Recovery Patterns in Stream Communities Impacted by the Mt. St. Helens Eruption

by

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ABSTRACT

Recovery patterns of benthic communities in seven small streams impacted to varying degrees by the eruption of Mt. St. Helens were examined in winter 1981-82, particularly in relation to habitat constraints. Overall abundance and diversity of the communities were low, and instability of channel banks and bottom appears to severely limit re-establishment of biota. Communities appear to be undergoing cycles of establishment and denudation in concert with changes in landscape geomorphology. Disturbance events of varying frequencies were also simulated in experimental stream channels to more closely evaluate the response of benthic communities to periodic, non-catastrophic disturbances and to compare this with the response observed to catastrophic perturbation associated with volcanic eruption. Results of simulations suggest that non-catastrophic disturances may not play a major role in determining stream community over ecological time because the predictability of these events may have enabled evolution in species of adaptive responses to cope with disturbance. Catastrophes appear to have different consequences on stream communities from other disturbances, and should be distinguished from them.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Life cycles of organisms are adapted to the stability of the habitat in which they occur, and organisms may evolve a dependency on the disturbance regime that regulates habitat persistence. When the ratio of disturbance interval to generation time becomes too large, or when disturbances are extreme, organisms are not capable of an adaptive response and cannot persist in an area (Paine 1979). For this reason, Harper (1977) suggests that catastrophes (large, extreme events destroying large portions of the population) should be distinguished from disasters (more frequent, locally disruptive influences) even though they form a continuum, because of the different consequences these events have on community structure.

The effects on the biota and habitat of small streams near Mt. St. Helens from the May 1980 eruption were certainly of catastrophic proportion. Impacts on stream channels associated with their eruption varied from light to heavy tephra deposits to pyroclastic flows, mudflows, flooding, and landslides. The effects realized by the biota included tissue abrasion, injury by impact with rock, smothering, burial, and incineration.

Rates and patterns of recovery of the impacted stream communities are dependent on the type and intensity of the impact received, and on its spatial scale. The areal extent of the damage affects the distance from a source of potential colonists, and this may determine the life history and behavioral attributes of the initial colonizing species. The type and intensity of the impact affects the extent of mortality in the community from the disturbance, and may also affect susceptibility of the stream channels to disruption from further perturbation.

Rates of recovery will vary inversely with disturbance intensity, and recovery will be faster in streams with refugia than in streams in which all internal sources of colonists were destroyed. Return to pre-eruption states should occur most quickly in streams in which damage was slight and patchy. The mechanisms and course of succession in this situation may be similar to those occurring on a small spatial scale in 'typical' streams experiencing patchy disturbance from periodic, non-catastrophic floods.

Little is known, however, of the role non-catastrophic disturbances play in determining stream community structure. For this reason, evaluation of recovery to prior equilibrial conditions is difficult. Periodic disturbances may prevent the attainment of local equilibria, and the species composition of a stream community may be continually changing.

The objectives of this study were to examine recovery of benthic communities in small streams impacted to varying degrees by the eruption of Mt. St. Helens, particularly in relation to habitat constraints, and to compare this with the response of benthic communities to periodic, non-catastrophic disturbances. The latter was evaluated by simulating disturbance events in artificial outdoor channels and monitoring colonization patterns of invertebrates and algae. Use of the Weyerhaeuser's Kalama Springs research facility for this purpose enabled us to examine response of a species source pool that is similar to that potentially available for recolonization of streams impacted by the eruption of Mt. St. Helens.

II. METHODS

Mt. St. Helens

Sites:

Seven sites, in small streams impacted to varying degrees by avalanches and mudflows from the May 1980 and subsequent eruptions of Mt. St. Helens, were selected for biological sampling. These were chosen to coincide with sites established by the U.S. Geological Survey's Cascades Volcano Observatory and the U.S. Forest Service for studies of erosion and sediment routing. Site locations are shown in Figure 1 and a description of impacts experienced and physical characteristics of the streams is listed in Table 1. One of the sites, on the upper Kalama River, received only minor mudflow from the eruption, and it was selected to serve as a control. Biological sampling and habitat surveys were conducted one to two times at each site from late October 1981 to early February 1982. Winter access to the sites was limited to helicopter travel, and unfavorable flying weather prevented more frequent sampling. Additional data from Ape Canyon are provided from short-term intensive "Pulse" studies (funded by the National Science Foundation and the U.S. Forest Service) during the summers of 1980 and 1981, and from subsequent studies of N. Anderson, and C. Hawkins (Oregon State University).

Biological Sampling:

Benthic invertebrates were sampled with a modified Hess sampler. Three to six samples were taken at each site and the substrate type associated with each sample was noted. Qualitative samples of the invertebrates attached to large woody debris were collected. Samples were preserved in 70% alcohol, and sorted in the lab. Invertebrate biomass was estimated from length-weight regressions (Rogers et al. 1976, K.W. Cummins, unpubl. data). Standing crop of chlorophyll-a and phaeophytin was estimated from rock scrapings to provide an index of algal biomass and photosynthetic capacity of the stream sites. Twenty rocks, each 8-12 cm in diameter, were collected from each site, and chlorophyll levels from these were measured by acetone extraction (Wetzel and Likens 1979).

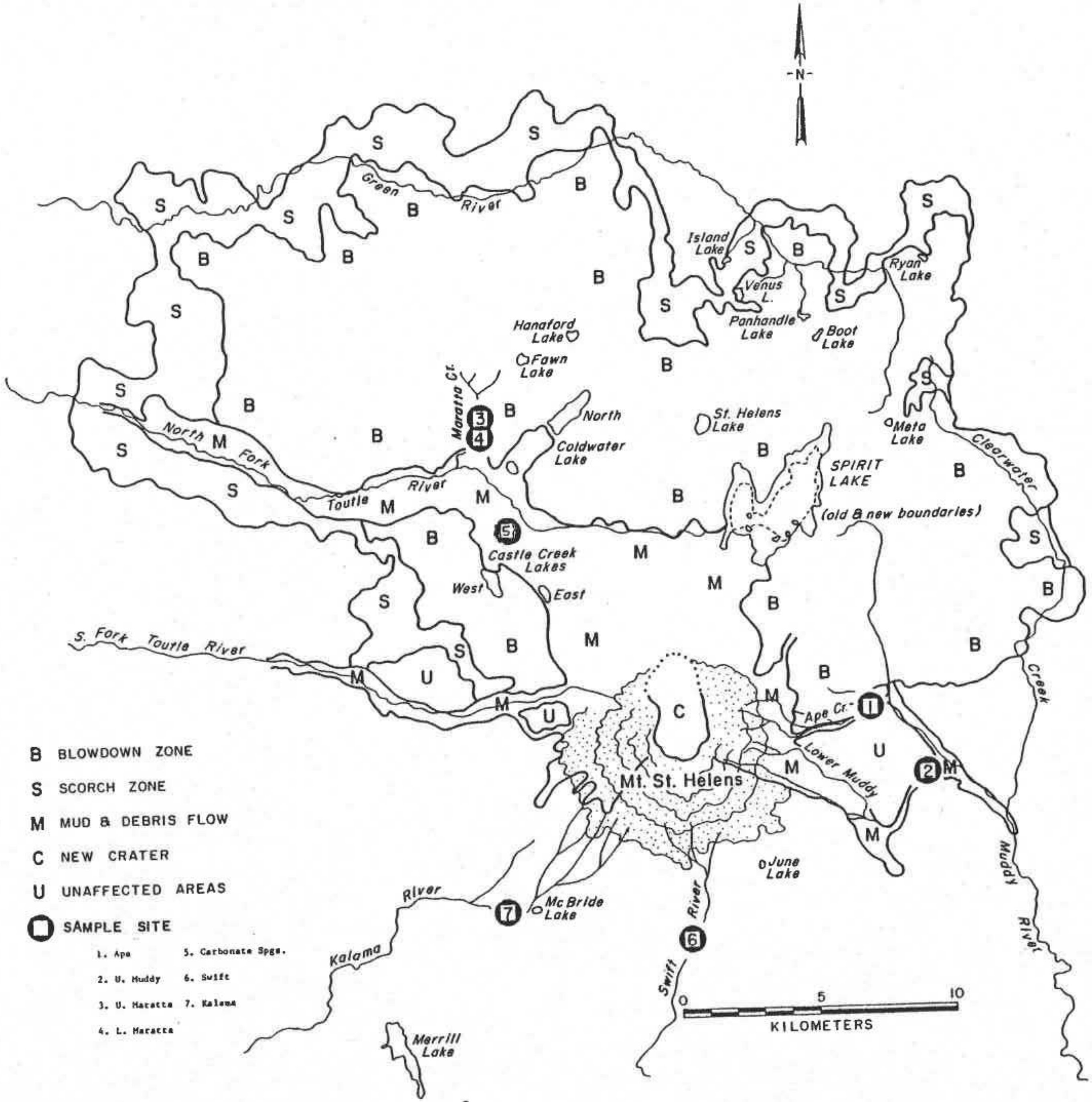


Fig. 1. Map showing location of study sites.

