Executive Summary

AN INTEGRATED WATERSHED STUDY: AN INVESTIGATION OF THE BIOTA IN THE EMERALD LAKE SYSTEM AND STREAM CHANNEL EXPERIMENTS

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Introduction

Many lakes and streams in the High Sierra are very dilute and weakly buffered; consequently they are sensitive to increased inputs of acid. Episodes of surface-water acidification have been recorded for some of these High Sierra waters but effects on the aquatic biota are largely unknown. Changes in stream invertebrate and algae populations have accompanied cultural acidification in other parts of the world. These population effects include declines in species diversity, changes in species composition, declines in invertebrate abundance, increases in algal standing stocks, and the local extinction of some species. Because some stream invertebrates and algae show sensitive responses to acid inputs, stream invertebrate and algae populations can act as indicators of environmental stress. Because the effects of cultural acidification depend on the chemistry of receiving waters, the biogeochemistry of affected watersheds, the species composition of aquatic plant and animal communities, and the genetic composition of plant and animal populations, it is necessary to examine the responses of the aquatic biota to acid inputs for each region separately. Unfortunately, data on the acid sensitivity of stream algae and invertebrates in the western U.S. are practically nonexistent. Such data are needed, however, to assess the current status of High Sierra stream systems, to act as a baseline for comparison should we see changes in the future, and to make predictions regarding the probable effects of acidification.

The work on stream algae and invertebrates described in this report is an integral part of the Integrated Watershed Study (IWS) supported by the California Air Resources Board. This research has allowed us to characterize the responses of stream algae and invertebrates to pulsed acidic inputs. This research calibrates our monitoring data by allowing us to determine which taxa are particularly sensitive to acid inputs, i.e. indicating the taxa on which to focus our attention in monitoring efforts. In addition, these studies allow us to predict the effects of increased acidification on some characteristics of High Sierra streams, which should ultimately allow the formulation of deposition standards for protecting sensitive waters. Data collected from these experimental studies will be used in concert with data from other IWS projects to assess the current status of, and stresses to, High Sierra waters.

Procedures

In the summer of 1986 we performed a series of stream channel experiments to determine the effects of different levels of acid input on common invertebrates and algae found in High Sierra streams. Twelve small channels, each 2.4 m X 20 cm X 20 cm, were constructed next to the Marble Fork of the Kaweah River in Sequoia National Park. Water from the Marble Fork was diverted through these channels and channels were stocked with natural substrates, algae, and invertebrates. During acid pulses sufficient acid was added to one set of four channels to reduce pH to 4.6, another set of four channels received sufficient acid to reduce pH to 5.2, and a third set of four channels was unmanipulated, acting as a control at pH 6.5. Every two weeks sulfuric and nitric acid (1:1 by equivalents) was added for eight hours in late morning and afternoon to simulate the magnitude and timing of acidic summer rain storms. Benthic densities of invertebrates and algae in each channel were measured before and after acid additions, and invertebrate drift was measured before, during, and after acidification. Drift refers to organisms carried downstream in the water column. Four experiments were run through the summer and early autumn.

Results

Additions of acid resulted in declines in total diatom abundance and shifts in the relative abundances of diatom species. Achnanthes minutissima, Taxon 99396-SN (Cymbella failaisencis or Gomphonema sp.), Fragilaria vaucheri, and, perhaps, Gomphonema subclavatum and Achnanthes levanderi were reduced by acid inputs, whereas Eunotia spp. tended to be more abundant in acidified than control channels. There were no differences in diatom live to dead ratios among treatments during or after acid pulses. The only common alga that was not a diatom, Zygnema sp., showed no response to acid inputs. Among the invertebrates, nymphs of the mayfly Baetis showed the most sensitive responses to declines in pH, showing increases in drift and declines in benthic density with decreasing pH. Other mayfly genera, such as Epeorus and Paraleptophlebia, showed increases in drift with increased inputs of acid, particularly when pH was reduced to 4.6. In an experiment spanning a month, benthic densities of Paraleptophlebia declined with decreasing pH. A caddisfly (Amiocentrus) and a stonefly larva (Zapada) also showed increased drift during pulses of strong acid (channel pH = 4.6). Chironomids and most other taxa showed few consistent responses to acidification, although chironomid drift was enhanced in strongly-acidified channels (pH = 4.6) in one experiment. The large proportion of dead individuals in the drift of channels showing significant acidification effects emphasized the importance of acid toxicity in enhancing drift rates for sensitive taxa (e.g. Baetis)

