



Restoration of the Turning Basin and Tidal Wetlands at Saugus Iron Works National Historic Site

2008 Post-Restoration Monitoring Data Report

Natural Resource Data Series NPS/NER/SAIR/NRDS—2010/054



ON THE COVER

Restored turning basin at Saugus Iron Works NHS, September 2008.
Photograph by: Mary-Jane James-Pirri

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Abstract

The National Park Service initiated a restoration project at Saugus Iron Works National Historic Site to restore the historic turning basin and wetland area adjacent to the Saugus River in 2007. To fulfill regulatory requirements and enhance understanding of freshwater wetland restoration practices, an intensive, pre- and post-restoration monitoring program was implemented. This report summarizes monitoring data collected prior to the restoration and the first year (2008) after restoration. Data summaries included in this report describe the status of biotic (e.g., vegetation, nekton, avian, benthic invertebrate, and vegetation communities) and abiotic parameters (e.g., tidal hydrology, river geomorphology, sediment, and water quality). This is first of several monitoring reports associated with the restoration of the turning basin and wetlands at Saugus Iron Works National Historic Site.

Introduction

Restoration of the historic condition and ecological functions of the Saugus Iron Works National Historic Site turning basin and southern marsh area was initiated in fall 2007. To fulfill regulatory requirements and enhance understanding of freshwater wetland restoration practices, the National Park Service (NPS) implemented a 5-year, post-restoration, intensive ecosystem research and monitoring program that began in the fall of 2008. The monitoring program is conducted by contractors, NPS staff, and University cooperators.

This report summarizes the first year of post-restoration monitoring for a wide variety of biological and physical parameters at Saugus Iron Works National Historic Site (SAIR). This summary report includes data collected by the University of Rhode Island, CH2MHill, and the NPS during the 2008 monitoring period. Information on physical and biological variables (tidal hydrology, river geomorphology, sediment composition, water quality, and benthic invertebrate community) has been excerpted from the draft 2008 Monitoring Data Report submitted to the NPS by CH2MHill (CH2MHill 2009).

Information from the 2004 monitoring report of vegetation and nekton conducted in conjunction with the NPS Inventory and Monitoring Program (James-Pirri 2004) has been excerpted and is included in this report in an effort to describe the pre-restoration conditions for vegetation and nekton. In subsequent monitoring years, statistical analyses will be performed to compare year-to-year changes in the monitored parameters; however, with just one season of post-restoration monitoring data it is premature to pursue these analyses in this data report. Data from the Massachusetts Division of Marine Fisheries annual smelt and eel sampling on the Saugus River will also be incorporated into the monitoring assessment in subsequent years.

Saugus Iron Works National Historic Site, located approximately 10 miles north of Boston on the upper reaches of the Saugus River, preserves the site of the first sustained ironworks of North America. The ironworks produced iron products from 1646 to 1668 and was critical in the development of America's iron manufacturing legacy (NPS 2006). Raw materials were delivered to the ironwork's wharf by shallow draft boats navigating the Saugus River while finished products were transported back down the river bound for Boston and beyond (NPS 2006).

In the late 1950's, a breach of an upstream dam caused extensive sedimentation and siltation of the historic turning basin, waterfront, and wharf area of the ironworks (NPS 2006). Over time the silted turning basin was colonized by invasive species and the southern marsh lining the Saugus River became choked with undesirable vegetation such as *Phragmites australis* (common reed) and other exotic species (Agius 2003, CH2MHill 2005). The Saugus River is a pivotal landscape feature of the historic setting and cultural interpretation of the Park, and in the fall of 2007 a restoration was initiated to restore the turning basin and remove much of the invasive vegetation from the marsh bordering the river. The goals of the restoration included removing sediment within the turning basin to restore the open water condition, removing invasive exotic plant species, improving

water quality, replacing the wharf and bulkhead, and making the river a more suitable nursery for aquatic and terrestrial organisms (CH2MHill 2005). This is one of the first tidal freshwater wetland restoration projects in New England.

To satisfy regulatory requirements, guide any necessary adaptive management actions, and to enhance understanding of tidal freshwater wetland restoration practices, the NPS, in collaboration with university researchers and a contractor, will study the restoration area for 5 years. Research and monitoring will follow protocols developed and utilized by the NPS Northeast Coastal and Barrier Network, NPS Northeast Temperate Network, and the environmental firm CH2MHill (2005). Data collected from 2008 to 2012 will be compared to baseline pre-restoration conditions. This data report summarizes the first year of data for post-restoration monitoring conducted in 2008.

Biological Variables: Marsh and Aquatic Vegetation

Methods: Marsh and Aquatic Vegetation

Vegetation of the restoration area (turning basin and southern salt marsh area) will be evaluated following protocols of the NPS Northeast Coastal and Barrier Network (Roman et al. 2001, James-Pirri and Roman in review). Vegetation, including intertidal freshwater marsh and submerged aquatic vegetation, will be sampled once per year at the end of the growing season in late summer/early fall for the years 2008 through 2012 (five successive years). Vegetation will be sampled in a minimum of 30, 1-m² plots that will be randomly located throughout the restoration area. Data recorded for each 1-m² plot will include species composition and species cover/abundance. Estimates of percent cover will be determined using the Braun-Blanquet (1965) visual cover scale method. For this method the observer stands over the plot and visually estimates the cover of each species present within the plot. Cover is estimated within standard cover classes as follows (0: absent; 1: <1%; 2: 1-5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%). In statistical analyses the Braun-Blanquet data are analyzed as ordinal data. Multivariate statistical techniques, including Analysis of Similarities (ANOSIM) among others, will be used to evaluate responses of the vegetation community to the restoration actions.

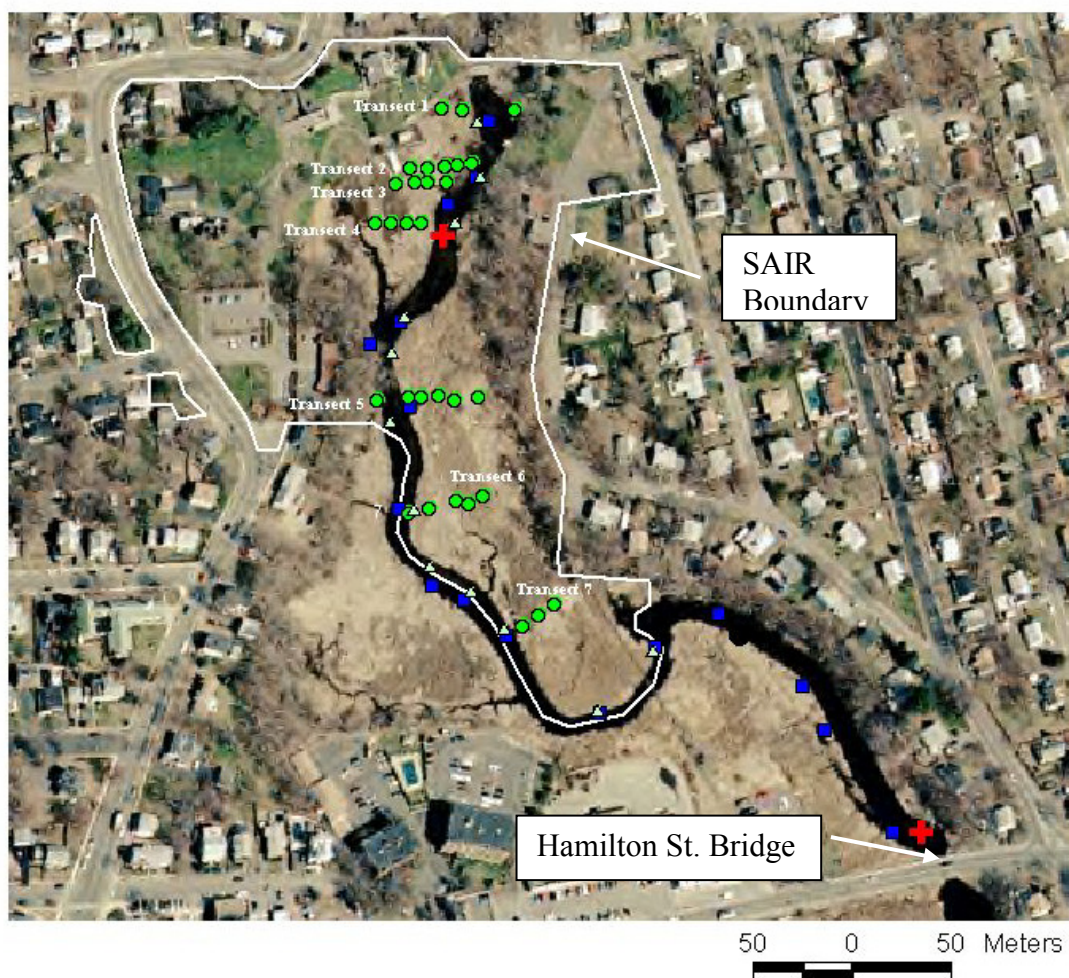
Results: Marsh Vegetation

Vegetation monitoring did not occur in 2008 as the planting of vegetation on the restored marsh was not completed until September 2008, and sampling would have negatively impacted the newly planted vegetation. Additionally, vegetation monitoring will be more informative after the planted vegetation has had one growing season to establish itself.

