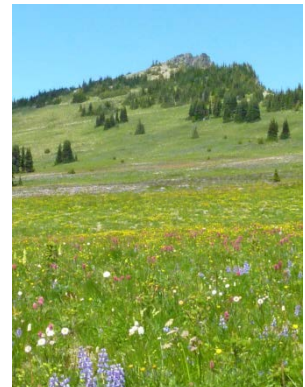
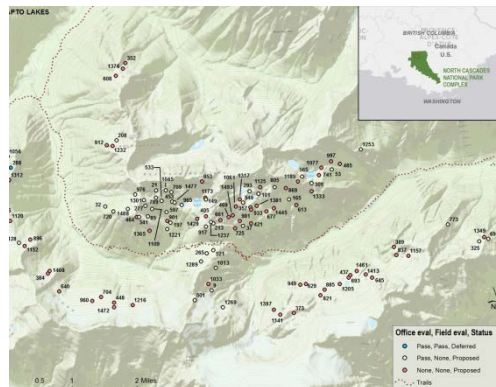
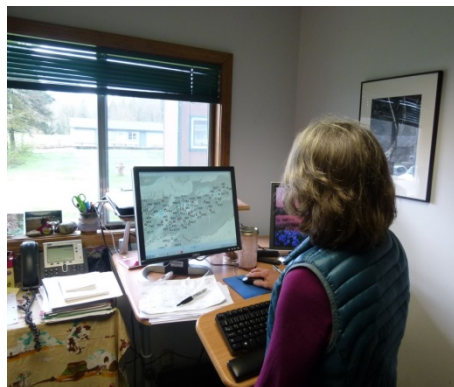




# Alpine and Subalpine Vegetation Monitoring in the North Coast and Cascades Network

## *2010 - 2013 Data Summaries*

Natural Resource Data Series NPS/NCCN/NRDS—2015/746



**ON THE COVER:** Main photo is Easy Peak, North Cascades National Park Service Complex. Bottom row photos, left to right: Mignonne Bivin conducting office screening, map of points in the Tapto Lakes area of North Cascades National Park Service Complex, Sunrise meadow in Mount Rainier National Park  
Photographs courtesy of North Cascades National Park Service Complex

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# **Alpine and Subalpine Vegetation Monitoring in the North Coast and Cascades Network**

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Natural Resource Data Series NPS/NCCN/NRDS—2015/746

Regina M. Rochefort<sup>1</sup>, Mignonne M. Bivin<sup>2</sup>, John R. Boetsch<sup>3</sup>, Steven A. Acker<sup>3</sup>, and Lou Whiteaker<sup>4</sup>

<sup>1</sup>National Park Service

North Coast and Cascades Inventory and Monitoring Program

North Cascades National Park Service Complex

810 State Route 20

Sedro-Woolley, WA 98284

<sup>2</sup>National Park Service

North Coast and Cascades Inventory and Monitoring Program

North Cascades National Park Service Complex

7280 Ranger Station Road

Marblemount, WA 98267

<sup>3</sup>National Park Service

North Coast and Cascades Inventory and Monitoring Program

Olympic National Park

600 E. Park Ave.

Port Angeles, WA 98362

<sup>4</sup>National Park Service

North Coast and Cascades Inventory and Monitoring Program

Mount Rainier National Park

55210 238th Ave.

East Ashford, WA 98304

January 2015

U.S. Department of the Interior

National Park Service

Natural Resource Stewardship and Science

Fort Collins, Colorado

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.

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Please cite this publication as:

Rocheftort, R. M., M. M. Bivin, J. R. Boetsch, S. A. Acker, and L. Whiteaker. 2015. Alpine and subalpine vegetation monitoring in the North Coast and Cascades Network: 2010 - 2013 data summaries. Natural Resource Data Series NPS/NCCN/NRDS—2015/746. National Park Service, Fort Collins, Colorado.

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## Abstract

Subalpine and alpine are ecologically important vegetation zones that provide popular recreational opportunities for visitors to the three mountain parks in the North Coast and Cascades Network (NCCN): Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). In the Pacific Northwest (PNW), these zones are among the most vulnerable to climate change because climate models project winters with lower snowpacks followed by warmer and drier summer seasons. These climate conditions will result in longer and drier growing seasons that facilitate rapid vegetation changes including tree establishment at higher elevations, expansion of shrub cover, and increased grass cover (vs. forbs). In 2012, the NCCN finalized and published a protocol to monitor long-term changes in subalpine and alpine vegetation communities (Rocheffort et al. 2012). Concurrent with protocol development, a sampling strategy was identified and potential monitoring points were identified using a Generalized Random Tessellation Stratified (GRTS) sample. Prior to the establishment of permanent plots, a two-step process was used to review potential plot locations. All GRTS points were first screened in the office using aerial photography to determine if they are in the target vegetation type and if they could be safely accessed. Points which passed office screening were then evaluated in the field using pre-determined criteria. Finally after successful field evaluation, points were rank-ordered by using GRTS and were selected in sequence for establishment of permanent monitoring plots, with a target population of 20-30 plots per park.

Initially panels of 1,500 GRTS points were generated for each park, a total of 4,500 for the NCCN. Between 2010 and 2013, office screening was conducted on 1,544 of the GRTS points and 1,255 passed and were recommended for field evaluation. Three hundred eighty five (385) points were evaluated in the field and 162 points passed this step. In 2013, six plots were established in the network: one subalpine plot in MORA, one subalpine and one alpine in NOCA, and three subalpine plots in OLYM. Field and office screening will continue on points in the priority order generated by GRTS before more plots are selected and established.

# Introduction

Alpine and subalpine are ecologically important vegetation zones that contribute to the character of mountain parks in the North Coast and Cascades Network (NCCN, Figure 1). Collectively, these areas are often referred to as the alpine treeline ecotone (ATE). Ecologically, the ATE is a transition zone extending from closed canopy forests (forest line), up through the mosaic of tree clumps and herbaceous meadows (subalpine parkland), to mountain peaks covered with permanent snow, ice, or rocks. Recreationally, the ATE is a primary destination for many park visitors to photograph flower fields, glaciers, and vistas, to hike, camp, and to climb. Vegetation distribution and composition in this zone is determined by low air temperatures, duration of snowpack, and topography (Douglas and Bliss 1977, Holtmeier and Broll 2005, and Malanson et al. 2007). Consequently, climate change is projected to result in rapid and dramatic changes in tree distribution and species composition of herbaceous meadows (Bachelet and Neilson 2000, Grace et al. 2002, Holtmeier and Broll 2007). Changes in plant species composition and upward expansion of the forest zone will reduce the extent and quality of wildlife habitat for alpine species and could alter visitor use patterns. Based on the ecological and social importance of the ATE and its sensitivity to climate change, the NCCN selected alpine and subalpine vegetation as a “vital sign” in its long-term monitoring program (Weber et al. 2009).

The ATE is a significant component of three NCCN parks: Mount Rainier National Park (MORA), North Cascades National Park Service Complex (NOCA), and Olympic National Park (OLYM). The overarching goal of the Alpine and Subalpine Vegetation Monitoring Protocol is to provide accurate information regarding the status and trends of vegetation in the ATE in order to inform management decisions affecting these areas (Rochefort et al. 2012). Specific objectives of the protocol are to:

1. Determine the status and trends in vegetation composition and structure of alpine vegetation in MORA, NOCA, and OLYM.
2. Determine the status and trends in vegetation composition and structure of subalpine vegetation in MORA, NOCA, and OLYM.
3. Determine the status and trends in vegetation composition and structure of legacy (historic, non-random) vegetation plots in MORA.
4. Determine the status and trends in soil temperature and snow cover period in subalpine and alpine communities in MORA, NOCA, and OLYM and at legacy plots in MORA.
5. Determine status and trends in the structure and condition of whitebark pine stands in MORA, NOCA, and OLYM.

This report presents results from the initial phase of the NCCN Alpine and Subalpine Vegetation Monitoring project. During this phase, potential plot locations were screened in the office to determine if they could be accessed safely and appeared to meet target population criteria. If points passed office evaluations, field evaluations were conducted to determine if the point met all target population criteria and to confirm that they could be accessed safely. Finally, points which passed field evaluations were selected as permanent plots and designated for establishment. This report

summarizes office and field evaluations of potential sites and the plot establishment that was conducted between 2010 and 2013.



**Figure 1.** Map illustrating the location of park units within the North Coast and Cascades Network.

## Methods

### NCCN Target Population and Sampling Frame

Our sample frame was developed using the Washington Gap Analysis Program v.5 (GAP) (Cassidy 1997) and data from Pacific Meridian Resources (PMR) (PMR 1996). Since vegetation maps of high-elevation areas in the NCCN were not available during protocol development, we used the GAP and PMR maps to create polygons of potential subalpine and alpine vegetation, or ATE, for each park. In addition to identifying areas designated as alpine or subalpine by GAP or PMR, we limited the ATE to elevations  $\geq 1,220$  m (4,000') in OLYM and  $\geq 1,524$  m (5,000') in NOCA and MORA. The maps we developed identified approximately 34% of MORA, 36% of NOCA, and 19% of OLYM as within the ATE. The target population for monitoring of alpine and subalpine vegetation in the NCCN was restricted to safely and easily accessible locations. Safely and easily accessible sites were considered to be areas within 1.5 km of trails and roads where the slope is  $\leq 35^\circ$ . Using this definition, our target population captured 12.5% of MORA, but only 3.5% of NOCA and OLYM due to limited road and trail access. (Table 1, Figures 2, 3, 4).

