



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

2009 Post-Restoration Monitoring Data Report

Natural Resource Data Series NPS/NER/SAIR/NRDS—2010/093



ON THE COVER

Restored turning basin at Saugus Iron Works NHS, October 2009.

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

In 2007, the National Park Service initiated a restoration program at Saugus Iron Works National Historic Site to restore the historic turning basin and wetland area adjacent to the Saugus River. To fulfill regulatory requirements and enhance understanding of tidal 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 two years (2008 and 2009) after restoration. Data summaries included in this report describe the status of biotic (e.g., vegetation, nekton, benthic invertebrate, and bird communities) and abiotic parameters (e.g., tidal hydrology, river geomorphology, sediment, and water quality). Statistical analyses for variables with more than one year of post-monitoring data are provided; however, given the short time-frame of post-restoration monitoring the results from these analyses should be viewed with caution. The monitoring program is intended to continue for five years post-restoration and perhaps longer. This is the second of several data reports associated with the restoration of the turning basin and wetlands at Saugus Iron Works National Historic Site.

Introduction

Saugus Iron Works National Historic Site (SAIR), located approximately 16 km north of Boston on the upper reaches of the Saugus River estuary, preserves the site of the first sustained iron works of North America. The iron works was in operation from 1646 to 1668 and was critical in the development of America's iron manufacturing legacy (NPS 2006). Raw materials were delivered to the iron work'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 at Prankers Pond caused extensive sedimentation and siltation of the historic turning basin, waterfront, and wharf area of the iron works (NPS 2006). Over time the silted turning basin was colonized by invasive plants and the southern wetland lining the Saugus River became choked with undesirable vegetation such as common reed (*Phragmites australis*) 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 project was initiated to restore the turning basin and remove much of the invasive vegetation from the wetland bordering the river (Figure 1). The goals of the restoration included excavating sediment in the turning basin to restore the open water condition, removing invasive exotic plants, improving water quality, replacing the wharf and bulkhead, and restoring the river to a more suitable habitat for aquatic and terrestrial organisms (CH2MHill 2005). Phase I of the project restored the open water area of the turning basin while Phase II removed invasive vegetation and restored the native freshwater wetland along the river. 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 National Park Service (NPS), in collaboration with university researchers and CH2MHill, are studying the restoration area for five years (2008 to 2012), with some monitoring to continue for the long-term. Research and monitoring follow protocols developed and utilized by the NPS Northeast Coastal and Barrier Network, NPS Northeast Temperate Network, and the environmental firm CH2MHill (2005). The monitoring program is conducted cooperatively by CH2MHill, NPS staff, and the University of Rhode Island.

This report summarizes the initial two years of post-restoration (2008 and 2009) monitoring for a wide variety of biological and physical parameters. This summary report includes data collected by the University of Rhode Island, CH2MHill, and the Northeast Temperate Network (NETN) of the NPS. Information on physical variables (tidal hydrology, river geomorphology, sediment and water quality) and benthic invertebrate community collected by CH2MHill in 2008 has been excerpted from the 2008 Monitoring Data Report submitted to the National Park Service by CH2MHill (CH2MHill 2009).

Information from the 2004 monitoring report of salt marsh 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

salt marsh vegetation and nekton. Also included in this report are data from the Massachusetts Division of Marine Fisheries annual smelt and eel sampling on the Saugus River.

The SAIR Turning Basin, Before and After Phase I Restoration

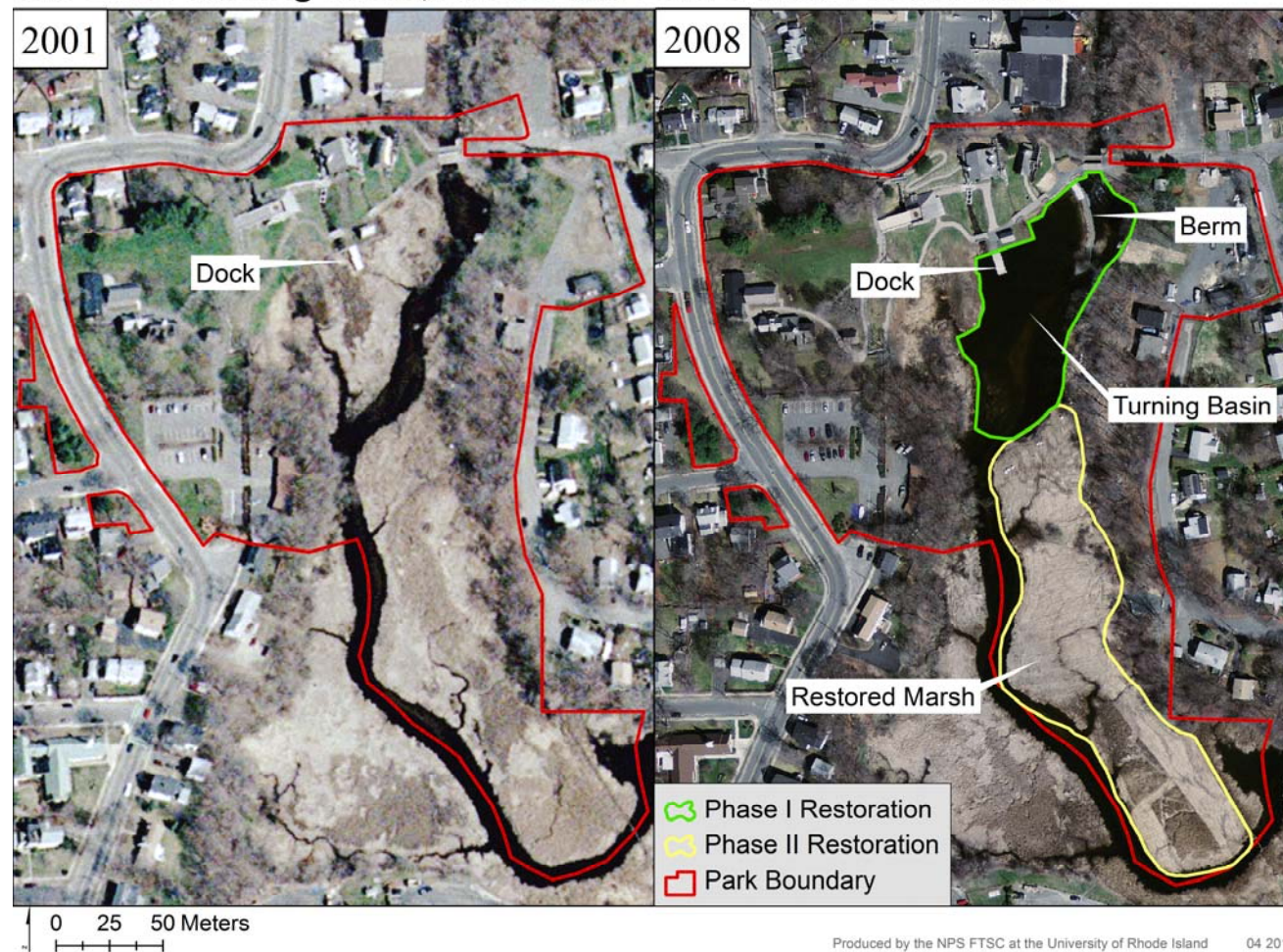


Figure 1. Pre-restoration (left image) and post-restoration (right image) aerial photographs of Saugus Ironworks NHS.

Biological Variables: Marsh and Aquatic Vegetation

Methods: Native Vegetation Planting

Following the excavation and removal of the *Phragmites*-dominated area along the Saugus River, the newly created wetland was planted with native freshwater wetland vegetation in October 2008. Native species were planted in three zones (low marsh, high marsh, streamside riparian buffer) according to elevation and location within the project area. More than 15,000 plants from four species were planted in the 0.54-ha low marsh zone and 165 plants from 12 species were planted in the 0.07-ha high marsh zone (Table 1) (NPS 2005). The low marsh planting also included distribution of cotton mesh bags containing gravel and a pinch of wild rice seeds (*Zizania aquatica*), which is difficult to grow from transplants due to its weak, floating stems. A streamside riparian buffer zone was established on the constructed gravel/cobble berm that separates the river channel from the turning basin. This 0.01-ha area was planted with 51 shrubs from four species, along with 350 sedge (*Carex* species) plants (Table 2) (NPS 2005).

Results: Native Vegetation Planting

Planting was conducted very late in the growing season (October 2008) due to project sequencing, and was largely unsuccessful. Qualitative monitoring to determine planting success was conducted by New England Environmental, Inc., along with NPS staff, on 28 July 2009 (New England Environmental 2009). It was determined that in the low marsh zone only a single patch of one planted species (hardstem bulrush, *Schoenoplectus acutus*) was evident. A few scattered individuals of green arrow arum (*Peltandra virginica*) and deep water duck potato (*Sagittaria rigida*) were found; no wild rice seedlings were observed (Table 1). In the high marsh, planting was more successful, with seven of the 12 species observed (Table 1), although total survivorship was well below 50%. On the streamside riparian buffer berm, 38 of 51 planted shrubs survived; however, only a few of the 350 planted sedges were observed (Table 2). Heavy rains and high water in March 2010 washed out many of the planted shrubs in the streamside riparian buffer that were observed in 2009, and only 15-20 plants were present on the berm as of May 2010.

Two planted high marsh species not observed during the July 2009 site visit by New England Environmental, Inc. (2009) were observed during September 2009 vegetation monitoring by the University of Rhode Island (Table 1). Crimsoneyed rosemallow (*Hibiscus moscheutos*) was observed in three of the vegetation plots. This plant was found in plots located along the upland border of the restored marsh and may have been wild plants as opposed to individuals that were planted. Pickerelweed (*Pontederia cordata*) seedlings were observed in nine plots throughout the newly restored wetland area.

A second round of planting, including replacement of failed plantings, from species in all planting zones will be conducted in early June 2010.

Methods: Marsh and Aquatic Vegetation

Quantitative vegetation monitoring of the restoration area (turning basin and southern salt marsh area) was conducted following protocols of the NPS Northeast Coastal and Barrier Network (Roman et al. 2001, James-Pirri and Roman in review). According to the protocol, vegetation, including intertidal freshwater marsh and submerged aquatic vegetation, is sampled once per

year at the end of the growing season in late summer/early fall. Vegetation was sampled in a minimum of 30, 1-m² plots that were randomly located throughout the restoration area (James-Pirri et al. 2007). Species composition and species cover/abundance were recorded for each 1-m² plot. Estimates of percent cover were 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 in the plot. Cover was estimated using 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 were analyzed as ordinal data. Multivariate statistical techniques, including Analysis of Similarities (ANOSIM, PRIMER version 6, Clarke and Gorley 2006) were used to evaluate responses of the vegetation community to the restoration actions. ANOSIM is a non-parametric multivariate permutation analysis and was used to compare vegetation community composition and abundance among years.

Submerged aquatic vegetation cover in the river was estimated during nekton throw trap sampling. Percent cover of aquatic vegetation was estimated using the Braun-Blanquet (1965) visual cover scale method in 1-m² plots randomly located throughout the river and in the restored turning basin.

Pre-restoration vegetation monitoring of the silted turning basin and wetlands was conducted on 13 July 2004 as part of the NPS Inventory and Monitoring Program. Thirty (30) vegetation plots were randomly located along seven transects. Four transects (16 plots) were randomly placed in the former turning basin with the remaining three transects (14 plots) placed in the southern wetland adjacent to the Saugus River (Figure 2). For ease of comparison with future vegetation data, the data from the former turning basin area and southern wetland are presented separately (Table 1).

The first year of post-restoration vegetation monitoring occurred in the fall of 2009 in both the newly restored and planted wetland adjacent to the Saugus River (11 September 2009, 53 plots sampled) and in two small natural wetland areas (13 October 2009, 17 plots sampled) that were not part of the restored wetland (Figure 3). Vegetation monitoring did not occur in 2008 as the planting of vegetation on the restored marsh was not completed until October 2008, and sampling would have negatively affected the newly planted vegetation.

Pre-restoration aquatic vegetation sampling was conducted on 12 July 2004 in the river (12 plots sampled) (Figure 2). Post-restoration monitoring of aquatic vegetation was conducted on 18 and 23 September 2008 with samples from the river (15 plots) and the restored turning basin (11 plots) (Figure 4), and on 15 July 2009 and 14 and 15 September 2009 (27 plots in the river and 21 plots in the turning basin) (Figure 3).

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores¹) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2009 (post-restoration). Also indicated are the planted native species and planting zone², for species planted in the created wetland in 2008, and presence³ in August 2009 during site visit by New England Environmental, Inc.