Pre-restoration vegetation monitoring was conducted on 13 July 2004 as part of the NPS Inventory and Monitoring Program. A total of 30 vegetation plots were randomly located along seven transects. Four transects (16 plots) were randomly placed in the marsh area of the former turning basin with the remaining three transects (14 plots) placed within the southern area marsh adjacent to the Saugus River (Figure 1). For ease of comparison with future vegetation data, the data from the former turning basin area and southern section of the marsh are presented separately (Table 1).

Pre-restoration vegetation of the former turning basin area (transects 1-4) was very complex, with a total of 23 species identified. Narrowleaf cattail (*Typha angustifolia*) was the dominant species representing 17% of the vegetation community of the marsh (estimated from mid-point of Braun-Blanquet scores, Table 1).

Prior to restoration, the southern marsh (transects 5-7) was dominated by common reed (*Phragmites australis*) which comprised approximately 44% of vegetation community. Narrowleaf cattail was also abundant, comprising 17% of the vegetation. A total of 13 species were identified in this area (estimated from mid-point of Braun-Blanquet scores, Table 1).



2004 Sampling Locations

-  Vegetation sampling plots (n=30)
 Aquatic vegetation sampling plots (n=12)
 Nekton throw trap sampling locations (n=16 each on 2 dates)
 Seine haul locations (n=7, on 3 separate dates)
- N ↑

Figure 1. Location of pre-restoration nekton and vegetation sampling stations at Saugus Iron Works NHS in 2004.

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores) for vegetation sampled at Saugus Iron Works NHS in 2004 prior to restoration activities. Transects 1-4 correspond to the upland area formerly in the turning basin and transects 5-7 correspond to the southern section of the marsh adjacent to the river.

Common Name	Scientific Name	Average Braun-Blanquet ² score (percent of total cover)	
		2004 Turning Basin Transects 1-4 (n=16)	2004 Lower marsh Transects 5-7 (n=14)
American black nightshade	<i>Solanum americanum</i>	0.1 (0.9%)	-
American bur-reed	<i>Sparganium americanum</i>	0.3 (2.3%)	0.1 (1.5%)
Arrow arum	<i>Peltandra virginica</i>	1.1 (8.1%)	0.6 (6.8%)
Black locust ¹	<i>Robinia pseudoacacia</i>	0.3 (2.3%)	-
Bluejoint reedgrass	<i>Calamagrostis canadensis</i>	0.1 (0.9%)	-
Climbing hempvine	<i>Mikania scandens</i>	0.5 (3.6%)	0.1 (1.5%)
Common boneset	<i>Eupatorium perfoliatum</i>	0.4 (3.2%)	-
Common reed ¹	<i>Phragmites australis</i>	0.2 (1.4%)	4.1 (43.6%)
Comon rush	<i>Juncus effusus</i>	0.2 (1.4%)	-
Curly dock	<i>Rumex crispus</i>	0.1 (0.9%)	-
Dotted smartweed	<i>Polygonum punctatum</i>	0.1 (0.9%)	0.1 (1.5%)
Estuary beggarticks	<i>Bidens tripartita</i>	0.1 (0.9%)	-
Hedge bindweed	<i>Calystegia sepium</i>	1.3 (9.0%)	0.4 (4.6%)
Jewelweed	<i>Impatiens capensis</i>	1.3 (9.0%)	0.1 (1.5%)
Litter	litter	1.0 (7.2%)	0.3 (3.0%)
Mud	mud or bare	1.4 (9.9%)	0.2 (2.3%)
Multiflora rose ¹	<i>Rosa multiflora</i>	1.0 (7.2%)	-
Narrowleaf cattail	<i>Typha angustifolia</i>	2.9 (17.1%)	1.6 (16.5%)
Pickernelweed	<i>Pontederia cordata</i>	0.3 (1.8%)	0.1 (1.5%)
Poison ivy	<i>Toxicodendron radicans</i>	0.1 (0.9%)	0.3 (3.0%)
<i>Polygonum</i> species	<i>Polygonum species</i>	0.3 (2.3%)	0.1 (1.5%)
Purple loosestrife ¹	<i>Lythrum salicaria</i>	0.6 (4.1%)	0.8 (8.3%)
Reed canary grass ¹	<i>Phalaris arundinacea</i>	0.4 (3.2%)	0.3 (3.0%)
Sweetscented joepeyeweed	<i>Eupatorium purpureum</i>	0.3 (1.8%)	-
Water starworts	<i>Callitriche species</i>	0.1 (0.5%)	-

¹ Invasive species as identified by the Massachusetts Invasive Plants Advisory Group (MIPAG) (2005).

² Braun-Blanquet cover class scale (0; 1: <1; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%).

“-” Species not present.

Results: Aquatic Vegetation

Submerged aquatic vegetation cover within the river was estimated in 12 plots on 12 July 2004. These plots were located adjacent to the 2004 nekton sampling stations. The dominant aquatic vegetation in the river in 2004 was horned pondweed (*Zannichella palustris*) which had an average cover of 16% (estimated from mid-point of Braun-Blanquet scores) and was found in five of the 12 plots (42%). Curly pondweed (*Potamogeton crispus*), an invasive species (Massachusetts Invasive Plant Advisory Group [MIPAG] 2005), was observed within four of the 12 plots. Other aquatic species that were present were *Callitriche* species and green alga. Forty-two percent (five plots) of the aquatic vegetation plots had no aquatic vegetation (Table 2).

In 2008, aquatic vegetation was estimated during the nekton throw trap sampling (18 and 23 September 2008). The only species of aquatic vegetation found in the river was horned pondweed. This species had an average cover of 9% (estimated from mid-point of Braun-Blanquet scores) and was found in three of the 15 plots (20%) (Table 2). In the newly restored turning basin, four aquatic vegetation species were present. The three dominant species were *Elodea* species, horned pondweed, and curly pondweed. Horned pondweed and *Elodea* species were present in 55% and 45% of the sampled plots, respectively; and their cover ranged from 8% to 12% (estimated from mid-point of Braun-Blanquet scores) (Table 2). Curly pondweed, an invasive species, was present in 27% of the plots and had an average cover of 7% (estimated from mid-point of Braun-Blanquet scores). An unknown pondweed (*Potamogeton* species) was observed in one of the plots in the restored turning basin.

Table 2. Species list, average Braun-Blanquet¹ score, and percent of plots species was observed for aquatic vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2008 (post-restoration). Aquatic vegetation was sampled in the river adjacent to 2004 nekton sampling stations.

Common Name	Scientific Name	Average Braun-Blanquet score and percent of plots observed		
		2004 River (n=12)	2008 River (n=15)	2008 Basin (n=11)
Curly pondweed ¹	<i>Potamogeton crispus</i>	0.6 (33%)	-	1.0 (27%)
Green algae	Green algae species	0.7 (17%)	-	-
<i>Elodea</i> species	<i>Elodea</i> species	-	-	1.8 (55%)
Horned pondweed	<i>Zannichella palustris</i>	1.5 (42%)	0.9 (20%)	1.2 (45%)
Water starwort species	<i>Callitriche</i> species	0.3 (17%)	-	-
Unknown pondweed species		-	-	0.2 (9%)

¹ Invasive species as identified by the Massachusetts Invasive Plants Advisory Group (MIPAG) (2005).

