CHEMICAL AND BIOLOGICAL ANALYSIS OF FOX RUN WATERSHED, MERCER COUNTY, PENNSYLVANIA[1]

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Abstract: The impact of 5 alkaline iron laden discharges was monitored for their impact on water quality and macroinvertebrate communities in Fox Run, Mercer County Pennsylvania. Water samples were collected monthly and analyzed by an independent laboratory and 6 macroinvertebrate surveys were completed over 9 months using the Pennsylvania Environmental Protection Agency rapid assessment protocol to calculate a Biotic Index. At the completion of the study, a Habitat Evaluation Index (HEI) using the Ohio Environmental Protection Agency Protocols was completed at each stream sampling location. The Biotic indexes and the number of individuals and taxa were inversely correlated with total iron concentrations and positively correlated with the overall HEI. Both water quality macroinvertebrate communities improved 1.3 and 3.5 km downstream from the discharges. The reclamation plan for Fox Run will involve the installation of settling ponds and aerobic wetlands to reduce suspended iron loading into Fox Run.

Additional Key Words: Alkaline discharges, macroinvertebrates, biotic indexes

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Introduction

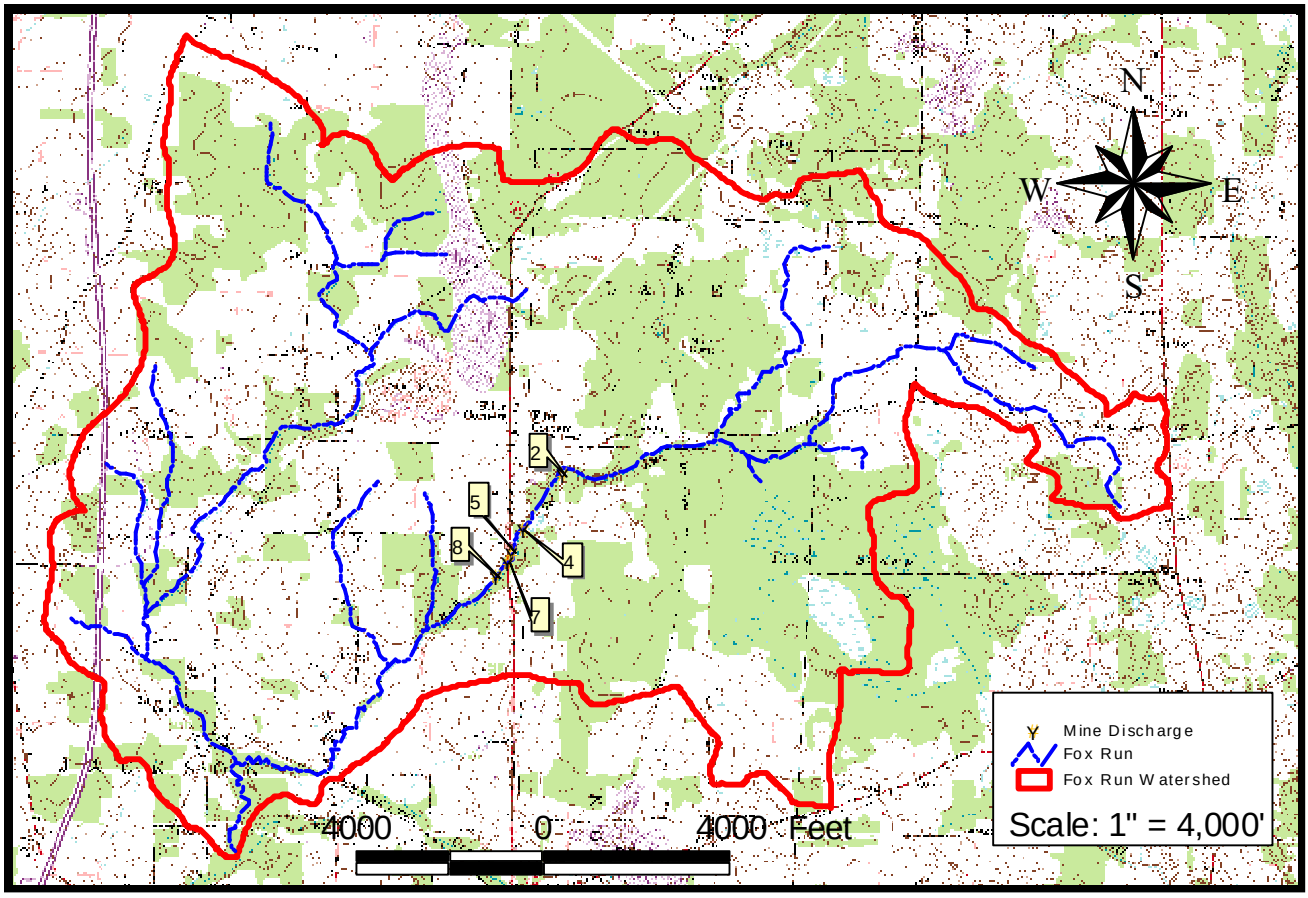
The Fox Run watershed comprises 21.91 km^2 located approximately 96 km north of Pittsburgh and 8 km east of I79 in Jackson Township, Mercer County, Pennsylvania (Fig. 1). Fox Run is a tributary of Yellow Creek which is classified as a stocked trout fishery. Fox Run has been adversely impacted by suspended and dissolved iron discharges from abandoned deep and surface mines for over 70 years resulting in an impairment of aquatic communities. A previous study by Brenner *et al.* (1977) reported iron concentrations significantly impacted both macroinvertebrate and fish diversities in Fox Run below mine discharges and that the accumulation of iron sediments appeared to be the major factor in reducing community diversity.

