State of the Forest: An Assessment of the Spruce-Fir Forest of Hurricane Island, Maine.

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Introduction

Hurricane Island is a 125-acre island in Penobscot Bay off the coast of Maine. The island served as a granite quarry town between the years of 1870-1914 and once sustained a population of over 600 people. Since then, it has served as a base camp for the Hurricane Island Outward Bound School from 1963 until 2005, and is now home to the Hurricane Island Center for Science and Leadership. Since the quarry era, the forests on the island have remained relatively untouched. This is particularly true for the spruce-fir stand located on the northern half of the island.

The study area is focused on the spruce-fir stand surrounding Slocum's Trail (See Appendix A). This area was chosen because it intersects the largest continuous spruce-fir stand on the island. Portions of this stand were deforested when the island was a quarry town and some were left untouched during that time (See maps in Appendices A & B). Red spruce (*Picea rubens*), white spruce (*Picea glauca*), and balsam fir (*Abies balsamea*) are the primary species found within the stand.

There were two main objectives of this study. The first was to assess and summarize the current health of the forest and determine any major threats to the trees themselves as well as the overall island ecosystem as a whole. The second was to recommend the best protocol for future monitoring of Hurricane's forests. This study was completed for the Hurricane Island Center for Science and Leadership (HICSL) in order to build the Center's baseline knowledge of the natural communities on the island since little to no previous research has been done on the island's forested ecosystem. The results of this study will be used to make forest management decisions and establish future forest monitoring efforts on Hurricane Island.

Methods

Twelve plots were set up along a 600 m transect on Slocum's Trail. The transect started 25 m into Slocum's Trail from the intersection of Broadway Road and Slocum's in order to sample only areas of spruce-fir and not shrubby edge habitat (See map in Appendix A). The distance of each plot from the beginning of the transect was determined using a random number generator. The numbers generator chose 12 numbers between 0 and 600. The following distances were generated and used: 15, 50, 169, 190, 222, 269, 324, 344, 402, 500, 546, and 576 m. At each designated distance along the transect, a coin was flipped to determine which side of trail the plot would be located on. Heads designated that the plot would be set on the right side of the trail; tails designated that the plot would be set on the left side of the trail. From there, the plot's distance off the trail was determined by rolling a di (1=5 m, 2 =25 m, 3=50 m, 4=75 m, 5=100 m, 6=150 m). Depending on which distance was rolled, I walked into the stand perpendicular to the trail, and recorded the bearing in which I walked. If an impassable obstacle was reached along the transect, I would turn back and continue walking the remaining distance towards the trail. If I reached the trail again before finishing the

distance, I would turn around again and walk finish the remaining distance walking back in the original direction. Once at each plot center, I set up a 10x10m square plot, marked the plot center, and marked the northeast, northwest, southeast, and southwest corners with flagging tape.

Within each plot, for each individual tree (>10 ft in height) I recorded the dbh (diameter at breast height), species, and any sign of disease, damage, or pests. I also recorded the same information for any snags within the plots. The amount of 1-hr, 10-hr, 100-hr, and 1000-hr fuel woods was estimated (Lutes 2006). The number of spruce (*Picea* spp.) saplings, balsam fir saplings, *Vaccinium* spp., and other shrub or saplings were tallied. Soil depth was measured in the northwest corner of the plot by using a blade to dig until bedrock was reached and then measuring using a meter stick. Notes were also taken about the herbaceous cover within the plot, presence of quarried stones, and deer sign.

Table 1. Plot Information: Distance along the transect, the side of the trail the plot center was located on, the distance off the trail, and the bearing walked (perpendicular to trail) to each plot center.

	Distance into transect (m)	**Side of trail (left or right)**	**Distance from trail (m)**	**Compass bearing**
Plot 1	15	Right	25	250°
Plot 2	50	Right	75*	100°
Plot 3	169	Left	100	260°
Plot 4	190	Right	25	80°
Plot 5	222	Left	50	290°
Plot 6	269	Left	50	270°
Plot 7	324	Left	75	230°
Plot 8	344	Right	10	60°
Plot 9	402	Right	100	20°
Plot 10	500	Left	25	200°
Plot 11	546	Left	75	220°
Plot 12	576	Right	25	70°

*Plot center ended up being 25m from the trail after going in 25m and reaching an impassable obstacle, going back 25m to the trail, and ending again 25m in.