² Braun Blanquet cover class scale (0; 1: <1; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%).

“-” Species not present.

Results: Invasive Plant Species

Six invasive and/or introduced plant species were encountered at SAIR during this monitoring program (USDA 2004, MIPAG 2005). All six species were observed in 2004, but only one of these species (*P. crispus*) was observed in 2008 (Table 3). Agius (2003) encountered several additional invasive species during his survey of the park. The restoration of the turning basin and wetland adjacent to the Saugus River has presumably eradicated these species in the restored sections; however, some invasive species likely persist in the remaining areas of the park not influenced by the restoration (e.g., upland forest and manicured landscapes). These plants have spread into native and minimally managed plant systems in Massachusetts. They have the potential to cause economic or environmental harm by developing self-sustaining populations and becoming dominant and/or disruptive to systems where they are established (MIPAG 2005).

Table 3. List of invasive and introduced plants observed during sampling. Status information is from USDA Plants Database and the Massachusetts Invasive Plant Working Group (MIPAG 2005). Note: wetland/marsh vegetation was not monitored in 2008.

Common Name	Scientific Name	Status	Year Observed
Black locust	<i>Robinia pseudoacacia</i>	invasive	2004
Common reed	<i>Phragmites australis</i>	invasive	2004
Curly pondweed	<i>Potamogeton crispus</i>	invasive	2004, 2008
Multiflora rose	<i>Rosa multiflora</i>	introduced, invasive	2004
Purple loosestrife	<i>Lythrum salicaria</i>	introduced, invasive	2004
Reed canary grass	<i>Phalaris arundinacea</i>	invasive	2004

Biological Variables: Nekton Community

Methods: Nekton

The nekton community of the turning basin and the Saugus River were monitored following protocols of the NPS Northeast Coastal and Barrier Network (Raposa and Roman 2001, James-Pirri et al. in review). Nekton will be sampled twice per year – once in mid-summer and once in late summer/early fall – for the years 2008 (late summer only), 2009, 2010, and 2012 on low or ebbing tides. Quantitative data on nekton composition and abundance (density) were collected using a 1-m² throw trap at a minimum of 15 stations randomly located throughout the turning basin-river system. The throw trap is an enclosure sampler that has excellent efficiency and provides quantitative, repeatable results (Kushlan 1981, Sogard and Able 1991, Rozas and Minello 1997). The trap has an open top and bottom, is 0.5-m in height and 1-m square, and the sides are covered with 3-mm (1/8 in) wire mesh. The trap is thrown into water, imbedding it in the bottom sediments, and capturing any nekton within the 1-m² area of the trap. All nekton are collected from the trap with a 1-mm mesh dip net that fits snugly within the trap. The trap is considered empty when three successive attempts with the dip net produce no organisms.

Qualitative samples of nekton were collected using a seine (6-m seine with bag, 3-mm mesh) at a minimum of five random locations throughout the turning basin and river system as ancillary information on the nekton community. Seine hauls were taken in an attempt to catch faster swimming fishes that may not be adequately sampled by the throw trap in order to achieve a more complete species list.

At each station, all fish and decapods were identified and enumerated. A representative number (up to 15 individuals) of each species collected was measured for length (total length for fish and shrimp, carapace width for crabs). Once identified and measured all organisms were returned to the water. Multivariate statistical techniques, including Analysis of Similarities (ANOSIM) will be used to evaluate responses of the nekton community to the restoration actions.

Physical variables (water temperature [°C], salinity [ppt], and dissolved oxygen [mg/L]) were recorded at each nekton sampling station with a YSI unit (model 85) at the time of sampling.

Results: Pre-restoration Nekton

Pre-restoration nekton throw trap sampling occurred on 9 June and 5 August 2004 in the Saugus River. A total of 16 stations were sampled during each day. Seven seine hauls were made on three separate days in 2004 (5 August, 11 August, and 2 September) at two locations in the river. Two hauls (on 11 August) were made in the upper portion of the Saugus River and the other five (on 5 August, 11 August, and 2 September) were made immediately north of the Hamilton Street Bridge (Figure 1).

During the 2004 pre-restoration sampling, 13 species (11 fish and two decapods) were sampled using seine and throw traps (Table 4).

Table 4. Nekton species sampled during pre-restoration monitoring (2004) and post-restoration monitoring (2008) at Saugus Iron Works NHS.

Common Name	Scientific Name	Pre-restoration (2004) River only		Post-restoration (2008) River & Basin	
		Seine	Throw Trap	Seine	Throw Trap
Alewife	<i>Alosa pseudoharengus</i>	X			
American eel	<i>Anguilla rostrata</i>	X	X		X
Bluegill	<i>Lepomis macrochirus</i>			X	X
Brook stickleback	<i>Culaea inconstans</i>	X	X		
Four-spine stickleback	<i>Apeltes quadracus</i>	X	X	X	X
Green crab	<i>Carcinus maenas</i>		X		
Harris mud crab	<i>Rhithropanopeus harrisii</i>	X			
Largemouth bass	<i>Micropterus salmoides</i>	X		X	
Mummichog	<i>Fundulus heteroclitus</i>	X			
Nine-spine stickleback	<i>Pungitius pungitius</i>	X			X
Redfin pickerel	<i>Esox americanus</i>	X			
Three-spine stickleback	<i>Gasterosteus aculeatus</i>		X		
White perch	<i>Morone americana</i>	X		X	
White sucker	<i>Catostomus commersoni</i>	X	X	X	X
Total species caught		11	6	5	5

In June, the throw trap catch was dominated by young-of-the-year white suckers (*Catostomus commersoni*) and four-spine sticklebacks (*Apeltes quadracus*) comprising 77% and 13% of the catch, respectively (Table 5). American eels (*Anguilla rostrata*) and three-spine sticklebacks (*Gasterosteus aculeatus*) were also present and composed 9% and 2% of the catch, respectively. In August, juvenile white suckers and four-spine sticklebacks again dominated the catch with each species comprising 39% of the catch. American eels comprised 15% of the catch and brook sticklebacks (*Culaea inconstans*) and green crabs (*Carcinus maenas*) each comprised 3% of the catch. More individuals were sampled in June, primarily due to the abundance of young-of-the-year white suckers (Table 5). Overall, the dominant species sampled in 2004 were white suckers (Figure 2). The catch also consisted of young-of-the-year or juveniles for most of the species (Figure 3).

A total of 11 species (10 fish and one decapod) were sampled using the seine in 2004 (Table 4 and Table 6). As expected seine hauls captured the faster swimming nekton such

as alewife (*Alosa pseudoharengus*), largemouth bass (*Micropterus salmoides*), and redfin pickerel (*Esox americanus*).

Table 5. Nekton density (number m⁻² ± SD) and total number of individuals captured (in parentheses) from 1m² throw trap sampling at Saugus Iron Works NHS in 2004 (pre- restoration) and 2008 (post-restoration). Sample size is given after date.

