



# Monitoring Forest Vegetation in the North Coast and Cascades Network

## *2012 Annual Report*

Natural Resource Data Series NPS/NCCN/NRDS—2013/452



**ON THE COVER**

*Pseudotsuga menziesii* and *Arbutus menziesii* at a potential long-term monitoring plot at English Camp, San Juan Island National Historical Park.

Photograph courtesy of Olympic National Park

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the North Coast and Cascades Network Inventory and Monitoring website (<http://science.nature.nps.gov/im/units/nccn/reportpubs.cfm>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm>).

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## Abstract

Late-successional, coniferous forest is critical for ecosystem function and biological conservation in the Pacific Northwest. Such forests are well-represented in the North Coast and Cascades Network (NCCN) of the National Park Service. As part of monitoring natural resources within the NCCN, we track trends in tree recruitment, growth, and mortality. Sampled forests span the range of environments in network parks, at elevations from near sea-level to almost 1800 m. Field activities in 2012 consisted of site selection for San Juan Island National Historical Park (SAJH) and annual checks for tree mortality at Lewis and Clark National Historical Park (LEWI), Mount Rainier National Park, North Cascades National Park Service Complex, and Olympic National Park.

For SAJH, after evaluating 200 point locations in the office, we determined that 70 were suitable for final evaluation in the field. Most rejections were due to insufficient distance from roads or trails, or non-target vegetation. We evaluated 61 points in the field, 11 of which met the criteria for permanent plots. Most rejections were due to non-target vegetation.

The data for 2012 represent the first observations of annual tree mortality for LEWI. Average mortality was higher than for the other combinations of elevation and park. The rate of tree mortality averaged over all elevations and parks was 0.79%, within the range for our first three measurements. As in previous years, most newly-dead trees died standing. As in two of the three previous years, a particular cause of death could not be identified for the majority of newly-dead trees.



## Introduction

This report presents results from monitoring of forest vegetation in the North Coast and Cascades Network (NCCN) as part of the Inventory and Monitoring Program of the National Park Service (NPS). The program focuses on “vital signs,” which are defined as “a relatively small set of information-rich attributes that are used to track the overall condition or "health" of park natural resources and to provide early warning of situations that require intervention” (Fancy et al. 2009). Monitoring is being implemented throughout the National Park System; for this purpose, 270 park units have been organized by ecoregion into 32 networks (Fancy et al. 2009). As one of these networks, the NCCN is composed of eight NPS units including five with significant forest area: Lewis and Clark National Historical Park (LEWI), Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), Olympic National Park (OLYM), and San Juan Island National Historical Park (SAJH). Starting in 1997, numerous monitoring workshops and meetings were conducted in the NCCN to identify key park ecosystem components and core indicators within each ecosystem component, in addition to allocating limited funding to the development and implementation of monitoring protocols (Weber et al. 2009). As part of this process, forest vegetation was identified as one of the park ecosystem components for protocol development. The U.S. Geological Survey (USGS), through the Forest and Rangeland Ecosystem Science Center, was integrally involved in the development of monitoring protocols in the NCCN (Weber et al. 2009), and was the lead agency for development of the original version of the forest monitoring protocol (Woodward et al. 2009). The protocol was subsequently revised to limit its scope and reduce costs, and was published by NPS in the Natural Resource Report Series (Acker et al. 2010). More information on the rationale and design of the program is available in the protocol document (Acker et al. 2010), and the first three annual reports (Acker et al. 2011a, 2011b, 2012). The first three annual reports also presented results pertaining to screening of potential plot locations and baseline information on permanent plots at LEWI, MORA, NOCA, and OLYM, and observations of tree mortality through 2011 at MORA, NOCA, and OLYM.

This report covers the following accomplishments from 2012:

- 1) Screening of potential plot locations at SAJH;
- 2) First observations of tree mortality at LEWI; and
- 3) Continued observations of tree mortality at MORA, NOCA, and OLYM.