Table 1. Impact experienced and physical characteristics of stream sites near Mt. St. Helens.

Site	Impact from the 18 May 1980 Eruption	Streamlength (km)	Order	Elevation (m)	Drainage Area (km^2)
Ape Canyon	pyroclastic flow blast deposit	7.7	2	600	3.15
Upper Muddy	severe mudflow	9.5	2	550	7.45
Upper Maratta	Blast deposit	4.3	2	750	1.50
Lower Maratta	blast deposit, mud-flow, landslides	4.8	2	750	1.75
Carbonate Springs	new stream in avalanche zone	*	1	900	*
Swift	moderate mudflow	8.9	3	700	4.10
Kalama	minor mudflow (control)	12.4	3	800	1.95

* Data not available

Habitat Characterization:

Ten line transects were established at 5-m meter intervals at each site. At each transect, width of the wetted channel, average depth, water velocity (measured at 0.6 water depth), and substrate type were recorded. Substrate categories were broken down into the following: sand (< 1cm), fine gravel (1-2 cm), coarse gravel (3-4 cm), pebble (5-8 cm), rubble (9-16 cm), cobble (17-32 cm), small boulder (33-64 cm), large boulder (> 64 cm) and bedrock. Pebble counts (measurement of the length of the longest linear dimension of 100 randomly selected sediment particles) were taken at each site to provide estimates of mean particle size. Channel stability of each site was evaluated with the Pfankuch rating scheme (1975, Appendix 1). Drainage areas, elevation, and stream length of the sites were estimated from U.S.G.S. topographic maps. Stream gradients were measured with a clinometer.

Kalama Springs

Site description:

Three outdoor artificial streams, built and owned by the Weyerhaeuser Company, were used to experimentally investigate the response of stream benthos to periodic, non-catastrophic disturbance. The streams are fed by Kalama Springs, a cold-water spring draining into the Kalama River, in Cowlitz Co., Washington. The three streams are designed as a series of alternating pools and riffles. The riffles are 6-10 cm deep and 1-2 m wide, in lengths varying from 8-16 m. The pools are 30-50 cm deep. Approximately 10% of the flow from Kalama Springs is diverted into a series of ponds above the streams. Manipulation of wiers between the ponds allows a constant flow to be maintained in each stream. Substrate of the channels consists of coarse gravel, 2-4 cm in diameter, which overlays a fine pumice base. Water temperature is 5-7°C throughout the year. The streams are open, with no riparian canopy.

Experimental manipulations:

Disturbance events were simulated in two of the three channels by releasing a flood of water from the holding ponds above the channels and by agitating the substrate with rakes. In channel 3, disturbances were simulated once every 2 weeks, and in channel 1, once a month. Channel 2 was left unperturbed. Benthic invertebrates and algae were monitored biweekly for 3 months following the initial perturbations in the first three riffles below the holding pond of each stream. Invertebrates were sampled with a modified Hess sampler, and 8-16 tiles were placed in each riffle to investigate algal colonization patterns. This experiment was conducted from June to September 1982.

III. RESULTS

Recovery Patterns In Streams Impacted By Mt. St. Helens

Habitat constraints:

Although a survey of habitat parameters based on one or two sampling dates can be misleading, the data provide some indication of constraints imposed by the physical setting that may limit the colonization and persistence of benthic invertebrate and periphyton populations.

Measurement of such properties as stream gradient and mean channel width and depth provided a means of scaling the study areas so that comparisons could be made. Values that were measured are all fairly similar among the sites surveyed (Table 2), indicating that comparisons among sites are appropriate. Water temperatures reflect the time of day and ambient temperatures at sites on the dates at which these were measured, and values are included only to indicate that these sites were not thermally affected at this time from volcanic activity. Discharge values that were estimated are not abnormally high, and flows at this time of year were probably stable. Peak flows in streams at these elevations generally occur in late sping - early summer and late fall - early winter. Unit stream power, the rate of doing work of a stream per unit of width, equals $\frac{\rho g Q s}{w}$, where ρ = density of water, g = acceleration of gravity, Q = discharge, s = slope gradient, and w = channel width (Leopold et al. 1964).

Channel widths of the impacted sites were somewhat greater than widths typical of streams of low (first to third) order. This sugggests that the channel banks of the sites, except where they are controlled locally by bedrock, are being continually eroded and re-worked. Because rooted riparian vegetation and large organic debris are absent from most of the sites, the stabilizing influence of these elements on channel morphology is likewise absent.

Pfankuch's (1975) rating scheme was used to evaluate channel stability of the impacted streams (Appendix 1). The value of this approach is that, particularly in sites experiencing a variety of impacts associated with the eruption, many different attributes of the channel banks and bottom are considered, and are scaled relatively in importance to sediment yield. When making an evaluation, one is less likely to be influenced by a single obvious destabilizing factor. Mass wasting, for instance, appears overwhelming in most streams surrounding Mt. St. Helens, but the presence in some sites of large, angular rocks and woody debris provided stabilizing influences.

Table 2. Habitat characterization of the study sites, winter 1981-1982.

	Ape Canyon	Upper Muddy	Upper Maratta	Lower Maratta	Carbonate Springs	Swift	Kalama
Elevation (m)	600	550	750	750	900-1000	700	800
H_2O Temperature (°C)	0.8	1.0	4.0	4.0	4.5	3.5	6.0
Stream Gradient (% slope)	7	6	8	6	6	12	7
Mean Width of wetted channel (m)	5.0	4.2	4.5	7.9	3.9	5.3	5.4
Mean depth (cm)	44.0	15.0	31.0	25.9	14.6	15.6	49.4
Width to depth ratio	11	28	14	31	27	34	11
Avg. Velocity ($m\ sec^{-1}$)	0.99	0.84	1.18	1.06	0.76	0.98	1.10
Avg. Discharge ($m^3\ sec^{-1}$)	2.18	0.53	0.79	2.17	1.33	0.81	2.93
Unit stream Power	30.5	7.6	14.0	16.5	20.5	18.3	37.9
Dominant Substrate type	Rubble	Cobble	Cobble, Sm. Boulder	Sand and Cobble	Sand and Rubble	Sm. Boulder	Cobble
Mean Particle size (cm), C.V.*	14, 72.6	16, 79.8	32, 88.3	21, 197.3	9, 106.1	37, 232.9	18, 97.3

*C.V. = $\frac{100\ s_x}{\bar{x}}$

Channel stability of the impacted sites was generally evaluated as poor (Table 3), and ranking of scores reflect reasonably well the type and magnitude of impact experienced. Carbonate Springs received a very poor rating. Stream power (indicating its potential to move sediments) of the site is high (Table 2); it is a very active, braided channel cutting a floodplain in the avalanche zone of Mt. St. Helens. Lower Maratta Creek received the worst score. It, too, is located in the avalanche zone and received blast deposits. Upper Maratta, 0.5 km upstream from the lower site, received a better stability rating. It received blast deposits but lies just outside of the landslide area. Differences in rating of the two sites largely reflect differences in channel capacity, especially indexed by width to depth ratios, and in cutting of the lower banks. The bank rock content of both sites is fairly high, but much more mud is present in the lower site.