Earlier studies reported on the impacts of iron hydroxide compounds on the survival and growth of a variety of macroinvertebrates and fish species (Brenner *et al.*, 1976 1977; Brenner and Cooper, 1978; Smith *et al.* 1973; Sykora ,1970; Sykora *et al.*,1972 a,b) As a tributary of Yellow Creek which is classified as a stocked trout fishery, these iron discharges may not only be adversely impacting macroinvertebrate and fish communities in Fox Run, but portions of Yellow Creek, below the junction with Fox Run as well. The current study was undertaken to re-evaluate the impact of these iron discharges on the composition of the aquatic communities prior to the installation of an aerobic wetland system to remove iron precipitates from Fox Run, thereby restoring the diversity of aquatic communities within the watershed.

Methods

Water samples were collected monthly for 9 months at 5 alkaline mine discharges along Fox Run, 1 location upstream of the discharges, and at 3 locations within the impacted sect ion of the stream (Fig. 1). As a control, samples were also collected from two nonimpacted tributaries of Fox Run and an additional sampling station was located at the junction of Fox Run and Yellow Creek, a stocked trout fishery. These water samples were analyzed by an independent laboratory for pH, alkalinity (mg/l), acidity (mg/l), total iron (mg/l), manganese (mg/l), aluminum (mg/l), conductivity (umhos/cm), sulfate (mg/l), and total dissolved solids (mg/l).

Macroinvertebrate communities were assessed using the rapid assessment protocol developed by the Izaak Walton



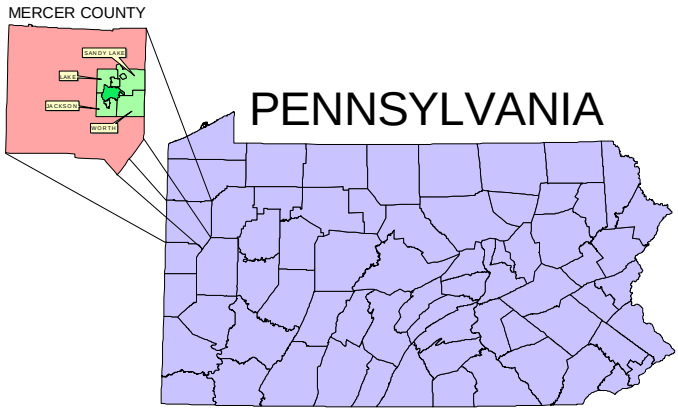


Figure 1: Sample point location map. The 21.91 km^2 Fox Run Watershed is located approximately 96 km north of Pittsburgh in Jackson Township, Mercer County, Pennsylvania.

