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CHANGES IN THE COMPOSITION OF THE FISH AGGREGATION IN BLACK ROCK POOL IN THE VICINITY OF CROMBY GENERATING STATION FROM 1970 TO 2007 AS A PARALLEL TO HOOKSETT POOL ON THE MERRIMACK RIVER, NH

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Changes in the Composition of the Fish Aggregation in Black Rock Pool in the Vicinity of Cromby Generating Station from 1970 to 2007 as a Parallel to Hooksett Pool On the Merrimack River, NH

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1.0 Introduction

Throughout the 19th and 20th centuries the water quality of the Schuylkill River was greatly impacted by mining, farming and industrialization, and consequently the aquatic ecological community was severely degraded. Following the implementation of various management practices, most notably those required by the Clean Water Act of 1972 and the banning of phosphate detergents, improvements in water quality were observed. These improvements are evident in the 40 years of fish collection data from studies in the vicinity of Cromby Generating Station (CGS) on Black Rock Pool of the Schuylkill River, PA.

The relevance of this presentation to Merrimack Station is that the temporal changes in the fish aggregation reflect a similar progression to that experienced by the fish aggregation in Hooksett Pool of the Merrimack River. Cromby Generating Station operated throughout a multi-decade period of time during which a pollution tolerant and ecologically flexible fish community, dominated by pumpkinseed, brown bullhead, redbreast sunfish and goldfish, was present in Black Rock Pool of the Schuylkill River. Prominence of these four fish species existed for twenty-five years or more following the initial operation of CGS. It was only when substantial improvements in water quality in the Schuylkill River occurred that the relative abundance of these fish species eventually declined. In the case of CGS, the decline of these four fish species was so great that they moved from predominance to minor components of the fish community. The mechanism for this transition was increased competition and predation facilitated by improving water quality.

2.0 Cromby Generating Station Description

Cromby Generating Station is located on Black Rock Pool of the Schuylkill River in Phoenixville, PA. Cromby Generating Station Units 1 and 2 were placed in service in 1954 and 1955, respectively. Unit 1 is a 144-megawatt coal-fired unit and Unit 2 is a 201-megawatt unit that operates on either natural gas or No. 6 fuel oil. Each unit is serviced by two circulating cooling water pumps, with each Unit 1 pump rated at 50,000 gallons per minute (gpm) and each Unit 2 pump rated at 62,500 gpm. When both Unit 1 pumps are running, water is circulating at the rate of 100,000 gpm, equivalent to 144 million gallons per day (mgd) or 223 cubic feet per second (cfs). When both Unit 2 pumps are running, water is circulating at the rate of 125,000 gpm, equivalent to 180 mgd or 279 cfs. Mean flow in the Schuylkill River for the period 1979-2006 was 2,018 cfs and Q7-10 was 327 cfs (ERM 2008).

Several parallels exist between Hooksett Pool on the Merrimack River, NH and Black Rock Pool on the Schuylkill River, PA. The two river systems were both exposed to intense pollution during the 19th and 20th and the respective pools are both used by power generating plants as a non contact cooling water source. The fish communities in each pool at the time of unit start-up consisted primarily of warmwater species, many capable of tolerating high nutrient levels and low dissolved oxygen content. With the reduction of pollutants, the composition of the fish community changed over time to reflect the improvement in riverine conditions.

3.0 Water Quality in the Schuylkill River

Industrialization and mining in the 19th and 20th centuries left the Schuylkill River as one of the most polluted rivers in the nation. In recent years, the river's water quality has improved and migratory fish are returning (PWD 2006).

