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Natural Resource Stewardship and Science

The Cascades Butterfly Project

A Protocol for Monitoring Subalpine Butterflies and Plant Phenology in the Cascade Mountains of Washington

Natural Resource Report NPS/NOCA/NRR—2017/1440






ON THIS PAGE
Clockwise from top left: Jennifer Gulbransen, Mary Prichard and Lois Bruhn on the Sunrise Rim Trail; Tanner Humphries and volunteers; NOCA BioBlitz Butterfly volunteers at Desolation Lookout, NOCA 2014; Kathy Acosta, Mazama Ridge Trail, 2016; Ana Casillas Brownson with volunteers Sunrise Rim Trail 2016; Mike Donofree and Ayako Okuyama-Donfree at Easy Pass
Photographs by: NPS

ON THE COVER
Butterfly survey crew hiking to the Easy Pass Survey Route in North Cascades National Park, August 2014
Photograph by: Regina M. Rochefort, North Cascades National Park Service Complex

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A Protocol for Monitoring Subalpine Butterflies and Plant Phenology in the Cascade Mountains of Washington

Natural Resource Report NPS/NOCA/NRR—2017/1440

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May 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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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.

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Please cite this publication as:

Rochefort, R. M., and J. F. McLaughlin. 2017. The Cascades butterfly project: A protocol for monitoring subalpine butterflies and plant phenology in the Cascade Mountains of Washington. Natural Resource Report NPS/NOCA/NRR—2017/1440. National Park Service, Fort Collins, Colorado.

NPS 168/138240, May 2017

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Executive Summary

The Cascades Butterfly Project (CBP) is a long-term monitoring program in which citizen scientists and National Park Service biologists monitor butterfly abundances and plant phenology in subalpine meadows of the Cascade Mountains. Our broad goals are to understand the influence of climate change on high-elevation ecosystems, document changes in species distributions and abundances, communicate these impacts to the public, and provide these data to inform protection of National Park Service and U.S. Forest Service lands.

Subalpine and alpine ecosystems are extremely vulnerable to the effects of climate change because species in these areas are adapted to long winters and short, mild growing seasons. Climate models project warmer air temperatures and declining snowpack which will result in longer snow-free summer seasons, but also warmer and drier conditions for plants and animals. We are monitoring butterflies and plant phenology because both are extremely sensitive to changes in temperature and precipitation and may provide us with an early warning into future ecosystem changes. Additionally, butterflies and plant flowering stages are easily identified and widely monitored, allowing us to invite citizen scientists to collect data and facilitate comparisons with ecosystems changes being observed in other geographic areas.

This report describes a program for long-term monitoring of butterfly abundances and plant phenology in subalpine areas in Cascade Mountains of Washington. Five objectives direct the program:

1. Document and detect trends in butterfly species richness and abundance at sample sites
2. Document and detect trends in phenology of selected butterfly species including dates of emergence, peak abundance, and length of adult flight season at sample sites
3. Document and detect trends in plant flowering times of selected subalpine plant species
4. Work with Citizen Scientists to collect field data, review documented trends, and communicate findings to the public and managers of protected lands
5. Provide opportunities for college students and recent graduates to gain work experience in applied science careers with an emphasis on recruiting diverse youth who are under-represented in natural sciences

Butterflies and plants are monitored at each site weekly throughout the summer using the Pollard walk methodology, an international standard supporting comparisons with other regions. Ten, 1km survey routes are located along trails in subalpine meadows in North Cascades National Park, Mount Baker-Snoqualmie National Forest, Okanogan-Wenatchee National Forest, and Mount Rainier National Park. All butterflies observed along survey routes are identified and recorded. Plant phenology of selected species is document weekly along each route. A companion report includes detailed standard operating procedures and maps of all survey routes. Monitoring results can be applied to adapt park management, to inform interpretive programs, to develop environmental

educational curricula, and to develop inferences about butterfly populations in sub/alpine areas in adjacent National Forests. In addition, butterfly monitoring data will support diverse scientific inquiries regarding biotic responses to climate change in protected areas of the Pacific Northwest region, and broader geographic scales.

Acknowledgments

We thank Dana Garrigan for generously sharing results of his prior butterfly research at Mount Rainier National Park. We thank Howard Selmer, seasonal ranger at Lake Tipsoo, for volunteering his time to conduct independent butterfly surveys at Mount Rainier National Park and for generously sharing his survey results. Dr. Leslie Ries (Georgetown University), Dr. Jason Ransom (National Park Service) and Lise Grace (National Park Service) reviewed this document and provided suggestions to improve the clarity and content. Natalya Antonova (National Park Service) developed all maps presented in the document. Robert C. Kuntz II, Mason Reid, and Roger Christophersen (all National Park Service) provided valuable input during protocol development and preliminary field inventories. Baseline inventories of Mount Rainier National Park (MORA) and North Cascades National Park Service Complex (NOCA) were conducted by Katherine Wetzel, Nicholas Crandall, Michelle Toshack, Kara Kuhlman, Ann Carlson, and Graham Goodman. Tanner Humphries, Ana Casillas Brownson, Salvador Silahua, Katherine Acosta, Michelle Wong, Justin Tran, Marian Bechtel, Michelle Toshack, James Heintz, Jedediah Tressler, Melanie Weiss, Deirdre Dethier, Patrick Verschoor, and Carolyn Bowie field tested monitoring methods and provided valuable suggestions to refine methods.

List of Terms

Citizen Scientist: a member of the public who volunteers to collaborate with scientists to collect scientific data following a prescribed methodology.

Date of (butterfly) emergence: the date of emergence is the date on which a butterfly pupa emerges from its chrysalis.

Date of (butterfly) first observation: first date when butterflies are documented along our survey route. Our goal is to document date of emergence, but depending on our ability to access the site (i.e., snow, staffing, road or trail conditions), our date of first observation may be later than the actual emergence date.

Observer: the person walking the route who is responsible for sighting butterflies that will be recorded as part of the survey. Often this person is the primary person responsible for identifying butterflies, but others participating in the survey can also assist.

Peak Abundance: the date when the highest total number of butterflies or highest number of one species is documented along a survey route.

Phenology: the study the timing of periodic plant or animal life cycle events such as flowering, seed set, hibernation, butterfly metamorphosis, breeding times. The timing of many of these life cycle events is triggered by climate and three abiotic factors that influence climate: sunlight, precipitation, and temperature.

Phenophase: a stage in a life cycle that can be observed and monitored. In the CBP, we monitor four phenophases in plants: **V** for vegetative (plant present but not yet in flower), **E** for early (at least one plant with flowers), **M** for middle (50% or more plants have flowers), or **L** for late (more than 50% of the plants have flowers that have wilted or are in fruit).For butterflies, we only monitor the adult phenophase.

Recorder: the person responsible for recording observations on data sheets, during the survey.

Route: an entire monitoring transect from beginning to end. In the CBP there are 10 survey routes, each is 1km in length and divided into five 200 m sections labeled as A, B, C, D, and E. The 10 survey routes are: Cascade Pass (CP), Easy Pass (EP), Maple Pass (MP), Sauk Mountain (SM), Skyline Divide (SD), Mazama Ridge (MR), Naches Loop (NL), Spray Park (SP), Sunrise Rim (SR); Skyscraper Mountain (SS).

Site: An area of interest for monitoring that contains one or more routes. In the CBP, we have four sites: Mount Rainier National Park (MORA), North Cascades National Park (NOCA), Mount Baker-Snoqualmie National Forest (MBS), and Okanogan-Wenatchee National Forest (OWNF). Each site contains multiple routes.

Univoltine: a butterfly, or other species, that produces one brood of offspring per year.

VIP: National Park Service acronym for Volunteer in the Park

Introduction

National parks and forests are special places protected in perpetuity for the American public. The resources protected by the National Park Service and U.S. Forest Service represent some of the most pristine and naturally functioning ecosystems within the United States. These ecosystems are being threatened by climate change in ways expected to become more severe in coming decades. In order to effectively protect these ecosystems, the agencies need to know which species occur in these ecosystems, understand species and ecosystem processes, and forecast how species will respond to changing climates (NPSABSC 2012, Urban 2016).

North Cascades National Park Service Complex (NOCA), Mount Rainier National Park (MORA), Mount Baker-Snoqualmie National Forest (MBS), Okanogan-Wenatchee National Forest (OWNF) have identified high-elevation ecosystems as very sensitive to climate change and a high management priority (Weber et al. 2009, Rochefort et al. 2012, Raymond et al. 2014, Hoffman et al. 2014, 2015). Although NOCA and MORA have on-going long-term monitoring programs to document status and trends of natural resources, none include a focus on butterflies, pollinators, or plant phenology. The Cascades Butterfly Project (CBP) was initiated to establish a long-term, interagency monitoring program to document trends in butterfly abundances and plant phenology across the northern Cascades landscape, include citizen scientists in collection and analysis of these data, and communicate results to the public, other scientists, and managers of protected areas.

1. Background and Objectives

A. Butterflies and Climate Change

Global change is occurring rapidly at global and regional scales. Mountain ecosystems are particularly susceptible to direct and indirect effects of climate change. Minimum and maximum winter temperatures in mountainous regions of the western United States increased 1.8°C and 1.5° C respectively during the latter half of the 20th century (Bonfils et al. 2008). Rising temperatures in these regions have reduced snowpacks and hastened snowmelt (Hamlet et al. 2005; Leung 2005; Martin and Etchevers 2005; Barnett et al. 2008; Mantua et al. 2010). Snowpack reductions and earlier melting have been particularly evident in the Pacific Northwest, including the two parks addressed in this report (Service 2004). These trends are expected to accelerate in coming decades (Bonfils et al. 2008). Ecotones, such as subalpine meadows, are susceptible to change (Rochefort et al. 1994; Ozgul et al. 2010) because organisms in this zone are at some kind of limit to their existence. Prior studies have documented that western treelines were up to 1,000’ (300 m) higher during warm periods in the early Holocene (Rochefort et al. 1994). Additionally, species composition of shrub and herbaceous understories has and continues to change in response to warmer temperatures (e.g., Brink 1959; Walther et al. 2002). Distribution of pollinating insects (Diptera, Hymenoptera, Lepidoptera, and Coleoptera) has been linked to elevation, reflecting environmental and vegetation gradients (Warren et al. 1988). Climate change impacts on plant-pollinator interactions are anticipated to be severe, potentially affecting as many as 50% of pollinator species (Memmott et al. 2007). Butterflies are extremely sensitive to climate change and recent studies have documented dramatic range shifts along altitudinal and latitudinal gradients in Europe and North

America (Walther et al. 2002). Parmesan et al. (1999) reviewed distribution records of 35 non-migratory butterflies in Europe and found that 63% have experienced range shifts of 35-240 km during the 20th century. Changes in butterfly ranges are predicted to continue with warming climates including range shifts, expansions, contractions, and extinctions (Hill et al. 1999, 2002; McLaughlin et al. 2002a; Memmott et al. 2007).

Environmental impacts of climate change are predicted to be diverse and substantial in mountain ecosystems. Although many biotic effects of climate change have been observed already, much uncertainty remains concerning the kind and magnitude of future impacts. Due to this uncertainty, there is a great need to monitor biotic effects as they occur, and to apply monitoring data to anticipate future changes (Morisette et al. 2009). Butterfly population monitoring programs have proven to meet these needs effectively, for five general reasons. First, butterfly life history traits and thermoregulatory requirements make them sensitive to changes in climatic variables (Pollard 1988; Warren et al. 1988; Roy et al. 2001; McLaughlin et al. 2002b). Second, changes in butterfly abundances and distributions correlate with changes in other terrestrial insect groups, particularly bumblebees, hoverflies, and ants (Thomas, 2005). Third, butterfly monitoring throughout the world facilitates comparisons between adjacent management zones, mountain ranges, and continents. Fourth, dependence on particular larval food plants simplifies habitat delineation for most butterfly species (Hanski et al. 2004), thereby allowing researchers to track responses to both climate and habitat shifts (e.g., Warren et al. 2001). Fifth, many butterflies are relatively easy to identify and have been used successfully in volunteer based monitoring programs (Bray 2010; Santiestevan 2010).

B. Climate Change and Biotic Effects in the Pacific Northwest

The current Pacific Northwest climate is characterized by mild wet winters and warm dry summers (Waring and Franklin 1979, Kruckeberg 1991). Most annual precipitation occurs in winter, which falls as snow in montane environments. Snow accumulation strongly influences plant characteristics and phenologies. In many montane habitats, deep snowpacks linger into late spring or early summer, which reduce the snow-free growing season and moisten soils during the dry season. Short growing seasons prevent tree establishment (Peterson and Peterson 2001; Rochefort et al. 1994; Graumlich et al. 2005) and facilitate establishment of meadows dominated by herbaceous perennials. These meadows provide habitat for many butterfly species. During the early Holocene (about 7-10,000 years ago), when temperatures were up to 4°C warmer, than current temperatures, in western North America, treelines were up to 300 m (1,000’) (Rochefort et al. 1994). More recently, increases in subalpine tree establishment and changes in herbaceous plant composition have been documented during warmer and drier summers (Harsch et al. 2009; Haugo and Halpern 2011). Shrub cover has expanded displacing many herbaceous species and continues to change in response to warmer temperatures (e.g., Brink 1959; Walther et al. 2002, Haugo and Halpern 2007).

Current and future climatic changes will alter conditions that determine the distribution of montane meadow habitats and phenologies of the plants and butterflies inhabiting them. In the Pacific Northwest, these warming trends are expected to continue, with average annual temperatures rising 5.5°C by the 2050s under high emissions scenarios (Mauger et al 2015). Warmer air temperatures have already resulted in reduced snowpacks and earlier snowmelt dates (Hamlet et al. 2005; Leung

2005; Martin and Etchevers 2005; Barnett et al. 2008). Snowpack is projected to continue to decline in Washington, with snowmelt dates up to 45 days earlier, especially west of the Cascade crest, by the 2040s (Snover et al. 2013, Little et al. 1994).

