Effects of trout farm effluent on the abundance of benthic stream invertebrates

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Abstract: Nitrogen and phosphorous input into water systems can alter aquatic community composition and diversity. Nutrient-rich water effluent from a trout pond near the Cuerici Biological Station empties into the Quebrada Los Leones stream. A previous study found marginally higher invertebrate diversity above this input than below it, but the study lacked controls and did not evaluate effects on specific taxa. We hypothesized that the effluent is altering the composition of pollution sensitive taxa in the aquatic invertebrate community due to an increase in nitrogen and phosphorous. We predicted that within the affected stream (Q. Los Leones), sensitive taxa would be less abundant below the effluent pipe than at the same elevation in the unaffected stream. Contrary to the hypothesis, there was a larger increase in total invertebrate abundance between sites above and below the effluent pipe than between comparable sites in the control stream. Abundance of Amphipoda and Trichoptera were significantly higher below the effluent pipe than above the pipe or in the control site. These taxa are usually good indicators of water quality, and their increased abundance suggests that the effluent is not polluting the stream water. This result does not imply that this nutrient addition is unequivocally good, but does demonstrate the potential for low-impact, high-profit aquaculture.

Key Words: Amphipoda, abiotic conditions, effluent, nutrient rich water, Simuliidae, stream position, Trichoptera, trout ponds

Introduction

Anthropogenic pollution into aquatic systems can have effects on the abundance and species composition of stream invertebrates. Nitrogen- and phosphorous-rich runoff, common in agricultural areas, is an example of pollution that can alter stream communities. The Cuerici Biological Station at Cerro de la Muerte is located between two small streams. Some of the water from one stream is diverted and used to fill 6 man-made ponds, which contain over 40,000 cultivated trout. The diverted water is channeled through each of the 6 ponds and then into a holding tank, where a majority of the large particles settle out of the water column. The water then flows into an underground pipe leading to the hydroelectric generator which provides electricity for the station. After passing through the generator, the trout pond effluent flows into another stream, the Quebrada Los Leones.

Brayce et al. (1999) examined the effects of this potentially nitrogen- and phosphorous-rich effluent on the diversity of aquatic invertebrates above and below the output pipe, and found that species diversity was higher 40 m above the pipe than 40 m below it. However, interpretations were complicated by the possibility that effects were due to something other than the trout effluent (e.g., elevation change). We extended their study by including a comparison of two sites, at comparable elevations, in a nearby stream that lacked trout effluent. We also did more thorough sorting of invertebrate taxa to test for impacts on specific taxa and evaluate whether taxa that decline in the presence of trout effluent are those that are recognized as indicators of high water quality.

Methods

Research was conducted on 26 - 27 January 2002 near the Cuerici Biological station, Cerro de la Muerte, Costa Rica. We sampled two sites along Quebrada del los Leones, 30 m above and below a pipe emptying trout farm effluent into the stream. We also sampled two control sites (at the same elevations) in an apparently similar stream ~50 m south of the experimental locations. At each site we performed two 5 min kick-net samples. We measured pH, temperature, flow rate, canopy cover, width of stream and water depth of each site. We used pHydrion strips to measure pH. Water temperature was measured 5 times per site (between 10:30 – 15:00) with a Physitemp BAT-12 thermometer. Flow force was calculated by attaching a cloth "parachute" to a penetrometer and measuring the pull (in grams) at 3 places within each site. A spherical densiometer was used to estimate canopy cover at 3 points within each site. We measured the width of the stream across 3 transects within each site and measured depth at 3 points across each of these transects. We used a chi-square test to compare the upstream and downstream abundance of the most common taxa in the trout effluent stream compared to the control stream.

Results

The two streams were very similar with respect to canopy cover, pH, water temperature, flow force and stream width and depth, although the temperature was ~1° C higher at the point of effluent input (Table 1). Our sampling produced 10 easily distinguished taxa including Amphipoda, Ephemerellidae, Gomphidae, Peltoperlidae, Planaria, Simuliidae, Tipulidae and 3 families of Trichoptera. There were 5 - 6 taxa in all reaches except below the input of trout effluent, where there were 8. Ninety-five percent of the individuals were amphipods, simuliids or Trichoptera (Appendix).

Total abundance of invertebrates increased somewhat from the upper reach to the lower reach in the control stream (135 to 188 individuals), but it increased more from above to below the trout effluent (111 - 285 individuals; test of no difference between streams in upper reach vs. lower reach: $\chi^2 = 14.98$, df = 1, $P < 0.0001$). Both amphipods and caddisflies (Trichoptera) showed a signal of increased abundance from trout effluent. The average abundance of amphipods and caddisflies was similar at high and low sites on the control stream (~25 individuals/sample for each taxon; Appendix). However, on the experimental stream, abundances of both taxa were about 3-fold higher below the trout pond than above it ($\chi^2 = 22.44$, df = 1, $P << 0.001$ and $\chi^2 = 15.52$, df = 1, $P << 0.001$ for amphipods and caddisflies respectively; Appendix).

