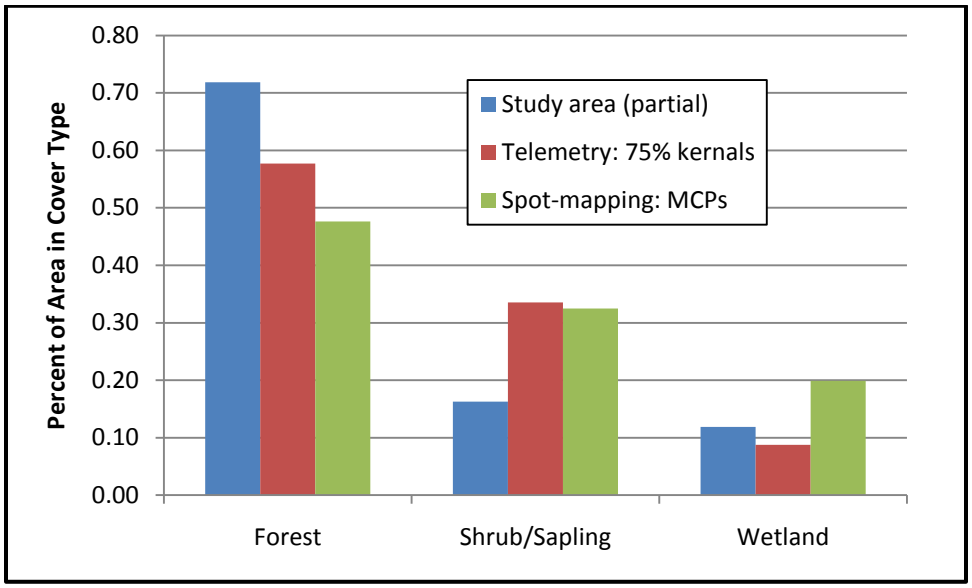
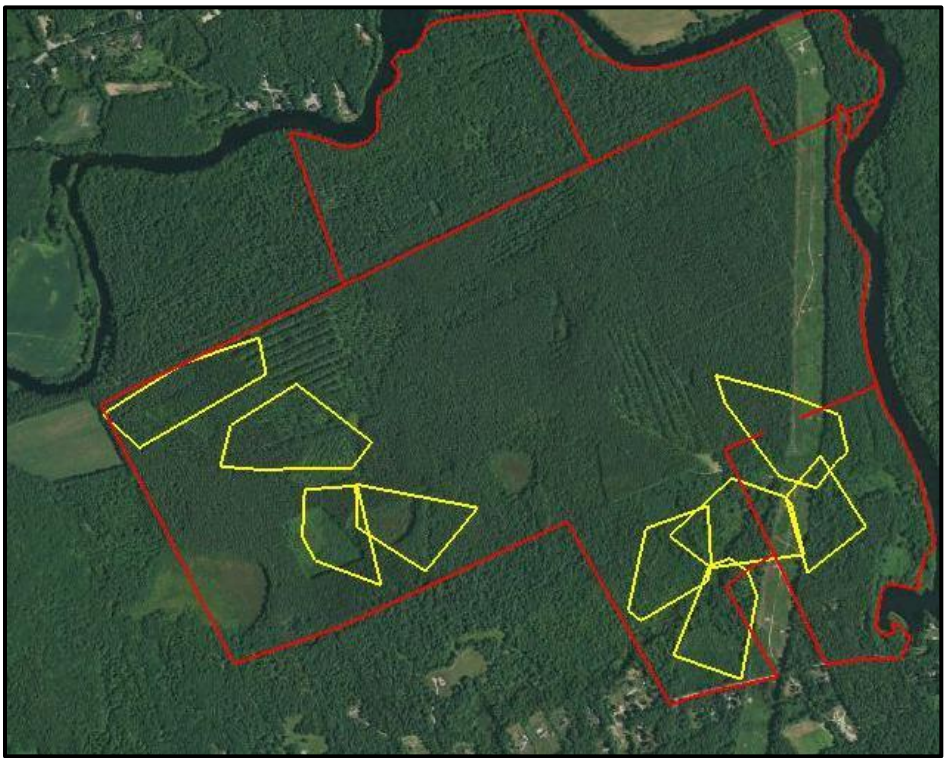
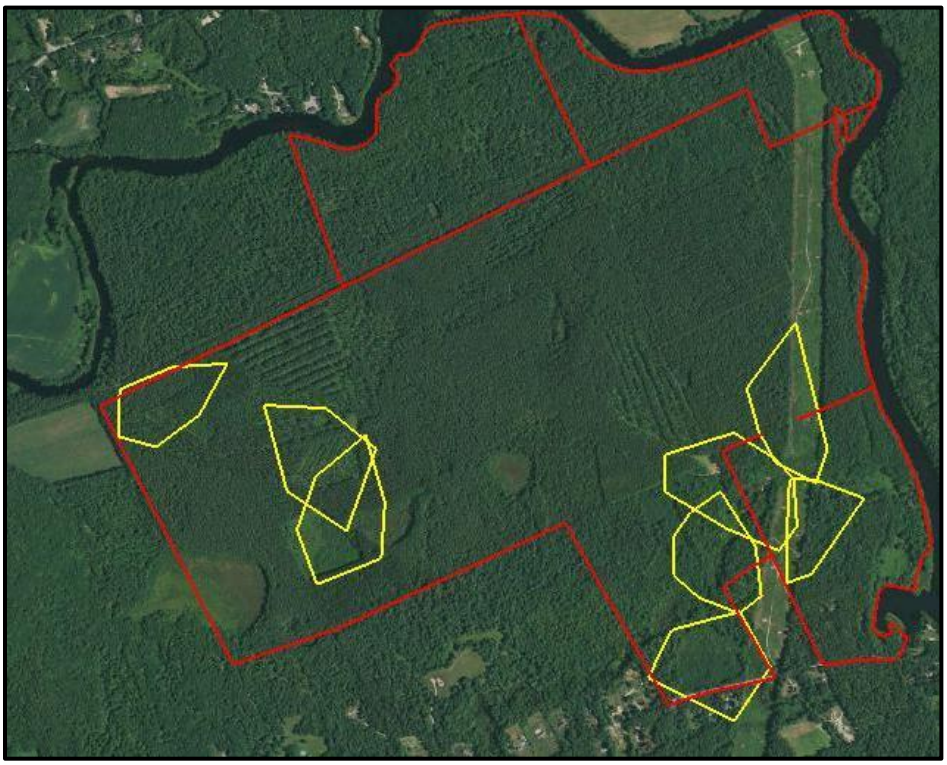


Figure 4. WPW territory locations at Mast Yard 2008-12. Note changes to habitat in northwest private parcel in 2010 and in south-central area in 2011.Red lines indicate conservation land.

