ENVIRONMENTAL STUDIES IN THE VICINITY OF THE SUSQUEHANNA STEAM ELECTRIC STATION

2002 WATER QUALITY AND FISHES

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INTRODUCTION

PPL Susquehanna, LLC (PPL) contracted Ecology III, Inc. to conduct nonradiological monitoring of the Susquehanna River in the vicinity of the Susquehanna Steam Electric Station (Susquehanna SES) in 2002. The Susquehanna SES is a nuclear power station with two boiling water reactors, each with a net electrical generating capacity of approximately 1,115 megawatts. It is located on a 1,700-acre site in Salem Township, Luzerne County, 5 miles northeast of Berwick, Pennsylvania. PPL owns 90 percent of the station and the Allegheny Electric Cooperative owns 10 percent.

The objective of the nonradiological environmental monitoring program is to assess the impact of operating the Susquehanna SES on the Susquehanna River water quality and relative abundance of fishes. This was accomplished in 2002 by comparing data at control and indicator stations and by evaluating results of preoperational (1971-82) and operational (1983-2002) studies. Monitoring was done at sites within a control station (SSES) upriver from the Susquehanna SES river intake structure and indicator stations (Bell Bend and Bell Bend I) downriver from the discharge diffuser.

To more objectively assess the impact of operating the Susquehanna SES on the Susquehanna River, a statistical procedure called BACI (Before-After:Control-Impact) analysis was applied to preoperational and operational monitoring data.

This report presents results of water quality and fishes studies.

WATER QUALITY

PROCEDURES

Water quality of the Susquehanna River relative to operation of the Susquehanna SES was monitored throughout 2002 at two control sites, the Susquehanna SES Environmental Laboratory and SSES; and two indicator sites, Bell Bend I and Bell Bend. River flow and temperature were monitored continuously at the Environmental Laboratory which is located on the west riverbank, 1,620 feet upriver from the Susquehanna SES river intake. Water quality samples were collected at the SSES, Bell Bend I, and Bell Bend river sites. SSES is 750 feet upriver from the intake; Bell Bend I and Bell Bend are 1,310 feet and 2,260 feet downriver, respectively, from the Susquehanna SES blowdown discharge (Fig. 1). Methods of analysis and references are listed in "Water Quality" (Ecology III, Inc. 1998a). Samples were collected once per week from April through September and twice per month for the other six months. Water quality samples have been collected at SSES, Bell Bend, and Bell Bend I since 1972, 1978, and 1985, respectively.

A cooling tower blowdown sample and SSES and Bell Bend river samples were collected once each quarter (three months) in 2002. Blowdown is river water used in the Susquehanna SES cooling cycle and is discharged back to the river. It has high conductivity and dissolved solids concentrations because of evaporative loss in the cooling towers (10,000 gallons/minute/tower evaporation during operation). In 2002, the daily average blowdown ranged from 4.8 to 26.8 cubic feet per second (cfs). These samples were analyzed by the Chemical Laboratory at the PPL Systems Facility Center, Hazleton, Pennsylvania. Temperature, dissolved oxygen, field pH, and field conductivity were measured by Ecology III. Blowdown samples have been collected as part of this program since 1991.

Water quality data were statistically analyzed to document changes in the river. Friedman's nonparametric two-way analysis of variance test determined if year-to-year changes occurred at the SSES control site, and Page's distribution-free test for ordered alternatives analyzed if these year-to-year changes established a trend (Hollander and Wolfe 1973). These tests were based on monthly mean data for parameters that have been continually monitored for the last 30 years. The BACI (Before-After:Control-Impact) model tested if the Susquehanna SES blowdown had a significant effect on downriver water quality. Individual parameters are tested to determine if there has been a significant change in the data since operation of the Susquehanna SES began. The BACI test was initiated in 1989 (Ecology III, Inc. 1990) and has continued on an annual basis. A 5% probability level was used for significance.

RESULTS AND DISCUSSION

River Flow and Temperature

In 2002, Susquehanna River flow was below average for January, March, April, July, August, and September (Fig. 2). There was above average precipitation in the Susquehanna River Basin in May and June and then drought conditions from mid to late summer. Daily mean river flow ranged from 897 to 81,400 cfs (Table 1). An estimated 4.6 billion cubic feet of water passed by the Susquehanna SES Environmental Laboratory in 2002, which was average for the last 42 years (Fig. 3).

Daily mean river temperature ranged from 0.0 to 28.9 Centigrade (C) (Table 2). For the period 2-4 August, the maximum daily river temperature was greater than 30 C. Monthly mean river temperature was above average in January, February, March, April, July, August, and September; and was below average in May, June, and October through December. River flow and temperature reflect the warm and dry conditions of the winter and summer, and the cold and wet conditions of the spring and autumn.

River Water Quality at the Susquehanna SES

The water quality of this section of the Susquehanna River continues to change for the better. A reduction of mine drainage pollutants and improvements to waste treatment upriver from the Susquehanna SES have caused this change. The concentration of total iron, sulfate, and acidity has decreased greatly at four major mine effluents monitored by the Pennsylvania Department of Environmental Protection (PADEP). The pH and alkalinity has increased at these drainages. Since our studies began in 1972, new wastewater facilities were constructed, existing facilities were upgraded, and more communities were connected to these facilities.

In 2002, turbidity, conductivity, sulfate, total iron, and total, dissolved, and suspended solids were below the preoperational and operational averages (Tables 3 and 4). Dissolved oxygen, pH, and total alkalinity were above the preoperational and operational averages. There were no new 2002 minimums or maximums in the database.

Control and indicator data were compared to PADEP water quality criteria (1995). The parameters encompassed by the criteria were alkalinity, ammonia nitrogen, dissolved oxygen, fluoride, total and dissolved iron, manganese, nitrate, pH, sulfate, temperature, and total dissolved solids.

Data for all parameters except total iron and temperature fell within the criteria for the year at both the control and indicator sites. The total iron average for the months of May and June exceeded the 1.5 mg/L 30 day average criteria in 2002, but none were caused by operation of the Susquehanna SES. For each sample set where the indicator data exceeded the criteria, the control data also exceeded the criteria. The source of metals to the river is drainage from abandoned coal mines in northeast Pennsylvania. The elevated concentrations that exceeded the criteria were caused by high river flows that flushed deposited iron downriver.

There were three days in 2002 when the river temperature exceeded the criteria, but none were attributed to the operation of the Susquehanna SES. On 26 February, the river temperature was 5.5 C at all three sampling sites, exceeding the February criteria of 4.4 C. On 15 April, the river temperature was 14.5 C at all three sampling sites, exceeding the 1-15 April criteria of 11.1 C. And on 22 April, the 15.0 C recorded at each site exceeded the 16-30 April criteria of 14.4 C.

The most significant change in the last 30 years of this water quality program has been the decrease of total iron in the Susquehanna River. This decrease is associated with the termination of anthracite coal mining upriver from the Susquehanna SES after Tropical Storm Agnes in 1972. In 1973, the annual mean concentration was 4.23 mg/L (Ichthyological Associates, Inc. 1974). The PADEP criterion for the river, 1.5 mg/L, was reached in only 42 of 575 samples collected in the 1970's. Prior to 1984, the annual mean concentration did not go below 2.0 mg/L. But in the 1980's concentrations began to decrease; in the beginning of the decade about 20% of the samples met the criterion and by the end of the decade almost 60% met the criterion. In the 1990's, more than 77% of the samples were within the criterion. In our 30-year database, the lowest concentration, 0.21 mg/L, and the lowest annual mean, 0.78 mg/L, occurred in 1999. The annual mean concentration of total iron has been < 1.5 mg/L the past six years.

Significant water quality trends continued at the Susquehanna SES site based on the Friedman-Page statistical tests. For the period 1973 through 2002, there was a significant decreasing trend in turbidity, sulfate, total iron, and total suspended solids; and a significant increasing trend in river temperature, pH, total alkalinity, and dissolved oxygen. These were first documented in 1976 (Ichthyological Associates, Inc. 1977). Each of these trends is associated with the termination of upriver coal mining and the decrease of iron in the river. No significant trends were found for river flow, conductivity, total solids, or total dissolved solids.

Control and Indicator Site Comparisons

Control and indicator water quality data were similar in many respects. The range of data for all parameters was similar between the control and indicator sites (Table 3). In many samples, the control and indicator values were equal (Table 5). Indicator data for conductivity, total alkalinity, sulfate, and total solids were usually higher than control data in a majority of samples (Table 5).

Higher values at both indicator sites are due to the high concentrations of solids in the blowdown. This relationship is evident in the quarterly samples collected at SSES, Bell Bend, and the blowdown (Tables 6 and 7).

Based on the mass balance of total mineral solids (tms),

$$Q_1C_1 + Q_2C_2 = Q_3C_3$$

where: Q_1 = River flow at Environmental Lab
C_1 = SSES tms
Q_2 = Blowdown flow
C_2 = Blowdown tms
$Q_3 = Q_1 + Q_2$

the concentration is expected to be higher at the indicator sites, especially during low river flow.

In 2002, the measured tms at the indicator site was within 18.3 mg/L of the expected tms for the quarterly samples (Table 6). Mass balancing has been used since 1991 to check the measured vs. expected tms concentration at the Bell Bend indicator site. The average difference between the measured and calculated concentrations in these 12 years has been 1.2 mg/L.

An inverse relationship exists between river flow and parameters associated with mineral solids concentrations (Fig. 4). Mineral solids concentrations and conductivity are above average at the indicator sites when river flow is less than 5,000 cfs and noticeably higher when flow is less than 2,000 cfs (Ecology III, Inc. 1996). There have been samples when indicator conductivity was 50 µmhos/cm higher than the control and when the indicator dissolved solids concentration was 30 mg/L higher. But, these indicator concentrations are usually no more than 10% higher than control values during low river flows.

BACI analysis of the water quality database from 1978 through 2002, showed that statistically, the conductivity ($P \leq 0.000$), sulfate ($P \leq 0.000$), total alkalinity ($P \leq 0.007$), total solids ($P \leq 0.002$), total suspended solids ($P \leq 0.018$), total dissolved solids ($P \leq 0.001$), and dissolved oxygen ($P \geq 0.017$) were significantly higher at Bell Bend since operation of the Susquehanna SES began. Conductivity was also highly significant in the original BACI analysis (Williams and Thórarinsson 1988) and in each annual analysis since (Ecology III, Inc. 1990-2002). Sulfate and total dissolved solids were significant for the twelfth consecutive year. This is the fourth consecutive year that total suspended solids was significant. These parameters continue to be significant because of the higher concentrations of mineral solids in the Susquehanna SES blowdown. These higher concentrations are within design limitations and have not caused any river water quality parameters to exceed PADEP criteria at either of the indicator sites.

CONCLUSION

Susquehanna River flow was average in 2002. Water quality at the Susquehanna SES site continued to statistically improve with respect to acid mine drainage. Control and indicator data were similar throughout the year, with indicator data relative to the mineral concentrations in the Susquehanna SES blowdown somewhat higher. The higher indicator values, even though statistically significant, were within PADEP criteria for the river.

FISHES

PROCEDURES

Electrofishing

Electrofishing samples were collected once each month in April, June, July, August and October in 2002. Sampling was done at four sites, and each site was approximately 1,100-yards long and parallel to the river shoreline. These sites are the same areas that have been sampled since 1976. Two sites were located upriver from the Susquehanna SES river intake structure along each bank of the river, and two sites were downriver from the intake (referred to as SSES and Bell Bend locations, respectively; Table 8, Fig.1).

Our electrofishing unit consisted of a 5-KW generator (direct current) with a variable-voltage pulsator. The unit was mounted on an 18-foot flat-bottomed boat, similar to the design of Novotny and Priegel (1974). In the interest of continuity, this same electrofishing unit has been used since the inception of this sampling program.

During sampling, the boat was driven parallel to the shoreline usually within 30 feet of the riverbank. For purposes of safety and sampling efficiency, all sampling was done at river levels less than 493.1 feet above mean sea level (msl) as measured at the environmental laboratory. Electrofishing was done only in the evening, and sampling began about one hour after sunset. Two observers stood in the bow of the boat and identified and counted fish during each sample. Data were recorded using a cassette tape recorder.

Seining

Shoreline fishes were collected with a 25-foot bag seine (0.25-inch mesh) at four seine sites in 2002. Similar to the electrofishing sampling sites, two seine sites were above the Susquehanna SES river intake along each shoreline and two were below (Table 8, Fig. 1). Samples were collected during July, August, and October when river levels were less than 490.2 feet above msl.