League's Save our Streams Program and currently being used to develop biotic indices (Beck, 1954; Jones *et al.* 1982; Brenner and Helm, 1991) for streams by state (i.e. Ohio and Pennsylvania) and federal (US EPA) regulatory agencies, as well as other citizen environmental organizations. A Habitat Evaluation Index (HEI) was calculated for each stream station at the

completion of the study using the Ohio Environmental Protection Agency Protocols (Rankin, 1989).

Results and Discussion

Water Quality

The mean alkalinity among the 5 discharges varied from 68.8 ± 23.8 to 231.9 ± 9.2 mg/l with a pH of 6.50 ± 0.07 to 7.27 ± 0.23 (Table 1). The dissolved ionic concentrations, as indicated by conductivity of the 5 sampling stations, varied from 751 ± 51.4 uohms/cm to 1237.9 ± 230.3 uohms/cm, which corresponds to the total dissolved solid concentrations of 526.6 ± 36.2 mg/l and 868.1 ± 159.2 mg/l. Sulfate concentrations varied among the 5 discharges from a low of 112.8 ± 23.4 mg/l to a high of 491.3 ± 224.8 mg/l. Iron was the major heavy metal component of the these discharges with concentrations varying from 5.0 ± 1.7 mg/l to 20.9 ± 5.44 mg/l. Whereas, manganese concentrations ranged between 0.73 ± 0.03 mg/l to 1.94 ± 0.34 mg/l and aluminum concentrations averaged from less than 0.02 mg/l to 1 mg/l among the 5 discharges.

The flow rates from the 5 discharges varied from 0.48 ± 0.22 to 3,181 ± 384.0 l/ min. The combined loading from all five discharges into Fox Run was 50.2 kg/day and 5.5 kg/day for iron and manganese, respectively, and the combined aluminum loading was less than 0.05 kg/day. The total combined sulfate loading into Fox Run from these 5 discharges was 1360.2 kg/day. The mean iron concentration in Fox Run above the discharges averaged 0.68 ± 0.29 mg/l with an average loading rate 5.14 kg/day increasing to an average of 3.24 ± 1.86 mg/l and 47.46 kg/day below the discharges. Manganese concentrations averaged 0.12 ± 0.07 mg/l (0.91 kg/day), increasing to 0.48 ± 0.18 mg/l (7.0 kg/ day) below the discharges. Aluminum concentrations decreased from 0.13 ± 0.07 mg/l to 0.09 ± 0.03 mg/l below the discharges, but, because of increased flows, the aluminum load within the stream increased from 0.98 kg/day to 1.32 kg/day. Sulfate concentrations also increased in Fox Run below the discharges from a mean of 42.5 ± 6.9 mg/l to 132.9 ± 21.0 mg/l. Likewise, the conductivity and dissolved solids increased from 203.7 ± 58.8 uohms/cm and 141.7 ± 39.9 mg/l to 514.1 ± 39.9 uohms/cm and 359.6 ± 44.8 mg/l, respectively. Although these discharges increased metal and ionic concentrations in the stream system, the alkalinity increased from 32.33 ± 12.1 mg/l to 132.3 mg/l above and below the 5 discharges, respectively.

Table 1: Water quality analysis of the five mine discharges.