Scientific Name	Common Name	Zone ² (if planted) and presence (V, +, or -)	Average Braun-Blanquet score (percent of total cover)			
			2004		2009	
			Turning Basin (n=16 plots)	Southern marsh (n=14 plots)	Natural marsh (n=17 plots)	Planted marsh (n=53 plots)
<i>Acer negundo</i>	Boxelder	- ⁷	-	-	0.1 (0.7%)	-
<i>Acorus americanus</i>	Sweet flag	HM (+)	-	-	0.1 (0.7%)	<0.1 (0.3%)
<i>Apios americana</i>	Groundnut	-	-	-	0.4 (2.1%)	-
<i>Aster lanceolatus</i> var. <i>lanceolatus</i>	White panicle aster	-	-	-	0.1 (0.7%)	-
<i>Aster novi-belgii</i>	New York aster	-	-	-	0.2 (1.4%)	-
<i>Aster</i> species	Aster species	-	-	-	0.2 (1.4%)	<0.1 (0.2%)
<i>Bidens frondosa</i>	Devil's beggartick	-	-	-	0.5 (2.8%)	-
<i>Bidens tripartita</i>	Estuary beggarticks	-	0.1 (0.9%)	-	-	-
<i>Calamagrostis canadensis</i>	Bluejoint reedgrass	-	0.1 (0.9%)	-	-	-
<i>Callitriche</i> species ³	Water starwort species	(V)	0.1 (0.5%)	-	-	0.9 (7.6%)
<i>Calystegia sepium</i>	Hedge bindweed	-	1.3 (9.0%)	0.4 (4.6%)	0.1 (0.7%)	-
<i>Carex</i> species	<i>Carex</i> species	-	-	-	-	<0.1 (0.3%)
<i>Echinochloa muricata</i>	Rough barnyardgrass	-	-	-	0.1 (0.3%)	-
<i>Eleocharis acicularis</i>	Needle spikerush	-	-	-	-	0.1 (1.0%)
<i>Eleocharis</i> species	<i>Eleocharis</i> species	-	-	-	-	<0.1 (0.5%)
<i>Epilobium coloratum</i>	Purpleleaf willowherb	(V)	-	-	-	-
<i>Eupatorium maculatum</i>	Spotted joeypyeweed	-	-	-	0.2 (1.0%)	-
<i>Eupatorium perfoliatum</i>	Common boneset	-	0.4 (3.2%)	-	-	-

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores¹) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2009 (post-restoration). Also indicated are the planted native species and planting zone², for species planted in the created wetland in 2008, and presence³ in August 2009 during site visit by New England Environmental, Inc. (continued).

Scientific Name	Common Name	Zone ² (if planted) and presence (V, +, or -)	Average Braun-Blanquet score (percent of total cover)			
			2004		2009	
			Turning Basin (n=16 plots)	Southern marsh (n=14 plots)	Natural marsh (n=17 plots)	Planted marsh (n=53 plots)
<i>Eupatorium purpureum</i>	Sweetscented joeypyeweed	-	0.3 (1.8%)	-	-	-
<i>Geum canadense</i>	White flowered avens	(V)	-	-	-	-
<i>Geum macrophyllum</i>	Largeleaf avens	-	-	-	0.1 (0.7%)	-
<i>Hibiscus moscheutos</i>	Crimsoneyed rosemallow	HM (-)	-	-	-	<0.1 (0.9%)
<i>Impatiens capensis</i>	Jewelweed	-	1.3 (9.0%)	0.1 (1.5%)	-	-
<i>Iris versicolor</i>	Blue flag	HM (+)	-	-	-	-
<i>Juncus effusus</i> ⁴	Comon rush	HM (+)	0.2 (1.4%)	-	-	-
<i>Juncus</i> species	<i>Juncus</i> species	-	-	-	-	0.2 (1.7%)
<i>Leersia oryzoides</i>	Rice cut grass	(V)	-	-	-	-
<i>Lycopus europaeus</i> ⁵	Gypsywort	-	-	-	0.5 (3.1%)	-
<i>Lythrum salicaria</i> ⁵	Purple loosestrife	(V)	0.6 (4.1%)	0.8 (8.3%)	1.1 (6.6%)	<0.1 (0.6%)
<i>Mikania scandens</i>	Climbing hempvine	-	0.5 (3.6%)	0.1 (1.5%)	0.6 (3.5%)	-
<i>Nasturtium officinale</i> ⁵	Watercress	-	-	-	0.2 (1.4%)	-
<i>Oenothera biennis</i>	Common evening primrose	-	-	-	0.4 (2.1%)	-
<i>Oxalis stricta</i>	Common yellow oxalis	-	-	-	0.4 (2.4%)	-
<i>Panicum flexile</i>	Wiry panicgrass	-	-	-	0.1 (0.7%)	-
<i>Panicum virgatum</i> ,	Switchgrass	HM (-)	-	-	-	-
<i>Peltandra virginica</i>	Green arrow arum	LM (+)	1.1 (8.1%)	0.6 (6.8%)	1.2 (6.9%)	<0.1 (0.3%)
<i>Phalaris arundinacea</i> ^{5, 6}	Reed canary grass	-	0.4 (3.2%)	0.3 (3.0%)	0.1 (0.7%)	-

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores¹) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2009 (post-restoration). Also indicated are the planted native species and planting zone², for species planted in the created wetland in 2008, and presence³ in August 2009 during site visit by New England Environmental, Inc. (continued).

Scientific Name	Common Name	Zone ² (if planted) and presence (V, +, or -)	Average Braun-Blanquet score (percent of total cover)			
			2004		2009	
			Turning Basin (n=16 plots)	Southern marsh (n=14 plots)	Natural marsh (n=17 plots)	Planted marsh (n=53 plots)
<i>Phragmites australis</i> ⁵	Common reed	(V)	0.2 (1.4%)	4.1 (43.6%)	-	-
<i>Phytolacca americana</i>	Pokeweed	-	-	-	0.2 (1.4%)	-
<i>Pluchea odorata</i> var. <i>succulenta</i>	Saltmarsh fleabane	(V)	-	-	-	-
Poaceae species	Unknown grass (Poaceae)	-	-	-	0.1 (0.7%)	-
<i>Polygonum hydropiper</i>	Marshpepper knotweed	-	-	-	0.3 (1.7%)	-
<i>Polygonum hydropiperoides</i>	Swamp smartweed	-	-	-	-	<0.1 (0.8%)
∞ <i>Polygonum persicaria</i>	Spotted ladythumb	-	-	-	0.4 (2.4%)	-
<i>Polygonum punctatum</i>	Dotted smartweed	-	0.1 (0.9%)	0.1 (1.5%)	-	-
<i>Polygonum pennsylvanicum</i>	Pennsylvania smartweed	-	-	-	0.2 (1.4%)	-
<i>Polygonum</i> species	<i>Polygonum</i> species	(V)	0.3 (2.3%)	0.1 (1.5%)	-	-
<i>Pontederia cordata</i>	Pickernelweed	HM (-)	0.3 (1.8%)	0.1 (1.5%)	-	0.3 (2.1%)
<i>Potamogeton crispus</i> ⁵	Curly pondweed	-	-	-	-	<0.1 (0.6%)
<i>Ranunculus sceleratus</i>	Cursed buttercup	(V)	-	-	-	-
<i>Robinia pseudoacacia</i> ⁵	Black locust	-	0.3 (2.3%)	-	-	-
<i>Rorippa palustris</i> var. <i>hispida</i>	Hispid yellowcress	(V)	-	-	0.1 (0.7%)	-
<i>Rosa multiflora</i> ⁵	Multiflora rose	-	1.0 (7.2%)	-	0.3 (1.7%)	-
<i>Rumex crispus</i>	Curly dock	-	0.1 (0.9%)	-	-	-
<i>Rumex</i> species	Water hemp species	-	-	-	0.1 (0.7%)	-

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores¹) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2009 (post-restoration). Also indicated are the planted native species and planting zone², for species planted in the created wetland in 2008, and presence³ in August 2009 during site visit by New England Environmental, Inc. (continued).

Scientific Name	Common Name	Zone ² (if planted) and presence (V, +, or -)	Average Braun-Blanquet score (percent of total cover)			
			2004		2009	
			Turning Basin (n=16 plots)	Southern marsh (n=14 plots)	Natural marsh (n=17 plots)	Planted marsh (n=53 plots)
<i>Sagittaria graminea</i>	Grassy arrowhead	HM (-)	-	-	-	-
<i>Sagittaria latifolia</i>	Broadleaf arrowhead	HM (+)	-	-	-	<0.1 (0.8%)
<i>Sagittaria rigida</i>	Deep water duck potato	LM (+)	-	-	-	-
<i>Schoenoplectus acutus</i>	Hardstem bulrush	LM (+)	-	-	-	0.4 (3.2%)
<i>Schoenoplectus pungens</i>	Common threesquare	HM (+)	-	-	-	0.2 (1.3%)
<i>Schoenoplectus validus</i>	Soft-stem bulrush	HM (-)	-	-	-	-
<i>Schoenoplectus/Scirpus</i> species	<i>Schoenoplectus/Scirpus</i> species	-	-	-	0.1 (0.7%)	-
<i>Sciyos angulatus</i>	Oneseed bur cucumber	-	-	-	0.2 (1.0%)	-
<i>Sium suave</i>	Hemlock waterparsnip	HM (+)	-	-	-	<0.1 (0.3%)
<i>Solanum americanum</i>	American black nightshade	-	0.1 (0.9%)	-	-	-
<i>Solanum dulcamara</i>	Climbing nightshade	(V)	-	-	-	-
<i>Sparganium americanum</i>	American bur-reed	-	0.3 (2.3%)	0.1 (1.5%)	-	-
<i>Spartina pectinata</i>	Prarie cordgrass	HM (+)	-	-	-	-
<i>Toxicodendron radicans</i>	Poison ivy	-	0.1 (0.9%)	0.3 (3.0%)	-	-
<i>Trifolium repens</i>	White clover	(V)	-	-	-	-
<i>Typha angustifolia</i>	Narrowleaf cattail	-	2.4 (17.1%)	1.6 (16.5%)	3.6 (21.5%)	1.5 (12.2%)
Unknown forb seedling	Unknown forb seedling	-	-	-	-	<0.1 (0.3%)
Unknown grass	Unknown grass	-	-	-	0.3 (1.7%)	0.2 (1.4%)

Table 1. Species list, average Braun-Blanquet score, and average percent composition (in parentheses, estimated from mid-point of Braun-Blanquet scores¹) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration) and 2009 (post-restoration). Also indicated are the planted native species and planting zone², for species planted in the created wetland in 2008, and presence³ in August 2009 during site visit by New England Environmental, Inc. (continued).

Scientific Name	Common Name	Zone ² (if planted) and presence (V, +, or -)	Average Braun-Blanquet score (percent of total cover)			
			2004		2009	
			Turning Basin (n=16 plots)	Southern marsh (n=14 plots)	Natural marsh (n=17 plots)	Planted marsh (n=53 plots)
<i>Verbena hastata</i>	Blue vervain	(V)	-	-	-	-
<i>Veronica serpyllifolia</i>	Thymeleaf speedwell	-	-	-	0.1 (0.3%)	-
<i>Zannichella palustris</i>	Horned pondweed	(V)	-	-	0.1 (0.3%)	1.3 (11.1%)
<i>Zizania aquatica</i>	Wild rice	LM (-)	-	-	-	-
Total species			25	15	35	21
Non living covers						
Bare ground	Bare ground	-	1.4 (9.9%)	0.2 (2.3%)	1.6 (9.7%)	5.6 (47.3%)
Litter/wrack	Litter/wrack	-	1.0 (7.2%)	0.3 (3.0%)	2.0 (11.8%)	0.6 (5.2%)
Woody dead	Woody dead	-	-	-	0.3 (2.1%)	-

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

² Native vegetation planting zones: HM: High marsh, LM: low marsh; and presence (+), absence (-), or volunteer plant (a plant that was present but not planted) (V) during site visit by New England Environmental, Inc. on 28 July 2009.

³ *Callitriche* species was possibly *C. terrestris* (identified by H. Leeson, Rhode Island Natural History Survey, October 2009).

⁴ Wetland Planting Table lists *Juncus balticus* and not *J. effusus*. It is likely that *J. effusus* was the planted species (M. Albert, National Park Service, pers. comm.).

⁵ Invasive or potentially invasive plants as identified by the Massachusetts Invasive Plants Advisory Group (MIPAG) (2005).

⁶ Tentatively identified as *Phalaris arundinacea* (flowers and seeds were not present) based on colonial growth form and absence of fringe hairs on ligule (identified by H. Leeson, Rhode Island Natural History Survey, October 2009).

⁷ "-" Indicates species was not observed.

Table 2. Species list for plants planted and observed on the berm area (streamside riparian buffer zone).