Three implications of these climate forecasts are relevant to meadow plants and associated butterflies. First, large projected reductions and fragmentation in suitable habitat area imply that local populations of many species will become extinct (Oliver et al. 2015). Many subalpine butterfly species may be extirpated from the parks. Second, growing seasons will begin earlier due to hastened melting of shallower snowpack. Date of peak snowmelt has shifted 10 to more than 20 days earlier in most Pacific Northwest locations, including the Parks addressed in this report (Service 2004). Third, plant senescence will commence earlier because soil moisture derived from melting snow will become depleted sooner. In the vicinity of meadow streams, the latter will be compounded by a reduction in summer streamflow (Kim et al. 2002; Mote et al. 2003; Mantua et al. 2010). The temporal shift in the growing season caused by such substantial snowpack reductions could be as much as two weeks: 30% snowpack reductions were found to hasten the date of plant emergence by five days. The temporal shift in plant senescence likely will be even greater, because warmer temperatures would hasten soil drying (Peterson and Peterson 2001; Mote et al. 2003).

Shrinking snowpacks and shifting plant phenologies may reduce the distributions of some montane butterflies. Local persistence of univoltine butterflies requires phenological overlap between larvae and larval host plants sufficient for larvae to complete development before plant senescence. Currently, lingering snowpacks maintain phenological overlap in Pacific Northwest montane meadow habitats. Snowpacks that persist until late spring or early summer synchronize larval and plant phenologies by delaying plant emergence until warm weather that also supports rapid larval development. This snow-induced delay in plant emergence allows larvae to complete development prior to plant senescence in late summer.

Climatic changes forecasted for the Pacific Northwest could reduce the overlap between plant and larval phenologies, and thereby convert some meadows from source habitats to sinks. Earlier melting of shallower snowpacks would induce plants to emerge earlier and in cooler weather that would retard larval development. With summer precipitation expected to remain low, soils could dry and plants could senesce before most larvae complete development. This shift in plant phenologies from summer toward spring would be exacerbated by hastened rates of soil drying due to warmer temperatures (Peterson and Peterson 2001; Mote et al. 2003). Consequently, larvae might not survive in otherwise suitable meadows containing larval host plants. Shrinking snowpacks would expose potential additional meadow habitat at higher elevations, but the loss of larger meadow areas at lower elevations due to earlier drying and forest expansion (Peterson and Peterson 2001; Harsch et al. 2009) would cause a net loss in butterfly habitat area.

C. Monitoring Objectives

This report describes a program for monitoring of butterflies and plant phenology in subalpine areas in of the Cascade Mountains using trained volunteers, and modeled after the successful Rocky Mountain National Park Butterfly Monitoring Program (Bray 2010, Figure 1). Monitoring results can be applied to adapt park management, to inform interpretive programs, to develop environmental educational, and to develop inferences about butterfly populations in sub/alpine areas in adjacent National Forests. In addition, butterfly monitoring data will support diverse scientific inquiries regarding biotic responses to climate change in NOCA and MORA, in the Pacific Northwest region, and broader geographic scales. Five objectives direct the program:

1. Document and detect trends in butterfly species richness and abundance at sample sites
2. Document and detect trends in phenology of selected butterfly species including dates of emergence, peak abundance, and length of adult flight season at sample sites
3. Document and detect trends in plant flowering times of selected subalpine plant species
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5. Provide opportunities for college students and recent graduates to gain work experience in applied science careers with an emphasis on recruiting diverse youth who are under-represented in natural sciences

Figure 1. Citizen scientists surveying butterflies at Naches Loop, Easy Pass, and Mazama Ridge.

2. Monitoring Approach and Sample Design

A. Rationale

Approach

Butterflies are sensitive indicators of climate change and habitat quality, but infrequently monitored in national parks (Pollard 1988, McLaughlin et al. 2002, Taron et al. 2004, Parmesan 2006, Cayton et al. 2015, Pardikes et al. 2015, NPS IRMA 2016). In 2007, we (i.e., biologists at NOCA and MORA) decided to establish a citizen-science, long-term monitoring program to document trends in butterfly abundances and plant phenology. We felt a citizen-science program would provide us with high-quality data and an opportunity to engage the public in our efforts to document the effects of climate change on park lands (Cosentino et al. 2014, Follett and Strezov 2015). Public engagement would also provide a method of communicating our science to the public, connect with local butterfly experts, and provide field experience for young scientists. Richard Bray and Dr. Paul Opler had initiated a successful volunteer butterfly monitoring program in Rocky Mountain National Park (ROMO) and this became the model for our program (Bray 2010). In ROMO's program, butterfly abundances were surveyed using the Pollard Walk to determine an index of butterfly abundance (Pollard 1977, Pollard and Yates 1993).

The Pollard Walk methodology is an international standard supporting comparisons with other regions (Taron and Ries 2015, Van Swaay et al. 2015). In the Pollard Walk, observers walk a fixed route at a standard pace (about 7 minutes per 100 m) on a regular (weekly) basis during "good" weather conditions (i.e., reasonable for butterfly flight activity). The observer identifies and records all butterflies that are observed in a fixed area (we use a 5 x 5 x 5 m box in front of the observer). This approach seemed appropriate for our study area because we could establish survey routes along designated trails and minimize off-trail travel to protect popular and sensitive subalpine meadows.

We are monitoring subalpine butterflies and plant phenology as indicators of climate driven changes in high-elevation ecosystems. Most of the high-elevation ecosystems (94%) in Washington State are managed by federal agencies and therefore, federal land managers and scientists have a responsibility to document the impacts of climate on the areas (Rochefort et al. 2012, Raymond et al. 2014). In 2000, the National Park Service established a long-term monitoring program to provide scientifically sound data on the conditions and trends of natural resources (NPS 2001, Fancy et al. 2009). Parks were assembled into networks or groups of parks and each network selected "Vital Signs" to monitor. NOCA and MORA belong to the North Coast and Cascades Network (NCCN) which also includes San Juan Island National Historical Park, Olympic National Park, Ebey's Landing National Historical Reserve, Lewis and Clark National Historical Park, and Fort Vancouver National Historic Site. One of the primary objectives of the NCCN's program was to document changes caused by climate change. By monitoring butterflies and plant phenology, our data will supplement monitoring of subalpine and alpine vegetation composition, mountain lakes, whitebark pine, and glaciers providing a more complete view of trends in high-elevation ecosystems in the northern Cascades (Weber et al. 2009).

Baseline Inventories

Our first step in developing the Cascades Butterfly Project was to assemble butterfly inventories for the lands in our project area (i.e., MORA, NOCA, MBS, and OWNF). In 2008 and 2009, the National Park Service (NPS) began working with Dr. John McLaughlin of Western Washington University and Dr. Dana Garrigan of Pacific Lutheran University (now Carthage College) to develop baseline inventories of butterflies in MORA, NOCA, and the adjacent forests (MBS and OWNF). Dr. Garrigan compiled a list of MORA butterflies MORA based on his field surveys and historical records (Garrigan 2008). Garrigan surveyed butterflies at Naches Peak, the Sunrise Silver Forest Trail, Paradise, Louise Lake, Reflection Lakes, and Bench Lake. NPS ranger Howard Selmer provided another list of MORA butterflies, detection locations, and species-specific flight seasons compiled from his field surveys at Naches Peak, Berkeley Park, Sunrise Silver Forest Trail, Sourdough Ridge Trail, and Palisades Lakes Trail. The historical records dated from1918 to 1995 and came from two sources: a small collection in the MORA museum (31 specimens) and John Hinchliff's "An Atlas of Washington Butterflies: The Distribution of Butterflies in Washington" (1996). Dr. McLaughlin conducted field inventories in nine subalpine areas of MORA in 2009: Naches Peak, Berkeley Park, Summerland, Indian Bar/Ohanepecosh Park, Paradise, Van Trump Park, Emerald Ridge, Indian Henry's Hunting Ground, and Spray Park. In 2008 he surveyed eleven areas in NOCA, MBS, and OWNF: Splawn Mountain, Twisp Pass, Stilletto Peak, South Pass, Maple Pass, Easy Pass, Crater Mountain, Church Mountain, Goat Mountain, Yellow Aster Butte, and Skyline Divide. Based on these records, we assembled a list of 70 species for MORA and 40 for the NOCA, MBS, and OWNF area (Figures 2, 3, Table 1).

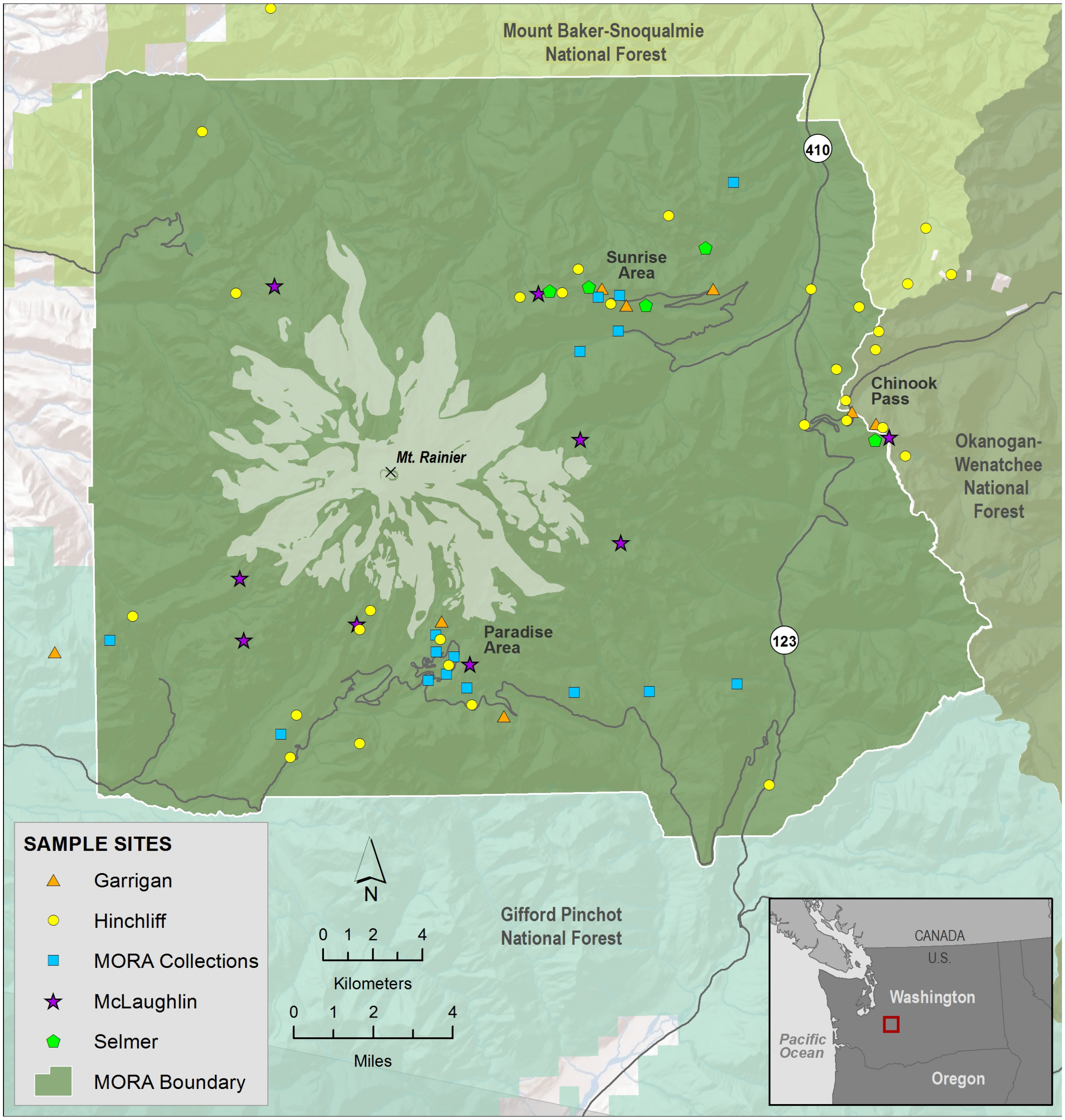

Figure 2. Map illustrating locations of butterflies documented in Mount Rainier National Park (MORA).

