Preface

The May 18, 1980 eruption of Mount St. Helens abruptly altered the geological and ecological systems of southwestern Washington State. The eruption was so well documented by the media that it was viewed around the world and it changed people's perception of volcanoes. The eruption created new landscapes that were subsequently studied by dozens of ecologists. This book integrates and analyzes much of the information learned from those studies and adds recent insights and findings by the contributors and their colleagues.

Many of the authors of this book have been studying ecological responses to the 1980 eruption since the early days. Several of us were on the first team of ecologists to enter the volcanic disturbance zones shortly after May 18. We were awed at the dramatic changes to the landscape and have returned for field studies in subsequent years. Others have joined the team over the ensuing years, and the loose-knit research group has met as a whole several times. Researchers working on the ecological recovery at Mount St. Helens gathered during the summer of 2000 when the USDA Forest Service's Pacific Northwest Research Station sponsored a week-long field camp, termed a "pulse." They visited each other's field sites and collected data on the 20-year status of ecosystems. The idea for this volume grew out of that pulse.

Over time, the physical and biological environment at Mount St. Helens has changed dramatically, yet the compelling character of the landscape remains. The eruption destroyed and buried much of the system of logging roads that had laced the landscape outside the remote, foot-access-only areas of Mount St. Helens and the Mount Margaret backcountry to the north. Thus, access was extremely limited in the first months and even years. Helicopters proved essential for many studies. As salvage logging proceeded outside the designated National Volcanic Monument and visitor access developed from 1981 to 1986, some of the preeruption road system was reestablished, and new roads were constructed, providing access to areas peripheral to the core of the volcanically disturbed area. With completion of salvage logging and closure of many roads by design and storm damage, access again became restricted in many areas. Yet scientists continued to return to find a fascinating, changing landscape.

Funding for ecological studies at Mount St. Helens has had a varied history. The Forest Service and National Science Foundation funded initial access and two 2-week-long field pulses in the summers of 1980 and 1981, which greatly facilitated cross-disciplinary interactions. Several National Science Foundation grants and Forest Service funding supported a series of studies from the 1980s to the present. Individual projects were funded by small grants from the National Geographic Society, Earthwatch, Washington Department of Fish and Wildlife, and several foundations. A great deal of work has been accomplished by personal initiative and by building upon related projects. The Forest Service has provided continuous support for work by Crisafulli, Swanson, and others at Mount St. Helens and for collecting, documenting, and archiving datasets from long-term ecological studies in the area.

This book is the direct result of the contributions of many people in addition to the authors. Frederick O'Hara did an excellent job as technical editor for the book. A special thanks is owed to the numerous scientists who reviewed drafts of the chapters. For this important work, we wish to thank Steve Acker, Wendy M. Adams, Joe Ammirati, Matt Ayers, Lee Benda, Edmund Brodie, Tom Christ, Warren Cohen, Kermit Cromack, Dan Druckenbrod, John S. Edwards, Roland Emetaz, Jerry F. Franklin, Scott Gende, Peter Groffman, Charlie Halpern, Miles Hemstrom, Jan Henderson, Sherri Johnson, R. Kaufmann, Jon Lichter, James A. MacMahon, Jon J. Major, Frank Messina, Randy Molina, Aaron Peacock, Daniel Schindler, Dave Skelly, Don Swanson, Lars Walker, Peter White, Amy Wolfe, Jingle Wu, and Wayne Wurtzbaugh. Theresa Valentine and Kathryn Ronnenberg (USDA Forest Service, Pacific Northwest Research Station) helped greatly with the preparation of maps and figures. Suzanne Remillard (USDA Forest Service, Pacific Northwest Research Station) assisted with information management. Jordon Smith assisted with editorial and compilation tasks. We also thank many colleagues at the U.S. Geological Survey, Cascades Volcano Observatory, for providing information and interpreting the events that occurred during the 1980 and other eruptions, particularly Jon J. Major, Dan Miller, Don Swanson, Richard Waitt, and Ed Wolf.

The editors' institutional homes provided essential support for their work at Mount St. Helens, including the writing and editing this book. Charlie and Fred gratefully acknowledge support of the Pacific Northwest Research Station and especially John Laurence, Peter A. Bisson, Tami Lowry, and Debby McKee. Virginia appreciates the support from the Environmental Sciences Division at Oak Ridge National Laboratory and specifically Linda Armstrong and Anne Wallace. The editors thank the Gifford Pinchot National Forest and Mount St. Helens National Volcanic Monument and their staffs for logistic support and access to records, maps, and research sites.

On a personal note, during the past 24 years we have spent much time in the volcanic landscape learning a great deal about disturbance ecology and Cascadian natural history and becoming quite familiar with the area. Perhaps most important have been the friends, colleagues, and family members with whom we have interacted and shared this fascinating landscape. Virginia especially thanks her family, who enjoyed assisting in the fieldwork and relinquished weekends and early mornings of her time. Fred gratefully acknowledges his family's tolerance of his Mount St. Helens fixation and the support of David Foster for the opportunity to work on the book while in residence at Harvard Forest. Charlie thanks James A. MacMahon, mentor and friend, for introducing him to Mount St. Helens and Charles P. Hawkins, Robert R. Parmenter, and Michael F. Allen for years of collaboration. Charlie thanks Hans Purdom, Josh Kling, Eric Lund, Aimee McIntyre, and Louise S. Trippe for their unwavering interest and collaboration at the volcano. Finally, Charlie thanks his daughters Erica and Teal Crisafulli, for their youthful wonder, and his parents, Helen and Carmelo Crisafulli, for tolerating his childish habitats of catching frogs and salamanders into adulthood. Collectively, the editors and authors owe special gratitude to Jerry F. Franklin, James A. MacMahon, and Jim Sedell for their personal commitments to science at Mount St. Helens and their colleagues who work there.

After 18 years of quiescence, Mount St. Helens broke her silence and entered an eruptive state on September 23, 2004. As we go to press, the volcano has been erupting for 18 continuous weeks; primarily building a new dome in the 1980 crater. Numerous small tephra falls have also been deposited near the mountain, and a few small mudflows have emanated from the crater and traveled down streams. Although it is not known how long this current eruption will last or if it will increase its activity, it is a testimony to the dynamic nature of Mount St. Helens.

As we reach the quarter-century anniversary of the major eruption, it is also timely for scientists who worked in the first posteruption period to begin passing the science baton to the next generation of scientists who will work at Mount St. Helens. This book describes observations, interpretations, and speculations from the first 25 years of ecosystem response and complements our efforts to leave well-documented, publicly accessible descriptions of long-term field plots and associated data. We hope to continue our research for years into the future but recognize the need and appreciate the opportunity to collect our thoughts and data at this juncture. Our greatest hope is that ecologists will continue to study and learn from the fascinating and complex interaction between organisms and their environment at Mount St. Helens.

VIRGINIA H. DALE
FREDERICK J. SWANSON
CHARLES M. CRISAFULLI
February 2005

Contents

Part V Lessons Learned

Note: A Web site has been established at http://www.fsl.orst.edu/msh/ containing background details (pictures, data details, graphs, etc.) to supplement the information included in this book.

2 Geological and Ecological Settings of Mount St. Helens Before May 18, 1980

Frederick J. Swanson, Charles M. Crisafulli, and David K. Yamaguchi

2.1 Introduction

Volcanoes and volcanic eruptions are dramatic players on the global stage. They are prominent landscape features and powerful forces of landform, ecological, and social change. Vesuvius, Krakatau, Pompeii, and, in recent decades, Mount St. Helens hold an important place in our perceptions of how the Earth works and the incredible, destructive effects of violent eruptions. Perhaps less appreciated is the great diversity of interactions between volcanoes and the ecological systems in their proximity.

Volcanic activity and ecological change at Mount St. Helens have been particularly dynamic and instructive. Frequent eruptions of diverse types have interacted with terrestrial and aquatic ecological systems to display a broad range of responses (Franklin and Dyrness 1973; Mullineaux and Crandell 1981; Foxworthy and Hill 1982). Leading up to the 1980 eruption of Mount St. Helens, Cascade Range volcanoes of the Pacific Northwest of the United States were the subject of a good deal of study for objectives that were both academic and applied, such as assessing volcanic hazards and prospecting for geothermal resources. The fauna and flora of forests, meadows, lakes, and streams of the region were generally well known and described. The 1980 eruption put a spotlight on Mount St. Helens, as the world watched volcanic and ecological events unfold in real time. These events also stimulated an interest to better understand the volcanic and ecological conditions that existed before 1980. The geological, ecological, and historical settings provide context for interpreting the physical and ecological responses following the 1980 eruption. [Here we use the term history in the broad sense to include geological time as well as recorded human history.]

Study of any ecological system should start with consideration of its context in space and time and in geographical, geological, and ecological dimensions. From a geographical perspective, the position of Mount St. Helens in a north–south chain of volcanoes along a continental margin sets up strong east–west geophysical and biotic gradients between the sea and mountain top and along a north–south climate gradient (Figure 2.1). Understanding of these broad gradients is useful in interpreting similarities and differences among different parts of a region. These gradients also organize fluxes of materials, organisms, and energy across broad areas. Marine air masses, for example, deliver water to the continental edge, and this abundant moisture flows back to the sea, forming a regional hydrologic cycling system. A well-connected marine–freshwater system fostered development of numerous stocks of anadromous fish. Similarly, the north–south climatic gradient and topographic features of mountain ranges and chains of coastal and inland wetlands form travel corridors for migratory birds. Movement of such wide-ranging terrestrial and aquatic species results in a flow of nutrients, propagules, genes, and organisms in and out of local landscapes within the region and even more widely.