Scientific Name	Common Name	Planted (P) and presence (+, -) or Volunteer plant (V)
<i>Alisma plantago-aquatica</i>	Water plantain	V
<i>Alnus incana</i> spp. <i>rugosa</i>	Speckled alder	P (+)
<i>Ambrosia artemisiifolia</i>	Common ragweed	V
<i>Bidens cernua</i>	Nodding beggar tick	V
<i>Bidens frondosa</i>	Devil's beggartick	V
<i>Brassica nigra</i>	Black mustard	V
<i>Calystegia sepium</i>	Hedge bindweed	V
<i>Carex lacustris</i>	Lake sedge	P (-)
<i>Carex stricta</i>	Tussock sedge	P (-)
<i>Carex</i> species	<i>Carex</i> species	P/V (+)
<i>Commelina communis</i>	Asiatic dayflower	V
<i>Cornus amomum</i>	Silky dogwood	P (+)
<i>Cornus sericea</i>	Redosier dogwood	P (+)
<i>Eleocharis obtusa</i>	Soft-stem spikerush	V
<i>Epilobium coloratum</i>	Purpleleaf willowherb	V
<i>Eupatorium perfoliatum</i>	Common boneset	V
<i>Glyceria grandis</i>	Tall mannagrass	V
<i>Humulus japonicus</i> ²	Japanese hop	V
<i>Impatiens capensis</i>	Jewelweed	V
<i>Juncus effusus</i>	Common rush	V
<i>Lepidium virginicum</i>	Wild peppergrass	V
<i>Lycopus americanus</i>	American water horehound	V
<i>Mimulus ringens</i>	Monkey flower	V
<i>Oenothera biennis</i>	Evening primrose	V
<i>Plantago lanceolata</i>	Narrowleaf plantain	V
<i>Polygonum persicaria</i>	Spotted ladythumb	V
<i>Potentilla norvegica</i>	Rough cinquefoil	V
<i>Potentilla simplex</i>	Old field cinquefoil	V
<i>Rorippa</i> species ¹	Watercress species	V
<i>Rosa multiflora</i> ²	Multiflora rose	V
<i>Rosa palustris</i>	Swamp rose	P (+)
<i>Sium suave</i>	Water parsnip	V
<i>Trifolium hybridum</i>	Alsike clover	V

¹ There are both native and introduced watercress, this individuals could not be identified to species; however, introduced watercress (*Nasturtium officinale*) was observed in the natural wetland in 2009 (refer to Table 1).

² Invasive or potentially invasive plants as identified by the Massachusetts Invasive Plants Advisory Group (MIPAG) (2005).



Figure 2. Location of pre-restoration nekton and vegetation sampling stations at Saugus Iron Works NHS in 2004.

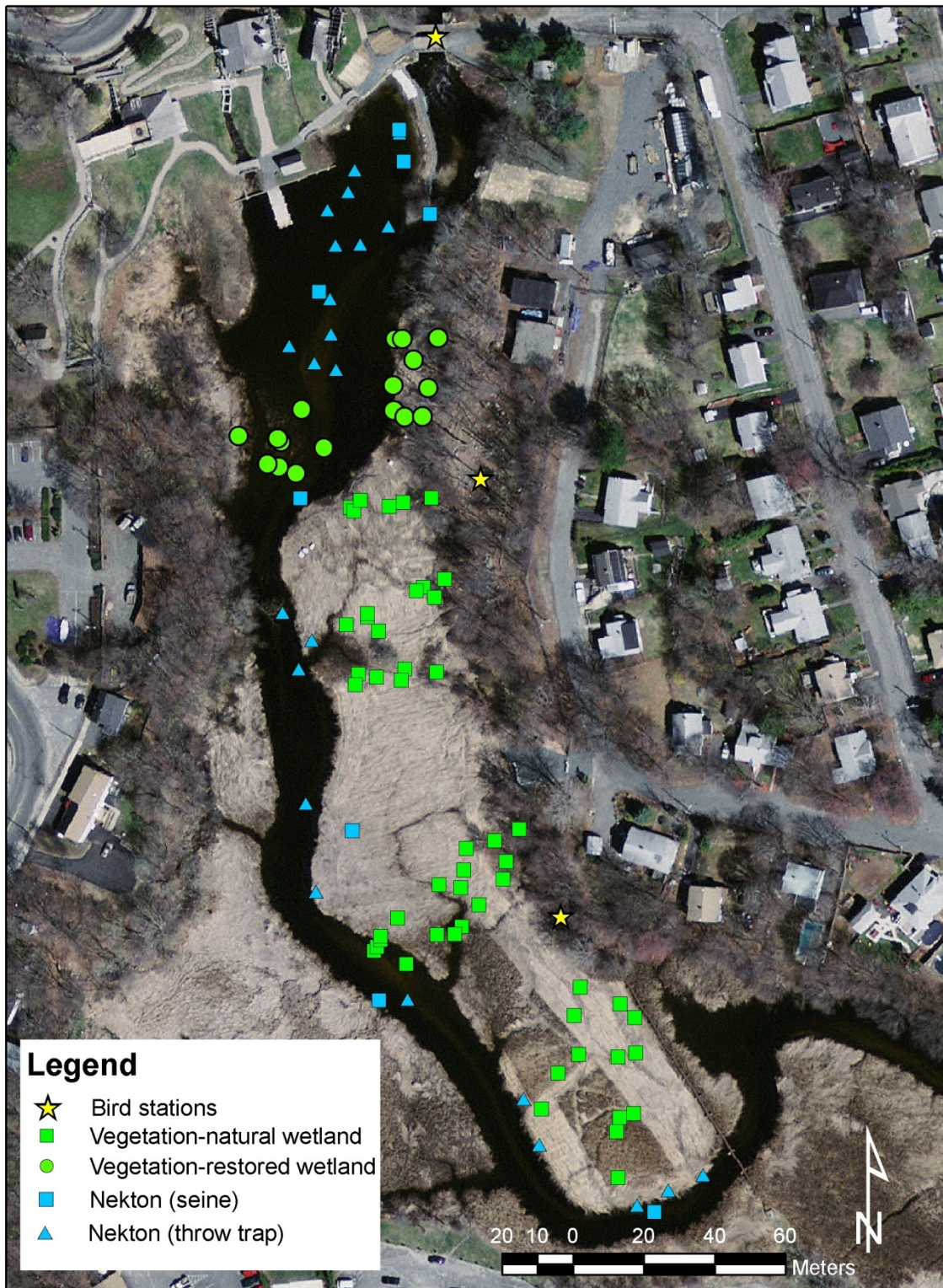


Figure 3. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2009.

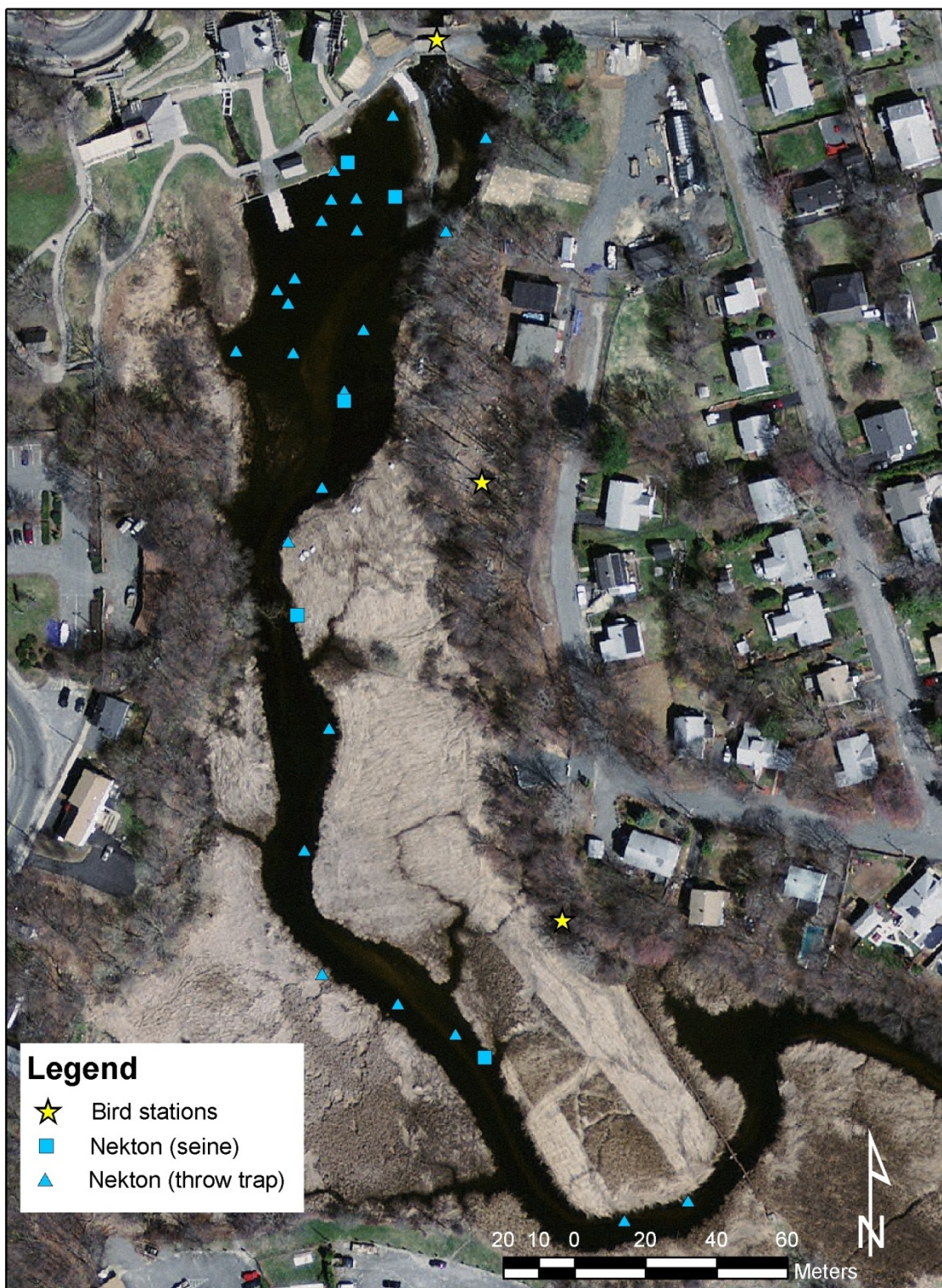


Figure 4. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2008. Note: vegetation was not sampled in 2008.

Results: Marsh Vegetation

Prior to restoration (2004 data) there was vegetation present in the area of the former turning basin (transects 1-4) and 23 species were identified in this location. Narrowleaf cattail (*Typha angustifolia*) was the most common representing 17% of the vegetation community (estimated from mid-point of Braun-Blanquet scores, Table 1). The southern wetland (transects 5-7) was dominated by common reed (*Phragmites australis*) and accounted for 44% of the vegetation community. Narrowleaf cattail was also abundant, comprising 17% of the vegetation. A total of 13 species were identified in southern wetland (estimated from mid-point of Braun-Blanquet scores, Table 1). Several invasive plants were also observed during pre-restoration monitoring (refer to Invasive Plants section for more detail).

Twenty-one species were observed in the newly restored and planted southern wetland adjacent to the Saugus River during the first year of post-restoration sampling in 2009. The restored wetland was sparsely vegetated and bare ground was the dominant cover type (47% of total cover, estimated from mid-point of Braun-Blanquet scores) (Table 1). This amount of bare ground was not surprising since the wetland was still recovering from the restoration activities. Other common plants included narrowleaf cattail (12% of total cover), horned pondweed (*Zannichella palustris*, 11% of total cover), and waterwort species (*Callitriche* sp., possibly *C. terrestris*, 8% of total cover) (estimated from mid-point of Braun-Blanquet scores).

An alternative description of the restored wetland can be illustrated by examining the percent of plots where common cover types were found. Cover types that were present in >10% of plots included bare ground, narrowleaf cattail, horned pondweed, *Callitriche* sp., wrack, hardstem bulrush, pickerelweed seedlings, and unknown grass (Figure 5). Three invasive plants, purple loosestrife (*Lythrum salicaria*), curly pondweed (*Potamogeton crispus*), and flowering rush (*Butomus umbellatus*) were also observed in the restored wetland (refer to Invasive Plants section for more detail).

The small natural wetland areas (sampled in 2009) near the turning basin was a diverse community with 35 plant species present (Table 1). The wetland on the eastern side of the river (closest to the picnic area) had a greater variety of vegetation with 88% of the species (31 of 35 species) observed. The wetland on the eastern side had 13 species (37% of the species). Overall, the most common plant in these small natural wetlands was narrowleaf cattail (22% of the total cover) that was primarily located in the wetland on the western side of the river. Other common plants were green arrow arum (7% of the total cover) and purple loosestrife, an invasive plant (7% of the total cover) (estimated from mid-point of Braun-Blanquet scores). The majority of species had a percent of total cover of less than 5% (estimated from mid-point of Braun-Blanquet scores, Table 1). Four invasive plants were also observed in these natural areas, including multiflora rose (*Rosa multiflora*), purple loosestrife, reed canary grass (*Phalaris arundinacea*), and watercress (*Nasturtium officinale*) (refer to Invasive Plants section for more detail).

Statistical analyses of the vegetation community before and after the restoration would not be meaningful. Phase II of the restoration effectively removed all vegetation from the area along the banks of the river and in 2009 the vegetation of the newly restored marsh was still in the early stages of recovery.