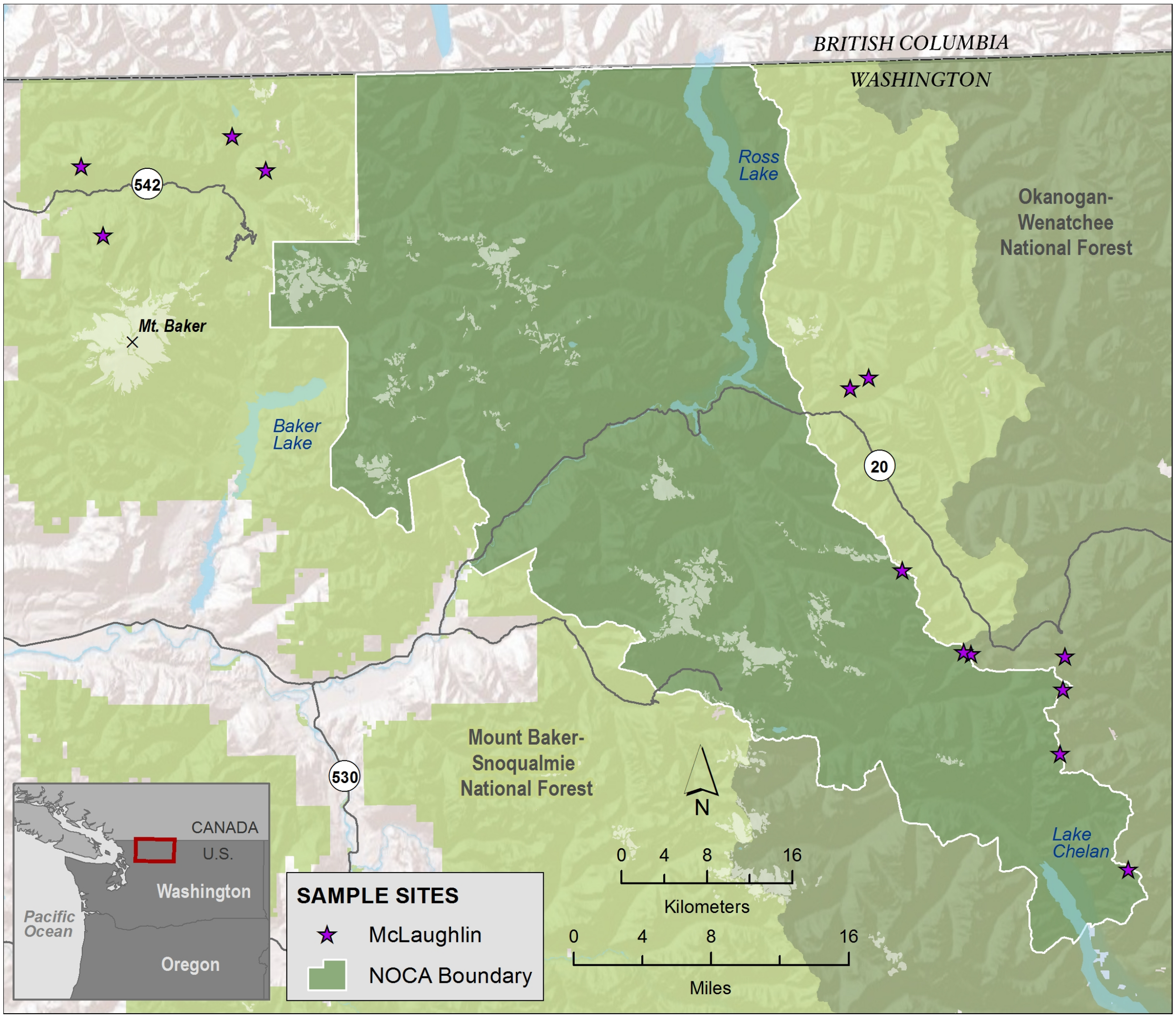

Figure 3. Map illustrating locations of surveys conducted by McLaughlin in North Cascades National Park, Mount Baker-Snoqualmie National Forest, and Okanogan-Wenatchee National Forest.

Table 1. List of Butterfly Species found in Mount Rainier National Park, North Cascades National Park Service Complex, and Okanogan-Wenatchee National Forest.

Species	Common Name	Historic	MORA[1]			NOCA/MBS/ OWNF[1]
			Garrigan 2005	Selmer 2008	McLaughlin 2009	McLaughlin 2008
Hesperidae						
Carterocephalus palaemon	Arctic Skipper	X		X		
Erynnis persius	Persius Duskywing	X		X		
Hesperia colorado	Western Branded Skipper	X			X	
Hesperia comma	Common Branded Skipper					X
Hesperia juba	Juba Skipper	X				
Ochlodes sylvanoides	Woodland Skipper					
Pyrgus ruralis	Two-banded Checkered Skipper	X	X			
Lycaenidae						
Agriades glandon	Arctic Blue	X		X	X	X
Callophrys augustinus	Brown Elfin		X			
Callophrys johnsoni	Johnson's Hairstreak	X				
Callophrys mossii	Moss' Elfin	X				
Celastrina echo	Echo Blue or Spring Azure	X	X			
Euphilotes ancilla	Rocky Mountain Blue	X				
Glaucopsyche lygdamus	Silvery Blue	X	X	X	X	X
Glaucopsyche pisasus	Arrowhead Blue				X	
Lycaena helliodes	Purplish Copper	X		X	X	X
Lycaena heteronea	Blue Copper	X			X	X
Lycaena mariposa	Mariposa Copper	X		X	X	X
Plebejus acmon	Acmon Blue	X	X	X	X	X

[1] MORA = Mount Rainier National Park, NOCA = North Cascades National Park Service Complex, MBS = Mount Baker-Snoqualmie National Forest, OWNF = Okanogan-Wenatchee National Forest

Table 1 (continued). List of Butterfly Species found in Mount Rainier National Park, North Cascades National Park Service Complex, and Okanogan-Wenatchee National Forest.

			MORA[1]			NOCA/MBS/ OWNF[1]
Species	**Common Name**	**Historic**	**Garrigan 2005**	**Selmer 2008**	**McLaughlin 2009**	**McLaughlin 2008**
Plebejus anna	Anna's Blue	X	X	X	X	X
Plebejus icarioides	Boisduval's Blue	X	X	X	X	X
Plebejus idas	Northern Bue				X	X
Plebejus melissa	Melissa's Blue	X				
Plebejus saepiolus	Greenish Blue	X		X		
Satyrium sylvinus	Sylvan Hairstreak	X				
Nymphalidae						
Aglais milberti	Milbert's Tortoiseshell	X	X	X	X	X
Boloria chariclea	Arctic Fritillary	X	X	X	X	X
Boloria epithore	Western Meadow Fritillary	X	X	X	X	X
Cercyonis oetus	Small Wood Nymph	X				
Cercyonis pegala	Common Wood Nymph	X				
Chlosyne hoffmanni	Hoffman's Checkerspot	X	X			
Chlosyne palla	Northern Checkerspot				X	X
Coenonympha tullia	Ochre Ringlet					X
Danaus plexippus	Monarch	X				
Erebia vidleri	Vidler's Alpine					X
Euphydryas anicia	Anicia Checkerspot					X
Euphydryas chalcedona	Chalcedona Checkerspot	X		X	X	X
Euphydryas colon	Snowberry Checkerspot				X	
Euphydryas editha	Edith's Checkerspot	X	X	X	X	X

[1] MORA = Mount Rainier National Park, NOCA = North Cascades National Park Service Complex, MBS = Mount Baker-Snoqualmie National Forest, OWNF = Okanogan-Wenatchee National Forest

Table 1 (continued). List of Butterfly Species found in Mount Rainier National Park, North Cascades National Park Service Complex, and Okanogan-Wenatchee National Forest.

			MORA[1]			NOCA/MBS/ OWNF[1]
Species	**Common Name**	**Historic**	**Garrigan 2005**	**Selmer 2008**	**McLaughlin 2009**	**McLaughlin 2008**
Limenitis lorquini	Lorquin's Admiral	X	X		X	
Nymphalis antiopa	Mourning Cloak	X	X	X		X
Nymphalis californica	California Tortoiseshell	X		X	X	X
Oeneis chryxus	Chryxus Arctic					X
Oeneis nevadensis	Great Arctic	X		X		
Phyciodes cocyta	Northern Crescent				X	
Phyciodes mylitta	Mylitta Crescent	X			X	
Phyciodes pulchella	Field Crescent	X	X	X	X	
Polygonia faunus	Green Comma	X		X		
Polygonia gracilis	Hoary Comma	X	X	X	X	X
Polygonia oreas	Oreas Comma	X				
Polygonia satyrus	Satyr Comma	X		X	X	X
Speyeria callippe	Callippe Fritillary	X	X		X	
Speyeria coronis	Coronis Fritillary	X	X		X	X
Speyeria cybele	Great-Spangled Fritillary	X				
Speyeria hydaspe	Hydaspe Fritillary	X	X		X	X
Speyeria mormonia	Mormon Fritillary	X	X	X	X	X
Speyeria zerene	Zerene Fritillary	X				
Vanessa annabella	West Coast Lady	X			X	
Vanessa atalanta	Red Admiral	X		X		
Vanessa cardui	Painted Lady	X	X	X	X	X

[1] MORA = Mount Rainier National Park, NOCA = North Cascades National Park Service Complex, MBS = Mount Baker-Snoqualmie National Forest, OWNF = Okanogan-Wenatchee National Forest

Table 1 (continued). List of Butterfly Species found in Mount Rainier National Park, North Cascades National Park Service Complex, and Okanogan-Wenatchee National Forest.

Species	Common Name	Historic	MORA[1]			NOCA/MBS/ OWNF[1]
			Garrigan 2005	Selmer 2008	McLaughlin 2009	McLaughlin 2008
Papilionidae						
Papilio eurymedon	Pale Swallowtail	X	X	X	X	X
Papilio indra	Indra Swallowtail	X				X
Papilio multi-caudatus	Two-tailed Swallowtail	X				
Papilio rutulus	Western Tiger Swallowtail	X				X
Papilio zelicaon	Anise Swallowtail	X	X	X	X	X
Parnassius clodius	Clodius Parnassian	X	X		X	X
Parnassius smintheus	Mountain Parnassian	X	X	X	X	X
Pieridae						
Anthocharis sara	Sara's Orangetip	X	X	X	X	X
Colias alexandra	Queen Alexandra's Sulphur	X				
Colias eurytheme	Orange Sulphur	X			X	X
Colias interior	Pink-edged Sulphur					X
Colias occidentalis	Western Sulphur	X		X		
Colias philodice	Clouded Sulphur	X	X		X	X
Neophasi menapia	Pine White	X		X	X	
Pieris marginalis	Margined White	X			X	X
Pieris rapa	Cabbage white	X				
Pontia occidentalis	Western White	X	X	X	X	X

[1] MORA = Mount Rainier National Park, NOCA = North Cascades National Park Service Complex, MBS = Mount Baker-Snoqualmie National Forest, OWNF = Okanogan-Wenatchee National Forest

B. Sample Design and Study Sites

We are using two approaches to study butterflies and plant phenology: inventory and monitoring. First, we are continuing to conduct qualitative inventories of butterflies across our landscape. These inventories are called qualitative because our goal is to document the butterfly species and distributions in the Cascades, but not abundances. Second, we have established 10 permanent transects to monitor quantitative changes in butterfly abundance and species diversity and timing of plant phenology. Permanent survey routes have been established in subalpine meadows in four federally managed protected areas: North Cascades National Park, Mount Baker-Snoqualmie National Forest, Okanogan-Wenatchee National Forest, and Mount Rainier National Park. Butterfly abundances and plant phenology are recorded along permanent survey routes at weekly intervals.

Photo-inventories of Butterflies

We are working with Butterflies and Moths of North America (BAMONA) to document butterflies across the Cascades ecosystem (http://www.butterfliesandmoths.org/). Park or forest visitors can upload photos to document a sighting or to add the photo gallery; it is not necessary to sign up as a volunteer or to go to a specific site. We are most interested in having photos added as sightings from many locations through the CBP project area. BAMONA works with butterfly and moth experts who will review uploaded photos and verify or identify the species that was uploaded.

Permanent Survey Routes for Butterflies and Plant Phenology

Monitoring of butterfly abundances and plant phenology is conducted weekly, during the summer season, along ten1-km survey routes located along maintained trails. Survey routes are located along maintained trails in subalpine meadows to minimize trampling of sensitive vegetation. We selected locations for survey routes primarily based on the distance from trailheads. Since our goal is to survey weekly with citizen scientists, we selected study areas that were easily accessible and relatively close to trailheads (within about 6.4 km or 4 miles, Table 2, Figure 4).

Table 2. Distance to survey routes and elevation gain along survey route.

Location	Trailhead	Distance to Start, km (mile)	Elevation at Start, m (ft)	Elevation Gain on Survey Route, m (ft)
Mount Baker-Snoqualmie National Forest				
Sauk Mountain	Sauk Mountain	2.9 (1.8)	1585 (5,200)	260 (853)
Skyline Divide	Skyline Divide	3.9 (2.4)	1,798 (5,900)	767 (2,516)
Mount Rainier National Park				
Skyscraper Mountain	Sunrise	3.0 (3.7)	2,063 (6,770)	112 (370)
Sunrise Rim	Sunrise	0.2 (0.1)	1,934 (6,343)	30 (98)
Naches Loop	Tipsoo Lake	0.6 (0.4)	1,615 (5,300)	183 (600)
Mazama Ridge	4^{th} Crossing	1.1 (0.7)	1,765 (5,790)	360 (1,180)
Spray Park	Mowich Lake Campground	4.8 (3.0)	1,768 (5,800)	488 (1,600)

Table 2 (continued). Distance to survey routes and elevation gain along survey route.

