20 April 1982

JOURNAL OF THE KANSAS ENTOMOLOGICAL SOCIETY
55(2), 1982, pp. 290–296

Volcanic Ash Accumulation and Ash-Voiding Mechanisms of Aquatic Insects[1]

F. M. GERSICH AND M. A. BRUSVEN
Department of Entomology, University of Idaho, Moscow 83843

ABSTRACT: Four species of aquatic insects (*Hesperoperla pacifica, Rhyacophila acropedes/R. vao, Drunella doddsi* and *Rhithrogena robusta*) were subjected to suspended ash concentration of ca. 2000 mg/l in laboratory streams for 48 hr. Macro- and microscopic examination revealed substantial ash accumulation on the exoskeleton; however, acute toxicity was not noted. Ash-impacted aquatic insects placed in a clean water environment voided appreciable amounts of ash within 24 hr. We conclude that the four species studied had high short-term exposure tolerances to ash and that behavioral attributes allowed for the removal of exoskeletal ash deposits once the perturbation ceased.

Volcanic activity in the Cascade Mountain Range of western Washington during 1980 represented a potentially detrimental influence on aquatic ecosystems within regions of ash fallout. Areas in northern Idaho were impacted by the primary ash plume from Mt. St. Helens 18 May and subsequent eruptions. Ash deposition within the effected area ranged from a few millimeters to five or more centimeters (Cook et al., 1981).

The mineralogical properties of volcanic ash have been studied by Fruchter et al. (1980) and Hooper et al. (1980). Cook et al. (1981) reported ash acting as an abrasive on the epicuticular wax layer on terrestrial insects causing rapid desiccation and death.

Information concerned with the effects of volcanic ash on aquatic insects is poorly known. Aquatic insects are integral components of stream ecosystems and serve as an intermediate link in the plant-to-fish food chain. Adverse effects of volcanic ash on the lower levels of the food chain could ultimately influence higher trophic levels and affect overall stream ecosystem stability.

Because of the general lack of information on the effects of ash on aquatic insects, we conducted a series of laboratory studies to: 1) examine the location and deposition of ash on the exoskeleton, especially respiratory structures, and 2) examine ash-voiding mechanisms of insects.

---

[1] Research support in part by USFS Research Agreement No. INT-80-121-CA. Approved by the Director of the Idaho Agricultural Experiment Station as Research Paper No. 8166.
Received for publication 10 July 1981.