Conclusions

These data allowed us to determine the effects of acid inputs on common stream invertebrates and algae found in the High Sierra. These data pinpointed sensitive taxa which can act as indicators of environmental stress, and also allowed us to predict changes in community composition resulting from episodes of acidification. The results indicate that diatom abundance is depressed by pulsed additions of acid. Some diatom taxa decline with acid addition, whereas others increase. Among invertebrates, mayfly nymphs in the genus Baetis are especially vulnerable to increased acidification, showing increases in drift rate and declines in benthic density. Other mayfly nymphs (Epeorus, Paraleptophlebia), and a stonefly nymph (Zapada) showed increased drift rates primarily when pH was reduced to 4.6. Most other taxa showed few consistent responses to acid inputs. The results indicate that some taxa, such as Baetis, may be potent indicators of acid-induced stress. Because some of the sensitive taxa are important components of trout diets in mountain streams, effects of acid deposition on stream invertebrates may, ultimately, affect the diets and growth of trout.

Recommendations

Stream invertebrates and algae show a variety of responses to acidification. In our studies we have measured the responses of common stream algae and invertebrates to pulsed inputs of acid. Based on our past investigations we recommend that the California Air Resources Board (CARB) do the following:

1. Continue qualitative monitoring of aquatic invertebrate populations in streams in the Marble Fork basin. Our investigations indicate that the disappearance of Baetis, in particular, may act as a potent early-warning indicator of acid stress.

2. Fund laboratory and field studies to experimentally examine the pH tolerances of different diatom species. Experimental data on the pH tolerances of diatoms are virtually nonexistent, despite the importance of diatom microfossils in reconstructing the pH histories of lakes.

3. Experimentally examine the effects of acidification on trophic interactions. The effects of acidification on stream algae and invertebrates may have important repercussions for their predators and prey. For example, reductions in stream invertebrates may cause algal blooms, thereby degrading water quality, or may result in significant alterations in the food base for fish.

4. Experimentally examine relationships between flooding and acidification. Because most inputs of acid are associated with potential flooding events (snow-melt, heavy rains) it is important to distinguish the effects of acidification from the effects of natural disturbances associated with flooding.

5. Integrate data on the effects of acid inputs on stream invertebrates and algae with data from other projects in the Integrated Watershed Study (IWS) to (a) provide predictions of changes in biological populations with changes in surface water chemistry and (b) assist in setting deposition standards which would prevent damage to aquatic resources in the High Sierra.

Our field experiments have shown the responses of aquatic invertebrates and algae to increased acidic inputs. CARB-sponsored modeling efforts, which integrate hydrological, meteorological, and biogeochemical data, are examining the responses of surface-water chemistry to different acid deposition scenarios. The models' output will allow investigators to predict the effects of changes in the loading of acidic species in wet and dry fall on the chemical composition of lake and stream water. These changes in surface-water quality in lakes and streams can be used in conjunction with the dose-response relationships developed for algae and invertebrate populations to predict biological responses to changes in water quality and, ultimately, acid loading. Model outputs can be used in empirical equations that relate surface-water pH and alkalinity to biological response.

The lakes and streams of the High Sierra are the most sensitive receptors for acidic wet and dry fall in the State of California. This means that they will be the first ecosystems to change with increases in acid deposition. Changes in surface-water chemistry will result in changes in biological populations. If changes are detected in surface-water chemical and biological parameters, then the California Air Resources Board should consider these experimental data when setting deposition standards for acidic pollutants in sensitive areas. The modeling efforts mentioned above would allow scientists to determine the effects of different acid loading levels on surface-water chemistry and, in turn, on biological populations. Deposition standards could be defined by "critical loadings" of acids, nitrates and sulfates that would result in deleterious changes in water quality. The regulatory strategy to achieve those standards would then have to be formulated and implemented by the California Air Resources Board to achieve this "level of protection".