The Pfankuch scheme does, however, possess limitations, particularly in relation to biological activity. It was developed for use in the Rocky Mountains, and was designed to predict how likely a channel is to yield sediment at high flows. The scheme is of ecological importance inasmuch as unstable sediments are of ecological importance. Considerable biological activity can occur, however, in unstable streams.

The major limitation of the Pfankuch scheme for evaluation of channel stability in streams of the Pacific Northwest, and perhaps the entire country, is the inadequate emphasis it places on the role of wood debris. The presence of wood debris on slopes is rated in the scheme as a destabilizing factor because it increases sediment yields when it is moved. The role large woody debris plays as a major structural feature within stream channels (Keller and Swanson 1979, Swanson and Lienkaemper 1978) is not considered. Wood debris creates a stepped gradient and although it increases stream power locally over channel drops, it decreases stream power throughout a reach; this lends stability to the channel. The 'control site' surveyed on the upper Kalama River received a stability rating of good. Even though the site has a high stream power (Table 2), the presence of considerable in-channel debris and of rooted riparian vegetation provides a geomorphic control that appears to override its capacity to move sediments, and the site stability should probably be rated as excellent.

Table 3. Channel stability evaluation of sites near Mt. St. Helens, winter 1981-82.

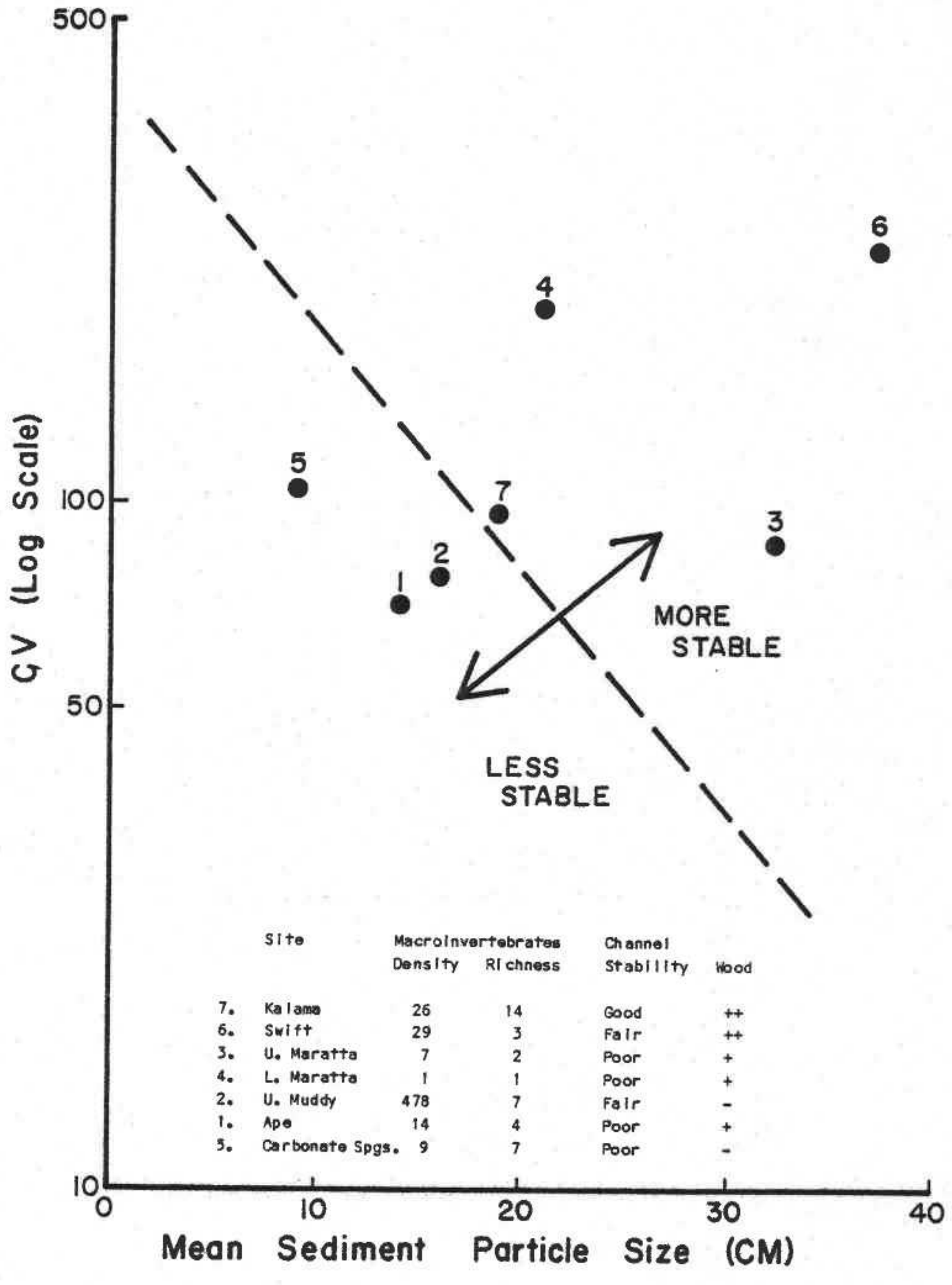
Item Rated	Ape Canyon	Upper Muddy	Upper Maratta	Lower Maratta	Carbonate Spgs.	Swift	Kalama
UPPER BANKS							
Slope	6	6	8	8	6	6	2
Mass Wasting	12	9	12	12	12	12	6
Debris Jam Potential	2	2	6	8	2	8	6
Vegetation cover	12	9	12	12	12	6	3
LOWER BANKS							
Channel capacity	2	3	2	4	4	4	2
Bank Rock content	8	4	4	4	8	8	2
Obstruction	4	4	8	8	2	6	4
Cutting	12	8	12	16	16	4	4
Deposition	12	6	11	12	16	12	4
BOTTOM							
Rock Angularity	2	2	1	1	2	1	1
Brightness	2	2	1	1	2	1	1
Consolidation	6	4	6	6	6	4	4
Bottom Size Distrib.	16	16	16	16	16	16	8
Scouring, Deposition	24	24	24	24	24	20	12
Moss and Algae	4	3	4	4	3	4	2
(Wood Debris)	+	-	+	+	-	++	++
TOTAL SCORE	124	102	127	136	131	112	61
	(Poor)	(Fair)	(Poor)	(Poor)	(Poor)	(Fair)	(Good)

The presence in the channel bottom of large angular rocks, according to the Pfankuch evaluation, is considered to be beneficial as these are not easily moved. Small, rounded rocks are destabilizing. More critical, perhaps, from a biological perspective, is the presence in the substrate of a diverse assortment of sediment sizes. Because they can interlock, sediments are probably less likely to shift if they are of different sizes. Substrate heterogeneity also provides habitat complexity, which is positively correlated with biological diversity (Gorman and Karr 1978). As another approach to channel stability evaluation, we plotted the coefficient of variation against mean sediment size (Figure 2). Large sediment sizes with a small coefficient of variation may provide substrate stability, but generally large particle size with a large coefficient of variation is indicative of good substrate stability, and small particle sizes with a small coefficient of variation indicate less stability. Evaluation of the stability of the study sites, with the exception of two outliers, corresponds fairly well with the Pfankuch rating. Upper Maratta, because of its large sediment size, and Lower Maratta, because of the large CV, were included among the more stable sites (Figure 2). The stream power of these sites may be too low to affect sediment distribution.

Biological Properties:

Overall abundance and diversity of winter assemblages of benthic invertebrates in Kalama River relative to the other sites (Table 4) indicate that it serves as a reasonable control site.