The following are excerpts from the publication above:

> *The Schuylkill River is a much healthier river now than it was over the past century, when it was branded as "too thin to cultivate, too thick to drink." The time when the river ran black with culm, smelled of raw sewage, and was covered in sheens of oil or foamed with detergent bubbles is gone.*
>
> *Better water quality has resulted in tremendous improvements in fish, wildlife, and recreational opportunities over the past 20 years. While some of these improvements were related to regulatory initiatives, many changes in water quality were caused by changes in economic and industrial activity within the watershed. These improvements can be directly related to the following major events:*
>
> - *The decline of the coal industry;*
> - *The decline in the presence and size of the manufacturing industry (steel, paper mills, textiles, glass, etc.) that discharged storm or process water to the river;*
> - *The construction of sewers and sewage treatment plants;*
> - *The improvements in sewage and industrial waste treatment plants;*
> - *Improved discharge regulation through the Clean Water Act;*
> - *Regulations limiting the presence of phosphates in detergents; and*
> - *Regulations phasing out the use of certain toxic chemicals.*
>
> *The Schuylkill River has seen significant improvements in important water quality parameters such as dissolved oxygen, ammonia, nitrate, and phosphorous since the 1970s. Schuylkill River nutrient levels (nitrogen and phosphorus measures) have remained stable or decreased over the past decade due to decreased agricultural runoff within the watershed, along with improved wastewater treatment practices. Dissolved oxygen values have been steadily increasing over the past several decades.*

Results of water quality sampling for the mainstem Schuylkill River at Philadelphia and Pottstown (which bracket CGS) indicate that from 1984 to 1995 at both locations there was a significant downward trend with seasonal dependence for total ammonium-nitrogen, and a significant downward trend for total phosphorus (Evans et al. 1996 *in* ANSNLTCF 2001). The decrease in phosphorus was attributed to the ban on phosphate detergents in the mid- to late 1980s. Downward trends in nitrogen and phosphorus along with the increasing trend in dissolved oxygen also occurred in the Merrimack River (Normandeau 2011b).

4.0 Review of Historic Black Rock Pool Fish Sampling

4.1 Trawl Surveys (1970-1973)

A total of 11,961 specimens representing 25 taxa was collected by trawl between 1970 and 1973 (Waterfield et al. 2008a) (Table 1). Pumpkinseed (43.9%), swallowtail shiner (17.2%), spottail shiner (16.5%), brown bullhead (8.9), redbreast sunfish (6.1%), spotfin shiner (2.8%), bluegill (1.3%), and goldfish (1.2%) were the most abundant species.

4.2 Electrofishing (1976)

A total of 916 fishes representing 22 taxa were collected by electrofishing near CGS from October 7 through December 1, 1976 (Waterfield et al. 2008a) (Table 2). Fishes of small adult size and any individuals less than 50 mm in length were intentionally excluded when electrofishing. The predominant species in decreasing order of abundance were redbreast sunfish (30.3%), pumpkinseed (28.2%), goldfish (16.7%), brown bullhead (4.9%), green sunfish (4.8%), black crappie (2.8%), smallmouth bass (2.3%), and carp (2.1%).

4.3 Electrofishing (1989-1990)

Electrofishing was conducted in the vicinity of CGS during 1989 and 1990 and a total of 706 specimens representing 21 taxa was collected (RMC 1991). Species composition and relative abundance are presented in Table 3. Pumpkinseed was most abundant species collected, representing 25.6% of the total, followed in order of decreasing abundance by goldfish (22.0%), redbreast sunfish (13.6%), carp (10.9%), brown bullhead (7.4%), channel catfish (5.1%), and bluegill (5.0%). The remaining 14 taxa together comprised only 10.4% of the catch. Pumpkinseed remained the most abundant species in the electrofishing catch in the vicinity of the station following 25 years of operation of both units at CGS.

4.4 Seining and Electrofishing (1995)

A total of 8,195 specimens representing 28 species were collected by combined gear types in 1995 (Table 4; Normandeau 1996). Spotfin shiner accounted for 75% of the total catch; all were collected by seine. This abundant species was purposefully omitted from the electrofishing catch as were other fishes with small adult sizes and individuals less than 50 mm in length. This procedure was consistent with previous electrofishing collections. Other collected species in order of decreasing abundance were swallowtail shiner (5.9%), redbreast sunfish (4.6%), pumpkinseed (4.3%), bluegill (3.6%), green sunfish (1.7%), and carp (1.1%). All other species individually comprised <1.0% and collectively comprised only 4.1% of the total collection.

