Recovery of Benthic Invertebrate Communities after the Diversion of Acid Mine Drainage Water from Junction Creek in Sudbury, Ontario

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Abstract

A three year study was conducted to assess the effects of the diversion of acid mine drainage water coming from the Frood-Stobie airstrip waste rock piles on the biology and chemistry of the downstream sections of Junction Creek in Sudbury, Ontario. The diversion was undertaken by INCO Ltd. and was completed in the winter of 2000. This study commenced in the spring of 2001, five months after the diversion, and used both historic chemical and biological data from two study sites and 42 nearby reference sites. The reference data were part of an associated Environmental Effects Monitoring (EEM) study. Monthly water samples were collected from the study area during the open water season and analyzed for pH, major ions, and metals. These data were used to compare to chemical data collected prior to the diversion. Benthic invertebrates were collected through a kick-and-sweep sampling method during mid-November using a standard <500 μm mesh net. The invertebrates were then identified into their taxonomic groups and used in a discriminant function model to develop an index of recovery.

Introduction

The Frood Branch is a tributary of Junction Creek that has been severely affected for decades by acid mine drainage (AMD) water seeping from the waste rock piles at the Frood-Stobie airstrip. To mitigate this problem, a 3.7m wide, 1020m long channel (undertaken by INCO Ltd.) was constructed in the winter of 2000 to divert the contaminated drainage water via an underground drainage drift to the Frood-Stobie Complex where it is treated at either Inco's Copper Cliff Waste Treatment Plant or the Nolin Creek Waste Water Treatment Plant.

The objectives of this three year study were to: 1) assess the rate of biological and chemical recovery following the diversion of acid mine drainage, 2) apply the Reference Condition Approach (RCA) for benthic invertebrate monitoring to test its usefulness and reliability in detecting the response to AMD diversion, and 3) determine suitable endpoints for biological recovery of the Frood Branch.

Methods

Monthly water samples were collected from May to October (1996, 2001, 2002). In 1996, duplicate one litre surface grab samples were collected from both test sites and shipped to

INCO's Central Process Technology Lab in Copper Cliff for analyses of pH, conductivity, alkalinity, trace metals and major ions. 2001 and 2002 surface water grab samples were collected in the same locations as in 1996, but were sent to Testmark Laboratories Ltd. in Sudbury for analysis of trace metals and major ions. Conductivity and pH were analyzed at the Cooperative Freshwater Ecology Unit.

To reduce seasonal variability, three, 1 m^2 replicate kick-and-sweep samples were taken with a 500 μm mesh D-net at reference and test sites (following David et al., 1998) within a two week period in November from 2000 to 2002. Replicates were taken at least 6 metres apart in the most ecologically similar habitat for that site.

As part of an associated Environmental Effects Monitoring (EEM) study, invertebrate communities from 42 reference sites were sampled then divided into three broad biological groups using correspondence analysis. A discriminant model was then created by Davidson (2002) to predict sites to the appropriate group using small-scale habitat descriptors.

Our study used Davidson's (2002) historical benthic data, collected from the Frood Branch prior to the AMD diversion, and data collected from the same site following the diversion in the fall of 2001 and 2002. The habitat descriptors, used to describe the Frood Branch test site in the fall of 2002, were then used in a discriminant model to predict which group the site belonged to. Metric calculations, which include diversity, richness, evenness, Hilsenhoff's FBI, % EPT, EPT taxa richness, % Oligochaetes, % Amphipods, % Non-dipteran insects, % Insects, % Gastropods, and % Chironomids, were compared to the univariate metric ranges for reference Group 3 (data from Davidson, 2002) to determine if the Frood Branch test site fell within the "normal" range of biological variation for an unstressed site.

Results and Discussion

As a result of the construction of the AMD diversion channel, water quality in the two tributaries has dramatically improved. The pH in the Frood-Stobie 1 tributary rose from a consistent low of 3.9 in 1996 to a high of 7.7 in 2001. Copper, nickel and zinc concentrations were also dramatically reduced by about 2 orders of magnitude (Figure 1).

With the improved water quality, species richness of benthic macroinvertebrates also improved in the Frood Branch (Figure 2). In the fall of 2000, prior to the AMD diversion, only one family of acid tolerant Chironomids were found and these were at very low density (total of 2 specimens were collected). During the fall of 2001, six months following the diversion, six relatively acid tolerant (Bode et al., 1996, 2002) families were present. In 2002, two years after the diversion, eleven different families were found. Not only has diversity increased, so too has the abundance of individuals. The two most frequently caught families were Chironomidae (N=128 in 2002) and Hydropsychidae.

The habitat descriptors were then used in the discriminant model to determine which group the test site belonged to. The test site was assigned to Group 3. Streams assigned to this group are typically fast flowing, erosional streams with sandy-cobble bottoms with little organic matter, silt and clay. There is generally a lack of submergent and emergent macrophytes and cattails are never found among these sites. To compare the test site to what is considered "normal" for Group 3, Table 1 summarizes the upper and lower limits of univariate metrics and CA scores for reference Group 3 and the test site. Limits are defined by +/- 2 standard deviations.