To sample, one end of the seine was kept stationary on the riverbank while we extended the other end about 20 feet into the river. The seine was then pulled upriver and onto shore. Two hauls were made in the same location at each site, and the catches from both hauls were combined and considered one unit of effort. Captured fish were placed in 10% formalin in the field and returned to the laboratory. After at least two weeks in formalin, the fish were rinsed with water, identified, enumerated, and preserved in 40% isopropanol.

Statistical Analysis

A statistical analysis known as the Before-After:Control-Impact (BACI), was applied to the electrofishing (1976-2002) and seining (1978-2002) data (Ecology III, Inc. 1990). Twenty species or categories of fish were analyzed from the electrofishing data, as were 12 species from the seining data. These species or groups were chosen based on their abundance during the years before Susquehanna SES operation.

Two different electrofishing data sets were analyzed. The first set included all months sampled by electrofishing through the years, and is referred to as the all-months data set. The second set included only the months from June through October to reflect a reduced monitoring effort since 1986. The seining data set analyzed by the BACI represents all months sampled through the years.

Williams and Thórarinsson (1990) recommended that future BACI analyses of SSES data use September 1982 through February 1985 as the demarcation between preoperational and operation data. This reflects the time period between startup of Unit 1 (September 1982) and Unit 2 (February 1985). To date, operational data have been defined as those samples collected after Unit 1 reached criticality during September 1982. Therefore, the electrofishing data sets were analyzed using both the traditional September 1982 date, as well as the extended time period (the 19 samples between the startup dates were not used in the second BACI analysis).

RESULTS AND DISCUSSION

Electrofishing

Electrofishing at the SSES and Bell Bend locations in 2002 resulted in the observation of 1,855 fish of 19 species (Tables 9 through 11). The total numbers of fish collected at both sites for the year were generally similar, as were most of the monthly totals. The range of sample sizes among the months at SSES was 148 fish, while the range at Bell Bend was 92 fish. Maxima of sample sizes occurred during August at SSES and Bell Bend.

Smallmouth bass was the most abundant species observed at SSES and Bell Bend overall in 2002 (39% and 35% of the total, respectively). Rock bass, smallmouth bass and walleye collectively represented 64% of the fish observed at SSES and 69% of those at Bell Bend. Smallmouth bass was the most abundant species in at least half the months sampled at both sampling stations. Exceptions to this included walleye in April and rock bass in October at both SSES and Bell Bend.

Fourteen species were observed at SSES and 18 at Bell Bend during 2002. Species richness per sample was greatest during the July and October samples at SSES (12) and the October sample at Bell Bend (15). Sucker and sunfish species dominated species richness in all months during 2002.

Seining

Seining at the SSES and Bell Bend locations in 2002 resulted in the capture of 6,046 fish of 14 species (Tables 9 and 12). Spotfin shiner was the most abundant species captured at SSES (54%) and Bell Bend (62%). Spotfin shiner plus spottail shiner comprised 67% and 94% of the fishes collected at both SSES and Bell Bend, respectively.

Similar to the previous years, the number of fishes captured at SSES was a fraction (37%) of those collected at Bell Bend. A similar discrepancy in fish numbers between the sites occurred in the October samples; remarkably, almost 44 times as many fish were collected at Bell Bend than SSES in October. Vastly greater numbers of spotfin shiner and spottail shiner were collected at the Bell Bend east sampling location.

A total of eleven species was collected at both SSES and Bell Bend. At both stations, species in the minnow and sunfish families predominated. Species richness was greatest at both SSES and Bell Bend during August, but was least at both stations during October. Species numbers in a given month at SSES ranged from seven to ten, while those at Bell Bend ranged from five to ten species. A single banded killifish was collected at the Bell Bend west site in October. This previously uncommon species is beginning to appear with regularity in the seine collections.

BACI Results: Electrofishing

Of the 20 species or categories of fish for which data were tested with the BACI analysis, nine species from the data set of all months sampled and eight species from the June through October data showed significant differences in the numbers of fishes above versus below the power plant discharge ($P<0.05$). Species in the all-months data set that indicated significant relative declines in their numbers at the Bell Bend locations included quillback, white sucker, northern hog sucker, shorthead redhorse, muskellunge, rock bass, smallmouth bass, and unidentified fish. Brown bullheads were also significantly different; however, their numbers showed significant increase at Bell Bend compared to the upriver sites. The June through October data set demonstrated declines in all of the same species, except white sucker. Brown bullheads again showed a significant increase at Bell Bend in the June through October data set.

Changing the time period demarcating preoperational and operational data made little difference in the outcome of the BACI analyis. The February 1985 all-months data set was identical to the September 1982 data set in the species indicated by the BACI to have significant differences below the discharge pipe. The only difference in the June through October data sets was the loss of significance for northern hog sucker from the February 1985 data set.

The BACI analysis compares differences in the numbers of species between the SSES and Bell Bend locations. These differences can occur in five possible ways (Fig. 5).

For example, numbers at SSES can increase more or decrease less than increases or decreases occurring at Bell Bend (Fig. 5 Types A and E). Additionally, differences can also occur if SSES numbers increase while Bell Bend numbers hold steady or decrease (Fig. 5 Types B and C). Finally, SSES numbers can hold steady while Bell Bend numbers decrease (Fig. 5 Type D).

Trend analysis of the annual catches per unit effort of significant species indicates that the relative "declines" in quillback, northern hog sucker, rock bass, smallmouth bass and unidentified fish were due to Type A differences, i.e. greater increases at SSES than those increases at Bell Bend (Fig. 6). Conversely, the declines in white sucker, shorthead redhorse, and muskellunge were due to Type E differences (greater decreases at Bell Bend than the decreases at SSES; Fig. 6). The relative increase in brown bullheads at Bell Bend is actually caused by a greater decrease in bullhead numbers at SSES than their decrease at Bell Bend.

While this analysis does not explain cause-effect relationships of fish populations to operation of Susquehanna SES, it does help us to understand how the differences occurred between the sites. It should be noted, however, that the actual BACI analyses were done on the differences in fish numbers per sample between SSES and Bell Bend, rather than annual catch per unit effort illustrated in this report. To date, it is not known if these relationships hold for plots of actual fish numbers through time. This is a direction for future analysis.

BACI Results: Seining

The results of the 12 seined species tested by BACI analysis indicated that none of the species tested were significant (P>0.05). This has been the general pattern for these results since BACI analysis was begun among seining data.

RECOMMENDATIONS

Fish are prominent indicators of water quality to the general public, as well as an important natural resource to the large angling community in this region. The value of continued monitoring of water quality and fish populations in the vicinity of Susquehanna SES cannot be overstated. This is especially true in light of known fish declines in the river, namely white sucker, likely independent of the operation of Susquehanna SES (Ecology III, Inc. 2000). Continued analysis of the water quality and fish data sets should provide further insight into the meaning of species declines below the power plant effluent.

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Table 1

Daily mean flow (cfs) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2002.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	5590	25700	11900	40900	33900	16200	11900	1750	1210	9540	10700	16200
2	5020	35900	11900	35900	29400	17200	9540	1750	1210	8120	9540	15300
3	5020	43900	11500	30000	29400	15800	8120	1940	1210	6490	8820	14900
4	4740	39500	11500	26300	27500	13100	6800	1750	1210	5020	8120	13100
5	4740	31300	11500	22900	23500	11100	6180	1750	1210	--[a]	7780	11900
6	5020	24000	11900	20200	20200	11900	5300	1750	996	--	7780	11100
7	5590	19200	11900	17700	17200	44600	4740	1570	897	--	8120	10700
8	5020	16200	10700	16200	15300	69500	4210	1390	897	3470	8120	10300
9	4740	14900	10300	14400	14900	55100	3960	1390	897	3230	8470	11100
10	4210	13100	10300	13500	14900	35200	3710	1210	897	3230	9180	9180
11	4480	16700	10300	13100	16200	24000	3710	1210	897	3960	9180	8820
12	4480	35900	11100	13100	17200	18700	3470	1210	897	10300	9180	10700
13	4480	43100	11500	12700	22900	16200	3230	1210	897	18200	9910	11900
14	4210	36600	11500	11900	63000	14400	3000	1390	897	11500	11100	15800
15	4480	26900	10700	13500	81400	15300	2770	1210	897	8120	11100	28100
16	4480	21300	10300	25200	71400	25700	2560	1210	1210	7780	11100	35900
17	4210	19200	10700	31900	53400	46200	2560	996	996	22300	12300	32600
18	4210	18200	10700	26900	44600	44600	2350	1210	996	24000	24000	26300
19	3710	16700	10700	22300	57700	34600	2350	996	897	22900	35200	20200
20	3470	14900	10300	19200	61200	25200	2770	996	996	21300	31300	18700
21	3230	13100	11900	16700	47000	19200	2560	996	1210	16200	25200	31300
22	3230	13100	14400	14900	36600	15300	2140	996	1750	14400	22900	41600
23	3470	14000	16700	13500	30000	12700	2140	996	2350	13100	24600	38700
24	3470	14900	15800	12700	25200	11500	2560	996	3470	10700	29400	30600
25	4210	14900	14900	11900	21300	10300	2560	996	2770	8820	31900	25700
26	6490	13100	14400	11100	18700	10700	2350	1210	2560	9540	28800	22900
27	10700	11900	38700	11100	16700	9910	2350	1210	4740	11100	25200	20700
28	12300	11500	77300	12300	15300	9540	2140	1210	6800	13100	22900	18200
29	12300		69500	21300	17200	18200	2140	1210	6800	14400	20700	15800
30	13500		56000	35900	17200	15800	2140	1210	7450	14400	17700	15800
31	17700		45400		15300		1940	1210		12700		15800
MEAN	5880	22100	19200	19600	31500	22900	3810	1300	2000	11700	16700	19700

[a] Equipment failure

Table 2

Daily mean temperature (C) of the Susquehanna River at the Susquehanna SES Environmental Laboratory, 2002.

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.0	2.9	3.7	7.6	9.7	19.8	24.2	27.8	21.0	17.8	7.0	2.6
2	0.0	2.8	3.5	7.8	10.0	20.3	24.9	28.5	20.9	18.6	6.2	1.9
3	0.0	2.1	4.1	7.8	10.5	20.0	26.5	28.7	21.8	19.4	5.8	1.2
4	0.0	1.6	4.1	7.4	10.7	19.8	27.8	28.9	23.3	19.1	5.7	0.2
5	0.0	0.6	2.9	6.8	11.7	19.7	27.5	28.3	23.0	19.2	5.8	0.0
6	0.0	0.5	3.1	6.2	12.8	20.2	26.4	26.4	22.7	18.6	6.0	0.0
7	0.0	0.8	3.4	6.0	13.8	18.9	25.0	25.1	22.8	18.5	6.1	0.0
8	0.0	1.3	4.3	6.4	14.8	17.1	25.0	24.3	23.1	17.3	6.0	0.0
9	0.0	2.0	5.5	7.4	14.9	17.7	25.2	24.1	23.3	16.2	6.3	0.0
10	0.1	2.8	6.1	8.9	14.7	18.9	25.1	24.5	23.8	16.0	7.1	0.0
11	0.2	3.4	5.1	9.6	15.1	20.4	24.5	25.2	22.7	15.5	8.7	0.0
12	0.6	2.5	4.9	10.1	15.0	21.3	24.2	25.9	21.5	14.9	9.2	0.2
13	0.9	2.0	4.6	10.7	14.1	21.2	24.0	26.7	21.3	14.1	9.0	0.3
14	0.8	1.3	5.4	12.4	12.8	20.6	23.8	27.1	21.6	13.9	8.7	0.5
15	1.0	1.1	6.7	14.1	11.9	19.1	24.5	27.1	21.8	13.0	8.4	1.0
16	1.1	1.7	7.6	15.3	11.7	18.5	24.9	27.6	21.8	12.3	8.1	1.2
17	1.2	2.3	6.5	15.7	12.4	18.0	25.3	27.9	21.3	11.4	7.8	1.1
18	0.9	2.2	5.8	17.0	12.3	17.2	26.2	27.8	21.3	11.0	6.9	0.5
19	0.1	2.4	5.2	18.2	11.5	17.6	26.3	27.6	20.7	10.8	5.8	0.3
20	0.1	3.0	5.0	18.3	10.6	18.8	26.5	27.3	21.4	10.4	5.3	1.1
21	0.1	3.9	5.3	16.6	10.2	20.2	26.3	26.5	21.8	10.2	5.0	2.1
22	0.7	4.1	4.7	14.7	10.5	21.6	27.2	26.3	21.7	10.0	5.2	2.0
23	1.3	4.1	3.8	13.0	11.5	22.8	27.3	26.1	21.3	9.9	5.3	1.9
24	1.8	4.0	4.1	12.4	12.9	23.6	26.2	25.3	20.8	9.2	5.0	1.9
25	1.9	4.2	4.6	11.9	14.0	24.5	25.7	25.4	20.2	8.8	4.9	1.4
26	1.6	4.7	4.3	11.1	14.8	25.4	24.3	24.7	19.2	8.8	4.6	0.5
27	1.7	5.0	3.7	11.4	15.9	25.6	24.0	24.7	18.4	9.1	4.2	0.6
28	1.8	4.2	3.0	11.8	17.5	25.0	24.2	24.1	18.2	9.2	3.4	0.5
29	2.2		3.6	11.1	17.5	24.9	25.2	22.6	17.9	8.7	2.8	0.7
30	2.9		5.2	10.0	18.4	24.2	26.3	22.0	17.6	7.9	2.8	0.6
31	3.1		6.6		19.6		26.8	22.1		7.4		1.3
MEAN	0.8	2.6	4.7	11.3	13.3	20.8	25.5	26.0	21.3	13.1	6.1	0.8

Table 3

Summary of water quality data collected from the Susquehanna River at SSES, Bell Bend, and Bell Bend I, 2002.

