Impacts of the Martin County Coal Slurry Spill on Fishery Resources in Eastern Kentucky Streams: A Case Study

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Abstract: On 11 October 2000, approximately 946.25 million liters of coal slurry waste spilled from a Martin County Coal Corporation impoundment into 2 stream drainages in Martin County, Kentucky. On the same day of the spill occurrence, water quality was assessed and periodic monitoring has continued to the present by state personnel from Kentucky and West Virginia. The resulting damage to fish in the streams was the focus of intensive investigation by both the Kentucky Department of Fish and Wildlife Resources and the West Virginia Department of Natural Resources. In addition to water quality measurements (pH and dissolved oxygen) an assessment of the fish kill in Coldwater Fork, Panther Fork, Wolf Creek, and the Tug Fork River, was conducted. The loss of fish resources from the streams were calculated based on existing data, and American Fisheries Society monetary values were utilized for assessed value. Personnel from both agencies concluded that there was a total fish kill in 92.8 km of stream including Coldwater Fork, Panther Fork, Wolf Creek, and the Tug Fork River. An estimated total number of 1,657,503 fish weighing 83,199.04 kg were killed. Kentucky and West Virginia losses totaled $563,927.56 for the fish kill and manpower used for investigation. Clean up of the spill has been extensive; however, substantial material remains in the streams and fishery resources continue to be compromised. It is unclear when the material from the spill will cease to impact the streams affected.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 55:95–104

Coal mining in the mountains of eastern Kentucky is still very active and is the primary focus of the region's economy. Streams and their aquatic resources are frequently impacted as a result of hollow fills, sediment deposition from massive land disturbance, and mine waste (slurry) spills from waste impoundments. Slurry is the by-product of washing waste material from mined coal before transport. This waste is stored in impoundments near washing plants on mine property to be later reclaimed. Literature documenting the effects on fishery resources due to coal mining disturbances is lacking. This case study describes the results of a fish kill investiga-

tion following a massive slurry spill in eastern Kentucky and is relevant to resource managers in the Southeast.

On the morning of 11 October 2000, Martin County Coal Corporation's 29.1-ha slurry impoundment leaked approximately 946.25 million liters of coal slurry waste into 2 different stream drainages in Martin County, Kentucky. Coal slurry waste from the washing process of mined coal leaked through a fault in the bottom of the impoundment into existing, abandoned deep mines, and ultimately into tributary streams feeding Wolf Creek and Coldwater Fork. Slurry from the south main portal entered Big Andy Branch, which flows into Panther Fork that finally drains into Wolf Creek. From another deep mine portal on the north side of the impoundment, slurry entered Road Fork that flows directly into Coldwater Fork. On the Coldwater Fork side, the slurry was more viscous and was slowed by driveway bridges and other constrictions associated with the smaller Coldwater Fork channel. The movement of slurry material in Coldwater Fork was slow, relative to the movement of slurry material downstream in Wolf Creek. This allowed the slurry input to be slowed on Blacklog Fork and Rockcastle Creek, the downstream recipients in succeeding order of the Coldwater Fork drainage. Slurry waste traveled down Wolf Creek and entered the Tug Fork, near Lovely, Kentucky, later that same day resulting in slurry and blackwater impacts from this point on the Tug Fork to its confluence with the Levisa Fork River, near Louisa, Kentucky. Slurry material carried by the Tug Fork eventually resulted in blackwater impacts on the entire length of the Big Sandy River and the lower 2.4 km of the Levisa Fork.

Impacts on fish were most severe in Coldwater Fork, Panther Fork, Wolf Creek, and the Tug Fork River, where fish kills were observed. Blacklog Fork, Rockcastle Creek, Levisa Fork River, and the Big Sandy River all received slurry input, but to a lesser degree and no fish kills were produced. The immediate recipient streams of the coal slurry spill, Big Andy Branch and Road Fork, are ephemeral in flow and at the time of spill were absent of fish species. Determining the extent and magnitude of the fish kill in Coldwater Fork, Panther Fork, Wolf Creek, and the Tug Fork River was the focus of this case study.

Methods

Water Quality Monitoring

To aid in determination of how the slurry would affect fish, both dissolved oxygen (D.O.) and pH levels were monitored during the month of the spill and the 2 months following the spill. These parameters were measured with a YSI Model 50B, for D.O. level and a pHTestr2™, for pH level. Measurements were monitored on Coldwater Fork, Blacklog Fork, and Rockcastle Creek for a greater temporal duration than on the other streams in the investigation. Approximately once a week from 12 October through 8 November these parameters were examined on Coldwater Fork and then one additional time on 19 December. Blacklog Fork and Rockcastle Creek were monitored on the same dates as Coldwater Fork, excluding the first and last

monitoring dates. Wolf Creek and Tug Fork were monitored only on 13 and 22 October and on 13 and 23 October, respectively. Dissolved oxygen and pH levels were recorded once on 14 October for the upper reach of the Big Sandy River and the lower reach of the Levisa Fork River.