Past activity of a volcano influences its surroundings and affects biophysical responses to new disturbance events. Legacies of earlier eruptive activity may be expressed in landforms, soils, lakes, streams, animal communities, and vegetation patterns. This pattern is especially true at Mount St. Helens, which has erupted about 20 times in the past 4000 years (Table 2.1 on page 16). Vestiges of both the preeruption ecological systems and recent eruptive activity can strongly influence the posteruption landscape and patterns of change in ecological systems. Across the region and over evolutionary time scales, climate and biota interact with disturbance regimes of fire, wind, floods, volcanism, and other agents. Thus, the ecological history of the local area and its regional context determine the pool of species available to colonize a disturbed area, the capabilities of those species to respond to disturbance, and the array of types and configurations of habitats available for postdisturbance ecological development.

Given the importance of spatial and temporal context, this chapter begins the analysis of ecological responses to the 1980 eruption of Mount St. Helens by describing the area before 1980. Our objective in this chapter is to set the stage for subsequent chapters, which detail the geological events and ecological responses unfolding on May 18, 1980, and during the subsequent quarter century. We characterize the Mount

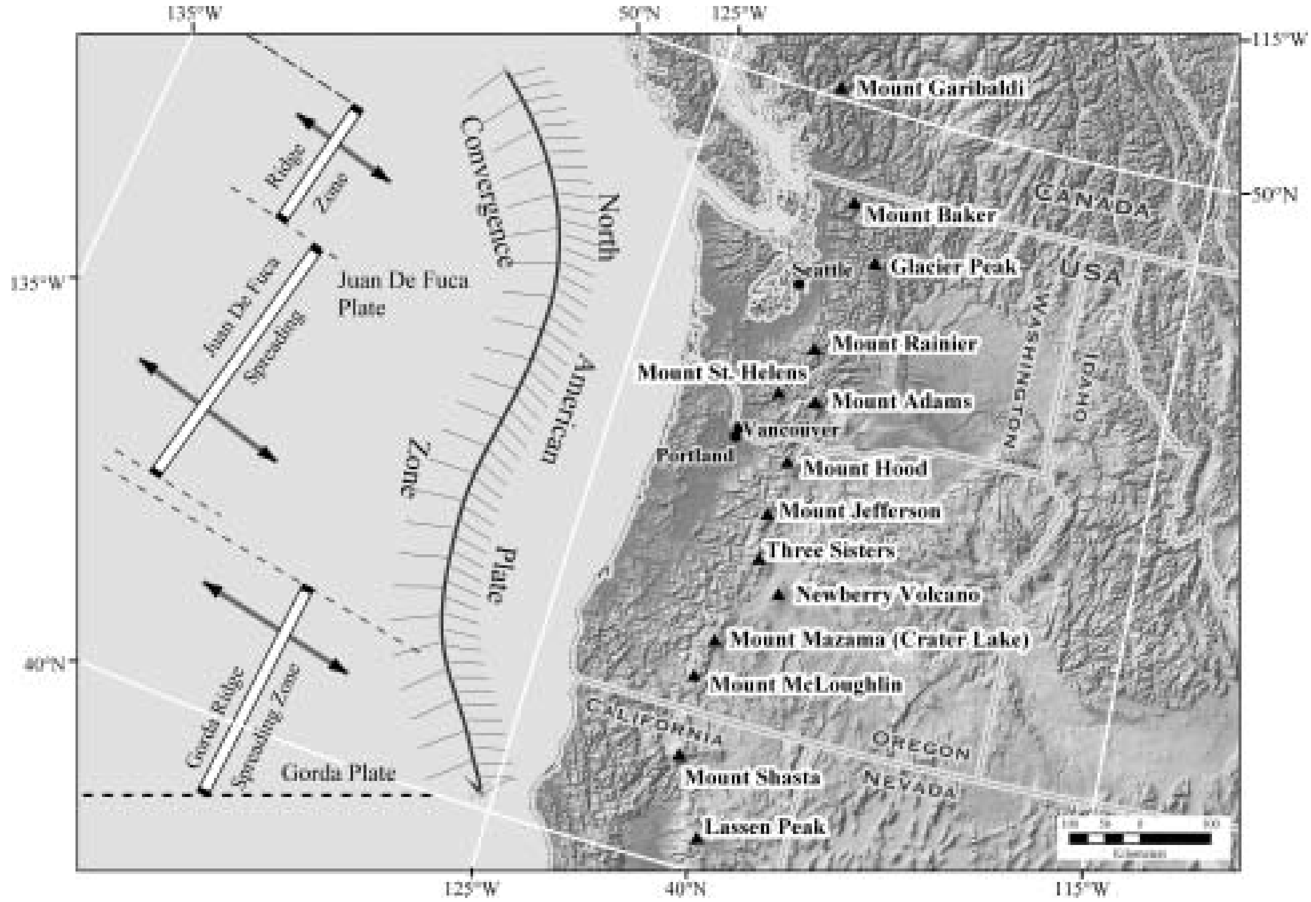

FIGURE 2.1. Regional context of Mount St. Helens, including major volcanic peaks and plate-tectonic setting in terms of spreading and convergence zones. [Adapted from Foxworthy and Hill (1982).]

St. Helens area in terms of its physiography, climate, geology, geomorphology, plant and animal assemblages, and ecological processes and its broader setting. Our geographical focus is the area affected by the 1980 event, generally within 30 km of the cone (Figure 2.2; see also Swanson and Major, Chapter 3, this volume).

Terminology in these discussions is summarized in the Glossary section of this book, generally following Lipman and Mullineaux (1981), Foxworthy and Hill (1982), and Fisher and Schmincke (1984). Plant-association and species nomenclature follows Franklin and Dyrness (1973) and the Integrated Taxonomic Information system (http://www.itis.usda.gov).

2.2 Geophysical Setting

2.2.1 Geological, Physiographic, and Geomorphic Setting

Mount St. Helens is part of the Cascade Range of volcanoes that extends from Canada to northern California (see Figure 2.1). The present and earlier alignments of Cascade volcanoes result from pieces of Pacific oceanic crust plunging beneath the North American continental plate (Figure 2.1). This geological setting has persisted for millions of years, thus shaping the broad outline of the region's physiography and the geophysical dynamics of chronic and catastrophic volcano growth and decay. These conditions are broadly representative of the circum-Pacific "ring of fire," where chains of volcanoes grow in response to geological forces operating within the Earth's mantle and crustal plates.

The structure of Mount St. Helens, as viewed before the 1980 eruption, had formed over the preceding 40,000 years on a geological foundation composed of volcanic rocks of Oligocene to early Miocene age (ca. 28 to 23 million years old). However, leading up to 1980, the entire visible cone had been constructed within only the preceding 2,500 years as an accumulation of volcanic domes, lava flows, and volcanic debris emplaced by other processes (Crandell and Mullineaux 1978; Mullineaux and Crandell 1981; Crandell 1987; Yamaguchi and Hoblitt 1995; Mullineaux 1996). The history of the volcano was read from deposits on its surface; from the types and ages of material it shed onto the surrounding countryside (subsequently exposed in the walls of deeply incised stream channels); and, after the 1980 eruption, in the volcano's internal anatomy exposed in the walls of the new crater. Deposits

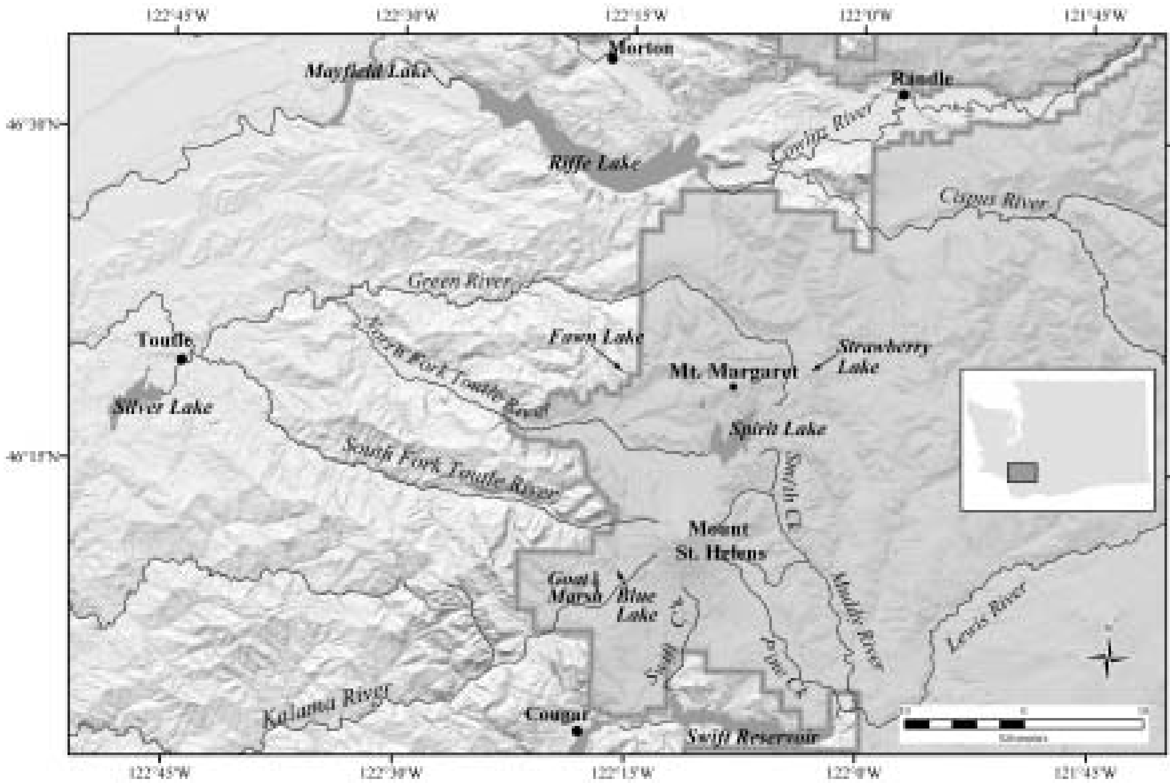

FIGURE 2.2. The Mount St. Helens area.

and events have been dated by analysis of tree rings, which give a record for much of the past millennium, and by radiometric dating of rock and organic material, which can extend much further into the past. The known eruptive history of Mount St. Helens spans periods of dormancy interspersed with periods of activity, which have been grouped into nine eruptive periods (see Table 2.1). Over the past seven eruptive periods, the length of dormant periods ranged from 50 to 600 years and averaged about 330 years.