PARAMETER	N	MINIMUM	MAXIMUM	MEAN	SE
SSES					
Turbidity (NTU)	38	2.3	48	8.3	1.8
pH	38	7.0	8.2	7.6	0.05
Conductivity (μmhos/cm)	38	130	480	270	16.7
Analysis (mg/L)					
Oxygen					
Dissolved	38	6.80	14.80	10.53	0.346
Percent saturation	38	81	130	102	1.7
Total alkalinity	38	34	86	60	2.5
Sulfate	38	1	81	37	3.5
Total iron	38	0.30	5.51	1.06	0.171
Solids					
Total	38	109	334	199	10.5
Total suspended	38	1	135	15	4.2
Total dissolved	38	91	332	183	11.5
BELL BEND					
Turbidity (NTU)	38	2.3	46	8.4	1.7
pH	38	7.0	8.3	7.6	0.05
Conductivity (μmhos/cm)	38	133	531	277	18.0
Analysis (mg/L)					
Oxygen					
Dissolved	38	6.70	14.80	10.41	0.356
Percent saturation	38	80	121	101	1.6
Total alkalinity	38	34	93	61	2.8
Sulfate	38	1	93	38	3.7
Total iron	38	0.29	5.38	1.05	0.171
Solids					
Total	38	109	377	206	11.7
Total suspended	38	1	133	16	4.1
Total dissolved	38	87	374	190	12.8
BELL BEND I					
Turbidity (NTU)	38	2.1	45	8.3	1.7
pH	38	7.0	8.4	7.7	0.05
Conductivity (μmhos/cm)	37	133	540	276	18.9
Analysis (mg/L)					
Oxygen					
Dissolved	38	6.70	14.80	10.44	0.353
Percent saturation	38	80	121	101	1.6
Total alkalinity	38	34	91	62	2.8
Sulfate	38	2	96	38	4.0
Total iron	37	0.30	5.16	1.02	0.169
Solids					
Total	38	110	384	208	12.2
Total suspended	38	1	124	15	3.9
Total dissolved	38	89	380	193	13.4

Table 4

Comparison of water quality data collected from the Susquehanna River at SSES and Bell Bend during preoperation (1978-82) and operation (1983-2002) of the Susquehanna SES.

	PREOPERATION					OPERATION				
PARAMETER	N	MIN	MAX	MEAN	SE	N	MIN	MAX	MEAN	SE
SSES										
Turbidity (NTU)	373	3.3	450	17	1.8	874	1.6	440	12	0.8
pH	375	6.6	9.0	7.5	0.02	875	6.8	9.0	7.5	0.01
Conductivity (µmhos/cm)	375	76	540	293	5.4	875	90	520	277	3.3
Analysis (mg/L)										
Oxygen										
Dissolved	375	5.20	14.70	10.26	0.098	868	5.40	15.20	10.40	0.091
Percent saturation	375	60	145	100	0.8	868	66	182	101	0.6
Total alkalinity	375	16	87	55	0.7	870	16	90	57	0.5
Sulfate	373	8	158	63	1.8	875	1	150	49	0.9
Total iron	374	0.96	22.00	2.30	0.105	873	0.21	35.20	1.66	0.067
Solids										
Total	372	106	736	222	4.2	874	104	822	212	2.4
Total suspended	375	1	658	26	3.0	874	1	708	21	1.5
Total dissolved	374	61	363	194	3.8	874	54	381	191	2.3
BELL BEND										
Turbidity (NTU)	373	3.1	450	17	1.8	874	1.6	460	12	0.8
pH	375	6.6	8.9	7.5	0.02	875	6.8	9.0	7.6	0.01
Conductivity (µmhos/cm)	375	74	525	293	5.4	875	91	540	283	3.5
Analysis (mg/L)										
Oxygen										
Dissolved	375	5.00	14.50	10.31	0.099	868	5.30	15.40	10.37	0.092
Percent saturation	375	58	157	100	0.8	868	65	160	100	0.6
Total alkalinity	375	16	88	55	0.7	870	16	97	58	0.6
Sulfate	373	9	158	62	1.8	875	1	152	49	0.9
Total iron	374	0.72	22.50	2.22	0.104	873	0.23	35.10	1.61	0.065
Solids										
Total	371	107	710	224	4.2	874	104	826	216	2.6
Total suspended	375	1	649	26	2.9	874	1	758	21	1.6
Total dissolved	373	55	366	195	3.8	874	59	393	195	2.5

Table 5

A comparison of 38 water quality sample sets collected from the Susquehanna River at the SSES (S) control and Bell Bend (B) and Bell Bend I (BI) indicator sites in 2002. S>, B>, and BI> denote the number of times a respective sample had a higher value, = denotes equal values at the compared sites.

	SSES vs. Bell Bend			SSES vs. Bell Bend I			Bell Bend vs. Bell Bend		
PARAMETER	S>B	B>S	S=B	S>BI	BI>S	S=BI	B>BI	BI>B	B=BI
Turbidity	12	12	14	14	14	10	12	9	17
pH	3	12	23	4	18	16	4	11	23
Conductivity	1	33	4	5	31	2	12	21	5
Dissolved oxygen	16	3	19	14	4	20	4	7	27
Oxygen percent saturation	16	4	18	14	5	19	3	7	28
Total alkalinity	2	19	17	2	23	13	3	12	23
Sulfate	7	19	12	8	22	8	11	15	12
Total iron	21	13	4	21	13	4	22	14	2
Total solids	7	27	4	9	26	3	11	20	7
Total suspended solids	6	12	20	13	9	16	13	7	18
Total dissolved solids	6	12	20	13	9	16	13	7	18

Table 6

Comparison of measured and calculated total mineral solids (tms) concentrations at Bell Bend on the Susquehanna River, 2002. Data from SSES and blowdown samples were mass balanced to calculate the Bell Bend concentration.

DATE	SSES		BLOWDOWN		BELL BEND		DIFFERENCE	
	Flow (cfs)	tms (mg/L)	Flow (cfs)	tms (mg/L)	Measured tms (mg/L)	Calculated tms (mg/L)	tms (mg/L)	%
20 Mar	10300	125.4	5.1	477.9	125.2	125.6	-0.4	-0.3
26 Jun	10700	131.6	26.4	420.6	131.9	132.3	-0.4	-0.3
26 Sep	2560	190.2	26.2	745.6	214.1	195.8	18.3	8.5
21 Nov	25200	97.6	13.3	449.6	98.9	97.8	1.1	1.1

Table 7

Water quality data collected quarterly from the Susquehanna River and the Susquehanna SES blowdown, 2002. River sites were SSES (control) and Bell Bend (indicator). Analyses were performed by the PPL Chemical Laboratory, Hazleton, PA. N.D. = Not Detected

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		3/20/2002	3/20/2002	3/20/2002	6/26/2002	6/26/2002	6/26/2002
Time		8:55	7:10	9:00	8:55	8:03	9:00
Temperature	C	5	14	5	25	28.5	25
pH, field		7.74	8.93	7.96	8.16	8.55	8.17
Conductivity, field	µmho	192	775	223	235	671	238
Turbidity, field	NTU	1.6	13	1.6	4.8	17	4.7
Dissolved oxygen	mg/L	13.1	9.6	13.2	9.1	6.8	9.1
pH, lab		7.95	8.9	7.9	8.35	8.83	8.35
Conductivity, lab	µmho	238	823	238	247	706	250
Total alkalinity	mg/L	57	200	57	65	190	65
Phenolphthalein alkalinity	mg/L	0	16	0	1	15	1
Total suspended solids	mg/L	2.5	17	2	14	32	12
Ammonia as N	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silicon dioxide	mg/L	0.98	7.41	0.99	1.49	8.63	1.53
Bicarbonate as CaCO3	mg/L	69.5	205	69.5	76.9	195	76.9
Carbonate by calculation	mg/L	0	19.2	0	1.2	18	1.2
Chloride	mg/L	22.8	92.6	22.9	21.8	70.3	20.9
Fluoride	mg/L	0.2	0.3	0.1	<0.1	0.2	<0.1
Nitrate as NO3	mg/L	2.5	12.3	2.5	1.3	7.5	<1.2
Nitrate ion as N	mg/L	0.6	2.8	0.6	<0.3	1.7	<0.3
Phosphorus as PO4	mg/L	0.077	2.27	0.08	0.19	2.141	0.175
Sulfate	mg/L	21.8	81.8	22.1	22.2	72.5	21.3
Aluminum, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	<50	N.D.
Aluminum, total	ug/L	<50	269	<50	266	638	230
Barium, total	ug/L	26	92	26	27	99	26
Calcium, dissolved	mg/L	24.3	89.4	23.9	25.3	80.6	26.5
Calcium, total	mg/L	24.1	89.8	24	27.2	80.1	26.5
Copper, dissolved	ug/L	N.D.	<10	N.D.	N.D.	<10	N.D.
Copper, total	ug/L	N.D.	11	N.D.	N.D.	11	N.D.
Iron, dissolved	mg/L	0.2	0.45	0.19	0.09	0.21	0.1
Iron, total	mg/L	0.34	1.56	0.34	0.79	1.73	0.71
Magnesium, dissolved	mg/L	4.99	18.2	4.92	5.46	17	5.72
Magnesium, total	mg/L	4.98	18.4	4.98	5.92	17	5.8
Manganese, dissolved	ug/L	47	28	47	9	10	5
Manganese, total	ug/L	53	172	53	98	229	89
Nickel, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Potassium, dissolved	mg/L	1.3	4.72	1.26	1.37	4.69	1.49
Potassium, total	mg/L	1.26	4.75	1.26	1.59	4.74	1.58
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	12.5	51.5	12.4	13.7	45.4	14.3
Sodium, total	mg/L	12.3	51.1	12.3	14.2	44.5	13.9
Strontium, total	ug/L	82	307	82	100	291	98
Vanadium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc, total	ug/L	N.D.	<10	N.D.	N.D.	10	N.D.
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chromium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lead, total	ug/L	N.D.	<3	N.D.	N.D.	<3	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<1.0	1.8	<1.0	<1.0	2.4	<1.0
Selenium, total	ug/L	N.D.	<1.0	N.D.	N.D.	<1.0	N.D.
Antimony, total	ug/L	N.D.	<5	N.D.	N.D.	<5	N.D.
Total mineral solids	mg/L	125.37	477.93	125.17	131.62	420.62	<131.94
Calcium hardness (C)	mg/L	60.7	223.2	59.7	63.2	201.3	66.2
Total hardness (C)	mg/L	80.7	300	80.4	92.3	270	90.1

Table 7 (cont.)