Fish Kill Investigation

Wolf Creek was sampled for fish once on 22 October 2000 using a 3.1-m long x 3.2-mm mesh seine. Three sites were sampled (Fig. 1), each with 3, 7.6-m seine hauls. The same sampling technique was used to sample 4 sites on Coldwater Fork, 1 site on Blacklog Fork, and 3 sites on Rockcastle Creek. Approximately once a week from 19 October through 8 November 2000, Coldwater Fork, Blacklog Fork, and Rockcastle Creek were sampled.

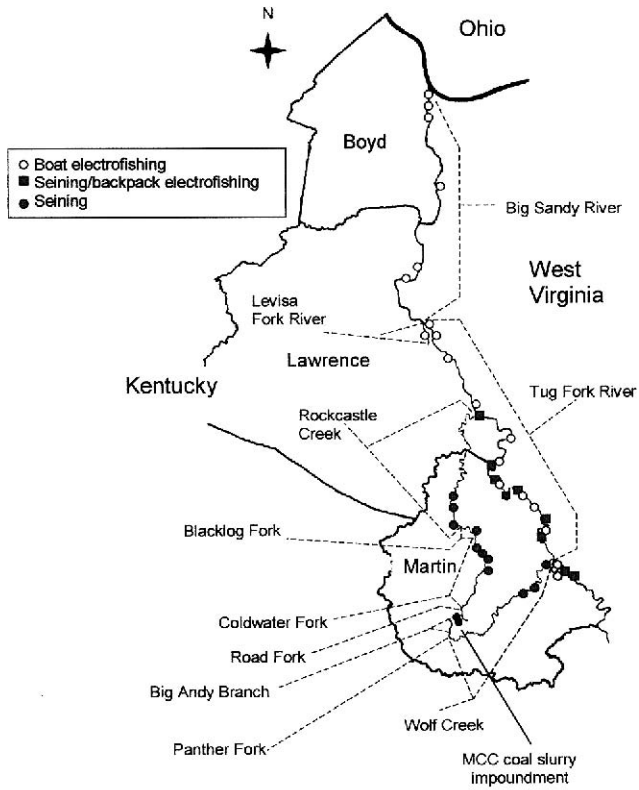

Figure 1. Location of Martin County Coal Corporation's coal slurry impoundment (MCC) and fish sampling stations in Boyd, Lawrence, and Martin Counties of Kentucky. Stream reaches identified with dashed lines are actual areas impacted with coal slurry during October 2000 spill.

On the Tug Fork, fish were sampled utilizing boat electrofishing and a seining/backpack electrofishing technique. All boat electrofishing samples at each site were of 15-minute length. The KDFWR sampled the 3 sites furthest downstream, near the confluence with Levisa Fork River, on 14, 20, and 23 October 2000. Seven sites were sampled by the Kentucky Department of Fish and Wildlife Resources (KDFWR) and West Virginia Department of Natural Resources (WVDNR) beginning downstream of the confluence with Wolf Creek and approximately ending at the confluence of Rockcastle Creek on 27 October 2000. Two additional sites were sampled with boat electrofishing on the Tug Fork River upstream of the slurry input as control reaches on 30 October 2000 by KDFWR. The KDFWR and WVDNR conducted further sampling on the Tug Fork River using a seining/backpack electrofishing technique on 27 October 2000. Two of these sites were upstream of the source of the slurry input to be used as control reaches and 7 sites were located in the slurry-impacted reach. Sampling consisted of backpack electrofishing a 1.8-m by 1.8-m area into a seine followed by another person kicking and disturbing the bottom to force fish into the waiting seine. This technique was repeated 10 times at each site.

Boat electrofishing was used to sample for fish in the lower reach of the Levisa Fork River near its confluence with the Tug Fork River at 1 site on 14 and 20 October 2000 by the KDFWR. The KDFWR and WVDNR conducted additional sampling at 6 sites in the Big Sandy River. On 23 October and 1 November 2000 the downstream 4 sites were sampled, and on 25 October and 2 November 2000 the upstream 2 sites were sampled.