Eruptive periods involved various combinations of a diverse suite of volcanic processes, which merit some definition. The term *tephra* refers to ejecta blown through the air by explosive volcanic eruptions. *Tephra fall* occurs when explosively ejected fine ash to gravel-sized rock debris falls to Earth and forms a deposit on vegetation, soil, or other surfaces. Eruption columns may extend kilometers into the air, and prevailing winds may cause tephra-fall deposits to accumulate in a particular quadrant around a volcano, generally the northeast quadrants of volcanoes in the Pacific Northwest. In contrast, hot (~800°C), pumice-rich eruption columns may collapse, forming *pyroclastic flows*, which move rapidly (tens of meters per second) down a volcano's flanks and onto the gentler surrounding terrain, accumulating in lobe-shaped deposits up to 10 m or more thick. Toward the other extreme of flow velocity, slow (e.g., millimeters per hour to meters per hour) extrusions of very viscous lava [e.g., with high silica (SiO_2) content] form *lava domes* with a circular or elliptical outline. Less-viscous lava may flow from vents and cool in *lava-flow* deposits, forming elongated lobes. Various interactions of water and the weak rocks (e.g., clay-rich or highly fractured) composing volcanoes can result in massive landslides, often termed *debris avalanches*. Volcanic debris avalanches may exceed a cubic kilometer in volume, enveloping a volcano summit and flank and spreading over tens of square kilometers at the base of the volcano. Volcanic *mudflows*, also termed lahars, may be triggered by many mechanisms, including drainage of debris avalanches, collapse of dams blocking lakes, and the movement of hot, volcanic debris over snow and ice. Mudflows have higher water content than do debris avalanches and, therefore, can flow at higher velocities and over greater distances (tens of kilometers) away from their sources. Less common volcanic processes are *lateral blasts*, which occur when superheated groundwater develops within a volcano by interaction of magma and infiltrating precipitation and then flashes to steam, producing an explosion. Such steam-driven blasts project large volumes of fragmented mountain-top rock laterally across a landscape. The resulting blast cloud, which can be hundreds of meters thick, topples and entrains vegetation along its path. Lateral blasts leave a blanket of deposits composed of angular sand, gravel, and fragments of organic material.

Some of these processes, such as dome growth and lava flows, contribute to volcanic-cone construction, while other processes contribute to the breakdown of volcanoes and the filling of surrounding valleys with volcanic debris. The Pine

TABLE 2.1. Summary of the Mount St. Helens eruptive history.

		Processes					
Eruptive period[a]	Approximate age (years)[b]	Tephra fall	Pyroclastic flow	Lava flow	Dome growth	Mudflow	Lateral blast
Current period	AD 1980–2005	X	X		X	X	X
Dormant interval of 123 years:							
Goat Rocks	AD 1800–1857	X		X	X	X	
Dormant interval of about 50 years:							
Kalama	AD 1480–mid-1700s	X	X	X	X		
Dormant interval of about 600 years:							
Sugar Bowl	1,080–1,060	X	X		X	X	X
Dormant interval of about 600 years:							
Castle Creek	Greater than 2,200–1,700	X	X		X	X	
Dormant interval of about 300 years:							
Pine Creek	3,000–2,500	X	X		X	X	
Dormant interval of about 300 years:							
Smith Creek	4,000–3,300	X	X			X	
Dormant interval of about 4,000 years:							
Swift Creek	13,000–8,000		X		X		
Dormant interval of about 5,000 years:							
Cougar	20,000–18,000		X	X	X	X	
Dormant interval of about 15,000 years:							
Ape Canyon	~40,000(?)–35,000		X			X	

The only lateral blasts interpreted within this record occurred during the Sugar Bowl period and on May 18, 1980.
[a] Dormant intervals are periods during which no unequivocal eruptive products from the volcano have been recognized.
[a] Ages of Goat Rocks–Kalama eruptive periods are in calendar years; ages of Sugar Bowl to Swift Creek periods, determined by radiocarbon dating, are expressed in years before AD 1950, following the calibrations of Stuiver and Pearson (1993). Ages of older periods are expressed less precisely in uncalibrated radiocarbon years.
Source: Adapted from Mullineaux and Crandell (1981), Mullineaux (1996), and Yamaguchi and Hoblitt (1995).

Creek, Castle Creek, and Kalama eruptive periods of Mount St. Helens (Table 2.1; Figure 2.3) were particularly voluminous, inundating neighboring areas north, southwest, and southeast of the volcano with pyroclastic-flow, mudflow, and lava-flow deposits. Lateral blasts were rare in the pre-1980 eruptive history of Mount St. Helens; only one has been noted in the geological record, and that was in the Sugar Bowl eruptive period (see Table 2.1). The numerous flowage deposits from Mount St. Helens significantly modified parts of all rivers draining the volcano. The deposits filled valleys, smoothing preexisting topography around the cone and disrupting earlier drainage patterns. The buildup of the Pine Creek assemblage diverted the Muddy River, which once followed the valley of Pine Creek, to the valley of Smith Creek. Similarly, accumulation of a broad fan on the north flank of the volcano intermittently dammed the head of the North Fork Toutle River, forming Spirit Lake. Periodically, this dam was partially breached, triggering massive mudflows down the Toutle River, several of which blocked Outlet Creek, forming Silver Lake, 45 km west-northwest of the summit of the volcano. Some streams draining the volcano subsequently cut deep canyons through these deposits, particularly on the south side of the volcano (Crandell and Mullineaux 1978).

Numerous eruptions spewed tephra on various trajectories to the east and northeast of the volcano (Table 2.1; Figure 2.4). The resulting deposits of fine ash to gravel-sized pumice and fragmented lava spread over many thousands of square kilometers, strongly affecting soil properties where their depth exceeded a few centimeters. These deposits have been dated with various tree-ring, radiocarbon, and other techniques, so they can be used as time markers to interpret landscape and vegetation conditions at times in the past (Mullineaux 1996). In some areas, such as 20 km northeast of the cone, tephra deposits of the past 3500 years exceed 5 m in thickness and contain several buried soils, including some trees buried in upright growth position (Franklin 1966; Yamaguchi 1993).

Lava flows during several eruptive periods covered parts of the southern and northern flanks of the volcano and flowed more than 10 km down the Kalama River and south-southeast to the Lewis River (Crandell 1987). Lava flows have been very resistant to erosion and therefore have tended to stabilize the land surfaces and deposits they cover. Hydrology is also strongly affected by lava flows, such as where massive volumes of water flow rapidly through lava tubes and beneath lava-flow deposits before discharging as large springs and streams with stable flow regimes.

