Early Plant Succession on the Muddy River Mudflow, Mount St. Helens, Washington

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Abstract: Long-term plant succession studies using permanent plots were initiated on the Muddy River mudflow in the Mount St. Helens area of southeastern Washington. Plant cover and geomorphic surface were observed on 126 circular plots (250 m^2). One hundred and eight species were identified and categorized based on occurrence in eight microsite types. Herb, shrub and tree seedling cover decreased with increasing distance from forest edges and with decreasing distance from the base of Shoestring Glacier. Greatest plant cover occurred on roadbanks, around bases of stumps and along streams.

Introduction

The eruption of Mount St. Helens on 18 May 1980 created a mosaic of volcanically disturbed sites that varied widely in character. Ecologists found a rare opportunity to study the disturbance and subsequent recovery of aquatic and terrestrial ecosystems. As part of a long-term research effort using permanent plots, we have examined the very early stages of succession on the mudflows of the Muddy River on the eastern side of Mount St. Helens.

Mud and debris flows are common near the major volcanoes in the Cascade Range. For example, more than 55 mud and debris flows originated at Mt. Rainier within postglacial time (Crandell, 1971). Some support communities of vegetation typical of the zone in which they occur (Franklin, 1966). More recent flows provide prime sites for study of succession and soil development (*e.g.*, Frehner, 1957). Frehner's study of the 1947 Kautz Creek mudflow beneath Rainier shows conifer invasion from adjacent forest. Distance from seed source and occurrence of standing snags appear to be important factors regulating the composition of the returning vegetation. *Populus trichocarpa, Salix* spp. and *Alnus rubra* have been major pioneers.

The Muddy River extends from the *Tsuga heterophylla* Zone on its lower reaches to the *Abies amabilis* Zone (Franklin and Dyrness, 1973) near its origin. Precipitation averages 1500-3000 mm in the *Tsuga heterophylla* Zone, and occurs mainly during the winter. The *A. amabilis* Zone is wetter and cooler, and much of the precipitation falls as snow. Mean annual temperatures average 8-9 C in the *T. heterophylla* Zone while they average ca. 5.5 C in the *A. amabilis* Zone. Summers are relatively dry.

The communities surrounding the Muddy River are principally mixed coniferous forests with *Pseudotsuga menziesii, Tsuga heterophylla, Thuja plicata, Pinus contorta* and *Abies* spp. Some of the alluvial flats contain large amounts of *Populus trichocarpa, Acer macrophyllum* and *Alnus rubra,* with *A. sinuata* at higher elevations.

As Mount St. Helens erupted, snow and ice on its flanks melted rapidly. These meltwaters combined with rock, sand, mud and organic material to form a slurry which rapidly moved down Smith Creek, Muddy River and Pine Creek. By noon, most of the material had entered Swift Reservoir (19 km from the base of the mountain) and at peak flow—between 9 and 10 AM—material was added at a rate of 1699 m^3/s (Cummans, 1981).

On the upper reaches of the Muddy River mudflow, deposits were so thick and extensive it was almost impossible to detect former topographic relief. During the winter of 1980-1981, deep gullies were formed near the base of Mount St. Helens while flooding and erosion were extensive below the confluence of Smith Creek and Muddy River. The geomorphic context in which succession is occurring is very complex, and the nature of the original mudflow, erosion and redeposition processes are important influences on succession.

METHODS

Sixteen transects were established during the summer of 1981 to include the mudflow from Cedar Flats to 2 km from the base of Shoestring Glacier (Fig. 1). The elevations of our transects ranged from 400-1200 m. All but transect 14 were perpendicular to the main axis of the mudflow. Transect endpoints and centerpoints were surveyed by electronic distance measuring (EDM) and were marked with 1-m-tall