Results

140 trees in total were sampled over the 12 plots. The average dbh of all sampled trees was 14.5 cm, the median dbh was 12.25 cm, maximum and minimum dbh's were 37.5 cm and 2cm, respectively. The average basal area per plot was 0.255 m^2/0.01 ha (Figure 1). In total among all the plots, there were 69 red spruce, 27 white spruce, and 12 balsam fir. There were 32 dead trees or snags overall and no other tree species were found within any of the plots.

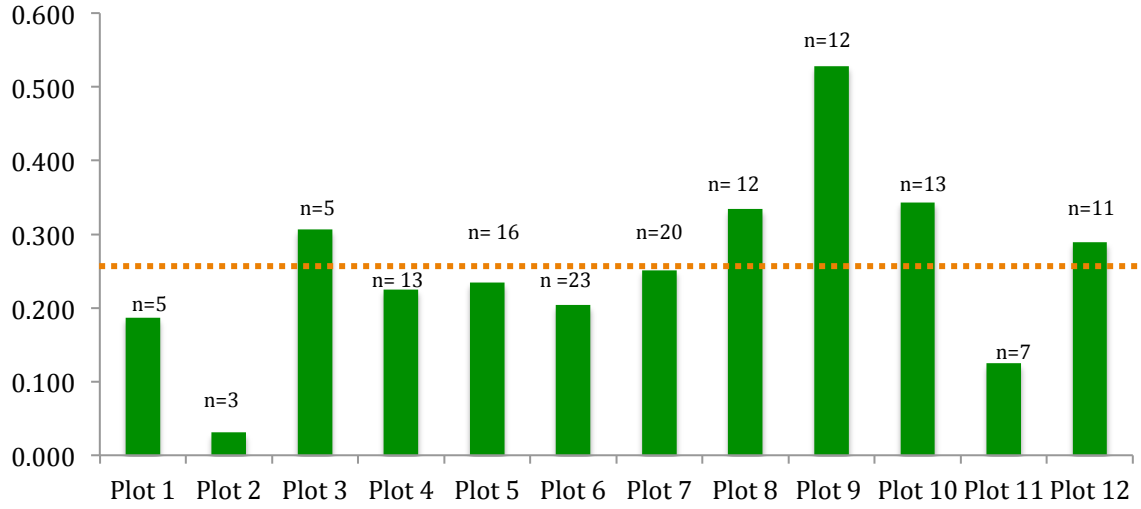

Figure 1. Basal Area per Plot: Basal area (m^2/0.01ha) of each plot. Dotted orange line represents average basal area per plot. (n = total number of trees in each plot).

Of the 108 living trees sampled, 51 had signs of damage or disease and 57 did not show signs of damage or disease. Red spruce abundance was highest in plots furthest away from habitat edges and the coast. Balsam firs were found mostly in plots that were closest to habitat edges and the coast. Similarly, white spruces were found in highest abundances near habitat edges and were the tallest canopy layer in plots where they were found (Figure 2). Eight of the twelve plots had trees with signs of witches' broom, a deformity created by a fungi that causes a dense mass of shoots to emerge from single points off of trees, in them. More than half of the total number of saplings tallied were red spruce, while the few balsam fir saplings generally occurred in groups among only a few plots (Figure 3).