Common Name Scientific name	Average Density (Number m ⁻² ± SD [total no. individuals])			
	River June 2004 n = 16	River Aug 2004 n = 16	River Sept 2008 n=15	Turning Basin Sept 2008 n=11
American eel <i>Anguilla rostrata</i>	1.6 ± 2.6 (25)	0.3 ± 1.0 (5)	0.2 ± 0.4 (3)	2.6 ± 3.3 (29)
Brook stickleback <i>Culaea inconstans</i>	0	0.1 ± 0.3 (1)	0	0
Bluegill <i>Lepomis macrochirus</i>	0	0	0	0.9 ± 1.4 (10)
Four-spine stickleback <i>Apeltes quadracus</i>	2.3 ± 4.9 (37)	0.8 ± 1.4 (13)	0.6 ± 1.6 (9)	1.4 ± 1.9 (15)
Green crab <i>Carcinus maenas</i>	0	0.1 ± 0.3 (1)	0	0
Nine-spine stickleback <i>Pungitius pungitius</i>	0	0	0.5 ± 2.1 (8)	0.09 ± 0.3 (1)
Three-spine stickleback <i>Gasterosteus aculeatus</i>	0.4 ± 1.5 (6)	0	0	0
White sucker <i>Catostomus commersoni</i>	13.9 ± 20.9 (223)	0.8 ± 2.5 (13)	0.07 ± 0.3 (1)	0
Total Nekton Density	18.2 ± 26.9 (291)	2.1 ± 3.2 (33)	1.4 ± 3.0 (21)	5.0 ± 3.3 (55)

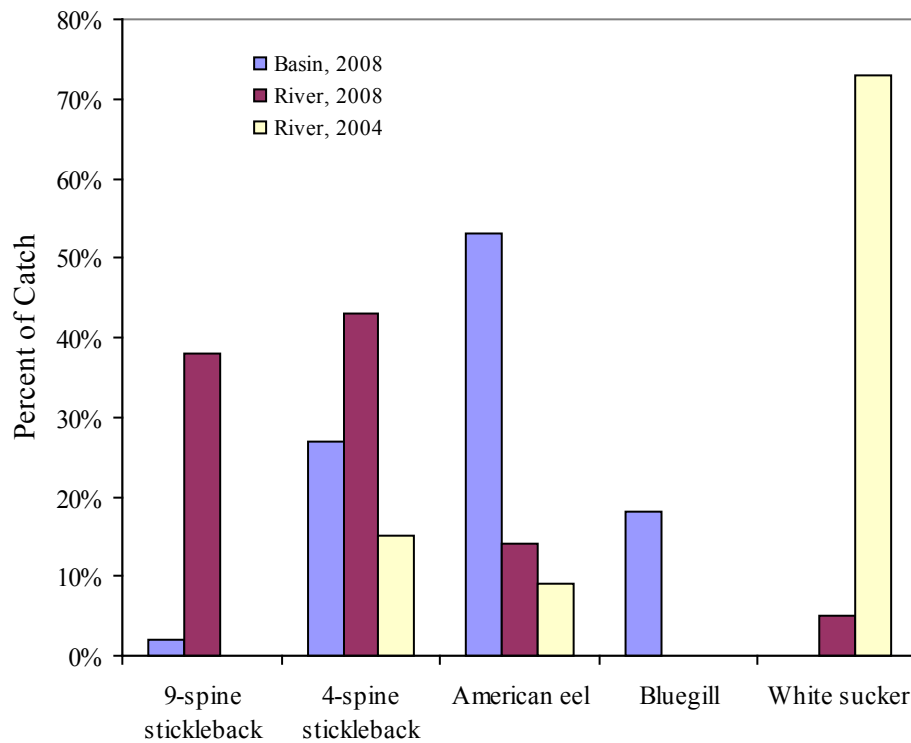


Figure 2. Percent catch of dominant nekton sampled from throw traps at SAIR in 2008 and 2004

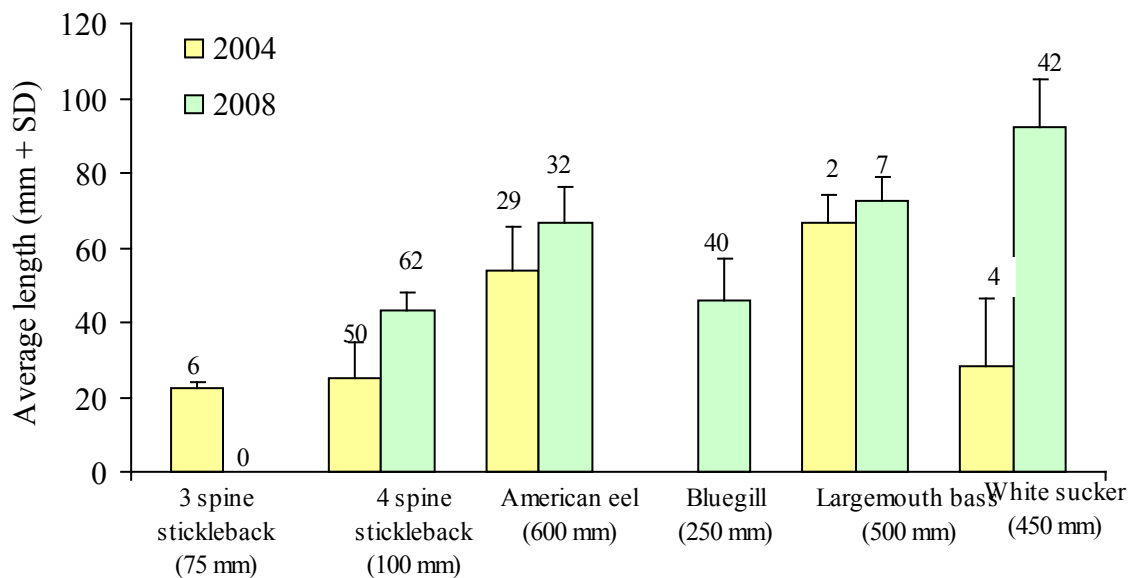


Figure 3. Average length (mm ± SD) of nekton sampled at SAIR with throw traps and seines in 2004 and 2008. Number of individuals measured indicated above bars. Average adult length (mm) is given under each species name for reference. Only species where more than five individuals were sampled (both years combined) are shown.

Table 6. Nekton species composition, average abundance per seine haul, and total number of individuals collected (in parentheses) with a seine at Saugus Iron Works NHS in 2004 (pre-restoration) and 2008 (post-restoration).

Common Name Scientific Name	Average abundance per haul (total catch)			
	2004 Upper portion of river n = 2	2004 Adjacent to Hamilton St. Bridge n=5	River 2008 n=6	Turning Basin 2008 n=3
Alewife <i>Alosa pseudoharengus</i>	2.5 (5)	0.2 (1)	0	0
American eel <i>Anguilla rostrata</i>	0.5 (1)	0 (0)	0	0
Bluegill <i>Lepomis macrochirus</i>	0	0	0.2 (1)	14.0 (42)
Brook stickleback <i>Culaea inconstans</i>	1.5 (3)	15.2 (76)	0	0
Four-spine stickleback <i>Apeltes quadracus</i>	4 (8)	23.4 (117)	2.2 (13)	5.7 (17)
Harris mud crab <i>Rhithropanopeus harrisi</i>	0	0.2 (1)	0	0
Largemouth bass <i>Micropterus salmoides</i>	0	0.8 (4)	0.3 (2)	2.0 (6)
Mummichog <i>Fundulus heteroclitus</i>	0	1.2 (6)	0	0
Nine-spine stickleback <i>Pungitius pungitius</i>	0	0.4 (2)	0	0
Redfin pickerel <i>Esox americanus</i>	0	0.2 (1)	0	0
White perch <i>Morone americana</i>	0	0.6 (3)	0	0.3 (1)
White sucker <i>Catostomus commersoni</i>	1 (2)	168.2 (841)	0	15.7 (47)
Avg. total abundance per haul	9.5 (19)	210.4 (1052)	2.6 (16)	37.7 (113)

Two nonindigenous (non-native) fish species, brook stickleback and largemouth bass, and one exotic crustacean (green crab) were sampled in 2004 (Table 7). Both of the fish species are native to North America but are introduced to Massachusetts (Fuller 2004a, 2004b, USGS 2009). The green crab is a well established exotic species (first recorded observation on the East Coast in 1817) that is abundant in coastal waters from Maine to Maryland (Benson 2004). Introductions have had a negative impact on soft-shell clams, young oysters, and native crabs in the Northeast beginning in the 1950s (Benson 2004).

Results: Post-restoration Nekton

The first post-restoration nekton sampling event occurred on 18 September 2008 (turning basin samples) and 23 September 2008 (river samples). Since construction activities were not completed until late summer, only the late summer nekton sampling was conducted. Twenty-six throw trap stations were sampled (11 stations in the basin, 15 in the river) (Figure 4). Nine seine stations (three in the turning basin and six in the river) were also sampled on these two days.

Table 7. List of exotic and native transplant (native species to the U.S. that have been introduced into areas outside of their original range) nekton species. Status information is from the USGS Nonindigenous Aquatic Species Database.