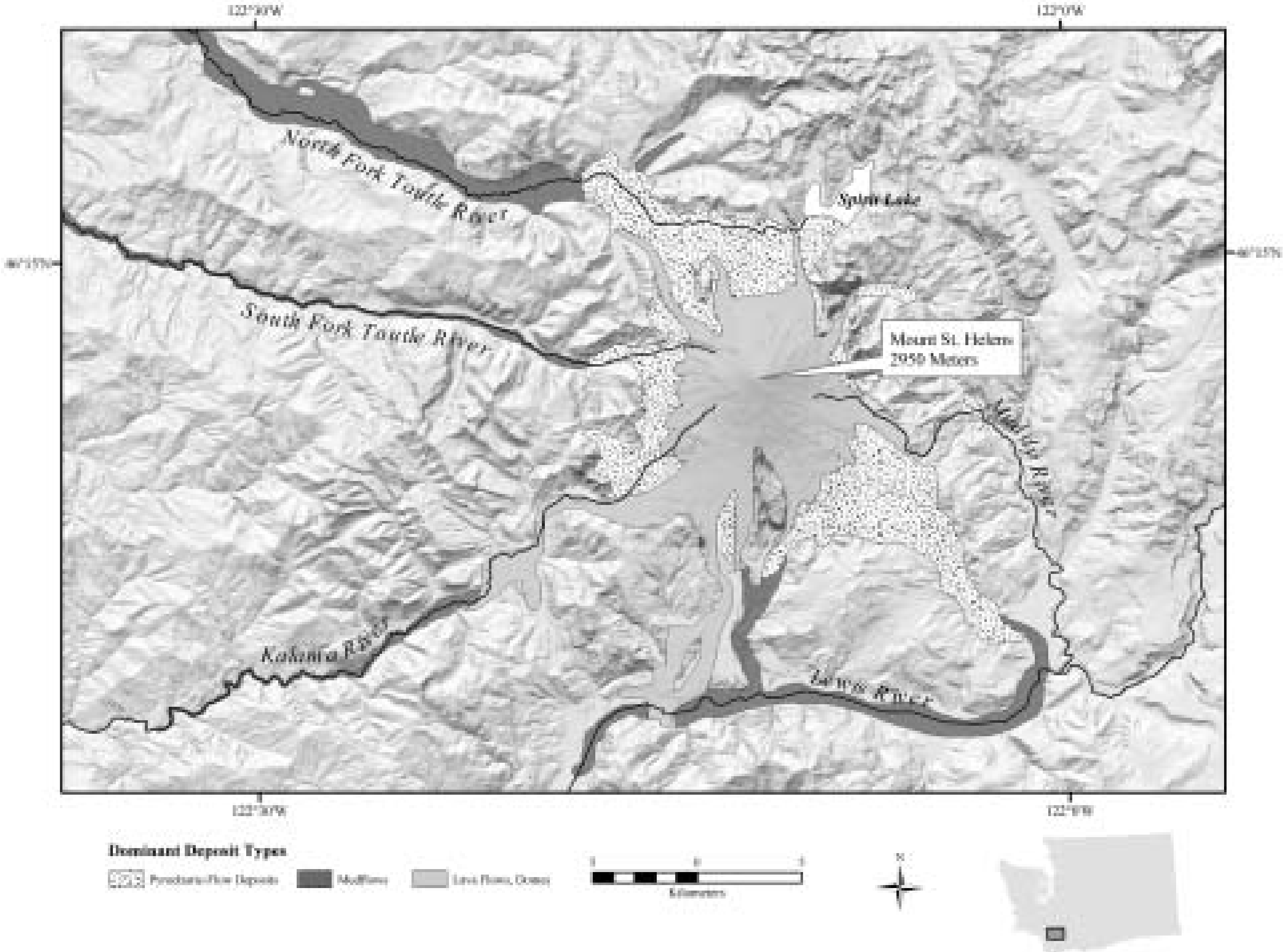

FIGURE 2.3. Approximate boundaries distinguishing Mount St. Helens and landforms composed of its products from older geological terrane of the southern Washington Cascade landscape. [Adapted from Crandell and Mullineaux (1978)].

Similar to many volcanic landscapes, landforms in the vicinity of Mount St. Helens can be broadly grouped into these categories:

- Extensive, older geological terrain with a long history of erosion, including glaciation, resulting in steep, rugged topography, and
- More gently sloping terrain, where younger volcanic flow deposits have accumulated during recent millennia, forming broad fans (see Figure 2.3).

The Mount St. Helens landscape has been sculpted during a long history of erosion and deposition by river, landslide, glacial, and other geomorphic processes both with and without the influence of volcanic activity. The steep, soil-mantled hill slopes in the Cascade Range landscape experience a variety of erosion processes, including subtle movement of the soil surface, transport of dissolved material, and diverse types of mass soil movement, most conspicuously shallow, rapid debris slides down hill slopes, and debris flows down narrow stream channels (Swanson et al. 1982a). Volcanic activity can greatly increase or decrease the rates of geomorphic processes that occur independently of volcanic influence.

During the Pleistocene (10,000 to 1,600,000 years before present), glaciers sculpted upper-elevation landforms in the vicinity of Mount St. Helens, creating very steep cliffs and cirques on north-facing slopes and broad, U-shaped valleys draining areas of extensive ice cover, such as the Mount Margaret high country about 15 km north-northeast of Mount St. Helens. Throughout the Holocene (the past 10,000 years), glaciers remained prominent features of most large Cascade Range volcanoes. Before the 1980 eruption, 11 named glaciers covered 5 km^2 of Mount St. Helens and extended from the 2949-m summit down to an elevation of about 1500 m (Brugman and Post 1981). However, the cone itself was so young that it had not been deeply dissected by glacial erosion.

This complex of processes, deposits, and landforms created numerous and varied terrestrial, lake, stream, and other types of habitats in a rather confined area around Mount St. Helens,

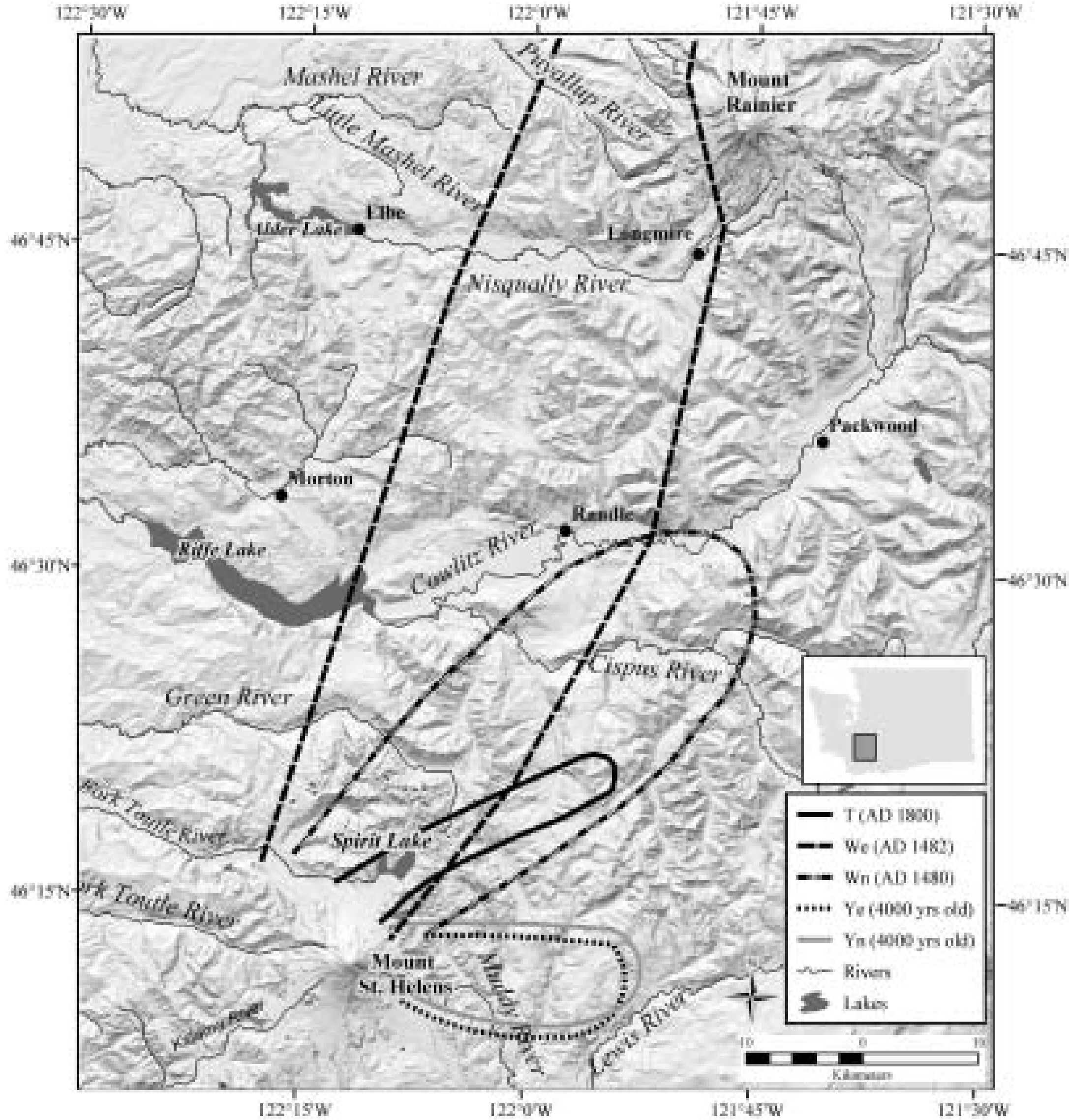

FIGURE 2.4. Extent of major pre-1980 tephra falls from Mount St. Helens. Mapped boundaries of deposits denote 20-cm isopachs. The letters T, We, Wn, Ye, and Yn refer to formal designations of particular pumice layer deposits. Date of each deposition is in parenthesis. [Adapted from Crandell and Mullineaux (1978) and Crandell and Hoblitt (1986).]

as it existed before the 1980 eruption. Lakes of various sizes and depths occur at a broad range of elevation as a result of their formation by both glacial excavation of bedrock basins and blockage of tributaries to the main channels draining the volcano's flanks. Stream and river habitats are similarly diverse, ranging from small, clear, headwater streams to large rivers. In addition to these extensive, common habitats, the geological complexity of the landscape created many localized, special habitats, such as cliffs, seeps, wetlands, lava caves, and dry meadows. Hydrothermal environments were limited to a few, small fumaroles before the 1980 eruption (Philips 1941), but these special types of habitats became important following the eruption.

2.2.2 Climate Setting

A large volcano and its associated large-scale disturbance events interact with the regional climatic regime in many ways. The regional climatic context sets the broad outline of moisture and temperature conditions, but local effects of a mountain edifice can substantially modify the regional climatic signal. A volcano of the stature of Mount St. Helens, and especially the more massive Mount Rainier 80 km to the north-northeast, captures moisture from the atmosphere, storing it in snowfields and glaciers high on the cone, and creates a local rain shadow in its lee. Thus, the climate of the Mount St. Helens area strongly reflects the effects of marine air masses moving eastward from

