



Distribution and Health of Red Pine (*Pinus resinosa*) in Response to Red Pine Scale (*Matsucoccus matsumurae*) in Acadia National Park, Maine

ACAD NR Report #: 2015-4



ON THE COVER

Dead red pines on the southwest slope of Norumbega Mountain in the Town of Mount Desert, ME.
Photo: NPS/Jesse Wheeler

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Executive Summary:

Red pine scale (*Matsucoccus matsumurae*) was confirmed on Mount Desert Island (Town of Mount Desert), Hancock County, ME in September, 2014. Red pine scale is an invasive insect from Japan that attacks red pine (*Pinus resinosa*), which is native to the northeastern US. Red pine is found in patchy stands of varying densities, sizes and age classes throughout lands administered by the National Park Service (NPS) as the Mount Desert Island district of Acadia National Park (ANP) and non-federal lands on Mount Desert Island (MDI). Two areas of symptomatic or dead trees were believed to be the epicenters of the infestation, while stands in other parts of the park show little, if any, symptoms of red pine scale infestations. The goals of this study were to determine the distribution of both red pine and the red pine scale infestation, and establish permanent plots that can be used in the future to quantify the health and changes in red pine stands within ANP over time. We assessed red pine presence and condition from 132 observation points in October, 2014, and established 63 permanent variable-radius plots with over 1000 trees measured. Field work was conducted in the winter when the scale is dormant to prevent spread.

We found that the scale is more widely distributed across MDI than originally thought; it is present at least 11 kilometers from the epicenters of the infestation. Red pine stands in the interior of MDI were healthier than those closer to the ocean. Red pine was the most abundant tree species measured within permanent plots (52%) and had an average diameter at breast height of 27.7cm and a density of 654 trees/ha, yet its dominance is declining. Signs and symptoms of red pine scale were seen on all age and size classes of red pine, and some trees that had no visible symptoms were infested. Average red pine health status for combined live and dead trees was 2.7 on a scale of 1 (healthy) to 5 (dead). Most of the red pines (71%) measured were alive, averaging 1.7 on the health status index. Red pine scale was detected on 30 of 52 twig samples analyzed with six twig samples coming from areas with pines that appeared healthy but were infested. Regeneration data collected was incomplete because of deep snow covering most seedlings. However, most plots were regenerating with spruce / fir (24 plots) or white pine (10 plots).

Dead red pine trees that appear to have been dead for five or more years showed very low levels of decay, averaging 1.4 on a scale of 1 to 5 with 1 being the least decay. Woodpecker damage was observed on 23% of 125 dead red pines. With a slow rate of decay and few trails and roads through the infested areas, we predict that few trees will become structurally unstable in the next three to five years. We do not recommend removing snags unless they present a hazard to people and property; however, repeat surveys are needed in the next few years to accurately assess the rate of decay and hazard potential of standing dead red pines. A baseline of regeneration in red pine stands has been collected to enable managers to track changes in forest dynamics, although deep snow affected our ability to fully quantify the understory. Long-term monitoring of red pine

in Acadia can be used to document the spread of red pine scale across the landscape as well as subsequent changes in forest composition as a result of widespread red pine mortality. Additional work is needed to analyze tree cores that we collected to determine if the date of infestation and red pine health decline are reflected in the cores.

Introduction:

In September 2014, *Matsucoccus matsumurae*, also known as red pine scale or Japanese pine bast scale, was detected and confirmed on Mount Desert Island, Hancock County, ME (Acadia National Park, 2014). Red pine scale is a piercing and sucking insect native to Japan. This was the first detection of this invasive forest insect pest in Maine. Red pine scale attacks red pine (*Pinus resinosa*), a northeastern hard pine tree found from Newfoundland, Canada, west to Manitoba, Canada and south to Pennsylvania, US. It also is a pest of other Japanese pines used in horticulture, but no other native pines found in the US are susceptible. Red pine is a conifer growing up to 35 meters in height. It has thick, reddish-brown fissured bark that forms broad, flat ridges. It is shade intolerant and does well on poor soils. In New England, it is often found on mountain slopes and hill tops (Rudolf, 1990). Because the wood is relatively hard and grows straight, red pine is of commercial importance and is harvested for use as telephone poles, lumber, cabin logs, railway ties, posts, pulpwood, and fuel (Moore, 2002). It is also planted as a windbreak and in reforestation projects where soils are poor.

Red pine scale has two generations a year, each completing a complicated life cycle with numerous morphological stages. The various stages range in size from 2 mm to 5 mm and are not readily identifiable without magnification (Maine Forest Service, 2014a). Red pine scale appears to be either more cold tolerant or more adaptable than initially hypothesized by Hartzell (1957), as it has been able to establish an apparently thriving population in Maine. In fact, populations in northern China overwinter longer than southern populations, suggesting that red pine scale can modify the timing of its life cycle to adapt to colder temperatures (Liu. *et al*, 2014). The mechanisms of spread are not well known, but wind is thought to play a part, as are migrating birds that perch on



Figure 1. A red pine tree showing symptoms of a severe red pine scale infestation. Note the brick red shade of the necrotic needles. Photo: NPS/Jesse Wheeler.

infected trees. The scale is most mobile from spring to fall when ‘crawler’ stage nymphs and adults can hitchhike on humans and animals moving through infected stands (Maine Forest Service, 2014a). However, the scale is normally sessile and attached to the twig on which it is feeding. One of the earliest symptoms of red pine scale infestation is needle discoloration: beginning as a light olive-green that replaces the healthy dark green needle shade, transitioning to yellow, and then to a distinctive brick red shade (Hartzell, 1957; Fig. 1). The pattern of



Figure 2. Flocculence from red pine scale on a red pine twig collected in the MCHT Norumbega Mountain Preserve on Mount Desert Island, ME in September, 2014. Photo: NPS/ Jesse Wheeler.

discoloration typically starts in the interior of the tree near the bole and moves up and outward towards the tips of the branches. This pattern can be contrasted with shoot tip blights, such as *Diplodia pinea* or *Sirococcus conigenus*, which normally display the opposite progression within a tree. Flocculence (white cotton-like covering)

associated with male cocoons is frequently visible with the naked eye on infested twigs (Fig. 2).

Twigs and branches may also start to look swollen and cracked when scale densities are high

(Hartzell, 1957). Infestations have resulted in stand death between two and five years after the introduction of the pest (McClure, 1991).

As of January 2015, red pine scale has been found in New York, New Jersey, eastern Pennsylvania, Connecticut, Rhode Island, Massachusetts, central New Hampshire, and now Hancock County, Maine. It has been in North America at least since 1946, when it was discovered in Easton, Connecticut, but it was likely introduced in 1939 at the New York World Fair. It appeared to be slowly expanding its range through New York, New Jersey, and Connecticut until it was discovered in Bear Brook State Park in New Hampshire in the fall of 2012.

Attempts at controlling the spread of red pine scale have not been very effective. McClure (1977b) found that “scale populations rapidly resurged following pesticide spraying.” Liu *et al.* (2014) found chemical insecticides ineffective because the insect’s waxy coating and habit of concealing itself under bark scales prevented coverage or uptake of insecticide. The Maine Forest Service suggests that biannual spraying of ornamental trees can provide some level

of protection (Maine Forest Service, 2014b). Salvage cuts, like the one conducted in Bear Brook State Park and on pine plantations in China, have not succeeded in slowing the scale's rate of expansion either (Liu *et al.*, 2014). From an integrated pest management perspective, many natural predators of red pine scale have been identified, including a few native to North America (Hartzell, 1957; Liu *et al.*, 2014), but most are generalists such as lady beetles and spiders that eat a variety of prey – none have yet emerged as an effective biocontrol. Promising research in China is investigating three entomopathogenic fungi as a possible means of control, but development is still in the preliminary stages (Liu *et al.*, July 2014).

With little information about red pine distribution and few practical options for managing scale infestations, the response to the Mount Desert Island infestation has focused on surveying red pine forests to learn more about red pine distribution, health, and stand characteristics, and sampling twigs to determine the distribution of red pine scale. Most of the red pine on MDI is found in ANP with a few notable stands and individual trees on private property. There are two areas of the island that appear to be the centers of the infestation: Norumbega Mountain, north of the village of Northeast Harbor, and St. Sauveur and Acadia Mountains, east of Echo Lake (Fig. 3). Private residences in Northeast Harbor have been the first source in the State of other invasive exotic pests, such as hemlock woolly adelgid, moved on landscaping materials from long distances away (Maine Forest Service, 1999). Red pines near these epicenters are either dead or display very severe symptoms. Interestingly, these are directly across Somes Sound from each other, raising questions about mode and direction of spread.

In response to the confirmation of red pine scale, we started to assess red pine distribution and health on MDI. Working closely with staff from Maine Coast Heritage Trust (MCHT), entomologists with the Maine Forest Service (MFS), and US Forest Service (USFS) Forest



Figure 3. Dead and symptomatic red pines on the southwest slope of Norumbega Mountain as seen from above. The patch of red/grey trees above the golf course, indicated by the red arrow, is a notably large and dense stand of red pine. The red color is from the necrotic needles that are indicative of a red pine scale infestation. Photo: Maine Forest Service.