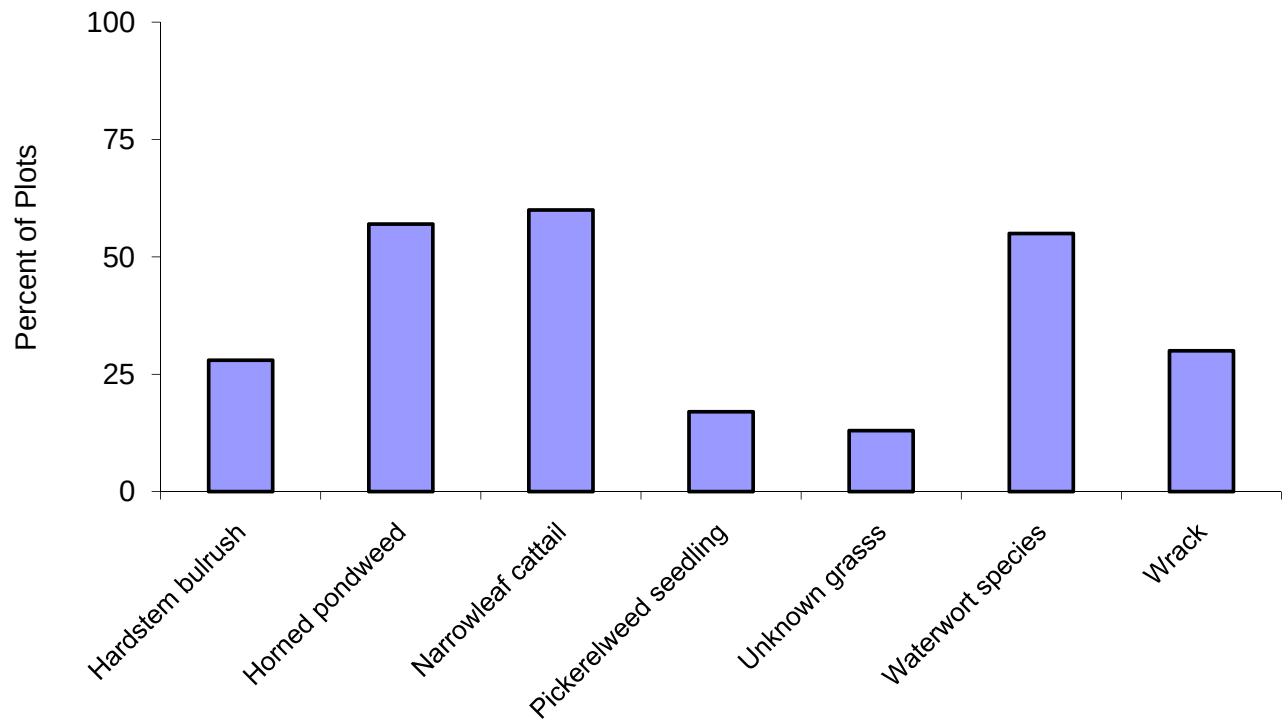


Figure 5. Cover type distribution in the restored wetland at Saugus Iron Works NHS in 2009. Presented is the percent of sampled plots where the indicated cover was found.

Results: Aquatic Vegetation

The most common aquatic vegetation in the river in 2004 was horned pondweed, found in 42% of the plots. Curly pondweed, an invasive plant (Massachusetts Invasive Plant Advisory Group [MIPAG] 2005), was observed within four of the 12 plots. Other aquatic taxa that were present were *Callitriche* sp. and green alga. Forty-two percent of the plots (five plots) had no aquatic vegetation (Table 3).

In 2008, the first year after restoration, the only type of aquatic plant found in the river was horned pondweed, observed at 20% of the stations (Table 3). In the restored turning basin, four aquatic plants were present. The three common taxa were *Elodea* sp., horned pondweed, and curly pondweed. Horned pondweed and *Elodea* sp. were present at 55% and 45% of the stations, respectively (Table 3). Curly pondweed, an invasive plant, was present in 27% of the stations. An unknown pondweed (*Potamogeton* sp.) was observed at one of the stations in the restored turning basin.

In 2009, the only aquatic vegetation in the river was horned pondweed, present in 96% of the plots, at an average cover of 26% to 50% (Table 3). In the restored turning basin, four aquatic taxa were present, with horned pondweed found at 52% of the stations. Curly pondweed was also abundant, observed at 38% of the stations. Both these plants had an average cover of about 1% to 5% (average Braun-Blanquet cover 1 to 1.5). Two other aquatic plants, ribbonleaf pondweed (*Potamogeton epihydrus*) and *Elodea* sp., were also present at sampling stations. Variableleaf pondweed (*Potamogeton gramineus*) was observed in the turning basin outside of the sampling plots (Table 3).

Based on Analysis of Similarities (ANOSIM), the aquatic vegetation community of the river was different in 2009 primarily due to a higher abundance of horned pondweed compared to the other years (Table 3 and Table 4). In both 2008 and 2009 there was a difference in the aquatic vegetation between the river and the basin habitats, with more species present in the basin than in the river in both years (Table 3 and Table 4). There were no differences between years for aquatic vegetation sampled in the turning basin.

Results: Invasive Plants

Nine invasive and/or introduced plants have been encountered at SAIR during pre- and post-restoration monitoring (USDA 2004, MIPAG 2005, New England Environmental, Inc. 2009). Prior to the restoration six invasive species (all either wetland or terrestrial plants) were observed in the former turning basin and wetland along the river. In 2008, only one invasive species was observed (*P. crispus*), but only aquatic vegetation was monitored in 2008 (the newly restored wetland was not sampled) (Table 5). In 2009, eight invasive plant species were observed, including three new ones (flowering rush, watercress, and Japanese hop [*Humulus japonicus*]).

Curly pondweed was primarily found in the restored turning basin, and if left unchecked it could outcompete the native pondweeds (e.g., ribbonleaf and variableleaf pondweed). Curly pondweed was also observed in the southern section of the restored wetland at lower elevations on the river floodplain (Figure 6). Purple loosestrife, was fairly abundant (representing 7% of the total cover) in the natural wetlands in the northern section of the river, and was also present along the upland border in the southern section of the restored wetland. Other notable invasive plants, included the

flowering rush (present along the upland edges of the restored marsh), watercress, and multiflora rose (the latter two were both present in the natural wetlands). A site visit by New England Environmental, Inc. (2009), observed two invasive species (Japanese hop and multiflora rose) on the streamside riparian buffer area (e.g., the berm) and a few stems of common reed in the restored wetland (Figure 6). These invasive plants provide seed sources, especially when they are well-established in the natural wetland areas, and potentially threaten the native wetland species currently found in the restored wetland area.

Table 3. Species list, average Braun-Blanquet¹ score, and percent of plots where species were observed during aquatic vegetation sampling at Saugus Iron Works NHS in 2004 (pre-restoration) and 2008 and 2009 (post-restoration). Aquatic vegetation was sampled at 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)	2009 River (n=27)	2009 Basin (n=21)
<i>Callitriche</i> species ²	Water starwort species	0.3 (17%)	- ⁵	-	-	-
<i>Elodea</i> species	<i>Elodea</i> species	-	-	1.8 (55%)	-	0.3 (14%)
<i>Potamogeton crispus</i> ³	Curly pond weed	0.6 (33%)	-	1.0 (27%)	-	1.0 (38%)
<i>Potamogeton epihydrus</i>	Ribbonleaf pondweed	-	-	-	-	0.4 (19%)
<i>Potamogeton gramineus</i>	Variableleaf pondweed	-	-	-	-	Present
Unknown green algae	Unknown green algae	0.7 (17%)	-	-	-	-
Unknown pondweed ⁴	Unknown pondweed	-	-	0.2 (9%)	-	-
<i>Zannichella palustris</i>	Horned pondweed	1.5 (42%)	0.9 (20%)	1.2 (45%)	4.0 (96%)	1.5 (52%)

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

² Possibly *C. terrestris* (identified by H. Leeson, Rhode Island Natural History Survey, October 2009).

³ Invasive plants as identified by MIPAG (2005).

⁴ Possibly *P. gramineus*, *P. gramineus* was present but was not observed in plots in 2009.

⁵ "-" indicates species was not observed.

Table 4. ANOSIM results comparing aquatic vegetation communities among years (2004, 2008, and 2009) and between habitats (river or basin). Only comparisons of interest (e.g., among years within the same habitat or between habitats in the same year are shown).

Comparison (sample 1, sample 2)	R Statistic	p-value
2009 River, 2009 Basin	0.372	0.00001* ¹
2009 River, 2008 River	0.630	0.00001* ¹
2009 River, 2004 River	0.604	0.00001* ¹
2009 Basin, 2008 Basin	0.097	0.06200
2008 River, 2008 Basin	0.430	0.00010* ¹
2008 River, 2004 River	0.135	0.02900

¹ "*" Indicates significant difference at alpha=0.0083 (Bonferroni adjusted alpha).

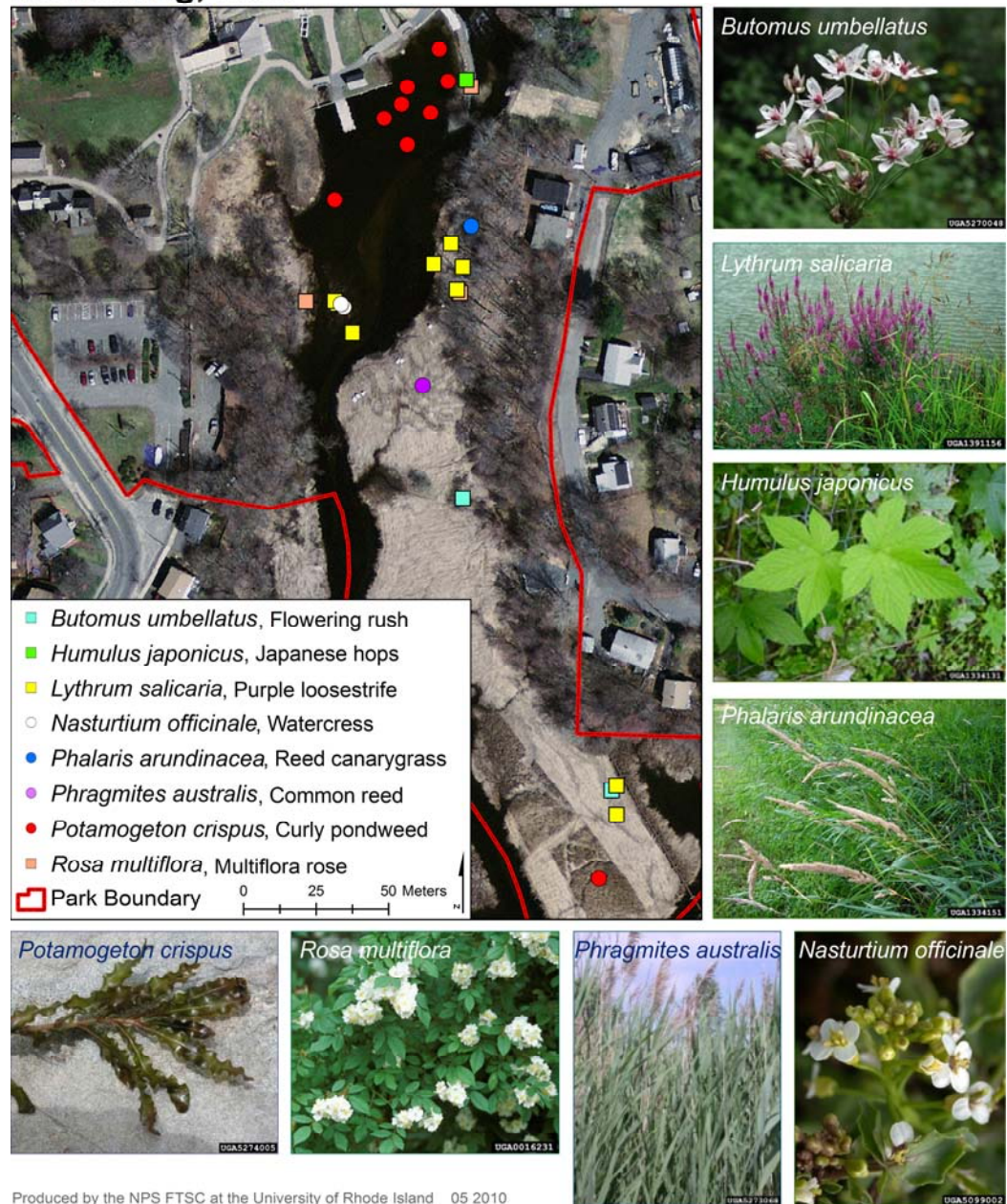
Table 5. List of invasive plants and the state where listed (in parentheses) observed during vegetation sampling at SAIR. Status information is from USDA Plants Database and the Massachusetts Invasive Plant Working Group (MIPAG 2005).

Scientific Name	Common Name	Status	Year(s) Observed
<i>Butomus umbellatus</i> ¹	Flowering rush	potentially invasive (CT)	2009
<i>Humulus japonicus</i> ²	Japanese hop	Invasive (MA)	2009
<i>Lythrum salicaria</i>	Purple loosestrife	Invasive (MA)	2004, 2009
<i>Nasturtium officinale</i>	Watercress	potentially invasive (CT)	2009
<i>Phalaris arundinacea</i>	Reed canary grass	Invasive (MA)	2004, 2009
<i>Phragmites australis</i> ²	Common reed	Invasive (MA)	2004, 2009
<i>Potamogeton crispus</i>	Curly pond weed	Invasive (MA)	2004, 2008, 2009
<i>Robinia pseudoacacia</i>	Black locust	Invasive (MA)	2004
<i>Rosa multiflora</i> ²	Multiflora rose	Invasive (MA)	2004, 2009

¹ *Butomus umbellatus* was not found in vegetation plots, but was observed along the upland marsh border and on the berm near the sewer pipe in the restored marsh.