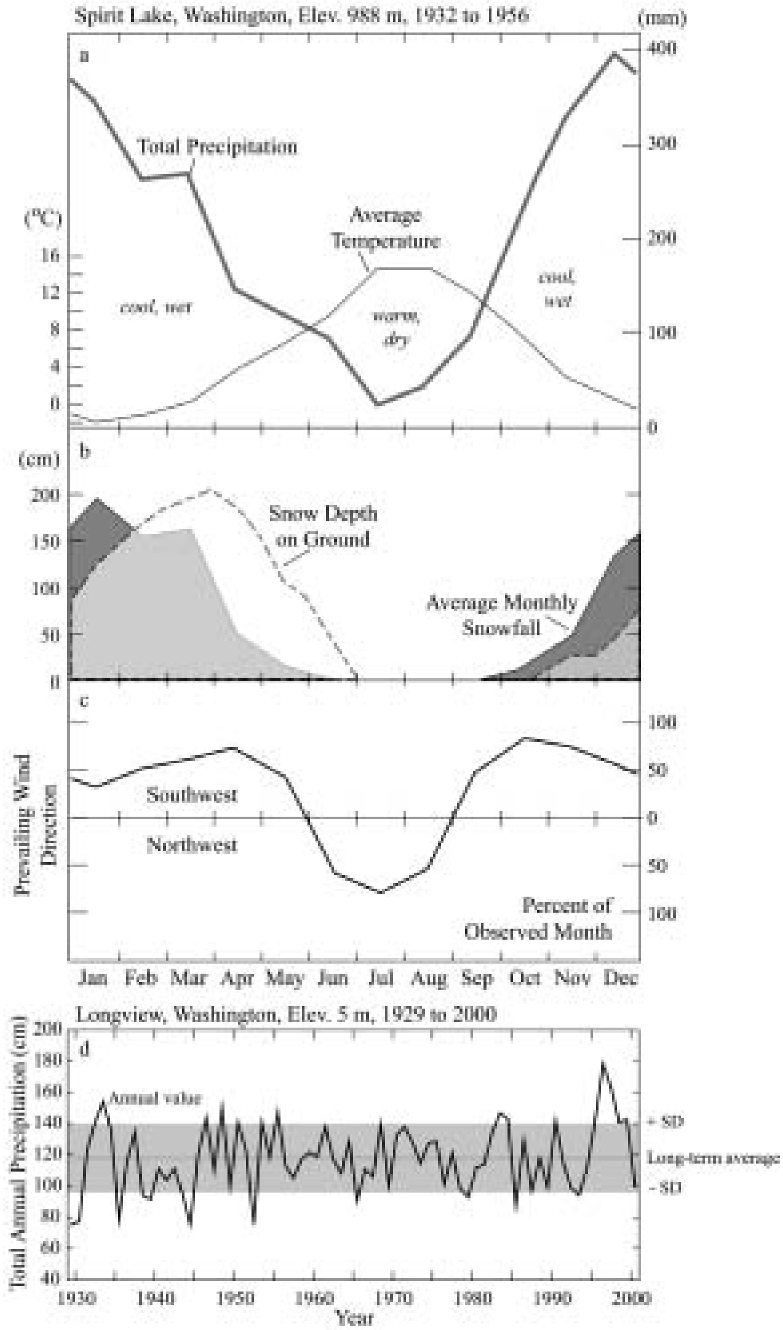

FIGURE 2.5. Climate of the Mount St. Helens area. (a) Climograph from Spirit Lake [after Walter (1973)]. (b) Average monthly snowfall and snow depth on ground. (c) Prevailing monthly wind directions and percent of observed months on record having prevailing directions. Mean number of monthly wind observations = 12. (d) Precipitation record for 1929 to 2000 at Longview, Washington, located 60 km west of Mount St. Helens. [(a), (b), and (c) are based on U.S. Weather Bureau (1932–1946, 1964) data collected at Spirit Lake (Figure 2.1; Easterling et al. 1996); (d) is based on U.S. Weather Bureau (1929–2000) data from Longview, Washington (Easterling et al. 1996) and updated by the Carbon Dioxide Information and Analysis Center, Oak Ridge National Laboratory.]

the Pacific Ocean and encountering the north-south Cascade Range. Broadly speaking, moisture decreases from west to east but increases with elevation. Temperature decreases from low to high elevation, and annual maxima increase from west to east as minima decrease.

The Pacific Northwest region experiences mild, wet winters and warm, dry summers. Mean annual precipitation at Spirit Lake (elevation, 988 m) was 2373 mm (from 1932 to 1962), of which only 162 mm (6.8%) fell between June and August (Easterling et al. 1996; Figure 2.5). Below about 600 m in elevation, precipitation falls mainly as rain. A seasonal snow pack occurs above an elevation of approximately 1000 m, and above an elevation of 1200 m, snowpacks of more than 3 m are common and may persist into July. An extensive area of intermediate elevation (approximately 300 to 1000 m) is within the transient snow zone, where rain-on-snow events can occur several times a year and can trigger major flooding (Harr 1981). Mean maximum and minimum temperatures in July are 22.3° and 7.3°C and in January are 0.4° and −4.4°C (Easterling et al. 1996). High topographic relief, steep slopes, and complex vegetation and wind patterns create very irregular patterns of snowpack across the landscape, especially in the spring when thick packs can persist on cold, north-facing, heavily forested sites while sunnier nearby sites at the same elevation can be snowless. These patchy, late-spring snowpack conditions existed at the time of the 1980 eruption, influencing the patterns of survival in both aquatic and terrestrial systems across several hundred square kilometers north of the mountain.

Precipitation in the vicinity of Mount St. Helens has varied substantially over the middle and late 20th century when records are available (see Figure 2.5d). Several decade-long periods of wetter- and dryer-than-average conditions may have affected terrestrial and aquatic ecological systems.

Prevailing winds are an important factor in the Mount St. Helens environment. They determine the pattern of tephra fall during eruptions, the spread of wildfire, and dispersal of wind-transported organisms and propagules that recolonize disturbed sites. Prevailing winds are from the southwest, except in summer, when they blow from the northwest. East winds during late summer and fall can be important drivers of wildfire, and during other seasons, east winds can cause windthrow and damaging ice accumulations on vegetation.

2.3 Ecological Setting

The Mount St. Helens area before 1980 was in many ways typical of Cascade Range fauna, flora, and ecological processes (Franklin 1966; Franklin and Dyrness 1973; Ruggiero et al. 1991; Matin 2001). Ecological conditions of large volcanic peaks within the Cascade Range can be considered in terms of three geographical strata:

- The volcano itself;
- Neighboring areas with little influence of past eruptive events (e.g., older geological terrain in the upwind direction, generally west and south of the volcano); and
- Neighboring areas with a strong, persistent legacy of tephra fall in soil profiles (e.g., northeast of the volcano).

These distinctions are particularly useful when examining effects of large-scale disturbance events, such as the 1980 eruption of Mount St. Helens, because conditions within each of these areas can strongly affect and are influenced by large-scale disturbance processes.

2.3.1 Soil

Soils in much of the southern Washington Cascades share common parent material broadly categorized as volcanic rocks, but differ in age and texture and, hence, in degree of development (Haagen 1990; D. Lammers, USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR, personal communication). Despite this common parentage, shortly before the 1980 eruption, soil properties varied greatly in the vicinity of Mount St. Helens and were related to prevailing wind patterns and distance from the volcano. Soils differ substantially among the three geographical strata of the volcanic cone, areas with tephra deposits downwind from the volcano, and relatively tephra-free areas in other quadrants around the volcano.

The volcanic cone was steep and covered with young volcanic materials exposed to a cold-winter–dry-summer climate, so soils were shallow and undeveloped, termed Entisols by soil scientists. In vegetated areas on the lower flanks, a thin surface A horizon had formed over unweathered material of the C horizon.

Soils in extensive areas of southwestern Washington are formed in tephra deposits from prehistoric eruptions of Mount St. Helens and other volcanoes, and some sites have tephra from more than one volcano. In areas of young, thick tephra deposits, soils are poorly developed Entisols, and older deposits have had time to develop Andisols and Spodosols. Buried soils commonly occur within the tephra deposits because intervals between deposition events often were long enough for accumulation of organic material (e.g., forest litter) and for development of weathering zones in the fine-grained ash deposits that commonly cap tephra deposits (Franklin 1966). Trees can be observed rooted in older tephra units and apparently survived deposition of up to several tens of centimeters of tephra. Trees growing on one soil surface commonly extended their root systems downward through coarse-grained, "popcorn" pumice tephra and into more nutrient-rich, buried soils and finer-grained deposits, producing layered root systems (Yamaguchi 1993).

Upwind of the volcano, the land surface had received little tephra from recent eruptions, so soils had been in place for sufficient time to develop a B horizon by weathering of volcanic glass and formation of the amorphous material allophone. These soils are classified as Andisols and Spodosols.

In addition to volcanic influences, soil development in the vicinity of Mount St. Helens has also been influenced by glacial, alluvial, and soil displacement from hill slopes.

2.3.2 Terrestrial Vegetation

Terrestrial vegetation of the Pacific Northwest is dominated by a few coniferous tree species that have long life spans (e.g., 300 to 1000 or more years) and attain massive size of individual trees and huge biomass of forest stands (Franklin and Dyrness 1973; Waring and Franklin 1979; Franklin and Hemstrom 1981). Forest vegetation reflects environmental forces, including the wet, cool, seasonal climate and the influences of diverse disturbance processes, especially fire and wind (Waring and Franklin 1979). This environmental variation also results in some nonforest vegetation types in Pacific Northwest mountain landscapes (e.g., wet and dry meadows, frequently disturbed shrub communities in riparian zones, and varied low-elevation wetlands).

Before the 1980 eruption of Mount St. Helens, plant life within about 30 km of the volcano was diverse with regard to the number of plant species, assemblages, and physiognomy. The volcanic cone was dominated by alpine and subalpine communities, and its lower flanks and surrounding area were extensively forested. The biotic diversity of this area developed in response to the broad range of elevation (500 to 3010 m), complex topography, wet and cool climate, past disturbances (both natural and anthropogenic), and variation in snow conditions, among other factors, which created a complex template influencing species distributions, plant growth, and community development. Of the floristic surveys covering different parts of the Mount St. Helens area conducted before the 1980 eruption (Lawrence 1954; Franklin 1966, 1972; St. John 1976; Franklin and Wiberg 1979; Hemstrom and Emmingham 1987; Kruckeberg 1987), the most comprehensive was St. John's 1925 survey of the north and south sides of the volcano. St. John (1976) lists approximately 315 species, including 17 fern, 13 conifer, 68 monocot, and 217 dicot taxa. The total number of plant species found in the larger area, including lowland, wetland, and riparian habitats not sampled by St. John, was likely significantly greater.