**Table 1.** Percentage of park area in alpine and subalpine zone and in target population.

|                                                     | MORA   | NOCA    | OLYM    |
|-----------------------------------------------------|--------|---------|---------|
| Park area (ha)                                      | 95,150 | 275,691 | 369,654 |
| Alpine/subalpine zone (ha)                          | 31,929 | 100,683 | 70,743  |
| % of park area in alpine/subalpine zone             | 34     | 37      | 19      |
| Sample frame area (ha)                              | 11,879 | 9,652   | 12,988  |
| % of park area in sample frame                      | 12     | 4       | 4       |
| % of alpine/subalpine zone captured by sample frame | 37     | 10      | 18      |

A probability-based sample design was created for monitoring the ATE of MORA, NOCA, and OLYM. A Generalized Random Tessellation Stratified (GRTS) sample was drawn for each park to produce a spatially balanced, random sample (Stevens and Olsen 2004). Points that fell within the boundaries of the target population were output to enumerate a sample frame of points for the park (297,244 in MORA, 241,297 in NOCA, and 324,556 in OLYM). These points composed the population from which the sample was drawn. Within each park, we selected 1,500 sampling points in the order they occurred on the list; thus we developed a list of 4,500 potential sampling points for the three NCCN mountain parks. Our next step was to screen points, in the office and field, to determine if they met the predefined criteria for the sample.