Composition of the invertebrate fauna present at each site suggests habitat conditions and the nature of the food resource base. In Carbonate Springs, only burrowing and/or case-building midges were present (Appendix 2). This indicates that the most likely food resource is fine particulate organic matter (FPOM), which is probably trapped in sediment interstices or in the periphyton film. The absence of taxa that require stable substrate for attachment, such as filter-feeding collectors or large mayfly or caddisfly scrapers, reflects substrate instability. That habitat instability may override food resource limitations is suggested by the presence in Carbonate Springs of a fairly high standing crop of chlorophyll-*a* (Table 4). The only site in which scrapers were collected is Kalama River, which exhibited slightly lower chlorophyll levels. Shredders were also abundant and diverse at Kalama River. This reflects availability of allochthonous coarse particulate organic matter (CPOM) from the



	Site	Macroinvertebrates Density	Richness	Channel Stability	Wood
7.	Kalama	26	14	Good	++
6.	Swift	29	3	Fair	++
3.	U. Maratta	7	2	Poor	+
4.	L. Maratta	1	1	Poor	+
2.	U. Muddy	478	7	Fair	-
1.	Ape	14	4	Poor	+
5.	Carbonate Spgs.	9	7	Poor	-

Fig. 2. Substrate stability indexed by mean particle size and the coefficient of variation (CV). $CV = \frac{100\, s_x}{\bar{x}}$

Dashed line represents a proposed boundary separating stable and unstable habitats.

Table 4. Biological parameters of benthic assemblages in streams near Mt. St. Helens, winter 1981-82. Standing crop of chlorophyll-*a* is estimated from means of scrapings from twenty rocks on one sampling date at each site. Invertebrate density and biomass are estimated from means of 3-6 Hess samples on one sampling date at each site. Taxonomic richness is the total number of taxa collected at each site. Sampling dates are 17 Dec. (Kalama), 18 Dec. (Swift), 7 Jan. (Carbonate Springs), 15 Jan. (Upper and Lower Maratta), 26 Jan. (Ape Canyon), and 10 Feb. (Upper Muddy).

	Chlorophyll-*a* (mg/m^2)	Invertebrate Density ($No/0.05\ m^2$)	Invertebrate Biomass ($mg/0.05\ m^2$)	Invertebrate Taxonomic Richness
Ape Canyon	14.4	14	2.25	4
Upper Muddy	74.0	47.8	113.32	7
Carbonate Springs	82.0	7	1.34	2
Upper Maratta	3.2	1	0.01	1
Lower Maratta	1.6	9	2.13	7
Swift	12.5	28	6.79	3
Kalama	66.3	26	19.23	14

undisturbed riparian zone. A nemourid stonefly was the only shredder found at any of the impacted sites. Its food resource probably consists of CPOM buried during the eruption and periodically re-excavated as the sediments move about. The dominant functional group of invertebrates at impacted sites is collectors. Their food source is also derived from buried organic matter as well as from sloughed periphyton. Predators were found only at sites that supported a fairly high richness of other invertebrate taxa. Because predators are typically long-lived, with life cycles of one or more years, habitat disruption may also prevent their re-establishment in impacted stream reaches. The life cycles of the dominant taxa (midges) found in the impacted streams are relatively shorter, with two or more generations per year.

Apart from burrowing, another strategy enabling persistence in unstable sediments is exhibited by Baetis mayflies, which actively swim about and utilize FPOM. This was the only species collected at Upper Maratta. Baetis spp. also occurred in Ape Canyon and Upper Muddy.

Taxonomic richness and abundance of the invertebrate fauna appear to be fairly closely linked with the evaluation of channel stability of the study sites (Figure 2). An exception to this relationship is exhibited by Upper Muddy, which has poor stability and a high invertebrate standing crop. No explanation is readily apparent for this anomaly. Perhaps an unidentified refugia exists nearby that provides a constant source of colonists.

Changes in density (Figure 3) and in taxonomic richness (Figure 4) of invertebrates in Ape Canyon since the 1980 eruption suggest that re-establishment of fauna is a temporary phenomenon, and that a succession of stable and non-stable cycles may occur in any given reach until the overall landscape instability is lessened. Complete recovery of stream communites affected by the eruption may be on a time scale of up to 10^2 years or longer.

Experimental Simulations of Disturbance

Benthic Invertebrates:

Two general trends were observed in the abundance among channels of taxa that appeared consistently in samples. One trend is that the abundance of some taxa was much greater at the termination of the experiment in the unperturbed channel (Channel II) than in the two disturbed channels (Figure 5a). This trend was exhibited by a number of taxa, occurring in different functional groups.

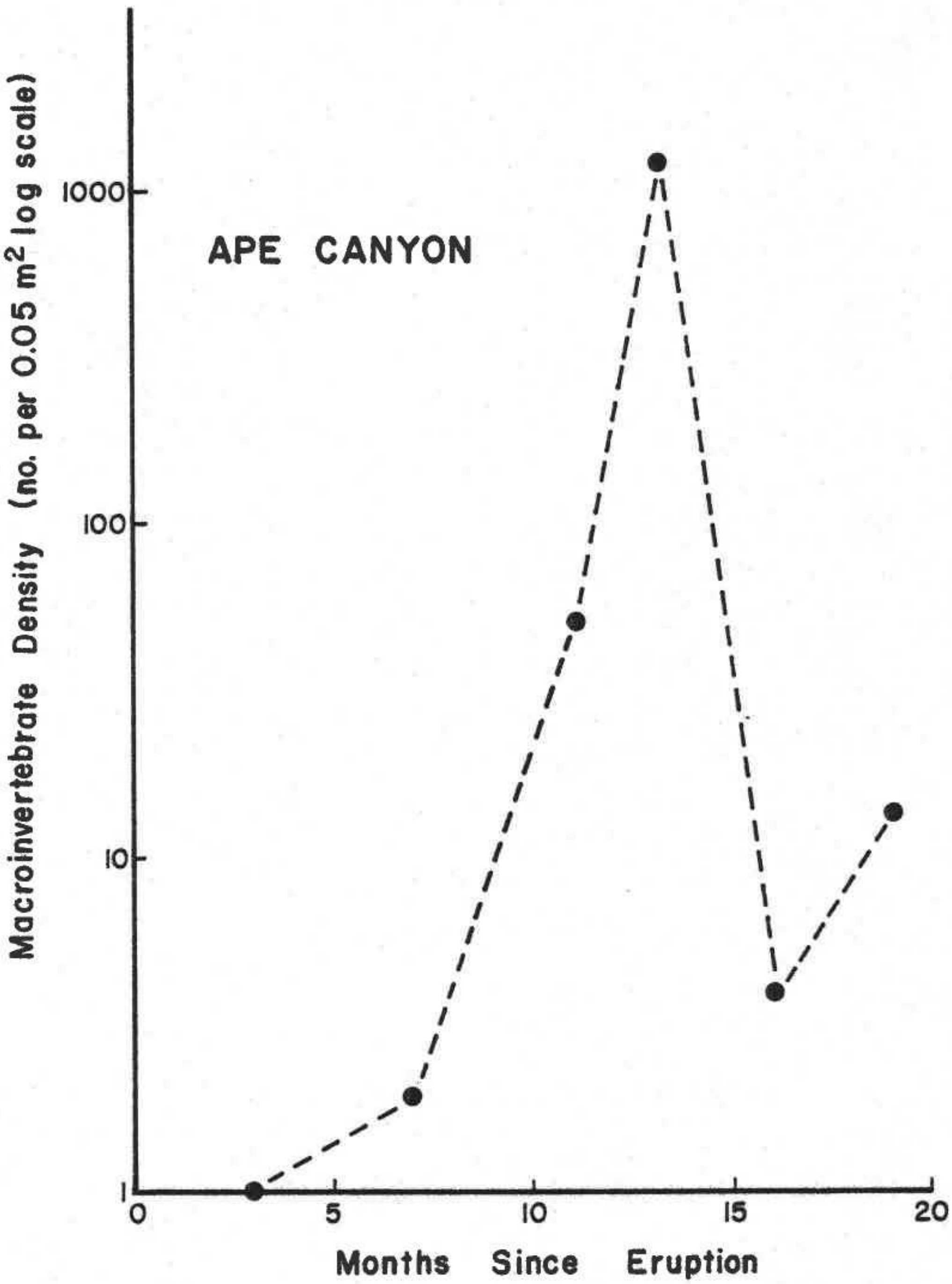


Fig. 3. Macroinvertebrate density in Ape Canyon since the eruption (May 1980) of Mt. St. Helens. Except for sample at 19 months, data are from Anderson and Hawkins (unpubl.).