Scientific Name	Common Name	Status	Year Observed
Bluegill	<i>Lepomis macrochirus</i>	Native transplant	2008
Brook stickleback	<i>Culaea inconstans</i>	Native transplant	2004
Green crab	<i>Carcinus maenas</i>	Exotic	2004
Largemouth bass	<i>Micropterus salmoides</i>	Native transplant	2004, 2008



Figure 4. Location of post-restoration nekton sampling stations at Saugus Iron Works NHS in 2008.

In 2008, seven nekton species were collected using both throw trap and seine in the restored turning basin and the Saugus River (Table 4). Only three of these species, the bluegill (*Lepomis macrochirus*), four-spine stickleback, and white sucker were caught in both the throw trap and the seine.

In the river, four-spine sticklebacks and nine-spine sticklebacks dominated the throw trap samples comprising 43% and 38% of the catch, respectively. American eels comprised 14% of the catch and white suckers comprised the remaining 5% of the catch (Table 5, Figure 3). The seine samples from the river stations were also dominated by four-spine sticklebacks (81% of the catch). Other species sampled with the seine in the river included largemouth bass (13% of the catch) and bluegill (6% of the catch) (Table 6).

Similar to 2004, the majority of fish sampled in 2008 were young-of-the-year or juveniles (Figure 4).

In the newly restored turning basin, American eels (all juveniles, average length 69 mm, Figure 4) dominated the throw trap samples comprising 53% of all species caught. Four-spine sticklebacks comprised 27% of the catch and bluegills comprised 18% of the catch. Nine-spine sticklebacks comprised the remaining 2% of the throw trap catch in the turning basin (Table 5, Figure 3). In the seine samples, white suckers (42% of the catch) and bluegill (37% of the catch) dominated the catch in the turning basin. Four-spine sticklebacks comprised 15% of the catch with largemouth bass (5%) and white perch (1%) making up the remainder of the samples (Table 6). The high incidence of American eels in the throw trap samples in the turning basin is likely due to the ability of the gear to sample the benthic sediment layer where these individuals are located.

In 2008, an additional non-native species, the bluegill, was collected (Table 7). The bluegill is a native transplant and it was not present in the 2004 fish samples. This species was most likely transplanted into Massachusetts waters by intentional stocking programs (USGS 2009).

Water temperature, salinity, and dissolved oxygen collected in conjunction with the nekton sampling events were similar between 2004 and 2008 (Table 8).

Table 8. Environmental data (average $\pm$ SD) associated with nekton throw trap sampling. Sample size is given after location.

Variable	Water Temperature (°C)	Salinity (ppt)	Dissolved oxygen (mg l⁻¹)
June 9, 2004 (n=16) (river)	21.5 $\pm$ 1.4	0.3 $\pm$ 0.04	7.4 $\pm$ 0.5
Aug 5, 2004 (n=16) (river)	19.9 $\pm$ 0.8	0.1 $\pm$ 0.1	7.5 $\pm$ 0.5
Sept 18, 2008 (n=12) (turning basin)	18.4 $\pm$ 0.8	0.5 $\pm$ 0.8	8.3 $\pm$ 1.3
Sept 23, 2008 (n=1) (turning basin)	20.6	0.2	6.5
Sept 23, 2008 (n=21) (river)	14.7 $\pm$ 0.4	0.3 $\pm$ 0.0	9.4 $\pm$ 0.2

Biological Variables: Bird Community

Methods: Bird Community

Bird utilization of the restoration area will be monitored by volunteers following the guidelines of the NPS Northeast Temperate Network (NETN) Breeding Bird Monitoring Protocol (NPS 2007). Birds will be monitored using the variable circular plot point counts at three observation stations (Figure 2). At each station all birds seen or heard will be recorded during 10-minute point counts. In addition, the distance from the observer to each bird will be estimated within distance bands (0-10 m, 11-25 m, 25-50 m, >50 m) so detection probabilities can be estimated. Birds will be surveyed twice annually, with replicates occurring about 7-14 days apart (NPS 2007). Bird observations will be conducted by volunteers and the NPS will coordinate the scheduling of volunteers. Data analyses and interpretation will be conducted by the University of Rhode Island.

Results: Bird Community

Birds were sampled on 11 July 2008. During this sampling event, a total of 21 species were recorded (Table 9). One species, Baltimore oriole (*Icterus galbula*) is listed by Partners in Flight (PIF) as “IA: High Continental Priority, High Regional Responsibility”, indicating that conservation of this species in southern New England is critical to the overall health of the species (Dettmers and Rosenberg 2000).

Table 9. Bird species observed in July 2008.

Common Name	Scientific Name	Number of detections
American Crow	<i>Corvus brachyrhynchos</i>	3
American Robin	<i>Turdus migratorius</i>	2
Baltimore Oriole ¹	<i>Icterus galbula</i>	1
Barn Swallow	<i>Hirundo rustica</i>	2
Belted Kingfisher	<i>Ceryle alcyon</i>	1
Blue Jay	<i>Cyanocitta cristata</i>	2
Common Grackle	<i>Quiscalus quiscula</i>	1
Common Yellowthroat	<i>Geothlypis trichas</i>	1
Downy Woodpecker	<i>Picoides pubescens</i>	2
European Starling	<i>Sturnus vulgaris</i>	2
Gray Catbird	<i>Dumetella carolinensis</i>	2
Herring Gull	<i>Larus argentatus</i>	1
House Sparrow	<i>Passer domesticus</i>	3
Mallard	<i>Anas platyrhynchos</i>	1
Mourning Dove	<i>Zenaida macroura</i>	1
Northern Cardinal	<i>Cardinalis cardinalis</i>	3
Northern Flicker	<i>Colaptes auratus</i>	1
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	1
Rock Dove	<i>Columba livia</i>	1
Song Sparrow	<i>Melospiza melodia</i>	3
Tufted Titmouse	<i>Baeolophus bicolor</i>	1

¹ Partner in Flight “High Continental Priority, High Regional Responsibility” species.

Biological Variables: Mammals and other Wildlife

Methods: Mammals and other Wildlife

Sightings of mammals and other wildlife incidentally observed during the course of monitoring activities will be recorded and sightings from other observers (e.g., park staff, consulting contractor) will be compiled. Beginning in summer 2009 park staff began implementing a systematic wildlife observation program, collecting observations from all tide conditions, times of day, and locations in and adjacent to the project area.

Results: Mammals and other Wildlife

In 2004, a large snapping turtle (*Macrochelys temminckii*) was seen during nekton sampling in the upper portion of the river in the area where the restored turning basin and river intersect (James-Pirri personal observation).

Physical Variables and Others (Monitored by CH2MHill)

CH2MHill conducted and analyzed parameters associated with tidal hydrology, river geomorphology, sediment and water quality, and benthic invertebrate community in 2008 (post-restoration). The following is a brief summary of the analyses that were excerpted from the draft 2008 Monitoring Data Report prepared by CH2MHill in February 2009. No new analyses are presented. This summary is not meant to replace the CH2MHill Data Report, but is presented with the intent of providing an integrated post-restoration monitoring summary. The CH2MHill Data Report (CH2MHill 2009) should be referred to if more detail is desired.

Methods: Tidal Hydrology

The tidal hydrology was monitored using two remote water quality meters (YSI, model 6600V2 data sonde) in the Saugus River deployed between 7 October 2008 and 18 November 2008 (Figure 5). The instrument recorded data (water level, specific conductance/salinity, dissolved oxygen, temperature, pH, and turbidity) at 15-minute intervals.

Results: Tidal Hydrology-water surface elevation

The water surface elevation of the turning basin fluctuated between approximately 1.5 ft and 4 ft between high and low tides over the monitoring period with the trend following the lunar cycles of high and low tide (Figure 6). This pattern was somewhat confounded by increased river discharge during lower magnitude tide events. USGS stream gage data from the Saugus River show a pulse in discharge that coincided with two large rainfall events, one on 25 and 26 October and one on 6 November, which resulted in considerable increases in river discharge levels on these dates.

The water surface elevation for the downstream data sonde (Hamilton Street) showed a diurnal fluctuation that ranged from approximately 2.5 to 8 ft between high and low tides during the monitoring period (Figure 7). The expected pattern of the tidal lunar cycle was confounded by the two large rainfall events that increased river discharge levels.