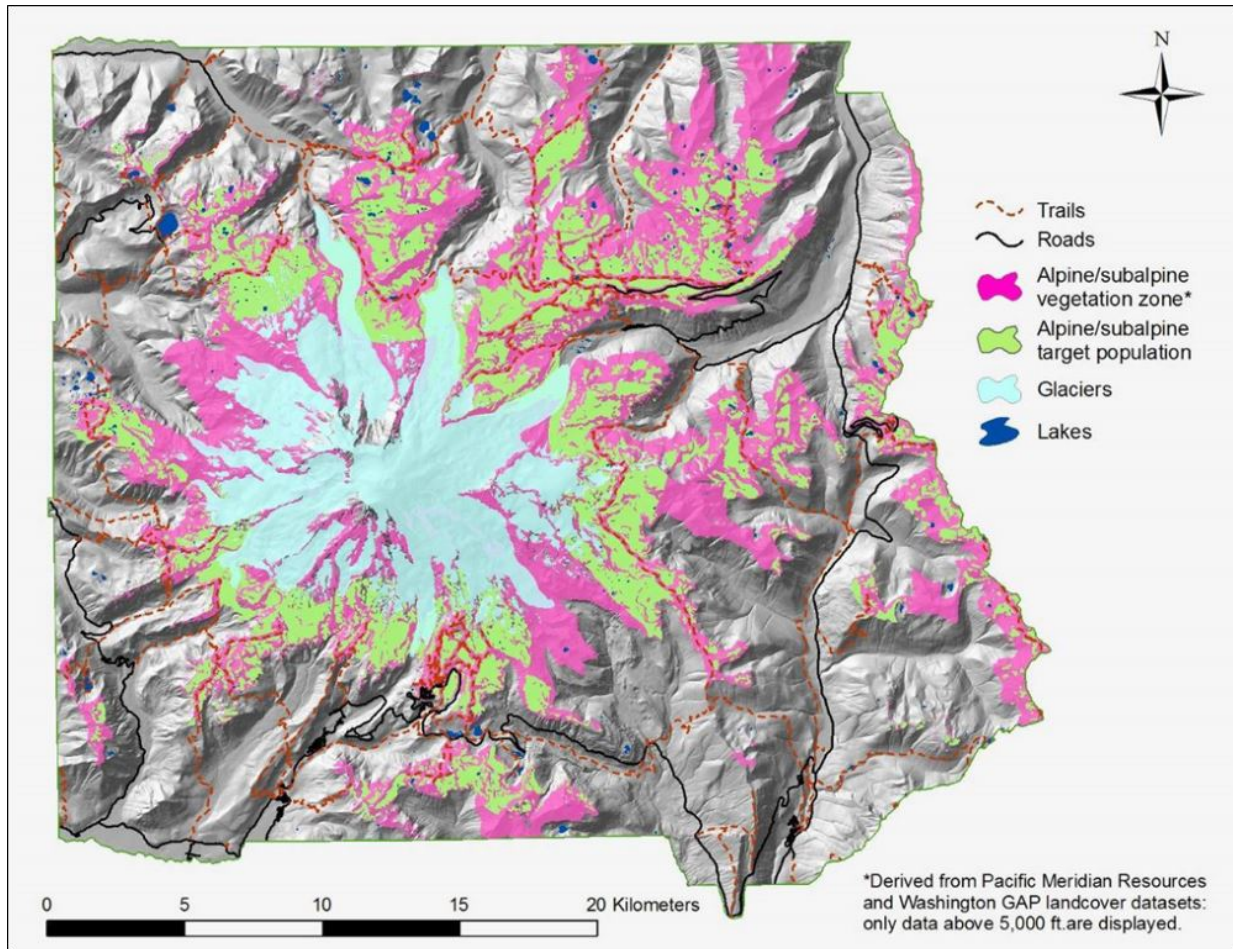


**Figure 2.** Alpine/subalpine vegetation zone and target population in Mount Rainier National Park.

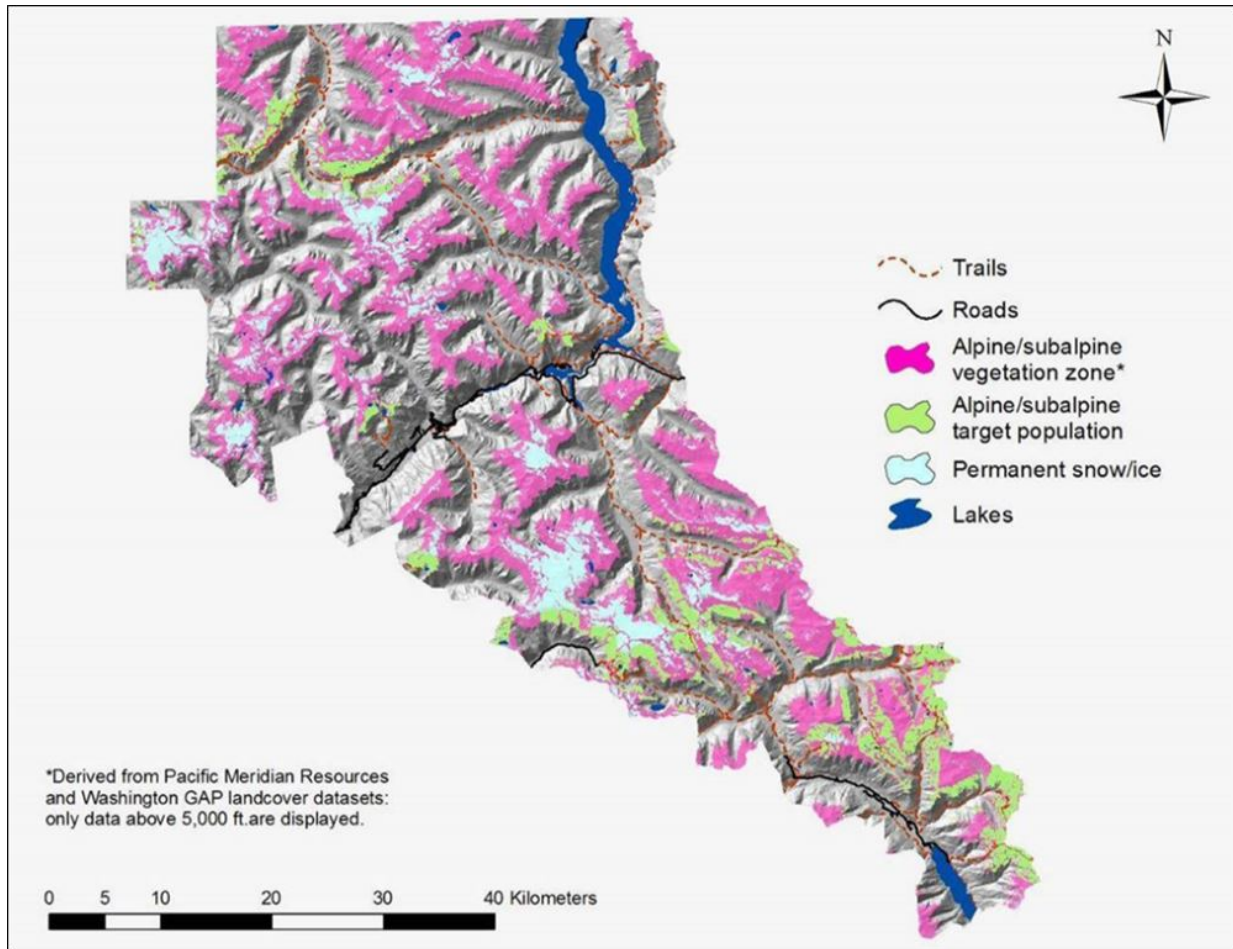


**Figure 3.** Alpine/subalpine vegetation zone and target population in North Cascades National Park Service Complex.

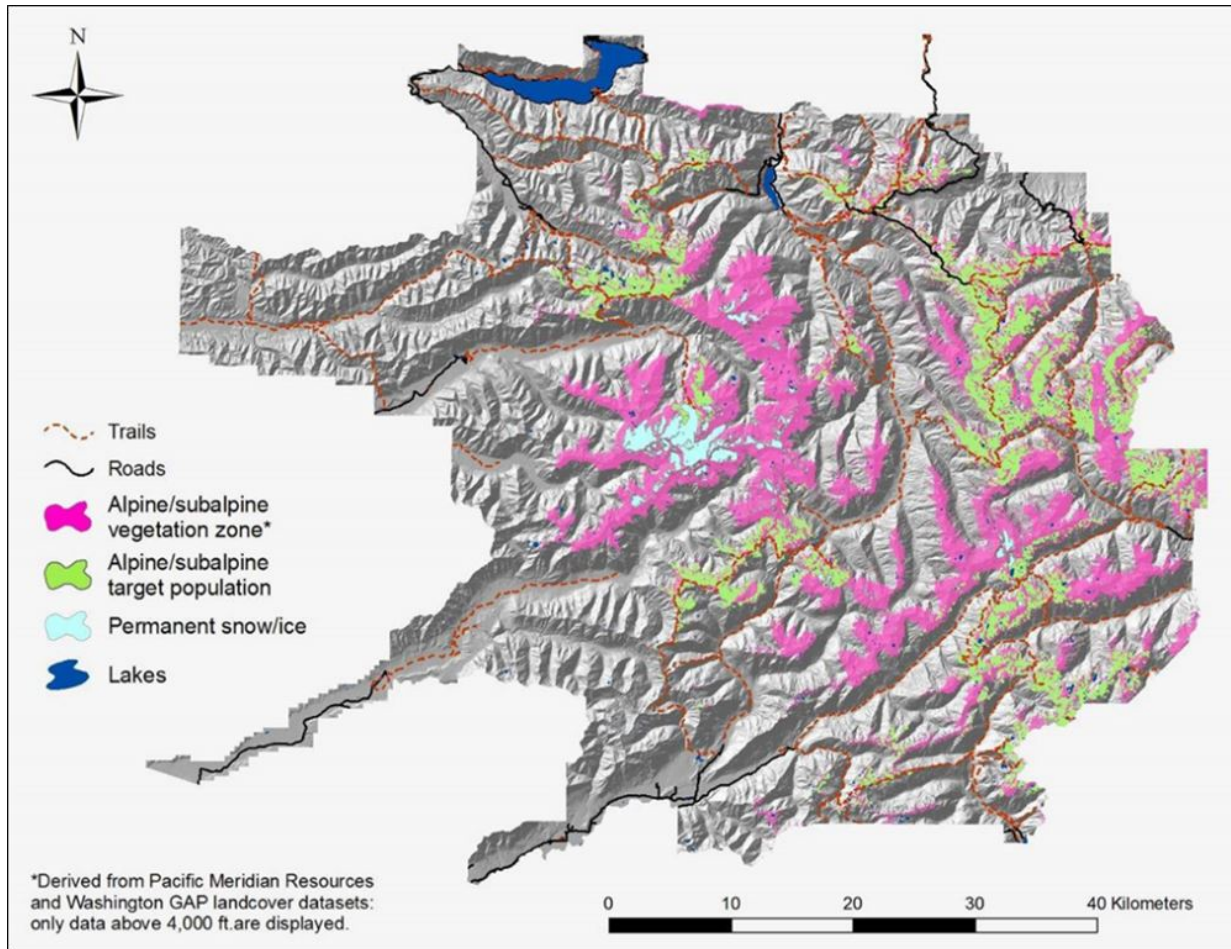


**Figure 4.** Alpine/subalpine vegetation zone and target population in Olympic National Park.

### Office and Field Screening Methods

Points were first screened in the office to determine if they were safely accessible and if they appeared to be in the target vegetation type (Rochefort et al. 2012). Points were deemed safely accessible if the access route did not require crossing a major river, cliff, or glacier and if access did not require traversing slopes  $>35^\circ$ . During office review, the points were examined using aerial photography to determine if they were in subalpine or alpine vegetation (i.e., target vegetation). If points were located in open water such as a major stream, river, lake or pond or in areas where tree canopy cover is  $>25\%$ , then they failed the office review and were removed from consideration as potential plots because they did not meet the criteria for target vegetation. However, if it was too difficult to assess the target vegetation criteria during office evaluation, the points were labeled as “pass” for the office review and a field evaluation was conducted.

During field assessments, each sample point was visited to determine if it met a set of predefined criteria: accessible by field crews and subalpine or alpine vegetation must have  $<25\%$  canopy cover of trees. Whitebark pine sample sites can have  $\geq 25\%$  tree cover, but must have a minimum of 10 whitebark pine trees  $\geq 2.54$  cm dbh. The canopy cover criterion complements the NCCN Forest Monitoring Protocol which requires  $\geq 25\%$  canopy cover at sample points (Acker et al. 2010). All

points must have <25% cover by open water or tall shrubs. If a GRTS point is accepted for alpine or subalpine vegetation monitoring during field review, it is next classified as subalpine or alpine based on tree form. Sample points are classified as subalpine if the point is located above forestline and below treeline (upright trees). If a point is located above treeline, it is classified as alpine; alpine areas are often recognized by the presence of krummholz growth forms. Upon classification and installation for monitoring, plots will remain in their original classified stratum (e.g., subalpine or alpine) through time even if they transition from one “type” to another (e.g., subalpine to forest or alpine to subalpine). The evaluation status and explanation of that status is recorded for each point during the screening process (Table 2).

**Table 2.** List of codes used to record evaluation status of GRTS points.

| <b>Evaluation Code</b> | <b>Evaluation Status</b> | <b>Explanation of Status</b>                                                                        |
|------------------------|--------------------------|-----------------------------------------------------------------------------------------------------|
| NE                     | Not evaluated            | No office evaluation or passed office evaluation and has not had a field evaluation                 |
| TS                     | Target selected          | Passed and selected for active monitoring                                                           |
| TD                     | Target deferred          | Passed but not currently selected for active monitoring                                             |
| AS                     | Access too steep         | Failed due to access route crossing slopes greater than 35 degrees in steepness                     |
| BP                     | Boundary proximity       | Failed due to being too close to park boundary                                                      |
| DI                     | Disturbance              | Failed due to significant disturbance (disease, fire, avalanche, etc.)                              |
| IN                     | Inclusion                | Failed due to a non-target inclusion                                                                |
| NT                     | Non-target               | Site not a member of the target population (e.g., talus, vegetation type)                           |
| PB                     | Physical barrier         | Failed due to a physical barrier preventing access to the site                                      |
| RI                     | River or stream          | Failed due to a river or stream crossing the site or access route preventing reliable access route  |
| RP                     | Road proximity           | Failed due to being too close to a road                                                             |
| SN                     | Snow-covered             | Snow prevented office evaluation or field access, may need further evaluation                       |
| SS                     | Site too steep           | Failed due to being too steep to be sampled safely                                                  |
| TC                     | Tree cover               | Failed due to tree cover being too high (i.e., >25%) to be considered part of the target population |
| TP                     | Trail proximity          | Failed due to being too close to or distant from a trail                                            |

## Plot Establishment Methods

The primary subalpine and alpine vegetation monitoring plot is a 100 m<sup>2</sup> plot (10 m x 10 m); nested within this plot are twenty subsamples or quadrats. Each quadrat is 0.25 m<sup>2</sup> (0.5 m x 0.5 m) and they are located systematically within the large plot (Figure 5). One corner of each quadrat is marked with a small diameter rebar; data loggers are buried 7-10 cm below the soil surface in two to five locations within the plot to monitor soil temperature and snow cover. During the first several years of the program, the variability in soil temperature and snow melt date among data loggers will be assessed and the number data loggers to be installed at each site will be finalized.