Health Monitoring Program in Durham, NH, we developed and implemented a monitoring protocol to address those project goals.

In the course of our work, other questions emerged. Do dead and decaying trees present a potential hazard to people and property along trails, carriage roads, and motor roads, as well as in picnic areas and campgrounds (Fig. 4)? Power lines passing near infested red pine stands are also potentially at risk. The rate of decay and length of time before a dead red pine becomes a hazard is unknown.

Finally, little is known about the effects this new invasive pest will have on Maine's forests. Having already caused localized mortality, will red pine decline become widespread and ubiquitous? Dead trees in the canopy cause canopy gaps and allow more light to reach the forest floor. How will the herbaceous and shrub cover respond? What tree seedlings will regenerate and what will replace red pine as the dominant canopy tree in areas of high red pine density? Will



Figure 4. Dead and dying red pines along Sargeant Drive, Mount Desert, ME. Dead trees near roads can present a hazard to drivers and vehicles. Photo: MCHT/William Helprin.

there be increased erosion on steep slopes with many dead trees? Will wildlife be affected either by the loss of a food source (pine cones) or dramatic increase in food source (woodpeckers and snags)? Will dead and dying red pines increase fuel loading and will the fire danger increase correspondingly? Will the loss of red pines impact forest dynamics in ways we cannot predict?

To begin to assess the status of red pine and distribution of red pine scale, we conducted a trail and roadside visual survey, installed and

collected baseline data at permanent monitoring plots, collected and examined twig samples, and evaluated tree health in both survey points and monitoring plots across NPS lands on MDI and in selected MCHT preserves. Park managers can use the information gained in this study to manage natural resources and protect life and property.

Methods:

Determining where red pine populations exist in and around ANP was a necessary first step in initiating red pine health assessments. To obtain this information we examined both the NPS vegetation map of MDI (Lubinski et al. 2003) and aerial photography showing symptomatic trees, spoke with NPS staff familiar with red pine distribution across NPS lands, and conducted a survey across MDI in October 2014, collecting GPS coordinates of all locations where we observed red pine trees. With few, if any, red pine stands known on Isle au Haut, other off shore islands, or the Schoodic Peninsula, we focused our efforts on MDI. We drove or biked along ANP and public roads, carriage roads, and hiking trails to cover as much NPS land on MDI as possible. Additionally, we recorded information on approximate stem count, condition of trees, canopy class, and general habitat characteristics for each mapped red pine location. With the information from 132 observation points we created a map to display red pine locations on MDI: a vital tool for subsequent work locating permanent monitoring plots (Appendix A: Map 2 and 3). Analyzing recent aerial photography also proved to be useful in determining areas of severe red pine mortality and plot placement.

In consultation with USFS and MFS staff, we developed protocols for establishing and collecting data in permanent forest monitoring plots and began to work in stands that appeared to be healthy. We purposely avoided working in stands with symptomatic trees during the fall to prevent inadvertently spreading the scale when mobile life forms of red pine scale were present.

In January and February, 2015, we established sixty-three permanent monitoring plots in ANP and in the MCHT Kittredge Brook, Norumbega and Acadia Mountain Preserves (Appendix A: Map 4 and 5). Because we wanted to ensure a high density of red pines within monitoring plots, and given the spotty distribution of red pine trees on MDI, randomly selected plot locations would not have met our goals. We positioned plots in previously surveyed and known locations of mixed red pine forest. Plots were located in healthy, stressed, and severely symptomatic stands, and strategically placed to detect future direction and rate of spread of red pine scale. Plots were also established in stands with a majority of dead red pines in order to track understory and species composition changes following red pine mortality.

A majority of plots were clustered in five general areas, although some plots were geographically isolated due to smaller red pine stand size (Appendix A: Map 1). Three of these

five areas were chosen because of the high density of red pine (identified on the ANP Vegetation Map) and seemingly healthy, nonsymptomatic trees: Aunt Betty Pond, Breakneck Ponds, and Witch Hole Pond. The remaining two clusters of plots were established around Norumbega Mountain on the east side of MDI, around St. Sauveur and Acadia Mountains on the west side of the island—areas with many dead or highly symptomatic red pines. We sampled in areas that appeared the healthiest first, and then progressed to areas in which decline was more apparent to avoid inadvertently moving the pest into uninfected areas.

Data collected at monitoring plots followed standard forest health monitoring protocols provided by the USFS Forest Health Office in Durham, NH. The protocol was adapted to provide a rapid assessment of forest stand health by using variable radius plots with a 10-factor prism. In an effort to address concerns about overall health of the forest and potential transitions in forest composition and structure, data were collected on tree species composition and density within each plot, and diameter at breast height (DBH) of each individual tree within a plot. Relative abundance and density (trees/ha) of tree species were calculated and averaged across all monitoring plots. Results are not assessed separately for each of the five monitoring areas in this report. Information specific to red pine health was recorded using an index ranking tree health into five categories (Table 1). Note that the health index is determined by percentage of dead needles only. Health assessments did not take into account yellowing or missing needles from the tree canopy, even though these conditions may have been present. Dead standing trees of all species were given a decay classification from 1 to 5 (Table 2). Woodpecker damage on red pine was recorded when and where observed. In addition to the data collected on tree composition and tree health, a 3-meter radius microplot around plot center was also sampled to quantify live saplings, established seedlings, and shrub cover. Microplot data can yield important information on advance tree regeneration and potential future cover. Six photographs were taken from plot center in the cardinal directions (N, E, S and W) as well as the canopy straight above and the plot tag.

Table 1. Red pine health status index.

Health Index Ranking	% Necrosis
1	<10% necrosis
2	10-50% necrosis
3	50-90% necrosis
4	90-100% necrosis
5	dead tree

Furthermore, to provide more conclusive information on locations of established red pine scale, we attempted to collect live twig samples from every plot. Some plots contained only dead trees and others had canopies beyond reach of our pole pruners, therefore twig samples were obtained at a majority of plots, but not every plot. We examined collected twig samples from January and February, 2015, under magnification of a dissecting microscope to determine the presence of scale insect.

To age red pine stands, we cored and counted tree rings from each plot. We selected one co-dominant live red pine tree inside the plot or in the area directly adjacent to the plot. Additionally a similarly sized, co-dominant tree of a different conifer species (i.e., white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), red spruce (*Picea rubens*), etc.). This additional tree was cored and aged in an effort to understand if any red pine specific growth trends were apparent. Tree rings were examined and counted with dissecting microscope to determine tree age. Tree ring analysis is ongoing and data are not included in this report.

To summarize our data we created a series of maps displaying what we deemed the most important information collected in our monitoring plots. Maps were developed demonstrating average red pine health in each plot and locations where red pine scale was confirmed on twig samples.

For additional information and a more detailed description of field procedures and protocols please see Appendix 1: Red Pine Health Monitoring Protocol.

Table 2. Decay stage classification of dead standing trees.

Decay Class	Bark	Branches and Twigs	Wood
1	firmly attached	branches retain many small twigs	sound wood covered by intact bark
2	if present, decayed, faded and not firmly attached	branches and small twigs may be present	hard wood that is impenetrable with fingernail or pen point, may be case hardened with powder wood beneath
3	generally absent	some branch stubs may remain, but no twigs	soft wood that responds to finger pressure and may exude moisture, powder wood
4	generally absent	no branch stubs or twigs	powder wood
5	bark absent	no branch stubs or twigs	powder wood (decay class 5 rarely observed)

Results:

With over a thousand trees surveyed, nine species were found in monitoring plots (Table 3). Red pine was the most abundant with 51.9% of all trees measured, followed by red spruce (*Picea rubens*) (19.3%) and white pine (*Pinus strobus*) (12.9%). Serviceberry (*Amelanchier* spp.) (0.1%) and balsam fir (*Abies balsamea*) (0.4%) were least abundant. The average diameter at breast height (DBH) of red pine was 27.7 cm with a density of 654 tree/ha (Table 4). White pine had a higher average DBH at 33.2 cm, but with a density of only 139 trees/ha. Pitch pine and red spruce both had average DBH of 25.2 cm, however red spruce had almost six times the density (312 trees/ha vs. 57 trees/ha).

The average red pine health status was calculated for each of the 63 monitoring plots with an overall index average of 2.7 on a scale of 1 (healthy) to 5 (dead). Most of the red pines surveyed (70.6%) were alive and the majority of these were healthy; if dead red pines are excluded from the analysis, the average health status index drops to 1.7. Health indices ranged from 0 to 4 with the majority of individuals in category 1 (n=207) or 2 (n=129).

Red pine dominance is declining within the forest areas we surveyed. Analyzing data related to live trees of all species, red pine relative abundance drops from 51% to 46% while red spruce and white pine increase slightly to 21% and 14% respectively. The average diameter of all live trees changed less than 1 cm when we include only live trees. This suggests that the mean dead tree (mostly red pine) was not of a particular size or age class.

Red pine stands around Aunt Betty Pond, Witch Hole Pond, Breakneck Ponds, and Long Pond were healthier, on average, than plots located around Norumbega, Acadia, and St. Sauveur Mountains (Appendix A: Map 6; Table 5). Red pine in the former group had greener canopies and very low levels of mortality, whereas red pine in the latter group frequently had high levels of necrosis and more frequent mortality. In fact, only plots on Norumbega Mountain and St. Sauveur Mountain contained predominately dead red pine. Of the 'healthy' areas, only one plot had an average health code over two, or greater than 50% necrosis in the red pine canopy.

