EVALUATING THE POTENTIAL IMPACT OF SURFACE MINING ON WATER QUALITY AND MACROINVERTEBRATE COMMUNITIES IN A NATIVE BROOK CHAR FISHERY[1]

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Abstract. Little Sandy Creek and its tributaries, located in Sandy Creek watershed of northwest Pennsylvania, are protected as cold water fisheries and portions of Little Sandy Creek proper are further protected as high quality waters by the Pennsylvania Department of Environmental Protection. Because of these designated protected uses, mining operations discharging into Little Sandy Creek and its tributaries were required to meet in-stream criteria and adequate buffers had to be maintained around all streams, groundwater discharges and wetlands within the permit boundaries. In order to insure adequate on-site treatment, the mining company increased the size of all erosion-sedimentation and treatment ponds by 25 percent. Prior to the commencement of mining, water samples and aquatic communities were surveyed upstream and downstream of the mine site on all streams within the permit boundaries. During mining, water samples were collected monthly from each of two unnamed tributaries to Little Sandy Creek and Little Sandy Creek proper upstream and downstream of the mine site and the aquatic communities were sampled quarterly from each location. There were no adverse impacts on either water quality or in the diversity of aquatic communities in streams located within the permit boundaries. Little Sandy Creek continued to support a reproducing native brook char (*Salvelinus fontinalis*) population and the endangered Eastern Massasauga rattlesnake (*Sistrurus catenatus catenatus*) was observed foraging on the mine site two years post-mining.

Additional Key Words: coldwater fishery, endangered species, watershed

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Introduction

With over 4666 km (32.6%) of the 14,320 km of streams in Pennsylvania adversely impacted by acidic discharges from abandoned mines, there is concern about issuing coal mining permits since discharges can negatively affect streams adjacent to the mine sites (Bernner and Pruent 2007). For over three decades, numerous studies (Brenner et al., 1976, 1977, 1978; Brenner and Cooper, 1978; Smith et al., 1973; Smith and Sykora, 1976; Sykora, 1970; Sykora et al., 1972, 1975; and Updegraff and Sykora, 1976) have documented the adverse impacts of acid mine drainage on fisheries and other aquatic resources. In addition, 45 of the 67 counties in Pennsylvania are impacted by 10,125 ha of un-reclaimed surface mine lands, including 1.99 billion m^3 of coal refuse and numerous abandoned underground mines throughout the state (Brenner and Pruent, 2007). In response to the adverse impacts of acid mine drainage and many un-reclaimed mine lands, discharge and monitoring criteria are commonly employed with the purpose of proactively alleviating the effects of acid mine drainage on the aquatic community. In 1965 an amendment to the Pennsylvania Clean Stream Laws required mine operators to treat acid mine drainage (Pennsylvania Act of Aug. 23, 1965, P.L.372, No.194) and beginning in 1984 scientific data were required to be collected at a potential mining site prior to issuance of a permit to detect the likelihood that the site would produce acid mine drainage (PA DEP, 1999). An evaluation of mining permits by the Pennsylvania Department of Environmental Protection found that a preventative and scientific-based approach to issuing mining permits has lessened new acid mine drainage problems so that acid mine drainage is mostly a problem in historic sites (PA DEP, 1999).

In addition to the general regulations followed by mine operators treating discharge and scientifically monitoring water quality, there are often considerations that are specific to the site where a mining permit is proposed. The Pennsylvania Department of Environmental Protection assigns protected water uses to surface waters that fit certain criteria. One such protected use is an aquatic life protection for cold water fishes where the indicated surface water must be protected to maintain and/or propagate a cold water aquatic ecosystem and specifically fish species within the family Salmonidae and flora and fauna native to that ecosystem (025 Pa. code § 93.3). Surface water within the area of a mining permit would be protected in general as surface water and also according to any additional water quality distinctions.