Sample Point	Date	Flow	Ph		Cond.	Temp.	Alk.	Acid.	T. Fe	T. Mn	T. Al	SO4	TDS
		(L/min)	Field	Lab	(umhos/cm)	C	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Mine Discharge 2	12/29/1999	2440.7	6.4	6.6	773	9.6	234.9	0.0	9.1	0.8	0.0	200.9	553
	1/31/2000	2446.7	6.3	6.8	782	9.8	242.8	0.0	10.3	0.8	0.0	211.4	547
	2/28/2000	2446.7	6.4	6.8	757	9.6	234.8	0.0	5.9	0.8	0.0	220.4	530
	3/13/2000	2906.9	6.6	6.7	769	9.7	228.0	0.0	5.9	0.7	0.0	194.3	537
	4/25/2000	5236.3	6.3	6.6	768	10.1	211.1	0.0	5.3	0.7	0.0	221.5	538
	5/25/2000	3893.8	6.4	6.6	761	10.1	225.7	0.0	5.8	0.7	0.0	237.3	533
	6/28/2000	4284.7	6.3	6.6	761	10.1	231.4	0.0	5.4	0.7	0.0	254.7	533
	7/31/2000	2906.9	6.3	6.6	760	9.9	235.3	0.0	5.9	0.7	0.0	235.7	532
	8/28/2000	2335.4	6.4	6.5	783	10.2	243.2	0.0	6.2	0.7	0.0	205.4	549
Mine Discharge 4	12/29/1999	315.9	6.4	6.6	751	10.3	213.2	0.0	7.5	1.3	0.0	201.6	534
	1/31/2000	425.1	6.4	6.8	739	10.4	208.0	0.0	7.0	1.3	0.0	233.7	517
	2/28/2000	425.1	6.3	6.7	686	10.3	189.6	0.0	6.0	1.1	0.0	206.7	481
	3/13/2000	425.1	6.5	6.7	681	10.5	189.3	0.0	6.2	1.2	0.0	175.7	476
	4/25/2000	702.1	6.4	6.6	736	11.3	186.5	0.0	6.3	1.0	0.1	209.9	515
	5/25/2000	368.5	6.4	6.7	842	10.5	232.1	0.0	7.1	1.3	0.0	307.3	590
	6/28/2000	269.5	6.4	6.7	744	10.7	206.5	0.0	6.3	1.2	0.0	304.4	521
	7/31/2000	316.7	6.3	6.7	802	10.7	221.0	0.0	6.7	1.3	0.0	231.2	561
	8/28/2000	316.7	6.5	6.6	778	10.6	225.5	0.0	6.8	1.3	0.0	241.8	544
Mine Discharge 5	12/29/1999	1.0	6.7	7.0	891	0.3	117.1	0.0	14.5	1.9	1.1	26.3	633
	1/31/2000	1.8	6.6	7.1	1016	0.3	127.5	0.0	8.5	1.1	0.4	73.9	711
	2/28/2000	9.9	6.9	7.4	1434	4.8	105.2	0.0	0.8	0.2	0.0	241.4	1005
	3/13/2000	9.9	7.4	7.3	1307	5.1	89.2	0.0	1.4	0.2	0.0	23.7	915
	4/25/2000	1.8	7.1	7.2	1447	10.9	118.0	0.0	4.8	0.8	0.1	297.7	1013
	5/25/2000	4.8	7.1	7.4	1454	14.5	142.3	0.0	2.4	0.5	0.0	254.2	1019
	6/28/2000	4.8	7.2	7.4	1116	17.5	163.7	0.0	2.5	0.6	0.0	13.6	781

Mine Discharge 7	12/29/1999	55.4	6.6	6.8	913	9.0	252.6	0.0	10.8	1.7	0.0	307.2	674
	1/31/2000	56.0	6.6	6.9	916	9.2	247.9	0.0	1.5	1.7	0.0	294.1	641
	2/28/2000	97.8	6.5	6.9	1012	8.5	250.0	0.0	10.4	1.7	0.0	408.3	707
	3/13/2000	56.0	6.9	6.8	920	9.8	245.4	0.0	9.8	1.6	0.0	313.3	643
	4/25/2000	56.0	6.5	6.7	1108	10.4	272.3	0.0	16.3	1.8	0.0	417.4	776
	5/25/2000	97.8	6.3	6.6	1473	11.1	326.0	0.0	23.1	2.3	0.0	795.8	1031
	6/28/2000	56.0	6.2	6.5	1476	11.0	325.3	0.0	26.6	2.5	0.0	926.2	1034
	7/31/2000	226.8	6.3	6.6	1356	11.3	333.6	0.0	20.3	2.3	0.0	530.9	950
	8/28/2000	75.2	6.5	6.6	1080	11.0	285.0	0.0	17.4	1.9	0.0	428.1	756

Mine Discharge 8	12/29/1999	2.0	6.5	6.4	761	0.6	55.8	0.0	23.8	1.4	2.3	92.6	533
	1/31/2000	0.0	6.5	6.5	788	0.9	55.0	0.0	11.8	1.9	0.1	133.5	552
	2/28/2000	0.3	6.2	6.6	825	7.0	57.3	0.0	18.2	1.3	0.1	149.3	578
	3/13/2000	0.3	6.7	6.5	865	3.2	44.9	0.0	24.6	1.2	2.9	126.6	606
	6/28/2000	0.8	6.4	6.6	803	15.8	93.0	0.0	17.3	1.2	0.1	95.6	562
	7/31/2000	0.0	6.3	6.4	847	18.7	65.0	0.0	22.6	1.2	0.1	101.6	593
	8/28/2000	0.3	6.5	6.5	872	17.0	110.4	0.0	27.9	1.5	1.5	90.5	611