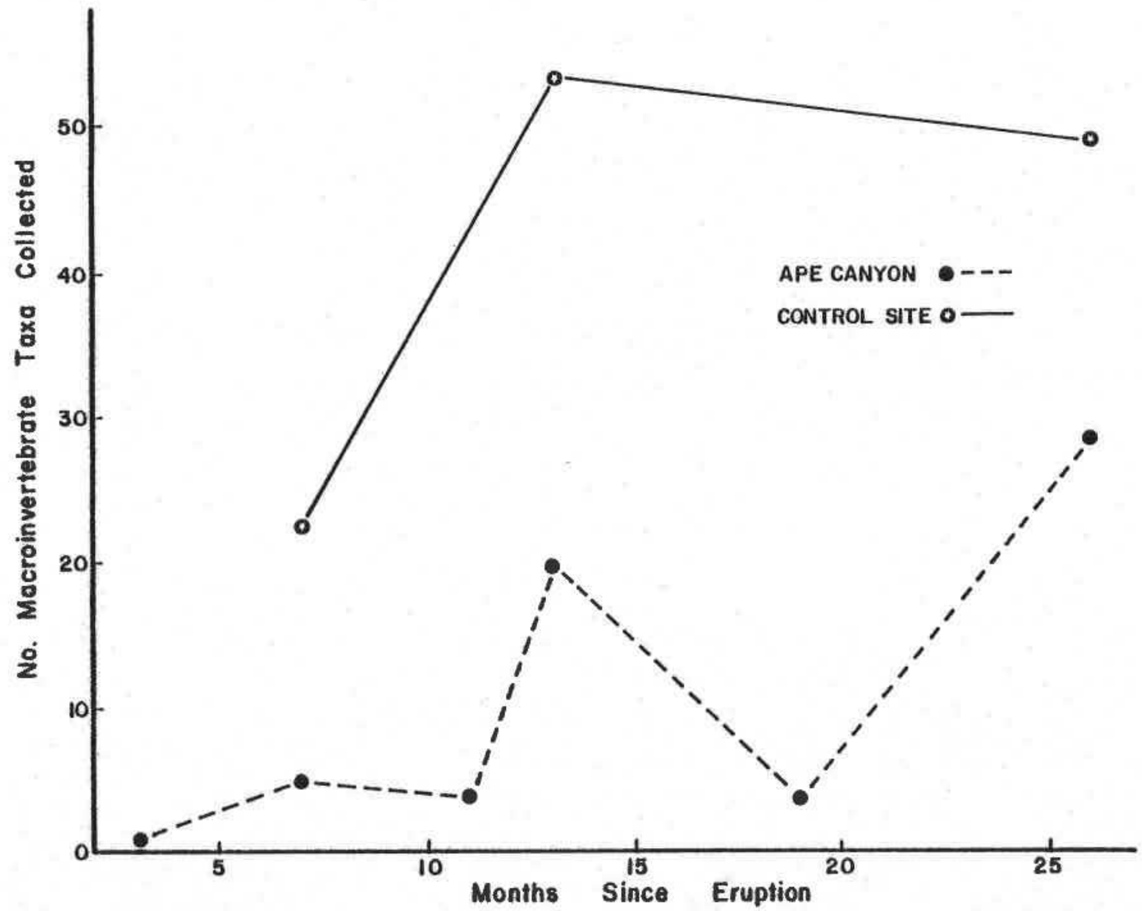


Fig. 4. Taxonomic richness of macroinvertebrates in Ape Canyon and an unimpacted stream since the eruption of Mt. St. Helens. Except for sample at 19 months, data are from Anderson and Hawkins (unpubl.). The unimpacted site is Norm's Creek, a tributary of the Middle Clearwater River.

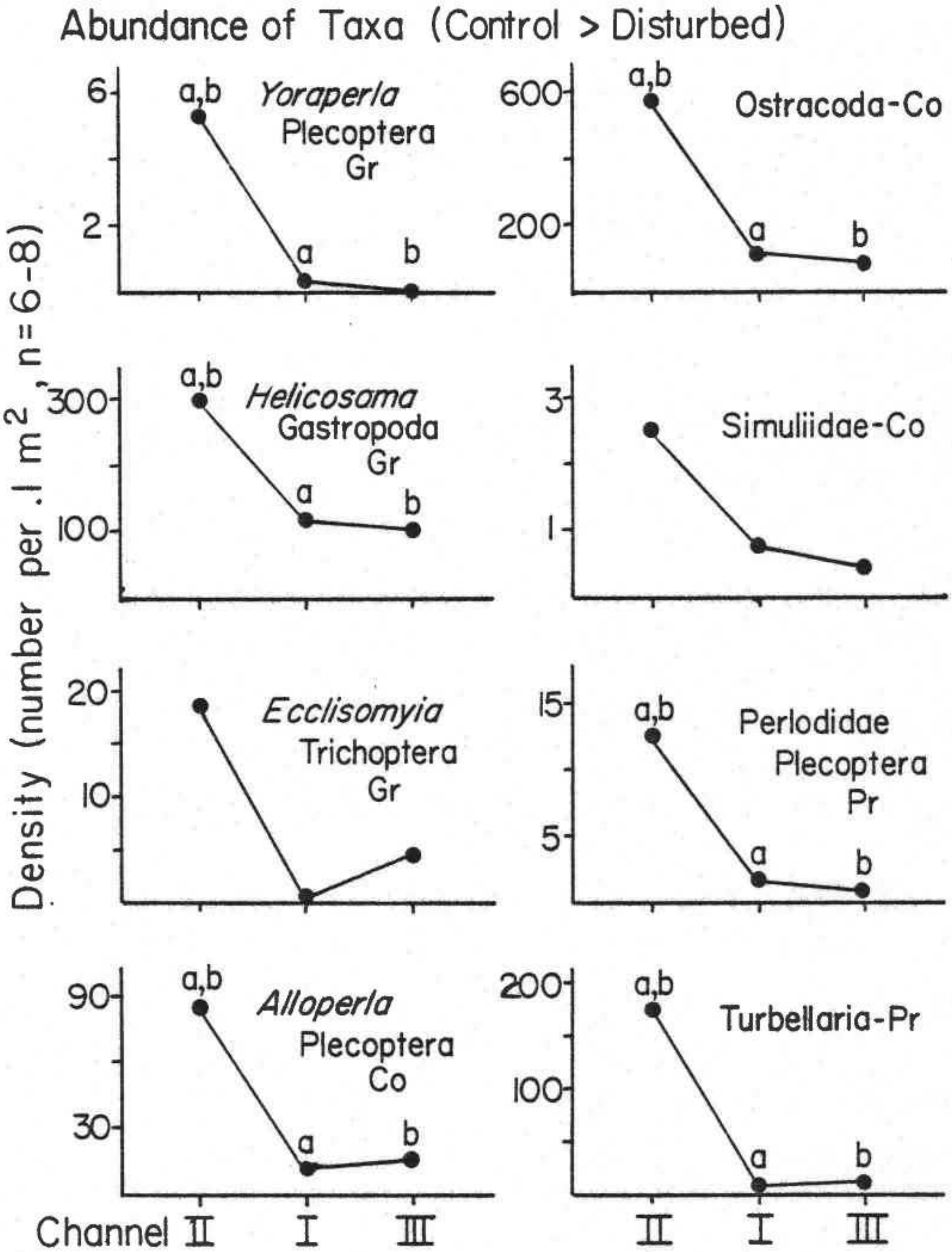


Fig. 5a. Abundance of macroinvertebrate taxa at Kalama Springs three months after disturbance simulations, (groups for which control > disturbed). Channels are ordered along an axis of increasing disturbance frequency. Co = collector, Sh = shredder, Gr = grazer (scraper), Pr = predator.