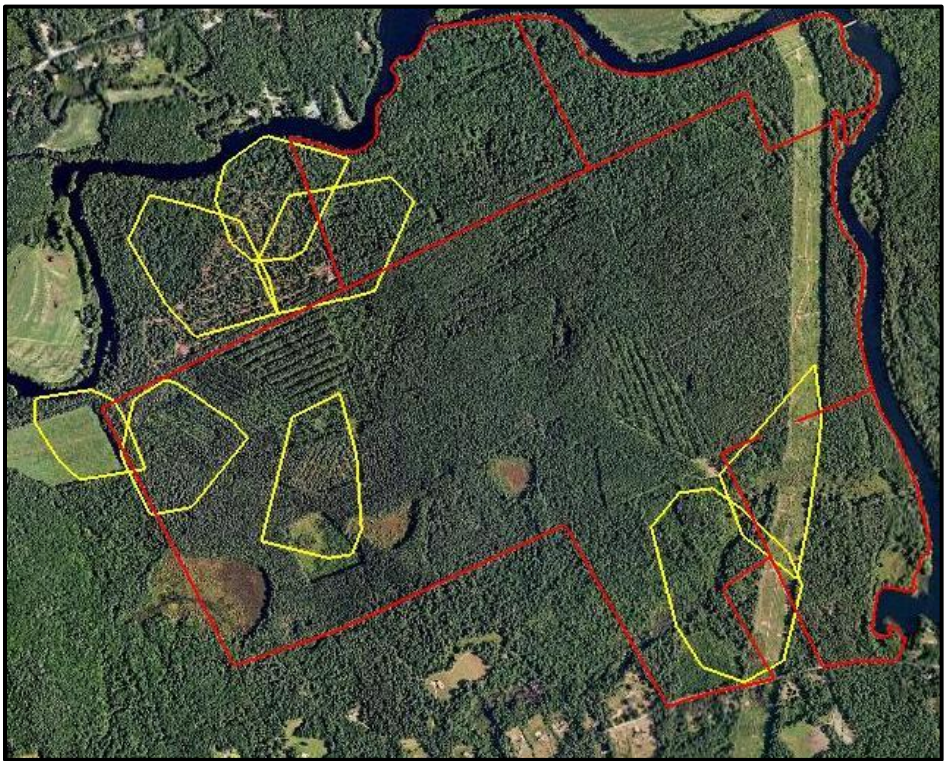


a) 2008

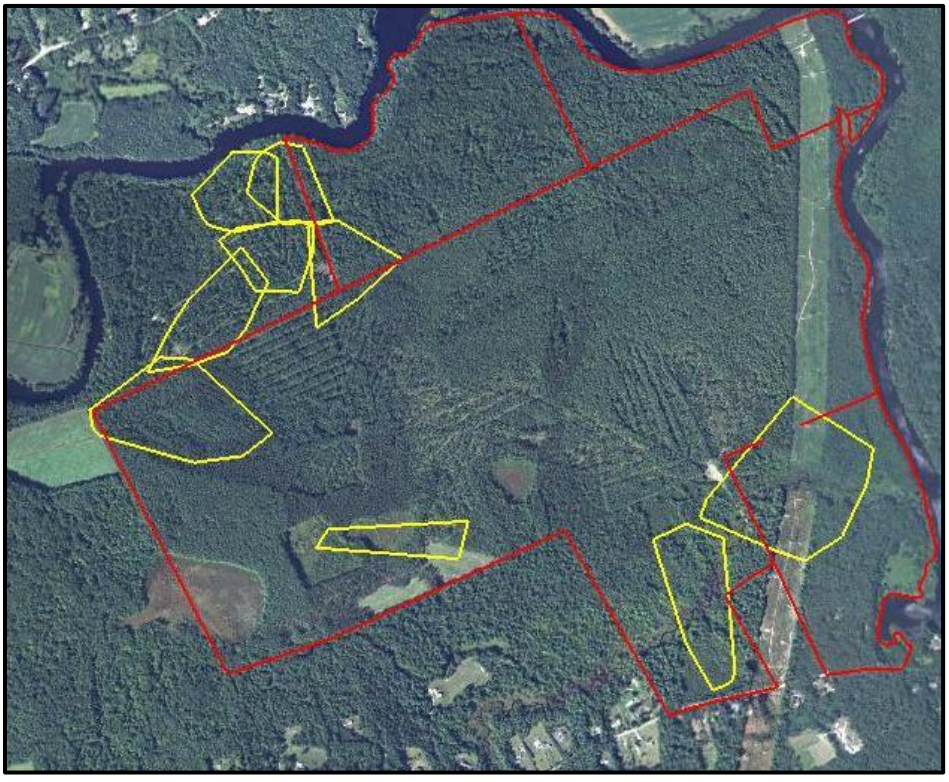


b) 2009

Figure B2 continued

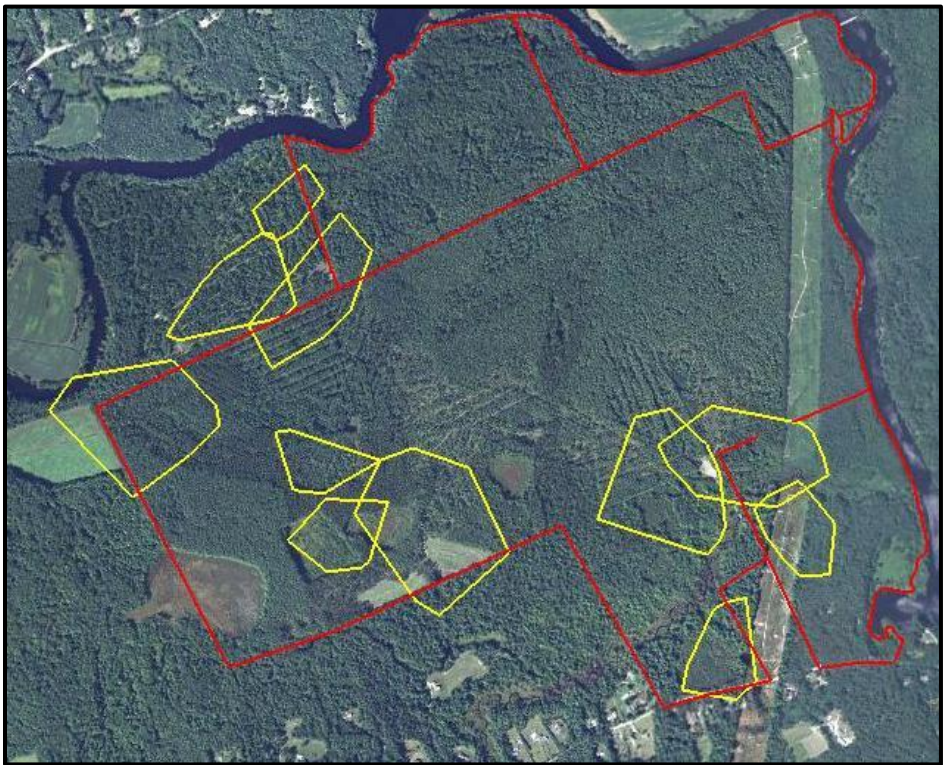


c) 2010



d) 2011

Figure B2 continued



e) 2012

Figure 5. Comparison of habitat composition of WPW home ranges with habitats available (= "study area") at Mast Yard State Forest. Changes to available habitat are the result of logging operations in summer-fall 2009 and winter 2010-11. Home range data calculated from minimum convex polygons based on high-precision spot-mapping locations (see text for details).