The Sandy Creek Watershed in portions of Mercer and Venango Counties in northwestern Pennsylvania is managed as a coldwater fishery and hence the watershed is very important to the commonwealth of Pennsylvania ecologically, recreationally, and aesthetically (025 Pa. code § 9.121). During mining, Little Sandy Creek was discovered supporting a native brook char (*Salvelinus fontinalis*) fishery. The endangered eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) historically existed within the Sandy Creek Watershed but there has been no recent recording of the eastern massasauga within or adjacent to the permit boundaries. In the early 1990's, a 350 acre permit was submitted for a surface coal mine that would discharge into two un-named tributaries to Little Sandy Creek in Millcreek Township, Mercer County, Pennsylvania. Public concern was expressed over the issuance of a mining permit within the watershed since adverse impacts previously occurred within Little Sandy Creek and the current threat of acid mine drainage on the aquatic community was likely if mining commenced. Additionally, the local chapter of Trout Unlimited expressed concerns about the possible impact of mining on the trout fishery in Little Sandy Creek.

To address the impact of mining on the adjacent streams and watershed, the mining company agreed to undertake studies on water quality and aquatic communities in the un-named tributaries and in Little Sandy Creek upstream and downstream of the mine site on tributaries of Little Sandy Creek prior, during and after the completion of the mine. The permit was issued in 1991 and mining commenced in 1992 and continued until 1995 when the mine was closed and the site reclaimed. The company also agreed to increase the size and retention capacity of the sedimentation ponds by 25 percent to ensure adequate retention treatment of potential discharges. The current study analyzes the results of the potential impacts of mining on the aquatic resources of Little Sandy Creek and two un-named tributaries to Little Sandy Creek that includes the results of an extensive macroinvertebrate, fish and water quality surveys before, during, and after mining. These monitoring efforts indicate that mining can occur in high quality streams without having an adverse impact on either water quality or the aquatic communities.

Methods

Study area

Two un-named tributaries and the portion of Little Sandy Creek within the permit boundary comprised the study area. Sampling stations were located upstream and downstream of the mine site on the two un-named tributaries of Little Sandy Creek. A sampling station was located on

Little Sandy Creek along the border of the active mine site but within the permit boundaries. Sampling station 1 (S1) and 1A (S1A) were located on un-named tributary 1 to Little Sandy Creek, sample station 11 (S11) was located on Little Sandy Creek within the mine site, sampling station 10 (S10) was located at the junction of un-named tributary 2 and Little Sandy Creek below the mine site, and sampling station 3 (S3) was located in the headwaters of un-named tributary 2 within the mine site. This stream originates from a large palustrine wetland within the permit boundary that was protected during mining.

Macroinvertebrate survey

Macroinvertebrates were surveyed quarterly before, during, and after mining at all five sampling stations (S1, S1A, S11, S3, and S10) from 1991 to 1996 using a combination of kick screen and stone lifting (Deemer *et al.*, 2003). Surveys were omitted for S1 and S3 during 1991 due to dry stream beds. The number of macroinvertebrates and the total number of taxa were calculated per year for each sampling station. The stations were grouped by tributary (see above) and the years were grouped by categories of before (1991), during (1992-1994), and after mining (1995-1996) for subsequent analyses using a Chi-squared analyses with an $\alpha=0.05$ level as significant.

Water quality survey

Water samples were collected monthly before, during and after mining. More specifically, surveys occurred at each sampling station once per month from September thru December in 1991, once per month except November in 1992, once per month in 1993 and 1994, once per month except December in 1995, and once per month between March and June in 1996. Water samples were analyzed for alkalinity, pH, acidity, conductivity, Fe, Mn, Al, SO_4^{2-}, $H_2PO_4^-$, NH_4, NO_3^-, hardness, Ca, Mg, total dissolved solids, suspended solids, fecal coliform, biological oxygen demand, dissolved oxygen, turbidity standard units, and water temperature was recorded at each sample location. Water samples were analyzed in accordance with the Standard Methods for Analysis of Water and Wastewater 18th edition (Greenberg *et al.*, 1992). The laboratory pH was determined using a standardized pH meter. Alkalinity was determined by titrating with 0.02N H_2SO_4 to a known end point (APHA 2320). All metals were analyzed using Atomic Absorption Spectrometry technology (APHA 3111) and suspended solids were based on evaporation dry weight (Brenner and Pruent, 2007).