Of the twelve metrics only four (% EPT, % Non-dipteran insects, % Insects and % Chironomids) fell within the normal range for Group 3. The other metric values were either at the limit of +/- 2 standard deviations or beyond. The mean metric values for Diversity, Richness, Evennes and EPT Taxa Richness fell far below the univariate metric ranges for Group 3. This suggests that the test site has not returned to "normal" and that although we have seen considerable improvements in water quality and species richness over the past three years, more time is required for benthic macroinvertebrate assemblages to return to their natural state.

Conclusions

The preliminary results shown here clearly illustrate how quickly benthic communities can recovery following improved water quality as a result of acid mine drainage mitigation and the power of the Reference Condition Approach at detecting change. We are continuing to work on this study and additional findings and results are expected.

Acknowledgements

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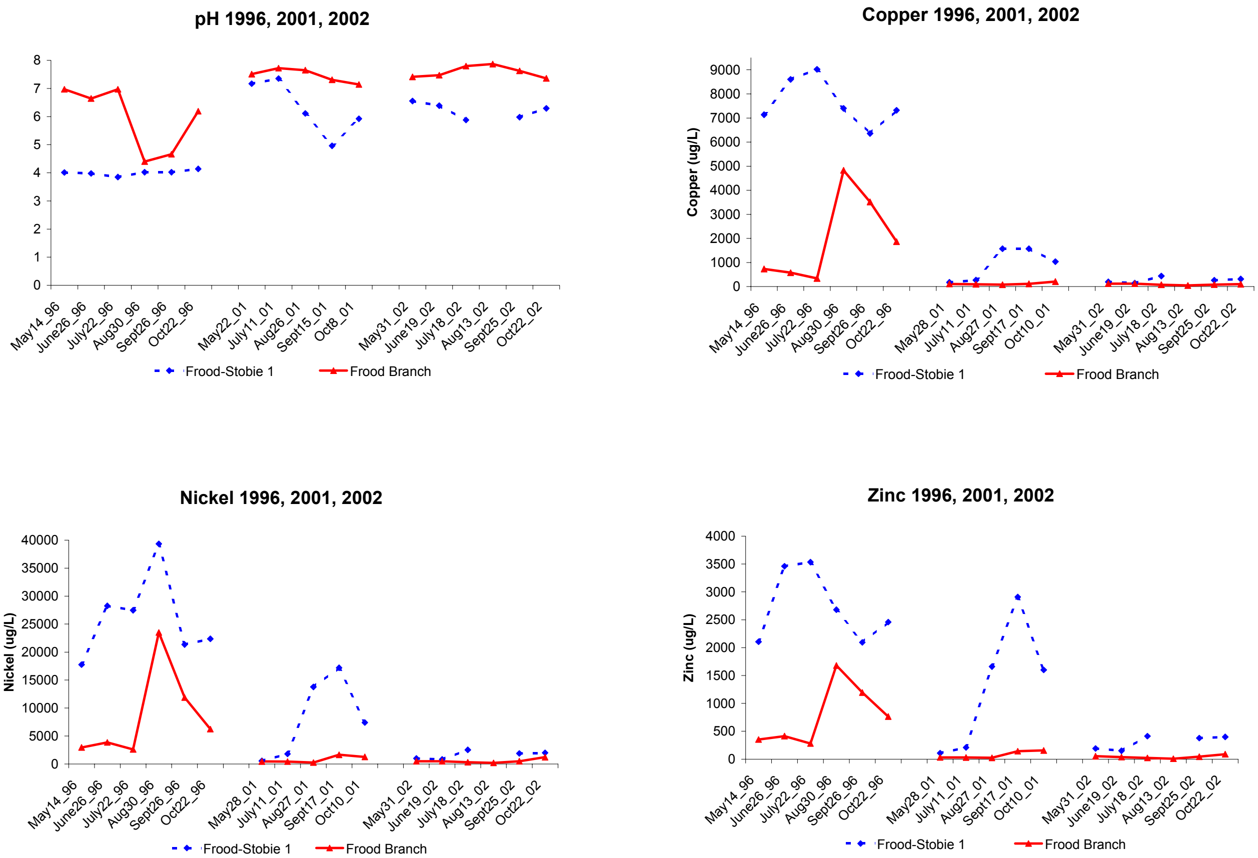

Figure 1. Water chemistry changes in the Frood Branch following the diversion of acid mine drainage water to the Frood-Stobie Complex in the winter of 2000 for two downstream Junction Creek test sites (Frood-Stobie 1 tributary and Frood Branch of Junction Creek). Monthly water samples, taken from May to October, are shown for 1996, 2001, and 2002. 1996 samples indicate pre-diversion conditions, whereas the 2001 and 2002 samples were taken after the acid mine drainage (AMD) diversion. The Frood-Stobie 1 tributary was the direct receiving water for the AMD coming from the waste rock piles at the Frood-Stobie airstrip. The Frood Branch site was located below the Nickeldale dam approximately 1km downstream from the diversion site.