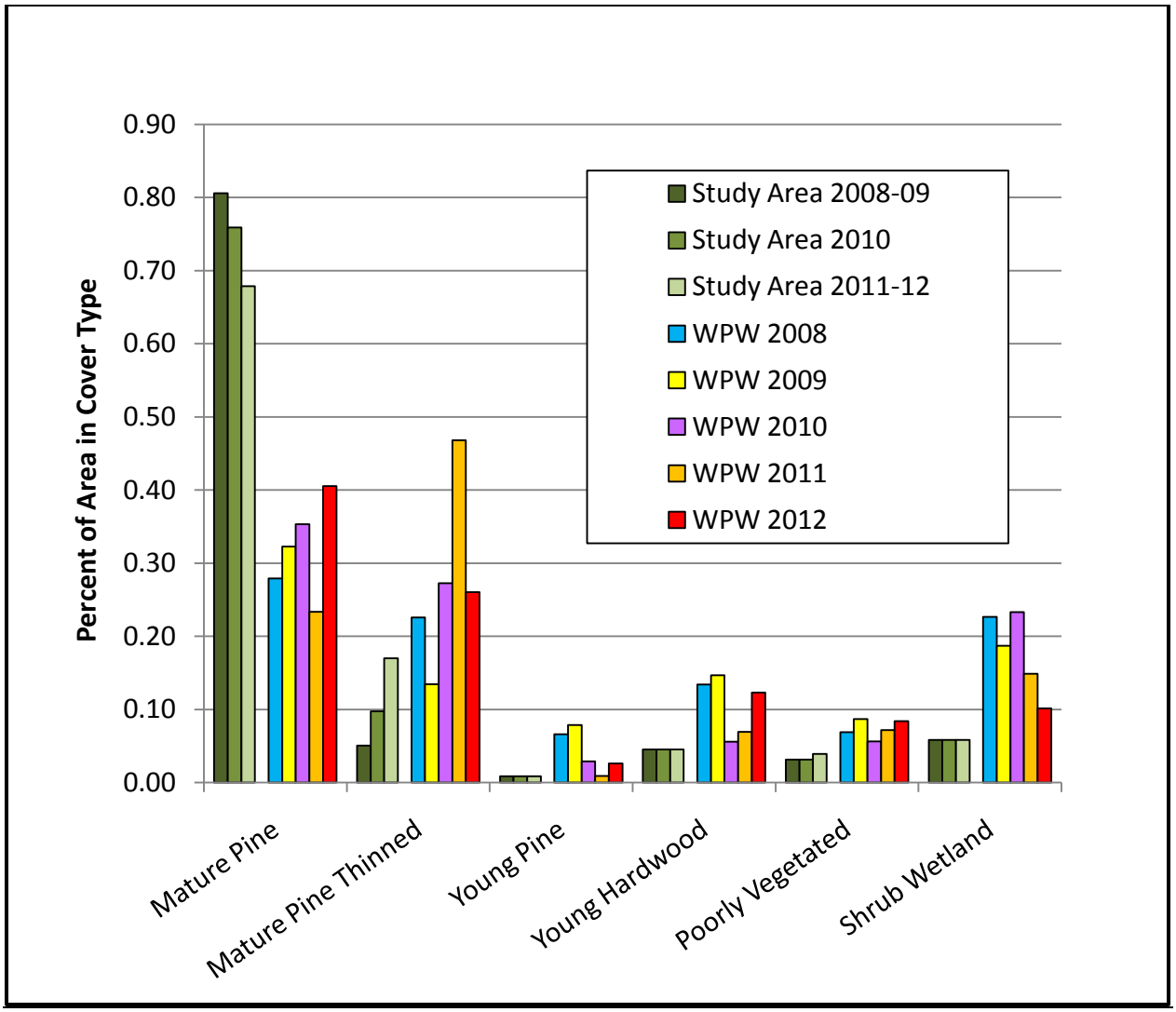


Figure 6. WPW territory locations (blue polygons) at the Ossipee Pine Barrens in 2010 (top) and 2011 (bottom). Shaded brown polygons represent total area managed by prescribed burn through each year. The higher number of territories in 2011 reflects a higher level of effort. Unoccupied northern third of study area is not shown.