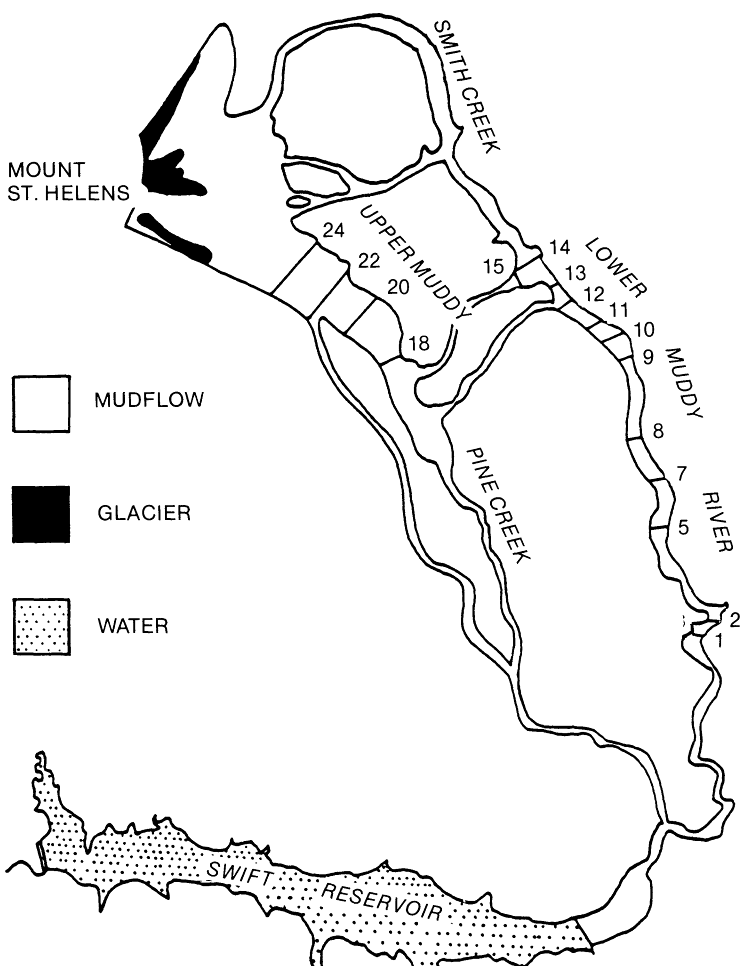

Fig. 1.—Mudflow study area with transect numbers and locations. Note, transect numbers are not sequential

metal rods, covered with white PVC pipe to increase visibility. Circular plots 250 m^2 were placed every 50 m along transects, skipping plots falling in streams. At each plot, the endpoints of four radii, each at a 45° angle to the transect line, were used to permanently mark microplot locations. Six microplots were placed on each radius for a total of 24 microplots per plot (2.4 m^2).

We categorized the surface substrate types as pumice, fine material (less than 2 mm), coarse rock (larger than 2 mm), coarse woody debris and litter. Two methods were used to estimate plant cover and stem density. First, cover was recorded for 0.2 x 0.5 m microplots using Daubenmire's cover classes modified to include a cover class less than 1%. Live and dead tree seedlings were also counted in microplots. Second, plant cover by species and tree-seedling densities were estimated for the entire 250 m^2 plot when few plants were present (transect 10-24). The Wilcox two-sample test (Sokal and Rohlf, 1969, p. 394) was used to detect significant differences between the Upper and Lower Muddy rivers transects in terms of plant and substrate cover, and seedling density. Tests were judged significant when P was less than 0.02 (two-tailed test).

RESULTS AND DISCUSSION

Mudflow description.—We divided the transects into lower and upper groups based on erosion history and surface characteristics. The boundary between groups was the junction of Smith Creek and the Upper and Lower Muddy rivers. The lower group included transects 1-13 and represented the mudflow surface subjected to severe erosion and reworking during the winter of 1980-1981. The upper group included transects 14-24. The surface here was also severely eroded during the winter of 1980-1981, but most of the original material remained and was dissected by deep gullies. The lower transects tended to be shorter than the upper (150-300 m vs. 300-1000 m), an important difference when considering seed rain and litterfall.

Log cover was significantly higher on the lower transects, ranging from 2-33%. Logs influence plant succession by stabilizing surfaces, protecting seedlings from stream scouring, and by providing shade, organic matter and nutrients. Cover of fine materials was significantly greater on the lower transects than the upper (46-98% vs. 17-45%); the opposite was true for pumice (0-33% vs. 20-64%). Presumably the pumice was deposited after the mudflow. Physical weathering of surface pumice is rapidly creating more fine particles. Cover of coarse material was significantly higher on the upper transects (15-46% vs. 1-61%); and though soil water-holding capacity may be lower here, variation in microhabitat is increased. The variation within each transect is high also. For example, log cover on the lower transects ranged from 5-85%, and pumice cover on the upper transects ranged from 10-99%. This emphasizes how variable initial conditions are for succession.