Red pine scales were detected on 30 of the 52 twig samples analyzed (Appendix A: Map 7). We found that 11 of 12 twig samples from both the north and south slopes of Norumbega Mountain, the site of the initial discovery of the pest on MDI, were infested with red pine scale. Some of those samples came from the northwest slope of the mountain. Around Acadia and St.

Sauveur Mountains, an area with many symptomatic and dead red pines, 13 of 22 twig samples were infested with red pine scale.

We found red pine scale on six twig samples from areas where trees appeared to be healthy. These samples were all collected on the east side of MDI including three twigs from near Witch Hole Pond, one twig from near Breakneck Ponds, one twig from the lower “Around Mountain” carriage road south of Aunt Betty Pond, and one twig from the Bear Brook picnic area.

Baseline regeneration data was collected in the microplot surrounding plot center. Red spruce was the most common seedling, found in 23 of 63 plots. Balsam fir and white pine were also relatively common, present in 13 and 12 plots respectively (Table 6). Almost half of the plots were found to have no seedlings at all, but this number could be an overestimate due to deep snow cover that made it hard to see seedlings in the lowest height class. Twenty-six plots had 100% snow cover at a depth sufficient to cover most tree seedlings, thus impacting the validity of the seedling data collected during those visits.

Saplings showed similar regeneration trends. Red spruce, balsam fir, and white pine were still present in the most number of plots, but red maple and white cedar (*Thuja occidentalis*) saplings were also recurring (Table 7). In addition, there were more than four times as many plots with red spruce saplings than the next common sapling species, balsam fir. This gap becomes even more pronounced when comparing red spruce sapling count in all plots to all other species (Table 7): 58 red spruce saplings were measured on all 63 plots and the next most numerous sapling species, red maple, had only nine saplings.

By pooling the seedling and sapling data, we were able to describe what forest type was regenerating in each plot. Dominance of one or two species or the presence of a noteworthy species indicative of a particular forest community, such as a pitch pine woodland, was used to classify and group plots with similar regeneration. Spruce/fir was the most common regenerating forest type: found in 24 plots. Mixed white pine was the second most frequent: found in 10 plots (Table 8).

The average decay class for all dead trees measured was 1.39 on a scale of 1 to 5 with 1 being the least decay. Of the 125 dead red pine trees assessed for woodpecker damage, 23% showed signs of woodpecker activity.

Table 3. Relative abundance and plot occurrence of all tree species found in Red Pine Health Monitoring Plots during the 2014/2015 sampling season.

Scientific name	Common name	Relative Abundance	# Plots Occurred
<i>Abies balsamea</i>	Balsam Fir	0.4%	4
<i>Acer rubrum</i>	Red Maple	2.2%	19
<i>Amelanchier</i> spp.	Serviceberry	0.1%	1
<i>Picea rubens</i>	Red Spruce	19.3%	45
<i>Pinus resinosa</i>	Red Pine	51.9%	63
<i>Pinus rigida</i>	Pitch Pine	4.0%	17
<i>Pinus strobus</i>	White Pine	12.9%	48
<i>Quercus rubra</i>	Red Oak	1.5%	6
<i>Thuja occidentalis</i>	White Cedar	7.6%	27
	Unknown conifer	0.2%	2

Table 4. Average diameter at breast height (DBH) and density (trees/ha) of tree species found in Red Pine Health Monitoring Plots during the 2014/2015 sampling season.

Scientific name	Common name	Average DBH (cm)	Trees / Ha
<i>Abies balsamea</i>	Balsam Fir	13.3	14
<i>Acer rubrum</i>	Red Maple	19.1	58
<i>Amelanchier</i> spp.	Serviceberry	14.5	3
<i>Picea rubens</i>	Red Spruce	25.2	312
<i>Pinus resinosa</i>	Red Pine	27.7	654
<i>Pinus rigida</i>	Pitch Pine	25.2	57
<i>Pinus strobus</i>	White Pine	33.2	139
<i>Quercus rubra</i>	Red Oak	23.9	26
<i>Thuja occidentalis</i>	White Cedar	20.9	148
	Unknown conifer	21.3	1

Table 5. Summary of health code results by plot and geographic location. Red pine scale was confirmed in all but two locations.

Location	Total # of Plots	# of Plots with an Average Health Code of:					Red Pine Scale
		1	2	3	4	5	
Witch Hole Pond	3	2	1	0	0	0	Present
Breakneck Ponds	4	3	1	0	0	0	Present
Aunt Betty Pond	8	8	0	0	0	0	Present*
Norumbega Mt.	20	0	0	5	3	12	Present
Kittredge Brook	1	1	0	0	0	0	Undetected**
Bear Brook	2	1	0	1	0	0	Present
Acadia Mt.	4	0	1	2	1	0	Present
St. Sauveur Mt.	16	0	9	3	2	2	Present
Long Pond/ Beech Mt.	5	2	2	1	0	0	Undetected
Total:	63	17	14	12	6	14	

*Scale confirmed in the plot farthest south in this group, not yet detected in main Aunt Betty Pond stand (See Appendix A: Map 6).

** No sample taken at this location

Table 6. Seedling species found in plots and the number of plots each species was found in. No seedlings were found in 31 plots but this number is inflated because deep snow cover on 26 plots made it hard to locate seedlings. Total number of plots: 63.

Scientific name	Common name	# of Plots with Seedlings
<i>Picea rubens</i>	Red Spruce	23
<i>Abies balsamea</i>	Balsam Fir	13
<i>Pinus strobus</i>	White Pine	12
<i>Acer rubrum</i>	Red Maple	3
<i>Picea glauca</i>	White Spruce	3
<i>Quercus rubra</i>	Red Oak	2
<i>Acer pensylvanicum</i>	Striped Maple	1
<i>Pinus resinosa</i>	Red Pine	1
<i>Pinus rigida</i>	Pitch Pine	1
<i>Populus grandidentata</i>	Big-toothed Aspen	1
<i>Thuja occidentalis</i>	White Cedar	1
None		31

Table 7. Total number of sapling species found in monitoring plots and the number of plots each species was found in. Total number of plots: 63.

Scientific Name	Common Name	# of Saplings	# of Plots with Saplings
<i>Picea rubens</i>	Red Spruce	58	22
<i>Abies balsamea</i>	Balsam Fir	7	5
<i>Acer rubrum</i>	Red Maple	9	5
<i>Pinus strobus</i>	White Pine	6	4
<i>Thuja occidentalis</i>	White Cedar	5	4
<i>Quercus rubra</i>	Red Oak	8	3
<i>Betula papyrifera</i>	Paper Birch	3	3
<i>Betula populifolia</i>	Grey Birch	3	2
<i>Pinus rigida</i>	Pitch Pine	3	2
<i>Acer pensylvanicum</i>	Striped Maple	1	1
<i>Fagus grandifolia</i>	American Beech	1	1
<i>Pinus resinosa</i>	Red Pine	2	1
None			27

Table 8. Number of monitoring plots displaying certain types of forest regeneration based on seedling and sapling composition. Regeneration type: None indicates no seedlings or saplings were found in the microplot, although snow likely inflated this number.

Type of Forest Regeneration	# of Plots
Spruce/Fir	24
Mixed White Pine	10
Spruce/Cedar	5
Mixed Deciduous	5
Mixed Pitch Pine	3
Other	3
None	13
Total	63

Discussion:

This study has provided important baseline information on the health status of red pine stands across MDI. As expected, trees found on or near Norumbega, Acadia, and St. Sauveur Mountains have the highest severity rating on our health index, indicating a higher percentage of needle death and mortality. Although it is not known when and how red pine scale was introduced on MDI, it seems possible that these more highly symptomatic areas could be the areas longest infested with the pest. These two “hot zones” of symptomatic red pine occur directly across Somes Sound from one another: Norumbega Mountain to the east and Acadia and St. Sauveur Mountains to the west. While local mechanisms of red pine scale spread are mostly unknown, we believe it is possible the pest may have moved across the Sound, facilitated perhaps by wind or wildlife.

To meet our project goals, we established plots in a gradient from highly symptomatic to healthy stands, as well as in areas geographically in between, in an attempt to enable researchers and future managers to track trends in pest infestation and spread. Red pines around Aunt Betty, Witch Hole, and Breakneck Ponds appeared to be healthier than those around Somes Sound, and our health index data reflect this observation. These will be important areas to monitor in the future to detect spread. Additionally, continued monitoring of plots located outside of the denser, previously mentioned stands (e.g., the plot located on the lower “Around Mountain” Carriage Road south of Aunt Betty Pond and the plot on Long Pond Fire Road) could provide valuable information about infestation movement and spread rates.

