Mortality of Rainbow Trout Due to Ingestion of Fire Ants in the Peruvian Andes

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INTRODUCTION

- Fish kills were documented on September 22 (at Chocopampa) and October 15, 2005 (near Qda. Shiloui) downstream of the Compañía Minera Antamina site in the Peruvian Andes (Figure 1).
- In 1998, Compañía Minera Antamina initiated an aquatic environmental effects monitoring (EEM) program during construction of their mine, the first such approach used in Peru (Tello and Farara 2005).
- The objectives of the EEM program are to monitor for any spatial or temporal changes in the health of fish or fish habitat that may be due to the mine operations (Tello and Farara 2005).
- Because the EEM program tracks the local and regional effects of the mine on downstream conditions through the assessment of water, benthic invertebrates, and fish, it was used to assess these fish kills.
- Past studies have identified introduced rainbow trout "trucha" (*Oncorhynchus mykiss*) (Image 1) and native catfish "bagre" (*Astroblepus* spp.; Image 2) as the only fishes in the high gradient and low productivity streams.

Image 1. Sample of rainbow trout.

Image 2. Dorsal and ventral view of a catfish.

Fish Kill Event Observations

- The fish kills occurred in two locales downstream of the Antamina mine (Figure 1).
- Dead fish were all rainbow trout; mainly adults, with a few juveniles (>1 year, but not sexually mature).

Understanding Fish Kill Events

- Fish kills can result from man-made or natural stressors and be of biological, chemical or physical origin (Table 1).
- Examples of stressors include the releases of a contaminants (e.g., pesticides, metals etc) to the water, low dissolved oxygen, high temperatures, disease or parasites.
- The kills tend to be acute in nature (i.e., many fish perish over short time) compared with a chronic event that takes place over months or years.

Table 1. Patterns of response to stressors to interpret fish mortality.

Nature of stressor	General mortality response
Biological (e.g., disease)	fish: both small and large lengths benthic invertebrates: no change
Chemical (e.g., high dissolved metal)	fish: small fish first followed by large fish benthic invertebrates: shift to tolerant species
Physical (e.g., low dissolved oxygen)	fish: both small and large lengths benthic invertebrates: shift to tolerant species

- Routine monitoring programs like the EEM provide an excellent method to identify and resolve fish kill events.

Identification Process

- Identification of cause of fish kills occur either through direct analysis of the dead fish or the collection of data to eliminate alternate hypotheses to explain the causative mechanism(s) (Figure 2).
- Frequently requires inference on all available information to make final assessment or identify cause.
- Alternate hypotheses:

  1) If the fish kills were due to contaminants originating from the Antamina operation, then it would be expected that: the most severe effects (i.e., most of the dead fish) would be close to the mine with the effect diminishing with increased distance away from the mine and a corresponding shift in benthic invertebrate communities;

  2) If the fish kills were due to a pesticide from local agricultural activities, then a similar pattern as noted for a contaminant would be expected;

  3) If the fish kills were due to a physical stressor, like low dissolved oxygen because of reduced stream flow, then some kind of spatial pattern would be expected in terms of the response of the fish kill and benthic invertebrates;

  4) If the fish kills were due to a biological stressor like disease, then length-independent consequences on whole populations of fish would likely be evident with no corresponding change in benthic invertebrates.

METHODS

- Following the fish kills, water quality, benthic invertebrate, and fish sampling was conducted (Image 7).
- Sampling areas included the near and far field sites downstream of the mine, the reference area, and the locations of the fish kills (Figure 1).
- Fish samples were sent for necropsy in Canada.

Image 7. Fish and benthic invertebrate sampling.

1. Document fish kill event
2. Quantify current aquatic environment upstream and downstream of event. Variables of interest include: a) water b) benthic invertebrates c) fish.
3. Contrast existing environment with observations from past, if available.
4. Conduct necropsy on fish, if necessary.
5. Assess all available information and resolve likely cause(s) of the fish kill.

Figure 2. Steps followed to investigate fish kills and identify likely cause(s).

Image 3. Stream at base of hill.