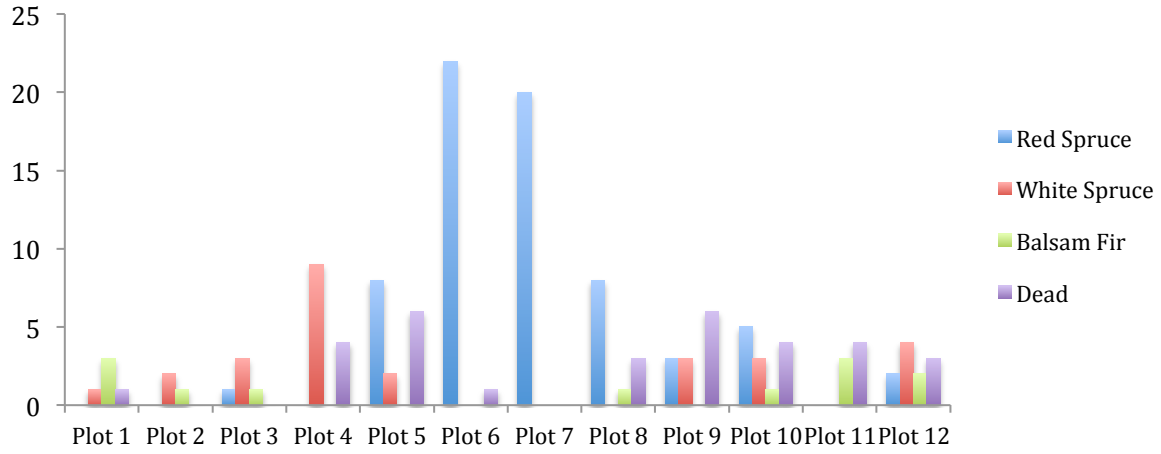

Figure 2. Species Abundance Plot Comparison: Tree species abundance per plot along the transect.

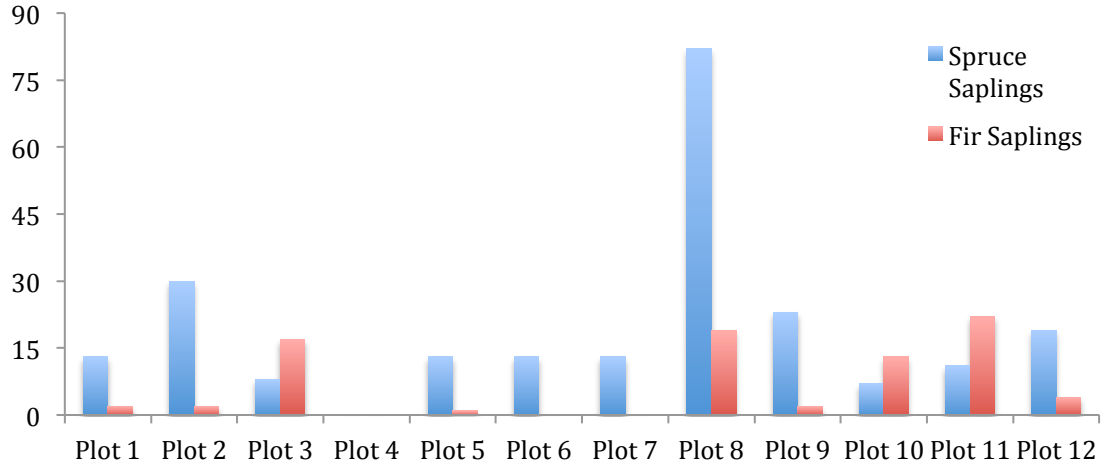

Figure 3. Plot Regeneration: Number of red spruce and balsam fir saplings (trees <10ft and >1ft in height) per plot.

The soil depth within all plots was very shallow, with the deepest being 33 cm (Table 2). Throughout all plots there were areas of exposed bedrock with less than 1 cm of soil. Large amounts of dead woody debris were present in all plots. Small fuel woods were the most abundant, however large fuels were present throughout sampling.

Table 2. Soil Depth: Soil depth of each plot and average soil depth among all plots.

Plot	Soil Depth (cm)
1	17
2	30
3	13.5
4	20.5
5	9
6	8
7	21
8	20.5
9	8.5
10	33
11	17
12	16
Average	17.8

Table 3. Fuel Wood Counts: The amount of 1-hr fuel woods (<1/4 inch diameter), 10-hr fuel woods (1/4-1 inch diameter), 100-hr fuel woods (1-3 inch diameter), and 1000-hr fuel woods (3+ inch diameter) within each plot.