In addition, water quality was measured by the macroinvertebrate taxa present at each sampling station each year by the Citizen Volunteer Monitoring Program (CVMP) Watershed Snapshot criteria (Deemer et al. 2003). Each invertebrate taxa was identified as ‘tolerant’, ‘facultative’, or ‘sensitive’ and the sampling station’s water quality rating was calculated each year according to the scoring criteria on the macroinvertebrate identification key. When studying the two tributaries from September of 1991 through March of 1996, a separate water quality index scale was created based on the different species discovered from each tributary and the pollution tolerance of each species. A sensitive species received an index number of 3, a facultative species received an index number of 2, and a tolerant species received an index number of 1. These numbers were used to judge the respective water quality of the tributary from which they were taken. A larger population of sensitive species would indicate a higher water quality than a large population of only tolerant species. A tolerant species would indicate poor water quality because they would be the only species that could survive in those conditions. The water quality categories of ‘poor’, ‘fair’, ‘good’, ‘very good’, and ‘excellent’ were assigned a numerical value of 1 (poor) to 5 (excellent) for the purposes of statistical analysis. Chi-squared analyses were conducted for the water quality numbers with an α=0.05 level as significant.

Fish survey

The fish community in the portion of Little Sandy Creek (S 11) located within the mine site was analyzed during and post-mining by electro-fishing 100m of stream. In 1995 and 1996, all fish collected were identification to species and their length and weight recorded millimeters and grams, respectively. The stomach contents were analyzed for all fish collected and categorized as either ‘macroinvertebrate’or ‘vegetation’. Due to the classification of Little Sandy Creek and its tributaries as a cold water fishery, the native brook char (*Salvelinus fontinalis*) captured were sexed and the number of eggs in gravid females recorded.

Results and Discussion

Macroinvertebrate Community

Eighteen different taxa were identified throughout the course of the study and represented sensitive, facultative, and tolerant invertebrates (Tables 1 and 2). Every year tributary No. 1 averaged more individuals than tributary No. 2, but the total number of taxa for each tributary was similar (Fig. 1). This difference in the number of macroinvertebrates may a result of the intermittent flows patterns in tributary 1. There was not a significant difference in the number of individuals among the different sampling years ($X^2 = 20.55$, P> 0.10) or before mining, during or after mining ($X^2 = 18.04$, P > 0.10). The number of taxa also did not vary significantly among the different sampling intervals ($X^2 = 6.76$, $P > 0.10$) or before mining, during mining, and after mining ($X^2 = 5.49$, P > 10).

Table 1. Pollution index and water quality index numerical value (CVMP's watershed snapshot criteria) for taxa found in two tributaries to Little Sandy Creek, Mill Creek township, Mercer county, Pennsylvania (sample period - Sept. 1991 to March 1996).

Taxa			Pollution	Numerical
Order	Family	Genus (if known)	index	value
Diptera	Dixidae		T	1
	Simuliidae		T	1
	Tipulidae		F	2
Ephemeroptera	Heptageniidae	*Stenonema*	S	3
	Siphlonuridae		S	3
Megaloptera	Sialidae	*Sialis*	F	2
Plecoptera	Leuctridae	*Leuctra*	S	3
	Perlidae		S	3
	Perlodidae	*Isoperla*	S	3
Trichoptera	Glossosomatidae	*Glossosoma*	S	3
	Hydropsychidae	*Hydropsyche*	F	2
	Limnephilidae	*Limnephilus*	S	3
	Rhyacophilidae	*Rhyacophila*	S	3
Annelida			T	1
Ostracoda	Physocypria		F	2
Malacostraca	Isopoda		F	2
Mollusca	Compeloma		T	1
Amphipoda			F	2

S = Sensitive species (receives a water quality index value of 3)
F = Facultative species (receives a water quality index value of 2)
T = Tolerant species (receives a water quality index value of 1)