Seining surveys in 1995 netted 6,733 fish representing 13 species. Spotfin shiner comprised 90.9% of the total collection and was the most abundant species at each collection site. Other species collected in order of decreasing abundance included swallowtail shiner (7.1%), bluntnose minnow (1.0%), spottail shiner (0.2%), and redbreast sunfish (0.2%). The remaining 8 species comprised only 0.6% of the collection and were represented by 10 or fewer individuals.

A total of 1,462 individuals representing 20 species were collected by electrofishing in 1995 (Table 5). The most abundant species included redbreast sunfish (24.7%), pumpkinseed (23.7%), and

bluegill (19.8%). The recreationally important largemouth bass and smallmouth bass comprised 2.7% and 2.1% of the overall collection, respectively.

4.5 Seining and Electrofishing (2007)

Fishes were collected by seining and electrofishing in 2007 (Normandeau 2008) in order to characterize fish distribution relative to thermal effluent and to detect any negative effects of the effluent upon the fish community. An effort was made to replicate efforts at stations utilized in previous surveys. Seining stations and electrofishing stations were the same as those utilized in 1976, 1989-90, and 1995. It should be noted that the 1989-1990 surveys were conducted only at the stations located immediately above the thermal effluent.

A total of 5,228 specimens representing 27 species of fish were collected by combined gear types in 2007 (Table 5). Spotfin shiner accounted for 72% of the total catch; all were collected by seine. This abundant species was purposefully omitted from the electrofishing catch as were other fishes with small adult sizes and individuals less than 50 mm in length. This procedure was consistent with previous electrofishing collections. Other collected species in the combined catch in order of decreasing abundance were smallmouth bass (9.1%), spottail shiner (6.2%), bluegill (4.6%), carp (1.7%), undetermined *Lepomis* (1.5%), and redbreast sunfish (1.1%). All other species individually comprised less than 1.0%, and collectively comprised only 3.8% of the total collection.

Seining surveys in 2007 (Table 4) netted 4,427 fish of 16 species. Spotfin shiner comprised 85.0% of the total collection and was the most abundant species at each collection site. Other species collected in order of decreasing abundance included spottail shiner (7.3%), bluegill (2.5%), and undetermined *Lepomis*, smallmouth bass (1.1%), common shiner (0.8%), creek chub (0.4%) and swallowtail shiner (0.4%). The remaining nine species collectively comprised only 0.6% of the collection and individual species were represented by 12 or fewer individuals.

A total of 801 individuals of 17 species were collected by electrofishing in 2007 (Table 5). The most abundant species included smallmouth bass (53.1%), bluegill (16.6%), carp (11.1%), redbreast sunfish (7.0%), and channel catfish (3.1%).

4.6 Observed Trends

Pumpkinseed, redbreast sunfish, brown bullhead and goldfish were dominant in both the 1976 and 1989-1990 electrofish sampling. These species accounted for 80.1% of the fish community as sampled by boat electrofishing in 1976, 68.6% in 1989-1990, 53.6% in 1995 and 7.5% in 2007. Of those four fish species in 2007, only redbreast sunfish (7.0%) constituted a considerable percentage of the Black Rock Pool fish community. Pumpkinseed (0.5%) were noticeable decreased while brown bullhead and goldfish were not captured during electrofish sampling at all. A total of 5,251 pumpkinseed (43.9% of all fish collected) were collected in trawl surveys at established locations between 1970 and 1973 despite the continuous operation of Unit 1 since 1954 and Unit 2 since 1955 at CGS (Waterfield et al. 2008a). The abundance of pumpkinseed in these numbers is especially notable due to their affinity for aquatic vegetation that would have made them less accessible to collection by trawl. The reduction in pumpkinseed abundance in Black Rock Pool does not appear to have been due to the thermal effluent from CGS. Seining and electrofishing were utilized in 1970 to collect and document the presence of pumpkinseeds which were utilizing an eddy adjacent to the thermal effluent for nesting (Denoncourt and Hocutt 1971). Pumpkinseed were observed to be

successfully nesting (based on the presence of greater than 50 nests, ripe and spent adult fish, as well as the presence of eggs within all nests examined). Water temperatures on the dates of sampling were 95-97° F.