# Methods

## Sampling Design

Our overall goal was to encompass the range of climatic regimes and elevation where forests occur in the network. To facilitate replication within different segments of these environmental gradients, we established 300-m elevation bands as fixed strata within each park. Our resources allow us to sample two strata in each of the large parks (MORA, NOCA, and OLYM), and one in the smaller parks (LEWI and SAJH). Thus we include one stratum each at low and high elevations, as well as one at intermediate elevations. We number strata consecutively from low to high elevations. We are monitoring within stratum 1 (0-300 m; LEWI, OLYM, and SAJH), stratum 3 (600-900 m; MORA, NOCA, and OLYM), and stratum 6 (1500-1800 m; MORA and NOCA).

We wanted the sample to be interpretable based on vegetation types, yet flexible enough to be useful in the face of expected future changes in community composition and/or elevation range (Gates 1993) as species respond independently to a changing environment (Peters 1991). Therefore, we conducted double-sampling by initially stratifying our sample using elevation, and secondly by current vegetation. We chose the Generalized Randomized-Tessellation Stratified algorithm (GRTS, Stevens 1997) to obtain a random sample of our target populations. GRTS samples have the advantage of being spatially dispersed but without a repeating interval. Unlike systematic samples, they have an excellent variance estimator and they allow for excluding sites when some selected sites cannot be sampled or are not within the population of interest. Permanent plots are added to the sample in the numerical order generated by GRTS. To identify the target number of plots for each combination of stratum and park, we used a set of power analyses based on tree mortality data from existing permanent plots in the Pacific Northwest. We concluded that six plots per combination of stratum and park was an appropriate compromise between statistical power and cost (Acker et al. 2010).

We are using sets of vegetation communities as proxies for climate within elevation strata, so as to increase the signal of vegetation change due to external drivers and decrease the potential for noise due to environmental differences within strata. The rationale for selecting target vegetation communities at LEWI, MORA, NOCA, and OLYM is available in the protocol document (Acker et al. 2010), and the first three annual reports (Acker et al. 2011a, 2011b, 2012). For SAJH, we selected the *Pseudotsuga menziesii* - (*Arbutus menziesii*) Forest and Woodland Alliance and the *Tsuga heterophylla* - *Pseudotsuga menziesii* / (*Holodiscus discolor*) Forest Alliance (Rocchio et al. 2012), inasmuch as they are similar in species composition, together they account for the majority of the wooded area in the park, and the dry sites on which they occur are more representative of the island's climate than moist sites occupied by other forest types.

Within the random sample for each stratum, we intensively sample mature or old-growth examples of a specific set of vegetation communities to get a biologically interpretable sample. Mortality of trees occurs throughout the life of any forest stand (Franklin et al. 1987, 2002). However, in earlier successional stages, tree mortality tends to result from competition with other trees rather than external factors (Franklin et al. 1987, 2002, Oliver and Larson 1990). Consequently plots are limited to mature or older forests (i.e., at least 80 years old), where the primary drivers of tree mortality are environmental factors external to the stand (Franklin et al. 1987, 2002).

In addition to stand age and vegetation community, sampled stands must meet criteria for safe accessibility and labor costs. In particular, plot locations are within 1.5 km of roads or trails, on slopes of less than 35°, and do not require dangerous access such as traversing steep slopes or crossing deep and/or swift rivers. We excluded points closer than 100 m to roads and trails at the larger parks, and closer than 30 m at LEWI and SAJH, to minimize vandalism and the visual impacts to park visitors. The closer allowable proximity to roads and trails at the smaller parks is due to the smaller total area of the parks and lower off-trail travel by visitors.

### **Sampling Frequency**

We record tree mortality annually for several reasons. Annual observations will better enable us to identify proximate causes of mortality (van Mantgem and Stephenson 2007), inasmuch as signs of relevant insects and pathogens may fade quickly and trees that die standing may soon fall or break. Annual observations also allow for correlation with specific weather events and short-term climate change (van Mantgem and Stephenson 2007). Finally, tree mortality is often an episodic process (Franklin et al. 1987). Longer measurement intervals lead to underestimates of the true rate of tree mortality (Sheil 1995, Sheil and May 1996) and of the temporal variability of tree mortality. Every five years we will measure diameter and crown attributes of trees and add trees that have grown large enough to include in the measured population.