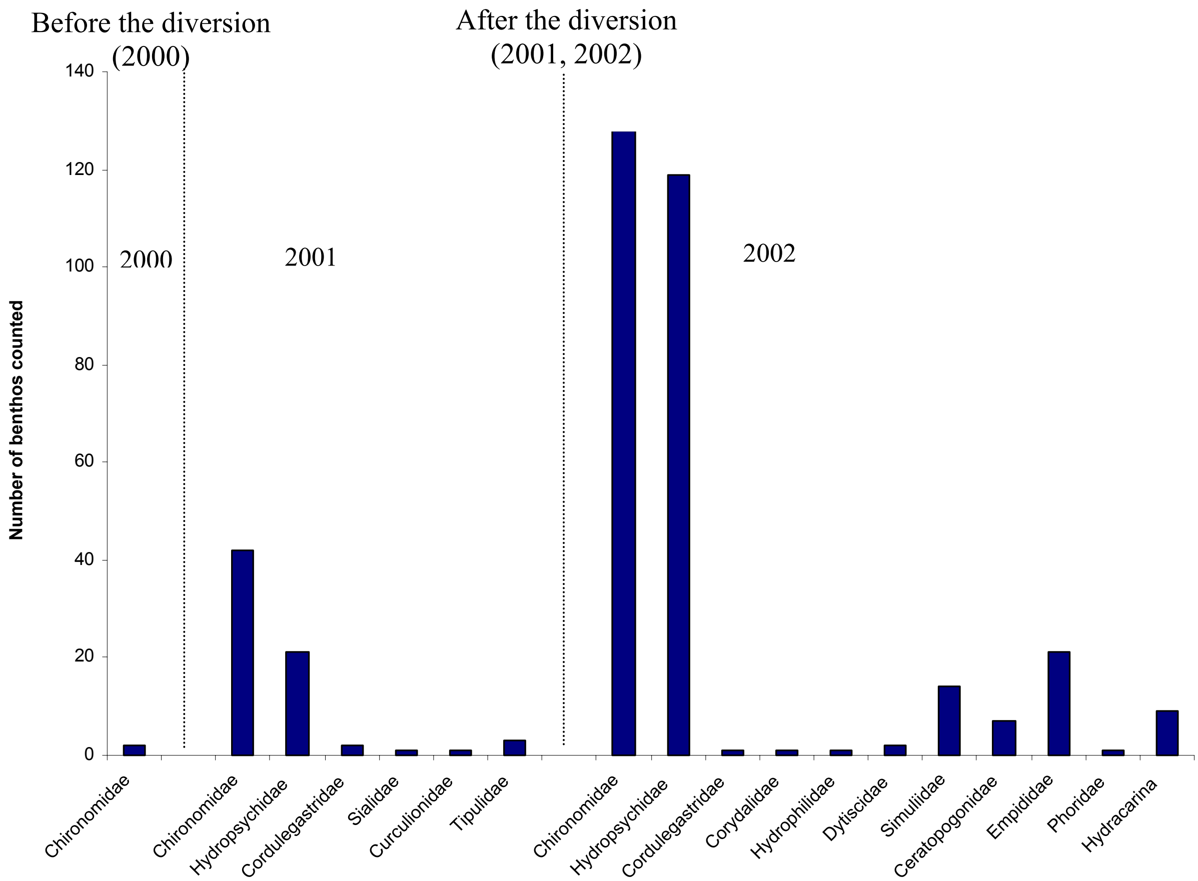

Figure 2. Changes in the abundance of invertebrates at the Frood Branch test site on Junction Creek following the diversion of acid mine drainage water to the Frood-Stobie Complex. The total number of benthos from three kick-and-sweep samples collected from the downstream Frood Branch test site is shown.

Table 1. Univariate metric ranges for reference group three (data from Davidson, 2002). Shown is the group mean +/- 2 standard deviations calculated from the mean site abundances. Metric values for the Frood Branch test site (mean of the three replicates) are also shown. Grey values indicate those that are at the limits of +/- 2 standard deviations of the reference group and red are beyond.

		Group 3 (N=17) +/- 2 SD MEAN	Frood Branch MEAN			Group 3 (N=17) +/- 2 SD MEAN	Frood Branch MEAN
Diversity	High	2.7	1.29	% Oligochaetes	High	*7	0
	Low	1.68			Low	*0	
Richness	High	23	7.67	% Amphipods	High	*1	0
	Low	12			Low	*0	
Evenness	High	0.89	0.63	% Non-dipteran insects	High	89	40.56
	Low	0.64			Low	34	
Hilsenhoff's FBI	High	5.26	5.47	% Insects	High	*100	96.95
	Low	2.87			Low	*74	
% EPT	High	86	38.89	% Gastropods	High	*2	0
	Low	22			Low	*0	
EPT Taxa Richness	High	14	1	% Chironomids	High	100	42.23
	Low	6			Low	28	

* Not normally distributed