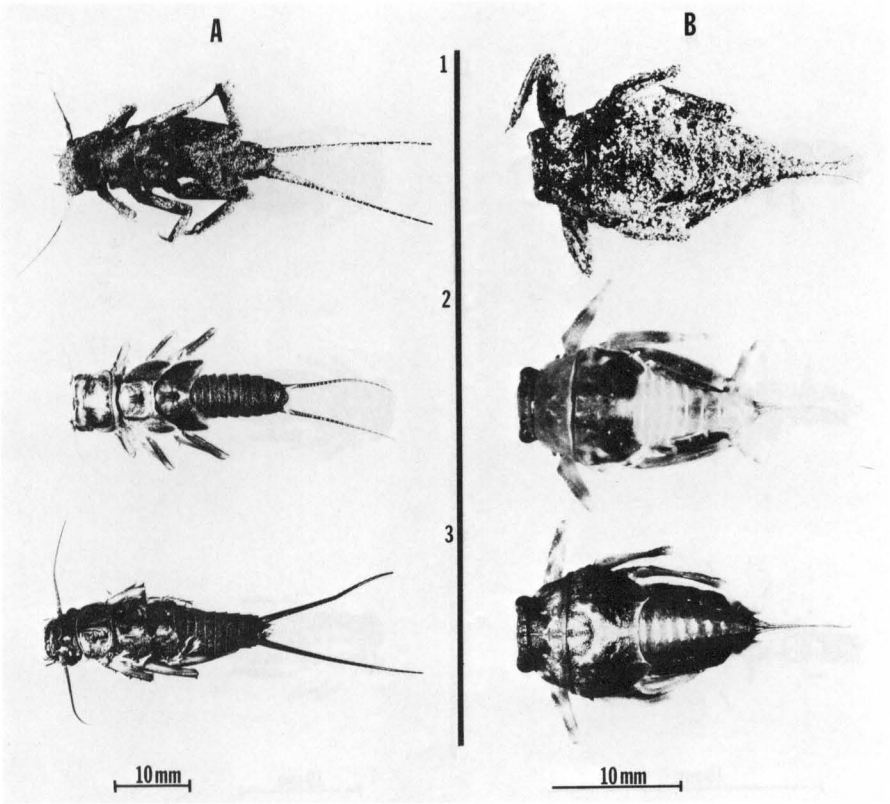

Fig. 1. Macroscopic dorsal views of *Hesperoperla pacifica* (A) and *Drunella doddsi* (B). (1 = ash-impacted, 2 = control, 3 = ash-voided).

Methods and Materials

Oval plexiglas streams described by Brusven (1973) were used. Insects were collected in the field and placed in 20 × 20 × 15 cm aluminum screened cages in control (ash-free) and test (ash-impacted) streams maintained at 8.0 ± 2.0°C and mean current velocity of 0.18 m/sec. The cages were suspended ≃3.0 cm above the stream bottom. Suspended ash in the impacted stream was maintained at 2000 ± 200 mg/l. The ash was collected immediately after the May 18 eruption and conformed to physical properties characterized by Hooper et al. (1980).

Fifteen late instar naiads or larvae of four insect species were examined for exoskeletal ash accumulation after 48 hr exposure to an ash and non-ash impacted stream. The four species studied were the stonefly *Hesperoperla pacifica* (Banks), the caddisfly complex *Rhyacophila acropedes* Banks/*R. vao*

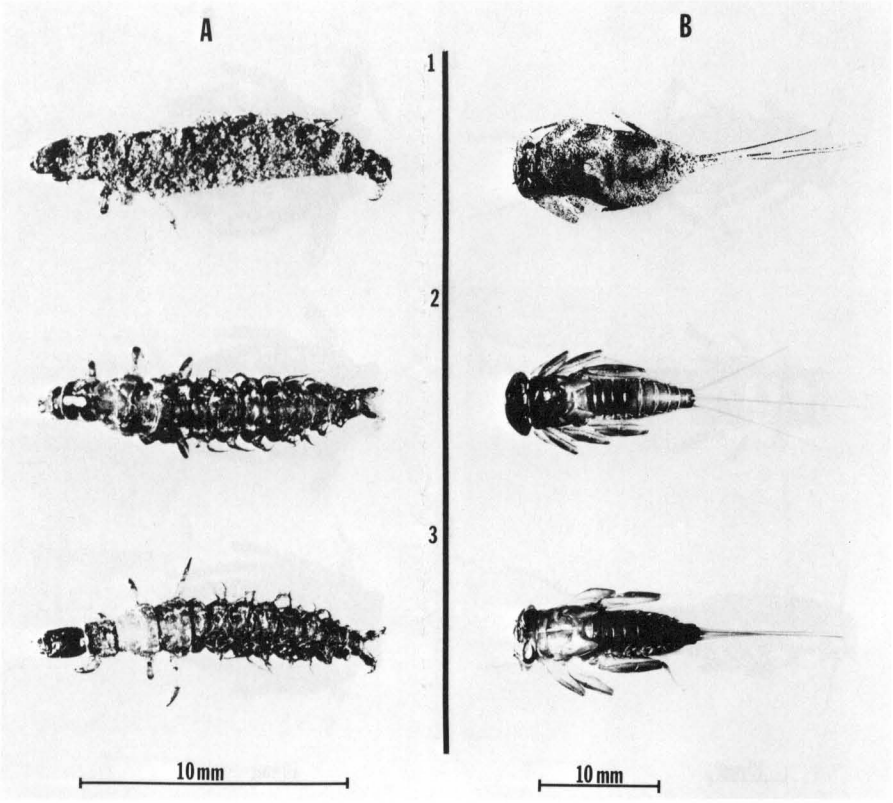

Fig. 2. Macroscopic dorsal views of *Rhyacophila acropedes/vao* (A) and *Rhithrogena robusta* (B). (1 = ash-impacted, 2 = control, 3 = ash-voided).