Location	Trailhead	Distance to Start, km (mile)	Elevation at Start, m (ft)	Elevation Gain on Survey Route, m (ft)
North Cascades National Park				
Cascade Pass	Cascade Pass	6.0 (3.7)	1,665 (5,461)	530 (1,740)
Easy Pass	Easy Pass	5.6 (3.5)	1,970 (6,500)	850 (2,800)
Okanogan-Wenatchee National Forest				
Maple Pass	Rainy Pass	5.6 (3.5)	1,940 (6,360)	550 (1,800)

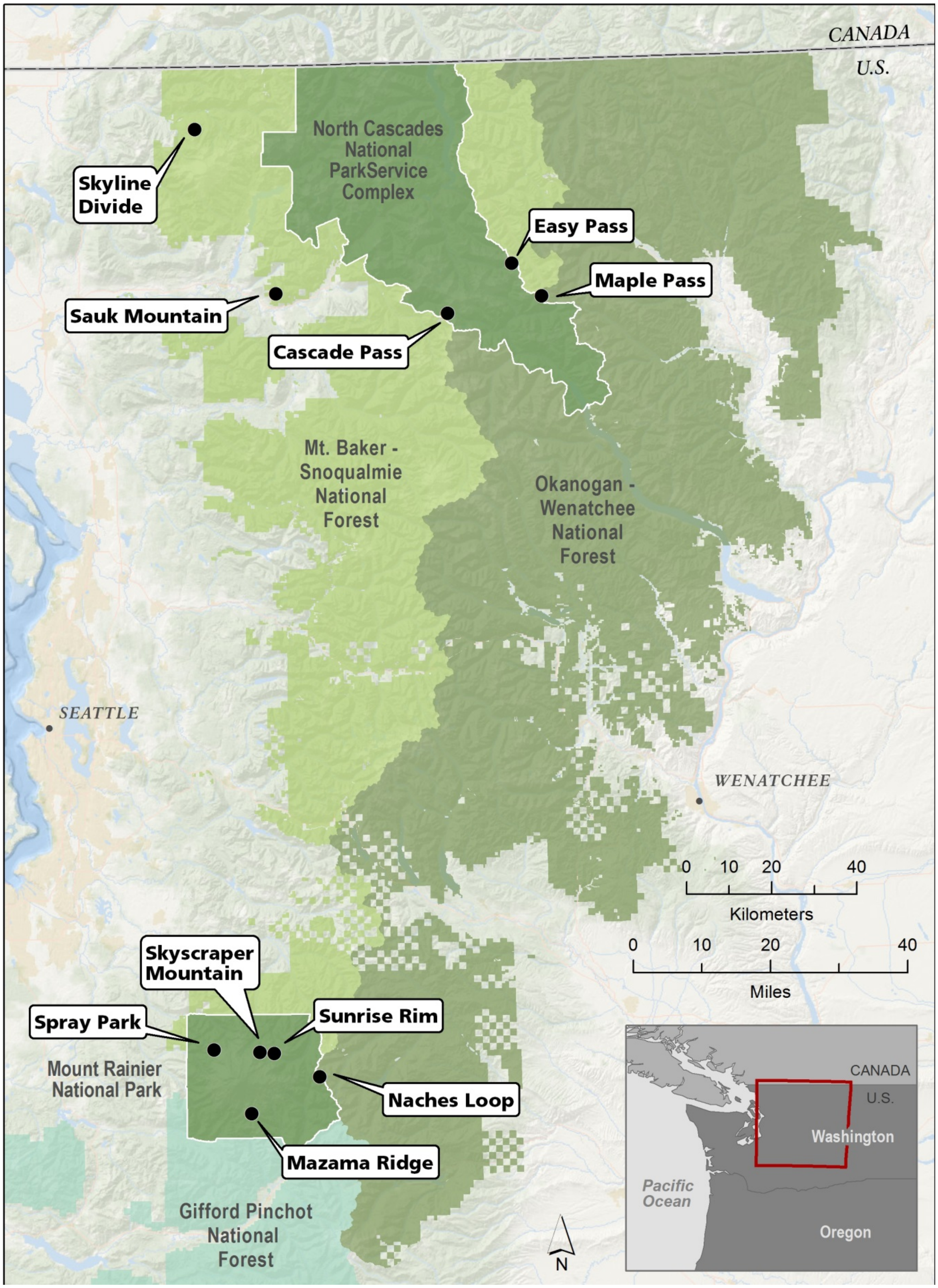

Figure 4. Locations of 10 survey sites for the Cascade Butterfly Project.

C. Sampling Frequency

Butterfly photo-inventories can be conducted at any time during the butterfly flight season. Monitoring of butterfly abundance and plant phenology is conducted at weekly intervals during the summer season. Summer season begins as soon as snow melts and sites are safely accessible until night temperatures drop close to freezing (Figures 5, 6). Generally, surveys begin in June or July and end close to Labor Day. The earliest date we have conducted surveys is June 8 (2016 at Sauk Mountain) and the latest is October 9 (2014 at Naches Peak). Since butterfly activity reflects weather conditions, it is sometimes advantageous to schedule more than one survey per week, in the event that rain or cool temperatures preclude one of the surveys. A companion report includes detailed standard operating procedures and maps of all the survey routes (Rochefort 2017).

Figure 5. Placing markers along the Mazama Ridge, Mount Rainier National Park survey route on July 6, 2016.

Figure 6. Surveying the Cascade Pass, North Cascades National Park Service Complex survey route July 20, 2016.

3. Field Methods for Quantitative Surveys

A. Butterfly Surveys

Butterflies are surveyed using the Pollard walk methodology, an international standard that will support comparisons with other regions (Pollard 1977 and Pollard and Yates 1993). Each survey route is 1 km in length and divided into five 200m segments. Surveys are generally conducted by a minimum of two people and up to five or six people; two people are the minimum for safety. One person is the observer and the second is the recorder; if more people are available, they can assist with plant surveys, identification of butterflies, and communication about the program with people encountered on the trail (Figure 7). Our goal is to identify all butterflies to species to understand how each species is responding to changing climates (Table 3). Citizen scientists initially work with NPS biologists and interns for several surveys to learn survey methods and local butterflies. During these training surveys, the NPS representative will point out key characteristics of species encountered to help the volunteer learn each species. We rely on several butterfly books or on-line keys, but Robert Michael Pyle's "The Butterflies of Cascadia" is our primary reference. Although we frequently catch and release butterflies to aid in identification, there may be days when butterfly abundance is high and butterflies can only be identified to complexes (e.g., Blues, Whites). Once citizen scientists feel confident in species identification and methodology, they can be designated as CBP Leaders and can survey independently and train new volunteers.

Figure 7. Butterfly surveys in North Cascades National Park, clockwise from left: Salvador Silahua surveying the Easy Pass route (NPS), survey route section marker (NPS), Vidler's Alpine examined for identification in insect viewing jar (photo by Mark and Irene Perry).

Table 3. Butterflies documented on each survey route.

Species	Common Name	NOCA[1]		OW[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SS[2]	SP[2]	SR[2]
Hesperiidae											
Carterocephalus palaemon	Arctic Skipper		x								
Erynnis persius	Persius Duskywing						x				
Hesperia comma	Common Branded Skipper		x	x							
Hesperiidae sp.	Unidentified Skipper	x	x	x	x	x					
Ochlodes sylvanoides	Woodland Skipper				x			x			
Lycaenidae											
Agriades glandon	Arctic Blue		x		x				x		
Callophrys augustinus	Brown Elfin				x						
Callophrys mossii	Moss' Elfin				x						
Celastrina echo	Echo Blue						x				
Glaucopsyche lygdamus	Silvery Blue	x	x	x	x	x	x	x	x	x	x
Lycaena helloides	Purplish Copper	x	x	x	x	x		x			
Lycaena heteronea	Blue Copper		x						x		
Lycaena mariposa	Mariposa Copper	x	x	x	x	x	x	x	x	x	x
Lycaeninae sp.	Unidentified Copper	x	x		x	x	x	x	x	x	x
Plebejus acmon	Acmon Blue										x
Plebejus anna	Anna's Blue	x	x	x	x	x	x	x	x	x	x
Plebejus icarioides	Boisduval's (Common) Blue	x	x	x	x	x	x	x	x	x	x
Plebejus lupini	Lupine Blue		x			x		x	x		
Plebejus saepiolus	Greenish Blue						x				

[1] Site abbreviations are: NOCA = North Cascades National Park, MBS= Mount baker-Snoqualmie National Forest, OWN = Okanogan-Wenatchee Nation Forest, MORA = Mount Rainier National Park

[2] Route abbreviations are: CP = Cascade Pass, EP = Easy Pass, MP = Maple Pass, SM = Sauk Mountain, SD = Skyline Divide, MR = Mazama Ridge, NL = Naches Loop, SP = Spray Park, SR = Sunrise Rim; SS = Skyscraper Mountain

Table 3 (continued). Butterflies documented on each survey route.

Species	Common Name	NOCA[1]		OW[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SS[2]	SP[2]	SR[2]
Polyommatinatinae sp.	Unidentified Blue	x	x	x	x	x	x	x	x	x	x
Strymon melinus	Gray Hairstreak						x				
Theclinae sp.	Unidentified Hairstreak/Elfin				x						
Nymphalidae											
Aglais milberti	Milbert's Tortoiseshell	x	x	x	x	x		x	x	x	x
Boloria chariclea	Arctic Fritillary	x	x	x		x	x	x	x	x	x
Boloria epithore	Western Meadow Fritillary	x	x	x	x	x	x	x	x		
Boloria sp.	Unidentified Lesser Fritillary	x	x	x	x		x	x	x	x	x
Chlosyne palla	Northern Checkerspot			x							
Erebia epipsodea	Common Alpine		x								
Erebia vidleri	Vidler's Alpine	x	x	x	x	x					
Euphydryas colon/anicia	Snowberry or Anicia Checkerspot	x	x	x		x		x	x		x
Euphydryas editha	Edith's Checkerspot	x	x	x			x	x	x	x	x
Euphydryas sp.	Unidentified Euphydryas checkerspot	x	x	x	x	x		x	x		x
Euphydryas/Chlosyne sp	Unidentified Checkerspot	x	x	x	x	x	x	x	x		x
Heliconinae sp.	Unidentified Fritillary	x	x	x	x	x	x	x	x	x	x
Limenitis lorquini	Lorquin's Admiral	x		x	x						
Nymphalis antiopa	Mourning Cloak			x			x			x	
Oeneis chryxus	Chryxus Arctic		x								
Oeneis nevadensis	Great Arctic							x			
Phyciodes mylitta	Mylitta Crescent				x						
Phyciodes pulchella	Field Crescent								x		x

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Table 3 (continued). Butterflies documented on each survey route.

Species	Common Name	NOCA[1]		OW[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SS[2]	SP[2]	SR[2]
Polygonia faunus	Green Comma	x						x			
Polygonia gracilis	Hoary Comma	x	x	x	x	x	x	x	x	x	x
Polygonia satyrus	Satyr Comma	x	x	x	x		x		x	x	x
Polygonia sp.	Unidentified Comma	x	x		x	x	x	x		x	
Speyeria coronis	Coronis Fritillary							x			
Speyeria hydaspe	Hydaspe Fritillary	x	x	x	x	x	x	x			x
Speyeria mormonia	Mormon Fritillary	x	x	x	x	x	x	x	x	x	x
Speyeria sp.	Unidentified Greater Fritillary	x	x	x	x	x	x	x	x	x	x
Vanessa atalanta	Red Admiral	x	x								
Vanessa cardui	Painted Lady					x					
Vanessa sp.	Unidentified Lady		x			x	x	x			
Papilionidae											
Papilio eurymedon	Pale Swallowtail		x		x						
Papilio indra	Indra Swallowtail			x							
Papilio zelicaon	Anise Swallowtail		x	x	x	x	x	x	x	x	x
Papilioninae sp.	Unidentified Swallowtail		x	x	x	x	x	x	x	x	x
Parnassius clodius	Clodius Parnassian	x	x	x	x	x		x	x		
Parnassius smintheus	Mountain Parnassian		x	x	x			x			
Parnassius sp.	Unidentified Parnassian				x		x	x			
Pieridae											
Anthocharis sara	Sara's Orangetip		x	x	x						x
Coliadinae sp.	Unidentified Sulphur			x			x		x	x	

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Table 3 (continued). Butterflies documented on each survey route.

Species	Common Name	NOCA[1]		OW[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SS[2]	SP[2]	SR[2]
Colias eurytheme	Orange Sulphur		x	x							
Colias philodice	Clouded Sulphur		x	x			x		x		x
Neophasia menapia	Pine White	x			x	x					
Pierinae sp.	Unidentified White	x	x	x	x	x	x	x	x	x	x
Pieris marginalis	Margined White	x			x	x					
Pieris rapae	Cabbage White										x
Pontia occidentalis	Western White	x	x	x	x	x			x	x	
Butterfly *sp.*	Unidentified Butterfly	x	x	x	x	x	x	x	x	x	x

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B. Plant Phenology

Plant phenology is documented along each survey route using phenophases and flower abundance. Phenophase and abundance is recorded by section based on the condition of the listed species that are growing within 2.5m on either side of the trail (i.e., the base of the imaginary box used for butterfly surveys). Each route has a list of plant species that were selected because they are easily identified and may either be a host plant or nectar plant for butterflies, or their flowering time has been pretty reliable. For example, glacier and avalanche lilies (*Erythronium grandiflorum, E. montanum*) are generally two of the earliest flowering species in subalpine meadows. Mountain bog gentian (*Gentiana calycosa*) is one of the latest flowering species (Table 4). By recording when each phenophase occurs, we can determine if there are changes in plant phenology patterns in subalpine meadows. We are recording abundances of flowers (in categories) as an estimate of floral nectar resource available for pollinators and to determine foliage condition as larval food.

The phenophases that we are using are:

- vegetative (V) - no plants in the section have flowers
- early (E) - at least one plant with flowers is observed in the section
- middle (M) **–** more than 50% of the selected species has flowers
- late (L) - when more than 50% of the plant of the selected species have flowers that are wilted or in fruit
- species not observed along the section (X)

Flower abundance is recorded for all species that the phenophase is E, M, or L:

- 1 for 1-10 flowers or flowering stalks
- 2 for 11-50 flowers or flowering stalks
- 3 for 51 or more flowers of flowering stalks

Floral abundance is surveyed in categories to provide a relative amount of floral resources and observers should feel comfortable using their best judgement of the categories. If individual flowers can be easily identified they are counted, but on a plant that has multiple inflorescences on a flowering stalk, just the stalk is counted if even one inflorescence is open (Figure 8).

Figure 8. Examples of plant abundance counts for bracted lousewort (*Pedicularis bracteosa*) in the left photo and pink mountain heather (*Phyllodoce empetriformes*) on the right. Bracted lousewort is counted by flowering stalks and is a category 1 since only 2 flowering stalks are visible and pink mountain heather is a category 2 since more than 11 flowers are visible.

Table 4. Plant species surveyed at each site.

Scientific Name	Common Name	NOCA[1]		OWN[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SP[2]	SR[2]	SS[2]
Achillea millefolium	Yarrow		X	X	X	X				X	X
Anaphalis margaritacea	Pearly Everlasting	X	X		X			X			
Anemone occidentalis	Western Anemone		X	X			X	X		X	X
Antennaria media	Rocky Mountain Pussytoes		X	X	X						
Arnica latifolia	Mountain Arnica	X	X	X	X	X	X	X		X	
Bistorta bistortoides	American Bistort	X	X		X	X	X	X	X	X	X
Cassiope mertensiana	White Heather	X		X		X	X		X		X
Castilleja hispida	Harsh Indian Paintbrush	X	X	X	X					X	
Castilleja parviflora var. *albida*	White Indian Paintbrush	X	X	X		X					
Castilleja parviflora var. oreopola	Magenta Indian Paintbrush						X	X	X	X	X
Cirsium edule	Edible Thistle	X	X		X						
Erigeron peregrinus	Subalpine Daisy	X	X	X	X	X	X	X	X	X	X
Eriogonum pyrolifolium	Alpine Buckwheat					X					
Erythronium grandiflorum	Glacier Lily	X	X	X	X	X					
Erythronium montanum	Avalanche Lily						X	X	X		
Eucephalus ledophyllus	Cascade Aster		X		X		X	X		X	
Gentiana calycosa	Mountain Bog Gentian		X	X			X		X		X
Heracleum maximum	Cow Parsnip	X	X		X						
Ligusticum grayi	Gray's Lovage			X			X	X		X	
Lilium columbianum	Tiger Lily				X						
Lomatium dissectum	Fern-leaved Desert Parsely		X	X	X						
Lomatium martindalei	Cascade Desert Parsley				X	X					

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Table 4 (continued). Plant species surveyed at each site.