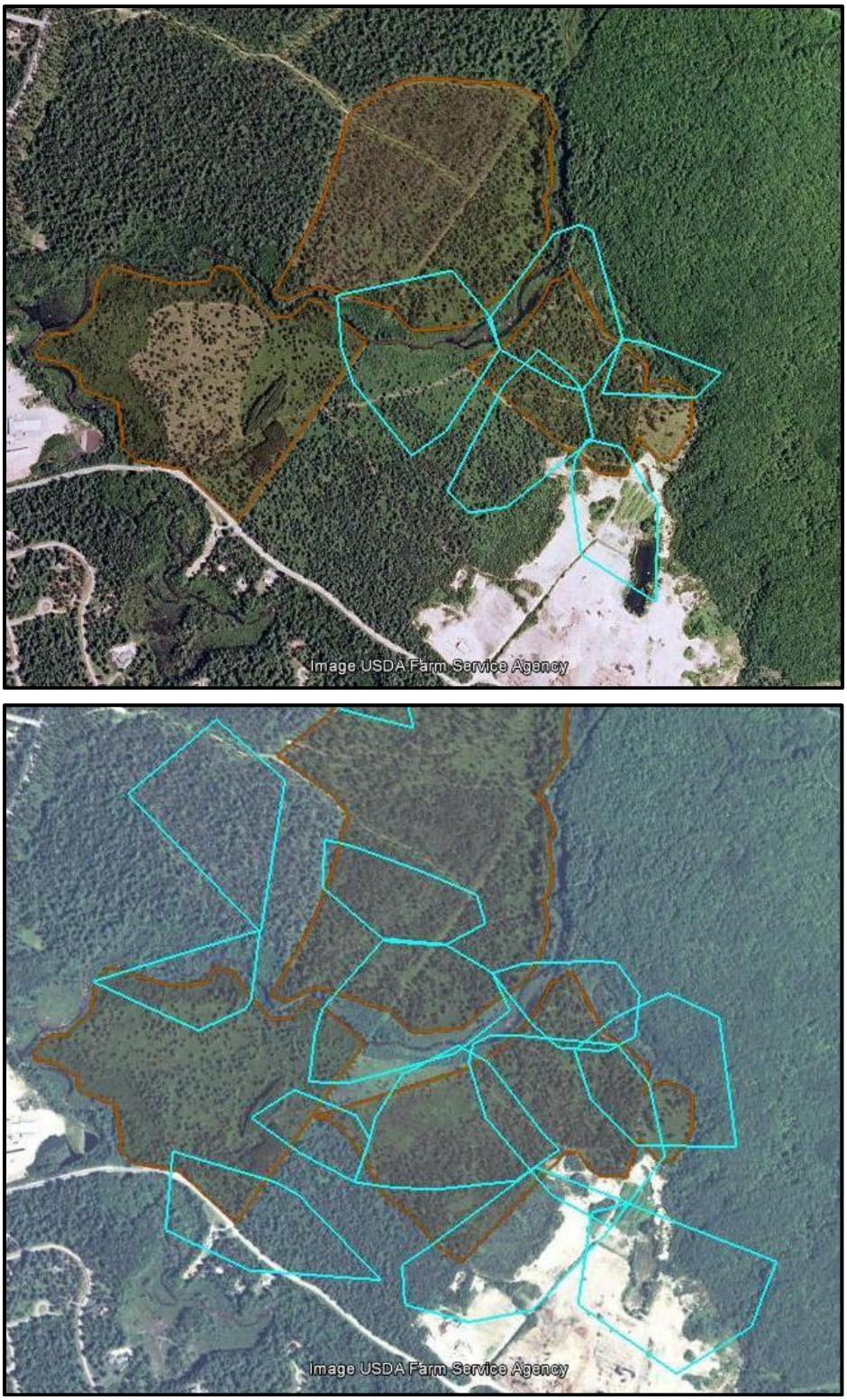


Figure 7. Comparison of habitat composition of WPW home ranges with habitats available at the Ossipee study area. Changes to available habitat are the result of management activity (Table 2) in the summer and fall of 2010. Home range data calculated from minimum convex polygons based on all spot-mapping locations (see text for details).

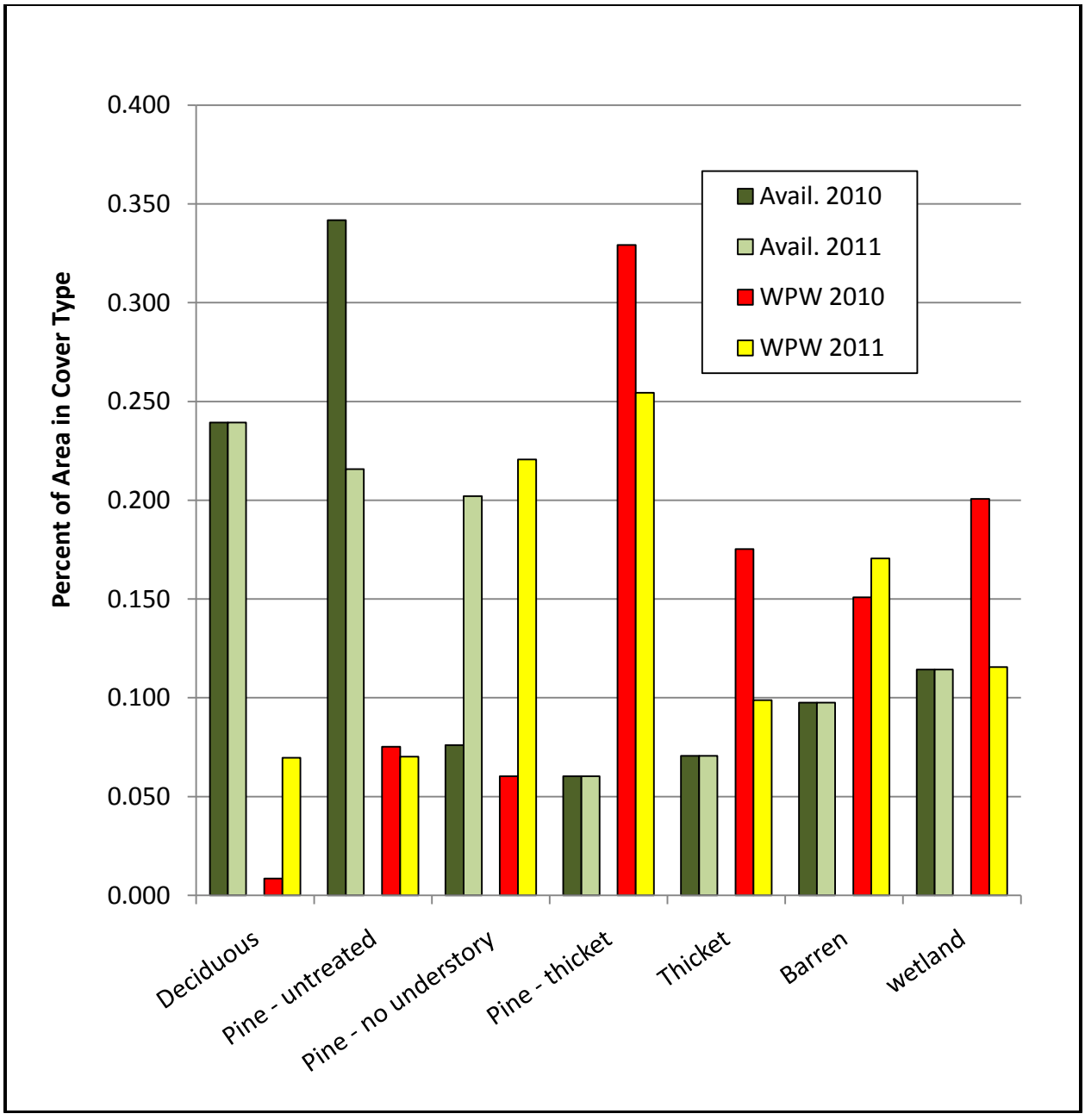


Figure 8. General distribution of WPWs during coordinated multi-observer counts in the Ossipee Pine Barrens in 2011 (top) and 2012 (bottom). Pink circles are approximate locations of singing WPWs. Purple shading indicates the approximate historic extant of pine barrens habitat. The Freedom airstrip (see text) is the easternmost linear cluster of WPW locations. See also Table 4.