Milne and the mayflies *Drunella doddsi* Needham and *Rhithrogena robusta* Dodds. These species were chosen because of their common occurrence in streams impacted by ash, availability and functional status. After 48 hr, five insects were removed from each stream and preserved. The remaining insects from the ash-impacted stream were removed and placed in an ash-free stream for 24 hr to observe and evaluate ash-voiding behavioral mechanisms. Mobility and other body movements (e.g. leg flexing) were the primary behavioral mechanisms examined.

The dorsum of insects taken from ash-free and ash-impacted streams was photographed using standard macrophotography techniques for purposes of documenting regions of ash deposition and ash-voiding properties.

The distribution and effects of volcanic ash on external respiratory structures of selected aquatic insects were investigated by scanning electron microscopy (SEM). Insects used in this experiment were those previously cited

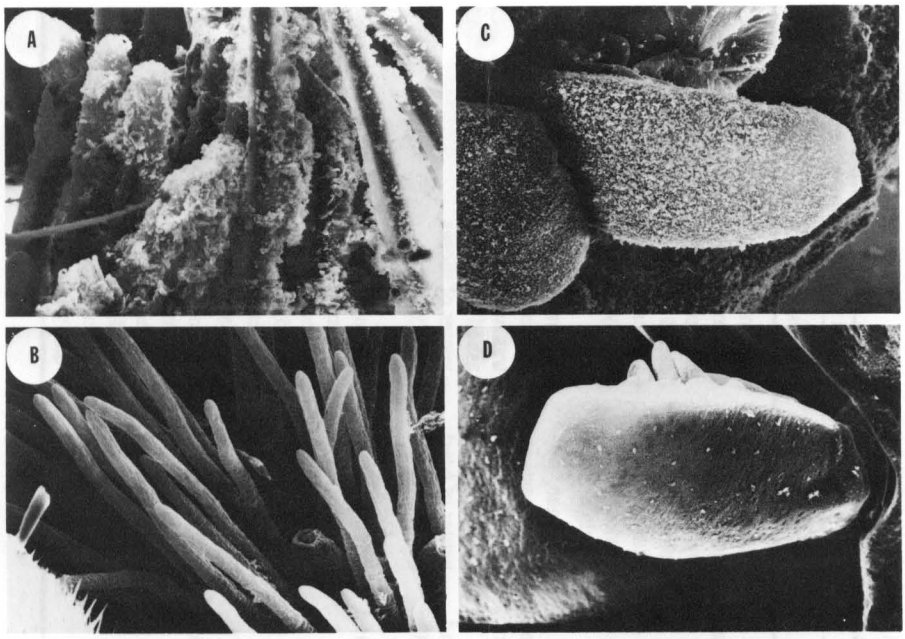

Fig. 3. Scanning electron micrographs of external gill structures of *Hesperoperla pacifica* (A = ash-impacted; B = control 360×) and *Drunella doddsi* (C = ash-impacted, D = control 220×).

except the caddisfly *Cheumatopsyche* sp. was substituted for *Rhyacophila arcopedes/vao* because of availability.

Results and Discussion

EXOSKELETAL CHARACTERIZATION AND ASH ACCUMULATION: Exoskeletal characterization and ash deposition on the insect bodies are given in Table 1. Insects exposed to an ash-impacted stream for 48 hr had substantial ash accumulations (Table 1, Figs. 1, 2). All four species exhibited heaviest ash deposits on the dorsum of the head, thorax and abdomen. The antennae, mouthparts, legs, intersegmental membranes and gills exhibited appreciable ash coatings. In all cases, a very light ashing was observed on the venter of the head and thorax. The venter of the abdomen was also lightly ashed with the exception of *Rhyacophila arcopedes/vao* and *D. doddsi.* The large ventral suction disc of *D. doddsi* and the moderately pubescent, deep membranous abdominal folds of *R. acropedes/vao* were heavily coated with ash. Aquatic insects possessing prominent exoskeletal sculpturing, body armature and pubescence had the highest ash retention properties.