The third most abundant group,

TABLE 1. Comparison of environmental attributes in a stream receiving trout effluent (above, at, and below the point of effluent input) and a paired stream lacking trout effluent. Data are means ± SD.

Treatment	Location	Ave. % Canopy Cover	pH	Ave. Water Temp ° C	Ave. Flow Force (g)	Ave. River Width (m)	Ave. River Depth (m)		
							Left bank	Middle	Right bank
Trout River	upper reach	81 ± 10	6.25	12.42 ± 0.04	44.0 ± 25.1	1.89 ± 0.45	6.67 ± 4.51	10.50 ± 3.50	7.67 ± 1.54
Trout River	at pipe	80 ± 5	6.75	13.50 ± 0.00	-	-	-	-	-
Trout River	lower reach	71 ± 19	6.25	12.90 ± 0.00	21.7 ± 10.0	0.57 ± 0.11	10.17 ± 2.93	10.67 ± 1.04	5.00 ± 1.00
Non-trout River	upper reach	70 ± 5	6.25	12.50 ± 0.04	10.7 ± 9.2	0.87 ± 0.29	5.50 ± 1.32	10.67 ± 4.73	7.17 ± 1.76
Non-trout River	lower reach	76 ± 6	6	12.52 ± 0.00	21.3 ± 22.6	0.85 ± 0.23	7.67 ± 4.51	9.167 ± 4.65	3.69 ± 1.04

Simuliidae, had a very patchy distribution and was abundant only in the lower elevation site of the control stream. All other taxa, representing <5 % of our sample, did not appear to vary between sampling points.

Discussion

Results were contrary to the hypothesis that nutrient enrichment from trout effluent leads to reduced diversity and abundance of stream invertebrates. In fact, the pattern was markedly increased abundance below the effluent input, including two taxa (amphipods and Trichoptera) that are usually regarded as very sensitive to low water quality. The most probable mechanism is that increased concentrations of nitrogen and phosphorous lead to increased primary productivity within the stream, which then permits increased abundance at all levels of the food web, including scrapers, collector-gatherers, and predators (which includes the functional groups for many amphipods and caddisflies). It is also possible that the predators of amphipods and caddisflies are somehow decreased by addition of trout effluent, but we know of no mechanism through which moderate increases of nitrogen and phosphorous would have direct, deleterious effects on invertebrate predation.

It is also possible that the effect of the effluent is due to increased temperatures rather than increased nutrients (Table 1). For example, the warmer water could accelerate development rates and increase survival below the effluent input. It is also possible that the temperature change has a negative effect on predators, which permits increased survival of amphipods and caddisflies. However, temperature differences' seem less likely than nutrient addition to impact invertebrate abundance over only 60 m of stream length than nutrient addition.

The high abundance of Simuliidae in the lower reach of the control stream might be due to a particular microclimate or pocket of nutrients that was especially suited for this group of organisms. It is also possible that the high abundance of Simuliidae at this site is a result of the lower abundance of one of their major predators, caddisflies (Pennak 1978).

Overall, our results suggest that the trout effluent is not currently harming invertebrate communities in Q. Los Leones, but instead seems to increase productivity with no decrease in diversity. This implies that stream ecosystems in this region are normally limited by availability of nitrogen and phosphorous. This could be further tested by comparisons of algal abundance (especially with grazers excluded). Results should not be taken to imply that nutrient addition to these streams is unequivocally good. For example, though limited additions of nutrients appear to benefit this stream, there is evidence from other systems that large inputs of nitrogen and phosphorous can decrease both productivity and diversity. This dynamic balance between concentration of nutrients and the diversity of the ecosystem may explain the apparent contradiction between our results and the findings of Brayce et al. (1999). Nonetheless, results indicate that this trout farm represents an excellent example of low-impact, profitable aquaculture.

Literature Cited

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APPENDIX. Number of each taxa found in two replicate samples at sites above (high) and below (low) the input of trout pond effluent and at comparable sites on a matched control stream.

Taxa	Control				Experimental			
	High		Low		High		Low	
	1	2	1	2	1	2	1	2
Trichoptera*	13	46	25	21	42	22	85	54
Simuliidae	1	2	77	0	0	1	0	3
Amphipod	3	53	8	48	36	3	22	110
Planaria	0	4	5	2	0	0	0	2
Gomphidae	0	0	1	0	0	1	0	1
Ephemerellidae	7	3	0	1	1	1	1	4
Peltoperlidae	1	2	0	0	2	2	0	1
Tipulidae	0	0	0	0	0	0	0	2
Total Numbers	25	110	116	72	81	30	108	177

*Included, in order of decreasing abundance, Brachycentridae(sand case), Polycentropodidae (pebble case) and Hydropsychidae (unknown case).