Whereas decreases were observed for those four fish species, abundance of other fish species increased. Smallmouth bass comprised 53.1 % of fishes collected in electrofish samples from 2007, representing a dramatic increase in abundance of this species compared to the 2-3% it represented from 1976 and 1996 electrofish sampling. Smallmouth bass appeared to be distributed across a number of year-classes as indicated by a wide range of lengths. The relative abundance of bluegill increased during each electrofish sampling from a low of 1.2% in 1976 to a high of 16.6 in 2007, becoming the dominant *Lepomis* species in Black Rock Pool. The continued increase in the bluegill population seen in both the seine and electrofishing data may reflect not only the effects of improved water quality, but also possibly behavior that tends to isolate bluegill from predation by flathead catfish, at least relative to the level of predation that is experienced by other species such as green sunfish and redbreast sunfish (Waterfield et al. 2008a).

The declines which were identified between 1976 and 2007 electrofish samples included goldfish and brown bullhead. Goldfish represented between 16% and 22% of the fish community in 1976 and 1989-1990 but declined to 4.9% in 1995 and were not captured in 2007. Goldfish are among a group of fishes that appear to have been declining for a number of decades, probably as a result of increased competition and predation facilitated by improving water quality. Similarly brown bullhead, which represented 4% and 8% of the fish community in 1990, declined to 0.3% in 1995 and was not captured in 2007. The observed increase in abundance of channel catfish and the decline of brown bullhead may have partially been the result of a competitive interaction between the two species that was facilitated by improving water quality. This mechanism has been proposed by Boyer (1995) as responsible for increasing numbers of channel catfish relative to white catfish and brown bullheads in the tidal Delaware River. Numerous other increases and decreases among species in the fish community are likely due to the natural shifting in compositions that occur over time, due to variables such as environmental factors and introduced species, as well as the improved water quality that has gradually occurred during this period.

5.0 Conclusions

The results of fisheries sampling in the vicinity of Cromby Generating Station (CGS) indicate the degree to which the fish community during the early 1970s represented an ecological community which remained adversely impacted by two centuries of water quality degradation of the Schuylkill River. The low diversity is reflected by the fact that 92.6% of the fishes collected by trawl during 1970 to 1973 were concentrated in five species (Table 1). The fish community in Black Rock Pool during the mid-1970s can be classified as having a Level 5 Biological Condition Gradient (Davies and Jackson 2006). A fish community in its native (i.e. non-degraded condition) would be considered as Level 1. The Black Rock Pool 1970s fish community was one that had been degraded such that tolerant species showed increasing dominance, sensitive species were rare, and ecological functions were altered. It is likely that the river previously had reached Level 6 (severe alteration of structure and function) and had improved to Level 5 over many decades prior to the 1970s, as resources such as timber and coal in the watershed had been largely depleted and wastes from these activities no longer were being actively dumped into the river. Over a period of more than thirty years, water quality in the Schuylkill River has improved and by 2005-2006 a more diverse fish community composed of

species of intermediate tolerance were collected in Black Rock Pool in the vicinity of CGS. The aquatic community had shifted, as described by The Biological Condition Gradient (Davies and Jackson 2006) by the late 2000s from a Level 5 to Level 4 with some characteristics of Level 3 (with the native or natural condition being Level 1). This level, although far from Level 1, had functions that were fully maintained and included large numbers of individuals of intermediate tolerance and a much more diverse fish aggregation.