The metal loading from these discharges impacted the entire length of Fox Run to the confluence with Yellow Creek. The iron load at two sampling stations, approximately 1 km and 1.3 km downstream from the discharges, averaged 16.7 kg/day and 14.1 kg/day, respectively, and the iron load approximately 3.5 km downstream from the discharges at the confluence with Yellow Creek averaged 18.4 kg/ day. The manganese load averaged 5.0, 4.1 and 5.2 kg/day at sampling points 1 km and 1.3 km and 3.5 km downstream from the sampling points, respectively. Aluminum loads were less than a kg/day at any sampling point downstream from the 5 discharges. By comparison, the heavy metal concentrations in the two unimpacted tributaries to Fox Run was less than 1 mg/ liter for either iron, manganese or aluminum with average loads of less than a kg/ day.

Macroinvertebrate Communities

The number of macroinvertebrate taxa and individuals varied among the different sampling stations. Twenty-seven individual macroinvertebrates representing 6 taxa were collected in the headwaters of Fox Run above the portion of the stream receiving iron discharges. Although the aquatic habitat was considered optimal with a HEI score of 182 (max. 240), the low abundance of macroinvertebrates and a biotic index of 14 indicates an impairment to aquatic life, possibly due to the natural tannins and organic matter in the stream at this point. Although the HEI score increased to 191 approximately 1 km downstream from the headwaters at a point approximately 10 meters above the first mine discharge, the collection of 59 individuals representing 5 taxa along with a biotic index of 13 $\pm$ 0.3 also indicated an impairment to aquatic life. Likewise collections from Fox Run approximately 1 km downstream in the area receiving mine drainage, the HEI of 173 indicated that the stream was suboptimal for aquatic life which was verified by Biotic Index of 9.8 $\pm$ 2.3 indicating impairment to aquatic life. At a sampling point approximately 1.3 km below the discharges, there was an improvement in stream habitat with the HEI of 192, which is considered to be an optimal aquatic habitat. Likewise, the Biotic Index of 19 indicates good water quality and the collection of 65 individuals representing 11 taxa, indicates that the stream was not impacted at this point. At the confluence of Fox Run and Yellow Creek, the HEI score of 215 was considered optimal for aquatic life and the Biotic Index of 19 along with the collection of 53 individuals representing 12 taxa suggesting that stream has

recovered 3.5 km below the discharges. In a nonimpacted unnamed tributary to Fox Run, the HEI score of 220 and the number of macroinvertebrates collected (50) and taxa (9) represented similar stream conditions and aquatic community that occur at the confluence of Fox Run and Yellow Creek.

For over three decades, studies have reported that dissolved and suspended iron adversely impact aquatic communities (Brenner *et al*. 1976, 1977; Brenner and Cooper, 1978; Smith *et al.* 1973; Sykora, 1970; Sykora *et al.* 1972a,b, 1973, 1975). In the current study, the number of individuals ($r = 0.825$, $P < 0.01$, taxa ($r = 0.924$, $P < 0.001$) and the rapid assessment Biotic Indexes ($r = 0.822$, $P < 0.01$) were inversely correlated with total iron concentrations (Fig. 2, 3, and 4). The HEI was positively correlated with both the number of individuals ($r = 0.946$, $P < 0.001$) and taxa ($r = 0.650$, $P < 0.05$), as well as the rapid assessment biotic index ($r = 0.615$, $P = < 0.05$), suggesting that the overall quality of the stream habitat is an important factor in determining the diversity of aquatic communities. Deemer *et al.* (2003) reported that the HEI, especially the substrate, was an important factor that counter acted the adverse impact of nutrient concentrations on the size and diversity of macroinvertebrate communities in a first order stream. These studies suggest that the overall habitat quality can be addressed during the restoration of stream systems receiving mine discharges. The results of this study were similar to those reported by Brenner *et al.* (1977), indicating that there has been little, if any, improvement in water quality or the size and diversity of macroinvertebrate communities over the last 30 years.