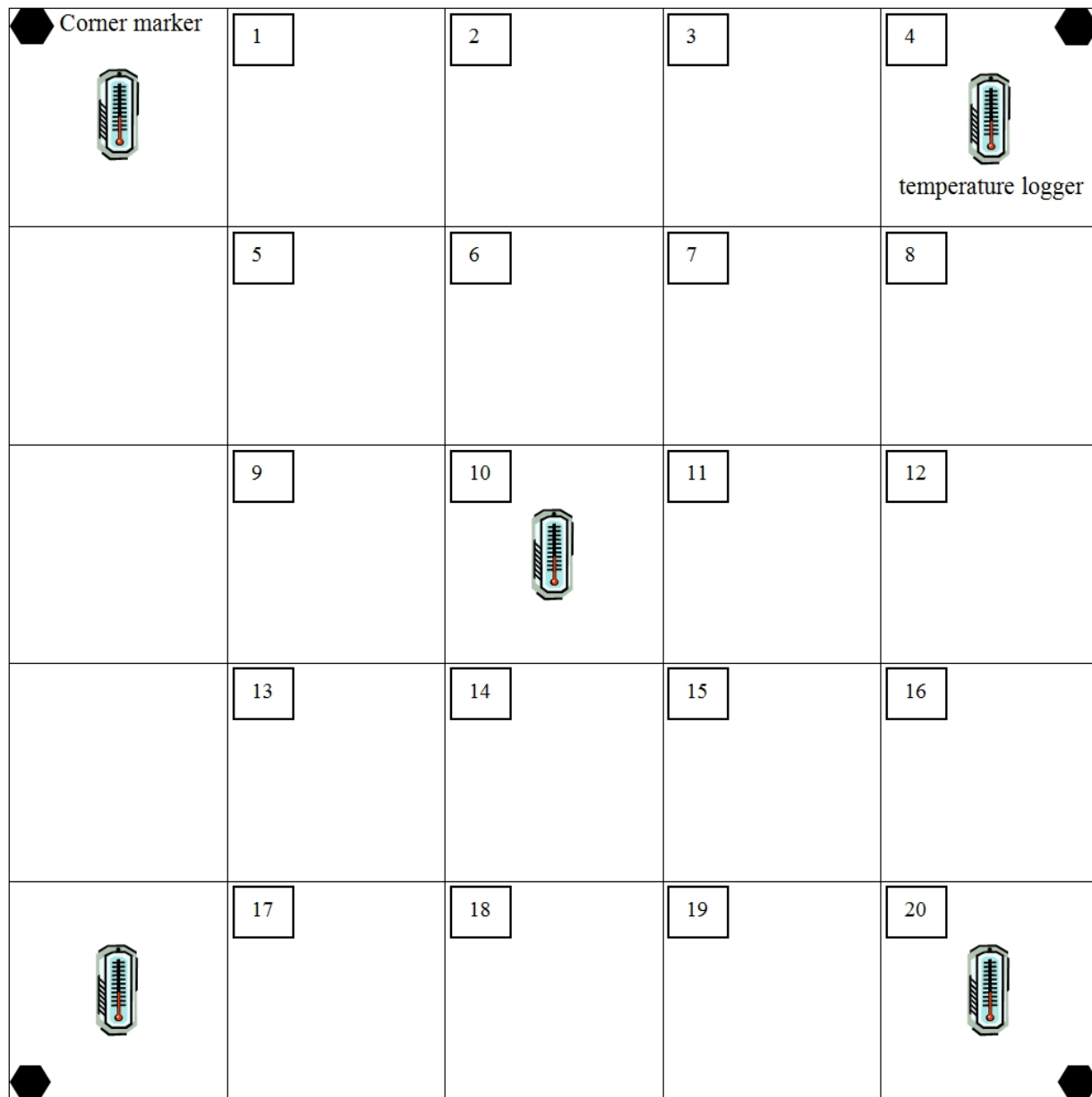


**Figure 5.** Diagram illustrating the layout of 10 x 10 m plot used to monitor subalpine and alpine vegetation.

### Alpine and Subalpine Vegetation Monitoring

In the large, 10 x 10 m plot, the location of trees ( $\geq 2.54$  cm dbh), tall shrubs (i.e., shrubs  $\geq 0.5$  m in height), krummholz trees, and total canopy cover are mapped, and the dbh and species of all trees are recorded. Krummholz are shrub-like trees that have been stunted by harsh conditions near treeline (i.e., wind, snow) and are more easily mapped as shrubs than measured as trees. Canopy cover and frequency of herbaceous vegetation and subshrubs (i.e., shrubs  $< 0.5$  m in height) are monitored in twenty  $0.25 \text{ m}^2$  quadrats located systematically within the  $100 \text{ m}^2$  (Figure 5). The appearance of the quadrat is described at two scales or resolutions. The first “scale” provides a general description of the quadrat by estimating the cover of six broad cover types (in one plane): rock, gravel, bare soil,

litter and dead plants, moss and lichen, and vascular plants. The second scale is a detailed description of all plant and lichen species in the plot using two metrics: frequency and cover. Frequency will be monitored using the nested frequency method. Four sub-quadrats will be superimposed over the 0.25 m<sup>2</sup> quadrat for frequency estimation: #1 is a 5 cm x 5 cm square in the northwest corner of the quadrat, #2 is a 25 cm x 25 cm square, #3 is 25 cm x 50 cm (half the 50 cm x 50 cm quadrat), and #4 encompasses the entire quadrat. For each species the smallest sub-quadrat in which the plant occurs will be recorded. Cover will be estimated using eleven cover classes: 1 (>0-5), 2 (>5-10), 3 (>10-20), 4 (>20-30), 5 (>30-40), 6 (>40-50), 7 (>50-60), 8 (>60- 70), 9 (>70-80), 10 (>80-90), 11 (>90-100). All vegetation species, both vascular and non-vascular, should be recorded and assigned a minimum of >0-5% cover. Finally, the permanent plot and each quadrat will be photographed during each monitoring time period to provide a visual record of the status of the site (Rochefort et al. 2012).



# Results

## Office and Field Screening

Between 2010 and 2012, office screening was completed on 1,544 potential points (Table 3). Initially we evaluated points according to their priority order. As our work progressed and we began to plan field reviews, we realized it would be more efficient to screen all points in close proximity to one another so we revised our screening methodology to accommodate field reviews.

**Table 3.** Summary of office evaluation results by park.

| Park  | Total Number of Points | Number Evaluated (% of park total) | Number Passed (% passed by park <sup>1</sup> ) |
|-------|------------------------|------------------------------------|------------------------------------------------|
| MORA  | 1,500                  | 338 (23%)                          | 295 (87%)                                      |
| NOCA  | 1,500                  | 812 (54%)                          | 666 (82%)                                      |
| OLYM  | 1,500                  | 394 (26%)                          | 322 (82%)                                      |
| TOTAL | 4,500                  | 1,544 (34%)                        | 1,255 (81%)                                    |

<sup>1</sup>Percent of all points evaluated in the office that passed

Approximately 81% of all points screened in the office passed this initial careening. The most common reasons for failing the office screening were: access to a potential site was too steep to allow safe access, permanent snow cover, or tree cover exceeded 25% (Table 4).

**Table 4.** Summary of reasons that points failed office screening.

| Evaluation Code | MORA<br>Number (% park total) | NOCA<br>Number(% park total) | OLYM<br>Number (% park total) |
|-----------------|-------------------------------|------------------------------|-------------------------------|
| Access to steep | 28 (65%)                      | 79 (54%)                     | 23 (32%)                      |
| Non-target      | 9 (21%)                       | 3 (2%)                       | 7 (10%)                       |
| Snow-covered    | 1 (2%)                        | 44 (30%)                     | 18 (25%)                      |
| Site too steep  | 0                             | 0                            | 1 (1%)                        |
| Tree cover      | 3 (7%)                        | 19 (13%)                     | 15 (21%)                      |
| Trail proximity | 2 (5%)                        | 1 (1%)                       | 8 (11%)                       |
| <b>Total</b>    | <b>43</b>                     | <b>146</b>                   | <b>72</b>                     |

Between 2010 and 2012, we conducted field evaluations on 385 potential plot locations; 42% passed the field evaluation (Table 5). The most frequent reasons that sites did not pass field reviews were non-target vegetation, tree cover >25%, and sites where access was too steep to allow for safe monitoring (Table 6).

**Table 5.** Summary of field evaluation results by park and year.

| Park         | 2010      |            | 2011      |           | 2012      |           | Total      |            |
|--------------|-----------|------------|-----------|-----------|-----------|-----------|------------|------------|
|              | Pass      | Fail       | Pass      | Fail      | Pass      | Fail      | Pass       | Fail       |
| MORA         | 3         | 3          | 0         | 0         | 27        | 17        | 30         | 20         |
| NOCA         | 60        | 90         | 10        | 11        | 23        | 37        | 93         | 138        |
| OLYM         | 25        | 23         | 0         | 0         | 14        | 42        | 39         | 65         |
| <b>Total</b> | <b>88</b> | <b>116</b> | <b>10</b> | <b>11</b> | <b>64</b> | <b>96</b> | <b>162</b> | <b>223</b> |

**Table 6.** Summary of reasons that potential points did not pass field evaluations.

| Evaluation Code    | MORA                  | NOCA                 | OLYM                  |
|--------------------|-----------------------|----------------------|-----------------------|
|                    | Number (% park total) | Number(% park total) | Number (% park total) |
| Access to steep    | 9 (45%)               | 18 (13%)             | 28 (43%)              |
| Boundary proximity |                       | 1 (<1%)              |                       |
| Disturbance        |                       | 5 (4%)               |                       |
| Inclusion          |                       | 10 (8%)              | 1 (1%)                |
| Non-target         | 7 (35%)               | 63 (46%)             | 11 (17%)              |
| River or stream    | 1 (5%)                | 3 (2%)               |                       |
| Road proximity     | 1 (5%)                |                      |                       |
| Snow-covered       |                       | 2 (1%)               | 2 (3%)                |
| Site too steep     |                       | 8 (6%)               | 9 (14%)               |
| Trail proximity    | 1 (5%)                |                      |                       |
| Tree cover         | 1 (5%)                | 28 (20%)             | 14 (22%)              |
| <b>Total</b>       | <b>20</b>             | <b>138</b>           | <b>65</b>             |