Figure 9. Examples of Eastern Whip-poor-will home ranges that followed the "shrubland-focused" pattern. Left hand map (pink markers) shows locations of a 2010 bird that used the two regenerating stands in the central portion of Mast Yard, while the right hand map (orange markers) is a bird that used a similar stand in the southeast. In both maps, diamonds represent spot-mapped locations and solid symbols telemetry locations. Note the concentrations of locations in regenerating areas as indicated by polygons.

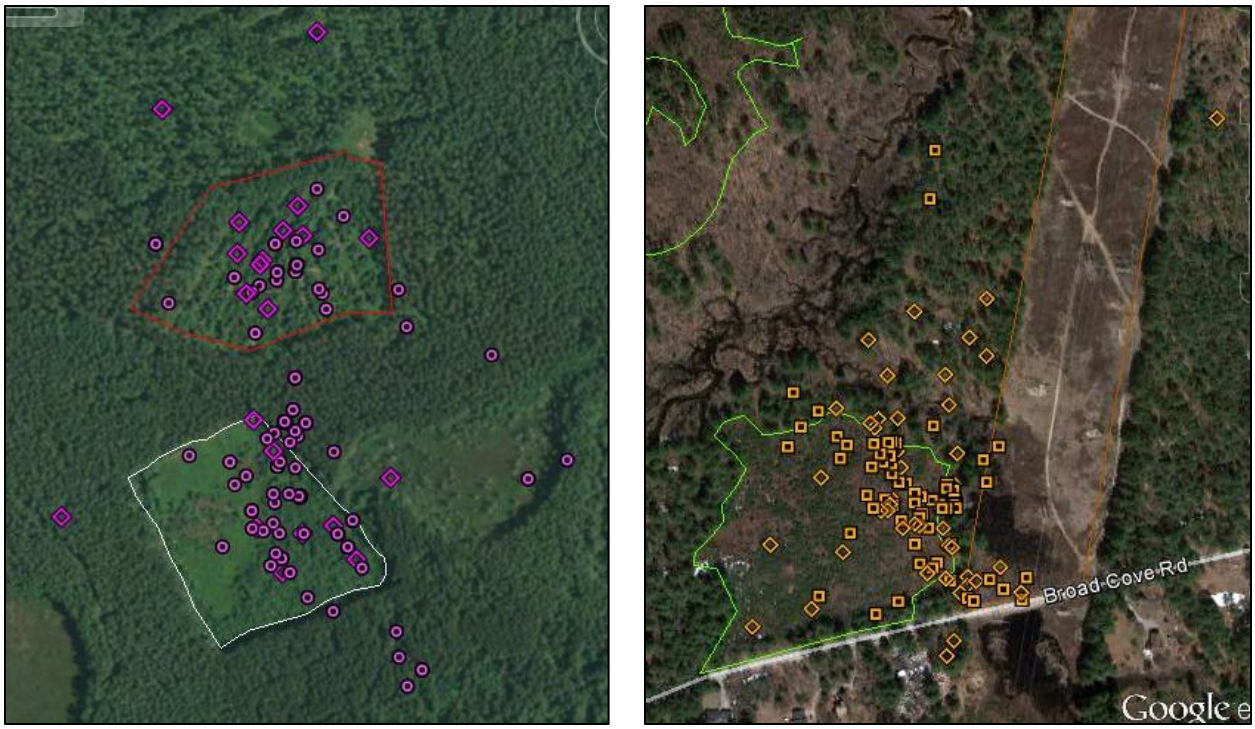


Figure 10. Examples of Eastern Whip-poor-will home ranges that followed the "edge-focused" pattern. Left hand map (orange and yellow markers) shows locations of a bird that abutted the 2011 clear cuts in the central portion of Mast Yard (orange=2011, yellow=2012). The right hand map (blue markers) is a bird that used the right-of-way in the east. In both maps, diamonds represent spot-mapped locations and solid symbols telemetry locations. Note the concentrations of locations along edges, and particularly the avoidance of the unvegetated clear cuts.

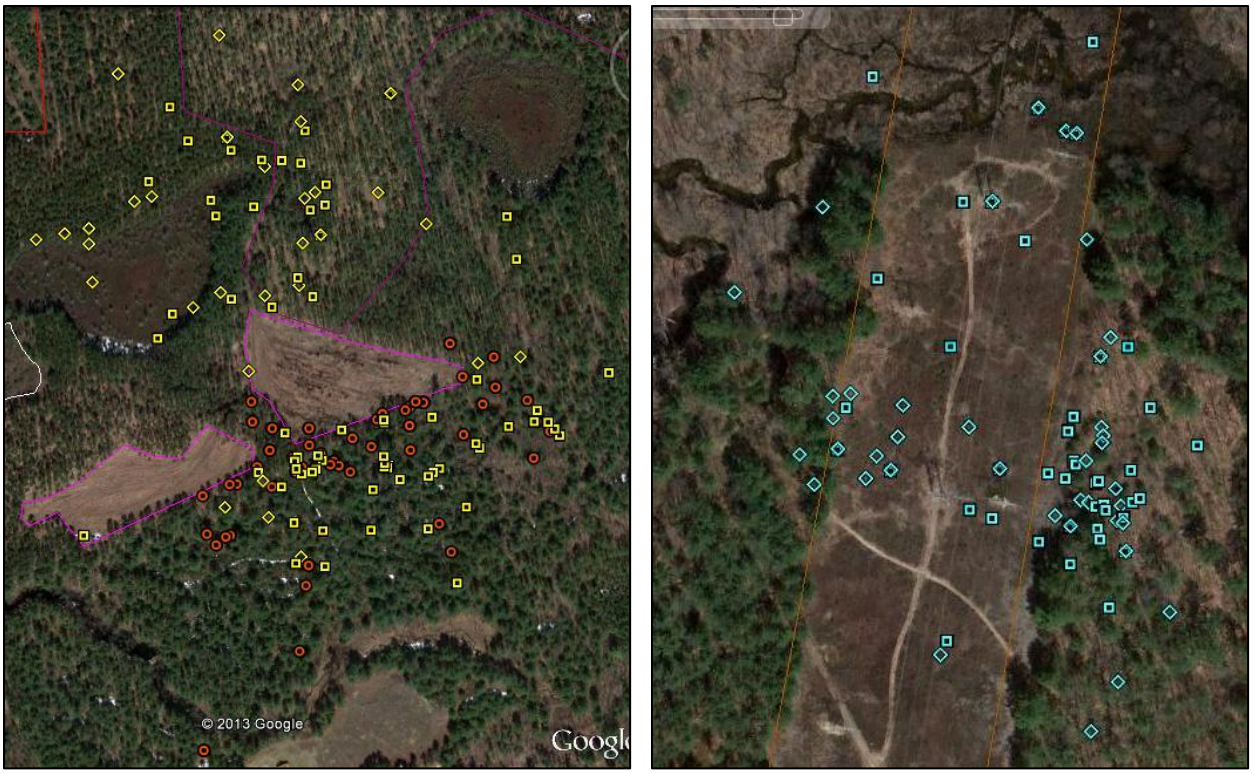


Figure 11. Examples of Eastern Whip-poor-will home ranges that followed the "forest-focused" pattern. Spot-mapped locations of five individual birds in 2011 are indicated by different colored diamonds, and the outline of the 2009 harvest is in blue. Note the relative absence of birds outside the harvest area, including pine forest to the east and south and hardwood forest to the northwest.