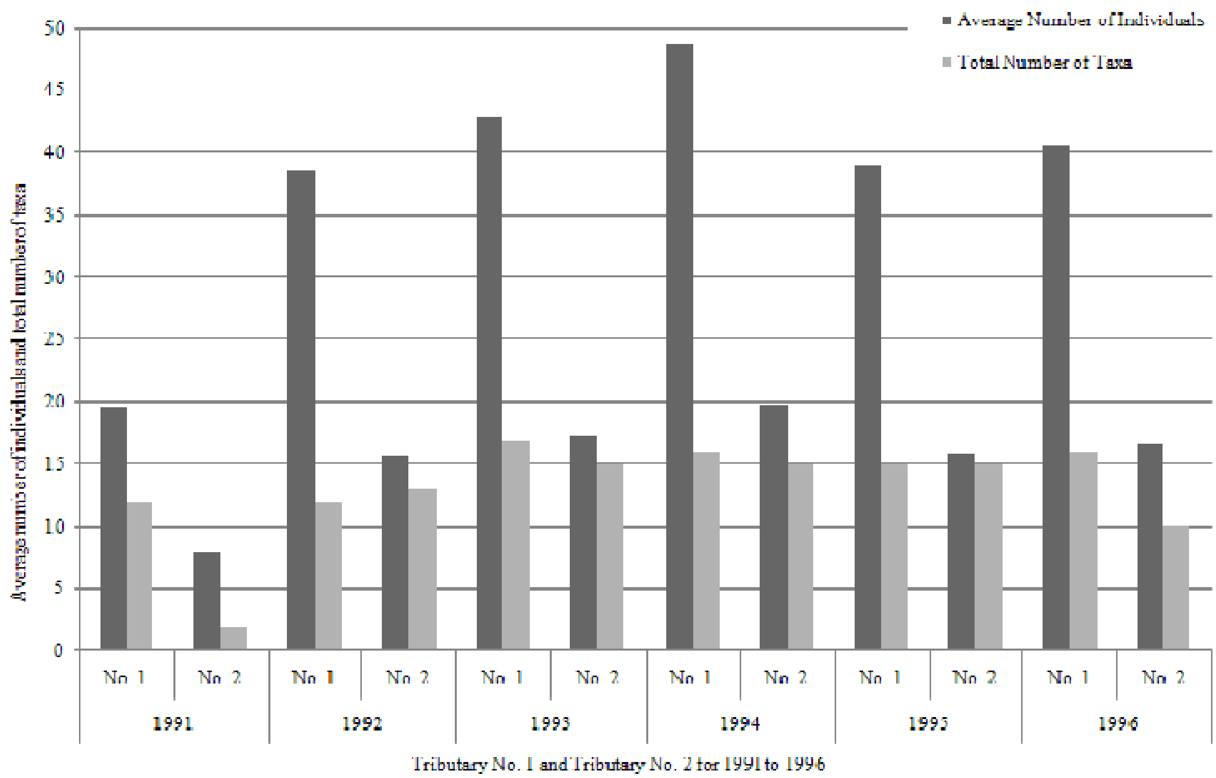

Figure 1. Average number of individuals and total number of taxa per year for tributary No. 1 and tributary No. 2 from 1991 to 1996 (n = 2 to 4 samples per year).

Table 2. Water quality rating, based upon the pollution index, determined for each sampling station for the years 1991 to 1996 (n = 2 to 4 samples/year).

	1991	1992	1993	1994	1995	1996
S1	N/A	Good	Good	Good	Good	Good
S1A	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
S11	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
S3	N/A	Good	Good	Very Good	Good	Good
S10	Poor	Excellent	Excellent	Excellent	Excellent	Excellent

Water quality

The sedimentation and treatment ponds were effective in eliminating any discharges from the mine site into either the two tributaries or Little Sandy Creek. Twenty water quality parameters were determined for each of the five sites on the Little Sandy Creek Watershed (S1, S1A, S11, S3 and S10). The data were grouped into three time periods: before mining (1991 Table 3a), during mining (1992, 1993, 1994; Table 3b), and after mining (1995 and 1996; Table 3c). For each of the parameters, the mean and standard deviation was determined for each time period. Water quality as indicated by ranking the macroinvertebrate taxa at each station based on a pollution tolerance index (PTI) (Tables 1 and 2) (Deemer *et al.* 2003) did not vary among the different years ($x^2 = 3.63$, $P > 0.30$) or before, during and after mining ($x^2 = 1.10$, $P > 0.5$).