Monetary Loss of Fishery

Existing biomass data was used for calculation of the monetary loss to the fishery resources. Previous rotenone studies were used to estimate the fish killed in each stream. On all streams with fish kills, estimates of numbers of fish per kilometer were determined and then expanded for the entire length of stream killed to give total number of each species or species group killed. These numbers were then multiplied by the monetary value of fish species that was determined by the American Fisheries Society (1992) to give total monetary loss of fish species from the 3 impacted streams.

Several different rotenone studies were used in the determination of fish killed in the coal slurry impacted streams. For calculation of the fish kill in Coldwater Fork, Panther Fork, and Wolf Creek, estimates were obtained from rotenone studies done in 1983 by the KDFWR on streams similar in size, topography, and land use practices in the Blaine Creek (Lawrence County, Ky.) watershed. Fish diversity and abundance data from 3 streams similar in watershed size to Coldwater Fork were averaged and used to estimate numbers of fish lost in Coldwater Fork. Five Blaine Creek sites similar in watershed size to Panther Fork and Wolf Creek were averaged and used in the same fashion. Rotenone studies performed by the WVDNR in the 1980s on stretches of the Tug Fork River were used for biomass data and number of fish per kilometer to apply to fish kill estimates on the Tug Fork River. Additional rotenone studies were not necessary for other streams impacted during the coal slurry spill.

Results

Water Quality Monitoring

Water quality measurements were recorded for a period of approximately 2 months. No D.O. or pH measurements were taken in the impacted upstream 6.5 km of Coldwater Fork, 0.6 km of Panther Fork, or upstream 17.4 km of Wolf Creek as the coal slurry mixture was so viscous that the stream channels were bank full with sediment. The lowest measure of pH occurred in Wolf Creek 2 days after the spill at 6.4 (Table 1). The pH rebounded back to approximately 7.9 in the following week. The pH of all other streams never sagged below 7.1 (Table 1). Lowest D.O. levels were observed on 13 October 2000 when the upstream 2 km of the impacted Tug Fork River had a D.O. level of 3.7 mg/liter and Wolf Creek had a D.O. of 1.0 mg/liter (Table 1). The oxygen concentration in Wolf Creek rebounded to levels over 8.0 mg/liter in the following week (Table 1) as the most viscous portion of the slug passed through Wolf Creek and entered the Tug Fork River. On 23 October 2000 the Tug Fork River D.O. concentration ranged from 9.0–9.5 mg/liter (Table 1).

Table 1. Range of recorded dissolved oxygen (mg/liter) and pH values during October–December 2000 in streams impacted by the coal slurry spill.

Date	Stream	Dissolved oxygen	pH
12 Oct	Coldwater Fork	11.0	8.0
13 Oct	Tug Fork River	3.7–9.5	7.1–8.2
	Wolf Creek	1.0	6.4
14 Oct	Levisa Fork River	9.5	8.0
	Big Sandy River	9.5	7.9
19 Oct	Coldwater Fork	9.5	7.9
	Blacklog Fork	8.5	7.5
	Rockcastle Creek	7.6–9.0	7.6–7.7
22 Oct	Wolf Creek	8.9–9.9	7.8–8.0
23 Oct	Tug Fork River	9.0–9.5	7.9–8.2
24 Oct	Coldwater Fork	7.6	7.4
	Blacklog Fork	5.5	7.4
	Rockcastle Creek	6.9–8.5	7.6–7.7
31 Oct	Coldwater Fork	9.0–10.0	7.7–7.8
	Blacklog Fork	7.9	7.6
	Rockcastle Creek	9.2–11.8	7.6–7.9
3 Nov	Coldwater Fork	9.5–10.2	7.7–8.0
	Blacklog Fork	8.8	7.7
	Rockcastle Creek	9.0–10.0	7.7–7.8
8 Nov	Coldwater Fork	7.0–7.8	7.3–7.8
	Blacklog Fork	6.8	7.5
	Rockcastle Creek	9.5–9.8	7.8–8.0
19 Dec	Coldwater Fork	11.5	8.2

Table 2. Distance in kilometers of impacted and fish kill reaches of streams in Kentucky and West Virginia during the October 2000 coal slurry spill.

Stream	Impacted distance	Fish kill distance
Tug Fork River, KY-WV	57.9	57.9
Wolf Creek, KY	27.7	27.7
Coldwater Fork, KY	10.5	6.6
Panther Fork, KY	0.6	0.6
Big Sandy River, KY-WV	41.8	
Rockcastle Creek, KY	26.9	
Road Fork, KY	4.7	
Blacklog Fork, KY	3.1	
Levisa Fork River, KY	2.4	
Big Andy Branch, KY	1.3	
Total	177.5	92.8

Fish Kill Investigation

Four streams were determined to have fish kills. Three of these streams, Panther Fork, Wolf Creek, and the Tug Fork River, had a total fish kill throughout their coal slurry impacted distance (Table 2). Coldwater Fork had a total fish kill in 6.6 km of its impacted 10.5 km distance (Table 2). All other coal slurry impacted streams were determined to have no fish kill. A total of 177.5 km of streams were impacted by the coal slurry spill and 92.8 km of this distance received a total fish kill (Table 2).