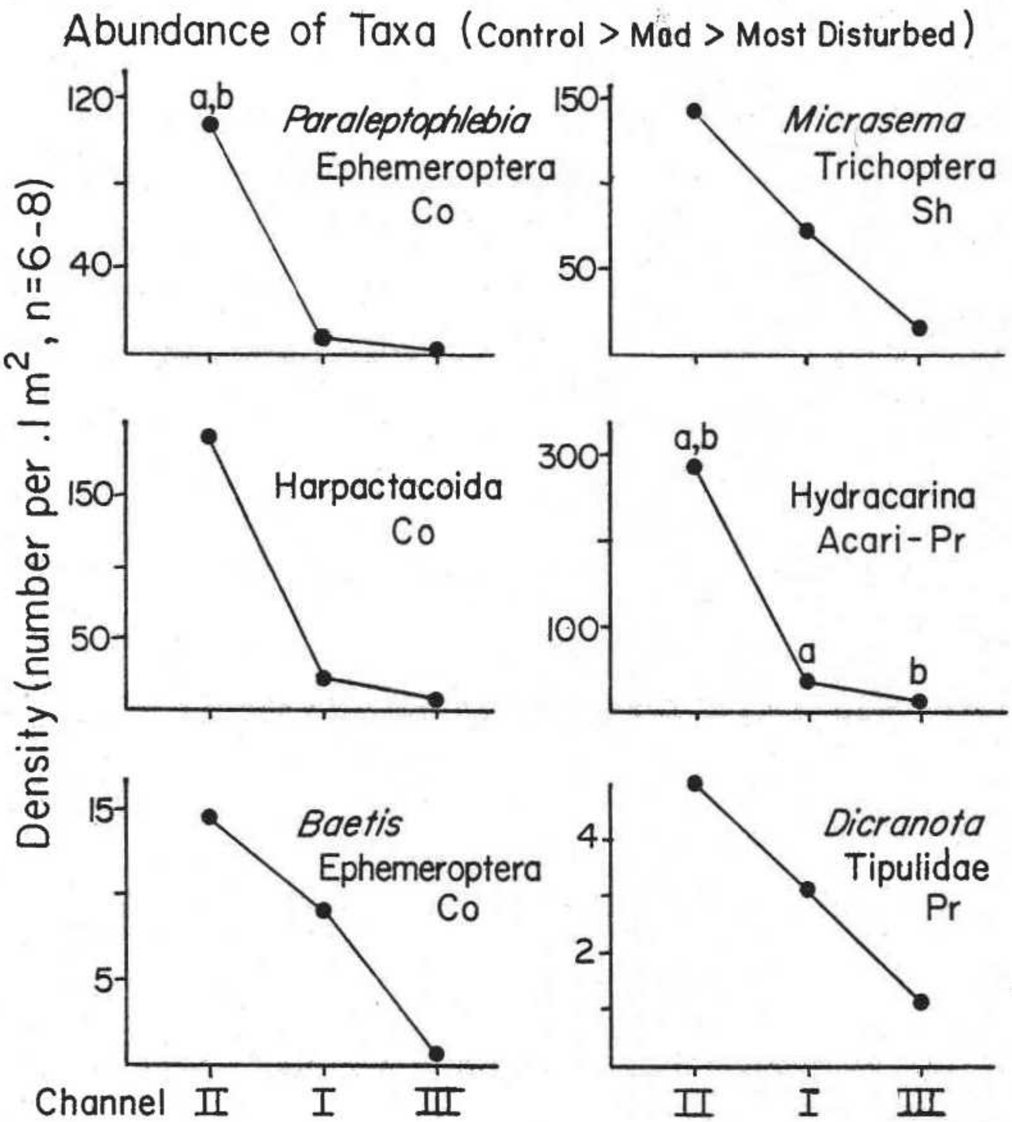


Fig. 5b. Abundance of macroinvertebrate taxa at Kalama Springs three months after disturbance simulations, (groups for which control > mod > disturbed). Channels are ordered along an axis of increasing disturbance frequency. Co = collector, Sh = shredder, Gr = grazer (scraper), Pr = predator.

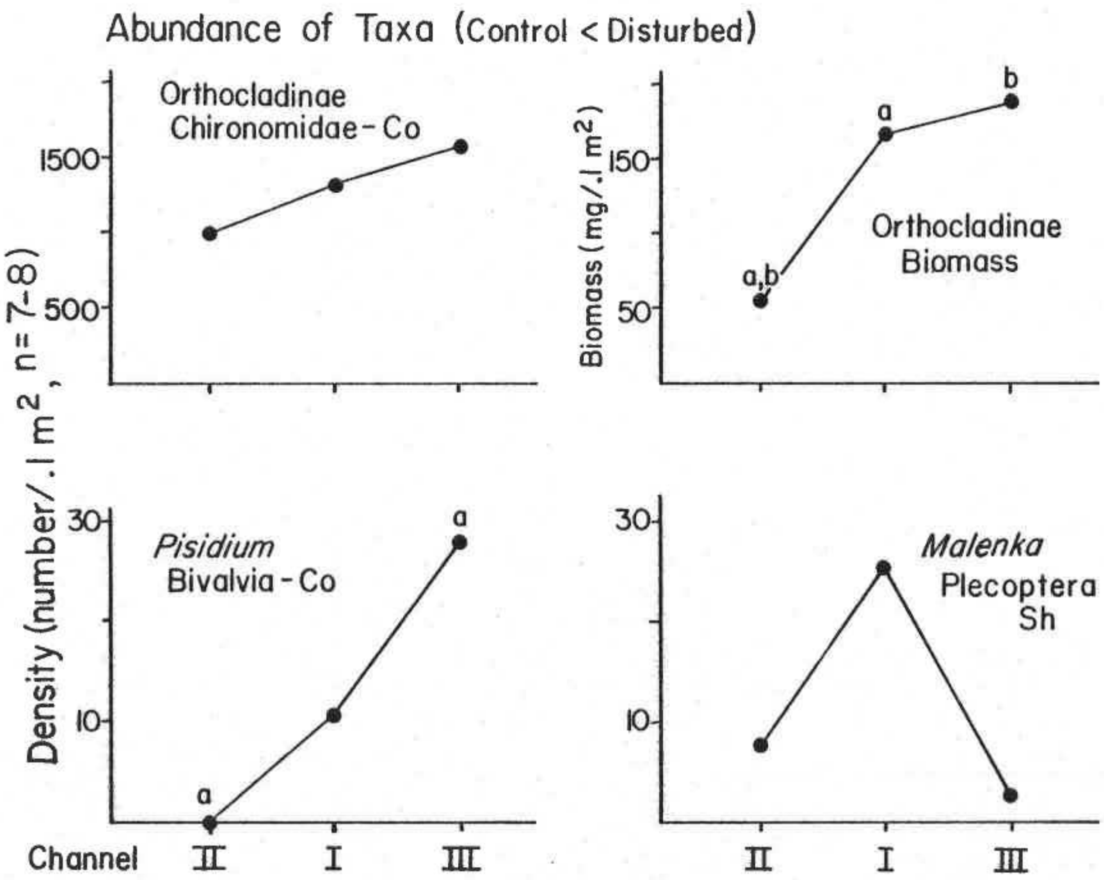


Fig. 5c. Abundance of macroinvertebrate taxa at Kalama Springs three months after disturbance simulations, (groups for which control < disturbed). Channels are ordered along a gradient of increasing disturbance frequency. Co = collector, Sh = shredder, Gr = grazer (scraper), Pr = predator.

Three of these taxa, the snail Helicosoma, Ostracods, and the planaria Drotophela, were very abundant in the unperturbed channel, attaining densities of 1800-6000 individuals m^{-2}. In some instances, the abundances of taxa were also greater in the moderately perturbed channel (I) than in the frequently perturbed one (III) (Figure 5b). Included here are the baetid mayflies and mites that are among the initial colonists of heavily impacted streams near Mt. St. Helens.