Table 3a. Chemical characteristics at the different sampling stations prior to mining, Millcreek Township, Mercer, Pennsylvania.

Sampling Site	**S1**		**S1A**		**S11**		**S3**		**S10**	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
pH	6.47	0.36	6.98	0.62	6.99	0.645	6.87	2.22	6.81	2.02
Alkalinity (mg/L)	7.00	2.00	19.55	5.47	24.7	13.11	15.00	7.63	18.85	9.87
Acidity (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	1.40	3.28	0.37	1.21
Conductivity	5.05	1.61	32.60	35.55	13.64	5.15	8.93	4.70	11.52	6.33
Iron (mg/L)	0.22	0.13	0.91	0.85	0.59	0.42	0.53	0.23	0.43	0.23
Manganese (mg/L)	BDL	BDL	0.03	0.05	0.03	0.05	ND	ND	0.1	0.05
Aluminum (mg/L)	0.03	0.08	0.01	0.02	0.01	0.02	ND	ND	0.03	0.09
Sulfate (mg/L)	10.50	9.50	29.10	23.50	29.90	18.65	19.85	15.90	32.75	35.10
Phosphate (mg/L)	0.39	0.38	0.32	0.295	0.48	0.47	0.43	0.49	0.37	0.44
Ammonia (mg/L)	0.02	0.01	0.02	0.020	0.02	0.02	0.02	0.02	0.03	0.03
Nitrate (mg/L)	0.05	0.02	0.05	0.020	0.05	0.03	0.05	0.02	0.05	0.02
Hardness (mg/L)	15.80	3.90	22.20	7.55	18.70	6.05	12.20	3.77	16.10	6.75
Calcium (mg/L)	8.00	2.92	10.80	6.40	9.90	4.33	5.50	1.87	6.90	3.82
Magnesium (mg/L)	7.10	3.99	11.40	5.30	9.20	4.74	6.90	2.72	8.70	5.15
Total Dissolved S. (mg/L)	14.45	8.80	10.00	2.64	11.00	4.89	9.15	3.54	10.75	3.74
Suspended Solids (mg/L)	2.38	2.00	6.13	5.200	3.68	2.59	4.87	2.65	2.92	1.63
Temperature (F)	25.15	5.40	46.85	5.175	47.75	7.47	43.05	14.95	46.60	15.95
Fecal Coliform	7.71	14.85	15.95	37.54	31.39	44.53	16.67	39.02	46.06	56.27
BOD	5.30	2.79	5.10	4.29	4.95	2.41	5.30	3.40	4.95	3.59
Dissolved Oxygen (mg/L)	2.48	0.78	2.76	0.70	2.68	0.63	2.18	0.84	2.46	0.72
Turbidity (Standard Units)	2.23	1.60	3.68	1.62	1.60	1.66	2.35	2.58	2.61	2.10

BDL defined as below detection limits

Table 3b. Chemical characteristics at the different sampling station during mining, Millcreek Township, Mercer, Pennsylvania.