Monetary Loss of Fishery

There was an estimated total of 1,657,503 fish weighing 83,199.04 kg, representing 15 different species or species groups killed in 3 Kentucky streams and in one stream shared by Kentucky and West Virginia. Values assigned to each length group of fish were obtained from the American Fisheries Society (1992) monetary values. These values vary based on species and size within species groups. Kentucky's losses totaled $322,244.17 for the fish kill and manpower used for the investigation and West Virginia's share for the Tug Fork River was $241,683.39 for a total of $563,927.56. Martin County Coal Corporation was also fined for impacts to Kentucky waters by the KDFWR. Under KRS 150.460 and KRS 150.990, the company was fined $45,000 for placing in public waters any substance which has an injurious impact on wildlife (Kentucky Tourism Development Cabinet, Dep. Fish and Wildl. Resour. 1998).

Discussion

Fish Kill Determination

The 11 October 2000 Martin County coal slurry spill was coined by news groups as the worst disaster of its kind in Southeast U.S. history. For fisheries profes-

sionals it produced a unique situation in which evaluating the fish kill as normally done was impossible due to the covering of fish by various depths of thick black slurry sediment. Usually, a fish kill investigation in a stream involves the visual counting and categorizing of the dead fish in a known length of that stream. Due to the inability for visual counts of dead fish, various sampling methods were incorporated to evaluate the extent of the fish kill in each stream. Once the fish kill reaches of impacted streams were determined; existing data was used to determine number and species group of fish lost in the impacted streams. This was not the preferred way to investigate a fish kill, but was the best way determined for this spill event. It will be important to determine if there are other methods of sampling that result in a significant difference in the fish kill investigation, as there is the potential for this type of event to occur again in the Southeast.

Fish kills were determined to be the result of suffocation due to the physical clogging of gills preventing material exchange. In Coldwater Fork, Panther Fork, and Wolf Creek the flow of water and slurry immediately following the spill resembled a black version of freshly poured concrete. In the Tug Fork River the slurry was less viscous than in the 3 previously mentioned streams, although it still carried a high sediment load. All municipal water plants drawing water from the Tug Fork River were forced to cease withdrawal of water from the river, as they could not filter the high turbidity level following the spill. Examination of dead fish revealed gill filaments and lamellae clogged with black sediment. Gill operculums and arches had lesions and abrasions from the presumed choking and emergency respiration that preceded suffocation. Measurements of all pH and most of the dissolved oxygen values were within the survivable range for warmwater fish species (Lucky 1977, Boyd 1979). The designation of warmwater streams (Rabeni 1993) includes all of the streams monitored during the investigation. Immediately following the spill, the lower D.O. levels of 1.0 mg/liter in Wolf Creek and 3.7 mg/liter in the Tug Fork River would have increased stress on fish that were simultaneously under the effect of physical clogging of gills and reduced respiratory efficiency. A D.O. level greater than 5.0 mg/liter is desirable for growth and health of fish (Lucky 1977, Boyd 1979). Dissolved oxygen levels below 3mg/liter lead to death in rapacious fish (Lucky 1977) and a minimum level of 1 mg/liter is necessary to support fish at rest for a prolonged period (Boyd 1979).

Clean-up Process

In the process of removing slurry from the streams, stream banks, and floodplain, there was a great deal of damage to the Coldwater Fork and Wolf Creek watersheds. Several techniques were used to try to contain and remove slurry material from the impacted areas. Initially, pump vacuum trucks were removing slurry directly from the stream channel. This process was soon found to be inefficient and slow given the tremendous volume of material in the streams. The next technique used was dredging material from the stream channel to allow some of the slurry on the banks of the stream to return to the channel. Concurrently, rock weirs were placed in both Coldwater Fork and Wolf Creek to contain as much material as possible. At