Scientific Name	Common Name	NOCA[1]		OWN[1]	MBS[1]		MORA[1]				
		CP[2]	EP[2]	MP[2]	SM[2]	SD[2]	MR[2]	NL[2]	SP[2]	SR[2]	SS[2]
Luetkea pectinata	Partridgefoot	X	X	X		X					
Lupinus latifolius	Broadleaf Lupine	X	X	X	X	X	X	X	X	X	X
Lupinus lepidus	Pacific Lupine										X
Oreostemma alpigenum	Alpine Aster						X		X		X
Pedicularis bracteosa	Bracted Lousewort	X	X	X	X	X	X	X	X	X	X
Pedicularis rainierensis	Mt. Rainier Lousewort						X		X		X
Penstemon serrulatus	Coast Penstemon	X			X					X	
Penstemon procerus	Small-flowered Penstemon	X	X	X		X					X
Phlox diffusa	Phlox	X	X	X	X	X	X	X		X	X
Phyllodoce empetriformes	Pink Heather	X	X	X		X	X	X	X	X	X
Polemonium pulcherrimum	Jacob's Ladder	X						X		X	
Potentilla flabellifolia	High Mountain Cinquefoil	X	X	X		X	X	X	X	X	X
Rhododendron albiflorum	White Rhododendron		X					X			
Sedum divergens	Pacific stonecrop				X						
Sedum oreganum	Oregon Stonecrop		X	X							
Spiraea densiflora	Mountain Spirea	X	X					X			
Vaccinium deliciosum	Cascade Huckleberry	X	X	X	X	X	X	X	X	X	X
Valeriana sitchensis	Sitka Valerian	X	X	X	X	X	X	X		X	
Veratrum viride	False Hellebore	X	X		X	X	X	X		X	
Veronica cusickii	Cusick's Speedwell	X	X	X			X	X	X	X	X
Viola sempervirens	Yellow Violet				X						

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C. Permitting and Compliance

This monitoring project is categorically excluded from further analysis under the National Environmental Policy Act (NEPA) because (a) the scope of work fits within the categorical exclusion (CE) under section 3.3.E.5 [Nondestructive data collection, inventory (including field, aerial, and satellite surveying and mapping), study, research, and monitoring activities] , and (b) no extraordinary circumstances exist that preclude the use of a CE (section 3.5) (NPS 2015).

As many of our monitoring sites are located within designated wilderness, this monitoring project has also been assessed via a Minimum Requirement Analysis in accordance with the Wilderness Act to ensure that wilderness character is protected (NPS 2006, section 6.3.5). Through this analysis, the NPS determined that this long-term monitoring project will help to answer important questions that cannot be reasonably addressed in a non-wilderness setting and that the benefits of this research far outweigh impacts to wilderness character (in accordance with DO41). This analysis also helped to clarify that the route markers were indeed necessary to identify plots, and were the minimum tool necessary to do so. (All route markers must follow guidelines developed by each protected area). Other than these small markers, which will be removed at the end of the monitoring project, there are no other uses associated with this project that are prohibited within designated wilderness. In short, this activity fully complies with the spirit and intent of the Wilderness Act.

4. Science Communication

Communicating the goals and scientific results of our monitoring is one of the most important components of the Cascades Butterfly Project. We utilize a variety of approaches to reach diverse audiences and modify our message to fit the audience.

A. Field Communication

Citizen scientists and NPS field personnel frequently encounter visitors while conducting field surveys. Our use of nets for capture and release butterfly identification often prompts questions from hikers about what we are doing. This is an ideal opportunity to explain the purpose of our project, climate change, and the sensitivity of butterflies and plant phenology to air temperature. It is important to take time to describe the project and answer all visitor questions. If there are at least three people working on the survey, one person can answer questions while the other two continue the survey. If there are only two people, then the survey should be stopped to answer questions and the break time is recorded on the butterfly data sheet. It is also important to tell people about the project and that butterflies and plants are sensitive indicators of changing climates, but not try to convince people that climate change is anthropogenic. We also put signs up at trailhead bulletin boards to let people know about the study and to request that they leave our section markers along the trail (Figure 9).

Figure 9. Cascade Butterfly Project trailhead sign.

B. Social Media

We are gradually expanding and improving our use of social media to communicate about the project and to recruit volunteers. Currently, we have small project descriptions on the NOCA and MORA websites and by the summer of 2017, we will have a more detailed description on the NCCN Research Learning Center website. In 2016, we posted weekly Facebook entries, during the summer, on both MORA and NOCA sites on butterflies of the week and volunteers. We also posted in Spanish on the NOCA site. In 2017, we will begin to utilize Twitter and Instagram through the NCCN Research Learning Center platform to reach a broader audience with more frequent updates on field surveys, research, and publications. Our goal is to reach the general public, the scientific community, and both Spanish and English speaking communities. We also plan on publishing short videos on the project and on field survey methods.

C. Resources Briefs, Reports, Publications, and Meetings

Each year we will publish Resource Briefs at the beginning and end of the season. Resource Briefs are short 2-page publications that can be posted on NPS websites and emailed to volunteers or prospective volunteers. Early season Resource Briefs will provide an updated overview of the program, and end of season Briefs will summarize season accomplishments (see Section 5 for more information, example Resource Briefs are provided in Appendix A). Annual reports and scientific publications will be used to provide more detailed program accomplishments and are described in more detail in Section 5. Each year a winter meeting will be held to invite new volunteers, update experienced volunteers on program results, and discuss suggestions from volunteers for program updates. This meeting will be held in February or March at a central location such as the Burke Museum at University of Washington.

5. Data Management and Reporting

This chapter describes the procedures for data management, analysis, and report development. Data management is still in development at this time. We are designing our procedures to generally follow guidelines in the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. Backups of all data, data sheets, and digital copies of data sheets are stored at North Cascades National Park Service Complex on the Project Lead's computer, on natural resource share drives, and in the Project Lead's files.

A. Data Storage

Photo-Inventories

Photographs of butterflies can be uploaded to the Butterflies and Moths of North America (BAMONA, www.butterfliesandmoths.org) website (Figure 10). There are two choices for photo submission: the image gallery or as a sighting. Photos uploaded to the image gallery should be high-quality photos that are used as one component of the BAMONA species profiles. Specific directions for preparing the photos are included on the website and photographers retain all copyrights for the photos. Images submitted in support of sightings should also be of good quality and it is optimal if there is both a dorsal and ventral photo of the butterfly. When the photos are uploaded, the photographer also submits the location and date; locations can be easily recorded using an on-line mapping tool. Sightings can also be annotated as part of the Cascades Butterfly Project survey area.

Figure 10. Butterflies and Moths of North America website for photo-inventories of butterflies.

Quantitative Butterfly Survey Data

Currently, quantitative butterfly observations are entered and stored in a database hosted on the PollardBase site (www.pollardbase.org) which is the product of a collaboration between Dr. Leslie Ries, Georgetown University, and Kelly Lotts and Thomas Naberhaus of Butterflies of North America (Figure 11). Field survey data are input to the site by citizen scientists or NPS employees and interns and then the data sheet is sent to the Project Lead who verifies the data (i.e. checks for errors). Prior to entering data, a login must be requested and the Project Lead will approve the requestor for access. Data can be downloaded by the Project Lead at any time.

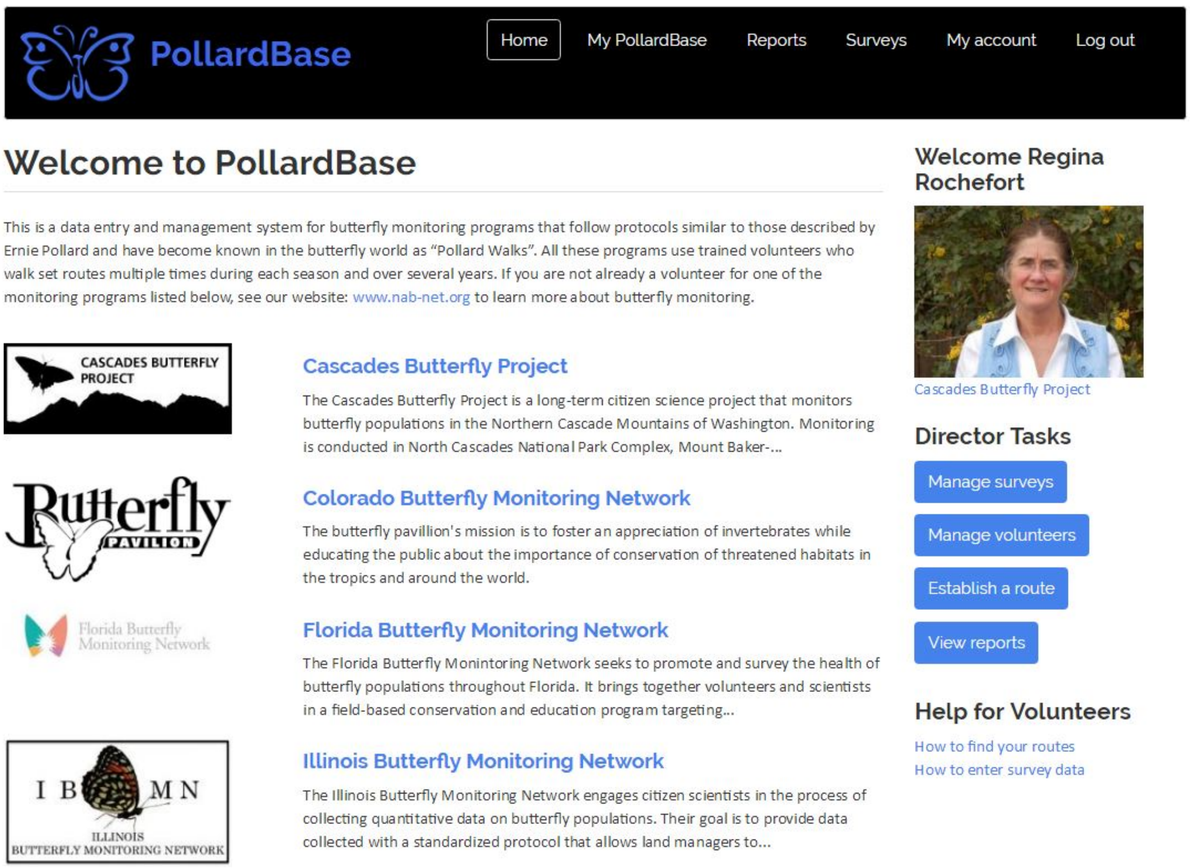

Figure 11. PollardBase database for quantitative butterfly data.

Plant Phenology Data

At this time, all plant phenology data is entered by NPS personnel into excel spreadsheets which are stored at NOCA. Dr. Ries and the BAMONA staff are planning on expanding the database to include plant phenology observations in the future.

B. Reporting

Resource Briefs

Resource Briefs are short, generally 2-page, summaries of the project goals, status, and recent changes or accomplishments. Resource Briefs should be updated each year; if time permits, it would be optimal to have two briefs per year - an early season brief to provide a program overview and a fall/winter brief to summarize the past season's accomplishments (see Appendix A). Resource Briefs will be published at the NPS Data Store (https://irma.nps.gov/DataStore/) and on park websites.

Periodic Reports and Journal Publications

Annual and five-year reports summarizing program accomplishments are the goal for the Cascade Butterfly Project. Annual reports should be published in the National Park Service Natural Resource Report series and should include summaries of volunteer efforts, number of butterfly species detected on each route, butterfly abundances and emergence curves, and plant phenology summaries. Annual reports will provide the opportunity for reviewing and revising methods and communicating with volunteers. Five-year reports provide the opportunity for more detailed analysis such as comparison of patterns with weather variables. Five-year reports may be published in a scientific journal rather than an NPS Report Series.

6. Personnel Requirements, Training, and Safety

A. Roles and Responsibilities

The CBP is interagency monitoring projects that is coordinated by the NOCA Science Advisor, but relies on project-based funding and support from Citizen Scientists, and staff from MORA, NOCA, and the NCCN (North Coast and Cascades) Network.

The roles associated with this Protocol are Project Lead, Field Leads, Field Interns, Citizen Scientists GIS Specialist, Park Contacts, Park Volunteer Coordinators, and Project Partners. One person may take on several roles. Specific responsibilities associated with the roles are found in Table 4.

Table 4. Roles and responsibilities for the Cascades Butterfly Monitoring Project.

Role	Responsibilities	Position (Name)
Project Lead	• Project administration, operations, and implementation • Track project objectives, budget, requirements, and progress toward meeting objectives • Coordinate and ratify changes to protocol • Lead training of field crews in scientific methods, species identification, and safe field procedures • Recruit volunteers • Communicate about the CBP through social media • Maintain and archive project records • Certify each season’s data for quality and completeness • Conduct data summaries and analysis, complete reports, metadata, and other products according to schedule	NOCA Science Advisor (Regina Rochefort)
Field Leads	• Assist Project Lead with scheduling of survey schedules and communication with Citizen Scientists • Assist with training of interns and Citizen Scientists • Ensure that NPS field crews follow safe field survey methods and follow individual park tracking procedures • Write entries for social media during field season • Coordinate data entry and verify data that has been entered • Acquire and maintain field equipment • Talk to hikers in the field about the CBP and monitoring to document climate induced ecosystem changes • Provide feedback to Project Lead on CBP protocols and refinements	2 Seasonal Biological Technicians
Field Interns	• Assist in training and ensuring safety of citizen scientists • Conduct field surveys safely • Conduct field surveys according to CBP scientific protocols • Talk to hikers in the field about the CBP and monitoring to document climate induced ecosystem changes • Enter data in database and file data in CBP files • Write entries for social media during field season • Talk to hikers in the field about the CBP and monitoring to document climate induced ecosystem changes • Provide feedback to Project Lead on CBP protocols and refinements	2 Seasonal Interns: college students or recent graduates

Table 4 (continued). Roles and responsibilities for the Cascades Butterfly Monitoring Project.