The average water surface elevation at the upstream location (turning basin) over the course of the monitoring period was approximately 3.0 ft, compared to an average of 1.4 ft at the downstream (Hamilton Street) location.

Results: Tidal Hydrology-salinity

There was little salt water intrusion into the turning basin during the first week of sampling (early October 2008); however, by mid to late October, high tide events brought higher salinity values into the area, indicating that saltwater intrusion was occurring as far upstream as the turning basin (Figure 6). This upstream movement of saltwater appears to be influenced heavily by stream flow because salinity values were low during periods of high stream flow. In general, the data suggests that if stream flow is higher than approximately 10 cfs, limited amounts of saltwater will reach the turning basin area, and if stream flow is less than approximately 10 cfs, saltwater will move upstream to the turning basin, except during neap tides.



Figure 2-1
Location Map
 Saugus Iron Works NHS
CH2MHILL

Figure 5. Location of water quality monitoring instruments in 2008 (figure excerpted from CH2MHill 2009).

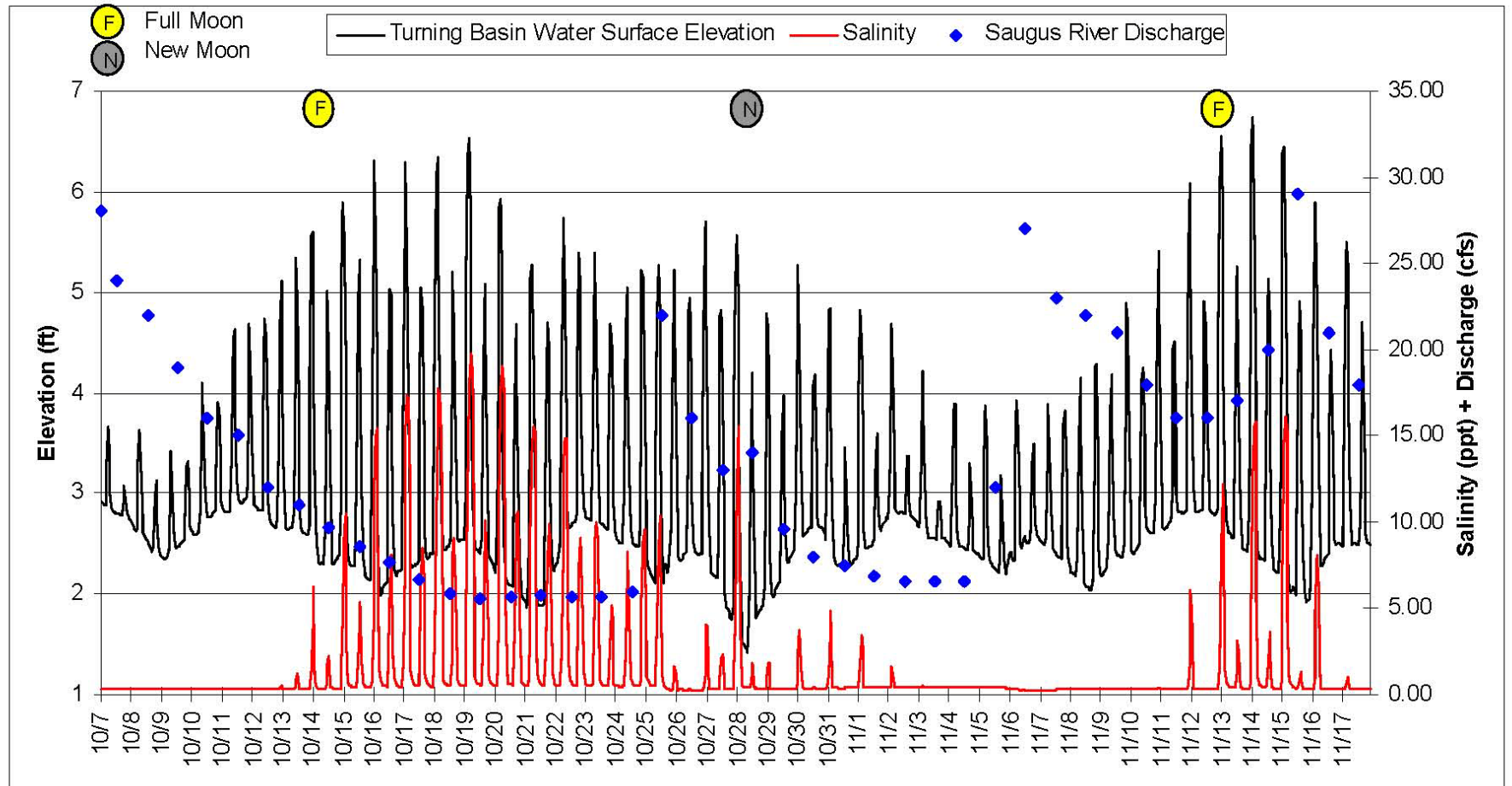


Figure 6. Water surface elevation and salinity at the turning basin in 2008 (figure excerpted from CH2MHill 2009).

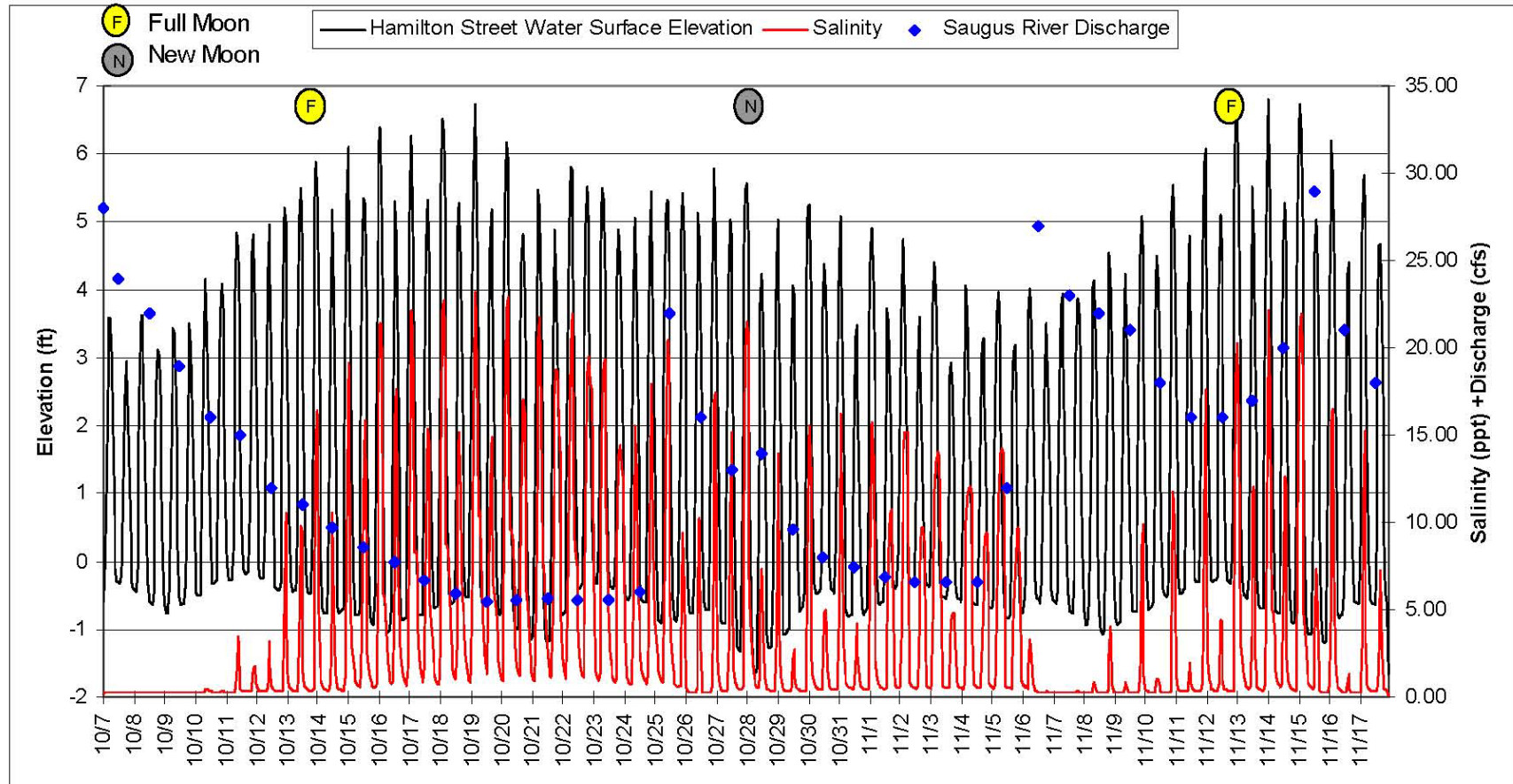


Figure 7. Water surface elevation and salinity at Hamilton Street in 2008 (figure excerpted from CH2MHill 2009).