² Observed during site visit (28 July 2009) by New England Environmental, Inc.

Invasive Plant Species Observed During Post-Restoration Monitoring, 2009



Produced by the NPS FTSC at the University of Rhode Island 05 2010

Figure 6. Location of invasive plants¹ observed during vegetation sampling at Saugus Iron Works NHS in 2009.

¹Symbols for multiple species collected at a single location have been shifted slightly for visual clarity. Representative photos of each species were obtained from the University of Georgia and USDA Forest Service website, "Invasive Plants of the US", www.invasive.org. Photo credit: John D. Byrd, Mississippi State University (*Lythrum*); Chris Evans, River to River CWMA, United States (*Humulus*, *Phalaris*); Mary Ellen Harte (*Nasturtium*); Leslie J. Mehrhoff, University of Connecticut (*Butomus*, *Phragmites*, *Potamogeton*); James H. Miller, USDA Forest Service (*Rosa*).

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 were sampled twice per year - once in mid-summer and once in late summer/early fall 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 (Raposa et al. 2003). The sampling area is limited to locations with standing water present at lower tide conditions, but not higher than the top of the side walls of the trap (0.5-m high) (i.e., the deepest portion of the river channel and the deeper areas in the turning basin and river edge were excluded). 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 wire mesh. The trap is thrown into water, embedding it in the bottom sediments, and capturing any nekton in the 1-m² area of the trap. All nekton were collected from the trap with a 1-mm mesh dip net that fits snugly within the trap. The trap was considered empty when three successive attempts with the dip net produced no organisms.

Qualitative samples of nekton were also 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 order to achieve a more complete species list by attempting to catch faster swimming fishes that may not be adequately sampled by the throw trap.

At each station (both throw trap and seine stations), all nekton 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. 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.

Pre-restoration nekton throw trap sampling occurred on 9 June and 5 August 2004 in the Saugus River, with 16 stations sampled on 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 2).

The first post-restoration nekton sampling event occurred on 18 September (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 in 2008. Twenty-six throw trap stations were sampled (11 stations in the basin, and 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.

The second year of post-restoration nekton sampling was conducted during two sampling periods on 15 July 2009 and on 14 and 15 September 2009. During each of these sampling periods, 24 to 25 throw trap stations were sampled (14 in the river and 10-11 in the basin) (Figure 3). Seventeen seine hauls (11 in the river and six in the turning basin) were sampled during these sampling events.

The Massachusetts Division of Marine Fisheries (MA DMF), in conjunction with the Saugus Watershed Council, has sampled rainbow smelt (*Osmerus mordax*) and young-of-year (YOY) American eel (*Anguilla rostrata*) at SAIR since 2005. Rainbow smelt were sampled using a fyke net (6-mm delta mesh, 0.8-m hoop entrance, and 1-m wings) set in the intertidal zone below the downstream limit of smelt egg deposition. Nets were set overnight, facing upstream, three times per week from early March through late May (Chase et al. 2007).

YOY American eel were sampled from April to June using Sheldon elver traps. Sampling occurs from the first week of April to the first week of June.

Results: Pre-restoration Nekton

During the 2004 pre-restoration sampling, 13 species (11 fish and two decapods) were sampled using seine and throw traps (Table 6). Young-of-the-year white suckers (*Catostomus commersoni*) dominated the catch (73% of total catch) (Table 7, Figure 7). Other nekton that were present were four-spine sticklebacks (*Apeltes quadracus*, 15% of the total catch), American eels (*Anguilla rostrata*, 9% of the catch), and three-spine sticklebacks (*Gasterosteus aculeatus*, 2% of catch). green crabs (*Carcinus maenas*) and brook sticklebacks (*Culaea inconstans*) each accounted for less than 1% of the catch. It is possible that the brook sticklebacks may have been mis-identified and were really nine-spine sticklebacks, unfortunately voucher specimens were not available. The catch consisted of young-of-the-year or juveniles for most of the nekton (Figure 8).

Eleven species (10 fish and one decapod) were sampled using the seine in 2004 (Table 6 and Table 8). As expected seine hauls captured the faster swimming nekton such as alewife (*Alosa pseudoharengus*), largemouth bass (*Micropterus salmoides*), and redbfin pickerel (*Esox americanus*). Two invasive and/or native transplant species were also found (green crab and largemouth bass, Table 9).

Table 6. Nekton sampled during pre-restoration monitoring (2004) and post-restoration monitoring (2008 and 2009) at Saugus Iron Works NHS.

Common Name Scientific Name	Pre-restoration (2004) River only		Post-restoration (2008) River & Basin		Post-restoration (2009) River & Basin	
	Seine	Throw Trap	Seine	Throw Trap	Seine	Throw Trap
<i>Alosa pseudoharengus</i> Alewife	X					
<i>Anguilla rostrata</i> American eel	X	X		X	X	X
<i>Apeltes quadracus</i> Four-spine stickleback	X	X	X	X	X	X
<i>Carcinus maenas</i> Green crab		X				
<i>Catostomus commersoni</i> White sucker	X	X	X	X	X	X
<i>Culaea inconstans</i> ¹ Brook stickleback	X	X				
<i>Esox americanus</i> <i>americanus</i> Redfin pickerel	X				X	
<i>Esox americanus</i> <i>vermiculatus</i> Grass pickerel					X	
<i>Fundulus heteroclitus</i> Mummichog	X				X	X
<i>Gasterosteus aculeatus</i> Three-spine stickleback		X				
<i>Lepomis gibbosus</i> Pumpkinseed					X	X
<i>Lepomis macrochirus</i> Bluegill			X	X	X	
<i>Micropterus salmoides</i> Largemouth bass	X		X		X	
<i>Morone americana</i> White perch	X		X			
<i>Pungitius pungitius</i> Nine-spine stickleback	X			X	X	
<i>Rhithropanopeus harrisii</i> Harris mud crab	X					
Unknown minnow species					X	
Total species caught	11	6	5	5	11	5

¹Possibly a nine-spine stickleback (voucher specimen not available for verification). Brook sticklebacks have not been verified to be present east of the Connecticut River.

Table 7. Nekton density (number $\text{m}^{-2} \pm \text{SD}$) and total number of individuals captured (in parentheses) from 1m^2 throw trap sampling at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 and 2009). Sample size is given after date.

Scientific Name	Common Name	Average Density (Number m ⁻² ± SD [total no. individuals])				
		June 2004 n = 16	Aug 2004 n = 16	Sept 2008 n=15	July 2009 n=14	Sept 2009 n=14
River samples						
<i>Anguilla rostrata</i>	American eel	1.6 ± 2.6 (25)	0.3 ± 1.0 (5)	0.2 ± 0.4 (3)	4.2 ± 3.5 (59)	0.5 ± 1.2 (7)
<i>Apeltes quadracus</i>	Four-spine stickleback	2.3 ± 4.9 (37)	0.8 ± 1.4 (13)	0.6 ± 1.6 (9)	6.7 ± 7.5 (94)	1.4 ± 2.2 (20)
<i>Carcinus maenas</i>	Green crab	0	0.1± 0.3 (1)	0	0	0
<i>Catostomus commersoni</i>	White sucker	13.9 ± 20.9 (223)	0.8 ± 2.5 (13)	0.1 ± 0.3 (1)	9.1 ± 10.1 (128)	0.4 ± 0.8 (6)
<i>Culaea inconstans</i>	Brook stickleback ¹	0	0.1± 0.3 (1)	0	0	0
<i>Fundulus heteroclitus</i>	Mummichog	0	0	0	1.5 ± 1.7 (21)	1.0 ± 2.6 (14)
<i>Gasterosteus aculeatus</i>	Three-spine stickleback	0.4 ± 1.5 (6)	0	0	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0	0	0.5 ± 2.1 (8)	0	0
Total Nekton Density		18.2 ± 26.9 (291)	2.1 ± 3.2 (33)	1.4 ± 3.0 (21)	21.6 ± 13.9 (302)	3.4 ± 4.5 (47)
Scientific Name	Common Name	June 2004 n/a	Aug 2004 n/a	Sept 2008 n=11	July 2009 n=10	Sept 2009 n=11
Basin samples						
<i>Anguilla rostrata</i>	American eel	- ²	-	2.6 ± 3.3 (29)	2.6 ± 4.0 (29)	8.3 ± 12.5 (83)
<i>Apeltes quadracus</i>	Four-spine stickleback	-	-	1.4 ± 1.9 (15)	7.5 ± 13.6 (83)	1.0 ± 1.4 (10)
<i>Catostomus commersoni</i>	White sucker	-	-	0	4.9 ± 13.7 (54)	0
<i>Fundulus heteroclitus</i>	Mummichog	-	-	0	0.1 ± 0.3 (1)	0.5 ± 1.3 (5)
<i>Lepomis gibbosus</i>	Pumpkinseed	-	-	0	0.1 ± 0.3 (1)	0
<i>Lepomis macrochirus</i>	Bluegill	-	-	0.9 ± 1.4 (10)	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	-	-	0.1 ± 0.3 (1)	0	0
Total Nekton Density				5.0 ± 3.3 (55)	15.3 ± 22.9 (168)	9.8 ± 13.5 (98)

¹ Possibly nine-spine stickleback (voucher specimen not available for verification). Brook sticklebacks have not been verified to be present east of the Connecticut River.

²“-“ Indicates samples were not taken (basin was not yet excavated).

Table 8. Nekton composition, average abundance per seine haul, and total number of individuals collected (in parentheses) with a seine at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 and 2009). Sample size is given after date.

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	River 2009 n=11	Turning Basin 2009 n=6
<i>Alosa pseudoharengus</i>	Alewife	2.5 (5)	0.2 (1)	0	0	0	0
<i>Anguilla rostrata</i>	American eel	0.5 (1)	0	0	0	0.1 (1)	0.8 (5)
<i>Apeltes quadracus</i>	Four-spine stickleback	4.0 (8)	23.4 (117)	2.2 (13)	5.7 (17)	74.5 (820)	150.5 (903)
<i>Catostomus commersoni</i>	White sucker	1.0 (2)	168.2 (841)	0	15.7 (47)	71.7 (189)	92.3 (554)
<i>Culaea inconstans</i> ¹	Brook stickleback	1.5 (3)	15.2 (76)	0	0	0	0
<i>Esox americanus americanus</i>	Redfin pickerel	0	0.2 (1)	0	0	0.3 (3)	0.2 (1)
<i>Esox americanus vermiculatus</i>	Grass pickerel	0	0	0	0	0.2 (2)	0
<i>Fundulus heteroclitus</i>	Mummichog	0	1.2 (6)	0	0	18.1 (199)	15.7 (94)
<i>Lepomis gibbosus</i>	Pumpkinseed	0	0	0	0	0	0.2 (1)
<i>Lepomis macrochirus</i>	Bluegill	0	0	0.2 (1)	14.0 (42)	0	5.2 (31)
<i>Micropterus salmoides</i>	Largemouth bass	0	0.8 (4)	0.3 (2)	2.0 (6)	0	9.0 (54)
<i>Morone americana</i>	White perch	0	0.6 (3)	0	0.3 (1)	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0	0.4 (2)	0	0	0.2 (2)	0.3 (2)
<i>Rhithropanopeus harrisii</i>	Harris mud crab	0	0.2 (1)	0	0	0	0
Unknown minnow species		0	0	0	0	0	0.2 (1)
Average total abundance per haul		9.5 (19)	210.4 (1052)	2.6 (16)	37.7 (113)	165.1 (1816)	274.3 (1646)

¹ Possibly nine-spine stickleback (voucher specimen not available for verification). Brook sticklebacks have not been verified to be present east of the Connecticut River.

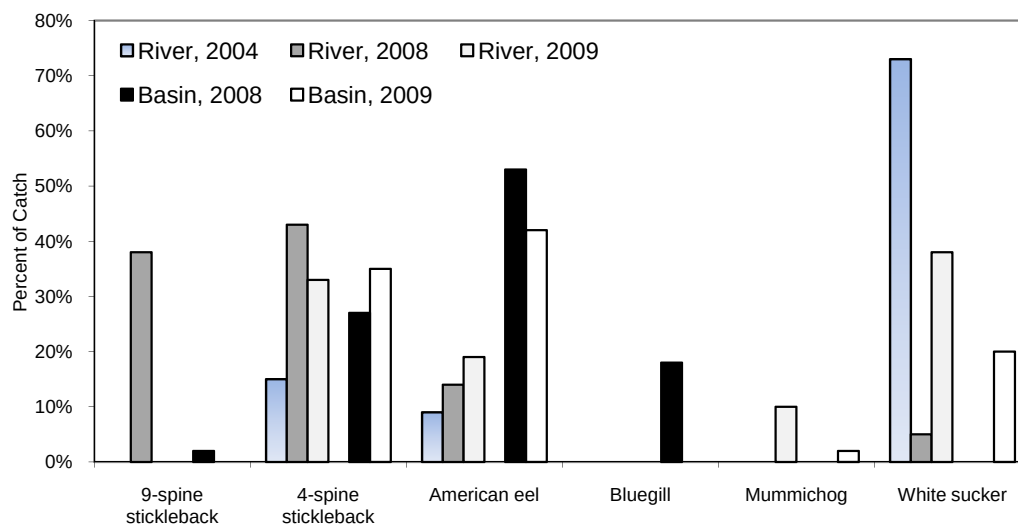


Figure 7. Percent catch of common nekton sampled from throw traps at Saugus Iron Works NHS during pre-restoration (2004) and post-restoration monitoring (2008 and 2009).