### **Plot Design**

Our permanent plots are slope-corrected one-hectare squares with edges oriented along cardinal directions (Figure 1). This total area is consistent with USFS Forest Inventory & Analysis (<http://www.fia.fs.fed.us/>) and other permanent monitoring plots in the Pacific Northwest (Acker et al. 1998). We permanently mark the corners and center of the plot with rebar. We centrally locate a 0.25 ha intensive plot (a 50 x 50 m square) divided into 25, 100 m<sup>2</sup> subplots (each a 10 x 10 m square) within the 1-ha macroplot (Figure 1; lengths represent one side of a square plot or subplot). The delineations within the 1-ha macroplot are used to subsample different segments of the tree population by size: large trees (>76.2 cm dbh) in the entire plot; small trees (12.7 to 76.2 cm dbh) in the 0.25 ha intensive plot; and saplings (2.5 to 12.6 cm dbh) in nine of the 100 m<sup>2</sup> subplots (see Figure 1). The outer corners of the 0.25 ha intensive plot are marked with rebar and the corners of the 100 m<sup>2</sup> subplots are marked with wooden stakes. The wooden stakes help minimize the visual impact of permanent markings in wilderness areas and can be replaced as they decay. At LEWI and SAJH, the 50 x 50 m square comprises the entire plot.