PARAMETER	UNITS	SSES	BLOW DOWN	BELL BEND	SSES	BLOW DOWN	BELL BEND
Date		9/26/2002	9/26/2002	9/26/2002	11/21/2002	11/21/2002	11/21/2002
Time		8:02	8:50	8:05	10:36	9:22	10:40
Temperature	C	20	22	20	5	15.5	5
pH, field		7.4	8.4	7.5	7.2	8.4	7.2
Conductivity, field	µmho	349	1140	369	175	719	175
Turbidity, field	NTU	3	15	3.3	6	37	5.8
Dissolved oxygen	mg/L	8.3	5.4	8.4	13.5	9.9	13.1
pH, lab		7.92	8.74	7.98	7.45	8.63	7.47
Conductivity, lab	µmho	372	1220	395	186	765	187
Total alkalinity	mg/L	68	208	72	37	173	38
Phenolphthalein alkalinity	mg/L	0	14	0	0	8	0
Total suspended solids	mg/L	6.7	19.3	5.3	9	55	10.5
Ammonia as N	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silicon dioxide	mg/L	1.67	5.81	1.65	4.23	16.44	4.24
Bicarbonate as CaCO3	mg/L	83	220	87.8	45.1	192	46.4
Carbonate by calculation	mg/L	0	16.8	0	0	9.6	0
Chloride	mg/L	40.7	168	45.8	16.1	75.9	16.6
Fluoride	mg/L	0.1	0.4	0.1	N.D.	0.2	N.D.
Nitrate as NO3	mg/L	<1.2	4.9	<1.2	2.8	11.8	2.8
Nitrate ion as N	mg/L	<0.3	1.1	<0.3	0.6	2.7	0.6
Phosphorus as PO4	mg/L	0.169	3.34	0.218	0.178	3.825	0.187
Sulfate	mg/L	35.8	185	47.2	17	84.4	17.1
Aluminum, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	<50	N.D.
Aluminum, total	ug/L	67	255	67	233	1240	244
Barium, total	ug/L	31	90	32	28	98	28
Calcium, dissolved	mg/L	31.9	109	33.7	18.8	84.9	18.9
Calcium, total	mg/L	31.8	110	33.4	18.9	87.4	19.3
Copper, dissolved	ug/L	N.D.	<10	N.D.	N.D.	10	N.D.
Copper, total	ug/L	N.D.	11	N.D.	N.D.	17	N.D.
Iron, dissolved	mg/L	0.06	0.16	0.06	0.14	0.37	0.15
Iron, total	mg/L	0.63	1.84	0.57	0.71	4.03	0.74
Magnesium, dissolved	mg/L	9.28	35.2	9.89	3.91	16.9	3.93
Magnesium, total	mg/L	9.32	35.6	9.88	3.99	17.6	4.06
Manganese, dissolved	ug/L	28	15	23	48	38	47
Manganese, total	ug/L	145	431	137	71	365	73
Nickel, total	ug/L	N.D.	<20	N.D.	N.D.	<20	N.D.
Potassium, dissolved	mg/L	2.65	8.85	2.81	1.41	6.22	1.42
Potassium, total	mg/L	2.7	8.96	2.81	1.48	6.49	1.5
Silver, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Sodium, dissolved	mg/L	26.2	104	28.6	11.1	49.2	11.1
Sodium, total	mg/L	26.2	105	28.1	11	48.7	11.1
Strontium, total	ug/L	153	618	161	63	312	64
Vanadium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc, dissolved	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Zinc, total	ug/L	N.D.	<10	N.D.	N.D.	20	N.D.
Beryllium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Cadmium, total	ug/L	N.D.	N.D.	N.D.	N.D.	<1	N.D.
Chromium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Lead, total	ug/L	N.D.	N.D.	N.D.	N.D.	3	N.D.
Thallium, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Arsenic, total	ug/L	<1.0	2.3	<1.0	<1.0	3.3	<1.0
Selenium, total	ug/L	N.D.	<1.0	N.D.	N.D.	<1.0	N.D.
Antimony, total	ug/L	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total mineral solids	mg/L	<190.20	745.56	<214.05	97.55	449.56	98.89
Calcium hardness (C)	mg/L	79.7	272.2	84.1	46.9	212	47.2
Total hardness (C)	mg/L	118	421	124	63.6	291	64.9

Table 8

Description of electrofishing (EL) and seining (SN) sites at SSES and Bell Bend on the Susquehanna River, 2002.

SITE	LOCATION
	SSES (Control)
EL-1	East bank, 426 feet upriver from gas-line crossing to 1,082 feet upriver from a point opposite the center of the Susquehanna SES intake structure
EL-2	West bank from gas-line crossing to a point 820 feet upriver from the center of the Susquehanna SES intake structure
SN-1	East bank, 1,837 feet upriver from a point opposite the center of the Susquehanna SES intake structure (33 feet upriver from the mouth of Little Wapwallopen Creek)
SN-2	West bank, 1,312 feet upriver from the center of the Susquehanna SES intake structure (328 feet downriver from the boat dock at the Susquehanna SES Environmental Laboratory)
	BELL BEND (Indicator)
EL-3	East bank, 1,279 feet downriver from a point opposite the Susquehanna SES intake structure to a point 1,640 feet upriver from the mouth of Wapwallopen Creek
EL-4	West bank, 1,246 feet downriver from the Susquehanna SES intake structure (558 feet downriver from the discharge diffuser) to a point near the southeastern boundary of PPL's Wetlands Nature Area
SN-3	East bank, 8,528 feet (1.6 miles) downriver from a point opposite the Susquehanna SES intake structure, at the launching ramp of the Berwick Boat Club
SN-4	West bank, 4,264 feet (0.8 miles) downriver from the Susquehanna SES intake structure, near the southeastern boundary of PPL's Wetlands Nature Area

Table 9

Fish species that were observed while electrofishing or collected by seining at SSES and Bell Bend on the Susquehanna River, 2002. Names of fishes and order of listing conform to Robins et al. (1991).

COMMON NAME	SCIENTIFIC NAME
Herrings	Clupeidae
Gizzard shad	*Dorosoma cepedianum*
Carps and Minnows	Cyprinidae
Spotfin shiner	*Cyprinella spiloptera*
Common carp	*Cyprinus carpio*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
Fallfish	*Semotilus corporalis*
Suckers	Catostomidae
Quillback	*Carpiodes cyprinus*
White sucker	*Catostomus commersoni*
Northern hog sucker	*Hypentelium nigricans*
Shorthead redhorse	*Moxostoma macrolepidotum*
Bullhead Catfishes	Ictaluridae
Yellow bullhead	*Ameiurus natalis*
Channel catfish	*Ictalurus punctatus*
Pikes	Esocidae
Muskellunge	*Esox masquinongy*
Killifishes	Cyprinodontidae
Banded killifish	*Fundulus diaphanus*
Sunfishes	Centrarchidae
Rock bass	*Ambloplites rupestris*
Redbreast sunfish	*Lepomis auritus*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieu*
White crappie	*Pomoxis annularis*
Perches	Percidae
Tessellated darter	*Etheostoma olmstedi*
Banded darter	*Etheostoma zonale*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*

Table 10

Number, mean, and percent total of fish observed while electrofishing at SSES on the Susquehanna River, 2002.

SPECIES	25 Apr				27 Jun				16 Jul				29 Aug				10 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Gizzard shad	0	0	0.0	0.0	0	0	0.0	0.0	10	0	5.0	4.2	0	0	0.0	0.0	2	0	1.0	1.7	1.2	1.3
Common carp	0	0	0.0	0.0	5	0	2.5	2.6	2	0	1.0	0.8	0	0	0.0	0.0	2	2	2.0	3.3	1.1	1.2
Failfish	0	0	0.0	0.0	0	1	0.5	0.5	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Quillback	2	16	9.0	18.0	0	6	3.0	3.1	10	7	8.5	7.1	8	1	4.5	3.6	6	4	5.0	8.3	6.0	6.7
White sucker	2	1	1.5	3.0	3	1	2.0	2.1	1	1	1.0	0.8	0	1	0.5	0.4	1	0	0.5	0.8	1.1	1.2
Northern hog sucker	2	1	1.5	3.0	0	0	0.0	0.0	0	5	2.5	2.1	2	18	10.0	8.1	1	0	0.5	0.8	2.9	3.2
Shorthead redhorse	0	0	0.0	0.0	2	1	1.5	1.6	42	6	24.0	20.1	16	15	15.5	12.5	2	0	1.0	1.7	8.4	9.3
Sucker spp.	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	3	2.0	1.6	0	0	0.0	0.0	0.4	0.4
Yellow bullhead	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.4	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Channel catfish	0	0	0.0	0.0	1	0	0.5	0.5	1	2	1.5	1.3	4	1	2.5	2.0	1	1	1.0	1.7	1.1	1.2
Rock bass	5	0	2.5	5.0	20	8	14.0	14.5	7	31	19.0	15.9	6	11	8.5	6.9	23	14	18.5	30.8	12.5	13.9
Bluegill	0	0	0.0	0.0	0	0	0.0	0.0	2	11	6.5	5.4	2	6	4.0	3.2	1	0	0.5	0.8	2.2	2.4
Smallmouth bass	18	4	11.0	22.0	72	37	54.5	56.5	45	27	36.0	30.1	44	74	59.0	47.6	19	8	13.5	22.5	34.8	38.7
Sunfish spp.	0	0	0.0	0.0	1	0	0.5	0.5	0	0	0.0	0.0	1	2	1.5	1.2	2	1	1.5	2.5	0.7	0.8
Yellow perch	0	0	0.0	0.0	1	0	0.5	0.5	0	0	0.0	0.0	0	2	1.0	0.8	1	1	1.0	1.7	0.5	0.6
Walleye	23	12	17.5	35.0	16	6	11.0	11.4	6	8	7.0	5.9	4	8	6.0	4.8	13	3	8.0	13.3	9.9	11.0
Fish (unidentified)	7	7	7.0	14.0	4	8	6.0	6.2	9	5	7.0	5.9	11	7	9.0	7.3	4	8	6.0	10.0	7.0	7.8
TOTAL	59	41	50.0		125	68	96.5		136	103	119.5		99	149	124.0		78	42	60.0		90.0	

Table 11

Number, mean, and percent total of fish observed while electrofishing at Bell Bend on the Susquehanna River, 2002.

SPECIES	25 Apr				27 Jun				16 Jul				29 Aug				10 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
Gizzard shad	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	3	2	2.5	2.3	0.5	0.5
Common carp	5	4	4.5	6.1	2	2	2.0	2.2	1	0	0.5	0.6	0	0	0.0	0.0	3	3	3.0	2.8	2.0	2.1
Fallfish	1	1	1.0	1.4	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.5	0.3	0.3
Quillback	2	4	3.0	4.1	1	0	0.5	0.6	12	1	6.5	7.5	3	4	3.5	2.9	4	9	6.5	6.0	4.0	4.2
White sucker	3	2	2.5	3.4	1	0	0.5	0.6	2	1	1.5	1.7	2	1	1.5	1.3	1	1	1.0	0.9	1.4	1.5
Northern hog sucker	2	0	1.0	1.4	0	0	0.0	0.0	2	1	1.5	1.7	5	1	3.0	2.5	1	1	1.0	0.9	1.3	1.4
Shorthead redhorse	1	0	0.5	0.7	0	0	0.0	0.0	1	0	0.5	0.6	2	0	1.0	0.8	0	3	1.5	1.4	0.7	0.7
Sucker spp.	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.5	0.1	0.1
Channel catfish	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.6	1	2	1.5	1.3	0	1	0.5	0.5	0.5	0.5
Muskellunge	0	2	1.0	1.4	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.2
Pike spp.	1	0	0.5	0.7	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Rock bass	8	10	9.0	12.2	22	13	17.5	19.7	30	11	20.5	23.7	19	24	21.5	17.9	26	39	32.5	30.1	20.2	21.2
Redbreast sunfish	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.6	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Green sunfish	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.6	0	0	0.0	0.0	0	0	0.0	0.0	0.1	0.1
Pumpkinseed	0	0	0.0	0.0	1	0	0.5	0.6	0	0	0.0	0.0	2	0	1.0	0.8	1	1	1.0	0.9	0.5	0.5
Bluegill	0	0	0.0	0.0	0	0	0.0	0.0	12	1	6.5	7.5	27	2	14.5	12.1	11	0	5.5	5.1	5.3	5.5
Smallmouth bass	19	13	16.0	21.6	66	34	50.0	56.2	33	26	29.5	34.1	34	69	51.5	42.9	14	23	18.5	17.1	33.1	34.7
White crappie	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	1	0	0.5	0.5	0.1	0.1
Sunfish spp.	1	2	1.5	2.0	1	0	0.5	0.6	10	0	5.0	5.8	4	5	4.5	3.8	7	8	7.5	6.9	3.8	4.0
Yellow perch	0	0	0.0	0.0	0	0	0.0	0.0	0	0	0.0	0.0	2	0	1.0	0.8	1	0	0.5	0.5	0.3	0.3
Walleye	20	34	27.0	36.5	15	8	11.5	12.9	8	1	4.5	5.2	5	7	6.0	5.0	15	13	14.0	13.0	12.6	13.2
Fish (unidentified)	7	6	6.5	8.8	10	2	6.0	6.7	12	5	8.5	9.8	13	6	9.5	7.9	10	12	11.0	10.2	8.3	8.7
TOTAL	70	78	74.0		119	59	89.0		124	49	86.5		119	121	120.0		99	117	108.0		95.5	

Table 12

Number, mean, and percent total of fish captured by seining at SSES and Bell Bend on the Susquehanna River, 2002.