	1-hr	**10-hr**	**100-hr**	**1000-hr**
Plot 1	1000+	51-100	11-50	1-10
Plot 2	11-50	11-50	11-50	1-10
Plot 3	1000+	51-100	51-100	11-50
Plot 4	251-500	11-50	1-10	1-10
Plot 5	251-500	51-100	11-50	11-50
Plot 6	101-250	51-100	1-10	1-10
Plot 7	150-200	51-100	11-50	1-10
Plot 8	251-500	51-100	11-50	1-10
Plot 9	500-1000	101-250	51-100	1-10
Plot 10	1000+	251-500	51-100	11-50
Plot 11	101-250	101-250	51-100	11-50
Plot 12	501-1000	101-250	51-100	1-10

Discussion

In "Spruce-fir Forests of the Coast of Maine" Ronald B. Davis studied the structural and developmental characteristics of Maine's coastal spruce-fir forest type and found red spruce to be well dispersed throughout stands while balsam fir tended to concentrate in groups of sapling-sized individuals (1966). He also found that in mixed red and white spruce stands, similar to the ones present on Hurricane, white spruce is more common close to the shore, whereas red spruce is more common where closed canopy conditions prevail (Davis 1966). My study found similar results to those of the Davis study. Red spruce was found in nearly all plots and was the most abundant species by far, particularly in areas with closed canopy forest conditions (Chart 2). Balsam fir regeneration and mature trees were always present in the same plots and trees did not occur singly within plots (Chart 2 & 3). All white spruce sampled were found on the outer edges of the sampling area near openings by trail edges or exposed coastal areas (Chart 2). There were also more white spruce in areas that were deforested during the quarry era on the island because it provided a more open and potentially grassy environment, which is the ideal environment for white spruce to grow in (Appendix B). The absence of white spruce saplings reflects its near inability to survive in suppressed conditions and reproduce in closed canopy conditions, which corresponds with the absence of white spruce in the interior plots (Burns et al. 1990). Red spruce was particularly abundant in plots towards the center of the stand where the forest canopy was more dense and continuous (Chart 2).

The high basal area per plot can be attributed to the large amount of smaller trees within each plot as opposed to a smaller amount of larger trees (Chart 1). For example, the plot with the most trees (n=23) had a below average basal area with only 0.204 m^2/0.01ha. Under favorable conditions, red spruce can be over 23cm in diameter in 60

years and mature red spruce and balsam fir tend to have dbh's greater than 30cm (Burns et al. 1990). The sampled trees in this case likely have not reached their full maturity and/or have grown in a competitive and less favorable environment. The microclimate of the island could be considered a harsh environment, which would alter the growth patterns of the trees on the island. Competition during the sapling stage cannot be ignored, however, since there was generally only one clear canopy layer within the plots, which were likely the surviving dominant individuals.

Coastal fog is one potential factor that could be causing harsher growing conditions on Hurricane Island, which could explain the species uniformity of the forest, as well as the current stand conditions. Along the Appalachian Mountains of eastern North America, red spruce dominated forests occur that are different from boreal spruce-fir environments because they are more affected by wind damage than fire damage and have a mean annual temperature above 2°C (Cogbill and White 1991). The climate conditions on Hurricane more closely match the montane spruce-fir forests than the boreal spruce-fir forests. In these montane spruce-fir ecosystems, the cloud line is often where the spruce-fir environment begins to dominate and tree species richness declines, potentially due to the added precipitation from fog moisture (Vogelmann et al. 1968). This could explain why the spruce-fir environment occurs so close to sea level since coastal fog regularly inundates it. Another potential explanation for the low tree species richness on Hurricane is its distance from the mainland. In "peninsulas in Maine: woody plant diversity, distance, and environmental patterns", Milne and Forman found a significant decrease in species richness as distance from the mainland the peninsula increased (Milne and Forman 1986).