Forests dominated the preeruption landscape. The area supported large expanses of coniferous forests that were punctuated by plantations of young forest created following clear-cut logging. Deciduous trees played a minor role and were often associated with areas of disturbance, notably riparian zones. Streamside areas supported deciduous shrubs and trees, especially red alder (*Alnus rubra*), black cottonwood (*Populus tricocarpa*), and willow (*Salix* spp.). The dominant tree species varied with elevation and time since past disturbance. Three general forest zones are included in this area: the western hemlock (*Tsuga heterophylla*), Pacific silver fir (*Abies amabilis*), and mountain hemlock (*T. mertensiana*) zones of Franklin and Dyrness (1973). The western hemlock zone extends up to about 900 m in the vicinity of Mount St. Helens and commonly includes Douglas-fir (*Pseudotsuga menziesii*) and western red cedar (*Thuja plicata*) along with western hemlock. The Pacific silver fir zone, which occurs from about 900 to 1300 m, also contains noble fir (*Abies procera*), Douglas-fir, western hemlock, western red cedar, and western white pine (*Pinus monicola*). The mountain hemlock zone, ranging from 1250 to 1600 m, includes Pacific silver fir and Alaska yellow cedar (*Chamaecyparis nookatensis*) as well as mountain hemlock.

The composition, abundance, and cover of forest understory communities were highly variable. Elevation and pre-1980 tephra-fall deposits played a major role in shaping understory development. In general, understory vegetation was composed of a mix of mosses, herbs, shrubs, and slow-growing, shade-tolerant tree species. Ericaceous shrubs were conspicuous components of the understory. Important herb species belonged to the Ericaceae, Saxifragaceae, Liliaceae, and Scrophulariaceae families. Ferns were widespread and frequently abundant. Mosses were common on downed wood and the forest floor, and lichens hung from the tree canopies and clung to tree boles. Beargrass (*Xerophyllum tenax*), a liliaceous species conspicuous in most Cascade Range subalpine landscapes, was relatively rare, perhaps because of repeated tephra falls and associated unfavorable soil conditions.

The vegetation at and above tree line at Mount St. Helens differed from that found on nearby volcanic peaks, such as Mount Rainier, Mount Adams, and Mount Hood, in several notable ways. First, the irregular tree line on Mount St. Helens was at an elevation of approximately 1340 m, compared to 1840 to 1980 m for the adjacent volcanoes, and was still advancing up the north slope of the volcano in response to volcanic disturbance in AD 1800 (Lawrence 1954; Kruckeberg 1987). This advance suggests that the tree line before the 1980 eruption was below the contemporary climatic limit for this latitude. Lawrence (1954) referred to this phenomenon as "trees on the march." Second, tree species composition at tree line consisted of an unusual mix of conifers and hardwoods (e.g., cottonwood, Douglas-fir, noble fire, western white pine, and lodgepole pine). Third, the meadows were limited in area, depauperate in species, and dry. At tree line, subalpine fir (*Abies lasiocarpa*) and mountain hemlock grew in dense, widely spaced patches, creating a parkland in the dry-meadow vegetation.

Similar to the well-documented Mount Rainier landscape (Hemstrom and Franklin 1982), the patterns of conifer forest age classes in the area surrounding Mount St. Helens reflected a millennium of wildfire and a half century of forest cutting. At Mount St. Helens, however, recent, vigorous volcanic activity gave volcanism a greater role in shaping the forests of the area (Yamaguchi 1993) than occurred in the vicinity of other volcanoes of the region, where most forests postdate significant volcanism. Forest age classes at Mount St. Helens had great diversity, such as very young stands in recently clear-cut sites, stands dating from fires in the late 19th and early 20th centuries in the Mount Margaret area, and older stands, including individual trees and groves dating to at least the 13th century (Yamaguchi 1993).

Nonforest vegetation types in the Mount St. Helens landscape were meadows, wetlands, cliffs, seeps, and avalanche paths. Collectively, these landscape features comprised only about 5% of the area. Meadow types included those located above tree line on the volcano that were composed of grasses and herbs and some subalpine heather species capable of growing on well-drained, steep scree slopes and more luxuriant meadows in upper-elevation areas, such as in the Mount Margaret area. Wetland communities occurred in scattered natural topographic depressions, near-shore environments of some lakes, streamside channels, and beaver ponds. Willows, sedges (*Carex* spp.), rushes (*Juncus* spp.), and bulrushes (*Scirpus* spp.) were common wetland plants. Snow-avalanche channels typified by steep slopes and deep snowpack supported dense growth of shrubs, especially sitka alder (*Alnus viridis*).

2.3.3 Terrestrial Animals

Before the 1980 eruption, the Mount St. Helens landscape provided habitat for a diverse fauna characteristic of montane, alpine, riparian, and aquatic habitats in western Washington (Aubry and Hall 1991; Manuwal 1991; Thomas and West

1991; West 1991; Martin 2001). Numerous invertebrate taxa, from nematodes to crawfish, and all five classes of vertebrates (amphibians, reptiles, fishes, birds, and mammals) were represented in the preeruption landscape. The presence, total coverage, and juxtaposition of specific habitat types in the landscape strongly influenced the distribution of species; and food availability, cover, parasites, predators, and weather determined their population sizes. Most forest-dwelling species were probably broadly distributed, whereas species associated with water, meadows, and rock (cliff or scree) were patchily distributed.

2.3.3.1 Vertebrates

Given the diversity of forest, meadow, and aquatic habitats that were present in the preeruption landscape, it is likely that most, perhaps all, of the vertebrate species indigenous to the southern Washington Cascade Range existed in the large area severely impacted by the 1980 eruption (see Swanson and Major, Chapter 3, this volume). The preeruption fauna was composed entirely of native species, with the notable exception of introduced fish (discussed below). Each of the five vertebrate classes is briefly described next.

Amphibians: Fifteen amphibian species, 5 frog and toad and 10 salamander and newt species, have ranges that extend into the Mount St. Helens area (Nussbaum et al. 1983; Crisafulli et al., Chapter 13, this volume). Of these, 3 are found only in forests; 2 live in streams as larvae and in forests as adults; 7 live in lakes as larvae and in forests, riparian zones, or meadows as adults; 2 are seep-dwellers; and 1 is a denizen of streams. Collectively, they are a taxonomically unique and diverse assemblage with several members having very specific habitat requirements. Because amphibians are thought to be highly sensitive to environmental change, have variable life-history strategies, and use several habitat types, they would presumably be profoundly impacted by volcanic-disturbance processes. Furthermore, 12 of the 15 species use streams or lakes for some part of their life cycles, so changes in the amount, distribution, and quality of water could have serious consequences for amphibians.

Reptiles: With a cool, wet environment, the Mount St. Helens area supported only four species of reptiles: two garter snakes (*Thamnophis sirtalis* and *T. ordinoides*), the rubber boa (*Charina bottae*), and the northern alligator lizard (*Elgaria coerulea*) (Nussbaum et al. 1983). Disturbances that remove forest canopy and increase temperature and dryness of localized habitats may improve conditions for all four of these reptile species. Thus, reptiles could respond favorably in the aftermath of past and future eruptions.

Birds: Approximately 70 to 80 permanent-resident and summer-breeding bird species reside in the southern Washington Cascade Range. In addition to these species, numerous other bird species pass through the area during fall and spring migrations. About 36 nonraptor species are associated with montane forests, including a core group of 10 ubiquitous species (Weins 1978; Manuwal 1991), about 6 species primarily associated with alpine habitats, 12 species that use lakes or streams, and about 16 raptors.

Perhaps more than any other vertebrate group, birds are ostensibly tightly coupled with habitat structure. Thus, alteration of avian habitat would be expected to lead to dramatic and predictable changes in bird species composition and abundance patterns across a disturbance-modified landscape. The pace of bird community response to disturbance would be expected to follow the pace of development of suitable habitat, which could be very slow, such as in the case of old-growth forest habitat.

Mammals: Likely 55 species of mammals, representing 7 orders and 20 families, were present on and adjacent to Mount St. Helens before the 1980 eruption (Dalquest 1948; Ingles 1965; West 1991; Wilson and Ruff 1999). These mammals include a diverse group of species that range in mass from the tiny and highly energetic Trowbridge's shrew (*Sorex trowbridgii*), weighing a mere 5 g, to majestic Roosevelt's elk (*Cervus elaphus roosevelti*), weighing nearly 500 kg. Other large mammals in the area included black-tailed deer (*Odocoileus hemionus columbianus*), mountain goat (*Oreamnos americanus*), American black bear (*Ursus americanus*), and mountain lion (*Puma concolor*). Many of the most abundant mammals (e.g., bats, mice, voles, and shrews) were inconspicuous because of their nocturnal schedule or cryptic habits. Most of the species associated with coniferous forest habitats were probably broadly distributed, whereas species found in meadows, such as the northern pocket gopher (*Thomomys talpoides*), or those tightly associated with riparian areas were likely spottily distributed across the landscape.

Mammals play important roles in ecosystem processes:

- By mixing soil
- Through trophic pathways as herbivores and secondary and tertiary consumers
- As scavengers
- As dispersers of seeds and fungal spores
- As prey for birds and reptiles

(See Crisafulli et al., Chapter 14, this volume, and references therein.) Gophers, for example, mix fresh, nutrient-deficient tephra with older soil as they forage for belowground plant parts. Bats and shrews consume enormous quantities of insects while foraging. Chipmunks (*Tamias* spp.) and deer mice (*Peromyscus* spp.) gather and cache seeds of trees, shrubs, herbs, and grasses, and many of these caches are not reclaimed, leading to the establishment of new plant populations. Similarly, ungulates consume seeds that are later egested at distant locations and germinate. Beavers (*Castor canadensis*), voles, and elk can strongly influence the cover, amount, form, and species of plants through herbivory.