SPECIES	8 Jul				28 Aug				29 Oct				OVERALL	
	East	West	Mean	% Total	East	West	Mean	% Total	East	West	Mean	% Total	Mean	% Total
SSES														
Spotfin shiner	207	569	388.0	88.4	0	91	45.5	13.4	7	10	8.5	21.3	147.3	54.0
Spottail shiner	65	12	38.5	8.8	22	84	53.0	15.6	20	3	11.5	28.7	34.3	12.6
Bluntnose minnow	7	3	5.0	1.1	19	44	31.5	9.3	4	8	6.0	15.0	14.2	5.2
Channel catfish	0	0	0.0	0.0	0	1	0.5	0.1	0	0	0.0	0.0	0.2	0.1
Rock bass	4	2	3.0	0.7	6	7	6.5	1.9	5	12	8.5	21.3	6.0	2.2
Redbreast sunfish	1	0	0.5	0.1	0	0	0.0	0.0	0	0	0.0	0.0	0.2	0.1
Green sunfish	0	2	1.0	0.2	8	6	7.0	2.1	2	1	1.5	3.8	3.2	1.2
Pumpkinseed	0	0	0.0	0.0	1	0	0.5	0.1	0	1	0.5	1.3	0.3	0.1
Bluegill	3	1	2.0	0.5	280	107	193.5	57.1	3	4	3.5	8.8	66.3	24.3
Tessellated darter	2	0	1.0	0.2	1	0	0.5	0.1	0	0	0.0	0.0	0.5	0.2
Banded darter	0	0	0.0	0.0	0	1	0.5	0.1	0	0	0.0	0.0	0.2	0.1
TOTAL	289	589	439.0		337	341	339.0		41	39	40.0		272.7	
BELL BEND														
Spotfin shiner	180	111	145.5	72.6	287	24	155.5	60.0	2142	9	075.5	61.6	458.8	62.4
Spottail shiner	8	77	42.5	21.2	11	77	44.0	17.0	1052	167	609.5	34.9	232.0	31.6
Bluntnose minnow	5	0	2.5	1.2	10	16	13.0	5.0	5	88	46.5	2.7	20.7	2.8
White sucker	2	8	5.0	2.5	1	0	0.5	0.2	0	0	0.0	0.0	1.8	0.2
Channel catfish	0	0	0.0	0.0	4	6	5.0	1.9	0	0	0.0	0.0	1.7	0.2
Banded killifish	0	0	0.0	0.0	0	0	0.0	0.0	0	1	0.5	0.0	0.2	0.0
Rock bass	0	4	2.0	1.0	15	12	13.5	5.2	0	22	11.0	0.6	8.8	1.2
Bluegill	3	0	1.5	0.7	11	27	19.0	7.3	1	3	2.0	0.1	7.5	1.0
Smallmouth bass	1	1	1.0	0.5	1	1	1.0	0.4	0	1	0.5	0.0	0.8	0.1
Tessellated darter	0	0	0.0	0.0	6	5	5.5	2.1	0	0	0.0	0.0	1.8	0.2
Banded darter	0	1	0.5	0.2	0	4	2.0	0.8	0	0	0.0	0.0	0.8	0.1
TOTAL	199	202	200.5		346	172	259.0		3200	291	745.5		735.0	

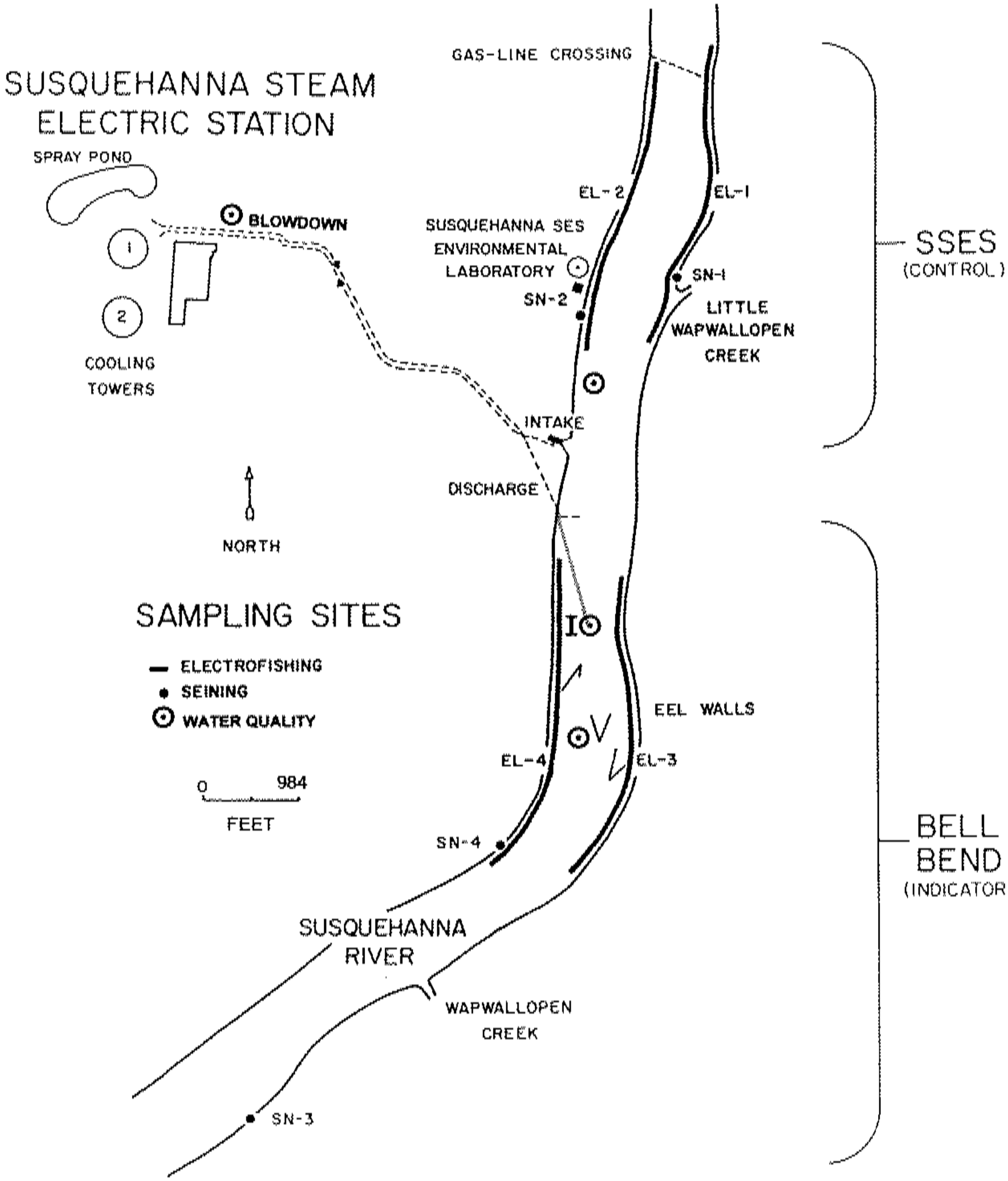


Fig. 1

Sampling sites for water quality, electrofishing (EL), and seining (SN) at SSES and Bell Bend on the Susquehanna River, 2002.

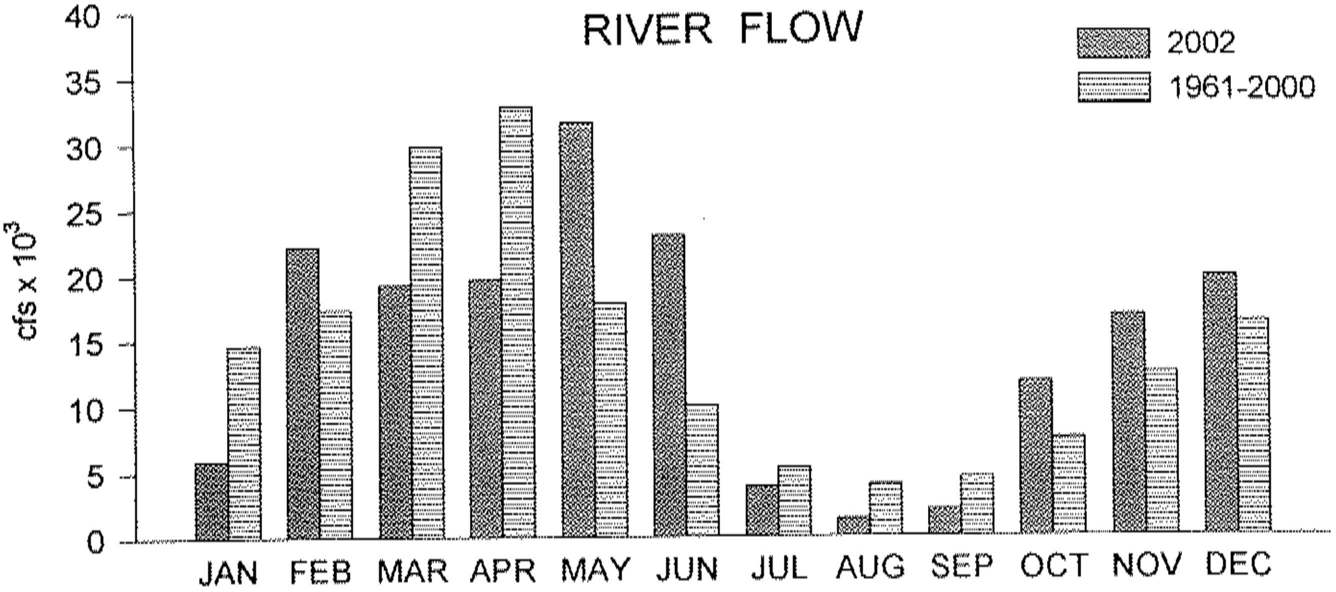


Fig. 2

The 2002 monthly mean flow of the Susquehanna River at the Susquehanna SES Environmental Laboratory compared to the forty year (1961-2000) mean. The means were calculated from U.S. Geological Survey and Environmental Laboratory data.

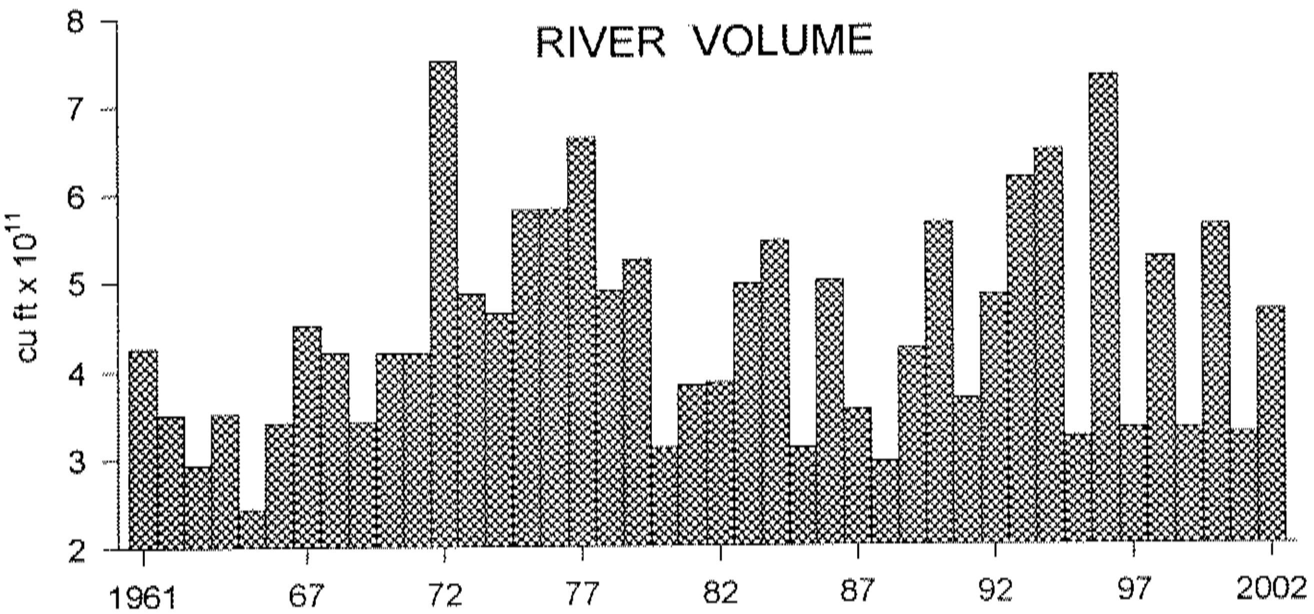


Fig. 3

Volume of Susquehanna River flow at the Susquehanna SES Environmental Laboratory, 1961-2002. The volumes were calculated from U.S. Geological Survey and Environmental Laboratory data.