The largest risks currently facing the spruce-fir stand on Hurricane are fire, windthrow, and an infestation of witches' broom. Spruce are very susceptible to fire damage due to their shallow roots, thin bark, and flammable needles (Burns et al. 1990). On top of that, all of the sampled plots had high abundances of dead woody debris of varying fuel loads (Table 3). This is such a huge a concern because an abundance of smaller pieces of dead woody debris increases the chances of fire ignition and an abundance of larger pieces intensifies the effects of a fire by fueling it for a longer period of time: combined those greatly increase the severity of a potential fire on Hurricane (Lutes 2006). The shallow roots of spruce, lack of wind protection on the island, and the shallow soils on the island put Hurricane's forest at huge risk for windthrow (Table 2). While windthrow can be beneficial in creating gaps in which new regeneration can thrive, if Hurricane were to be hit by hurricane force winds, there is a high potential for a massive windthrow event, which could alter the entire forest dynamic. Witches' brooms were the most common damage recorded during the study and while they do not kill trees immediately, it can kill a tree slowly over time by putting all of the nutrients towards the brooms and not the rest of the tree. More research would need to be done to determine the exact cause of the witches' brooms on Hurricane in order to determine the best method of eradication.

The actual ratio of damaged or diseased trees to not damaged or diseased trees is however likely much lower than found. Some misidentification of witches' broom could have occurred during data collection, which would have led to more trees being identified

as damaged or diseased than actually were. Additionally, throughout data collection, trees with live crown ratios of less than 0.6 were considered to be damaged or diseased which is not necessarily true since a lot of dead lower branches is common when the tree starts to mature and reach the top of the canopy (Burns et al. 1990).

Forest Monitoring Project Recommendations:

While the methods used in this study were successful in determining major threats to Hurricane Island's spruce-fir stand, changes should be made in order to set up a more long term monitoring project. Adding a transect along the Costal Trail (green dotted line on map in Appendix A) between its intersection with Broadway Road on the western side of the island around the northwestern coast to Valley Cove or increasing the potential distance walked into the stand from the Slocum's transect would provide a more representative sample of plots by increasing the overall sampling area. In order to obtain more accurate and useful soil depth data, an increase in the number of measurements taken per plot to at least five is recommended. Taking core samples of at least a few, if not all trees within each plot could provide useful historical data as well a better understanding of the forest's age structure. Ratio of live crown to total height, especially of red spruce, is another aspect that could be valuable to collect as it can be good indicator of growth vigor. Lastly, more detailed herbaceous data should collected including species present and some measure of abundance, possibly percent ground cover over the entire plot.

Forest Management Recommendations:

Removal of dead standing and fallen trees is highly recommended in order to reduce fuel wood availability and decrease fire risk as well as to allow new regeneration to occur. Trees infected with witches' broom should be pruned of infected branches or cut down entirely in order to decrease the risk of spread, incase their formation has been caused by a dispersing fungus. Additional management recommendations depend on the needs and want of HICSL and should be advised by a forester. The New Forestry techniques discussed in "The red spruce-balsam fir forest of Maine: Evolution of silvicultural practice in response to stand development patterns and disturbances" written by Robert S. Seymour and Malcolm L. Hunter, Jr. could be a useful and practical starting point.

Additional Notes:
Of the 8 tree cores taken in varying locations of various species around the island in early August, two cores were not decipherable. Four were over 100 years old: three red spruces and one white spruce. Two of the 100+-year-old trees showed potential sign of a spruce budworm outbreak in the 1970s/1980s. For more information about spruce bud worm: http://na.fs.fed.us/spfo/pubs/fidls/sbw/budworm.htm

	Species	**DBH (cm)**	**Approximate Age (years)**	**Additional Notes**
Tree 1	White Spruce	50	65	-
Tree 2	Red Spruce	31.9	109	-
Tree 3	Horsechestnut	79	-	No apparent rings
Tree 4	White Spruce	45.9	95+	1 inch section undecipherable; spruce budworm sign
Tree 5	Red Spruce	46.7	158	Spruce budworm sign
Tree 6	Red Spruce	27.5	101	-
Tree 7	Red Spruce	47.2	-	Rings undecipherable
Tree 8	White Spruce	48	57	-

Appendix A

A current trail and facilities map of Hurricane Island. The approximate study area is within the boundary marked by the yellow line.