In general, the salinity values for the downstream (Hamilton Street) location were noticeably higher for a given tide event than those at the upstream location. Similar to the upstream location, it appears that saltwater reaches Hamilton Street during low flow periods, even on neap tides, if the river discharge level remains below about 15 cfs (Figure 7).

Methods: River Geomorphology and Sediment Composition

A section of the Saugus River immediately downstream of Bridge Street contains valuable smelt spawning habitat. Monitoring changes in river channel geomorphology are important because river flow and bed composition can influence rainbow smelt spawning. Cross-sectional dimensions and substrate composition (i.e., gravel, sand, and silt/clay composition) of the river channel were collected at five transects across the river.

Pebble counts were conducted for three of the five transects: Transect A, Transect C, and Transect 7 (Figure 8, Figure 9). Pebble counts were not conducted for Transect F and Transect 23 because the substrate along these transects was uniformly sand. A total of 50 randomly selected particles were measured along each transect. The particles were selected by taking one step along the transect and reaching down and picking up the first particle touched. Particles were measured along the intermediate axis, not the longest or the shortest side for each particle.

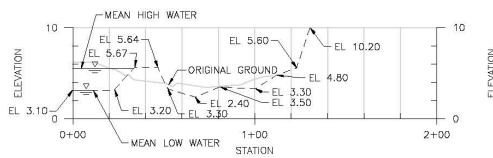
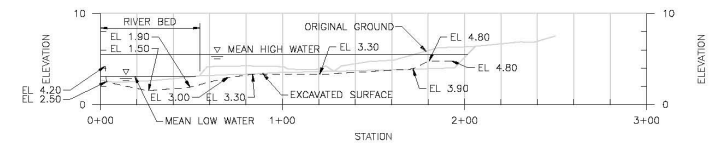
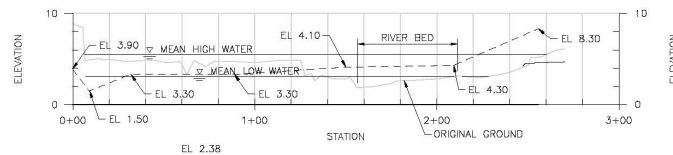
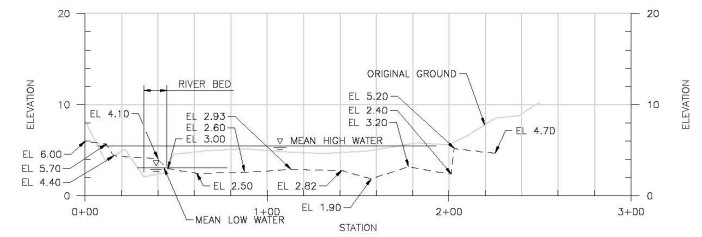
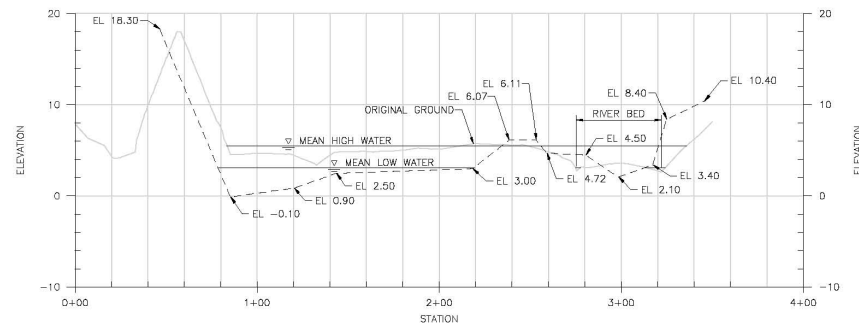
Results: River Geomorphology and Sediment Composition

The elevation changes observed within the river channel portions of the cross-sections demonstrate the dynamic nature of the river, as some of the bedload sediment shows redistribution between the 2004 and 2008 surveys (Figure 8). Cross-sections A and C show how the gravel bar just downstream of Bridge Street has migrated and built up on the west side of the channel as a result of high stream flows, likely related to the extreme flows that occurred in May 2006. The discharge reached a record level for the Saugus River of 1,420 cfs, a level that is estimated to occur once every 40 years (USGS 2006). Cross-sections F and 7 show a build up of bedload material in the river channel, while Cross-section 23 shows evidence of scouring as the elevation decreased within the channel at this location. These changes are likely related to the extreme flows in May 2006, but also demonstrate the dynamic nature of rivers, where the movement and redistribution of bedload is a natural occurrence.

Medium to coarse gravel dominated the substrate compositions at Transect A and Transect C. In contrast, the substrate along Transect 7 was characterized by finer grained substrate, dominated by sand and fine gravel (Table 10).

Methods: Sediment Analyses and Water Quality

Six sediment samples were collected from 0 to 6 inches below the sediment surface to monitor post-restoration sediment quality. Five of the samples were collected at the transition point from the subtidal to intertidal zones along the five cross-sections selected for monitoring.



NOTES:

1. BOTTOM OF EXCAVATION APPROXIMATES 1954 CONTOURS. DO NOT EXCAVATE BELOW LIMITS SHOWN. SEE C6 FOR EXCAVATED CONTOURS.
2. MEAN HIGH WATER AND MEAN LOW WATER ELEVATIONS ARE BASED ON DATA MONITORING BETWEEN MAY 28, 2004 AND JULY 23, 2004.
 - MEAN HIGH WATER ELEVATION = 5.5 FEET
 - MEAN LOW WATER ELEVATION = 3.1 FEET
3. FOR VERTICAL DATUM, SEE C-3.



FIGURE 3-1
SAUGUS RIVER CROSS SECTIONS
SAUGUS IRON WORKS
SAUGUS, MASSACHUSETTS

CH2MHILL

Figure 8. Cross-sections of river channel (figure excerpted from CH2MHill 2009).



Figure 5-1
Benthic Invertebrate Sample Locations
Saugus Iron Works NHS
Saugus, Massachusetts

CH2MHILL

Figure 9. Pebble count and benthic invertebrate sampling stations in 2008 (figure adapted from CH2MHill 2009).

Table 10. Pebble count size distribution (table excerpted from CH2MHill 2009).

Size Range (mm)	Number of Particles		
	Transect A	Transect C	Transect 7
<2mm: Sand	6	6	26
2 to 4mm: Very fine gravel	2	1	7
4 to 8mm: Fine gravel	6	2	15
8 to 16mm, Medium gravel	14	5	2
16 to 32mm, Coarse gravel	16	18	0
32 to 64mm, Very coarse gravel	5	17	0
64 to 90mm, Small cobble	0	1	0
90 to 128mm, Medium cobble	1	0	0

Results: Sediment Analyses and Water Quality

Chromium, copper, lead, nickel, and zinc were detected in all the sediment samples. Arsenic was detected in only three of the samples and was not detected in sample SD-07R, where it was previously found at the highest concentration. Antimony, beryllium, selenium, silver, and thallium were not detected in any of the samples. Polycyclic Aromatic Hydrocarbons (PAHs) were not detected in three of the samples (S-23, S-C, and S-F). Only one PAH compound (pyrene) was detected in sample SD-07R at a concentration of 221 ug/kg. Only two PAH compounds (fluranthene and pyrene) were detected in sample S-A at concentrations of 204 and 207 ug/kg, respectively. Only one sample (S-7) contained several PAH compounds. The average concentrations of all the detected metals in the 2008 samples were consistently lower than in the pre-restoration samples (Table 11). Therefore, the sediment quality seems to have improved substantially as a result of the restoration efforts.