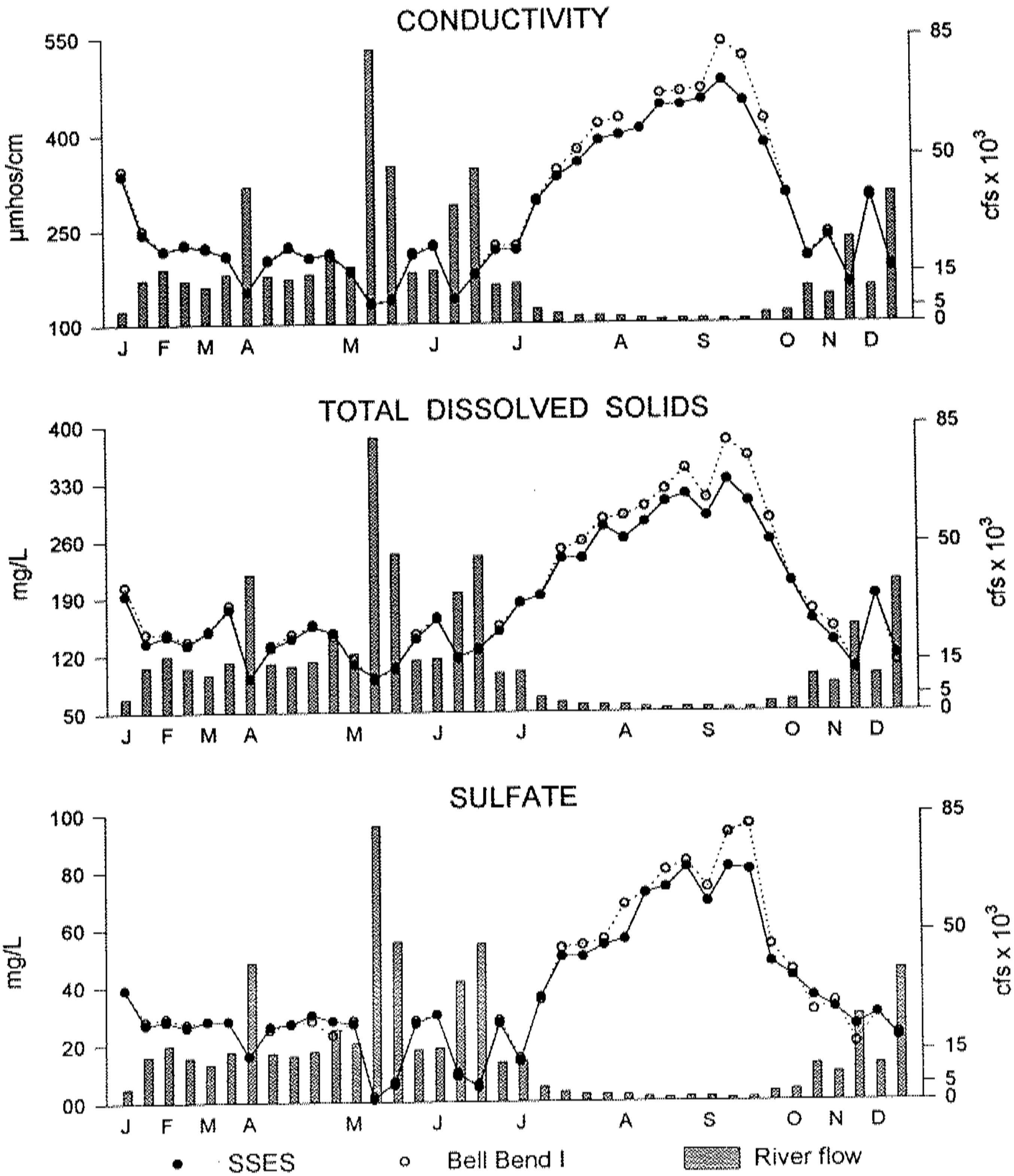


Fig. 4

The relationship of conductivity, total dissolved solids, and sulfate to Susquehanna River flow at the SSES (control) and Bell Bend I (indicator) sites for 2002 water quality samples.

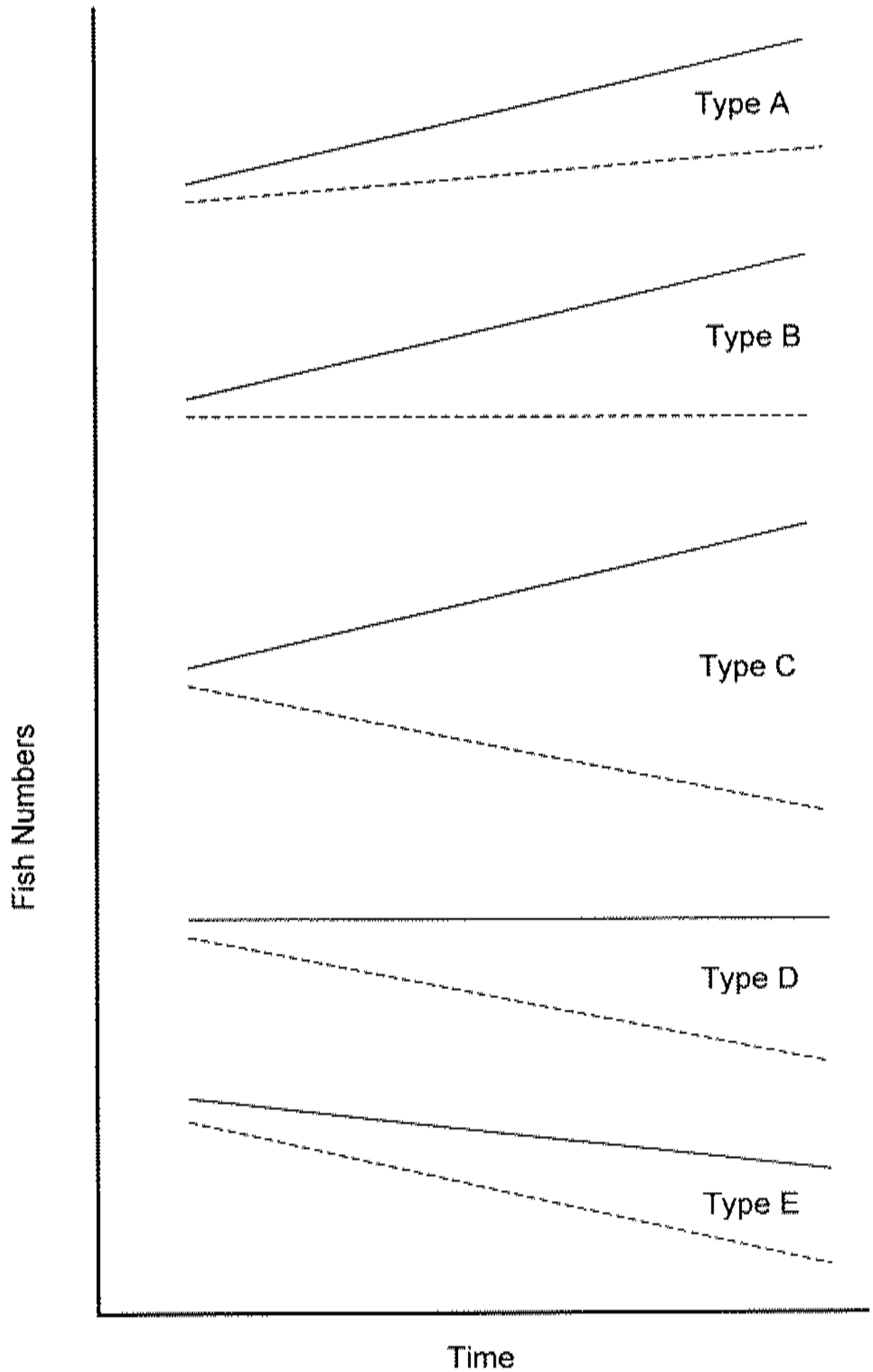
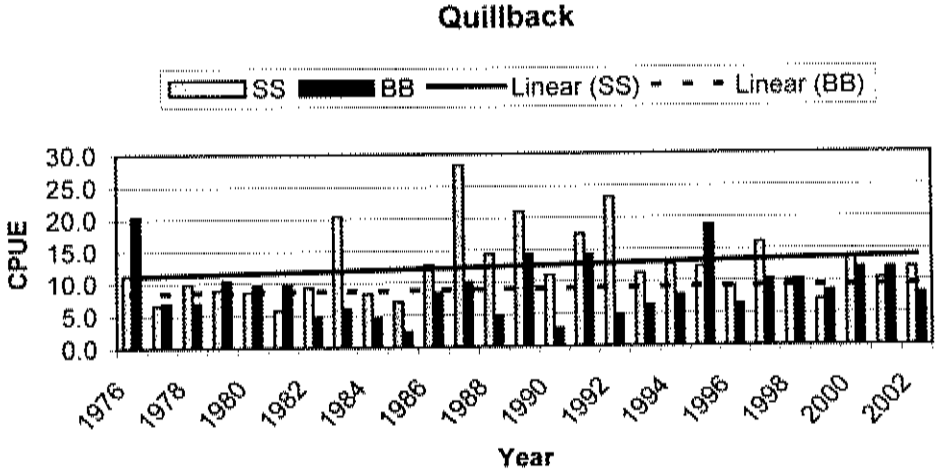


Fig. 5

Five types of relative "declines" that can occur between SSES and Bell Bend fishes. Solid lines depict SSES trends and dashed lines depict Bell Bend .



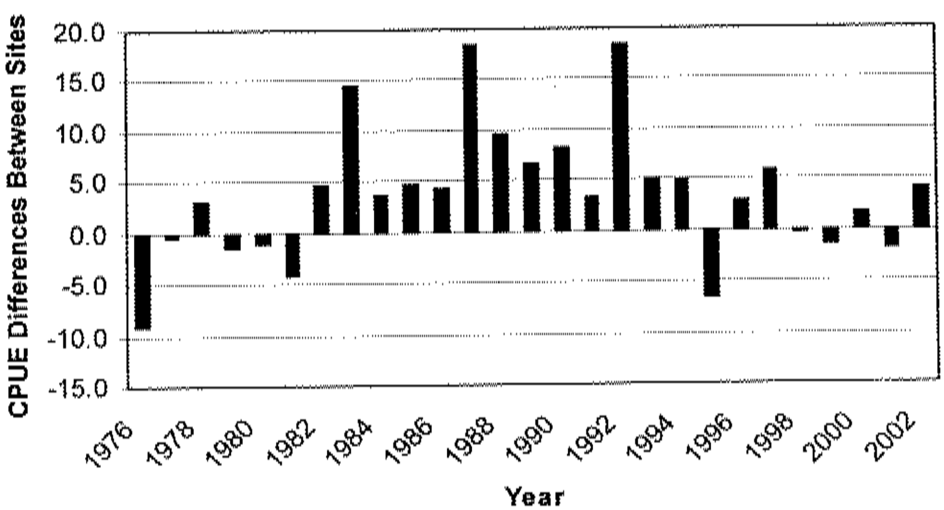
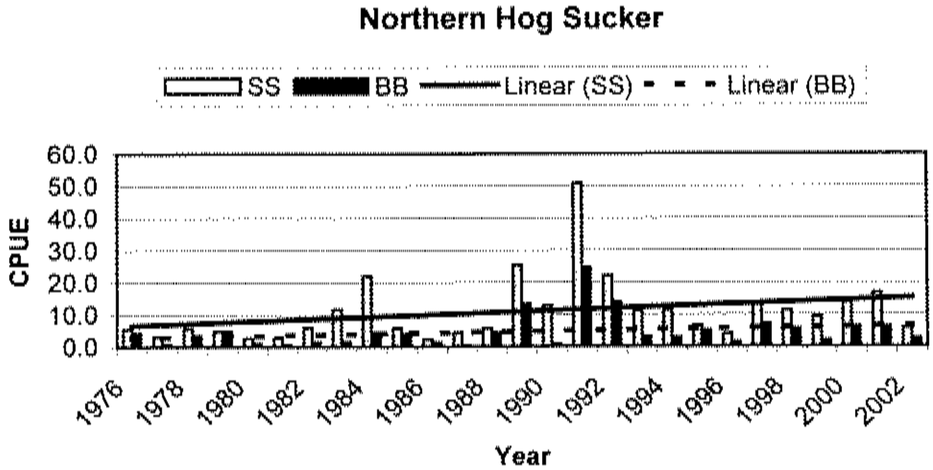


Fig. 6

Annual catch per unit effort and differences in annual catch per unit effort at SSES (SS) and Bell Bend (BB) for each species indicated as significant by the BACI analysis.