We expect mammals to have quite varied responses to volcanic eruptions. Many species have high vagility, so they can flee some volcanic events and rapidly disperse back into disturbed areas. More-cryptic species with underground habits could survive some types of eruptions but not extremely severe ones; also, longer-term survival is not assured if food and other resources are inadequate for continued life.

2.3.3.2 Invertebrates

The invertebrate fauna of the Mount St. Helens landscape was poorly known before the 1980 eruption, but the inventory of an Oregon Cascade Range forest landscape by Parsons et al. (1991) provides a relevant frame of reference. This work at the H.J. Andrews Experimental Forest about 200 km to the south identified more than 4000 species of terrestrial and aquatic insects and other arthropods, including a rich spider fauna, occupying terrestrial habitats as diverse as deep within the soil, in the tops of 70-m-tall trees, and within the soggy interior of rotting logs. Several groups or habitats may not have been exhaustively sampled during this inventory, so the actual invertebrate richness in the preeruption Mount St. Helens landscape may have been substantially greater.

Arthropods are expected to have strong negative responses to volcanic disturbance because of the loss of habitat and food resources, such as foliage consumed by phytophagous insects; physiological effects of abrasive, desiccating tephra; and burial of the forest floor with tephra that would alter and seal off the belowground organisms from the surface. The reduction or elimination of insects has important implications during biological reassembly because of the roles these species play in pollination and as prey for secondary consumers, such as birds, mammals, and amphibians. On the other hand, many taxa are highly mobile and quickly reinvade disturbed landscapes.

2.3.4 Lakes

Before the 1980 eruption, approximately 39 lakes were located within 30 km of Mount St. Helens. Of these lake basins, 32 were formed by Pleistocene glacial activity, and the remaining 7 were formed where volcanic debris or lava flows blocked streams (see Figures 2.2 and 12.1). Glaciers carved cirques into bedrock on north- and northeast-facing slopes in upper-elevation areas of the highest parts of the landscape. Many of these cirques contain small lakes (surface areas ranging from 1.5 to 32 ha) at elevations ranging from 1000 to 1500 m. These lakes, extending in a band from Fawn Lake on the west to Strawberry Lake at the east, have persisted since their formation more than 10,000 years ago. Lakes above 1000 m were generally ice covered for 5 to 7 months of the year.

In contrast, lakes formed by volcanic-flow deposits from Mount St. Helens were generally restricted to a zone 8 to 12 km around the volcano, where slopes are gentle enough to cause volcanic flows from the cone to stop and form deposits thick enough to block stream drainages. In at least one instance, mudflows from Mount St. Helens traveled more than 45 km down the Toutle River to block a stream and create Silver Lake. These blockage lakes occur at lower elevations (760 to 1040 m) than do the cirque lakes and range in size from less than 1 ha to the 510-ha extent of Spirit Lake. The small, low-elevation lakes have shorter lifetimes than cirque lakes because they may fill with sediment or their outlet streams may cut through the weak deposits forming the blockage. Filled and partially breached lakes commonly became wetlands, such as Goat Marsh southwest of the volcano.

Before the 1980 eruption, ecological study of lakes in the vicinity of Mount St. Helens was scant, but some information from the area and other Cascade Range lakes gives a useful picture of pre-1980 lakes (Wolcott 1973; Bortleson et al. 1976; Crawford 1986; Dethier et al. 1980; Wissmar et al. 1982a,b; Bisson et al., Chapter 12, this volume; Dahm et al., Chapter 18, this volume). Lakes in this subalpine, forested, mountain landscape generally had clear, cold, well-oxygenated water with low levels of nitrogen, phosphorus, and other nutrients that reflect:

- The low-nutrient water delivered to the lakes by streams, groundwater, and precipitation;
- The young age of the lakes;
- The low solubility of geological parent material; and
- The cool, wet climate.

These water-quality conditions supported only sparse phytoplankton and zooplankton communities and only several tens to perhaps a hundred aquatic insect species. Amphibians, particularly the aquatic forms of the northwestern salamander (*Ambystoma gracile*), were probably widespread, occurred at high densities, and served as a top predator in most lakes without fish or before fish introductions. Lakes were important habitat for waterfowl and shorebirds, for semiaquatic mammals (such as beavers), and for riparian-associated species (such as the northern water shrew and water vole).

Fish are a critical part of the ecological story of Mount St. Helens lakes. Before active management by European settlers, most lakes were barren of fish, but widespread stocking for several decades resulted in the presence of introduced trout in many of the lakes. However, Spirit Lake was connected to a river without barriers, permitting the presence of coastal cutthroat trout (*Oncorhynchus clarki clarki*), coastal rainbow trout (winter steelhead, *O. mykiss irideus*), and coho salmon (*O. kisutch*). Beginning in the early 1900s and continuing through 1979 (the year before the eruption), fish were repeatedly planted in most of these lakes.

The decades-long presence of fish in lakes that were naturally without fish probably dramatically altered lake conditions, resulting in a biota that was far from pristine. Planted fish likely exerted a top-down effect through predation on amphibians, crawfish, large mobile macroinvertebrates, and zooplankton (Pilliod and Peterson 2001; Schindler et al. 2001). In turn, predation on these species likely rippled through the aquatic food web (Parker et al. 2001).

Volcanic and other disturbance processes can have both transient and persistent effects on lake ecosystems. Tephra deposits from pre-1980 eruption accumulated in pumice beaches and deltas along the shores of some lakes. These deposits had important biological effects, such as influences on development of emergent plant communities and breeding, rearing, and foraging sites for insects, snakes, amphibians, birds, and mammals. Disturbances that caused major, short-term alteration in water quality, water quantity, habitat, or biotic structure could have profound impacts on the biological diversity of both lakes and the landscape as a whole.

2.3.5 Streams and Rivers

The area within 30 km of Mount St. Helens is steep and highly dissected by a complex, high-density drainage network with origins in headwater seeps, springs, lakes, or glaciers (see Figure 2.2). Streams and rivers draining the older geological terrain of the Mount St. Helens landscape (see Figure 2.3) were cold (8°–15°C), clear, and fast-flowing over irregular beds of boulders, bedrock, and fallen trees in forested areas neighboring the volcano. Muddy River and other streams fed by glaciers on Mount St. Helens, on the other hand, ran turbid with silt in the summer. Streams cutting through recent volcanic deposits commonly had mobile streambeds and banks. Stream discharge through steep, lower-elevation channels was highly seasonal, driven by the wet-winter, dry-summer climate and by spring melting of the seasonal snowpack in upper-elevation areas.

Specific descriptions of the preeruption biota and ecological processes in these streams are unavailable in most cases (however, see general descriptions on amphibians, birds, mammals, and fish above), so we draw on findings from studies of similar stream systems elsewhere in the Cascade Range.

The vast majority of streams are small (1 to 3 m wide) and shallow, with high-gradient channels composed of steep cascades and small pools with boulder, cobble, and bedrock substrate. Large amounts of downed wood, including whole, massive trees, strongly influence the physical and biological characteristics of small Cascade streams (Triska et al. 1982). Dense coniferous forest canopies intercepted sunlight and limited primary productivity within these headwater systems. Thus, food webs were largely driven by organic matter entering streams from adjacent forests. The steep, straight tributary streams plunged rapidly down slope and entered larger, lower-gradient streams that flowed through broad, U-shaped valleys, such as Clearwater Creek and Green River valleys. Localized floodplains along these larger streams provided room for some channel meandering and formation of secondary channels. Streambeds were composed of cobble and gravel substrates and scattered log jams. These streams were wide enough to allow sunlight to reach channels and promote growth of diatoms, algae, and mosses on the streambed and banks. These streams also had steep reaches, including impressive waterfalls with deep plunge pools. Finally, these midsized streams flowed into the larger rivers draining the Mount St. Helens landscape. These large rivers had more extensive floodplains, gravel bars, and riffles, but large downed wood was less common than in smaller channels because of the transport capacity of high flows in wide channels. Ample sunlight reached the stream to promote food webs based on the stream's primary production (e.g., by diatoms, filamentous algae, and macrophytes) as well as on material transported from upstream and from tributaries. Productivity of the streams increased from small headwater streams to large rivers.

Fish are an important component of the four river systems draining the Mount St. Helens area, the Toutle, Kalama, Lewis, and Cispus (see Figure 2.2). These rivers eventually flow into the Columbia River, which, in turn, flows to the Pacific Ocean. Geological processes and landforms have modified these river networks over time, affecting their function as corridors for dispersal and creating natural barriers, such as waterfalls. These habitat features determined the fish species distributions within these watersheds before the 1980 eruption. Eight families, including about 25 species, represent the preeruption fish fauna (see Bisson et al., Chapter 12, this volume). The native fauna was a mix of anadromous and resident species, including lampreys (*Lampetra* spp.), salmon (*Onchorhynchus* spp.), trout (e.g., *Salvelinus confluentus*), and sculpins (*Cottus* spp.) (Reimers and Bond 1967; Wydoski and Whitney 1979; Behnke 2002). In addition to the native fishes, several trout species (e.g., brook, rainbow, and brown trout) had been stocked in the streams and rivers draining Mount St. Helens.

The specific distribution of most of these species was poorly documented as of 1980, but substantial information existed for a handful of salmonid species that had commercial or sport value. Most notable were the spectacular runs of steelhead (*O. mykiss irideus*) in the Toutle River and Kalama River systems, coho salmon (*O. kisutch*) runs in the Toutle River, and Chinook salmon (*O. tshawytscha*) in the Lewis River. Most of the nonsalmonids were likely confined to the lower reaches of these river systems, where the water was warmer, slower, and deeper.