Plant habitats.—Of 108 species found on the mudflow, 29 were present on stump bases, 33 in mudflow channels, 41 on mudflow surfaces, 5 on soil clumps, 4 in log jams, 37 in rootwads, 36 in buried soil and 18 in buried roadbanks (Table 1).

These observations may reflect not only the tendency for plants to revegetate certain microsites, but the abundance of the microsites themselves. Plant cover was greatest where organic material or old soil was available. Rhizomatous and tuberous perennials such as *Smilacina stellata, Achlys triphylla, Trientalis latifolia, Vancouveria hexandra, Disporum smithii* and *Berberis nervosa* were intact on these sites, indicating many species survived in rootwad, stump base and roadbank refugia. Similarly, annuals and biennials such as *Senecio sylvaticus, S. vulgaris, S. jacobaea, Cirsium vulgare* and *Conyza canadensis* were important on these microsites. These may be areas of relatively high nutrient availability and water-holding capacity.

Reworked and eroded mudflow areas, such as mudflow channels, are unstable but important sites of revegetation and support many species. The mudflow channels often contained standing or moving water and occasionally had exposed original soil material. Species such as *Carex mertensii, Juncus bufonius, J. ensifolius* var. *ensifolius,*

TABLE 1.—Checklist of vascular species on Muddy River mudflow, presence on eight habitats,[1] and frequency (percent) of occurrence on 126 plots

		Habitat[2]								
		SB	MC	M	SC	LJ	RW	BS	BR	Frequency (%)
ACERACEAE	*Acer circinatum*						+			3
	A. macrophyllum		+	+			+	+	+	8
APOCYNACEAE	*Apocynum androsaemifolium*			+						1
BERBERIDACEAE	*Achlys triphylla*						+			
	Berberis nervosa	+					+		+	
	Vancouveria hexandra	+			+					
BETULACEAE	*Alnus rubra*		+	+				+	+	14
CAPRIFOLIACEAE	*Linnaea borealis*						+			
	Lonicera ciliosa						+			
	Lonicera sp.						+			1
	Sambucus cerulea	+	+							
CARYOPHYLLACEAE	*Arenaria macrophylla*							+	+	
	Spergularia sp.							+		
	Stellaria sp.	+					+			2
COMPOSITAE	*Anaphalis margaritacea*			+					+	2
	Aster sp.			+						1
	Cirsium arvense var. *horridum*	+			+			+		
	C. vulgare	+	+	+				+	+	6
	Conyza canadensis	+						+		2
	Eriophyllum lanatum							+		
	Gnaphalium microcephalum var. *thermale*	+	+	+						1
	G. palustre			+						
	G. purpureum							+		
	Hieraceum albiflorum			+						1
	Hypochaeris radicata							+		2
	Lactuca sp.						+			
	Petasites frigidus					+	+			1
	Senecio jacobaea						+			
	S. sylvaticus			+						2
	S. triangularis							+		
	S. vulgaris	+			+		+	+		
CORNACEAE	*Cornus canadensis*						+			
	C. nuttallii			+						

TABLE 1.—(Continued)