Northern Hog Sucker
SS
BB
Linear (SS)
Linear (BB)
CPUE
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

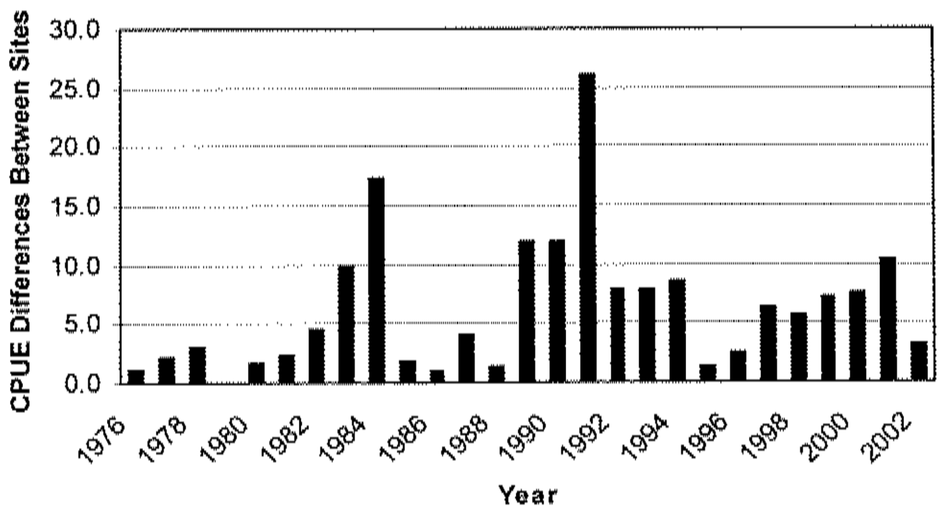

CPUE Differences Between Sites
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)

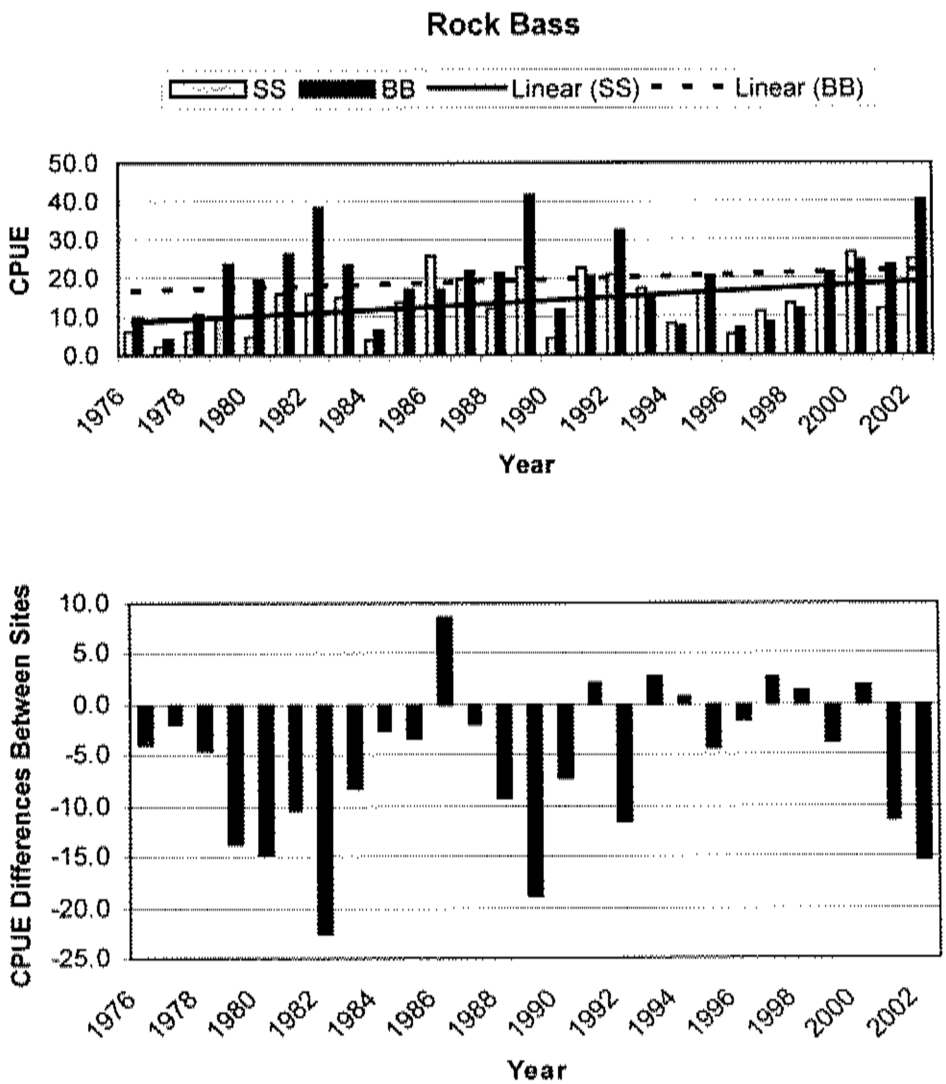
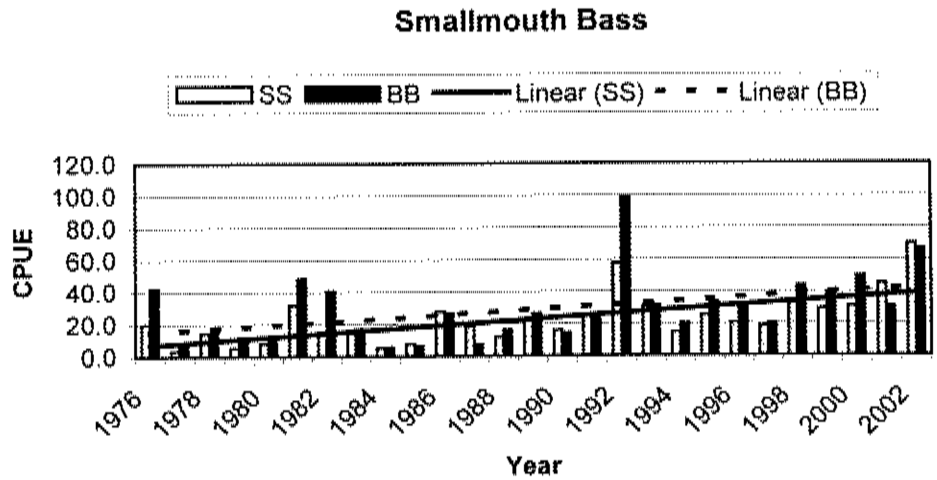

Rock Bass
SS
BB
Linear (SS)
Linear (BB)
CPUE
50.0
40.0
30.0
20.0
10.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
CPUE Differences Between Sites
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)


Smallmouth Bass
SS
BB
Linear (SS)
Linear (BB)
CPUE
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

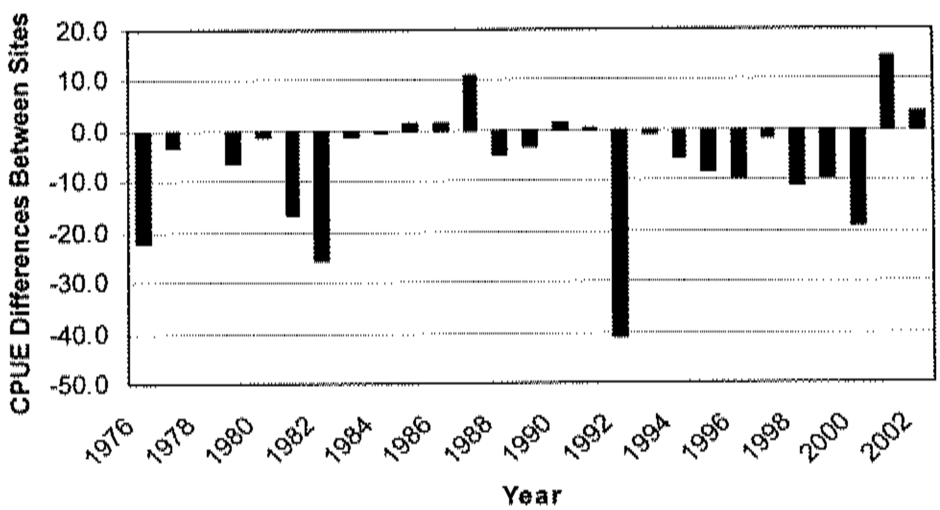
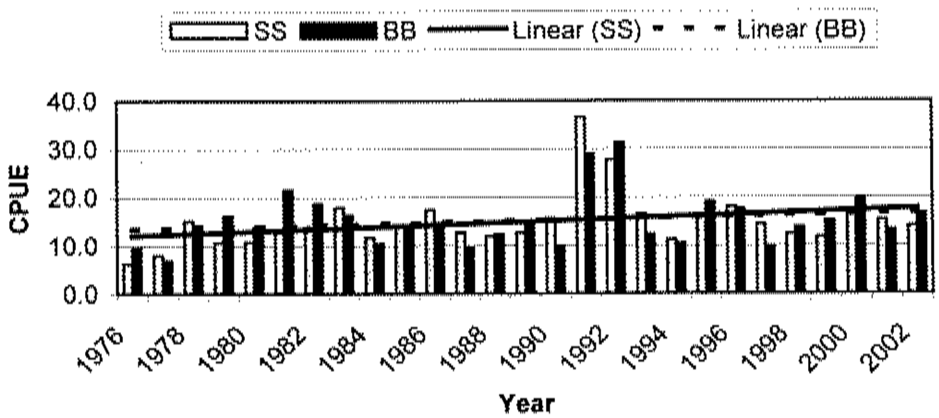

CPUE Differences Between Sites
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)

Unidentified Fish



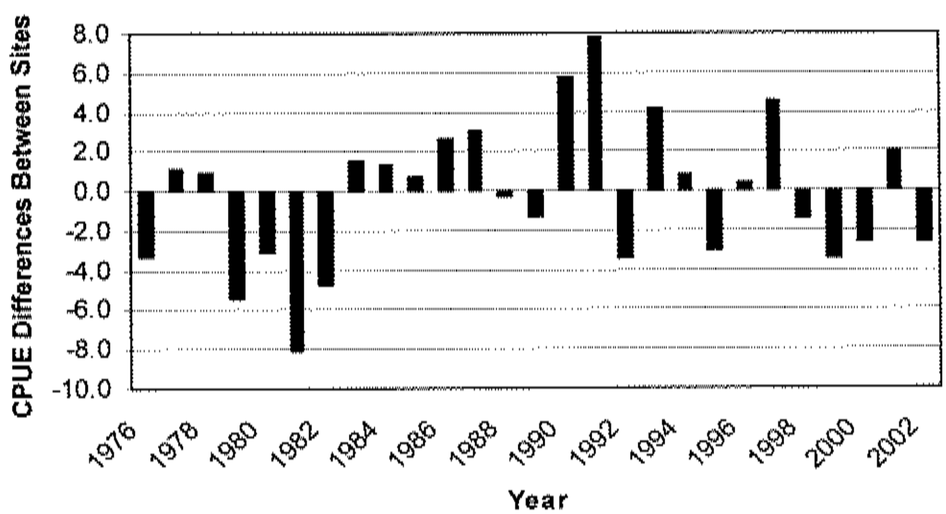
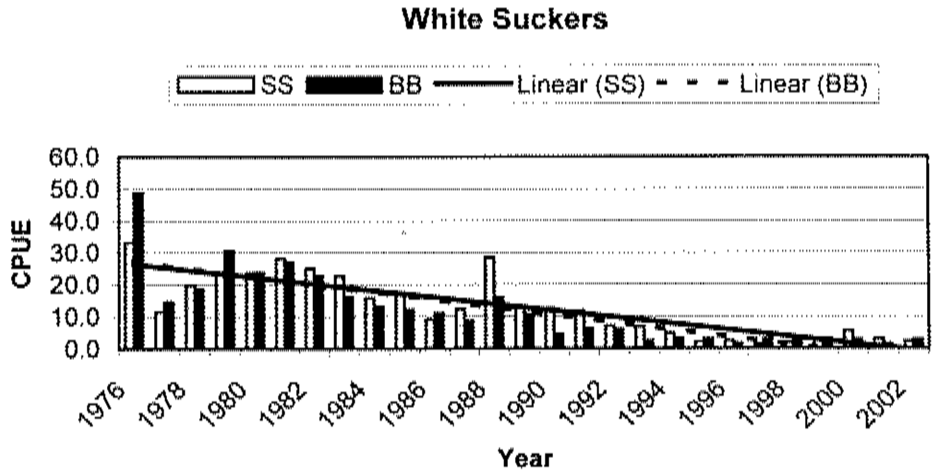


Fig. 6 (cont.)