A second trend was exhibited by a few taxa in which abundance was greater at the termination of the experiment in one or both of the disturbed channels than in the unperturbed channel (Figure 5c). This pattern may represent a release in numbers, either from the elimination of competitors or predators, or an increase in resource availability that occurs in the presence of non-catastrophic disturbance events. This trend occurred among the orthoclad midges, which largely dominated the community of the disturbed channels, reaching densities of up to 15,000 individuals per m^2, but it is statistically significant only for biomass ($p < .05$, ANOVA) and not for density. An unidentified orthoclad species occurred in the most frequently perturbed channel that was fewer in number but much larger in size than the species inhabiting other channels, and this accounts for the greater biomass observed in this channel. The clam Pisidium never occurred in any sample taken from the unperturbed channel.

Total density, biomass, and diversity of the invertebrate assemblages were similar enough among channels prior to disturbance simulations to make us confident that the differences we observed following disturbance were attributable to the disturbance regime (Table 5). Both density and diversity of the assemblages after the initiation of the disturbance events were higher in the channel never perturbed, and were somewhat greater in the channel more frequently perturbed, than in the more moderately perturbed. The diversity in the moderately perturbed channel (I) declined after one month of disturbance simulations, suggesting that one might observe in this channel a hyperbolic curve of species diversity over time, similar to that observed in other successional communities (Connell and Slatyer 1977). A decline in diversity over time was not observed in channel III, probably because disturbances occurred too frequently to allow the colonization of competitively superior taxa. Biomass following disturbance simulations was remarkably similar among

Table 5. Community composition parameters of benthic invertebrates prior to and after disturbance simulations at Kalama Springs. Values represent means of six samples within each channel.

	Channel		
	II	I	III
	Increasing Disturbance→		
Before Disturbance			
Density/0.1 m^2	3043	2441	3464
Biomass/0.1 m^2	378.0	386.9	453.6
M.D.I.*	1317.6	1451.0	1832.8
After Disturbance (1 mo.)			
Density/0.1 m^2	2989	1343	1787
Biomass/0.1 m^2	287.8	333.0	296.8
M.D.I.*	1447.1	604.3	240.8
After Disturbance (3 mos.)			
Density/0.1 m^2	2800	1758	1957
Biomass/0.1 m^2	246.4	238.2	244.0
M.D.I.*	1483.2	357.2	240.8

*M.D.I. = McIntosh Diversity Index = $N- \sum_{i=1}^{s} n_i^2$

channels (Table 5). This suggests that compensatory changes occur in stream community structure that act to maintain a constancy in at least some aspects of community function.

The structural resemblance of pairs of channels with each other was estimated by use of the Curtis percentage similarity measure, which ranges from 0 to 100. A value of 100 indicates complete similarity. All channels were structurally similar prior to disturbance (Table 6). After three months, channel II, the unperturbed channel, was very different from both channels I and III. Similarity here was altered both because of the dominance of orthoclad midges in the disturbed channels and because of the loss in these channels of some sensitive taxa, such as the predatory perlodid stoneflies and the grazing

Invertebrate assemblages were partitioned into functional groups to enable an assessment and comparison among channels of the trophic as well as taxonomic structure. Functional group designations were assigned according to Merritt and Cummins (1979). The proportional biomass of shredders three months after

Table 6. Similarity of invertebrate assemblages among channels prior to and three months after disturbance simulations at Kalama Springs.

PS* Channels	Before Disturbance	After Disturbance
1,2	.769	.288
2,3	.806	.427
1,3	.941	.835

*PS is the Curtis Percentage Similarity Measure.

$$PS = \frac{200 \; \Sigma \; MIN \; (N_{IH}, N_{IK})}{\sum_{i=1}^{s} (N_{HI} + N_{KI})}$$

disturbance was small in all channels (Figure 6). This was expected, as the resource base in the channels is largely autotrophic. The collector component, largely comprised of midges, dominated the disturbed channels, and a large relative increase in the predator functional group was observed in the unperturbed channel. The proportional biomass of grazers (scrapers) in the unperturbed channel was also somewhat larger than in the disturbed channels. The functional group structure of the invertebrates colonizing heavily impacted, unstable streams near Mt. St. Helens is similar to that observed in the experimentally disturbed streams. Scrapers and predators occur in low abundance in these streams, because the large and stable substrate required by scrapers for attachement is absent, and the abundance and predictability of food resources required by both groups is low.

Periphyton:

The early colonizing species in all channels was predominantly *Diatoma hiemale* var. *mesodon*, which forms a gelatinous matrix after one month. Successive algal taxa included the filamentous xanthophyte *Tribonema* and the chrysophyte *Hydrurus foetidus*. *Diatoma* was most abundant in the most frequently perturbed channel. Chlorophyll-*a* levels of the periphyton assemblages were highly variable within and among channels, ranging from 1.3 to over 400 Mg m^{-2}. The standing crop of chlorophyll-*a* was generally greater, but not significantly so, in the unperturbed than in the perturbed channels.

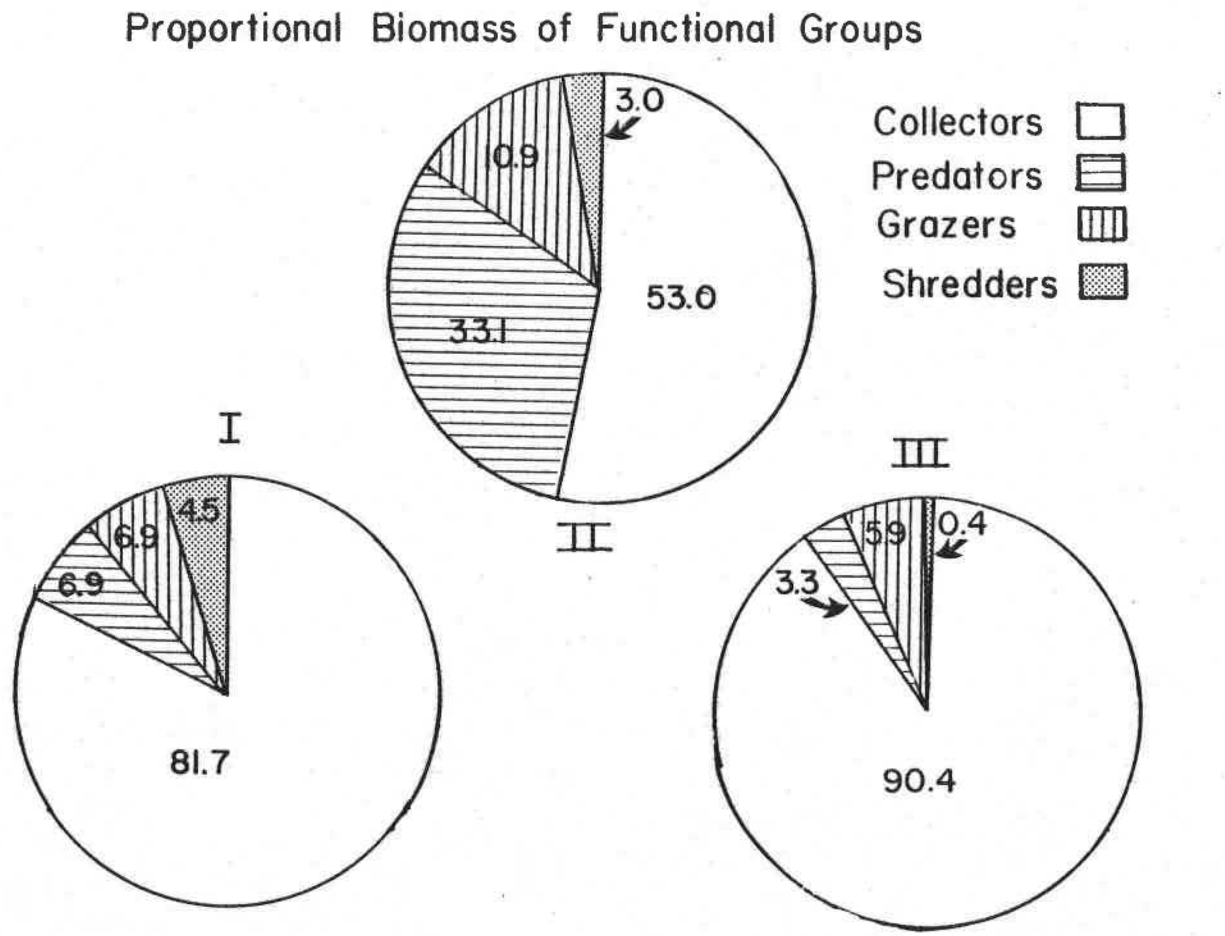


Fig. 6. Proportional biomass of invertebrate functional groups at Kalama Springs three months after disturbance simulations. Channel II was unperturbed, Channel I was disturbed every two weeks, Channel III was disturbed once a month.