Role	Responsibilities	Position (Name)
Citizen Scientists	• Conduct field surveys safely • Conduct field surveys according to CBP scientific protocols • Talk to hikers in the field about the CBP and monitoring to document climate induced ecosystem changes • Enter data in database and send data sheets to Project Lead	Volunteers
GIS Specialist	• Prepare GPS units for field season, • Provide training to Field Leads and Interns on navigation and data recording • Develop maps for publications	GIS Specialist (Natalya Antonova)
Park Volunteer Coordinators	• Provide Agreement forms for Volunteers in Parks (VIPs) • Assist with advertisement of VIP (Citizen Scientist) opportunity with CBP • Consult with Program Lead on managing volunteers and tracking hours	MORA VIP Coordinator (Kevin Bacher) NOCA VIP Coordinator
Park & USFS Partners	• Assist with logistics for office space, computer use, housing, and other administrative needs • Review CBP Reports • Facilitate coordination with researchers who might be interested in expanding on the program	MORA Botanist MORA Wildlife Biologist NOCA Wildlife Biologist NOCA Plant Ecologist MBS Biologists OWNF Biologists
Project Partners	• Provide technical advice on butterfly survey methods and analysis • Lead coordination with other Pollard Walk Groups • Database development, maintenance, and portal to database • Collaborate on data analysis and manuscripts	Pollard Walk Group Coordinator (Dr. Leslie Ries) Butterflies & Moths of North America (Thomas Naberhaus & Kelly Lotts) Dr. John McLaughlin, Western Washington University

B. Qualifications for Field Personnel

Field Leads will be hired each year as Biological Technicians. Field leads should have experience conducting field surveys in plant ecology and/or butterflies, hiking and backcountry travel, and supervision of field crews. Field interns will be current students or recent graduates with a science major. The goal for field interns is to give young or new scientists field experience and to recruit from wide and diverse audiences that include underrepresented groups in science and first generation college graduates. Currently, the NPS has several funded programs with partners who have expertise in advertising to and recruiting from a broad student audience (e.g., Latino Heritage, Mosaics in Science, GeoScientists in the Parks). All field personnel must be fit and prepared to spend extended periods of time in the field and hiking in steep terrain. Field personnel should be individuals who enjoy working as a member of a crew and who enjoy communicating with people they encounter in the field.

The qualifications for Field Citizen Scientists is much the same as interns – a desire to learn, physically able to hike in steep terrain, commitment to the environment, ability to work as a member of a crew, and a desire to communicate and teach people they encounter in the field about the program. As our program is evolving, we are beginning to have opportunities for volunteers who would like to work indoors or during the winter to support the program. Some of these positions are social media, data entry, data analysis, writing of butterfly and plant guides, and development of training videos or on-line quizzes (to learn species identification).

C. Training Procedures

Prior to the field season, an indoor meeting will be held at a central location to explain the program to potential volunteers and update returning volunteers on the program. Generally this program will be in February or March. Seasonal field personnel generally begin working in June and will spend the first two to three weeks in park and safety orientation and learning about the CBP. The Program will spend at least one week teaching the crews how to mark survey routes, butterfly and plant identification, and practicing survey methods. The GIS Specialist will set-up the GPS units and will instruct the crews on operation of the GPS units. In the summer, generally July, two field days will be set aside to introduce potential volunteers to field methods and butterfly identification. Generally, one field day will be held at Sauk Mountain and the other at Sunrise along the Sunrise Rim Trail and the road to the walk-in campground. After the initial group training days, volunteers training will be integrated into regular surveys.

D. Safety

Safety is a major component of the CBP. Our goal is a completely safe program without any accidents. No survey is worth risking the safety or health of our personnel. Field leads and interns will discuss potential safety risks with volunteers and field crews. A Job Hazard Analysis is included in Appendix B as a foundation for discussing hazards prior to field surveys. Park personnel will carry radios and follow backcountry travel procedures for each park (i.e. filing routes and checking in and out). Volunteers who are working without park personnel will also follow individual park guidance, either checking in with the Communication Center or with the Program Lead after field surveys. Our preferred method of surveys is to have a crew of at least two people – both for safety and to collect accurate data.

Literature Cited

Barnett T. P., D. W. Pierce, H. G. Hidalgo, C. Bonfils , B. D. Santer, T. Das, G. Bala, A. W. Wood, T. Nozawa. A. A. Mirin, D. R. Cayan, and M. D. Dettinger. Human-induced changes in the hydrology of the western United States. *Science* 319(5866):1080-1083.

Bertin, R. I. 2008. Plant phenology and distribution in relation to recent climate change. *Journal of the Torrey Botanical Society* 135(1):126–146.

Boetsch, J. R., B. Christoe, and R. E. Holmes. 2009. Data management plan for the North Coast and Cascades Network Inventory and Monitoring Program (2005). Natural Resource Report NPS/NCCN/NRR—2009/078. National Park Service, Fort Collins, CO.

Bonfils C., B. D., Santer, D. W Pierce., H. G. Hidalgo, G. Bala, T. Das, T. P. Barnett, D. R. Caaan, C. Doutriaux, A. W. Wood, A. Mirin, and T. Nozaa. 2008. Detection and attribution of temperature changes in the mountainous western United States. *Journal of Climate* 21(23):6404-6424.

Bonney, R., C. B. Cooper, J. Dickinson, S. Kelling, T. Phillips, K. V. Rosenberg, and J. Shirk. 2009. Citizen science: A developing tool for expanding science knowledge and scientific literacy. *BioScience* 59(11):977-984.

Bray R. 2010. Rocky Mountain butterfly project. Rocky Mountain National Park, National Park Service. Available online: http://www.nps.gov/romo/naturescience/rocky-mountain-butterfly-project.htm (accessed 2 August 2010).

Brink, V. C. 1959. A directional change in the subalpine forest-heath ecotone in Garibaldi Park, British Columbia. *Ecology 40*(1):10-16.

Brookman, T. J. 2010. Analyzing the alpine treeline ecotone changes on Goode Mountain in the North Cascades National Park, Washington from 1958 to 2009. MS Thesis, Central Washington University, Ellensburg, WA.

Cayton, H. L., N. M. Haddad, K. Gross, S. E. Diamond, and L. Ries. 2015. Do growing degree days predict phenology across butterfly species? *Ecology* 96(6):1473-1479.

Cleland, E. E., I. Chuine, A. Menzel, H. A. Mooney, and M. D. Schwartz. 2007. Shifting plant phenology in response to global change. *TRENDS in Ecology and Evolution* 22 (7):357-364.

Cosentino, B. J., D. M. Marsh, K. S. Jones, J. J. Apodaca, C. Bates, J. Beach, K. H. Beard, K. Becklin, J. M. Bell, C. Crockett, G. Fawson, J. Fjelsted, E. A. Forys, K. S. Genet, M. Grover, J. Holmes, K. Indeck, N. E. Karraker, E. S. Kilpatrick, T. A. Langen, S. G. Mugel, A. Molina, J. R. Vonesh, R. J. Weaver, and A. Willey. 2014. Citizen science reveals widespread negative effects of roads on amphibian distributions. *Biological Conservation* 180 (2014):31–38.

Elsner, M. M., L. Cuo, N. Voisin, J. S. Deems, A. F. Hamlet, J. A. Vano, K. E. B. Mickelson , S. Y. Lee, and D. P. Lettenmaier. 2010. Implications of 21st century climate change for the hydrology of Washington State. *Climatic Change* 102:225–260.

Fancy, S. G., J. E. Gross, and S. L. Carter. 2009. Monitoring the condition of natural resources in US National Parks. *Environmental Monitoring and Assessment* 151:161-174.

Follett, R., and V. Strezov. 2015. An analysis of citizen science based research: Usage and publication patterns. *PLOS ONE* 10(11):e0143687. Doi:10.1371/journal.pone.0143687.

Franklin, J. F., and C. T. Dyrness. 1988. Natural vegetation of Oregon and Washington. Oregon State University Press, Corvallis, OR.

Franklin, J. F., W. H. Moir, G. W. Douglas, and C. Wiberg. 1971. Invasion of subalpine meadows by trees in the Cascade Range, Washington and Oregon. *Arctic and Alpine Research* 3:215-224.

Garrigan, D. 2008. Butterflies of Mount Rainier National Park, preliminary research summary. Unpublished Report to the National Park Service.

Hamlet, A. F., P. W. Mote, M. P. Clark, and D. P. Lettenmaier. 2005. Effects of temperature and precipitation variability on snowpack trends in the western United States. *Journal of Climate* 18(21):4545-4561.

Hanski I., J. J. Hellmann, C. L. Boggs, J. F. McLaughlin. 2004. Checkerspots as a model system in population biology. Page. 245-263 *in*: P. R. Ehrlich and I. Hanski, eds. *On the wings of checkerspots: A model system for population biology*. Oxford University Press, Oxford, UK.

Harsch M.A., P. E. Hulme, M. S. McGlone, and R. P. Duncan. 2009. Are treelines advancing? A global meta-analysis of treeline response to climate warming. *Ecology Letters* 12:1040-1049.

Haugo, R. D., and C. B. Halpern. 2007. Vegetation responses to conifer encroachment in a western Cascade meadow: A chronosequence approach. *Canadian Journal of Botany* 85:285–298.

Haugo, R. D., and C. B. Halpern. 2010. Tree age and tree species shape positive and negative interactions in a montane meadow. *Botany* 88:488–499.

Hill, J. K., C. D. Thomas, R. Fox, M. G. Telfer, S. G. Willis, J. Asher, and B. Huntley. 2002. Responses of butterflies to twentieth century climate warming: implications for future ranges. *Proceedings of the Royal Society of London B* 269:2163-2171.

Hill, J. K., C. D. Thomas, and B. Huntley. 1999. Climate and habitat availability determine 20th century changes in a butterfly's range margin. *Proceedings of the Royal Society London B* 266:1197-1206.

Hinchliff, J. 1996. An atlas of Washington butterflies: The distribution of butterflies in Washington. The Oregon State University Bookstore, Inc., Corvallis, OR.

Hoffman, R. L., A. Woodward, P. Haggerty, K. Jenkins, P. Griffin, M. J. Adams, J. Hagar, T. Cummings, D. Duriscoe, K. Kopper, J. Riedel, B. Samora, L. Marin, G. S. Mauger, K. Bumbaco, and J. S. Littell. 2014. Mount Rainier National Park: Natural resource condition assessment. Natural Resource Report NPS/MORA/NRR—2014/894. National Park Service, Fort Collins, CO.

Hoffman, R. L., A. Woodward, P. Haggerty, K. Jenkins, P. Griffin, M. J. Adams, J. Hagar, T. Cummings, D. Duriscoe, K. Kopper, J. Riedel, L. Marin, G. S. Mauger, K. Bumbaco, and J. S. Littell. 2015. North Cascades National Park Service Complex: Natural resource condition assessment. Natural Resource Report NPS/NOCA/NRR—2015/901. National Park Service, Fort Collins, CO.

Kim J., T. K. Kim, R. W. Arritt, and N. L. Miller. 2002. Impacts of increased atmospheric CO2 on the hydroclimate of the western United States. *Journal of Climate* 15:1926-1942.

Leung, L. R. 2005. Effects of climate variability and change on mountain water resources in the western U. S. Pages 355–364 *in* U. M. Huber, H. K. M. Bugmann, and M. A. Reasoner, editors. Global change and mountain regions: An overview of current knowledge. Springer, Dordrecht, Netherlands.

Little, R. L., D. L. Peterson, and L. L. Conquest. 1994. Regeneration of subalpine fir (*Abies lasiocarpa*) following fire: Effects of climate and other factors. *Canadian Journal of Forest Research* 24:934-944.

Mantua, N., I. Tohver, and A. Hamlet. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102:187-223.

Martin, E., and P. Etchevers. 2005. Impact of climatic changes on snow cover and snow hydrology in the French Alps. Pages 235–242 *in* U. M. Huber, H. K. M. Bugmann, and M. A. Reasoner, editors. Global change and mountain regions: An overview of current knowledge. Springer, Dordrecht, Netherlands.

Mauger, G. S., J. H. Casola, H. A. Morgan, R. L. Strauch, B. Jones, B. Curry, T. M. Busch Isaksen, L. Whitely Binder, M. B. Krosby, and A. K. Snover. 2015. State of knowledge: Climate change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle, WA. doi:10.7915/CIG93777D.

McKinley, D. C., A. J. Miller-Rushing, H. L. Ballard, R. Bonney, H. Brown, D. M. Evans, R. A. French, J. K. Parrish, T. B. Phillips, S. F. Ryan, L. A. Shanley, J. L. Shirk, K. F. Stepenuck, J. F. Weltzin, A. Wiggins, O. D. Boyle, R. D. Briggs, S. F. Chapin III, D. A. Hewitt, P. W. Preuss, and M. A. Soukup. 2015. Can investing in citizen science improve natural resource management and environmental protection? *Issues in Ecology* 19.

McLaughlin, J. F., J. J. Hellmann, C. L .Boggs, and P. R. Ehrlich. 2002a. Climate change hastens population extinctions. *Proceedings of the National Academy of Sciences* 99:6070-6074.

McLaughlin, J. F., J. J. Hellmann, C. L. Boggs, and P. R. Ehrlich. 2002b. The route to extinction: Population dynamics of a threatened butterfly. *Oecologia* 132(4)538-548.