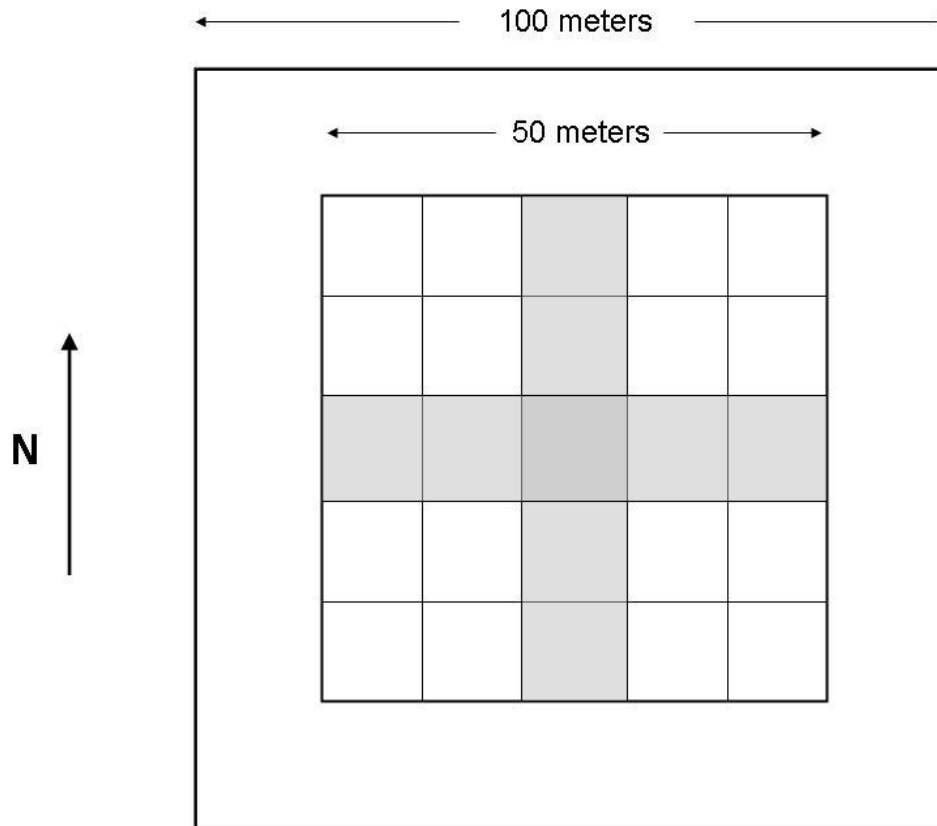


**Figure 1.** One-ha macroplot showing location of 0.25 ha intensive plot divided into 100 m<sup>2</sup> subplots. All plots are oriented along cardinal directions. The subplots within which saplings (2.5 to 12.6 cm dbh) are monitored are shaded. Small trees and snags (12.7 to 76.2 cm dbh) are measured within the entire 0.25 ha intensive plot. Large trees and snags are measured within the entire macroplot. At Lewis and Clark National Historical Park and San Juan Island National Historical Park, the 50 x 50 m square comprises the entire plot. The diagram is not to scale.



## Results and Discussion

### Site Selection at SAJH

#### **Office Evaluation**

In 2012 we carried out office screening for 200 points at SAJH, a number we anticipated would be sufficient to yield more than six locations for permanent plots. Of the 200 points, 70 passed the office screening. Over 40% of the points rejected in the office evaluation were excluded due to insufficient distance from roads or trails; nearly as large a percentage were rejected due to non-target vegetation (Table 1). Points rejected for non-target vegetation were judged from inspection of aerial photographs to occupy areas that were not forested or had less than 25% tree cover. The rate of acceptance in office screening was slightly lower than the overall average for the other combinations of park and stratum (i.e., 35% for SAJH, 42% elsewhere). SAJH was similar to LEWI, the other smaller park, in that insufficient distance from roads and trails and non-target vegetation accounted for most of the rejections in office screening (Acker et al. 2011b).

**Table 1.** Breakdown of reasons for failure of office evaluation for San Juan Island National Historical Park.

| Reason for rejection | Number of cases | Percentage of cases |
|----------------------|-----------------|---------------------|
| Boundary proximity   | 17              | 13.1                |
| Inclusion            | 8               | 6.2                 |
| Non-target           | 48              | 36.9                |
| Privately owned      | 1               | 0.8                 |
| Road proximity       | 16              | 12.3                |
| Site too steep       | 2               | 1.5                 |
| Trail proximity      | 38              | 29.2                |

#### **Field Evaluation**

In 2012 we also completed field evaluation of most of the points which passed the office screening. Of the 61 points, 11 passed the field evaluation and 50 failed. Over half of the points rejected in the field were excluded due to non-target vegetation (Table 2). Just over half of the points rejected for non-target vegetation represented types other than the two target alliances (i.e., dominated by broad-leaved trees species, *Thuja plicata*, or herbaceous plants). The other points rejected for non-target vegetation represented the target alliances but consisted of stands less than 80 years old. Nearly a third of the points rejected in the field were excluded due to insufficient distance from a trail (Table 2). The rate of acceptance in field screening of potential monitoring locations in stratum 1 at SAJH was slightly lower than the overall average for other combinations of stratum and park (i.e., 18% for SAJH, 21% elsewhere). SAJH was similar to LEWI in that non-target vegetation accounted for most of the rejections in field screening; however, insufficient distance from trails was a more common cause for rejection at SAJH than it was at LEWI (Acker et al. 2011b).

**Table 2.** Breakdown of reasons for failure of field evaluation for Lewis and Clark National Historical Park.

| Reason for rejection | Number of cases | Percentage of cases |
|----------------------|-----------------|---------------------|
| Boundary proximity   | 2               | 4                   |
| Inclusion            | 2               | 4                   |
| Non-target           | 28              | 56                  |
| Site too steep       | 2               | 4                   |
| Trail proximity      | 16              | 32                  |