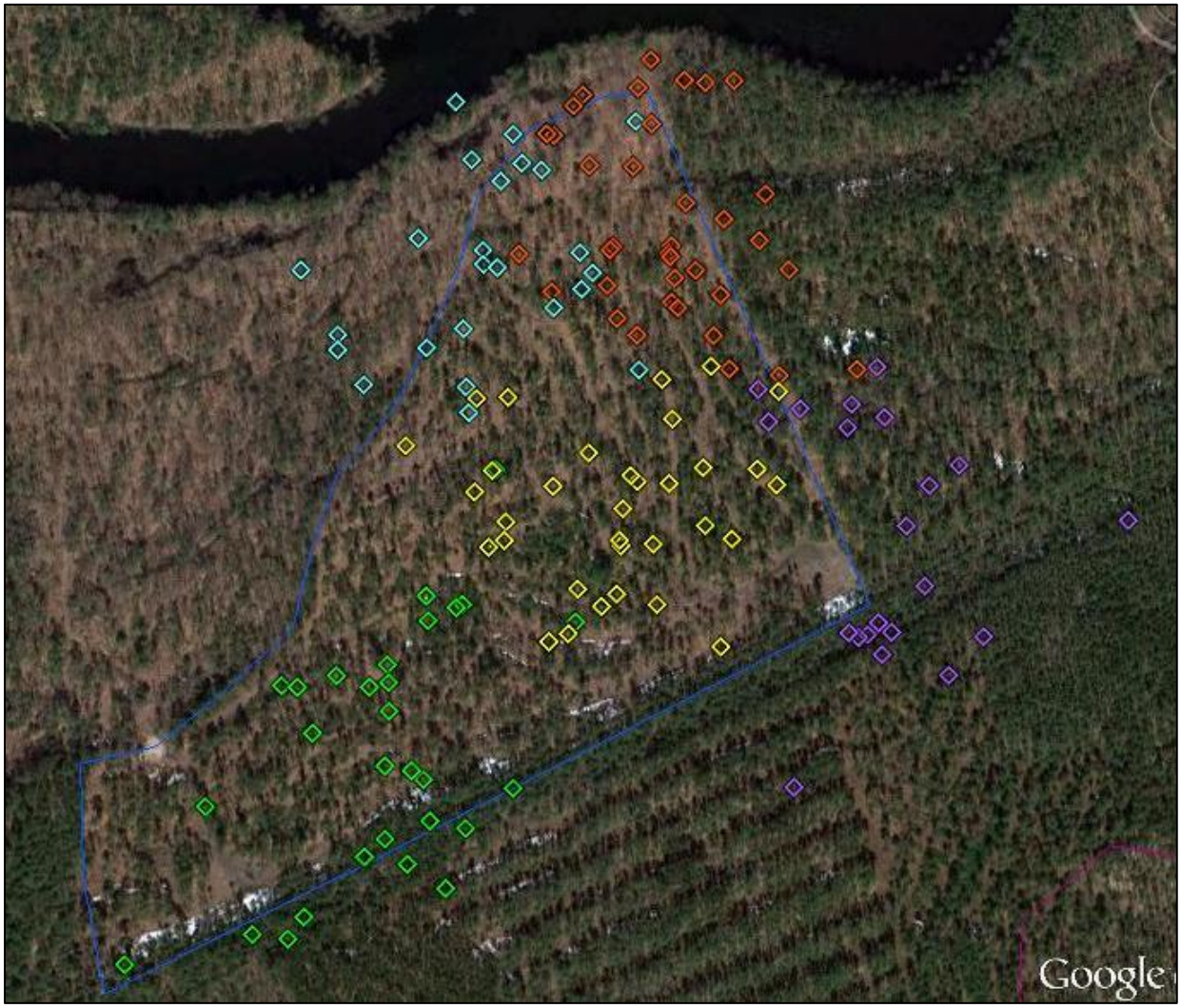


Figure 12. Proposed focal areas for Eastern Whip-poor-will management in New Hampshire.