Memmott J., P. G. Craze, N. M. Waser, and M. V. Price. 2007. Global warming and the disruption of plant-pollinator interactions. *Ecology Letters* 10(8):710-717.

Morisette, J. T., A. D. Richardson, A. K. Knapp, J. I. Fisher, E. A. Graham, J. Abatzoglou, B. E. Wilson, D. D. Breshears, G. M. Henebry, J. M. Hanes, and L. Liang. 2009. Tracking the rhythm of the seasons in the face of global change: phenological research in the 21st century. *Frontiers in Ecology and the Environment* 7:253-260.

Mote, P. W., E. A. Parson, A. F. Hambet, W. S. Keeton, D. Lettenmaier, N. Mantua, D. W. Peterson, D. L. Peterson, R. Slaughter, and A. K. Snover. 2003. Preparing for climatic change: The water, salmon, and forests of the Pacific Northwest. *Climatic Change* 61:45-88.

National Park Service (NPS). 2001. Park vital signs monitoring – a commitment to resource protection. National Park Service, resource brief. National Resource Program Center, Fort Collins, CO.

National Park Service (NPS). 2006. Management Policies 2006. U.S. Department of the Interior, National Park Service. Available online: https://www.nps.gov/policy/mp2006.pdf

National Park Service (NPS). 2015. National Park Service NEPA Handbook. Available online: https://www.nps.gov/orgs/1812/upload/NPS_NEPAHandbook_Final.pdf (accessed 21 March 2017).

National Park Service (NPS). 2016. Integrated Resource Management Applications (IRMA) Data Store. Available online: https://irma.nps.gov/DataStore/ (accessed 15 October 2016).

National Park System Advisory Board Science Committee (NPSABSC). 2012. Revisiting Leopold: Resource stewardship in the National Parks. National Park System Advisory Board Science Committee, Washington, DC. Available online: https://www.nps.gov/calltoaction/PDF/LeopoldReport_2012.pdf (accessed 3 May 2016).

Oliver T. H., H. H. Marshall, M. D. Morecroft, T. Brereton, C. Prudhomme, and C. Huntingford. 2015. Interacting effects of climate change and habitat fragmentation on drought-sensitive butterflies. *Nature Climate Change* 5:941-945.

Ozgul, A., D. Z. Childs, M. K. Oli, K. B. Armitage, D. T. Blumstein, L. E. Olson, S. Tuljapurkar, and T. Coulson. 2010. Coupled dynamics of body mass and population growth in response to environmental change. *Nature* 466:482-485.

Pardikes, N. A., A. M. Shapiro, L. A. Dyer, and M. Forister. 2015. Global weather and local butterflies: Variable responses to large-scale climate pattern along an elevational gradient. *Ecology* 96(11):2891-2901.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* 37:637-669.

Parmesan, C., N. Ryrholm, C. Stefanescu, J. K. Hillk, C. D. Thomas, H. Descimon, B. Huntleyk, L. Kaila, J. Kullberg, T. Tammaru, W. J. Tennent, J. A. Thomas, and M. Warren. 1999. Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399:579-583.

Peterson, D. W., and D. L. Peterson. 2001. Mountain hemlock growth responds to climatic variability at annual and decadal time scales. *Ecology* 82(12):3330-3345.

Pollard, E. 1977. A method for assessing changes in the abundance of butterflies. *Biological Conservation* 24:317-328.

Pollard, E. 1988. Temperature, rainfall and butterfly numbers. *Journal of Applied Ecology* 25:819-828.

Pollard, E., and T. J. Yates. 1993. Monitoring butterflies for ecology and conservation. Chapman & Hall, London, UK.

Pyle, R. M. 2002. The butterflies of Cascadia. Seattle Audubon Society, Seattle, WA.

Raymond, C. L., D. L. Peterson, and R. M. Rochefort. 2014. Climate change vulnerability and adaptation in the North Cascades region, Washington. General Technical Report PNW-GTR-892. U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Research Station, Portland, OR.

Rochefort, R. M. 2017. Cascades butterfly project: survey routes, standard operating procedures, and field forms. North Cascades National Park Service Complex, Sedro-Woolley, WA. Available online: https://irma.nps.gov/DataStore/Reference/Profile/2240163.

Rochefort, R. M., M. M. Bivin, J. R. Boetsch, L. Grace, S. Howlin, S. A. Acker, C. C. Thompson, and L. Whiteaker. 2012. Alpine and subalpine vegetation monitoring protocol for the North Coast and Cascades Network. Natural Resource Report NPS/NCCN/NRR—2012/570. National Park Service, Fort Collins, CO.

Rochefort, R. M., R. L. Little, A. Woodward, and D. L. Peterson. 1994. Changes in sub-alpine tree distribution in western North America: A review of climatic and other causal factors. *The Holocene* 4(1):89-100.

Rochefort, R. M., and D. L. Peterson. 1996. Temporal and spatial distribution of trees in subalpine meadows of Mount Rainier National Park. *Arctic and Alpine Research* 28:52-59.

Roy, D. B., P. Rothery, D. Moss, E. Pollard, and J. A. Thomas. 2001. Butterfly numbers and weather: Predicting historical trends in abundance and the future effects of climate change. *Journal of Animal Ecology* 70:201-217.

Service, R. F. 2004. As the west goes dry. *Science* 303:1124-1127.

Snover, A. K., G. S. Mauger, L. C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate change impacts and adaptation in Washington State: Technical summaries for decision makers. State of knowledge report prepared for the Washington State Department of Ecology. Climate Impacts Group, University of Washington, Seattle, WA.

Stueve, K. M., D. L. Cerney, R. M. Rochefort, and L. L. Kurth. 2009. Post-fire tree establishment patterns at the alpine treeline ecotone: Mount Rainier National Park, Washington, USA. *Journal of Vegetation Science* 20:107-120.

Taron, D., and M. Manner. 2004. Illinois butterfly monitoring network guidelines. Website Edition. Available at: http://www.bfly.org/ (accessed 14 October 2016).

Taron, D., and L. Ries. 2015. Butterfly monitoring for Conservation. Invited book chapter *in:* J. Daniels, editor. Butterfly Conservation in North America. Springer Press.

Urban, M. C., G. Bocedi, A. P. Hendry, J. B. Mihoub, G. Pe’er, A. Singer, J. R. Bridle, L. G. Crozier, L. De Meester, W. Godsoe, A. Gonzalez, J. J. Hellmann, R. D. Holt, A. Huth, K. Johst, C. B. Krug, P. W. Leadley, S. C. Palmer, J. H. Pantel, A. Schmitz, P. A. Zollner, and J. M. J. Travis. 2016. Improving the forecast for biodiversity under climate change. *Science* 353(6304):aad8466 1-9.

Van Swaay, C., Regan, E., Ling, M., Bozhinovska, E., Fernandez, M., Marini-Filho, O.J., Huertas, B., Phon, C.-K., K”orösi, A., Meerman, J., Pe’er, G., Uehara-Prado, M., Sáfián, S., Sam, L., Shuey, J., Taron, D., Terblanche, R., and Underhill, L. (2015). Guidelines for standardised global butterfly monitoring. Group on Earth Observations Biodiversity Observation Network, Leipzig, Germany. GEO BON Technical Series 1, 32pp.

Visser, M. E., and C. Both. 2005. Shifts in phenology due to global climate change: The need for a yardstick. *Proceedings of the Royal Society London B. Biological Sciences* 272:2561-2569.

Walther, G.-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J. M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. *Nature* 416:389-395.

Warren, S. D., K. T. Harper, and G. M. Booth. 1988. Elevational distribution of insect pollinators. *American Midland Naturalist* 120(2):325-330.

Warren, M. S., J. K. Hill, J. A. Thomas, J. Asher, R. Fox, B. Huntley, and others. 2001. Rapid response of British butterflies to opposing forces of climate and habitat change. *Nature* 414 (6859):65-69.

Weber, S., A. Woodward, and J. Freilich. 2009. North Coast and Cascades Network vital signs monitoring report (2005). Natural Resource Report NPS/NCCN/NRR—2009/098. National Park Service, Fort Collins, CO.

Appendix A. Resource Brief Examples

Citizen Science

Cascades Butterfly Project

National Park Service
U.S. Department of the Interior

North Cascades National Park Service Complex
Mount Rainier National Park

Monitoring Subalpine Butterflies as Climate Changes

2016 Summary of Accomplishments

Background

Future Pacific Northwest summers will be warmer and drier, snow will melt earlier, and forest fires may be more frequent. High-elevation ecosystems are especially vulnerable to warming climates because plants and animals are adapted to long winters and short summers with mild temperatures. We are monitoring butterfly abundances and plant phenology to understand how pollinators in our parks will be influenced by warming climates.

Program Objectives

Citizen scientists monitor butterfly abundance and plant phenology at ten permanent survey sites in two national parks and two national forests each summer, starting in 2011.

2016 Survey Results

- First survey of the year was June 8 at Sauk Mountain - 61 butterflies, 6 species: Anise Swallowtail, Clodius Parnassian, Western Meadow Fritillary, Sarah Orangetip, Silvery Blue, Milbert's Tortoiseshell

- Last surveys of the year were September 16 on Mazama Ridge (38 butterflies, 4 species) and Cascade Pass (19 butterflies, 4 species). The same 4 species were observed at both sites: Anna's Blue, Mormon Fritillary, Hydaspe Fritillary, and Mariposa Copper

- 7 new species were documented : Echo blue, Persius Duskywing, & Greenish Blue (Mazama Ridge), Common Alpine (Easy Pass), Cabbage White & Acmon Blue (Sunrise Rim), and Coronis Fritillary (Naches Loop)

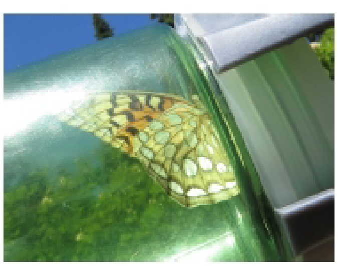

Figure 1. Coronis Fritillary, Naches Loop. Photo by Melanie Weiss.

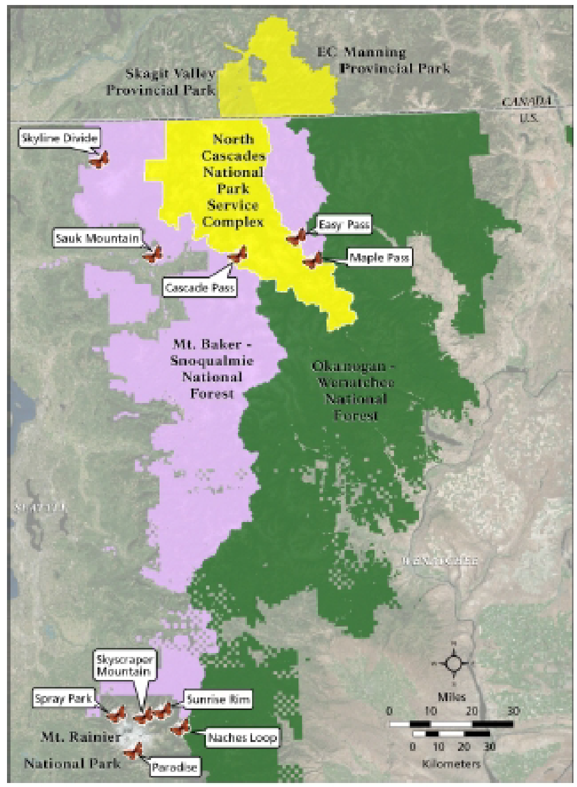

Figure 2. Map of survey sites.

Table 1. Summary of surveys completed by year.

Year	# Surveys	# Species	# Butterflies
2011	29	23	819
2012	29	21	480
2013	34	21	1,585
2014	65	30	2,519
2015	100	36	4,431
2016	82	37	3,573

Butterfly Abundance & Flight Times

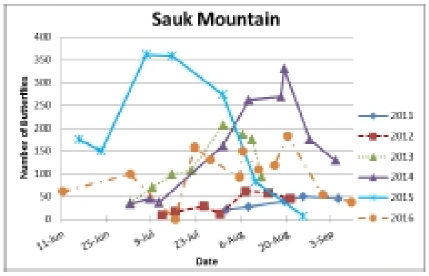

Figure 3. Sauk Mountain butterfly abundances, 2011-2016.

At almost all sites, peak abundances were lower and occurred later than in 2015 (e.g. Sauk Mountain, Figure 3, Table 2)

Anna's Blue was recorded at all 10 sites, Boisduval's Blue and Mormon Fritillary at all sites except Maple Pass

Table 2. Peak butterfly abundance by route and date for 2015 and 2016.

Site	2016 Date	#	2015 Date	#
Cascade Pass	Aug 29	116	Aug 11	111
Easy Pass	Aug 4	118	Jul 14	169
Maple Pass	Aug 3	35	Jul 14	24
Sauk Mountain	Aug 19	183	Jul 15	358
Skyline	Aug 15	67	Jul 7	125
Mazama	Aug 25	87	Jul 6	242
Naches	Aug 16	59	Jul 8	96
Skyscraper	Aug 16	58	Jul 15	99
Sunrise	Aug 16	90	Jun 30	113
Spray Park	Aug 22	44	Jul 15	72

Plant Phenology Surveys

This year we worked on refining a list of plants for each survey route. Currently we have between 14 (Spray Park) and 29 species (Easy Pass) listed for surveys at each site. Phenophase data will be analyzed during the winter of 2016-2017.

Figure 4. Mid (left) and late (right) phenophases of Bracted Lousewort.

Volunteer Involvement

This year we had 36 great volunteers! Thank you Everyone!