While our health index data provided information about red pine scale presence and level of symptoms, symptoms alone do not confirm presence or absence of red pine scale because other insects and diseases can manifest in similar ways. By collecting and examining red pine twig samples, we gained more accurate information about red pine scale distribution on MDI. As expected, twigs from areas of highly symptomatic and dead red pine trees were infested with red pine scale. Similarly, the pest was not detected on samples from many of the areas where red pines were less symptomatic, such as near Aunt Betty Pond. However, we confirmed the presence of red pine scale in several areas displaying few, if any symptoms. With the presence of scale confirmed near Paradise Hill, Witch Hole Pond, Breakneck Ponds, on the lower “Around Mountain” carriage road south of Aunt Betty Pond, and Bear Brook picnic area, the infestation

of red pine scale is more widespread than previously assumed on MDI. This discovery implies that red pine scale infestations may be occurring in locations currently not displaying symptoms, and can exist without immediate detection. This may be related to why salvage cuts in other locations have often proved ineffective: the scale had spread to areas appearing healthy, and thus were not included in the salvage cut. A lag in scale detection coupled with the very quick rate of mortality after infestation (two to five years), could have swift and dramatic effects on red pine stands, and highlights the importance of continuing monitoring efforts to inform management decisions, both by park managers and local landowners with infested stands.

Thus far we have assumed that distance and time from the initial infestation is the underlying cause beneath the range of symptoms in red pine trees across MDI. In other words, that trees with mild to no symptoms farther from the “hot zones” are less affected because they have been infested for a shorter amount of time. However, this pattern could also be explained by the physical location and associated microclimate of red pine stands on the island. Currently, the trees exhibiting the most severe symptoms are located close to the shoreline where temperatures are generally milder and conditions are wetter. The healthiest trees are located in the interior of MDI, which is characterized by colder winter temperatures and drier air, conditions which could negatively impact the ability of red pine scale to overwinter. Future monitoring will reveal whether microclimate or rate of expansion is the driving force behind the geographic distribution of symptomatic red pine trees on MDI.

While most of the forest community types sampled were red pine / mixed conifer, there were several associated conifer tree species that could become dominant over the next few years. At this point, it is likely that red spruce, white pine and to a lesser degree, white cedar, will endure as the dominant canopy species in these declining red pine forests. Red pine relative abundance has and will continue to drop in these areas. With no evidence for size preference of host trees, red pine scale will likely continue to kill red pine trees of all ages. The data collected on established seedlings and saplings suggests the majority of red pine plots will likely succeed to spruce/fir forests.

This year’s data will provide a baseline for future resampling, especially in stands that show no red pine scale symptoms. It will be interesting to see if red spruce continues to dominate regeneration or if the increased light availability allows other species to colonize areas when red pine declines. Shrub cover (not analyzed in this report) could also benefit from a more open

canopy and could compete with tree seedlings for space in the understory. Changes in canopy cover may favor invasive exotic species such as barberry (*Berberis* spp.). Because 50 cm of snow in January and February buried the understory and influenced our data related to regeneration, microplot data collection should be repeated as soon as possible.

In order to prevent spreading red pine scale by surveyors, sampling must be done during the winter months, a challenge on MDI, where the average snowfall per month is over 38 cm from December through March. Average temperature highs for those four months hover just over freezing but the temperature can fall below zero (Climate Bar Harbor, 2015). It is unclear if winter low temperatures will reduce the rate of spread of red pine scale, even after the coldest month on record (February, 2015) for Bangor, ME was observed this past winter (National Weather Service, 2015). Therefore, we suggest that sampling in following years be in late November and December, but recognize that even then snowfall could influence data collection.

Management Implications:

As in other exotic invasive forest insect pest detections across the country, a local citizen played an important role by submitting symptomatic red pine samples for diagnosis. In this case, the samples from Sargeant Drive, near the village of Northeast Harbor, were sent to the Maine Forest Service's Forest Insect and Disease Laboratory, leading to the confirmation of the presence of red pine scale on MDI. Public education and outreach about possible forest insect pests can be an important management tool for early detection and management.

In recent years, park managers have received many inquiries from neighbors and the visiting public regarding dead and dying red pine trees, especially those trees on Norumbega Mountain. Dead and dying trees can detract from the perceived beauty of a landscape and are often considered 'unsightly.' Many of Acadia National Park's red pine stands are very visible when viewed from boats off-shore and along highways, carriage roads, lakeshores, or on exposed mountainsides. One response to stand mortality that was used in the past, exemplified by actions taken in Acadia after the widespread fire in 1947, would be to remove dead trees and present a manicured appearance to park visitors. This practice, however, removes nutrients and potential habitat from the ecosystem and would not meet current NPS management policies. Furthermore,

the steep slopes and backcountry location of much of the red pine makes the safety and financial considerations of such an approach prohibitive.

That said, hazard trees are of concern and are one of the most pressing logistical problems that will result from widespread red pine die-off. Hazard trees are trees that are both structurally weak and located in areas where people or property could become a target should the trees fall unexpectedly. NPS managers are legally liable to use reasonable judgment and action to manage preventable risks to public safety, property, and infrastructure and require both staff time and money to address. There are already dead red pines in the Norumbega Mountain area, as well as across the Somes Sound near St. Sauveur and Acadia Mountains that could fall on power lines or roads. Fortunately, we found very little sign of structural decay in standing dead red pines. However, almost a quarter of dead red pines did show signs of woodpecker damage, indicating that insect recyclers have begun to occupy tree snags. It will be important to track the rate of decay in future years to be able to predict when a stand may begin to fall, and to plan for future hazard tree management related to red pine scale infestations. Our preliminary data suggests that dead red pines might remain sound for several years before falling. This conclusion is supported by the fact that red pines usually have a well-developed root system that is both spreading and moderately deep, making them very wind firm and unlikely to be blown down, especially in stands that have a solid makeup of healthy trees in the canopy (Rudolf, P.O., 1990). There is little data specific to rate of red pine decay, but lodgepole pines (*Pinus contorta*) killed by mountain pine beetle (*Dendroctonus ponderosae*) did not experience significant decay for 15-20 years in dry sites (Lewis and Hartley, 2006). However, basal decay developed between 4-7 years after death, after which the tree was more likely to fall. In Oregon, Mitchell and Preisler (1998) found that lodgepole pines began falling five years after death in un-thinned stands and three years after death in thinned stands. Fifty percent of pines had fallen after eight or nine years in thinned and un-thinned stands respectively. While there is discrepancy in reported decay rates of lodgepole pines, it is probably safe to conclude that the red pines that have succumbed to red pine scale recently will not pose an immediate threat and consequently, park managers should have several years to develop a response plan.

Conclusion:

Due to limited staff time, much of the data collected during the past winter field season has not been analyzed. Important questions about red pine stands in ANP remain, such as: how does canopy closure differ between healthy stands and symptomatic stands? Is the date of the initial infestation reflected in the tree rings? Is there a relationship between red pine density and type and amount of regeneration? Furthermore, will this insect pest cause high density red pine stands to experience a different succession than more mixed stands following red pine mortality from scale and diseases such as shoot tip blights? Many of the most interesting lines of inquiry appertain to the ecological response of the forest to red pine scale and subsequent consequences. This makes the continuing long-term study of affected and currently unaffected stands of the utmost importance. Thus far, we have recorded a baseline; subsequent surveys will track the spread of the scale and monitor forest response.

While this study has provided data on a variety of metrics related to forest health, not all areas of interest could be addressed and included in the protocol. Fire danger related to an increase in fuel load is an area deserving further investigation, especially because ANP and MDI have a history of human-caused and widespread wildland fires. The potential impacts that red pine mortality will have on wildlife are also unknown. Many birds and mammals that feed on red pine cones may have to find alternative food sources, while wildlife that finds food in snags or rotting logs may have more feeding opportunities as dead pines decay. We hope our data will provide a foundation of information upon which to build in the future, both by NPS staff and other researchers interested in the effects of red pine scale on the forests of ANP and coastal Maine.

Acknowledgments:

We extend our most sincere thanks to Allison Kanoti (Maine Forest Service), Kevin Dodds (US Forest Service), and Michael Simmons (University of New Hampshire) for their time and effort helping us design and implement a protocol. Thanks especially to Allison for her expert knowledge on identifying red pine scale symptoms in the field and identifying various life stages of the insect in the laboratory.

William Helprin with Maine Coast Heritage Trust was also an integral member of the team, providing detailed information on red pine locations and health in MCHT preserves and encouraged us to install monitoring plots on MCHT land. This allowed us to acquire a more complete understanding of the distribution of red pine scale on MDI.

Special thanks to the Resource Management Staff at Acadia National Park, particularly Karen Anderson for her help using ArcGIS, and Shannon Wiggan and Bruce Connery for letting us borrow their snowshoes and other field gear in this, one of the coldest and snowiest winters here since weather records have been kept.

Finally, we would like to thank Joe Kelley and Kate Orlofsky for their dedicated help collecting data in the field, and Alex Fetgatter and Julie Churchill for assisting with data collection on the last plot of the study.

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Appendix A: Maps



Map 1. Overview of the five main areas of clustered plots. Red ovals indicate the epicenters of the red pine scale infestation; areas of severe symptoms and mortality. Green ovals indicate areas where red pine trees appeared healthy and few symptoms were found. January 2015.

Red Pine Survey Locations on East Mount Desert Island



20150218 MFS, CES

Map 2. All red pine survey points located on the east side of Mount Desert Island, ME. Red pine stand locations were recorded with survey points taken along roads, carriage roads, and trails. Approximate size and density was recorded for each stand, as well as a visual health assessment of the trees. Most of the red pine was found on Norumbega Mountain (Survey points 1 – 15), Aunt Betty Pond (Survey point 46), and Breakneck Ponds (Survey points 73 - 89).