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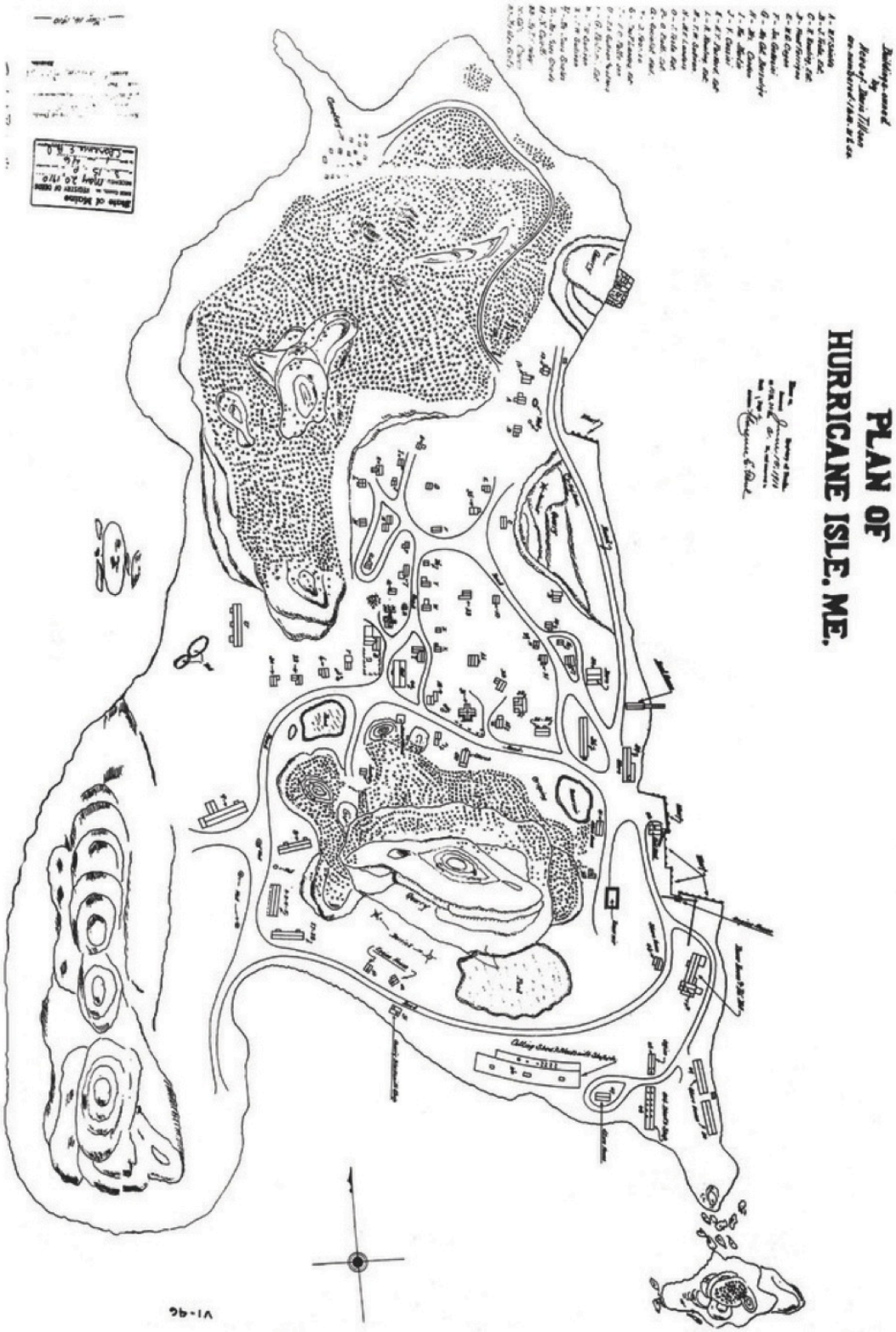
Appendix B

Historical map of Hurricane Island from 1910. Northern half of the study area intersects the portion of the island that was forested at that point in time.



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