Reclamation Plan

The reclamation plan for the Fox Run is divided into two phases. The first phase involves the construction of linear wetland to collect 7 discharges, a settling pond, and an aerobic wetland. The second phase will involve the construction of an aerobic wetland that will treat a discharge of over 3000 liters/min with an iron load of over 30 kg/day. Based on 90% iron removal, these combined systems will prevent over 45 kg/day of suspended iron from entering into Fox Run. Based on the diversity of aquatic communities in a nonimpacted tributary and 3.5 km downstream from the discharges, both the macroinvertebrate and fish communities should recover throughout the stream system.

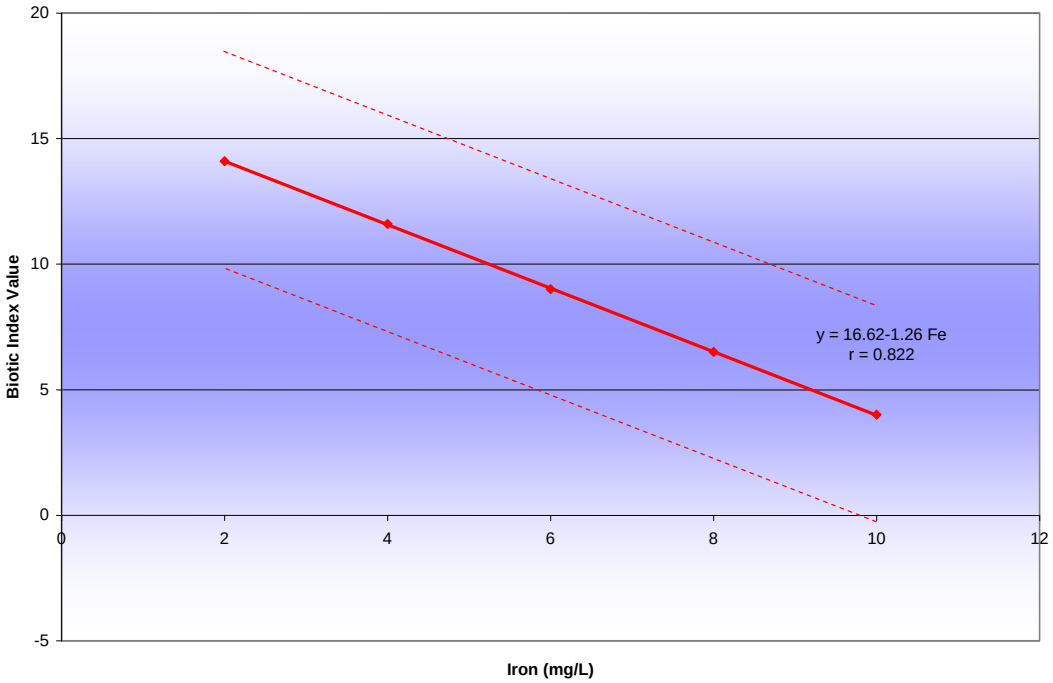


Figure 2: Comparison of Rapid Assessment Biotic Index Value with Total Iron Concentrations within Fox Run