		Habitat[2]								
		SB	MC	M	SC	LJ	RW	BS	BR	Frequency (%)
CRASSULACEAE	*Sedum* sp.			+						
CRUCIFERAE	*Arabis* sp.		+							
CUPRESSACEAE	*Thuja plicata*		+	+		+	+	+		17
CYPERACEAE	*Carex hoodii*		+							
	C. mertensii	+	+	+				+		10
EQUISETACEAE	*Equisetum arvense*	+	+	+			+		+	
ERICACEAE	*Arctostaphylos uva-ursi*			+						3
	Gaultheria shallon		+						+	1
	Menziesia ferruginea			+						1
	Phyllodoce empetriformis			+						2
	Vaccinium membranaceum			+						3
	V. ovalifolium			+						1
FUMARIACEAE	*Dicentra formosa*	+								1
GROSSULARIACEAE	*Ribes lacustre*			+						
GRAMINEAE	*Agrostis alba*	+	+	+			+			1
	Cinna latifolia						+			
	Dactylis glomerata							+		
	Elymus glaucus								+	
	Festuca rubra			+						2
	Lolium perenne	+	+							
	Puccinellia pauciflora			+						1
HYDROPHYLLACEAE	*Hydrophyllum fendleri*	+					+	+		
	H. teniupes	+						+		
	Phacelia heterophylla		+							
JUNCACEAE	*Juncus bufonius*		+							
	J. effusus		+							1
	J. ensifolius var. *ensifolius*		+	+			+			1
	Luzula sp.			+						
LABIATAE	*Mentha arvensis* var. *glabrata*							+		
	Prunella vulgaris							+		
	Stachys cooleyae	+	+	+			+	+		1

TABLE 1.—(Continued)

		Habitat[2]								
		SB	MC	M	SC	LJ	RW	BS	BR	Frequency (%)
LEGUMINOSAE	*Lotus corniculatus*		+	+						10
	L. micranthus			+						
	Lupinus latifolius			+		+				24
	L. lepidus			+			+			18
	Trifolium repens		+	+				+		2
LILIACEAE	*Disporum smithii*						+			
	Smilacina stellata						+	+	+	
ONAGRACEAE	*Circaea alpina*						+	+		
	Epilobium angustifolium	+					+			10
	E. watsonii	+	+				+	+		
	Epilobium sp.		+							
PINACEAE	*Abies* sp.			+						1
	Pseudotsuga menziesii	+	+	+				+	+	57
	Tsuga heterophylla			+						21
PLANTAGINACEAE	*Plantago lanceolata*							+		1
	P. major var. *major*							+		
POLEMONIACEAE	*Collomia heterophylla*	+					+	+	+	1
POLYGONACEAE	*Rumex acetosella*			+						1
POLYPODIACEAE	*Athyrium filix-femina*			+			+		+	1
	Blechnum spicant									1
	Polystichum munitum	+							+	1
	Pteridium aquilinum						+		+	1
PORTULACACEAE	*Montia siberica*		+					+		
PRIMULACEAE	*Trientalis latifolia*						+			

TABLE 1.—(Continued)

		Habitat[2]								
		SB	MC	M	SC	LJ	RW	BS	BR	Frequency (%)
ROSACEAE	*Fragaria vesca*						+		+	
	Luetkea pectinata			+						1
	Rosa gymnocarpa	+			+					
	Rubus lasiococcus			+						1
	R. leucodermis		+							
	R. parviflorus	+			+		+	+		1
	R. ursinus	+	+	+			+	+	+	5
	Sorbus sitchensis									
RUBIACEAE	*Galium triflorum*	+	+				+	+		
SALICACEAE	*Populus trichocarpa*		+			+				6
	Salix sitchensis	+	+					+		
	Salix sp.	+	+	+			+	+		10
SAXIFRAGACEAE	*Heuchera micrantha*						+			
	Tiarella trifoliata var. *trifoliata*			+					+	
	Tolmiea menziesii	+	+							1
SCROPHULARIACEAE	*Mimulus moschatus*		+							
	Penstemon sp.			+						4
	Synthyris reniformis							+		
	Veronica anagallis aquatica		+	+						
TYPHACEAE	*Typha latifolia*		+							

[1]Scientific nomenclature, taxonomy, and common names follow Hitchcock and Cronquist (1973)
[2]Key to habitat abbreviations:
SB stump base—material around *in situ* stump; usually organic in nature; deposit can be fairly deep (over 0.25 m)
MC mudflow channel—a channel which contains water or has contained water recently; includes moist habitats such as sinks and depressions
M mudflow surface—reworked nonorganic substrate with no shallow buried soil (less than 0.25 m)
SC soil clump—pieces of soil (can have root material) on surface of mudflow; not associated with tree root system
LJ log jam—piles of logs, excluding rootwads; includes shallow deposits of mudflow (approx. 2.54 cm)
RW rootwad—pertaining to tipped up trees; material held by tree root system and in wood of tree at base, below swell of trunk
BS buried soil—original soil with shallow layer of mudflow, or exposed through erosion. Soil is *in situ*
BR buried roadbank—buried roadbank and roadside

Equisetum arvense, Salix sp., *Populus trichocarpa, Alnus rubra* and *Stachys cooleyae* were relatively abundant here.