A few facts on our Citizen Scientists:

Most Surveys this Season

- 7 surveys - Melanie Weiss & Doug Murphy
- 6 surveys - Mary Prichard & Paul Metzner, close second

Longest Volunteers

- 6 seasons - Melanie Weiss
- 5 seasons - Ayako Okuyama-Donofree, Mike Donofree, Elena Bianco, Irene Perry, and Cathy Clark

Most Sites Surveyed

- 3 sites - Lee Wales
- 2 sites - Ayako Okuyama-Donofree & Mike Donofree, Irene & Mark Perry, Sue Casillas, Paul Metzner

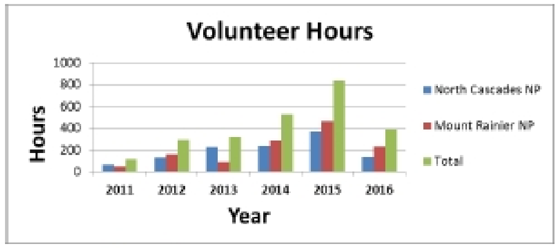

Figure 5. Volunteer hours 2011-2016.

2016 Field Crew

Figure 6. 2016 NPS field crew: Kathy Acosta, Tanner Humphries, Eddie Silahua, Michelle Wong, Regina Rochefort, Ana Casillas Brownson, Angelina Nguyen.

More Information

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Citizen Science

Cascades Butterfly Project

National Park Service
U.S. Department of the Interior

North Cascades National Park Service Complex
Mount Rainier National Park

Monitoring Subalpine Butterflies as Climate Changes

2017 Field Season

Introduction

Butterflies and plants are sensitive indicators of climate change because air temperature influences their life cycles and their geographic distribution. As butterflies develop from egg to larvae to pupae and finally to full maturation, temperature thresholds may trigger these changes. Plant budburst, flowering, and fruiting times are also influenced by temperature and precipitation. Butterflies depend on plants as host plants – providing nectar or shelter for eggs and developing larvae.

Climate models project warmer summers, earlier snowmelt, more frequent forest fires, and changes in distributions of plants and animals, but not details on how species in our area will respond to these conditions. Studies in Europe and California have documented range shifts in butterflies in response to changing temperatures. Some species have moved northward or to higher elevations to track their optimal temperature range.

We are monitoring butterflies and plant phenology to understand how species in our parks are being influenced by warmer climates.

What Are We Doing?

We are monitoring butterfly abundance and plant phenology at ten permanent survey sites in two national parks and two national forests:

- North Cascades National Park Service Complex
- Mount Rainier National Park
- Mount Baker-Snoqualmie National Forest
- Okanogan-Wenatchee National Forest

Monitoring Objectives

1. Monitor long-term trends in butterfly species richness and population abundance in select areas
2. Monitor long-term trends in plant phenology
3. Engage citizen scientists in collection of data and communication of information to the general public
4. Provide field science internship opportunities to young scientists
5. Provide data to national parks and forests to inform and adapt land management practices as climate changes

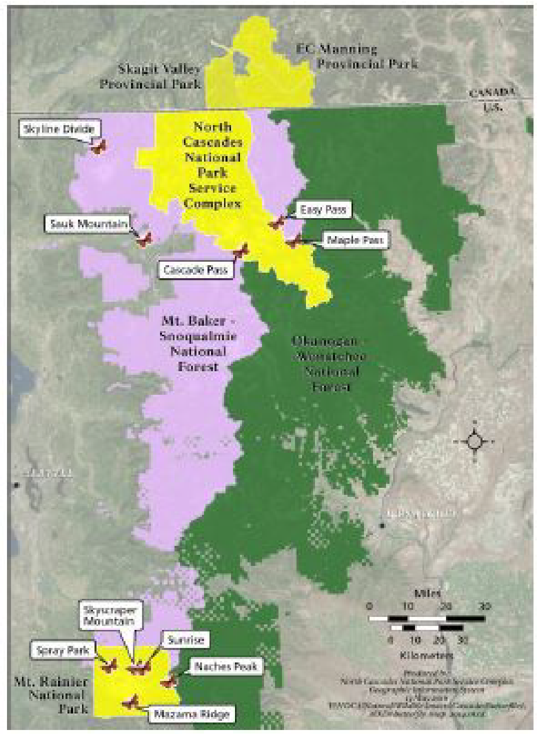


Figure 1. Map of survey sites

Monitoring Methods

- Butterfly abundance and plant phenology is monitored along ten 1-kilometer survey routes in 2 national parks and 2 national forests
- Monitoring is conducted weekly from snow-melt (~early July) until the first frost (~early September)
- Butterfly abundances are monitored using the Pollard Walk method
- Butterfly data are stored in partnership with the North American Butterfly Monitoring Network's Pollard Base database (NABA) and Butterflies and Moths of North America (mp.butterfliesandmoths.org)

Results - Butterflies

Each year we have completed more surveys and documented more species with our volunteers and interns.

Table 1. Summary of number of surveys, species documented, and butterflies from 2011 – 2016.

Year	# Surveys	# Species	# Butterflies
2011	29	23	819
2012	29	21	480
2013	34	21	1,585
2014	65	30	2,519
2015	100	36	4,431
2016	82	37	3,573

In 2016, our first date of butterfly observations and peak abundances were lower than we had seen in the early snowmelt, warm summer of 2015.

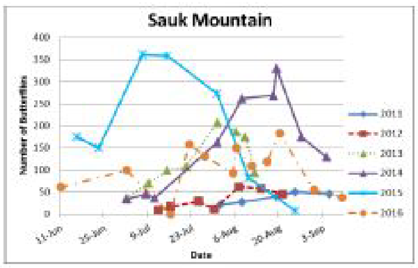


Figure 2. Butterfly abundances on Sauk Mountain, 2011- 2016

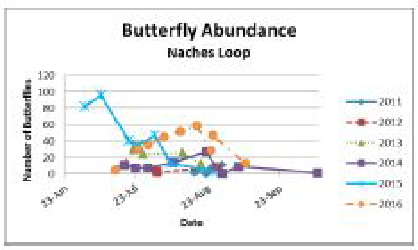
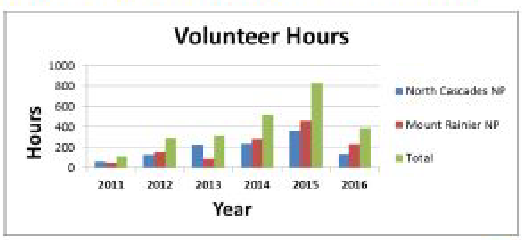


Figure 3. Butterfly abundances on Naches Peak, 2011- 2016

Results - Volunteer Involvement

Our program started in 2011 and our volunteer corps is growing allowing us to survey sites more frequently.



2017 Field Crew

North Cascades National Park Service Complex

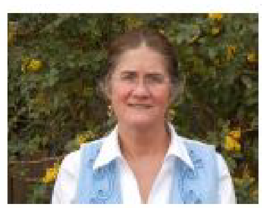
Tanner Humphries is the Field Lead for North Cascades. Tanner has worked with the Cascades Butterfly Project (CBP) since 2013. He graduated from Western Washington Univ. in 2013

Alex Brito graduated with his MS in Forest Ecology from University of Wisconsin in 2016. This is his first season with the CBP as an intern through the NPS Latino Heritage Program.

Mount Rainier National Park

Ana Casillas Brownson is back for her second season as the Field Lead for CBP at Mount Rainier National Park. She has an MSc from Bangor University (Wales) in 2013 and a BA from Evergreen State University.

Tucker Grigsby graduated from U. of California, Santa Barbara in 2016. This will be his first season with the CBP as an intern with the NPS "Mosaics in Science Program."



Regina Rochefort is the CBP Program Lead and a Plant Ecologist and Science Advisor. She received her PhD from U. of Washington while conducting research on subalpine and alpine plants in Mount Rainier NP.

More Information

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Phone: 360-854-7202

Appendix B. Job Hazard Analysis

JOB HAZARD ANALYSIS (JHA)		Date: 9/30/2016	☐ New JHA ☐ Revised JHA
Park Unit: NOCA and MORA	Division: Science	Branch:	Location: NOCA
TASK TITLE: Cascades Butterfly Project Surveys		JHA Number:	Page ______ of ______
Job Performed By:	Analysis By: Tanner Humphries	Supervisor: Regina Rochefort	Approved By:

Required Standards and General Notes:	
Required Training:	
Required Personal Protective Equipment:	
Tools and Equipment:	

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Foot travel on trails in mountainous terrain	Tripping, falling due to uneven and steep terrain which may be wet, slick, muddy, rocky, or exposed. There's potential for more than a ground-level fall)	Plan ahead to identify necessary footwear, clothing, and PPE for the planned trail. Guard against overloading and traveling with a pack too heavy for one's body size, fitness level, and abilities. Strike a good balance between preparedness and excess. Work with supervisor and experienced employees to know one's own balance and needs and excess. Achieve and maintain a level of fitness adequate for the job. Use hiking poles to assist with balance and strain.
	Snow-covered trails	Plan ahead and have awareness as to whether the intended route is likely to or is known to be snow-covered. Consider the time of year that the hike is occurring. If doing snow travel, carry the appropriate gear (ice axe, etc.) and have it at hand and ready when first encounter snowy terrain

JHA - CONTINUATION SHEET

JHA Number:

Page ______ of ______

Sequence of Job Steps	Potential Hazards	Safe Action or Procedure
Exposure to the elements	Getting lost	Plan ahead for intended trip with right maps and understanding of the work project location. Carry a compass and GPS unit at all times. Travel in pairs or in groups. Follow SOP on radio communication and check-ins with Comm Center.
	Heat, sun, and wind exposure	Wear appropriate clothing and take appropriate sun protection measures at all times.
	Dehydration and exhaustion	Eat and drink plenty of food and water throughout the day.
Lead groups of volunteers	Injured volunteer	Seek training in First-Aid techniques and understand how to approach each accident situation and feel confident in best method of remedying the situation. Radio SOP.
	Medical conditions (allergic reaction, etc.)	Ask volunteers before hitting the trail about allergies and other medical conditions. Know where their EPIPENs are located and how to use them.
Driving to and from survey sites	Accidents (minor and major)	Take defensive driving course. Allows pay attention to the road and your surrounding and follow all the safe driving skills you've learned.

JHA - CONTINUATION SHEET	JHA Number:	Page ______of ______

Text Description of Task When it is Done Safely

The Cascades Butterfly Project leads groups of citizen scientists (volunteers) to on-trail transects (routes) established throughout the Northern Cascade Range in Washington State. When done safely everybody has a great time and returns home in better health (mental and physical) then when they left home.

Authorized Employee Information

Employee ID	Last Name	First Name	Qualifications/Remarks

INSTRUCTIONS FOR COMPLETING THE JOB HAZARD ANALYSIS FORM

Job Hazard Analysis (JHA) is an important accident prevention tool that works by finding hazards and eliminating or minimizing them *before* the job is performed, and *before* they have a chance to become accidents. Use your JSA for job clarification and hazard awareness, as a guide in new employee training, for periodic contacts and for retraining of senior employees, as a refresher on jobs which run infrequently, as an accident investigation tool, and for informing employees of specific job hazards and protective measures. Set priorities for doing JHA's: jobs that have a history of many incidents, jobs that have produced disabling injuries, jobs with high potential for disabling injury or death, and new jobs with no accident history. Here's how to do each of the three main parts of a Job Hazard Analysis:

SEQUENCE OF JOB STEPS

Break the job down into steps. Each of the steps of a job should accomplish some major task. The task will consist of a *set* of movements. Look at the first *set* of movements used to perform a task, and then determine the next logical *set* of movements. For example, the job might be to move a box from a conveyor in the receiving area to a shelf in the storage area. How does that break down into job steps? Picking up the box from the conveyor and putting it on a hand truck is one logical set of movements, so it is one job step. Everything is related to that one logical set of movements is part of that job step.

The next logical *set* of movements might be pushing the loaded hand truck to the storeroom. Removing the boxes from the truck and placing them on the shelf is another logical set of movements. And finally, returning the hand truck to the receiving area might be the final step in this type of job.

Be sure to list *all* the steps in a job. Some steps might not be done each time checking the casters on a hand truck, for example. However, that task is a part of the job as a whole, and should be listed and analyzed.

POTENTIAL HAZARDS

Identify the hazards associated with each step. Examine each step to find and identify hazards – actions, conditions, and possibilities that could lead to and accident.

It's not enough to look at the obvious hazards. It's also important to look at the entire environment and discover every conceivable hazard that might exist.

Be sure to list health hazards as well, even though the harmful effect may not be immediate. A good example is the harmful effect of inhaling a solvent or chemical dust over a long period of time.

It's important to list *all* hazards. Hazards contribute to accidents, injuries, and occupational illnesses.

In order to do part three of a JHA effectively, you must identify potential and existing *hazards*. That's why it's important to distinguish between a hazard, and accident and an injury. Each of these terms has a specific meaning:
HAZARDS – Potential danger. Oil on the floor is a hazard.
ACCIDENT – An unintended happening that may result in injury, loss or damage. Slipping on the oil is an accident.
INJURY – The result of an accident. A sprained wrist from the fall would be an injury.

Some people find it easier to identify possible accidents and illnesses and work back from them to the hazards. If you do that, you can list the accident and illness types in parentheses following the hazard. But be sure you focus on the *hazard* for developing recommended actions and safe work procedures.

SAFE ACTION OR PROCEDURE

Using the first two columns as a guide to decide what actions are necessary to eliminate or minimize the hazards that could lead to an accident, injury, or occupational illness.

Among the actions that can be taken are, 1) engineering the hazard out; 2) providing personal protective equipment; 3) job instruction training; 4) good housekeeping; and 5) good ergonomics (positioning the person in relation to the machine or other elements in the environment in such a way as to eliminate stresses and strains).

List recommended safe operating procedures on the form, and also list required or recommended personal protective equipment for each step of the job.

Be specific. Say *exactly* what needs to be done to correct the hazard, such as, "lift using your leg muscles." Avoid general statements like, "be careful."

Give a recommended action or procedure for *every* hazard.

If the hazard is a serious one, it should be corrected immediately. The JSA should then be changed to reflect the new conditions.

NPS 168/138240, May 2017

National Park Service
U.S. Department of the Interior

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