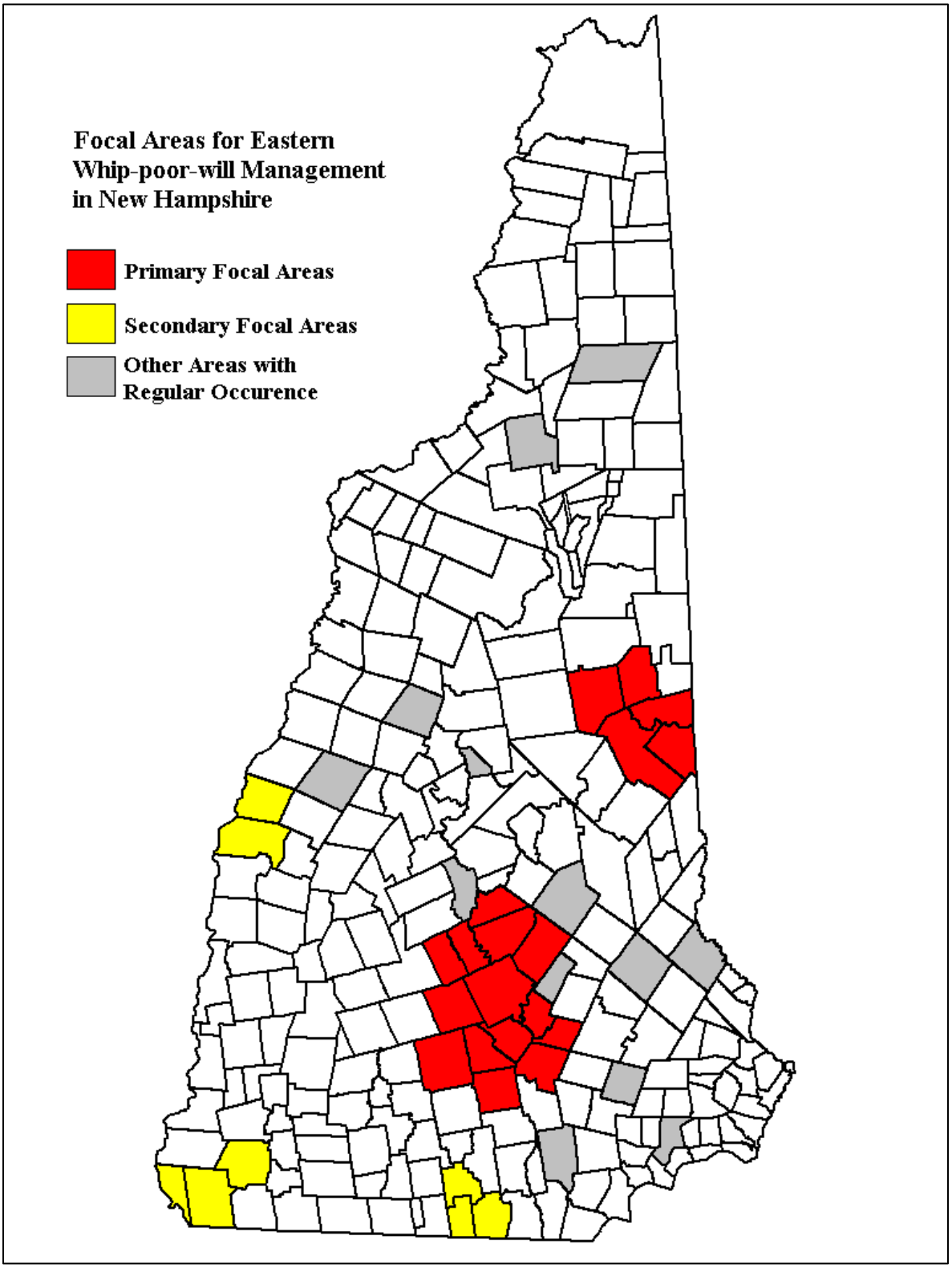


Figure 13. Detail of the Ossipee WPW Focal Area, showing locations of well-drained soils (orange) and predicted pine barrens habitat (pale blue). Focal towns shaded gray and water bodies in dark blue. See text for details.

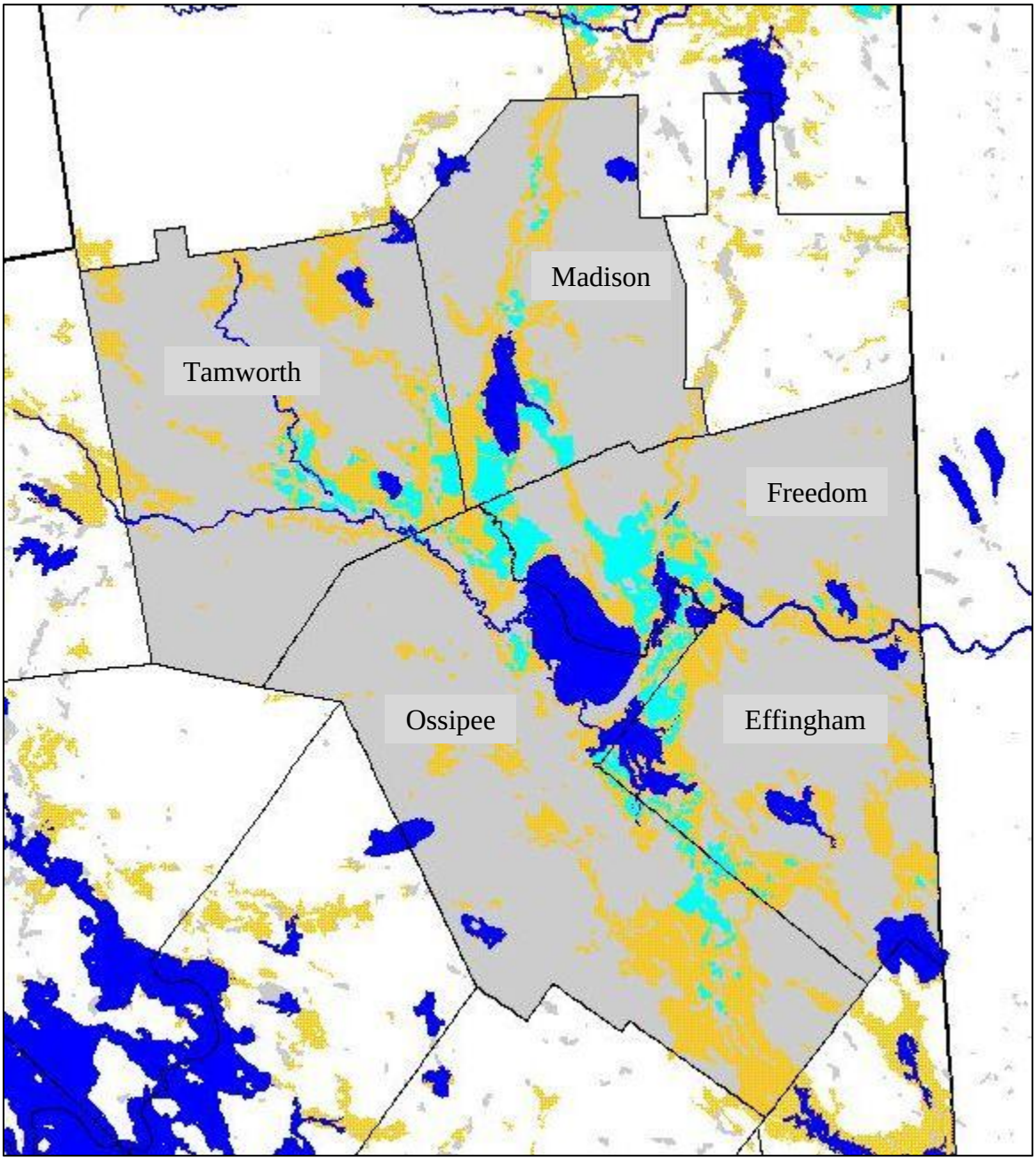
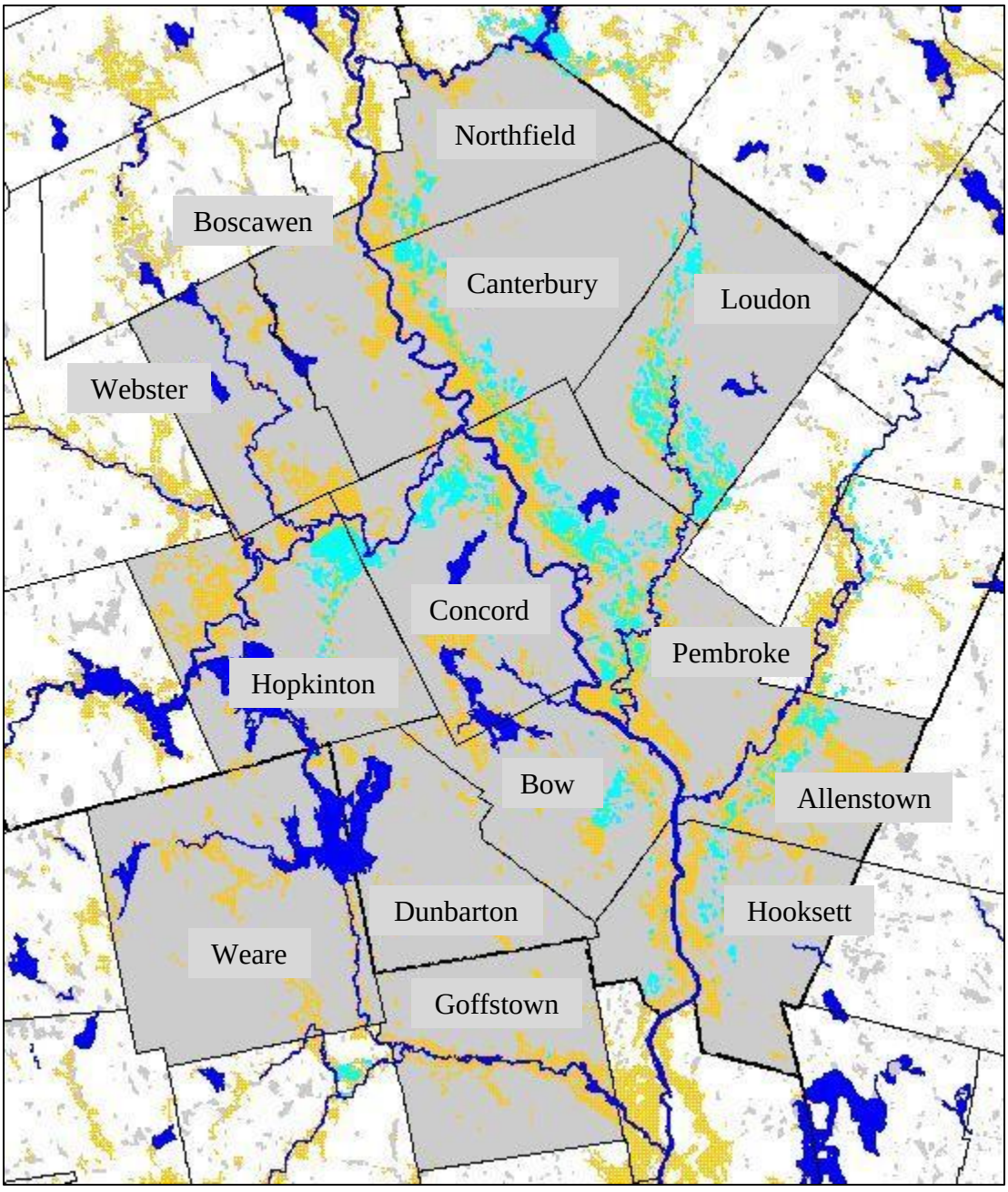