The mudflow surface itself was the largest area and supported the greatest number of species. Vegetation cover was usually low unless species such as *Rubus ursinus* or *Lupinus latifolius* had extensive lateral growth. Leguminous species, in general, were most frequent on the relatively sterile mudflow surface. Nitrogen fixation would confer an advantage on these sites. Areas with *Lupinus latifolius, L. lepidus* and *Lotus corniculatus* occasionally attained plant cover over 3%.

Several species occurred on a wide range of microsites. *Rubus ursinus* occurred on six of the eight site types while *Cirsium vulgare, Salix* sp., *Equisetum arvense* and *Stachys cooleyae* occurred on five. Other species were restricted to particular microsites. For example, *Vaccinium membranaceum* and *V. ovalifolium* occurred solely on the mudflow surface as sprouts while *Juncus bufonius* and *J. effusus* were found in mudflow channels only; *Linnaea borealis, Achlys triphylla* and *Disporum smithii* appeared solely in the rootwad habitat.

Herb cover on transects. — Plant cover across a transect generally decreased as the distance from the forest edge increased. Transect 14, situated above the confluence of the Upper and Lower Muddy rivers and Smith Creek, exemplified this pattern (Fig. 2). This trend was quite variable, however, and was dependent on: (1) transect location along the mudflow; transects on the Lower Muddy River generally had greater plant cover than transects on the Upper Muddy; (2) presence of roadbanks; (3) occurrence of old stream channels, and (4) occurrence of stable sites such as rootwads, stump bases and old soil clumps. The occurrence of these favorable microsites was usually accompanied by local increases in plant cover.

Density of plant cover with regard to position from origin of the Muddy River was similarly quite variable. The general trend indicated plant cover was greatest at the lower transects and sparsest near the upper transects. On the upper transects, 49% of the plots had herbs. On the lower transects, 66% of the plots had herbs; however, herb cover on the Upper and Lower Muddy rivers was not significantly different. Cover and species composition tended to vary with geomorphic and microsite characteristics of the particular plots.

Near the base of Mount St. Helens, transects 22 and 20 exhibited little plant cover and low species richness. All plots, except for one on each transect, contained only trace amounts of vegetation, if any at all. Only three species appeared important, *Lupinus latifolius, L. lepidus* and *Vaccinium membranaceum. Vaccinium* was not represented on the lower transects. Transect 24 was an exception to the general pattern, as it intersected two large "tree islands," sites which were elevated and not deeply buried by the mudflow. Trees were dead but standing, and there was copious sprouting of *Lupinus* spp. and *Vaccinium membranaceum.* Several plots on this site had 20-60% cover, though it may have been greater elsewhere on the "islands." Transects 14 and 15 at the confluence of Muddy River and Smith Creek exhibited high plant cover; some plots here had cover 1.5-2.01 m^2 (0.6-0.8%). Transect 14 had over 20 herb and shrub species while transect 15 had 12 species.

It appears as if the herb and shrub revegetation processes will be dominated by: (1) invasion through seed dispersal from the forest edge; (2) vegetative expansion from roadbanks, and (3) expansion from somewhat stable sites on rootwads, stump bases and old stream channels. Of lesser importance will be vegetative sprouting of species such as *Populus trichocarpa,* scattered through the mudflow material.

Tree seedlings. — Density of tree seedlings decreased with distance from the forest edge. This relationship will change as the canopy of the forest margin continues to die back and the distance of the edge increases. Beyond 200-250 m from the present edge, seedlings were scant. Within 50 m of the forest edge, densities ranged from 100-4200 seedlings per 250 m^2, whereas at a distance of over 150 m, density was 0-400 seedlings per 250 m^2. Tree seedling density was significantly different between the Upper and

Lower Muddy rivers. The Upper Muddy transects also had slightly fewer plots with seedlings (58%) than the Lower Muddy transects (64%).

Seedlings appeared mainly on the mudflow surface itself. On the mudflow, no differences in occurrence with regard to microenvironment were noticeable; there were no apparent advantages to establishment near logs or boulders.