### Plot Establishment and Vegetation Monitoring

During field evaluations, sites which met the pre-established criteria were then classified as subalpine, alpine, or whitebark pine plots (Table 7). Field evaluations were completed in late August 2012 when it was too late to monitor vegetation (i.e. due to plant phenology). Consequently, we decided to “partially” establish plots in each park in order to test and refine the field methods. Six permanent plot locations were selected across the three parks: one subalpine in MORA, one alpine and one subalpine in NOCA, and three subalpine in OLYM (Figures 6-15). In each of the six plots, corners were marked, photographs taken, and data loggers were installed. In 2013, data loggers were downloaded at two plots (MORA-0009 and NOCA-0029) and vegetation was monitored at MORA-0009. Plot MORA-0009 (Figure 9) was located in Grand Park and although there were patches of trees within this subalpine meadow, there were no trees or tall shrubs within the plot. Vegetation cover ranged from 63- 96% with a mean of 86.6%. There were 18 species recorded in the plot: one subshrub, 13 forbs, one fern, one sedge, and two grass species. *Vaccinium deliciosum* was the only subshrub species, and it occurred with the highest cover and frequency across the plot. *Oreostemma alpigenum*, *Antennaria lanata*, *Ligusticum grayi*, *Erythronium montanum*, and *Pedicularis contorta* were the most numerous forbs. *Carex spectabilis*, *Danthonia intermedia*, and an *Agrostis* species represented the sedges and grasses.

**Table 7.** Summary classification of plots by vegetation type and park.

| Vegetation Type | MORA        |                       | NOCA        |                       | OLYM        |                       |
|-----------------|-------------|-----------------------|-------------|-----------------------|-------------|-----------------------|
|                 | Established | Deferred <sup>1</sup> | Established | Deferred <sup>1</sup> | Established | Deferred <sup>1</sup> |
| Alpine          | 0           | 5                     | 1           | 59                    | 0           | 8                     |
| Subalpine       | 1           | 3                     | 1           | 4                     | 3           | 29                    |
| Whitebark pine  | 0           | 3                     | 0           | 28                    | 0           | 0                     |
| <b>Total</b>    | <b>1</b>    | <b>11</b>             | <b>2</b>    | <b>81</b>             | <b>3</b>    | <b>37</b>             |

<sup>1</sup>Deferred plots are plots that have passed field and office review, but have not been established as permanent monitoring plots.

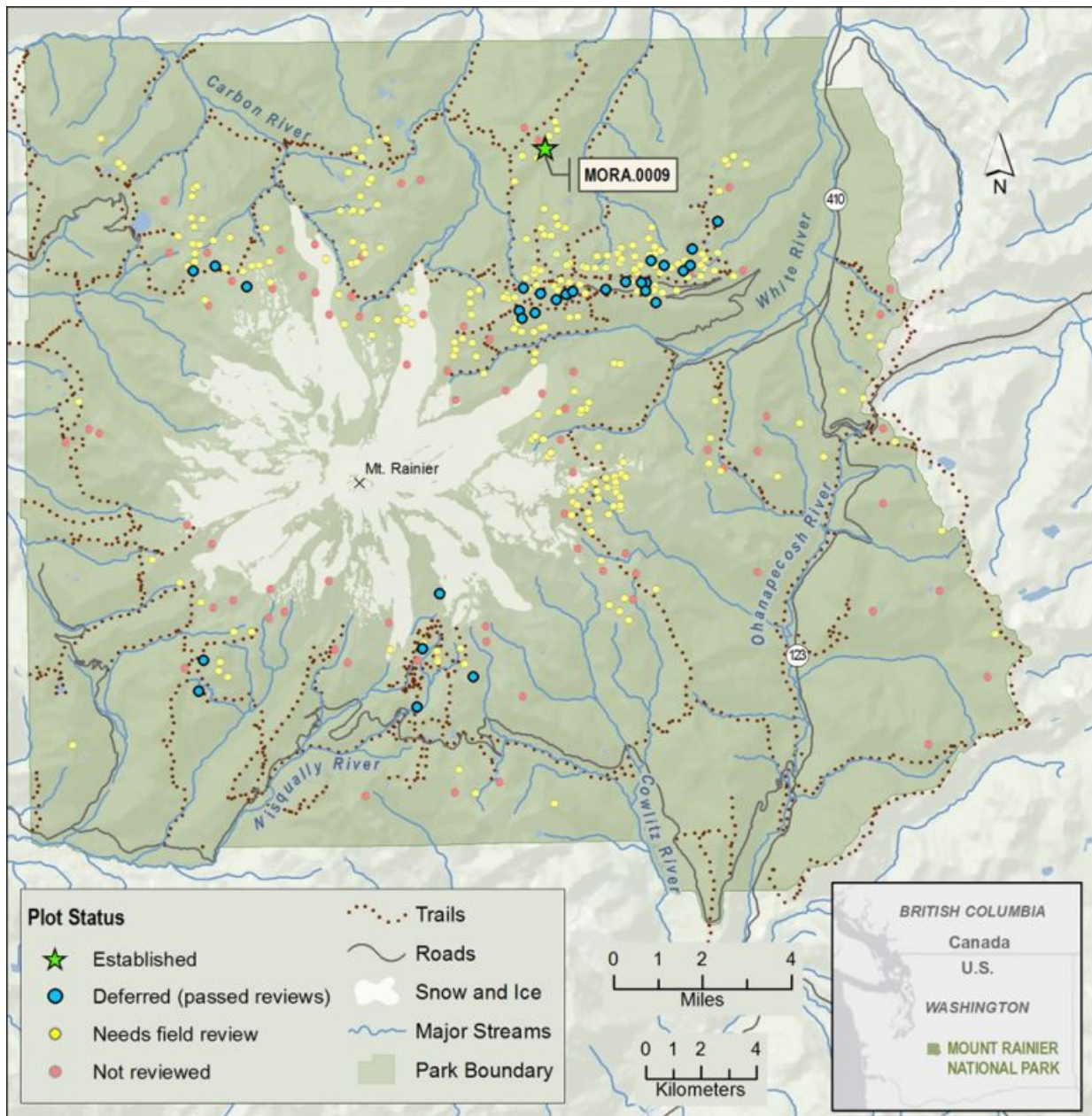


**Figure 6.** Map illustrating locations of established plots and all remaining potential sites in Mount Rainier National Park (MORA). Potential Generalized Random Tessellation Stratified (GRTS) points that failed office or field reviews are not shown.

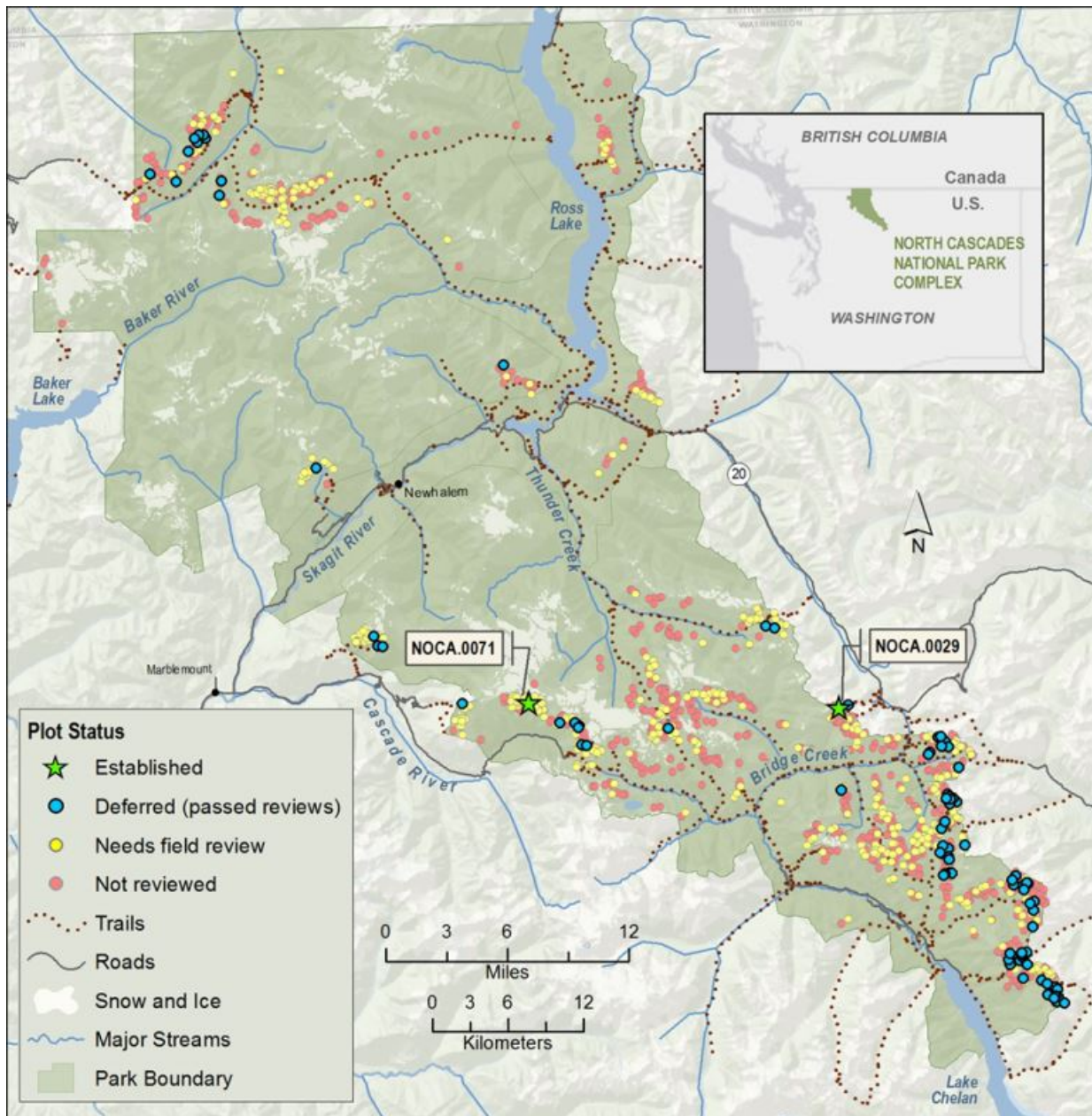


**Figure 7.** Map illustrating locations of established plots and all remaining potential sites in North Cascades National Park Service Complex (NOCA). Potential Generalized Random Tessellation Stratified (GRTS) points that failed office or field reviews are not shown.