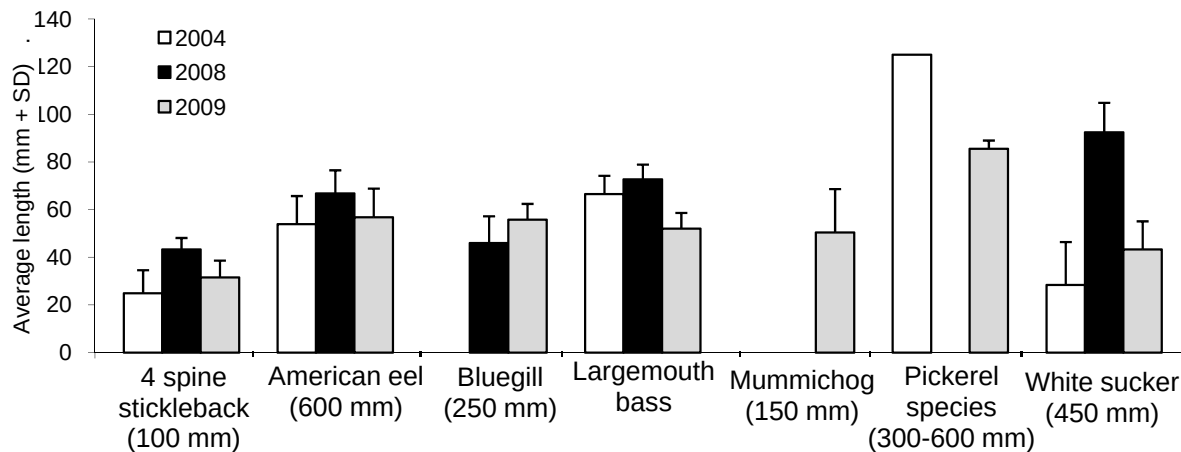


Figure 8. Average length (mm $\pm$ SD) of nekton sampled at Saugus Iron Works NHS with throw traps and seines during pre-restoration (2004) and post-restoration (2008 and 2009) monitoring. Average adult length (mm) is given under each species name for reference. Only nekton where more than five individuals were sampled (all years combined) are shown.

Table 9. List of exotic and native transplant nekton (species native to the U.S. that have been introduced to areas outside of their original range). Status information is from the USGS (2004) Nonindigenous Aquatic Species Database.

Scientific Name	Common Name	Status	Year Observed
<i>Carcinus maenas</i>	Green crab	Exotic	2004
<i>Lepomis macrochirus</i>	Bluegill	Native transplant	2008, 2009
<i>Micropterus salmoides</i>	Largemouth bass	Native transplant	2004, 2008, 2009

Results: Post-restoration Nekton

In 2008, seven nekton species were collected using both throw trap and seine in the restored turning basin and the Saugus River (Table 6). 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 and comprised 43% and 38% of the catch, respectively. American eels comprised 14% of the catch and white suckers accounted for the remaining 5% of the catch (Table 7, Figure 7). The seine samples from the river stations were also dominated by four-spine sticklebacks (81% of the catch). Other nekton sampled with the seine in the river included largemouth bass (13% of the catch) and bluegill (6% of the catch) (Table 8).

In the newly restored turning basin, American eels (all juveniles, average length 69 mm, Figure 8) dominated the throw trap samples and comprised 53% of all individuals caught in 2008. 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 7, Figure 7). In the seine samples, white suckers (42% of the catch) and bluegills (37% of the catch) dominated the catch in the turning basin. Four-spine stickleback comprised 15% of the catch with largemouth bass (5%) and white perch (*Morone americana*) (1%) making up the remainder of the individuals captured (Table 8). The high incidence of American eels in the throw trap samples in the turning basin is likely due to the fine sediment in the basin and the ability of the gear to sample the benthic sediment layer where these individuals are located.

In 2009, four nekton species were observed in the throw trap samples from the river: white sucker (38% of the catch), four-spine stickleback (33% of the catch), American eel (19% of the catch), and mummichog (10% of the catch) (Table 7, Figure 7). Three of these species (white sucker, four-spine stickleback, and mummichog) were also abundant in the seine samples from the river (Table 7, Figure 7). Additional nekton sampled in the river with the seine included: nine-spine stickleback, redbfin pickerel, grass pickerel (*Esox americanus vermiculatus*), and American eel (Table 8).

The turning basin throw trap samples were dominated by American eel, four-spine stickleback, and white sucker in 2009 (Figure 7). Seine samples from the turning basin were also dominated by four-spine stickleback and white sucker (Table 8). Other nekton observed in the turning basin included mummichog, largemouth bass, bluegill, nine-spine stickleback, and pumpkinseed (*Lepomis gibbosus*).

In both 2008 and 2009, the catch consisted of YOY or juveniles for most of the nekton (Figure 8).

One nonindigenous (non-native) fish, the largemouth bass, and one exotic crustacean (green crab) were found in 2004. In 2008 and 2009, an additional non-native species, the bluegill, was collected (Table 9). Both the largemouth bass and the bluegill are native transplants, North American species that were most likely transplanted into Massachusetts waters by intentional stocking programs (Fuller 2004, USGS 2004). 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).

Based on ANOSIM analyses, there were significant differences in the nekton community sampled with the throw trap between the river and the basin in 2008 and in the river between 2008 and 2009 (Table 10). No other comparisons of interest were significant. In 2008, American eel and four-spine stickleback were more abundant in the basin than in the river (comprising 74% of the dissimilarity between the habitats). Bluegills were only sampled in the basin, while white suckers were only found in the river (Table 7). In the river, the density of all species in 2009 (four-spine stickleback, white sucker, American eel, and mummichog) were all higher than in 2008 (Table 7).

Water temperature, salinity, and dissolved oxygen collected in conjunction with the nekton sampling events were similar between 2004 and 2008 (Table 11). In 2009, water temperature and dissolved oxygen occasionally exceeded thresholds established for acceptable habitat for warm water fisheries (Lombard et al. 2006).

Results: Rainbow smelt and American eel monitoring

In 2005 (prior to restoration), rainbow smelt were present in 56% of the Saugus River samples (32 samples or hauls), but at a low density (4.4 individuals haul⁻¹) compared to the other smelt monitoring stations in Massachusetts (Chase et al. 2007). The presence of alewife and white perch were also documented in the Saugus River during MA DMF smelt surveys. The catches for both species were low in 2005, but were still highest among fyke net stations in Massachusetts. Fish species richness from the fyke net surveys in 2005 ranked third among MA stations (11 species) with a relative high presence of freshwater yellow perch and white sucker present at SAIR (Chase et al. 2007). At the SAIR fyke net station, smelt numbers were highest in 2006 and 2007 (pre-restoration) and then declined in 2008 (during the restoration of the turning basin) (Brad Chase, Massachusetts Division of Marine Fisheries, unpublished data) (Figure 9). Data from the 2006 to 2009 smelt surveys are currently being analyzed by MA DMF.

In 2006, the catch per unit effort (CPUE) of 0.4 YOY American eel per set hour was slightly lower than the 0.6 CPUE observed in 2005. Historically, the Saugus River was noted for large catches of American eel, but recent catches have been small (Chase 2007). Juvenile American eel (< 50mm total length) are frequently observed in the throw trap samples (University of Rhode Island monitoring program), particularly in the restored turning basin (Table 7, Figure 8).

More recent data on species richness data at other MA smelt sampling stations and American eel abundance are currently being compiled by MA DMF (Brad Chase, Massachusetts Division of Marine Fisheries, personal communication).

Table 10. ANOSIM results comparing nekton communities among years (2004, 2008, and 2009) and between habitats (river or basin). Only comparisons of interest are shown (e.g., among years within the same habitat or between habitats in the same year).

Comparison (sample 1, sample 2)	R Statistic	p-value ¹
2009 Basin, 2009 River	0.01	0.299
2009 Basin, 2008 Basin	-0.042	0.716
2009 River, 2008 River	0.237	<0.001 *
2009 River, 2004 River	0.049	0.058
2008 Basin, 2008 River	0.295	0.004 *
2008 River, 2004 River	-0.016	0.543

¹ "*" Indicates significant difference at alpha=0.0083 (Bonferroni adjusted alpha).

Table 11. Environmental data (average $\pm$ SD) associated with nekton throw trap sampling. Sample size is given after location. Bold face and underlined indicate values that exceed warm water fisheries water quality criteria^{1,2}.

Variable	Water Temperature °C ¹ (maximum)	Salinity ppt	Dissolved oxygen ² mg l ⁻¹ (minimum)
June 9, 2004 (n=16) (river)	21.5 $\pm$ 1.4 (23.9)	0.3 $\pm$ 0.04	7.4 $\pm$ 0.5 (6.3)
Aug 5, 2004 (n=16) (river)	19.9 $\pm$ 0.8 (20.9)	0.1 $\pm$ 0.1	7.5 $\pm$ 0.5 (6.3)
Sept 18, 2008 (n=11, basin)	18.4 $\pm$ 0.8 (20.1)	0.5 $\pm$ 0.8	8.3 $\pm$ 1.3 (7.5)
Sept 23, 2008 (n=15, river)	14.7 $\pm$ 0.4 (15.5)	0.3 $\pm$ 0.0	9.4 $\pm$ 0.2 (8.9)
July 15, 2009 (n=13, basin)	24.1 $\pm$ 4.7 (<u>31.0</u>)	0.4 $\pm$ 0.06	6.1 $\pm$ 5.3 (<u>1.7</u>)
July 15, 2009 (n=19, river)	19.7 $\pm$ 1.8 (26.5)	0.4 $\pm$ 0.05	6.4 $\pm$ 3.2 (<u>2.6</u>)
Sept 14 & 15, 2009 (n=13, basin)	18.6 $\pm$ 1.0 (21.0)	0.7 $\pm$ 0.1	7.2 ³ $\pm$ 0.2 (7.0)
Sept 14 & 15, 2009 (n=20, river)	18.6 $\pm$ 0.7 (19.9)	0.3 $\pm$ 0.1	8.6 $\pm$ 0.4 (7.2)

¹ Acceptable value for temperature (warm water fisheries) is <28.3°C (Lombard et al. 2006).

² Acceptable value for dissolved oxygen (warm water fisheries) >6 mg l⁻¹ (Lombard et al. 2006).

³ Only three readings taken.

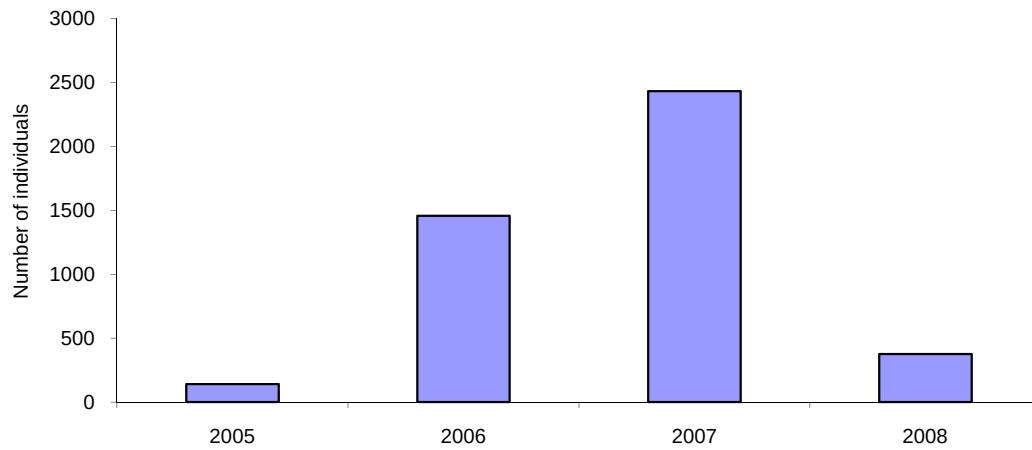


Figure 9. Rainbow smelt catch from MA-DMF fyke net monitoring (2005 to 2008) at Saugus Iron Works NHS.

Biological Variables: Bird Community

Methods: Bird Community

Bird use of the restoration area was monitored by volunteers (coordinated by NPS staff) following the guidelines of the NPS Northeast Temperate Network (NETN) Breeding Bird Monitoring Protocol (Faccio et al. 2010). Birds were monitored using variable circular plot (VCP) point counts at three observation stations (Figure 4). At each station, all birds seen or heard were recorded during 10-minute point counts. Birds were surveyed twice annually, with replicates occurring about 7-14 days apart (Faccio et al. 2010). The avian community of SAIR was also surveyed in 2002 and 2003 by the NETN (Trocki and Paton 2005). During these surveys three VCP stations were randomly located in the park (one each in the forest and wetland areas and one in a developed area) (Trocki and Paton 2005).