Increase in diversity and other positive changes to the fish community of Black Rock Pool in the vicinity of Cromby Generating Station can be attributed to water quality improvements that were exerted upon a fish community that was dominated by ecologically flexible and pollution-tolerant fish species. This community was greatly predominated by pumpkinseed when first sampled in the early 1970s. Pumpkinseed flourished in Black Rock Pool in the vicinity of Cromby Generating Station after nearly twenty years of operation of the station between 1954 and the early 1970s, and continued to do so, although in slightly reduced numbers, for most of the next twenty years. Other prominent species in this group which dominated during the early decades of operation of CGS were brown bullhead, white sucker and goldfish. Subsequently, greater fish diversity as evidenced by the declines in abundance of these species and large increases in abundance of species of intermediate pollution tolerance reflected the effects of increased competition and predation and an improved food supply facilitated by improving water quality.

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TABLES

Table 1. Fishes taken by trawl in Black Rock Pool, 1970-1973 (from Philadelphia Electric Company 1977).

Taxon	Year				Combined	
	1970	1971	1972	1973	Number	Percent
Pumpkinseed	4	5,154	80	16	5,254	43.9
Swallowtail shiner	385	810	735	139	2,069	17.2
Spottail shiner		1,820	105	49	1,974	16.5
Brown bullhead	16	548	217	284	1,065	8.9
Redbreast sunfish	2	591	68	65	726	6.1
Spotfin shiner	8	44	266	11	329	2.8
Bluegill	1	126	19	5	151	1.3
Goldfish		39	39	68	146	1.2
White sucker		29	20	19	68	0.6
Lepomis hybrid		42			42	0.4
White catfish	2	6	13	7	28	0.2
Channel catfish	3	11	4	9	27	0.2
Carp		6	10	10	26	0.2
Banded killifish		14			14	0.1
Golden shiner				10	10	0.1
White crappie	1	3	1	1	6	0.1
Tessellated darter	1	2	3		6	0.1
Green sunfish		6			6	0.1
Black crappie			3	2	5	*
Yellow perch		1	1		2	*
Longnose dace			2		2	*
Rock bass			1	1	2	*
Smallmouth bass	1				1	*
Creek chubsucker		1			1	*
Yellow bullhead		1			1	*
Total	**424**	**9,254**	**1,587**	**696**	**11,961**	

*less than 0.1%

Table 2. Fishes collected by electrofishing from the Schuylkill River near Cromby Generating from October 7 through December 1, 1976 (data from Philadelphia Electric Company 1977) (total electrofishing time = 306 minutes).

Taxon	Number	Percent of Total
Redbreast sunfish	278	30.3
Pumpkinseed	258	28.2
Goldfish	153	16.7
Brown bullhead	45	4.9
Green sunfish	44	4.8
Black crappie	26	2.8
Smallmouth bass	21	2.3
Carp	19	2.1
Largemouth bass	14	1.5
Bluegill	11	1.2
Golden shiner	10	1.1
White sucker	9	1
Creek chubsucker	8	0.9
American eel	6	0.6
White catfish	3	0.3
Yellow perch	3	0.3
Rock bass	2	0.2
Lepomis hybrid	2	0.2
Bowfin	1	0.1
Quillback	1	0.1
Channel catfish	1	0.1
White crappie	1	0.1
Total	**916**	

Table 3. Composition of the electrofishing catch between August 1989 and May 1990 from the Schuylkill River near Cromby Generating Station (data from RMC Environmental Services 1991).

Taxon	Number	Percent Composition
Pumpkinseed	181	25.6
Goldfish	155	22
Redbreast sunfish	96	13.6
Carp	77	10.9
Brown bullhead	52	7.4
Channel catfish	36	5.1
Bluegill	35	5
Smallmouth bass	20	2.8
Carp x goldfish hybrid	18	2.6
Rock bass	8	1.1
Largemouth bass	4	0.6
Green sunfish	4	0.6
Yellow bullhead	3	0.4
White sucker	3	0.4
White crappie	3	0.4
Golden shiner	3	0.4
Quillback carpsucker	2	0.3
Lepomis hybrid	2	0.3
Black crappie	2	0.3
American eel	1	0.1
White catfish	1	0.1
Total	**706**	

Table 4. Table 4. Summary by sampling method of the abundance and percent composition of fishes collected in Black Rock Pool in 1995 (from Normandeau Associates 1996).