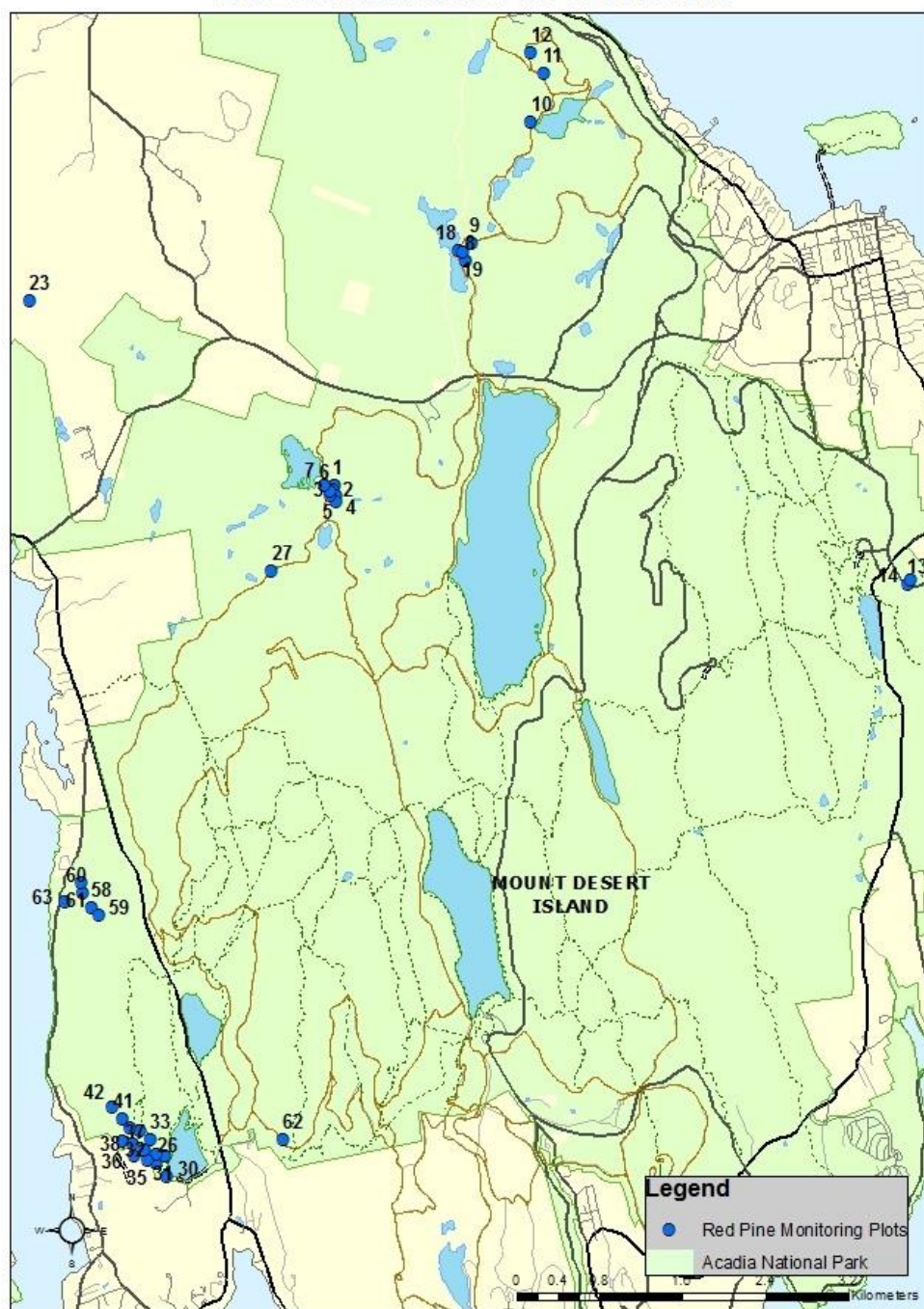
Red Pine Survey Locations on West Mount Desert Island



20150218 MFS, CES

Map 3. All red pine survey points located on the west side of Mount Desert Island, ME. Red pine stand locations were recorded with survey points taken along roads, carriage roads, and trails. Approximate size and density was recorded for each stand, as well as a visual health assessment of the trees. Red pine stands on the west side were concentrated on Acadia and St Sauveur Mountains to the east of Echo Lake (Survey points: 29-37, 128-132).

Red Pine Monitoring Plot Locations on East Mount Desert Island



20150218 MFS, CES

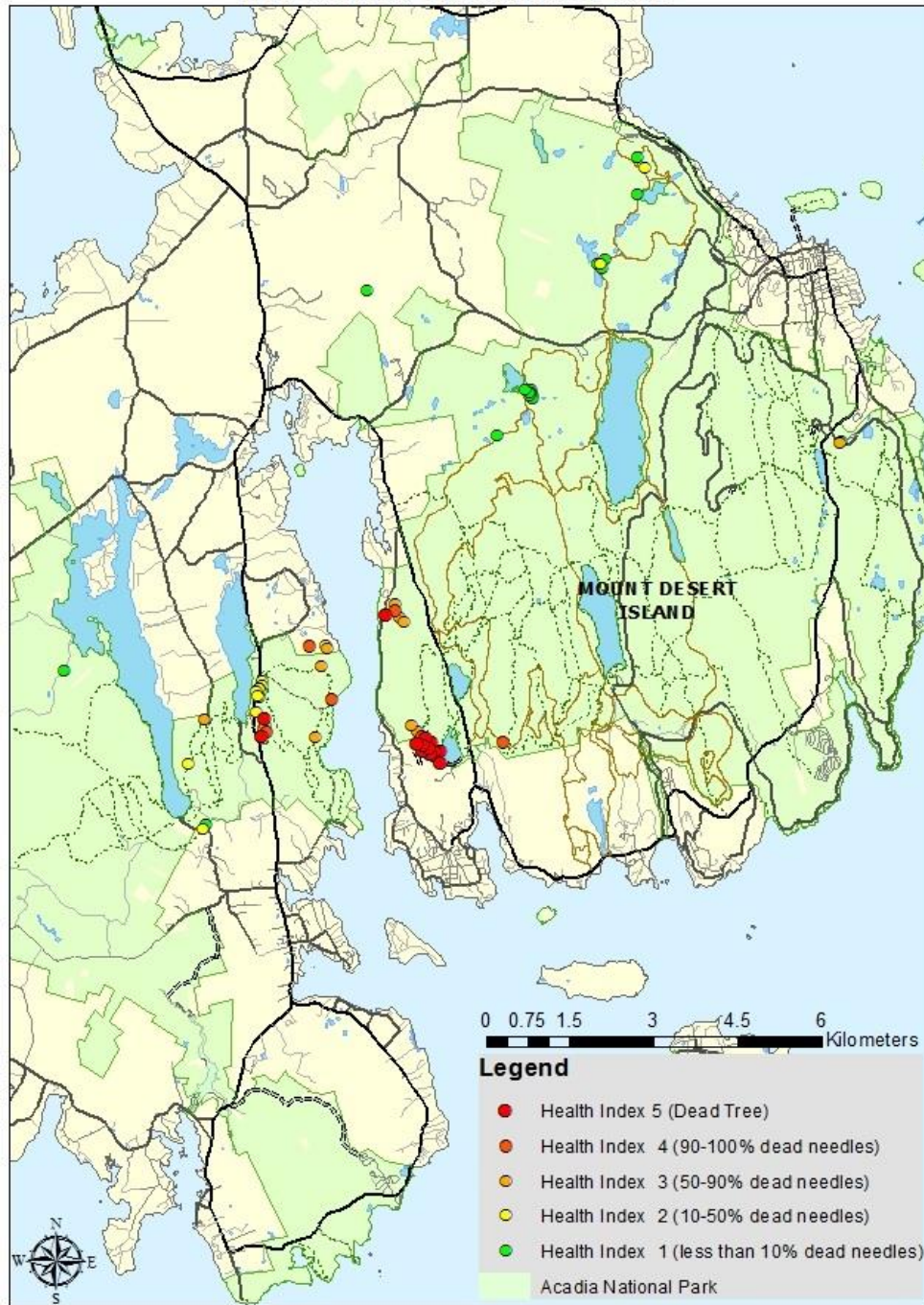
Map 4. Permanent plot locations on the east side of MDI. Plots are clustered around Witch Hole Pond (Plots 10-12), Breakneck Ponds (8, 9, 18, 19), Aunt Betty Pond (1-7), and Norumbega Mountain (Plots 26, 30-42, 58-61, 63).

Red Pine Monitoring Plot Locations on West Mount Desert Island



Map 5. Permanent plot locations on the west side of MDI. The majority of plots are located on the west side of St. Sauveur Mountain (Plots 24, 25, 28, 29, 47-57) and Acadia Mountain (Plots 43-45).