One surface water sample was collected from the river channel and analyzed for priority pollutant metals in 2008. The only metal detected in the surface water sample was zinc at a concentration of 0.0271 mg/L, which is below the criteria for the protection of aquatic life for this metal. No other metals were detected above the reporting limits.

Methods: Benthic Invertebrate Community

The benthic community was surveyed by collecting benthic community samples on 24 September 2008 from six stations within the study area (Figure 9). Samples were collected from three cross-sections within the project area. Two samples were collected from each cross-section, one within the river channel or subtidal habitat and one from the transition zone from subtidal to intertidal habitat. The samples were collected using an Eckman dredge with a sampling surface area of 81 in² (9 in x 9 in). Three replicate grabs were collected at each sampling station and sieved (500-µm mesh) in the field. Care was taken to replicate the sampling depth for each grab as much as possible (i.e., 3-4 in sample depth). The benthic samples were preserved with a 5-10% formalin solution. The preserved samples were shipped to Pennington & Associates, Cookeville, Tennessee for identification (identified to the lowest practical taxonomic level) and enumeration.

Results: Benthic Invertebrate Community

Chironomids (order Diptera), commonly known as midges, were the most abundant organism in the 2008 benthic samples comprising 45% of the total number of organisms collected (Table 12). The second most abundant organisms were oligochaetes (majority

of individuals from the family Tubificidae), which comprised 41% of the organisms collected. The third most abundant organisms were amphipods (*Gammarus tigrinus*), which comprised 9% of the total number of organisms. Fourth in abundance were gastropods, or snails, which comprised about 3% of the total number of organisms collected. Eight other groups of organisms were found, but together comprised less than 1% of the total number of organisms.

Table 11. Comparison of pre- and post-restoration average concentrations of detected metals. One-half of reporting limit used for non-detected samples in calculating the average concentration (table excerpted from CH2MHill 2009; units were not provided in the report).

Detected Metal	Average Concentration (mg/kg)			
	2004 Northern Area	2004 Southern Area	2004 Average	2008 Average
Arsenic	14.9	13.9	14.3	2.36
Cadmium	1.45	1.53	1.5	0.589
Chromium	57.3	69.5	63.5	18.7
Copper	60.0	61.8	61.0	13.9
Lead	171.4	162.4	164.7	30.1
Mercury	0.291	0.139	0.316	0.057
Nickel	46.7	44.7	45.8	19.9
Zinc	261.4	266.7	263.7	68.7

Table 12. Benthic invertebrate species abundance from 2008 sampling (table excerpted from CH2MHill 2009).

Class or Order	Family	Average number (individuals m ⁻²)	Percent of total
Diptera	Chironomidae	5,087	45.06
Oligochaeta	Tubificida, Lumbriculida	4,671	41.37
Amphipoda	Gammaridae	1,064	9.43
Gastropoda	Mesogastropoda, Basommatophora	387	3.43
Bivalvia	Unionoida, Veneroida	23	0.21
Ostracoda	Not Identified	20	0.18
Polychaeta	Nereidae, Spionidae	10	0.08
Coleoptera	Elmidae	10	0.08
Isopoda	Anthuridae	9	0.08
Turbellaria	Tricladida	3	0.03
Hirudinea	Not Identified	3	0.03
Trichoptera	Leptoceridae	3	0.03

Station F-1, a sand-dominated, subtidal location, contained the greatest abundance of organisms of all the stations. Station 7-1, a sand and gravel, subtidal location, contained the greatest number of taxa and highest Shannon-Weiner Diversity index, although it had a relatively low abundance of organisms (Table 13). There were no distinct differences in these measures between the subtidal and intertidal locations, although generally the intertidal locations tended to have a higher abundance of organisms.

The intertidal samples were generally dominated by chironomids (i.e., Diptera) (approximately 49% to 68%) in contrast to the subtidal samples where these organisms

comprised only about 16% to 31% of the organisms present (Table 14). The subtidal samples collected in the uniform sand substrate habitats (samples F-1 and 23-1) were dominated by oligochaete worms, which comprised 63% to 73% of the organisms in the samples. The subtidal samples collected in the sand and gravel area (sample 7-1) was the only sample where gastropods dominated the community, with 59% of the organisms in the sample. This sample also contained the highest diversity and this is likely related to the more diverse habitat than that of the uniform sand substrate stations. The differences in the benthic community composition within the various habitats are likely related to differences in substrate preference among species, although the dominance of oligochaetes, primarily tubificid worms, in two of the subtidal stations, may be an indicator of degraded habitat. Dominance of tubificid worms can be an indication of an organically enriched or polluted environment because oligochaete worms of the family Tubificidae are generally classified as a contaminant-tolerant indicator species.

Table 13. Average number of benthic invertebrates, average number of taxa, and diversity index at each of the sample stations from 2008 sampling (table excerpted from CH2MHill 2009).

Sample Location	Average number (individuals m ⁻²)	Average number of Taxa	Shannon-Weiner Index of Diversity
7-1 (subtidal)	3,419	14	2.137
7-2 (intertidal)	18,122	9	1.959
F-1 (subtidal)	18,855	8	1.422
F-2 (intertidal)	10,378	9	1.565
23-1 (subtidal)	2,673	9	1.929
23-2 (intertidal)	14,294	8	1.604

Table 14. Benthic invertebrate community at each of the sample stations for 2004 and 2008 (data excerpted from CH2MHill 2009). Comparisons with 2004 samples are only for the five dominant taxa (n/a notation).

Class or Order	Percent by Number of Organisms						2004 samples	
	2008 samples							
	7-1 subtidal	7-2 intertidal	F-1 subtidal	F-2 intertidal	23-1 subtidal	23-2 intertidal	Sand-1	Sand -2
Diptera	16.4	48.9	25.0	67.7	31.0	59.7	1.5	1.2
Oligochaeta	6.3	44.8	72.8	30.6	63.0	7.7	14.7	8.8
Amphipoda	14.4	5.0	1.6	1.5	2.1	31.3	81.9	86.6
Gastropoda	58.6	0.8	0.4	0.1	1.0	0.4	0.2	0.4
Bivalvia	1.5	0.3	0.2	-	0.2	-	-	0.7
Ostracoda	-	-	-	-	0.5	0.8	n/a	n/a
Polychaeta	0.4	-	-	-	1.0	0.1	n/a	n/a
Coleoptera	0.7	0.2	-	-	-	-	n/a	n/a
Isopoda	-	-	-	0.2	1.2	-	n/a	n/a
Turbellaria	0.6	-	-	-	-	-	n/a	n/a
Hirudinea	0.6	-	-	-	-	-	n/a	n/a
Trichoptera	0.6	-	-	-	-	-	n/a	n/a

The benthic data from this survey were compared with the pre-restoration benthic data to determine if and how the composition of the benthic community might have changed. This comparison revealed that there may have been a shift in the benthic community structure within the sand substrate habitat since the restoration project was completed.

The dominant organisms found in the sand substrate samples in 2004 were amphipods, which comprised more than 80% of the organisms in the samples (Table 14). In contrast, amphipods were third in numerical dominance in the 2008 samples, and comprised only 1.5% to 31.3% of the samples. The dominance of diptera in the 2008 samples is contrasted sharply by low abundance of these organisms in the 2004 samples (less than 2% of the total organisms). A similar increase in the abundance of oligochaete worms was observed. Oligochaete worms comprised only about 9% to 15% of the organisms in the 2004 samples, but in contrast, comprised approximately 6% to 73% of the organisms in the 2008 samples.

The apparent shift in the benthic community may be related to seasonal differences in benthic invertebrate abundance because the 2004 samples were collected in July and the 2008 samples were collected in late September. However, the changes in the dominant species within the community might also be related to the disturbance created from the restoration project. The changes may represent a community in transition that has not yet returned to baseline conditions. Future monitoring efforts will provide data to determine whether this change is temporary or related to long-term water quality issues in the Saugus River.

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