Table 1. Exoskeletal characterization and ash accumulation on four aquatic insects.

	Ash-free insect			Ash-exposed insect "deposition locations"		
Species	Body characterization	Gills and type	Degree of sclerotization	Head	Thorax	Abdomen
Hesperoperla pacifica	—roughly sculptured head, thorax and abdomen —moderate to heavy pubescence	—profusely branched filamentous gills on the thorax and tip of abdomen	—heavily sclerotized head, thorax and abdomen	—antennae, mouthparts and top of head heavily coated with ash —venter of head lightly ashed	—pro, meso and metanotum, legs and gills heavily ashed —venter of thorax lightly ashed	—abdominal terga and cerci heavily ashed —venter of abdomen lightly ashed
Rhyacophila arcopedes/vao	—smooth head and prothorax —light pubescence	—clustered filamentous gills on the abdomen	—heavily sclerotized head and prothorax —mesothorax, metathorax and abdomen lightly sclerotized	—antennae, mouthparts and top of head heavily ashed —venter of head lightly ashed	—pro, meso, metanotum and legs heavily ashed —venter of thorax lightly ashed	—abdomen and gills heavily ashed
Drunella doddsi	—moderately sculptured head, thorax and abdomen —light pubescence	—lamellate gills on the abdomen	—head, thorax and abdomen moderate to heavily sclerotized	—antennae, mouthparts and top of head heavily ashed —venter of head lightly ashed	—pro, meso, metanotum and legs heavily ashed —venter of thorax lightly ashed	—abdominal terga and gills heavily ashed —ventral suction disc heavily ashed
Rhithrogena robusta	—smooth head, thorax and abdomen —light pubescence	—lamellate gills on the abdomen	—head, thorax and abdomen moderate to heavily sclerotized	—antennae, mouthparts and top of head heavily ashed —venter of head lightly ashed	—pro, meso, metanotum and legs heavily ashed —venter of thorax lightly ashed	—abdominal terga and gills heavily ashed —venter of abdomen lightly ashed