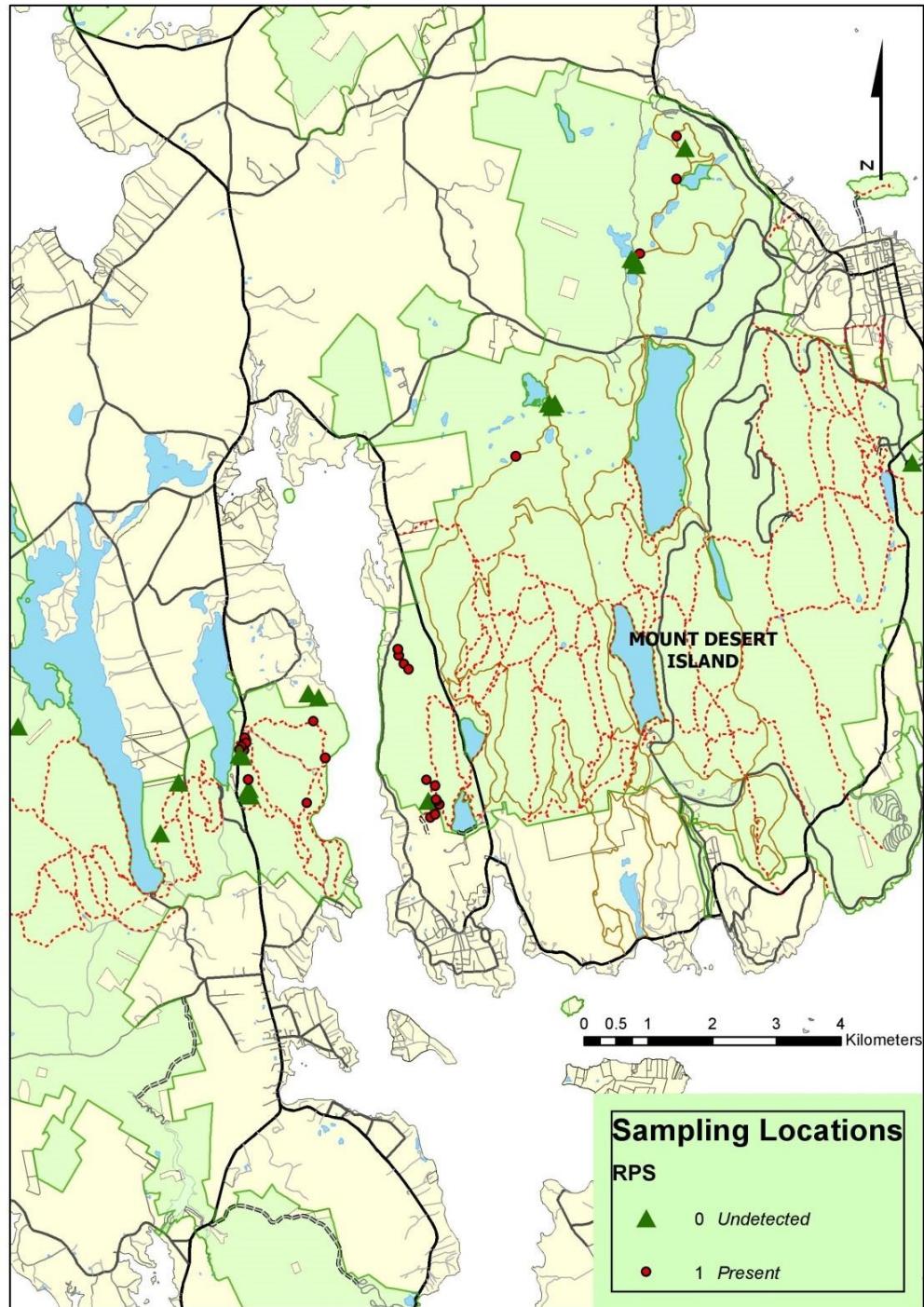
Red Pine Average Health Index by Plot in Acadia National Park



20150218 MFS, CES

Map 6. Average health code for each plot on a color gradient: ranging from very healthy trees with few symptoms (green, 1), to very severe symptoms (orange, 4), and majority dead trees (red, 5). Note the concentration of red plots (Health code 5) straddling Somes Sound.

Presence of Red Pine Scale in Samples taken on MDI



Map 7. Locations of all twig samples taken and whether red pine scale was identified on the sample. Note that red pine scale was confirmed on samples from trees in the north end of the park where red pine trees still do not display symptoms.

Appendix B: Protocol

Red Pine Health Monitoring Protocols

Background and Introduction:

In September 2014, *Matsucoccus matsumurae*, also known as red pine scale or Japanese pine bast scale, was detected and confirmed on Mount Desert Island, Hancock County, ME. It is a piercing and sucking insect native to Japan, but it has been in the US since 1946. This is the first confirmed occurrence of red pine scale in Maine. In North America red pine scale feeds on red pine (*Pinus resinosa*), which has been observed to die in 2-5 years after being infected. Much of the red pine on Mount Desert Island is in Acadia National Park, where it is found in scattered stands of varying density. Two areas, Norumbega Mountain on the east side of the island and Acadia Mountain and St. Sauveur Mountain on the west side, are considered the epicenters of the infestation because of the severity of the symptoms displayed by the red pine trees in those areas and the high rates of mortality. Other stands, such as the red pine trees near Aunt Betty Pond, Breakneck Ponds, and Witchhole Pond showed little if any symptoms in the fall of 2014. In response to the confirmation of red pine scale, Acadia National Park's Resource Management staff spearheaded an effort to assess the red pine distribution and health on Mount Desert Island (MDI).

Goals and objectives:

The immediate goals of the study were to establish the current range of the scale and the health of red pine stands throughout the park. Based on the permanent plots that we established, long-term sampling can track the direction and the rate at which the scale spreads, as well as changes in canopy and understory composition following the expected widespread death of red pines. We also hope to be able to understand how quickly dead red pines decay in order to better predict when they will become a hazard to people and property.

Methods: Much of the vegetation survey methods described in this protocol was adapted from the Northeast Temperate Network's long-term forest health monitoring protocol (Tierney et al. 2014) and incorporated suggestions from the USFS forest health monitoring office in Durham, NH. Initial steps included determining where red pine populations exist in and around Acadia National Park and was accomplished using available aerial photography, vegetation maps, institutional knowledge of Park staff and conducting visual surveys throughout Mount Desert Island in October, 2014. Sixty-three permanent vegetation monitoring plots were then identified and established in red pine forests of varying health. The standard operating procedures (SOPs) which follow this narrative provide detailed, step-by-step instructions for data collection and analysis. These SOPs include instructions on preparation, site selection and establishment, as well as data analysis and collection. An example datasheet can be found in Appendix C.

Plot Layout and Forest Measurements:

Vegetation data were collected for the overstory using Variable Radius Plots and the regenerating understory using microplots (Figure 1). Within each plot, tree and site measurements will be collected within the stand, determined by the trees counted in the variable radius plot. Tree regeneration and shrub cover will be measured within one, 3-m radius circular microplots embedded within each plot. Photographs will be taken of the plot and overstory to document change in appearance and light penetration potential over time. Red pine twig samples will be collected where possible to ascertain the presence of red pine scale. One or two red pine trees (some plots may add another tree species) will be cored to get an approximation of stand age and to capture a signature of growth rates change.

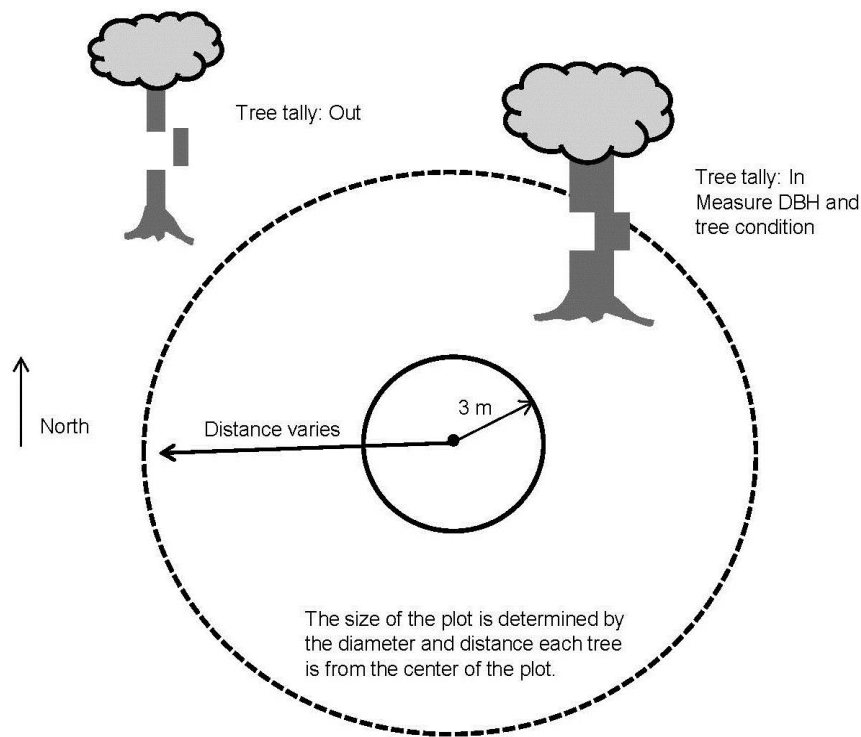


Figure 1. Variable Radius Plot layout with example tree measurements and nested 3m radius regeneration microplot.