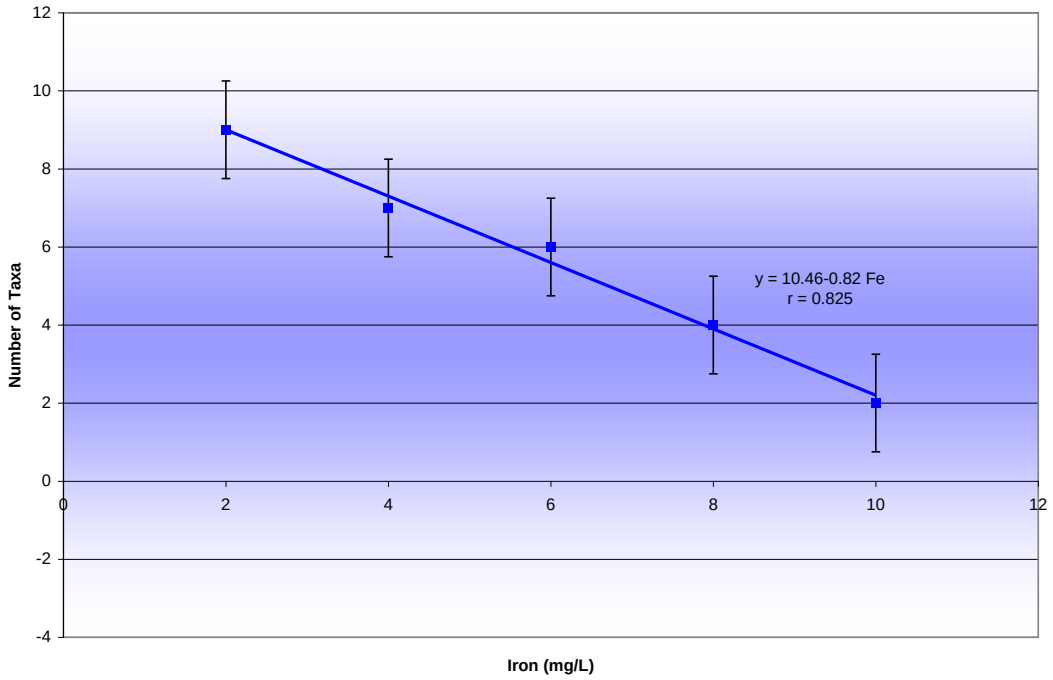


Figure 3: Comparison of the Number of Taxa with Total Iron Concentrations within Fox Run

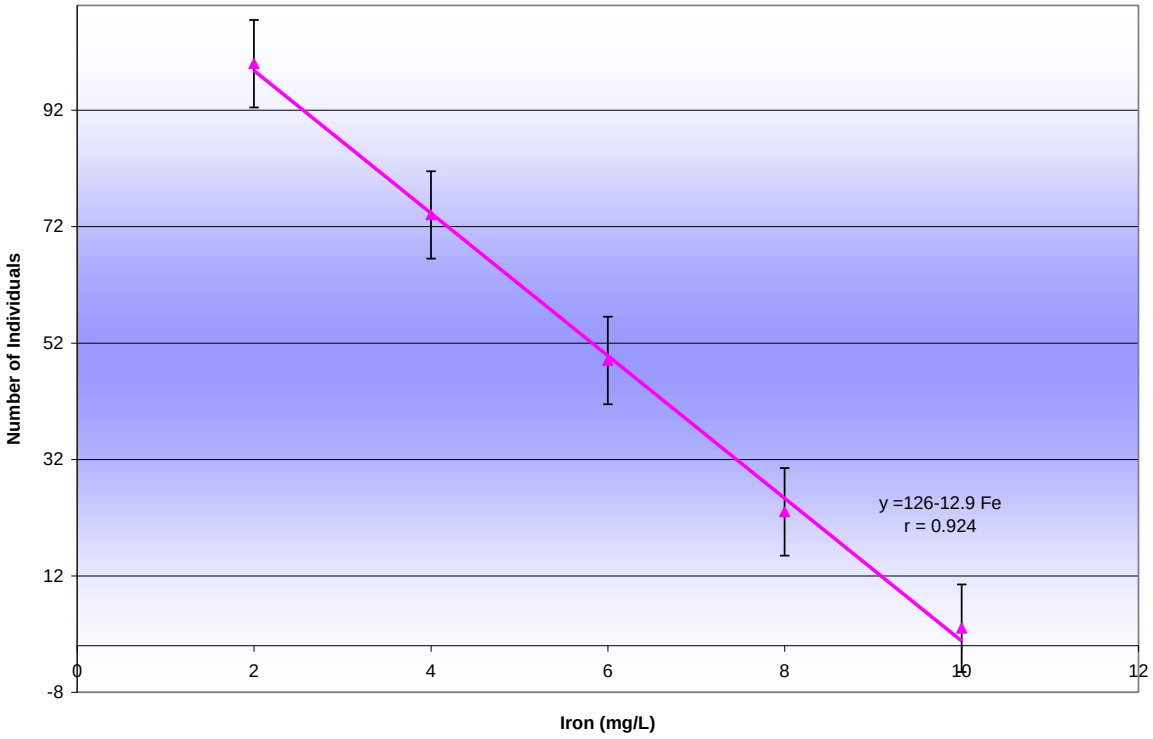


Figure 4: Comparison of the Number of Individuals with Total Iron Concentrations within Fox Run

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