Wildlife observations, including birds, were recorded during the systematic wildlife observation program that was implemented in 2009 as part of the post-restoration monitoring of the turning basin (McNiff and Albert 2010). Observations of wildlife were conducted during all tide conditions, times of day, and locations in and adjacent to the restoration area. Briefly, wildlife observations occurred at least once a day, three days a week for 30 to 90 minutes from June through September 2009 (38 observation days) (McNiff and Albert 2010). Wildlife observations were recorded in ten wildlife observation zones (Figure 10); however, only data from the restoration area (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle zones, Christine McNiff, National Park Service personal communication) are presented herein.

Results: Bird Community

NETN avian monitoring was initiated in 2008. Sampling was conducted once in 2008 (11 July 2008) and on three occasions in 2009 (4, 10, and 18 June 2009). Twenty-one species (35 individuals) were observed in 2008 and 33 species (151 individuals) were recorded in 2009. A net total of 35 species have been detected during the NETN monitoring, with 19 species observed in both years (Table 12). In 2008, the mean abundance (per point) was 11.7 individuals and was 17.0 individuals in 2009 (only first survey included in 2009 for consistency between NETN survey years) (Faccio and Mitchell 2009). During wildlife observations in 2009, 31 species (excluding five taxa that were only identified as duck, heron, gull, shorebird, or sparrow) and 633 individuals were observed in the restored area (Table 12).

Data from the 2002-2003 NETN avian surveys (wetland and forested station data only) (Trocki and Paton 2005) were used to compare the bird community before and after the restoration. Since the restoration of the turning basin there has been an increase in the number of waterbirds (waterfowl, waders, and shorebirds) observed at the park (Figure 11). Prior to the restoration of the turning basin no shorebirds (e.g., sandpipers, plovers), and only a few waders (e.g., egrets, herons) and waterfowl (e.g., geese, ducks, mergansers) were observed. After the restoration several waterbird species were observed, likely a result of the newly created open water and tidal flats of the turning basin.



Figure 10. Wildlife observation zones established in 2009, “*” denotes locations within the restoration area (figure excerpted from McNiff and Albert 2010).

Table 12. Birds observed in 2008 (one survey date) and 2009 (three survey dates) during NETN monitoring and park wildlife observations (38 survey dates). Partners in Flight status¹, if applicable, is indicated in parentheses after name.

Scientific Name ³	Common Name	Category	Number of detections		
			NETN 2008	NETN 2009	2009 ² Park
<i>Actitis macularia</i>	Spotted sandpiper	Shorebird	0	0	1
<i>Agelaius phoeniceus</i>	Red-winged blackbird	Non-waterbird	1	17	5
<i>Anas platyrhynchos</i>	Mallard	Waterfowl	1	14	164
<i>Anas rubripes</i>	American black duck	Waterfowl	0	0	13
<i>Ardea alba</i> (V)	Great egret	Wader	0	3	14
<i>Ardea Herodias</i> (V)	Great blue heron	Wader	0	2	7
<i>Baeolophus bicolor</i>	Tufted titmouse	Non-waterbird	1	1	0
<i>Botaurus lentiginosus</i> (V)	American bittern	Wader	0	0	3
<i>Branta canadensis</i>	Canada goose	Waterfowl	0	2	142
<i>Buteo jamaicensis</i>	Red-tailed hawk	Non-waterbird	0	0	1
<i>Butorides virescens</i>	Green Heron	Wader	0	0	2
<i>Calidris minutilla</i>	Least sandpiper	Shorebird	0	0	2
<i>Calidris pusilla</i>	Semipalmated sandpiper	Shorebird	0	0	117
<i>Cardinalis cardinalis</i>	Northern cardinal	Non-waterbird	3	3	3
<i>Carduelis tristis</i>	American goldfinch	Non-waterbird	0	1	3
<i>Ceryle alcyon</i>	Belted Kingfisher	Non-waterbird	1	0	5
<i>Chaetura pelagica</i> (IIA)	Chimney swift	Non-waterbird	0	5	0
<i>Charadrius vociferus</i>	Killdeer	Shorebird	0	1	0
<i>Colaptes auratus</i>	Northern/Yellow shafted flicker	Non-waterbird	1	1	0
<i>Columba livia</i> *	Rock pigeon	Non-waterbird	1	5	22
<i>Corvus brachyrhynchos</i>	American crow	Non-waterbird	3	4	11
<i>Cyanocitta cristata</i>	Blue jay	Non-waterbird	2	3	0
<i>Dendroica petechia</i>	Yellow warbler	Non-waterbird	0	0	1
<i>Dumetella carolinensis</i>	Gray catbird	Non-waterbird	2	6	2
<i>Egretta thula</i> (V)	Snowy egret	Wader	0	0	4
<i>Geothlypis trichas</i>	Common yellowthroat	Non-waterbird	1	3	0
<i>Hirundo rustica</i>	Barn swallow	Non-waterbird	2	7	40
<i>Icterus galbula</i> (IA)	Baltimore oriole	Non-waterbird	1	2	0
<i>Larus argentatus</i>	Herring gull	Gull	1	5	0
<i>Larus delawarensis</i>	Ringed-billed gull	Gull	0	0	5
<i>Larus marinus</i>	Great black-backed gull	Gull	0	1	0
<i>Lophodytes cucullatus</i>	Hooded Merganser	Waterfowl	0	0	1
<i>Melospiza melodia</i>	Song sparrow	Non-waterbird	3	21	1
<i>Molothrus ater</i>	Brown-headed cowbird	Non-waterbird	0	1	0
<i>Nycticorax nycticorax</i> (V)	Black-crowned night-heron	Wader	0	4	12
<i>Passer domesticus</i> *	House sparrow	Non-waterbird	3	0	1
<i>Phalacrocorax auritus</i>	Double-crested cormorant	Waterfowl	0	0	8
<i>Picoides pubescens</i>	Downy woodpecker	Non-waterbird	2	2	0

Table 12. Birds observed in 2008 (one survey date) and 2009 (three survey dates) during NETN monitoring and park wildlife observations (38 survey dates). Partners in Flight status¹, if applicable, is indicated in parentheses after name (continued).

Scientific Name ³	Common Name	Category	Number of detections		
			NETN 2008	NETN 2009	2009 ² Park
<i>Pluvialis squatarola</i>	Black-bellied plover	Shorebird	0	0	4
<i>Poecile atricapillus</i>	Black-capped chickadee	Non-waterbird	0	1	0
<i>Quiscalus quiscula</i>	Common grackle	Non-waterbird	1	6	0
<i>Sayornis phoebe</i>	Eastern phoebe	Non-waterbird	0	6	0
<i>Sturnus vulgaris</i> *	European starling	Non-waterbird	2	12	5
<i>Thryothorus ludovicianus</i>	Carolina wren	Non-waterbird	0	2	0
<i>Troglodytes aedon</i>	House wren	Non-waterbird	0	1	1
<i>Turdus migratorius</i>	American robin	Non-waterbird	2	6	4
<i>Vireo olivaceus</i>	Red-eyed vireo	Non-waterbird	0	1	0
<i>Zenaida macroura</i>	Mourning dove	Non-waterbird	1	2	0
-	Unknown duck	n/a	0	0	12
-	Unknown gull	n/a	0	0	13
-	Unknown heron	n/a	0	0	2
-	Unknown shorebird	n/a	0	0	1
-	Unknown sparrow	n/a	0	0	1
<i>Number of species detected</i>			21	33	31

¹ Partners in Flight status: IA: High Continental Priority, High Regional Responsibility; IIA: High Regional Priority, High Regional Concern; V: Additional State Listed.

² Only data for birds observed in the six restoration zones in 2009 (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle area) are presented.

³ (*) Indicates non-native species.

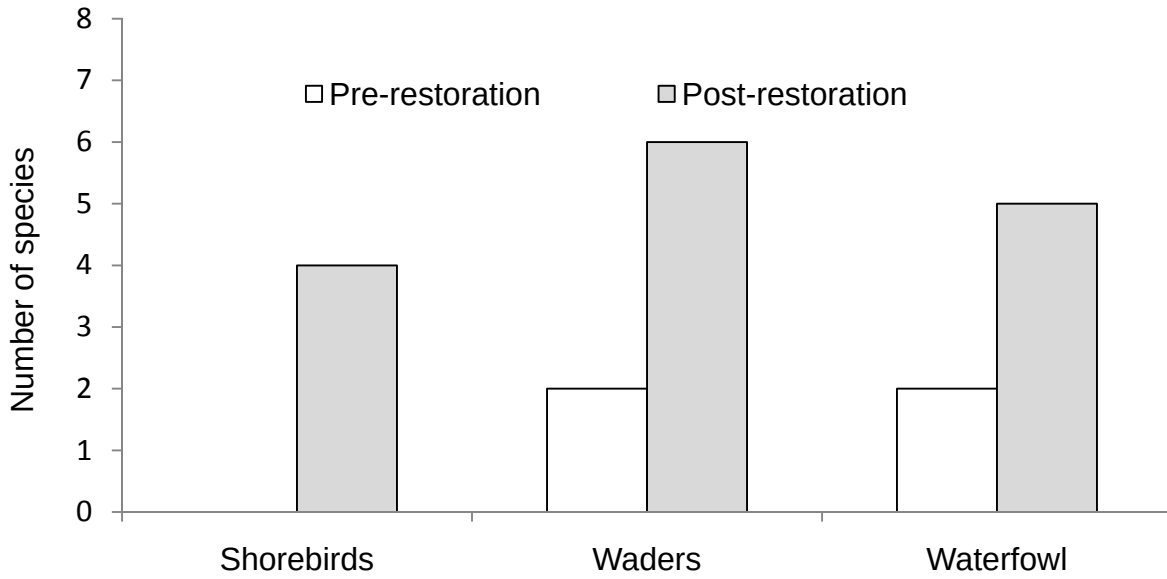


Figure 11. Number of waterbird species observed before (2002-2003) and after (2008-2009) the restoration of the turning basin and marsh.

Biological Variables: Mammals and other Wildlife

Methods: Mammals and other Wildlife

Sightings of mammals and other wildlife incidentally observed in the restoration area during the course of monitoring activities and sightings from other observers (e.g., park staff, consulting contractor) were recorded annually. Wildlife observations were also made during the systematic wildlife observation program that was implemented in 2009 as part of the post-restoration monitoring of the turning basin (McNiff and Albert 2010). Observations of wildlife were conducted during all tide conditions, times of day, and locations in and adjacent to the restoration area. Briefly, wildlife observations occurred at least once a day, three days a week for 30 to 90 minutes from June through September 2009 (38 observation days) (McNiff and Albert 2010). Wildlife observations were recorded in ten wildlife observation zones (Figure 10); however, only data from the restoration area (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle zones, Christine McNiff, National Park Service, personal communication) are presented herein.

Results: Mammals and other Wildlife

Three species of mammals (Eastern gray squirrel [*Sciurus carolinensis*], Northern American river otter [*Lontra canadensis*], and raccoon [*Procyon lotor*]) were observed in the restoration area in 2009. The Northern American river otter, observed in 2009, was not observed during the 2004 NETN Mammal Inventory at SAIR (Gilbert et al. 2008).

Two reptiles, common snapping turtle (*Chelydra serpentina*) and painted turtle (*Chrysemys picta*), were also observed in the restoration area in 2009.

Water Quality (monitored by NETN)

Water-quality is monitored at SAIR by the NETN as part of the National Park Service Inventory and Monitoring Program following the Lakes and Streams Water Quality Protocol (Lombard et al. 2006). A continuous-record streamflow-gage has been operated on the Saugus River just upstream of the park boundary by the USGS since 1994 (USGS 01102345 Saugus River at Saugus, MA). Temperature and specific conductance have been measured at this station continuously since 2001. In addition, the NETN monitors water quality annually in May and August in the Saugus River (at the USGS stream gage 01102345, latitude 42°28'05", longitude 71°00'27") and in the restored turning basin (William Gawley, National Park Service, personal communication).

Methods: NETN Water Quality monitoring

The methodology for NETN water quality monitoring is detailed in the Lakes and Streams Water Quality Protocol (Lombard et al. 2006). Briefly, water samples are taken twice per year during the summer and analyzed for nutrients by a laboratory at the University of Maine, and a YSI 600XL sonde is used to sample temperature, pH, conductivity, and dissolved oxygen (William Gawley, National Park Service, personal communication).

Results: NETN Water Quality monitoring

The NETN has monitored water quality at SAIR since 2006 (Table 13). Based on the NETN

water quality monitoring, temperature, dissolved oxygen, and pH of the restored turning basin are within acceptable ranges as determined by NETN Lakes and Streams Water Quality Protocol (Lombard et al. 2006). Elevated values for total nitrogen and total phosphorus have been observed in the turning basin and the Saugus River since monitoring was initiated (with the exception of total phosphorus in the Saugus River in 2006 and 2007) (Table 13).

Table 13. Water quality measurements from NETN monitoring (data courtesy of W. Gawley).