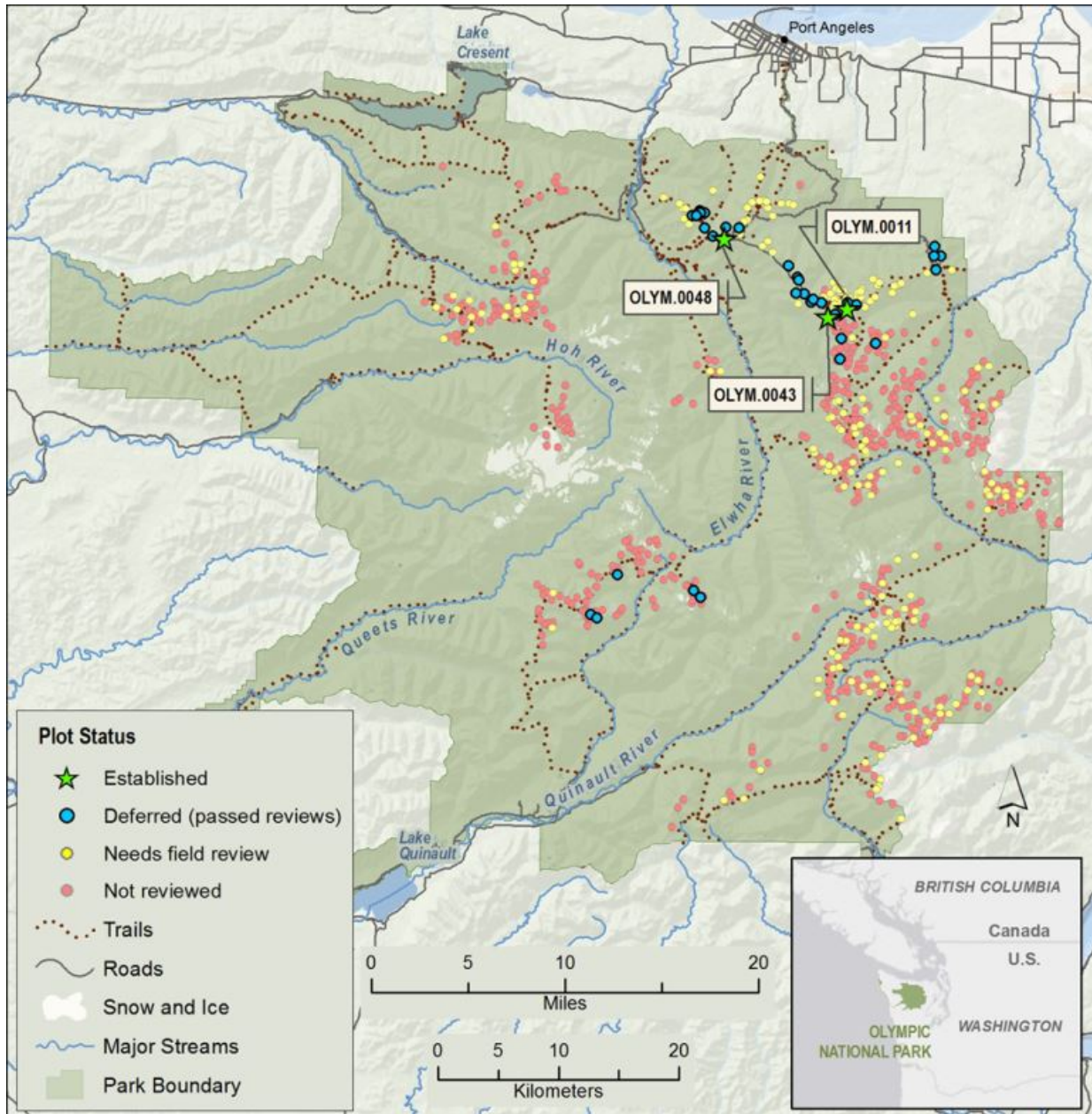


**Figure 8.** Map illustrating locations of established plots and all remaining potential sites in Olympic National Park (OLYM). Potential Generalized Random Tessellation Stratified (GRTS) points that failed office or field reviews are not shown.