Figure 14. Detail of the Upper Merrimack Valley WPW Focal Area, showing locations of well-drained soils (orange) and predicted pine barrens habitat (pale blue). Focal towns shaded gray and water bodies in dark blue. Note that pine barrens on this map are shifted slightly east because of the quality of digital soils data when the model was originally created. See text for details.



Literature Cited

Bennett, K.P. (ed.). 2010. Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire (second edition). Univ. NH Cooperative Extension, Durham.

Cadman, M.D., D.A. Sutherland, G.G. Beck, D. Lepage, and A.R. Couturier (eds.). 2007. Atlas of the Breeding Birds of Ontario, 2001-2005. Bird Studies Canada, Environment Canada, Ontario Field Ornithologists, Ontario Ministry of Natural Resources, and Ontario Nature, Toronto.

Cink, Calvin L. 2002. Whip-poor-will (*Caprimulgus vociferus*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/620

COSEWIC. 2009. COSEWIC assessment and status report on the Whip-poor-will *Caprimulgus vociferous* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 28 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Fitch, H.S. 1958. Home ranges, territories, and seasonal movements of vertebrates of the Natural History Reservation. Univ. of Kansas Publ. Mus. Nat. Hist. 11(3): 63-326.

Garlapow, R.M. 2007. Whip-poor-will prey availability and foraging habitat: Implications for management in pitch pine/scrub oak barrens habitats. Master's Thesis, University of Massachusetts, Amherst.

Hallworth, M.T., K. Parent, and L. Reitsma. 2009. Modified version of the leg harness technique for mounting radio transmitters. N. Am. Bird Bander 34: 50-53.

Hunt, P.D. 2006. An Analysis of Whip-poor-will Habitat Use in the Piscataquog River Watershed: 2003-2005. Report to the Piscataquog Watershed Association. Audubon Society of New Hampshire, Concord.

Hunt, P.D. 2009a. Whip-poor-will territory mapping at two New Hampshire sites. Report to the Nuttall Ornithological Club. New Hampshire Audubon, Concord.

Hunt, P.D. 2009b. The State of New Hampshire's Birds. Report to the NH Fish and Game Department, Nongame and Endangered Wildlife Program. Audubon Society of NH, Concord.

Hunt, P.D., and S. Gallo. 2007. Northeast Nightbird Monitoring. Report to the Northeast Coordinated Bird Monitoring Partnership. NH Audubon and Maine Audubon, Concord and Falmouth.

Litvaitis, J.A. 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7: 866-873.

McGowan, K.J., and K. Corwin (eds.). 2008. The Second Atlas of Breeding Birds in New York State. Cornell University Press, Ithaca, NY.

Renfrew, R.B. 2013 (ed.). The Second Atlas of Breeding Birds in Vermont. University Press of New England, Hanover, NH.

Sauer, J.R., J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2011. The North American Breeding Bird Survey, Results and Analysis 1966 - 2010. Version 12.07.2011. USGS Patuxent Wildlife Research Center, Laurel, MD

Schweitzer, D.F. 2004. Gypsy Moth (*Lymantria dispar*): Impacts and Options for Biodiversity-Oriented Land Managers. NatureServe, Arlington, VA.

Summerville, K.S. 2011. Managing the forest for more than the trees: Effects of experimental timber harvest on forest Lepidoptera. Ecol. Applic. 21: 806-816.

Summerville, K.S., and T.O. Crist. 2002. Effects of timber harvest on forest Lepidoptera: Community, guild, and species responses. Ecol. Applic. 12: 820-835.

Wilson, M.D. 2003. Distribution, abundance, and home range of the Whip-poor-will (*Caprimulgus vociferus*) in a managed forest landscape. Master's Thesis, College of William and Mary, Williamsburg, VA.

Wilson, M.D., and B.D. Watts. 2008. Landscape configuration effects on distribution and abundance of Whip-poor-wills. Wilson J. Ornith. 120:778–783.