Sampling sites	**S1**		**S1A**		**S11**		**S3**		**S10**	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
pH	7.36	0.32	7.35	0.31	7.55	0.48	6.48	0.71	7.25	0.47
Alkalinity (mg/L)	15.20	5.62	12.72	7.06	22.85	7.33	8.75	2.43	15.25	7.39
Acidity (mg/L)	8.63	4.60	0.75	3.44	0.25	0.87	1.02	2.49	0.34	1.16
Conductivity	6.20	2.61	19.67	5.50	17.92	5.71	6.88	20.60	10.71	6.08
Iron (mg/L)	0.72	1.46	0.29	0.34	0.43	0.34	0.52	0.38	1.38	0.38
Manganese (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Aluminum (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BLD	BDL
Sulfate (mg/L)	13.85	9.29	24.20	16.80	15.05	8.94	15.00	11.03	12.90	5.38
Phosphate (mg/L)	2.38	2.88	2.06	2.04	1.72	1.99	1.25	1.59	2.09	2.81
Ammonia (mg/L)	0.18	0.24	0.31	0.54	0.16	0.27	0.20	0.32	0.15	0.22
Nitrate (mg/L)	0.15	0.38	BDL	BDL	0.56	1.49	BDL	BDL	0.59	1.82
Hardness (mg/L)	50.15	17.80	69.10	25.30	61.90	20.20	34.85	15.29	36.00	14.82
Calcium (mg/L)	18.40	5.03	38.20	15.71	32.35	13.60	13.25	5.48	16.50	4.36
Magnesium (mg/L)	32.15	14.17	31.25	17.10	28.75	15.70	21.65	11.75	19.90	13.08
Total Dissolved S. (mg/L)	52.20	25.90	76.95	33.00	67.75	23.55	33.25	13.07	43.35	20.55
Suspended Solids (mg/L)	4.00	1.72	3.73	2.56	3.44	2.53	3.67	1.84	3.84	2.81
Temperature (F)	46.65	8.74	46.55	7.39	24.54	11.38	49.75	12.40	49.20	13.55
Fecal Coliform	60.98	93.94	9.18	21.11	31.75	38.23	19.00	32.35	75.11	90.89
BOD	8.98	10.81	10.94	14.66	18.60	6.00	12.53	14.88	13.37	13.01
Dissolved Oxygen (mg/L)	7.36	1.98	8.37	2.10	8.27	2.12	5.85	1.49	7.75	2.23
Turbidity (Standard Units)	8.25	12.54	3.72	4.85	3.15	3.36	2.45	3.22	2.80	3.03

BDL defined as below detection limits

Seven fish species were collected from Little Sandy Creek during and after the completion of mining with the brook char (trout) (*Salvelinus fontinalis*) being the most numerous species collected (Table 4). All the brook char were aged using scale annuli and three age classes were present in the population. The total length of 0+ age class varied between 66 and 90mm and the 1+ and 2+ age classes varied between 135 and 187 mm and 210-325 mm, respectively. Two gravid females (135 and 168 mm) were collected containing 119 and 131 eggs, respectively and since 0+ age classes were also collected during the surveys of the fish community, it was concluded that Little Sandy Creek supported a reproducing brook char population that was not adversely impacted by mining. The other species included the mottled sculpin (*Cottus bairdi*), bluegill (*Lepomis macrochirus*), blacknose dace (*Rhinichthys atraulus*), largemouth bass (*Micropterus salmoides*), white sucker (*Catostomus commersonnii*), and the bigeye club *Hybopsis amblops*. Of the seven species, only the white sucker was feeding entirely on vegetation (Table 4). Based on the stomach analyses of these seven species, macroinvertebrates are an important and major component of the diet of these species.

Table 3c. Chemical characteristics at the different sampling stations after the completion of mining, Millcreek Township, Mercer, Pennsylvania after mining.

Sampling sites	**S1**		**S1A**		**S11**		**S3**		**S10**	
Parameter	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
pH	7.37	0.25	7.58	0.26	7.44	0.25	6.52	0.48	6.88	0.41
Alkalinity (mg/L)	18.45	6.38	19.65	4.98	26.35	5.38	9.15	1.58	12.80	2.58
Acidity (mg/L)	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.06	0.05	0.06
Conductivity	22.63	4.33	24.35	3.26	24.29	3.28	9.95	1.35	11.38	2.35
Iron (mg/L)	0.35	0.12	0.42	0.32	0.48	0.30	0.53	0.20	0.55	0.24
Manganese (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Aluminum (mg/L)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sulfate (mg/L)	11.60	4.75	11.70	4.96	12.60	4.36	14.75	6.43	14.65	7.15
Phosphate (mg/L)	0.49	0.22	0.94	1.36	0.73	0.71	0.56	0.33	0.89	0.52
Ammonia (mg/L)	0.03	0.02	0.03	0.01	0.04	0.01	0.10	0.05	0.14	0.16
Nitrate (mg/L)	0.02	0.02	0.05	0.07	0.13	0.16	0.07	0.09	0.10	0.23
Hardness (mg/L)	63.80	43.75	62.60	19.40	59.45	17.40	36.90	19.20	39.95	19.50
Calcium (mg/L)	36.55	28.15	37.45	10.04	32.50	10.08	17.45	7.80	5.79	9.09
Magnesium (mg/L)	25.80	18.05	24.25	12.61	24.45	10.76	19.45	14.83	2.46	11.49
Total Dissolved S. (mg/L)	10.52	51.45	11.93	20.80	11.05	2.11	6.28	20.65	77.25	1.79
Suspended Solids (mg/L)	1.95	1.28	1.98	0.69	3.18	1.59	2.95	1.77	2.83	1.40
Temperature (F)	46.30	27.00	48.50	4.27	31.65	10.60	46.80	13.55	51.90	13.80
Fecal Coliform	34.32	21.00	51.45	62.64	62.74	46.97	52.76	32.16	136.49	75.59
BOD	3.33	2.52	3.37	1.29	5.22	3.08	4.31	1.63	7.20	4.53
Dissolved Oxygen (mg/L)	7.44	1.14	8.08	1.53	9.28	1.68	5.35	0.73	6.85	0.79
Turbidity (Standard Units)	2.24	1.19	2.21	1.21	2.48	1.42	2.72	1.37	3.93	2.75