### Tree Mortality in Most Recent Interval

In the 2011 to 2012 interval, tree mortality at individual plots ranged from zero to over 6% (Figure 2). Twenty of the 45 plots had no tree mortality, while three plots had mortality greater than 2%. This interval included the first observations of tree mortality at LEWI; two plots there had the highest mortality in the interval (both about 6%). Proximate causes of mortality and conditions of newly-dead trees differed between these two plots. In one plot, all three deaths were attributed to weather; the trees were found with broken boles. In the other plot, both trees died standing and no cause of death was identified. Due to the smaller plot size at LEWI, and the relatively low tree density (Acker et al. 2012), high annual rates of mortality can result from relatively few tree deaths. The other plot with notably high mortality in the interval (in stratum 3 at MORA) was also among the high-mortality plots in the 2010-2011 interval (Acker et al. 2012). As in the previous interval, the majority of the newly dead trees at the plot were judged to be have been effected by weather, either directly or indirectly (i.e., crushed by a neighboring, uprooted tree). The annual mortality rate at the plot declined markedly from the previous interval (from 9.3% to 4.0%). Tree mortality also declined markedly at the other plot with notably high mortality in the 2010-2011 interval (in stratum 3 at NOCA). Mortality was elevated at the plot in the 2009-2010 and 2010-2011 intervals (8.4% and 6.5%, respectively), mostly due to the bark beetle *Dendroctonus pseudotsugae* (Acker et al. 2012). In the 2011-2012 interval, the tree mortality rate at the plot was less than 1%. There was only one new mortality at the plot and it was evidently not due to the beetle (the tree was found uprooted). Between the various combinations of stratum and park, the average rate of tree mortality varied from zero (i.e., no mortality in any of the plots in stratum 1 at OLYM) to over 2% (Table 3). The overall average rate of tree mortality was 0.79% (standard error 0.20%). Tree mortality in the 2011-2012 interval averaged over all plots was within the range for the first three intervals (i.e., 0.6% to 1.1%; Acker et al. 2012).