each weir, large diesel pumps removed the slurry from the stream and transported it to a series of nearby settling ponds. These ponds were treated with a chemical flocculent allowing the coal waste to settle out so that clean water could be returned to the streams below the weirs. Once channels were re-established in Coldwater Fork and Wolf Creek, the material on the stream banks, yards, and flood bottoms was dried with lime and removed with excavator equipment and transported to other holding areas on the mine site. This was very effective at removing the bulk of the material along the streams. High-pressure washers on hydroseeding trucks were used briefly on Wolf Creek and Coldwater Fork and their headwater streams to wash slurry sediment from stream banks down into adjacent channels. This proved futile as each high water event following a high-pressure washing would blacken the banks again with slurry sediment. Presently, little has been done to remove slurry material from the lower Wolf Creek or Coldwater Fork channels. Also, as of this date, no removal of material has been performed on the Tug Fork River though a vast quantity of slurry material was deposited and remains in the river. Naturally occurring high water events have and continue to move and redistribute the remaining slurry sediment. Plans regarding a stream and floodplain restoration assessment and a slurry impact and biota recovery assessment were completed by November 2001 by various private consulting firms for Martin County Coal Corporation. During 2002 results of these plans will be discussed among officials from the coal company and its consultants, and federal and state government agencies overseeing the restoration process, to determine future restoration priorities.

Future remedial actions will have to recover streams to a healthy stream channel pattern. Removal of the slurry by various processes caused additional stream degradation. To remove the slurry from the floodplain areas, it was necessary to remove material to bare soil. Since it was too late in the year to plant vegetation on this bare soil, the areas eroded and deposited sediment into streams, compounding the problem of material in the water columns. In several areas of streams it was also necessary to remove trees and build temporary dirt roads to gain access for heavy equipment to the stream bank. This also resulted in erosion, and the removal of trees will allow bank failure and excessive erosion in the future. The final insult to both streams from the clean-up process was to the stream channel and substrate. Heavy equipment was used in the headwaters of both Coldwater Fork and Wolf Creek to scoop material from the stream bottoms. This resulted in wide, uniform stream channels void of the necessary pool, riffle, run habitats that are essential for sustaining fish abundance (Orth and White 1993).

Impacts and Recovery

Recovery of the impacted streams will be a slow process that will require the use of intelligent restoration practices. Altered stream channels will recover through natural fluvial and biotic processes, but recovery may require decades or even centuries (Orth and White 1993). The clean-up process heavily impacted both the Wolf Creek and Coldwater Fork riparian zones and stream channels. The riparian areas

were stripped of nearly all plant life and the stream channels were disturbed from dredging of the slurry from the stream. Riparian areas will have to be revegetated with grasses, hardwoods, and woody shrubs to help return these systems to a pre-impact state. Although the Tug Fork River was not impacted from clean-up processes, there are still severe impacts in this system. There is still coal slurry material in the Tug Fork River that is remobilized every time there is a large rain event increasing flows. Unless this material is removed manually, there could be impacts from the stored slurry for several years or until natural events recover the system. This slurry will continue to impact aquatic life by destroying any fish spawn sites and killing recolonized macroinvertebrate populations. When the material ceases to impact these stream systems, the aquatic life will recover in time. It may also help to speed recovery of the Tug Fork River if fish species are reintroduced to the system through stocking programs. This will be a costly process with genetic integrity and fish availability driving the effort to recover the fish population. The best option will probably be to collect adult fish for brood stock from unimpacted sections of the Tug Fork River. The time frame on recovery of these streams is uncertain at this time. Before any fishery can be re-established, it will be necessary to wait for the slurry to leave the system and allow macroinvertebrates to recolonize the impacted miles of streams.

Conclusions

Because there is a very real potential for this type of accident to occur again, several issues need to be addressed by state agencies to better investigate and build cases where fish kills are involved. There is a definite lack of biomass data on most of the streams in eastern Kentucky; examples include Wolf Creek and Coldwater Fork. This information could be obtained through rotenone studies targeted at larger order streams that lie below high-risk slurry impoundments. This will be labor intensive and probably not good for public relations, but does seem necessary in light of the limitations we faced while investigating the Martin County Coal spill. Another limitation observed in this process was communication between all the state and federal agencies involved in the spill investigation and clean up. Lines of communication improved as the process progressed, but it seemed that all the agencies did not share the same commitment in the extent of clean-up expected of the company. It would benefit all agencies involved in this process to form a group with representatives from each agency to draft an incident plan for potential future slurry spills. This plan should outline each agency's responsibility and agenda for such a spill and should also address the magnitude of the clean-up expectations (i.e., remove all material in the stream channel or let some be transported downstream with high water events). Finally, for future fish kill investigations of this kind, it would be beneficial for the American Fisheries Society "Investigation and Valuation of Fish Kills" manual to have a section that would specify best methods to accurately determine fish mortality.

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