**Figure 9.** Subalpine plot MORA-0009 at Grand Park in Mount Rainier National Park at 1,698 m elevation.



**Figure 10.** Subalpine plot NOCA-0029 in North Cascades National Park Service Complex at 1,929 m elevation.



**Figure 11.** Alpine plot NOCA- 0071 in North Cascades National Park Service Complex at 1,821m elevation.



**Figure 12.** Subalpine plot OLYM-0011 in Olympic National Park at 1,697 m elevation.



**Figure 13.** Subalpine plot OLYM-0043 in Olympic National Park at 1,769 m elevation.

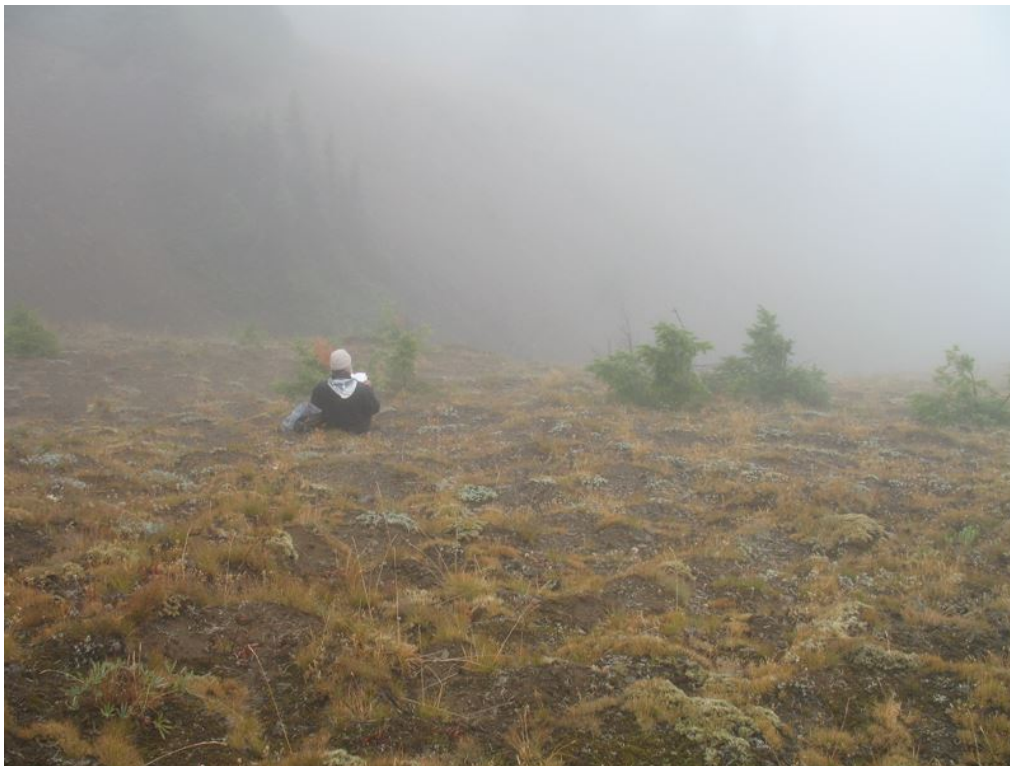


**Figure 14.** Subalpine plot OLYM-0048 in Olympic National Park at 1,567 m elevation.

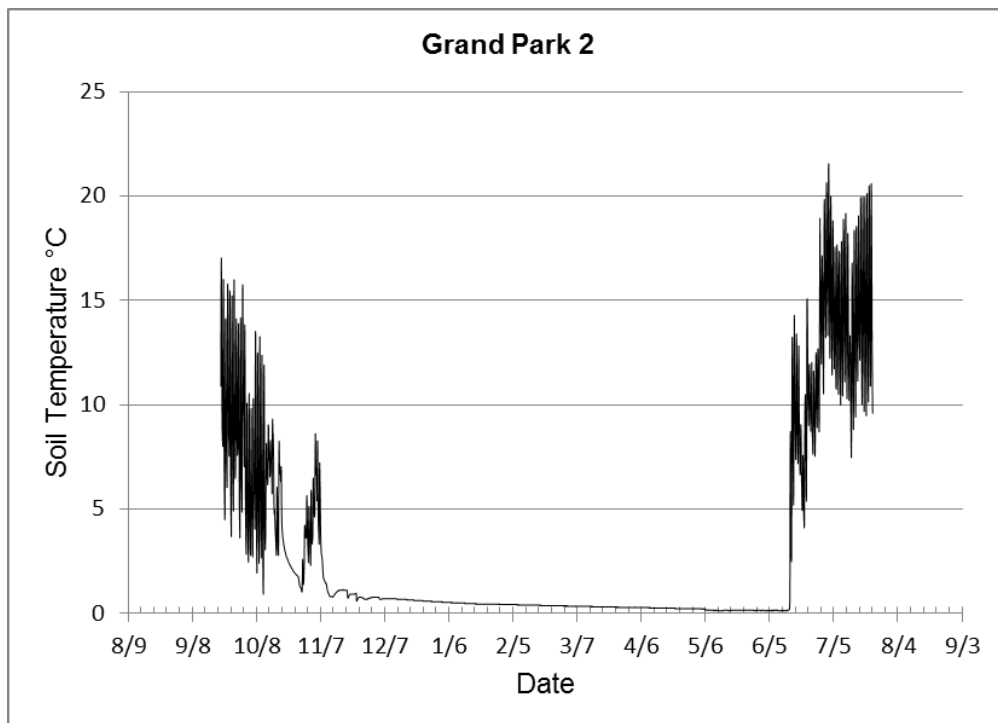
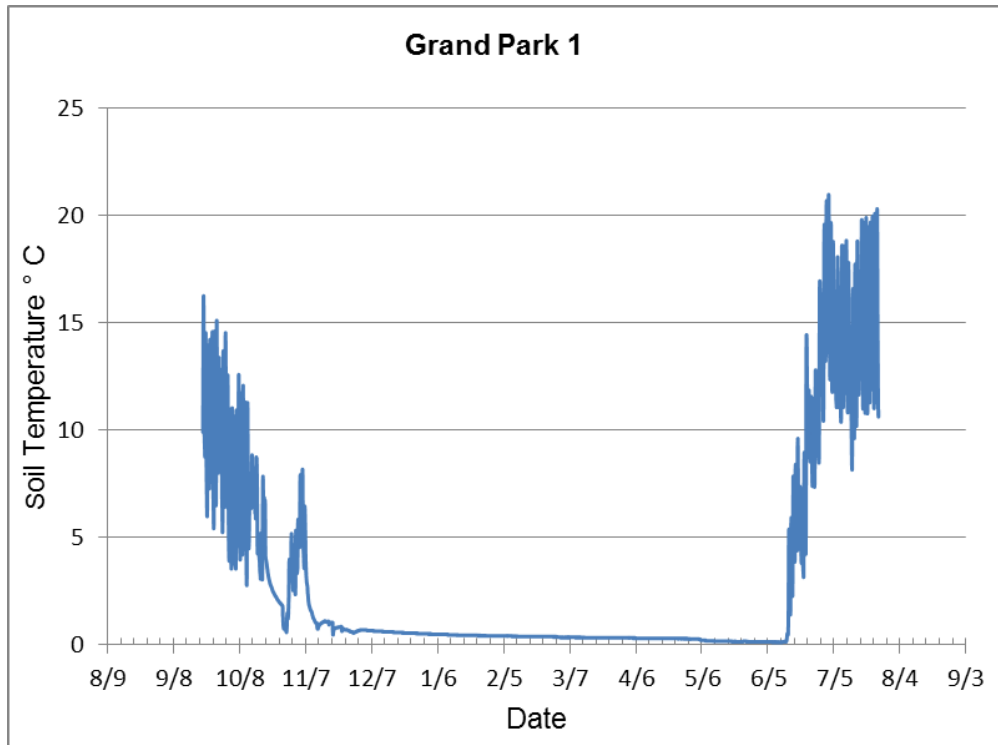


**Figure 15.** Soil temperatures (°C) from two data loggers at the Grand Park study plot in Mount Rainier National Park for the period from August 9, 2012 through September 3, 2013. Temperatures indicate permanent snow cover extended from November 10, 2012 through approximately June 13, 2013.

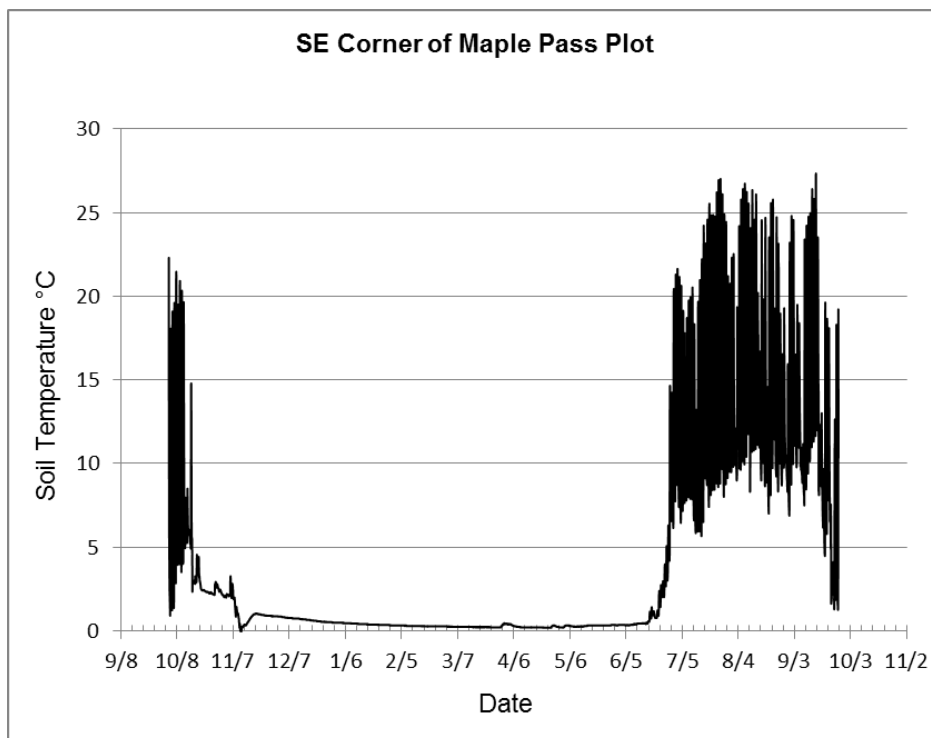
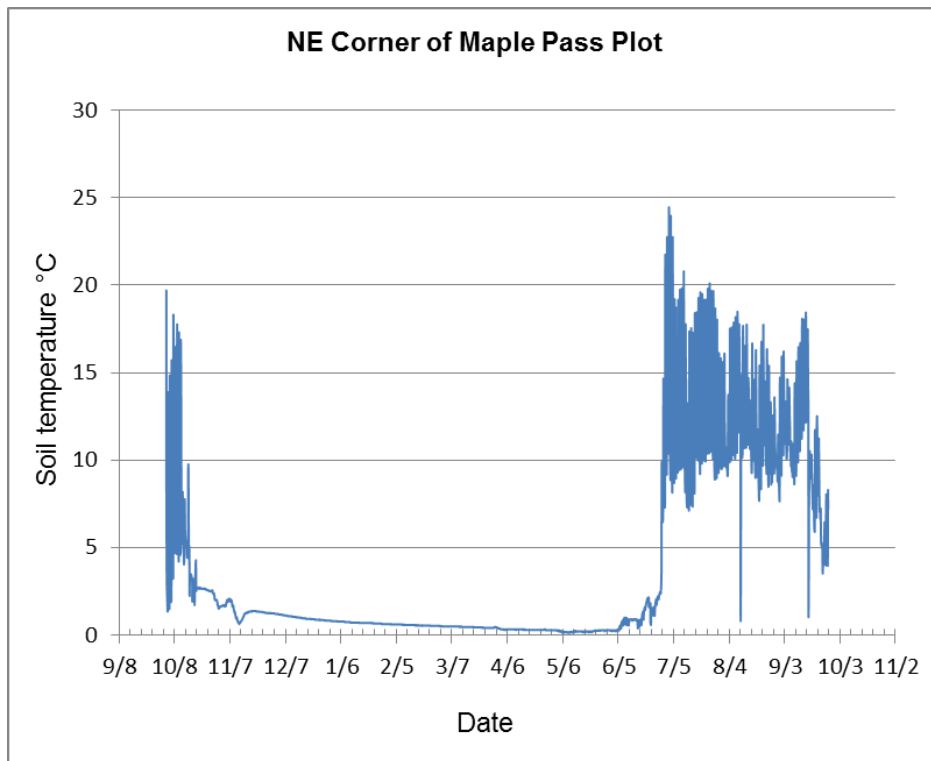


**Figure 16.** Soil temperatures (°C) from five data loggers at the Maple Pass study plot in North Cascades National Park Service Complex for the period from October 3, 2012 through September 3, 2013. Data logger temperatures (°C) indicate permanent snow cover extended from November 8, 2012 through approximately June 13, 2013. The data loggers in the NW and SW corners of the plot were washed out from the soil in fall rains and so document below 0 temperatures.