Literature Cited:

Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2014. Northeast Temperate Network long-term forest monitoring protocol: 2014 revision. Natural Resource Report NPS/NETN/NRR—2014/805. National Park Service, Fort Collins, Colorado.

SOP 1: Plot selection and establishment

Overview:

This SOP documents the procedure for selecting and establishing plots. Due to the patchy and often sparse distribution of red pine (*Pinus resinosa*) within Acadia National Park, randomly selected plot locations would not have included red pine trees, and so plots were placed in areas where red pine was known to occur.

Plot Selection:

Before plot selection began, surveys were conducted to identify red pine stands within the park. Recorded GPS locations of all red pine stands found using public roads, carriage roads, and trails. At each survey point, we gathered data on approximate stem count, condition of trees, canopy class, and general habitat characteristics. Plots were established in healthy, stressed, and severely symptomatic stands, and strategically located to pick up future direction and rate of spread of the pest. Plots were also established in stands with a majority of dead red pines in order to track understory and species composition changes following red pine mortality.

Plot Establishment:

Locate a stand of red pine. The stand does not need to have a minimum density but the plot should have at least three canopy red pines. Plots will be of variable radius but allow 20 meters between plot center and a hazardous or unforested feature (e.g. a motor road, cliff, lake, etc.). In woodlands where overall tree density is very low, two or more red pines are acceptable. Ideally, plots would be installed where red pine is the dominant or a co-dominant canopy tree in the stand. Plots should be a minimum of 50 meters apart.

Once a location has been selected, use a mallet to drive a 40 cm long, 1 cm diameter fiberglass center stake into the soil. Use care not to bias the regeneration data by always choosing open sites or, conversely, by always choosing sites with high numbers of seedlings or saplings. A certain amount of bias is expected because of the emphasis on maximizing red pine representation.

Attach a Standard Plastic Acadia National Park research tag with the words “Red Pine Health Monitoring Plot” and the plot number written as ACAD## to the center stake with a zip tie.

Witness Trees:

Select three sturdy trees near plot center that are greater than 30 degrees away from one another relative to plot center. Choose trees that are likely to still be standing next time the plot is sampled. Mark each witness tree with a small square (4 x 4 cm) located at around eye level facing toward plot center using white tree paint or paint stick. The witness trees both make it easier to locate plot center and to re-establish the center of the plot if the center stake is lost.

Data Collection:

Location: Record the general location of the plot (e.g., north slope of Norumbega Mountain)

Coordinates: Record the Universal Transverse Mercator (UTM) East and UTM North value for plot center.

Surveyors: Record the initials of all the people present on plot collecting data.

Plot #: Record the unique plot identification number.

Date: Record the date the plot was sampled.

SOP 2: Photopoints

Overview:

This SOP documents the procedure for photographing plots. Photographs will be digitally archived on the Acadia NP shared network drive (L:) using the path: \\INPACAD-HQ03\Division Folders\Resource Management\Vegetation Management\Forest Health\Red Pine Scale\Red Pine Scale Photos. They will be used as visual reference for change in appearance of plots over time.

Data Collection:

Five scenes and the plot tag are photographed at each plot. All scene photos are taken standing at plot center and holding the camera in a horizontal orientation (landscape). The first four scenes are taken at each of the four cardinal directions, beginning with North and rotating clockwise (North followed by East, South, and West). The final scene is a photograph of the canopy, which is taken standing at plot center with the camera aimed up toward the canopy. After the scenes are captured, a final photograph is taken of the plot tag, clearly displaying the plot number.

Capture only one photograph of each scene. Do not zoom-in on the scene. Use automatic camera setting to allow the appropriate aperture setting for given light conditions. Use highest resolution setting available (at least 1024 x 768 pixels). Do not use a flash. If photos are accidentally taken in wrong order, are out of focus, taken with flash, etc., it is only acceptable to delete flawed photos and start again if all photopoints from previous plots have already been downloaded and named. Otherwise, take a photo (back of hand, blank sheet of paper, etc.) that makes it clear the photo sequence will start over after that photo.

Data Management:

After field work is complete, download photos to a computer photograph directory. Rename photos using the following format:

Four character park code + 2-digit plot code + Scene (N, E, S, W, C=canopy, ID=ID photo) + Date (YYYYMMDD), with each element separated by an underscore (_). So the canopy photo at Acadia plot 10, taken January 15, 2015 would be "ACAD_10_C_20150115.jpg"

SOP 3: Stand and Site Measurements

Overview:

This SOP collects stand-level and site measurements. These data will allow proper interpretation of other measures (e.g. if snow is covering 100% of the plot, groundcover data is suspect) and will be used to assess stand structure.

Data Collection:

Stand Structure:

Record the basic stand structure in the plot using these codes:

1 Even-aged: A succeeding stand dominated by a single cohort of closely competing trees of relatively uniform size and height with a closed canopy ($\geq 60\%$ tree canopy cover). Smaller trees are typically stressed or overtopped and have fallen behind their associates. Regeneration and/or tall relics from a previous stand may be present.

3 Multi-aged: A later-successional or mature stand characterized by a distinct canopy with typical regeneration below including trees of many sizes and heights. Canopy trees vary in age and diameter. Typically has a closed tree canopy ($\geq 60\%$ tree canopy cover) but gap dynamics may be evident. This is currently the most common stand structure found in the red pine stands in Acadia National Park.

4 Mosaic: Plot contains at least two distinct structural classes each covering at least 25% of the stand.

5 Early-successional: A succeeding stand without a closed tree canopy ($< 60\%$ canopy cover). The stand may be dominated by a mix of trees, saplings, shrubs, and herbaceous vegetation.

6 Woodland: A stand with at least 25% but less than 60% canopy tree cover, giving the area an open appearance. Trees are open-grown, or growing in small groups interspersed with shrub or herbaceous cover or bare rock.

Crown Closure:

Estimate % of plot area covered by live tree crowns directly overhead and record appropriate code. If foliage is not present due to seasonal variation or temporary defoliation, visualize the amount of live crown that would normally be present. This is especially important for determining crown area of deciduous trees during the winter red pine health monitoring. Do not visualize foliage that formerly existed on dead branches. Codes are associated with % crown closure as follows:

1	<10%
2	10 to 25%
3	25 to 50%
4	50 to 75%
5	> 75%

Dead Red Pine Crown Closure:

Estimate % of plot area covered by dead red pine crowns directly overhead and record appropriate code. This estimated value attempts to quantify the decrease in crown closure due to red pine mortality.

1	<10%
2	10 to 25%
3	25 to 50%
4	50 to 75%
5	> 75%

% Vascular Cover by Layer:

Estimate the total cover of vascular plant foliage by layer within the plot. A rapid cover estimate is made, ignoring overlap among species. Estimate total cover for each layer: Ground (Low), <0.5m above ground; Mid-understory (Mid), 0.5-2m above ground; and High understory (High), 2-5m above ground. Use canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%.

% Bryophyte Ground Cover:

Estimate the total cover of non-vascular plant foliage within the plot in the ground layer only. Use these canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%.

% Lichen Ground Cover:

Estimate the total cover of lichen within the plot in the ground layer only. Use these canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100%.

% Trampled:

Record the percentage of the plot showing evidence of trampling by humans, wildlife, or livestock. Estimate the percentage as: 0, 1-5, 5-25, 25-50, 50-75, 75-95, or 95-100%.

% Cover Bare Soil:

Record the percentage of the plot covered by bare soil as: 0, 1-5, 5-25, 25-50, 50-75, 75-95, or 95-100%. Bare soil is defined as exposed mineral soil with no leaf litter or duff litter present.

% Cover Rock:

Record the percentage of the plot covered by exposed bedrock or large rocks (> 10cm) as: 0, 1-5, 5-25, 25-50, 50-75, 75-95, or 95-100%. Except for crustose lichen that are 2-dimensional, rock does not include lichen cover.

% Surface Water Cover:

Estimate the total cover of surface water in the plot (can be temporary or permanent). Use these canopy cover classes: 0, 1-5, 5-25, 25-50, 50-75, 75-95, or 95-100%.

% Snow Cover:

Record the percentage of the plot covered by snow as: 0, 1-5, 5-25, 25-50, 50-75, 75-95, or 95-100%.

SOP 4: Microplot

Overview:

This SOP quantifies live saplings, established seedlings, and shrubs by species in one 3 meter radius microplot. Seedlings are also quantified by size class. These data yield information on advance regeneration and potential cover.

Definitions:

Saplings are defined as juvenile trees with diameter-at-breast-height (DBH) at least 1.0 cm but less than 10 cm.

Established Seedlings are defined as live juvenile trees that are at least 15 cm tall with at least two true leaves and no cotyledons present, and are smaller than saplings (i.e. less than 1.0 cm DBH). Any juvenile tree ≥ 15 cm tall but less than 1 cm diameter at breast height (1.37 m tall) is considered a seedling.

Shrubs are woody, sub-canopy species. To qualify for counting in the protocol, shrubs must be at least 30 cm tall.

Height of seedlings or shrubs is defined as the distance from the root crown to the top of the terminal bud, or to the top of the tallest fork. Do not include leaves or needles in this measurement. To measure height, gently align seedling or shrub along a ruler or DBH pole with 15 cm, 30 cm, and 1 m markings.