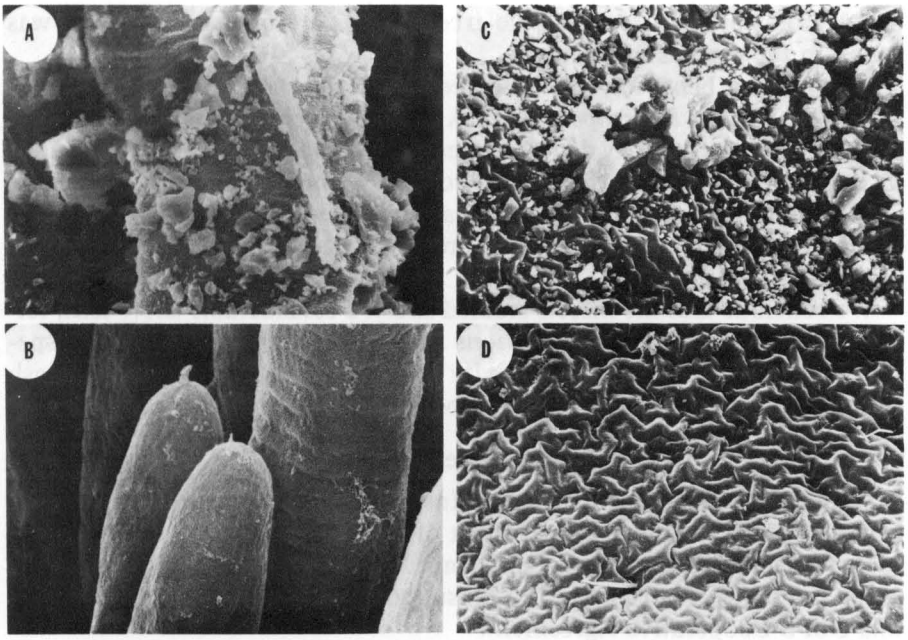

Fig. 4. Scanning electron micrographs of external gill structures of *Cheumatopsyche* sp. (A = ash-impacted; B = control 2700×) and *Rhithrogena hagenii* (C = ash-impacted, D = control 1300×).

Previously ash-exposed insects, *H. pacifica, D. doddsi* and *R. robusta,* voided the majority of ash within 24 hr in an ash-free stream (Figs. 1, 2). The only ash found on these insects was a small quantity on top and beneath the wing pads and on the thoracic gill filaments of *H. pacifica. Rhyacophila acropedes/vao,* however, retained appreciable quantities on the abdominal gills.

Microscopic examination (SEM) of insects exposed to high concentrations of ash revealed substantial accumulations of ash on respiratory structures (Table 1, Figs. 3, 4). In no instance did we observe lesions or abrasions on these delicate structures.

While short-term acute ash effects were not noted, long-term chronic effects are possible, particularly if insects were subjected to long periods of ash perturbation.

INSECT BEHAVIOR AND ASH-VOIDING MECHANISMS: Selected aquatic insects subjected to ashed and ash-free conditions exhibited no appreciable behavioral differences. Mobility during daylight hours in test and control environments was greatest for *H. pacifica* and *R. robusta* followed by *D. doddsi* and *R. acropedes/vao.* In both environments, the insects resided on the sides

and bottoms of the cages, with the exception of *R. acropedes/vao* which was found in the corners of the cages.

Ash-voiding behavior was observed for *H. pacifica, R. robusta* and *D. doddsi* but not for *R. acropedes/vao.* After ash-covered nymphs were placed in an ash-free stream they demonstrated higher levels of activity than control insects for approximately the first two hr. The majority of the test insects were found on the sides of the cages and oriented upstream. Except for *R. acropedes/vao* ash-covered insects were largely successful in eliminating the ash within 24 hr.

We conclude that the insects studied showed considerable short-term tolerance to external ash accumulations and that behavioral attributes, especially involved with increased activity contributed to the elimination of ash from exoskeletal structures once the perturbation ceased.

Acknowledgments

We would like to thank Ron Davis, Instructor and Manager of the Electron Microscope Department, Department of Veterinary Science, University of Idaho, for providing technical assistance with the scanning electron microscope and Dr. W. Platts, USFS, for his support in initiating and implementing this USFS Cooperative Agreement.

Literature Cited

Brusven, M. A. 1973. A closed system plexiglas stream for studying insect-fish-substrate relationships. Prog. Fish Cult. 35:87–89.

Cook, R. J., J. C. Barron, R. I. Papendick, and G. J. Williams III. 1981. Impact on agriculture on the Mount St. Helens eruptions. Science 211:16–22.

Fruchter, J. S., D. E. Robertson, J. C. Evans, K. B. Olsen, E. A. Lepel, J. C. Laul, K. H. Abel, R. R. Sanders, P. O. Jackson, N. W. Wogman, R. W. Perkins, H. H. Van Tayl, R. H. Beauchamp, J. W. Shade, J. L. Daniel, R. L. Erikson, G. A. Schmel, R. N. Lee, A. V. Robinson, O. R. Moss, J. K. Briant, and W. C. Cannon. 1980. Mount St. Helens ash from the May 18, 1980 eruption: Chemical, physical, mineralogical and biological properties. Science 209:1116–1125.

Hooper, P. R., I. W. Herrick, E. R. Laskowski, and C. R. Knowles. 1980. Composition of the Mount St. Helens ashfall in the Moscow-Pullman area on 18 May, 1980. Science 209:1125–1126.