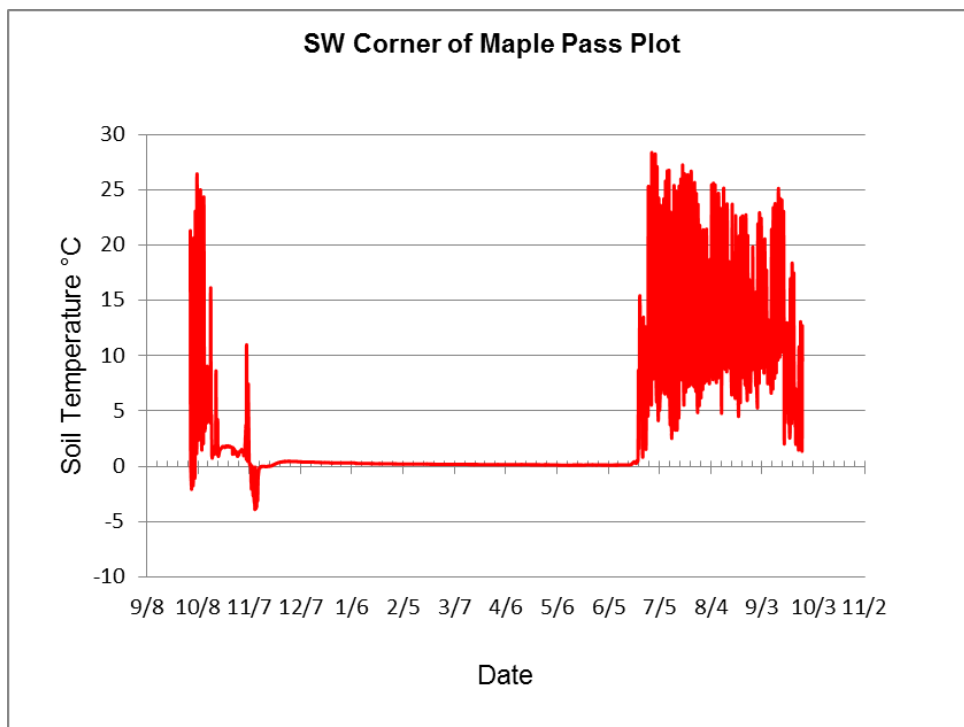
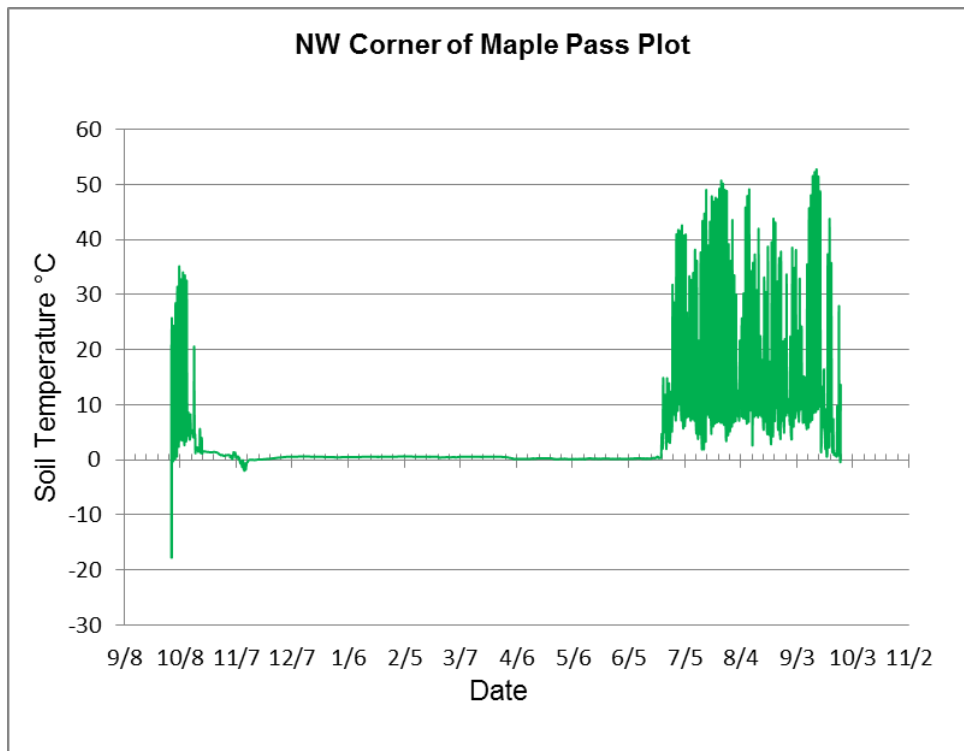


**Figure 16.** Soil temperatures (°C) from five data loggers at the Maple Pass study plot in North Cascades National Park Service Complex for the period from October 3, 2012 through September 3, 2013. Data logger temperatures (°C) indicate permanent snow cover extended from November 8, 2012 through approximately June 13, 2013. The data loggers in the NW and SW corners of the plot were washed out from the soil in fall rains and so document below 0 temperatures (continued).

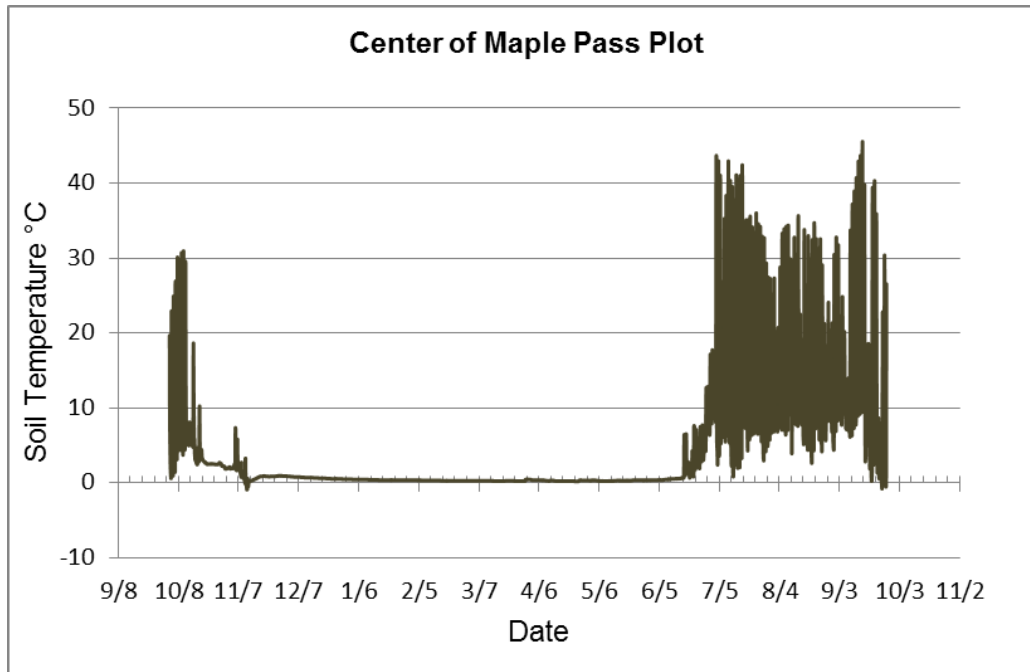


**Figure 16.** Soil temperatures (°C) from five data loggers at the Maple Pass study plot North Cascades National Park Service Complex for the period from October 3, 2012 through September 3, 2013. Data logger temperatures (°C) indicate permanent snow cover extended from November 8, 2012 through approximately June 13, 2013. The data loggers in the NW and SW corners of the plot were washed out from the soil in fall rains and so document below 0 temperatures (continued).

## **Applications for Future Monitoring**

Office and field screening methods (SOPs) worked well and allowed us to screen 1,544 points in the office, of which 1,255 points passed. Field screening was conducted on 385 points leading to 162 possible permanent plot locations. However, in order to increase the efficiencies of field surveys, crews surveyed points located in a general area, rather than planning field work based on GRTS priorities or firing order. Consequently, prior to further plot establishment, office and field screening must be completed on plots that occur earlier in the GRTS firing order. In MORA, 57 of the top 100 (102 of the top 300) points still require field and/or office screening. In NOCA, 31 of the top 100 (135 of the top 300) require screening and in OLYM 55 of the top 100 (146 of the top 300). In OLYM, the crew estimated that all points that can be reached by a day trip in the top 300 points have been surveyed. During this initial period of the monitoring project, plot set-up methods were improved by the OLYM crew resulting in an estimate of 4-5 hours to delineate and mark one plot. Vegetation was monitored at MORA-0009 in Grand Park and data sheets were revised to streamline data recording. Data loggers were downloaded at two sites revealing fairly consistent snow melt among sites, but temperatures were more variable at the NOCA site which may reflect the fact that several loggers washed out of the ground by heavy rainfall and were found on top of the soil (i.e. rather than buried).

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NPS 168/127628, January 2015

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**Natural Resource Stewardship and Science**

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