Image 4. Area of 22 September fish kill.

Figure 1. Study locales in Peru, downstream of Antamina mine.

Image 5. Stream upstream of fish kill.

Image 6. Antamina mine impoundment.

RESULTS

Water Quality

- A review of Anamina's daily routine water quality data did not reveal any parameter (e.g., metals, pesticides) at concentrations that would have resulted in the fish kill (data not shown).
- Additional water samples that were collected from the area of the fish kills also showed no elevated levels of parameters that would be toxic to fish (data not shown).

Other Physical Parameters

- Limnology was typical but flow rates did spike after rain (that just preceded both fish kill events; Figure 3).
- At each fish kill area, water quality measurements indicated that dissolved oxygen was saturated (i.e., > 5 mg/L), water temperatures were seasonal (i.e., ranged from 12 to 13 ºC), pH showed a range of 7.9 to 8.1, and conductivity was typical, and ranged from 365 to 418 µS/cm.

Benthic Invertebrate Community

- Benthic invetebrate samples were collected from five areas in October 2005 following the fish kills and compared with observations from July 2005.
- The comparison of benthic invertebrate community between July and October 2005 identified no decline in mean species richness or mean density (Figures 4 and 5).

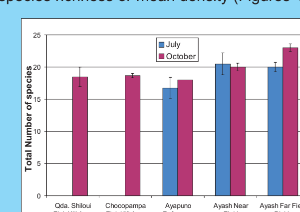

Figure 4. Benthic invertebrate species across study sites (mean ± 1 standard error).

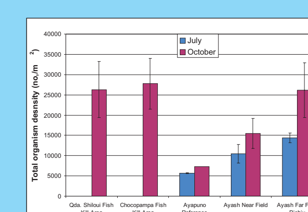

Figure 5. Benthic invertebrate density across study sites.

Fish Community

- Total rainbow trout density was higher in October than in July, at all monitoring locations, primarily due to the presence of young-of-the-year that are not usually present during the July surveys (Table 2).
- Observation of only dead rainbow trout (i.e., no catfish) at both fish kill sites.

Table 2. Density of adult and juvenile rainbow trout in July and October, 2005.

Area	Total Rainbow Trout Captured		Number of Fish Caught Per Minute		Number of Adults		Juveniles	
	July EEM	October Study	July EEM	October Study	July EEM	October Study	July EEM	October Study
At Tailings Dam	36	54	2.9	3.2	28	43	8	11
Ayash Near Field	33	130	1.4	7.8	26	16	7	114
Ayash School downstream	-	100	-	8.0	-	25	-	75
Chocopampa Fish Kill Area	-	105	-	8.4	-	5	-	100
Pichiu Reference	12	22	0.7	1.0	10	6	2	16
Pichiu Far Field	21	81	0.6	4.3	19	28	2	53
Qda. Shiloui Fish Kill Area	-	119	-	4.1	-	64	-	55

Image 8. Stomach contents of dead rainbow trout from 15 October near Qda. Shiloui.

Fish Pathology

- Necropsy indicated the fish appeared healthy and free of any external or internal infections.

Fish Stomach Analysis

- Stomach analysis for dead and dying fish revealed all had non-native fire ants (*Solenopsis invicta*; Image 8).

DISCUSSION

- Because the aquatic invertebrates are generally the most sensitive to contaminants (Niemi *et al*., 2004), the fact that there were no differences in these groups between July and October suggested that the fish kills were not due to chemical stressors.
- In addition, many of the invertebrates present are very sensitive to temperature and dissolved oxygen (Niemi *et al*., 2004, so their high density also indicates that physical factors were unlikely to be the cause of the fish kills.
- Fish density in October at sites downstream of the mine increased relative to July and was concordant with the benthic invertebrate and water chemistry data that suggested the fish kills were not due to a physical or chemical stressor entering the stream.
- Spatial patterns in the abundance of adult and juvenile rainbow trout and the temporal patterns (i.e., changes between July and October) are consistent with inference the fish kills did not appear to be associated with any discharges from the Antamina mine.
- If the mine been the source of the fish kill, it would be expected a response would have been detected in the benthic invertebrate community and most of the dead fish would have been found upstream of Ayash Village with a decrease in number further downstream towards Pichiu Village.
- The pattern of the documented fish kills (i.e., at Chocopampa and near Qda. Shiloui) suggested there were two localized sources that followed the rain storms that increased stream flows.
- This local effect suggests that the fish kills were due to some focal stressor or perhaps a disease outbreak in the areas where there were high densities of fish.
- Interviews with local residents by Antamina staff suggested that fish were being killed by ants and this episodic event generally occurs further downstream at lower elevations after the dry season.