BDL Defined as below detection limits

Table 4. Length, weight and stomach content of fish species at S11, Millcreek Township, Mercer County, Pennsylvania during 1995 and 1996.

Genus	Species	Year	Length mm	Weight g	Stomach content
Cottus	*bairdi*	1995	64	3.1	Macroinvertebrates
			66	3.9	Macroinvertebrates
			66	4.0	Macroinvertebrates
		1996	46	1.3	Macroinvertebrates
			67	4.3	Macroinvertebrates
			67	4.4	Macroinvertebrates
Lepomis	*macrochirus*	1995	80	11.2	Macroinvertebrates
		1996	83	11.2	Macroinvertebrates
Rhinichthys	*atraulus*	1995	56	2.6	macroinvertebrates
			57	2.7	Macroinvertebrate/veg
			65	2.8	Macroinvertebrates/veg
			65	3.8	Macroinvertebrates
		1996	69	4.1	Macroinvertebrates
			78	6.3	macroinvertebrates
Micropterus	*salmoides*	1996	67	4.0	Macroinvertebrates
Catostomus	*commersonnii*	1996	104	14.2	Vegetation
Hybopsis	*amblops*	1996	74	6.1	Macroinvertebrates
			110	16.7	Macroinvertebrates
Salvelinus	*fontinalis*	1995	66	3.5	Macroinvertebrates
			78	3.6	Macroinvertebrates
			87	7.1	Macroinvertebrates
			88	7.1	Macroinvertebrates
			90	7.1	Macroinvertebrates
			90	7.2	Macroinvertebrates
			155	47.4	Macroinvertebrates
			156	38.7	Macroinvertebrates
			187	69.0	Macroinvertebrates
			210	105.3	Macroinvertebrates
			228	126.8	Macroinvertebrates
			225	275.0	Macroinvertebrates
			250	412.0	Macroinvertebrates
			325	275.0	Macroinvertebrates
		1996	135	29.0	Macroinvertebrates
			147	34.0	Macroinvertebrates
			168	49.0	Macroinvertebrates

Eastern Massasauga (*Sistrurus catenatus catenatus*)

In May, 1996, an eastern massasauga was observed foraging in the reclaimed grassland adjacent to a palustrine wetland that was protected during the mining by the establishment of a 91 m buffer created during mining. Although this species historically occurred within the Little Sandy Creek Watershed, this was the first recent documentation of the existence of this species within the portion of the watershed in Mercer and Venango Counties, Pennsylvania.

Conclusions

The results of this study indicate that it is possible to surface mine adjacent to a reproducing brook char fishery in a designated high quality watershed providing that stream and wetland buffers are established and that all erosion and sedimentation and treatment facilities are in place and functioning as designed. During the reclamation of the site, it is possible to either create or enhance habitats for rare and endangered species as well as maintaining a coldwater fishery in streams within and adjacent to the mine site. Although the erosion and sedimentation and treatment ponds were increased by 25 percent, it is not known whether this was necessary. But it provided assurance to the regulatory agencies and concerned public that the company was interested in maintaining the ecological balances that existed within the watershed.

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