White Suckers
SS
BB
Linear (SS)
Linear (BB)
CPUE
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

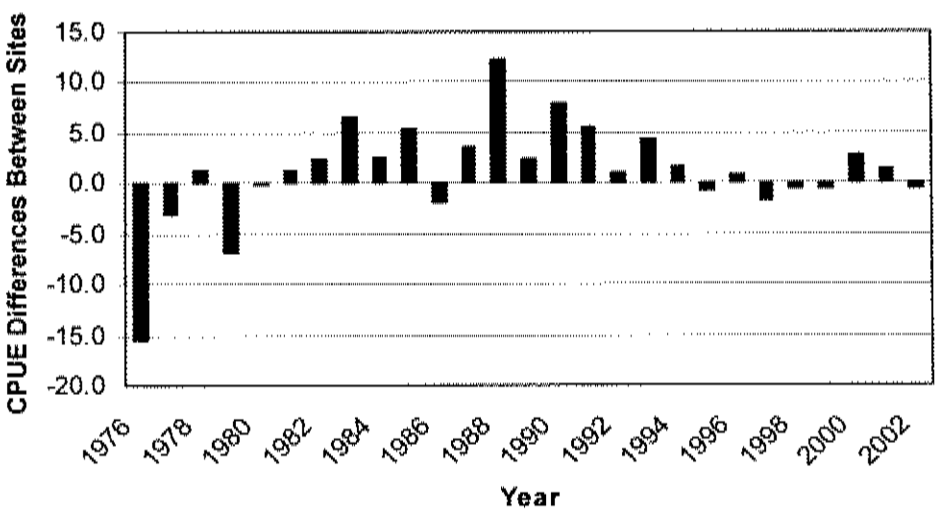
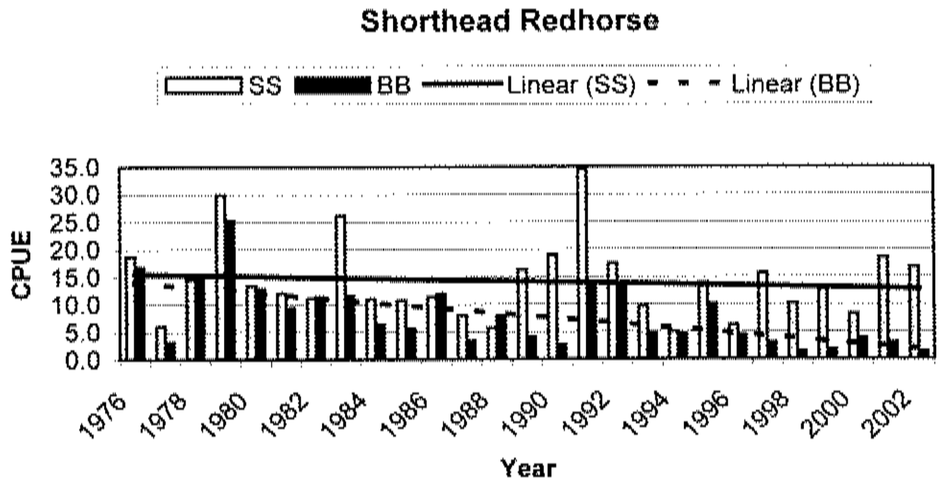
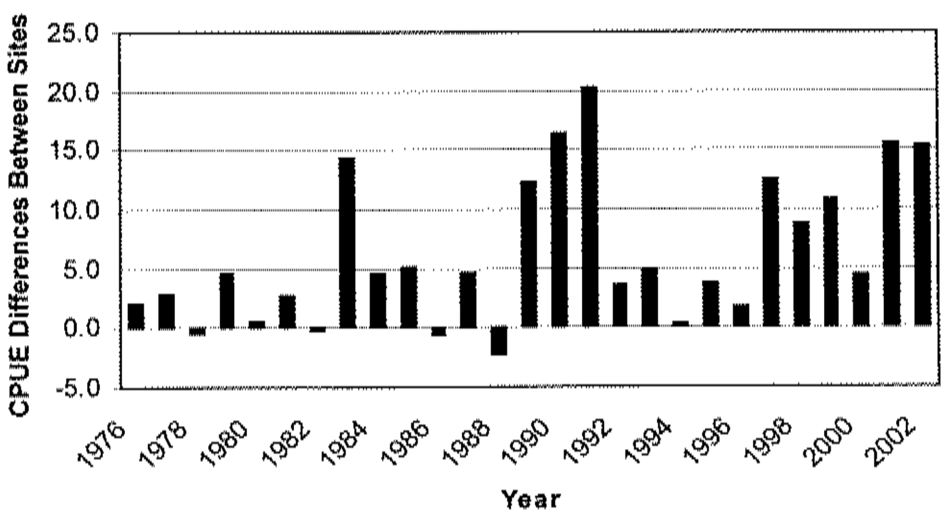

CPUE Differences Between Sites
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)



Shorthead Redhorse
SS
BB
Linear (SS)
Linear (BB)
CPUE
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year



CPUE Differences Between Sites
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)

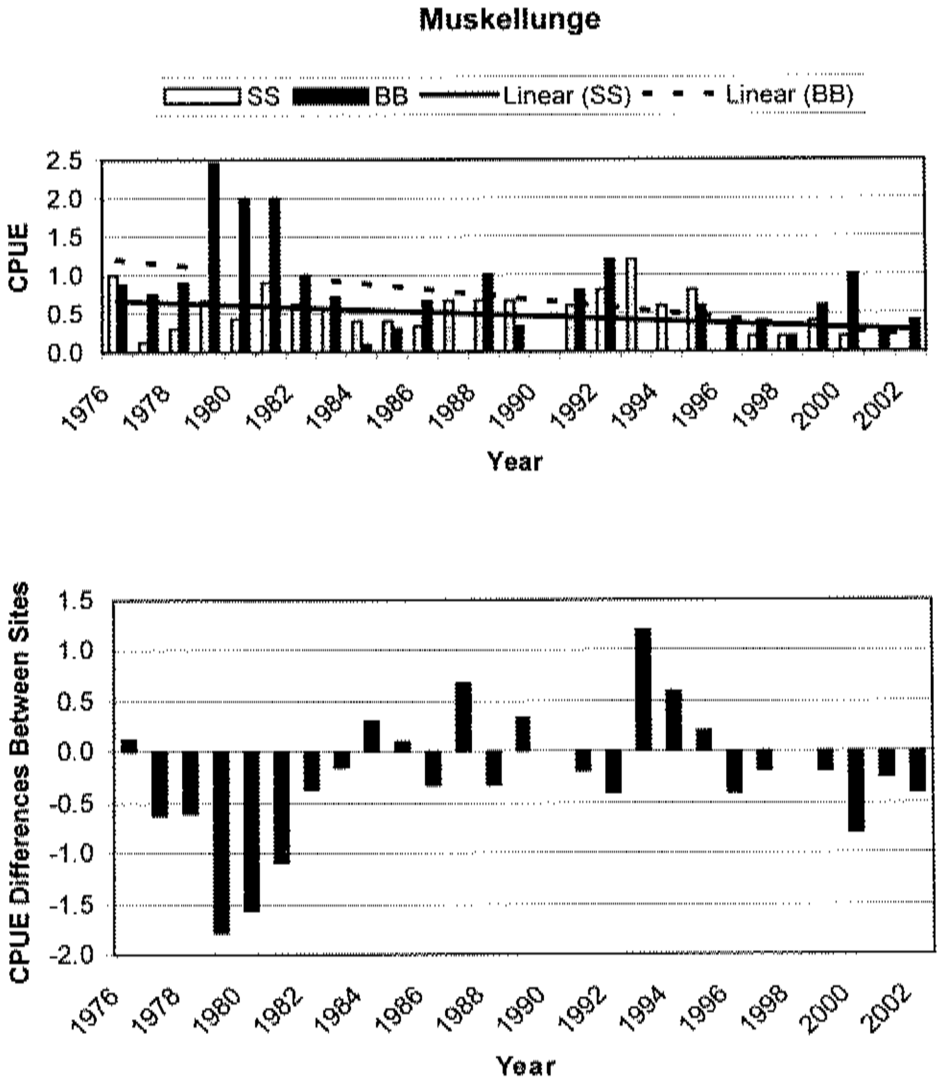

Muskellunge
SS
BB
Linear (SS)
Linear (BB)
CPUE
2.5
2.0
1.5
1.0
0.5
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
CPUE Differences Between Sites
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)

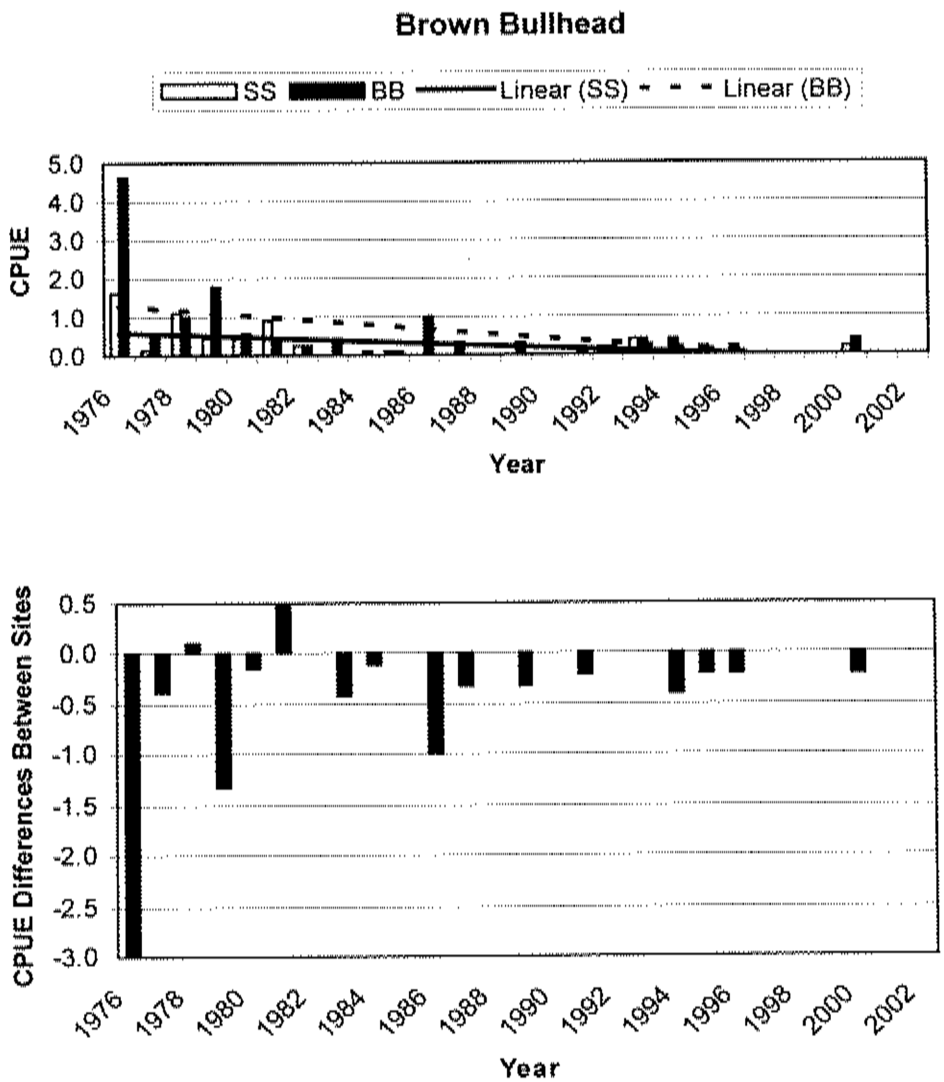

Brown Bullhead
SS
BB
Linear (SS)
Linear (BB)
CPUE
5.0
4.0
3.0
2.0
1.0
0.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
CPUE Differences Between Sites
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

Fig. 6 (cont.)