Tree species differed greatly in seedling establishment and survival during the first growing season. Survival in this sense simply reflected whether the seedlings observed were live or dead; this method overestimated survival because dead individuals may have disappeared by the time of the sampling. *Pseudotsuga menziesii* was very abundant and had 75% survival. *Acer macrophyllum* and *Tsuga heterophylla* were similar in survival (62-64%, respectively) but the latter was 10 times more abundant. The most abundant species, *Thuja plicata,* had the poorest survival (36%). Although *Alnus rubra* was the least abundant species, we observed no dead individuals.

Our initial observations of revegetation of the mudflow indicate that successional patterns are quite variable as there is a variety of surface substrates for colonization, means of reproduction (*e.g.,* seed vs. vegetative) and distances to seed source. Site stress (*sensu* Grimes, 1979) and exposure to disturbance, such as gully erosion and flooding, will influence successional patterns. Our initial data and evaluation of sites in terms of stress and disturbance indicate:

(1) Tree islands, roadbanks, and old soil surfaces which were buried lightly (.10 to .25 m) or exposed by erosion should have relatively rapid, steady accumulations of biomass with vegetative reproduction being very important.

(2) Seed reproduction will dominate surfaces along streams and overflow channels; these sites should exhibit a cyclical pattern of biomass accumulation due to mortality caused by seasonal flooding, erosion and deposition.

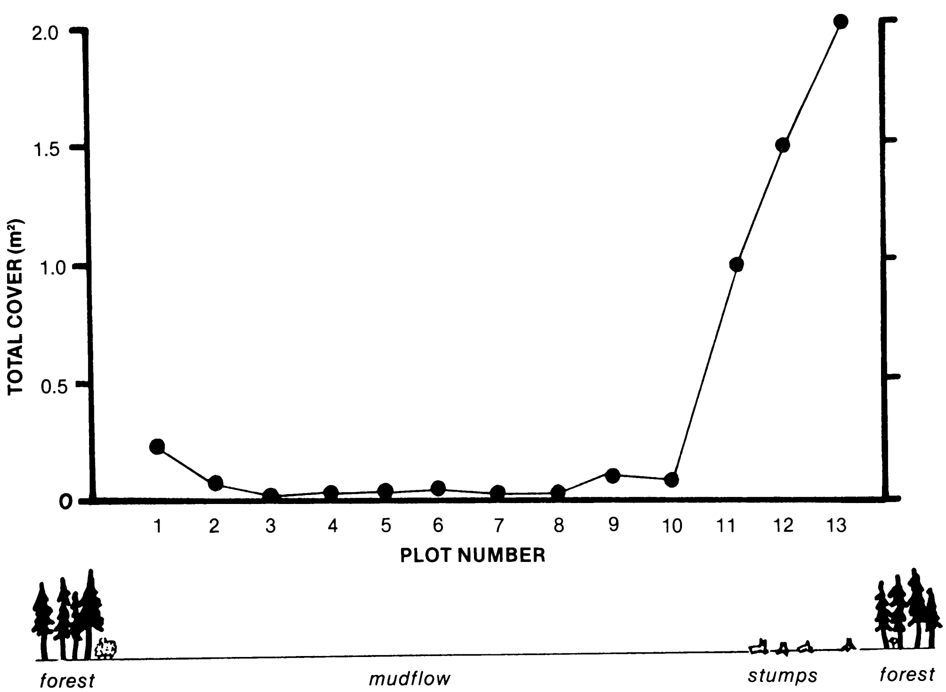

Fig. 2.—Total herb cover (square meters) for plots of transect 14 during September 1981

(3) Seed reproduction will also dominate gravel bars, sandbars and low terraces formed from reworked mudflow material and show a cyclical pattern of biomass accumulation. Exposure to floods, erosion and deposition should be less severe on these higher sites, so we expect biomass accumulation to be more rapid than in number 2.

(4) Surfaces on the Upper Muddy River which are not eroded greatly from year to year will show a steady increase in biomass. Because much of this area is far from seed sources and stressful in terms of low nutrients, temperature extremes and moisture, we expect biomass accumulation to be very slow.

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