The salmonids and some other fish species (e.g., sculpin) in the Mount St. Helens landscape required cold, clear water with gravel streambeds for foraging and spawning and would be expected to suffer deleterious effects of a major disturbance of these habitat features. Clearly, salmonids had to contend with major habitat disruption in the past but have several attributes that enabled them to persist or even flourish in this dynamic volcanic landscape. Chief among these characteristics are their tendency to stray from one watershed to another; their life-history trait of having one to several cohorts of their population at sea for several years; and their high mobility, which enables them to recolonize areas once conditions have improved.

2.4 Ecological Disturbance

Steep, forested volcanic landscapes in wet climates, such as the Pacific Northwest, are subject to a great variety of natural and human-imposed ecological disturbance processes, ranging from strictly geophysical processes, such as those associated

TABLE 2.2. Chronology of known, natural, stand-replacing disturbance events affecting forests near Mount St. Helens during the past 700 years.

Year or interval (AD)	Type of disturbance	Sector	Reference
May 18, 1980	Forests killed by lateral blast and associated events	N	Lipman and Mullineaux (1981)
1885	Forests on floor of upper South Fork Toutle River valley inundated by mudflow	W	
1844	Forests on north floor of South Fork Toutle River valley inundated by mudflow	W	Yamaguchi and Hoblitt (1995)
1800	Forests on flank of volcano inundated by lava flow; trees along flow edges killed or injured by heat	NW	Lawrence (1941); Yamaguchi and Hoblitt (1995)
1800	Forests killed by tephra fall (layer T)	NE	Lawrence (1939); Lawrence (1954); Yamaguchi (1993)
Ca. 1780	Hot mudflow kills forests on Pine/Muddy fan	SE	Yamaguchi and Hoblitt (1995)
1722	Mudflows down Muddy River briefly dam Smith Creek; forests at Muddy/Smith confluence buried	SE	
1647–mid-1700s	Mudflows down lower Muddy River kill at least some valley-bottom stands	SE	
1647	Pyroclastic flow inundates forests in upper valley of South Fork Toutle River, and, possibly, Castle Creek	W	Hoblitt et al. (1981); Yamaguchi and Hoblitt (1995)
1482	Forests killed by tephra fall (layer We); area, 30 km^2	E	
1480–1570	Forests on floor of Kalama River inundated by pyroclastic flows	SW	Yamaguchi and Hoblitt (1995)
1480	Forests killed by tephra fall (layer Wn); area, 65 km^2	NE	
Ca. 1300	Forests killed by extensive fire(s); area greater than 100 km^2	NE, E, also possibly W	Yamaguchi (1993)

Note that fire history was investigated only in the northeast quadrant (Yamaguchi 1993).
Source: Data from Yamaguchi and Hoblitt (1995) unless otherwise noted.

with volcanic eruptions, to strictly biological processes, such as insect and disease outbreaks (Lawrence 1939, 1941; Hemstrom and Franklin 1982; Yamaguchi 1993; Yamaguchi and Hoblitt 1995). Many disturbance processes involve interaction of geophysical and biological components, such as landform effects on fire and wind toppling of trees (Swanson et al. 1988; Sinton et al. 2000).

The pace and complexity of forest-disturbance history in the vicinity of Mount St. Helens are represented by a chronology of known stand-replacing disturbances during the 700 years leading up to the 1980 eruption (Table 2.2). The occurrence of disturbance events and the state of our knowledge about them are not uniform around the volcano. Tephra-fall events, well documented by the resulting deposits, are concentrated in the northeast quadrant from the volcano. On the other hand, in the past 700 years, wildfires probably affected nearly all forests surrounding the volcano with a mean recurrence interval of several centuries (Hemstrom and Franklin 1982; Agee 1993; Yamaguchi 1993). During the past 700 years, forests, lakes, and streams northeast of the volcano experienced several tephra-fall events and one extensive and several less-extensive wildfires. Many streams draining the volcano as well as many plant and animal communities were disturbed periodically by hot pyroclastic flows and cold mudflows from the upper slopes of the volcano. During the past millennium, large floods occurred without the influence of volcanic processes. These floods triggered small landslides on hill slopes, debris flows down stream channels, and lateral channel migration along larger rivers in the area, as observed for such storms elsewhere in the Cascade Range (Swanson et al. 1998).

Humans, first indigenous people and then European settlers, had many and varied effects on the landscape. Most conspicuously, forestry operations in the vicinity of Mount St. Helens in the several decades leading up to 1980 profoundly altered the stature, composition, and spatial pattern of forest cover. Clearcutting opened the forest canopy in scattered 20-ha patches on USDA Forest Service lands east and south of the volcano. Much larger clear-cut patches were created on state and forest industry lands to the south, west, and northwest. These clearcut areas were typically planted to monocultures of Douglas-fir below an elevation of 1000 m and to noble fir at higher elevation. These plantations developed into dense, young stands within one to two decades. A network of forest roads provided access for forestry operations, recreation, mining, and other uses. The rugged, sparsely forested Mount Margaret country north of the volcano experienced little logging and was designated mainly for high-country recreational use without roads. Fire suppression throughout the area tended to reduce fire extent at the same time that other human uses of the landscape increased fire ignitions.

Major geological and ecological changes have occurred at a similar pace in the vicinity of Mount St. Helens. The multicentury life spans of the dominant tree species in the area (Waring and Franklin 1979) and the frequency of nonvolcanic processes, such as major wildfires, are comparable to the mean quiet interval between eruptive periods. Close to Mount St. Helens, disturbance by volcanic processes may preclude some nonvolcanic disturbances, such as the effect of tephra-fall deposits that reduce the amount and continuity of forest fuels, thereby limiting spread of wildfire. Farther from the peak, volcanic disturbances may simply add to the disturbance regime of nonvolcanic processes.

2.5 Conclusions

Volcanoes are distinctive types of mountains. They repeatedly send rock debris into the surrounding landscape, reminding people of their presence. As a result of frequent eruptions during the past 40,000 years, Mount St. Helens has become an island of young, volcanically constructed deposits and topography set in a far older, deeply eroded landscape. Records and biological legacies of the many volcanic events are contained in deposits, landforms, and ecosystems around the volcano. The long temporal reach of volcanic influences prompts consideration of history in assessing the effects of new events, such as the 1980 eruption.

As discussed in Chapter 3, the 1980 events at Mount St. Helens follow the pattern to which this volcano has been accustomed. An eruptive period lasting less than a year to many decades is followed by several centuries of quiescence. A new eruptive period involves various volcanic and associated hydrologic processes occurring over a period of months to a few years. Both primary and secondary erosion processes alter the form of the main cone and the surrounding landscape, creating and modifying a variety of terrestrial and aquatic habitats.

Ecological features of the Mount St. Helens landscape are broadly representative of the Cascade Range in many specific respects and of more extensive temperate ecosystems in some general respects. These similarities include the following:

- A diverse flora is dominated by a few coniferous tree species that attain massive size and biomass. Also, many nonforest vegetation types comprise an important, but small, proportion of the landscape.
- The terrestrial fauna includes diverse vertebrate assemblages, composed of several regional endemic species, and thousands of invertebrate species.
- Stream and lake ecosystems are varied and, although limited in productivity by the clear, cold, low-nutrient waters, they provide habitat for numerous species that contribute to the biodiversity of the landscape.
- These ecological systems respond at varying paces to disturbances, ranging from the rapid chemical transformations occurring in lakes to the slow growth of long-lived trees to the multimillennial time scale of soil development.

Despite the history of frequent, severe disturbance in the vicinity of Mount St. Helens, these species and ecological systems have been very persistent for a variety of reasons. The complex terrain and diversity of microhabitats leaves many refuges after severe disturbance by fire, volcanic, or other processes. The wetness of the landscape, including areas with persistent snow cover, can buffer ecological systems from some types of disturbance. Another key factor is that the deposits originating from Mount St. Helens, with a few notable exceptions, are sufficiently unconsolidated that plants can root and animals (e.g., pocket gophers and ants) can excavate and burrow. The importance of this characteristic is clear when comparisons of ecological development are made to basalt flows. A variety of life-history strategies contributes to the resistance and resilience of many taxa to disturbance. For example:

- Anadromous fish spend long periods at sea away from the influences of terrestrial disturbances.
- Ballooning spiders and many other taxa have the capacity to disperse over distances much greater than the size of individual disturbance patches.
- The landscapes surrounding even the largest disturbance patches in the Cascade Range harbor an intact pool of native species available for recolonizing disturbed areas.

Mount St. Helens is an exceptional setting, where scientists can address many aspects of this interplay of ecology and volcanoes, particularly for the temperate, forested landscapes common around the Pacific Rim. The Mount St. Helens landscape continues to change at a rapid pace, and prospects for future eruptive activity seem high, so its role as a special place for learning about succession, disturbance, and interactions of humans with volcanoes will persist.

Acknowledgments. This work was funded by the USDA Forest Service's Pacific Northwest Research Station and Gifford Pinchot National Forest, the National Science Foundation, and the National Geographic Society. Yamaguchi's work was supported in part by a National Research Council–USGS research associateship at the U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, Washington. We have benefited from the knowledge of many people and give special thanks to Jerry Franklin, Jim MacMahon, Chuck Hawkins, Virginia Dale, and an anonymous reviewer for helpful reviews and to Duane Lammers for information about soils.

http://www.springer.com/978-0-387-23868-5

Ecological Responses to the 1980 Eruption of Mount
St. Helens
Dale, V.H.; Swanson, F.J.; Crisafulli, C.M. (Eds.)
2005, XX, 342 p., Hardcover
ISBN: 978-0-387-23868-5