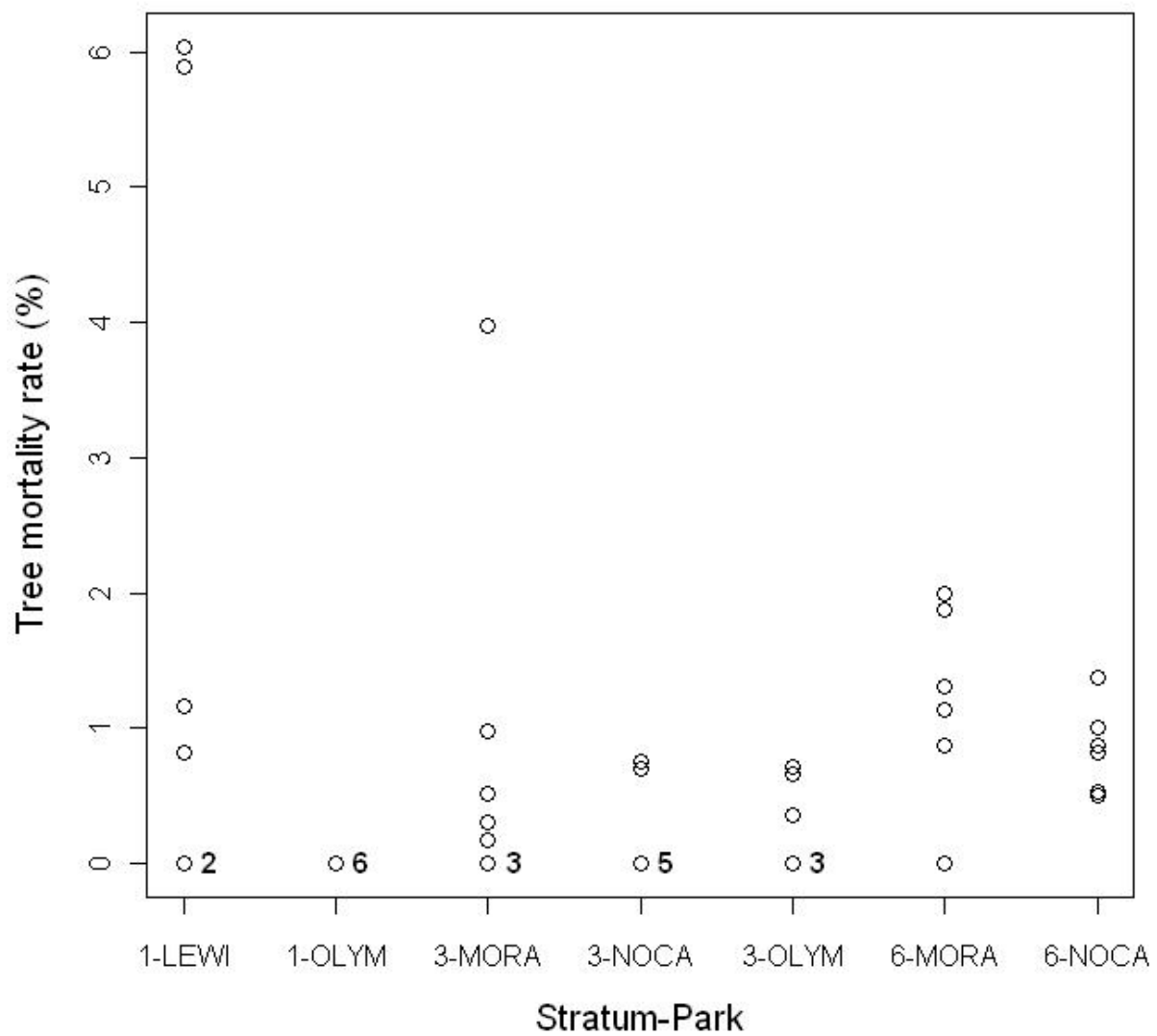


**Figure 2.** Rates of tree mortality observed from 2011 to 2012, by stratum and park. The numbers next to several of the points indicate the number of plots within a combination of stratum and park which had the same rate of tree mortality (i.e., 0.0).

**Table 3.** Rate of tree mortality from 2011 to 2012, in percent, by stratum and park.

| Stratum | Park | Tree mortality rate (%) |      |         |
|---------|------|-------------------------|------|---------|
|         |      | Minimum                 | Mean | Maximum |
| 1       | LEWI | 0.0                     | 2.3  | 6.0     |
| 1       | OLYM | 0.0                     | 0.0  | 0.0     |
| 3       | MORA | 0.0                     | 0.7  | 4.0     |
| 3       | NOCA | 0.0                     | 0.2  | 0.8     |
| 3       | OLYM | 0.0                     | 0.3  | 0.7     |
| 6       | MORA | 0.0                     | 1.2  | 2.0     |
| 6       | NOCA | 0.5                     | 0.9  | 1.4     |

The most common condition of trees reported dead in 2012 (55%) was standing with no obvious cause of death (Table 4). Including all reported causes, standing dead trees accounted for 69% of cases. A smaller number of newly dead trees were found with broken boles (20%), crushed (6%), or uprooted (4%). The preponderance of standing dead trees is consistent with previous years (Acker et al. 2012). *Abies lasiocarpa*, *Pseudotsuga menziesii*, *Abies amabilis*, and *Tsuga heterophylla* accounted for most of the trees reported dead in 2012 (35%, 20%, 16%, and 14%, respectively). Three of the four species have accounted for most of the tree mortality in previous years (Acker et al. 2011a, 2011b, 2012); *Abies amabilis* was among the species accounting for most of the mortalities for the first time.

**Table 4.** Characteristics of trees reported dead in 2012.

| Tree position | Reported cause of death | Number of cases | Percentage of total |
|---------------|-------------------------|-----------------|---------------------|
| Standing      | Unknown                 | 27              | 55.1                |
| Broken        | Weather                 | 6               | 12.2                |
| Standing      | Insects                 | 5               | 10.2                |
| Broken        | Unknown                 | 3               | 6.1                 |
| Crushed       | Weather                 | 2               | 4.1                 |
| Standing      | Disease                 | 2               | 4.1                 |
| Broken        | Vegetation              | 1               | 2.0                 |
| Crushed       | Vegetation              | 1               | 2.0                 |
| Uprooted      | Disease                 | 1               | 2.0                 |
| Uprooted      | Weather                 | 1               | 2.0                 |

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