Taxon	Seining		Electrofishing		Total	
	Number	Percent	Number	Percent	Number	Percent
Spotfin shiner	6,121	90.9	-	-	6,121	74.7
Swallowtail shiner	481	7.1	-	-	481	5.9
Redbreast sunfish	13	0.2	361	24.7	374	4.6
Pumpkinseed	5	0.1	346	23.7	351	4.3
Bluegill	9	0.1	289	19.8	298	3.6
Green sunfish	7	0.1	134	9.2	141	1.7
Carp	-	-	92	6.3	92	1.1
Goldfish	-	-	72	4.9	72	0.9
Bluntnose minnow	67	1	-	-	67	0.8
Largemouth bass	-	-	40	2.7	40	0.5
Smallmouth bass	3	+	30	2.1	33	0.4
Channel catfish	-	-	23	1.6	23	0.3
Yellow bullhead	-	-	21	1.4	21	0.3
Sunfish hybrid	-	-	14	1	14	0.2
Spottail shiner	14	0.2	-	-	14	0.2
Rock bass	-	-	11	0.8	11	0.1
Banded killifish	10	0.1	-	-	10	0.1
Black crappie	-	-	7	0.5	7	0.1
American eel	-	-	5	0.3	5	0.1
Brown bullhead	-	-	5	0.3	5	0.1
White sucker	-	-	5	0.3	5	0.1
Quillback	-	-	3	0.2	3	+
Carp x goldfish	-	-	2	0.1	2	+
Comely shiner	1	+	-	-	1	+
Esox hybrid	1	+	-	-	1	+
Golden shiner	1	+	-	-	1	+
White catfish	-	-	1	0.1	1	+
White perch	-	-	1	0.1	1	+
Total number	**6,733**		**1,462**		**8,195**	
Total taxa	**13**		**20**		**28**	

+ = less than 0.1%

Table 5. Total number and percent composition of fishes collected by boat electrofishing and seining within and just upstream of Black Rock Pool, July - December 2007.

	Seining		Electrofishing		Total	
Common Name	**Number**	**Percent**	**Number**	**Percent**	**Number**	**Percent**
Spotfin shiner	3,765	85.0			3,765	72.0
Smallmouth bass	49	1.1	425	53.1	474	9.1
Spottail shiner	323	7.3			323	6.2
Bluegill	109	2.5	133	16.6	242	4.6
Common carp			89	11.1	89	1.7
Undetermined Lepomis	81	1.8			81	1.5
Redbreast sunfish	2	+	56	7.0	58	1.1
Common shiner	36	0.8			36	0.7
Rock bass	12	0.3	22	2.7	34	0.7
Channel catfish			25	3.1	25	0.5
Creek chub	19	0.4			19	0.4
Swallowtail shiner	18	0.4			18	0.3
Flathead catfish			12	1.5	12	0.2
Green sunfish	1	+	9	1.1	10	0.2
Pumpkinseed	4	0.1	4	0.5	8	0.2
Sunfish hybrid			6	0.7	6	0.1
American eel			4	0.5	4	0.1
Largemouth bass			4	0.5	4	0.1
Tessellated darter	4	0.1			4	0.1
White perch			4	0.5	4	0.1
White sucker	1	+	3	0.4	4	0.1
Black crappie			2	0.2	2	+
Quillback			2	0.2	2	+
Banded killifish	1	+			1	+
Comely shiner	1	+			1	+
Golden shiner	1	+			1	+
White crappie			1	0.1	1	+
Total number	4,427		801		5,228	
Total species	16		17		26	

+ = less than 0.1%