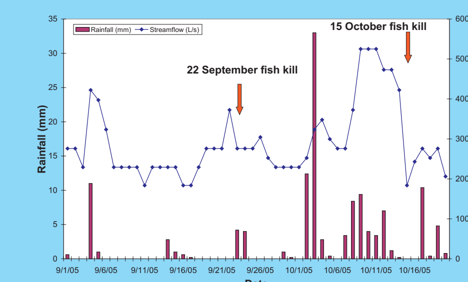

Figure 3. Rainfall and streamflow from September to October.

Image 10. Fire ant mound adjacent to stream.

CONCLUSIONS

- Presence of ants in all fish stomachs indicates a simple mechanism to explain the mortality patterns.
- Ingestion of fire ants by fish would release the venom that is composed of formic acid, alkaloids, and proteins (that collectively act as general toxins on fish).
- The inference is that the large trout were killed by the ingestion of fire ants, as dominant fish would be more likely to feed on surface insects than smaller trout or catfish.
- Since the fish kill events occurred after the rain storms, it is highly probable that flooding of localized ant colonies on the banks of the river resulted in large numbers of ants entering the stream.
- Fish likely consumed both live and dead ants during and after the observed rain events.
- Generally, the reported fish kills due to fire ants do not present a serious problem to the ecology of these low productivity Andean streams as they typically do not reduce the fish population. This situation was observed in Qda. Ayash where fish density was still high in the areas after the fish kills occurred.

Fire Ants: Impacts on fish in North America

- Swarming of the winged form of fire ants has resulted in a number of fish kills in the southeastern United States where the fire ant has become established after being introduced in the 1930s.
- Fish that ingest small quantities (e.g., one or two) of ants generally recover (e.g., Fontenot *et al*., 1999).
- Others have speculated the ants that are still alive when consumed may actually sting the animal in their stomachs and this leads to death if the number of stings is excessive (Allen *et al*.,. 2004).
- It is likely the consumption of dead ants by fish also releases the venom without stings.
- In 1986, the Department of Environment Quality in Louisiana documented a fish kill of sunfish (*Lepomis* spp.) was due to formic acid poisoning from ingestion of fire ants (St. Pe 1994).
- In 1998, there was a major fish kill in the Guadalupe River where Texas officials estimated that 22,000 trout were killed over a 25 km stretch of river due to ingestion of fire ants (Conteras 1999).
- Fish kill incidents in the United States have generally occurred when ant colonies flood or when swarms of adult ants migrate from colonies en masse. The former situation seems to be identical to that observed in Peru.

REFERENCES

Allen, C.R. *et al*. 2004. Red imported fire ant impacts on wildlife. *Am. Midl. Nat.* 152:88-103.

Conteras, C. 1999. Rainbow trout kills induced by fire ant ingestion. *Texas J. Sci.* 51:199-200.

Fontenot, Q.C. *et al*. 1999. Effects of Ingesting Red Imported Fire Ants on Yellowfin Shiners. Proceedings of the 1999 Imported Fire Ant Conference.

Niemi, G.J. *et al*. 2004. Application of ecological indicators. *Annu. Rev. Ecol. Syst.* 35:89-111.

St. Pe, K. 1994. Solving the mystery of fish kills. Fish kills offer challenge to DEQ. Louisiana Environmentalist.

Tello, G., and D. Farara. 2005. The importance of comprehensive aquatic environmental monitoring: programs at new mines in developing countries. SME conference, Lake Placid, NY, 15 p.