IV. DISCUSSION

A lower density and diversity of invertebrate fauna, both taxonomically and trophically, were observed in stream channels in which disturbance events were simulated than in an unperturbed channel. There is some indication, however, that some community properties, notably biomass, remain constant among different disturbance regimes.

These findings suggest that non-catastrophic disturbances may not play a major role in determining stream community structure over ecological time. Non-catastrophic disturbances in many streams are fairly predictable events, and species may have evolved behavioral and other adaptations to deal with them. Adaptations relevant to competitive situations, be it in usurping resources or in withstanding attacks from natural enemies that might be necessary in the absence of disturbance, may not have evolved.

We are reluctant to generalize from our findings, however, to dismiss the potentially large role that non-catastrophic disturbance may play in streams, because a number of factors not considered in our experiment will also affect the role disturbance plays. The spatial distribution of disturbance is one of these. Effects of non-catastropic disturbance in most streams are patchy in nature as some microhabitats are more immune to disruption than others. A given disturbance regime produces a distribution of patch ages, and the effect on the community is properly the summation of patch effects. And, critically, the exact effect of periodicity of disturbance events is unresolved. Disturbances at a rate of once per month, relative to the annual hydrographs typical of streams in the Pacific Northwest, are probably too frequent to allow more slowly dispersing colonists to enter a community.

Life history attributes and composition of the invertebrate fauna that were collected in streams severely impacted by the eruption of Mt. St. Helens are similar to those of the invertebrate fauna in the most frequently disturbed channel at Kalama Springs. In both cases, communities are dominated by chironomid midges. Abundances, however, are greatly reduced in the streams surrounding Mt. St. Helens, and evidence that the communities are undergoing cycles of establishment and denudation in concert with changes in landscape geomorphology indicates that catastrophes have different consequences on stream communities from other disturbances, and should be distinguished from them.

Instability of channel banks and bottoms in streams severely impacted by the eruption appears to pose a major impediment to recovery of benthic communities. Until these elements stabilize, communities will consist only of short-lived fugitive-type species that will be swept downstream with each successive high flow event. Community recovery can perhaps be enhanced by management practices that promote channel stability, such as planting of riparian vegetation or introduction of stable substrates into a stream.

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VI. APPENDICES

1. Channel Stability Evaluation
2. Invertebrate Taxa Collected From Stream Impacted By Mt. St. Helens, winter 1981-82.

Appendix 1. Channel stability evaluation (Pfankuch 1975).

Item Rated	Stability Indicators by Classes							
	EXCELLENT		GOOD		FAIR		POOR	
UPPER BANKS								
Landform Slope	Bank slope gradient <30%	2	Bank slope gradient 30-40%	4	Bank slope gradient 40-60%	6	Bank slope gradient 60%+	8
Mass Wasting Existing or Potential	No evidence of past or potential for future mass wasting into channels.	3	Infrequent and/or very small. Mostly healed over. Low future potential.	6	Moderate frequency & size, with some raw spots eroded by water during high flows.	9	Frequent or large, causing sediment nearly yearlong or imminent danger of same.	12
Debris Jam Potential Floatable Objects	Essentially absent from immediate channel area.	2	Present but mostly small twigs and limbs.	4	Present, volume and size are both increasing.	6	Moderate to heavy amounts, predominantly larger sizes.	8
Bank Protection from Vegetation	90% + plant density. Vigor and variety suggests a deep, dense root mass.	3	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	6	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	9	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	12
LOWER BANKS								
Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio<7.	1	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8-15.	2	Barely contains present peaks. Occasional overbank floods. W/D ratio 15-25.	3	Inadequate. Overbank flows common. W/D ratio 25.	4
Bank Rock Content	65%+ with large, angular boulders 12"+ numerous	2	40-65%, mostly small boulders to cobble 6-12".	4	20-40%, with most in the 3-6"diameter class.	6	<20% rock fragments of gravel sizes, 1-3" or less.	8
Obstructions Flow Deflectors Sediment Traps	Rocks, old logs firmly embedded. Flow pattern of pool & riffles stable without cutting or deposition.	2	Some present, causing erosive cross currents and minor pool filling. Obstructions and deflectors newer and less firm.	4	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sed. traps full, channel migration occuring.	8
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	4	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12".	8	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
Deposition	Little or no enlargement of channel or point bars.	4	Some new increases in bar formation, mostly from coarse gravels.	8	Moderate deposition of new gravel & coarse sand on old and some new bars.	12	Extensive deposits of predominately fine particles. Accelerated bar development.	16
BOTTOM								
Rock Angularity	Sharp edges and corners, plane surfaces roughened.	1	Rounded corners & edges, surfaces smooth & flat	2	Corners & edges well rounded in two dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
Brightness	Surfaces dull, darkened, or stained. Gen. not "bright".	1	Mostly dull but may have up to 35% bright surfaces.	2	Mixture, 50-50% dull and bright, ± 15%; i.e., 35-65%.	3	Predominately bright, 65%+ exposed or scoured surfaces.	4
Consolidation or Particle Packing	Assorted sizes tightly packed and/or overlapping.	2	Moderately packed with some overlapping.	4	Mostly a loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
Bottom Size Distribution Percent Stable Material	No change in sizes evident. Stable materials 80-100%	4	Distribution shift slight. Stable materials 50-80%.	8	Moderate change in sizes. Stable materials 20-50%.	12	Marked distribution change. Stable materials 0-20%.	16
Scouring and Deposition	Less than 5% of the bottom affected by scouring and deposition.	6	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
Clinging Aquatic Vegetation Moss & Algae	Abundant. Growth largely moss like, dark green, perennial. In swift water too.	1	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	2	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	3	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4
	COLUMN TOTALS							

Record the values in each column for a total reach score. (E.___ + G.___ + F.___ + P.___ = __)

Reach score of: 38 = Excellent, 39-76 = Good, 77-114 = Fair, 115+ = Poor.

APPENDIX 2. Invertebrate taxa collected in stream sites impacted by Mt. St. Helens, winter 1981-82.

Ape Canyon
Ephemeroptera
  Baetis bicaudatus
  Baetis tricaudatus
Plecoptera
  Shipsa sp.
Diptera
  Diamesinae spp.

Upper Muddy
Ephemeroptera
  Baetis tricaudatus
Plecoptera
  Malenka sp.
  Megarcys sp.
Trichoptera
  Rhyacophila sp.
Diptera
  Limnophora sp.
  Orthocladiinae spp.

Upper Maratta
Ephemeroptera
  Baetis tricaudatus

Swift Creek
Diptera
  Orthocladiinae spp.
  Diamesinae spp.
  undetermined Tipulidae
Other:
  Acari (exuvia)
  centipede (terrestrial)

Carbonate Springs
Diptera
  Orthocladiinae spp.
  Diamesinae spp.

Lower Maratta
Hemiptera
  Trichocorixa spp.
Trichoptera
  Pseudostenophylax sp.
Diptera
  Simulium sp.
  Empididae
  Orthocladiinae spp.
  Diamesinae spp.
Other:
Naididae (Oligochaeta)

Kalama River
Ephemeroptera
  Ephemerella coloradensis
  Drunella sp.
  Epeorus longimanus
Plecoptera
  Malenka sp.
  Megarcys sp.
  Perlodidae
Trichoptera
  Lepidostoma quercina
  Hydatophylax sp.
  Pseudostenophylas sp.
  Micrasema sp.
  Neotheremma sp.
  Rhyacophila sp.
Diptera
  Dicranota sp.
  undetermined Tipulidae
  Twinnia sp.
  Orthocladiinae spp.
  Empididae sp.
Other:
Naididae (Oligochaeta)