Data Collection:

The microplot is centered on plot center and is therefore marked by the plot center stake. The microplot is circular with a 3 m radius. To identify seedlings or shrubs within the microplot, one crew member holds a tape at the microplot center, while a second crew member stretches the tape out 3 m. The second crew member then slowly circles clockwise at this fixed distance. Both crew members examine the ground for all saplings, established seedlings, and shrubs that fall within the 3 m radius.

Sapling Diameter:

Measure DBH at 1.37 m on the uphill side of the sapling. Round the measurement down to the nearest 0.1 cm. Saplings > 4 cm are measured with the DBH tape. Saplings < 4 cm are measured with calipers. Saplings do not receive identification numbers.

Seedling Count:

Record the number of live, established tree seedlings by species within each height class: 15-30 cm, 30-100cm, 1 - 1.5 m, >1.5 m. Multiple “suckers” that originate from a common base are considered one seedling. Do not count stump sprouts from a live tree; however, do count stump sprouts from a dead bole, counting all sprouts from a common base as one seedling. Do not count “layers” - undetached branches partially or completely covered by soil, usually at the base.

Shrub % Cover:

Estimate % shrub cover by species using the following classes: 0, <1, 1-5, 5-10, 10-25, 25-50, 50-75, 75-95, 95-100%. Shrubs must be ≥ 30 cm tall to be counted.

SOP 5: Tree Measurements

Overview:

This SOP details how to measure species, diameter, and condition of all live and standing dead trees $\geq 10\text{cm}$ diameter-breast height (DBH) within each variable radius red pine monitoring plot. These data will yield information on tree growth, mortality, and condition, and stand structure and composition.

Definitions:

Diameter-at-breast-height (DBH) is measured at 1.37m above the ground line on the uphill side of the tree.

Live trees are trees with any living parts (leaves, buds, or cambium) present at or above DBH, including trees that have been temporarily defoliated.

Dead standing trees are dead trees that lean < 45 degrees from vertical.

Standing trees are free standing < 30 degrees from vertical.

Leaning trees are trees leaning > 30 degrees from vertical.

Broken trees are trees whose main stem or branch is broken or missing.

Procedure:

Delineate the variable radius plot using a 10 factor prism. This sampling technique uses tree size and proximity to plot center to determine whether a tree is inside or outside the plot. To determine this, stand about an arm's length from plot center with the prism directly above plot center. Trees are sighted through the prism at approximately DBH height. Starting from any fixed point, rotate clockwise and sight all trees. Trees are considered inside the plot if the offset image in the prism overlaps with the tree viewed without the prism. Trees are considered borderline if the offset prism image touches and aligns with the tree viewed without the prism, but does not overlap. The first borderline tree is considered to be inside the plot; the next borderline tree is considered outside the plot, and this pattern for borderline trees continues the entire way around the plot. Additionally, to be considered a tree within the plot, the DBH of a tree must be $\geq 10\text{cm}$.

Data Collection:

Once a tree is determined to be inside the plot the following data are collected:

Species:

Record full species name for each tree

DBH:

Measure tree diameter at breast-height (1.37m) above ground line on the uphill side of the tree. Round measurement down to the last 0.1cm.

Tree Status:

Record a tree status for each tree using a two letter code. The first letter designates whether the tree is alive (A) or dead (D). The second letter designates whether the tree is standing (S), leaning (L), or broken (B).

Crown Class:

Assign code describing tree crown position in canopy relative to immediate neighbors.

1 Open-grown: Crown has received full sunlight from above and all sides through much of its life, particularly during early development, as seen by well-developed lower branches.

2 Dominant: Crown extends above canopy. Taller than average tree in stand and has well-developed crown.

3 Co-dominant: Crown is at general level of the canopy. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns. Red pine in Acadia is most often in the co-dominant crown class.

4 Intermediate: Crown is shorter than co-dominant trees but with a crown that extends into the general canopy. Tree has small crown and is very crowded from the sides.

5 Sub-canopy: Crown entirely below the general level of the canopy.

Red Pine Tree Health Status:

Record a health status for all red pine in a plot using the following classification:

- | | |
|---|------------------|
| 1 | <10% necrosis |
| 2 | 10-50% necrosis |
| 3 | 50-90% necrosis |
| 4 | 90-100% necrosis |
| 5 | dead tree |

Decay Class:

For each dead standing tree, record code indicating the tree's stage of decay using the following scale:

1 Bark firmly attached; branches retain many small twigs; sound wood covered by intact bark.

2 Bark, if present, is decayed, faded, and not firmly attached; branches and small twigs may be present; hard wood that is impenetrable with fingernail or pen point, may be case hardened with powder wood beneath.

3 Bark generally absent; some branch stubs may remain but no twigs; soft wood that responds to finger pressure and may exude moisture, and powder wood

4 Bark generally absent; no branch stubs or twigs; powder wood

5 Bark absent; no branch stubs or twigs; powder wood; rarely, if ever, observed

Woodpecker damage:

Record Yes or No if obvious sign of woodpecker feeding activity is present anywhere on the stem of the tree. Signs of woodpecker activity may include bark and wood debris surrounding the base of tree as well as holes at any height of the stem of the tree that have been excavated by a woodpecker's bill.

SOP 6: Twig Sample Collection and Pest Identification

Twig Collection:

Attempt to collect a red pine live twig sample from each plot (if live red pine exists on plot) using pole or hand pruners. If unable to reach a twig on a tree within a plot, a twig can be collected from trees immediately adjacent to the plot. If a twig sample is collected outside a plot or a plot-adjacent area, a GPS location should be taken and UTM E and UTM N coordinates recorded. Because all red pine in an area could potentially be dead, or if all live twigs are beyond the reach of pole pruners, it may be impossible to collect a twig sample from each plot. Place twig samples in a large ziplock bag and label in permanent marker with the following information: plot number (or GPS coordinates when appropriate), collector's initials, date, and descriptive location information (e.g., Acadia Mountain). Store collected twig samples in ziplock bags in a refrigerator.

Pest Identification:

Examine collected twigs under magnification using a dissecting microscope to determine the presence of red pine scale (*Matsucoccus matsumurae*). Record the observed presence or absence of the scale insect on each twig and the initials of the individual(s) analyzing the twig.

Proper identification of red pine scale is critical. When a specimen's identity is uncertain, send a photograph or the twig to the Maine Forest Service's Insect and Disease Laboratory at 168 State House Station, 50 Hospital street in Augusta, ME 04333 for confirmation.

SOP 7: Collecting and Aging Tree Cores

Coring the Tree:

At each plot, select one co-dominant live red pine tree inside the plot or in the area directly adjacent to plot. Additionally select a similarly sized, co-dominant tree of a different conifer species (i.e. white pine (*Pinus strobus*), pitch pine (*Pinus rigida*), red spruce (*Picea rubens*), etc.). Selected trees should be as representative of the trees in the plot as possible. Using an increment borer, cores should be collected at DBH, in an area free of wounds, branch stubs, unusual swellings, etc. Ensure alignment of the borer is aimed into the pith of the tree to avoid missing any annual rings.

Store core samples in a slotted plastic tray and record the following information: plot number, core tray number, core slot number, tree species, crown class (this should almost always be co-dominant, but note if a different crown class, such as dominate or intermediate, was cored), and corer initials.

Analyzing Tree Cores:

Prepare cores by allowing them to air dry for several days. Cores should be sanded by hand with progressively finer grits. Rings can be counted using a 10x dissecting microscope. If a core is missing the pith of a tree, a pith locator should be used to estimate the number of missing rings. A pith locator designed by Applequist (1958) is a commonly used method.

References

Applequist, M. B. "A simple pith locator for use with off-center increment cores." *Journal of Forestry* 56.2 (1958): 141.

Appendix C: Sample Datasheet

Red Pine Scale Task Force Regeneration Microplot and Stand Data Sheet

Photos (N,E,S,W, Canopy, Center):

Microplot Data

Shrubs:

Species	% Cover

Seedlings 15-30 cm:

Species	Count

Seedlings 30 cm-1m:

Species	Count

Stand Data:

Stand Structure:

Even-aged (1), Multi-aged (3), Mosaic (4),
Early Sucessional (5), Woodland (6)

Crown Closure:

Dead RP in Canopy:

<10 (1), 10-25 (2), 25-50 (3), 50-75 (4), >75 (5)

Witness Trees:

#	Species	Distance	Angle
1			
2			
3			

Location:

Plot #:

Coordinates:

Date:

Surveyors:

Saplings:

Species	DBH

Seedlings 1 m-1.5m:

Species	Count

Seedlings > 1.5m:

Species	Count

% Trampled:

% Cover Bare Soil:

% Cover Rock:

% Surface Water:

% Bryophyte Cover:

% Lichen Cover:

% Snow Cover

Vascular Plant Cover <0.5 m:

Vascular Plant Cover 0.5-2 m:

Vascular Plant Cover 2 m-5m:

Cover Classes for % Covers:

0 (0), 1-5 (1), 5-25 (2), 25-50 (3),
50-75 (4), 75-95 (5), 95-100 (6)

Appendix C: Sample Datasheet (continued)

[illegible]