Parameter	Acceptable value or range ¹	2006	2007	2008	2009
Turning Basin²					
Temperature (°C) (warm water fishery)	<28.3	- ³	14.0	16.5	20.7
Dissolved oxygen (mg l ⁻¹)	>6	-	9.01	9.05	5.05
Specific conductance (uS cm ⁻¹)	None given	-	1000	644	13721
pH	6.5-8.3	-	7.44	7.54	7.23
Total Nitrogen (mg l ⁻¹)	<0.71	-	-	0.95	1.00
Total phosphorus (ug l ⁻¹)	<31.25	-	-	45.00	51.00
Saugus River (at USGS stream gage)					
Total Nitrogen (mg l ⁻¹)	<0.71	0.91	1.05	0.95	1.14
Total phosphorus (ug l ⁻¹)	<31.25	30.00	27.50	41.50	99.50

¹ Acceptable range or value after Lombard et al. 2006.

² The turning basin was restored in the fall of 2007, prior to that it was vegetated wetland area

³ "-" indicates data were not available

Physical Variables and Benthic Invertebrates (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). Additional rounds of sampling will be conducted in 2010 and 2012. The following is a brief summary of the analyses that were excerpted from the 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 12). 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 13). 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 2008, 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 14). 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 13). 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

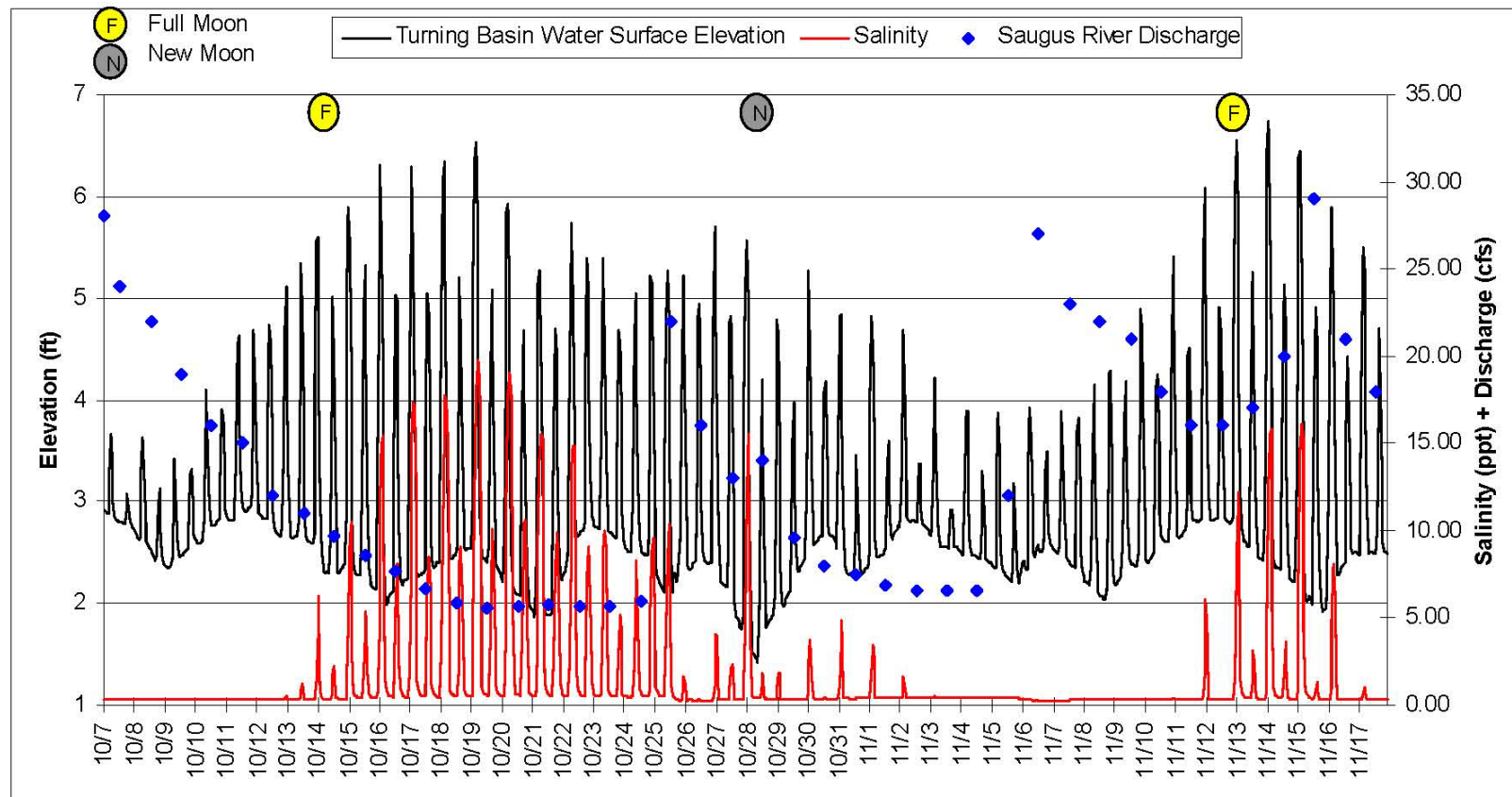


Figure 13. Water surface elevation and salinity at the turning basin in 2008 (figure excerpted from CH2MHill 2009).

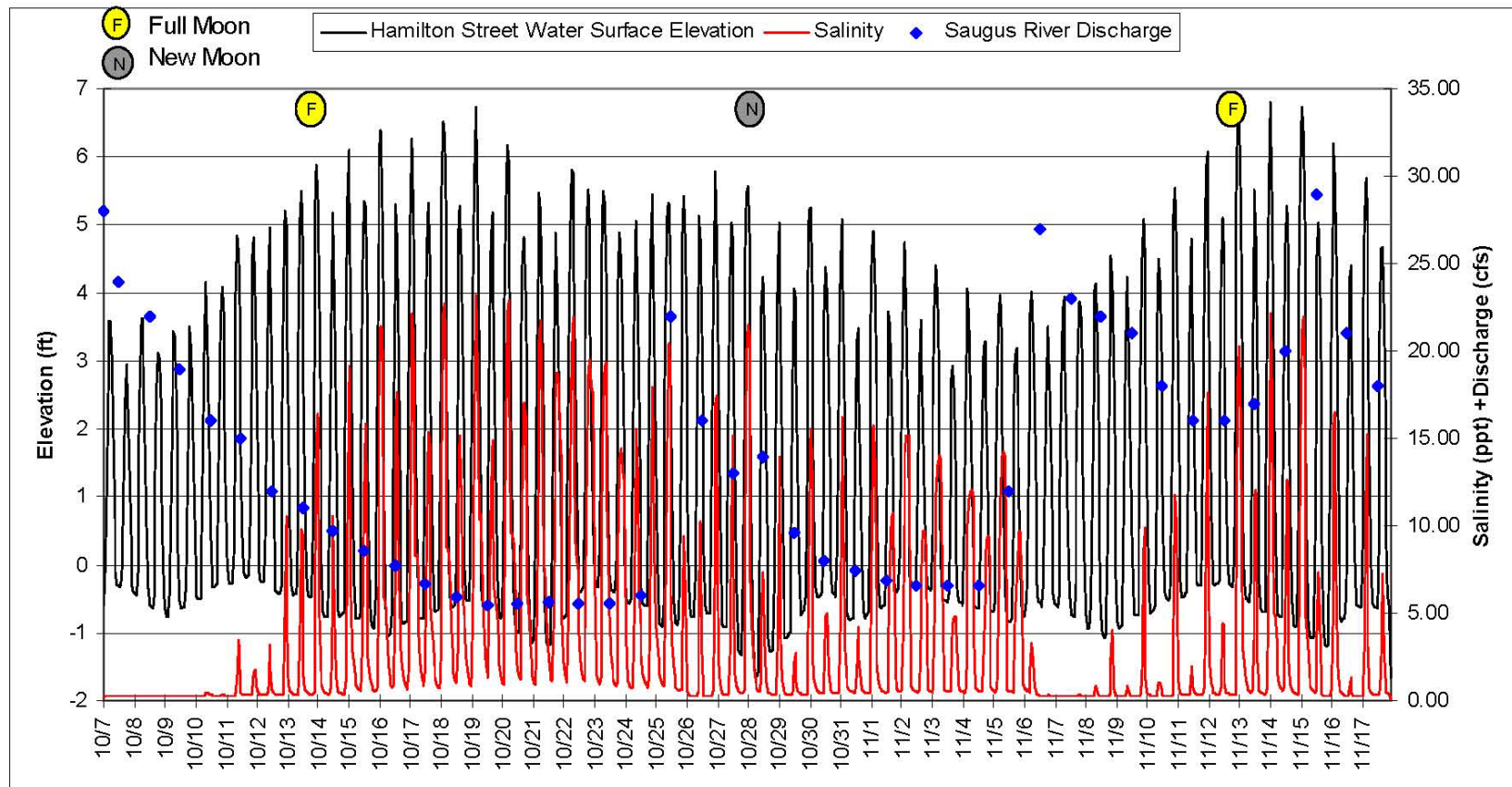


Figure 14. Water surface elevation and salinity at Hamilton Street in 2008 (figure excerpted from CH2MHill 2009).

if stream flow is less than approximately 10 cfs, saltwater will move upstream to the turning basin, except during neap tides.

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 14).

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 15, Table 14). 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 in the river channel portions of the cross-sections demonstrate the dynamic nature of the river, as some of the bedload sediment showed a redistribution between the 2004 and 2008 surveys (Figure 16). 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 in 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 14).

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. The sixth sediment sample was collected within the turning basin.

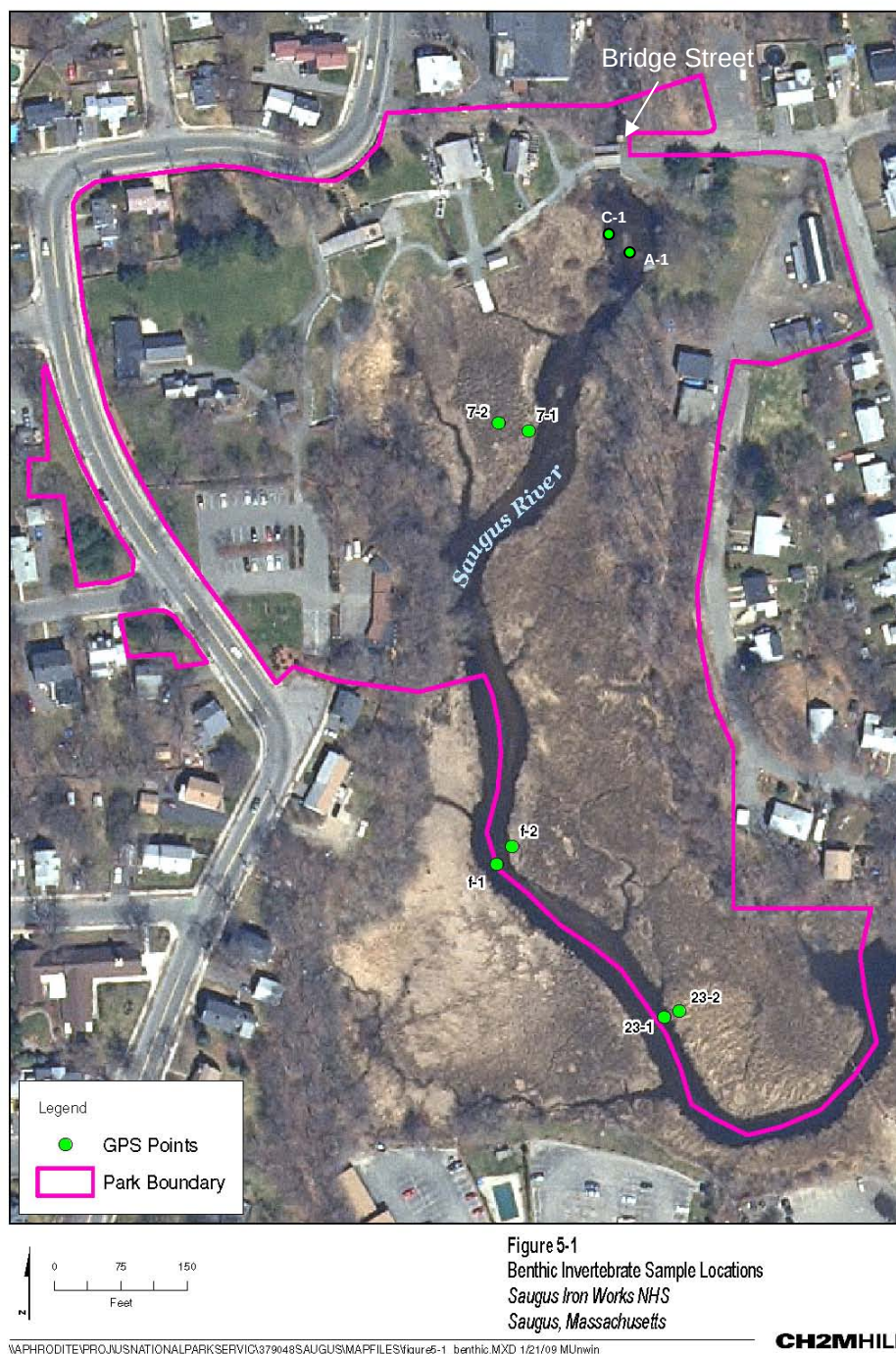


Figure 15. Pebble count and benthic invertebrate sampling stations in 2008 (figure excerpted and modified from CH2MHill 2009)

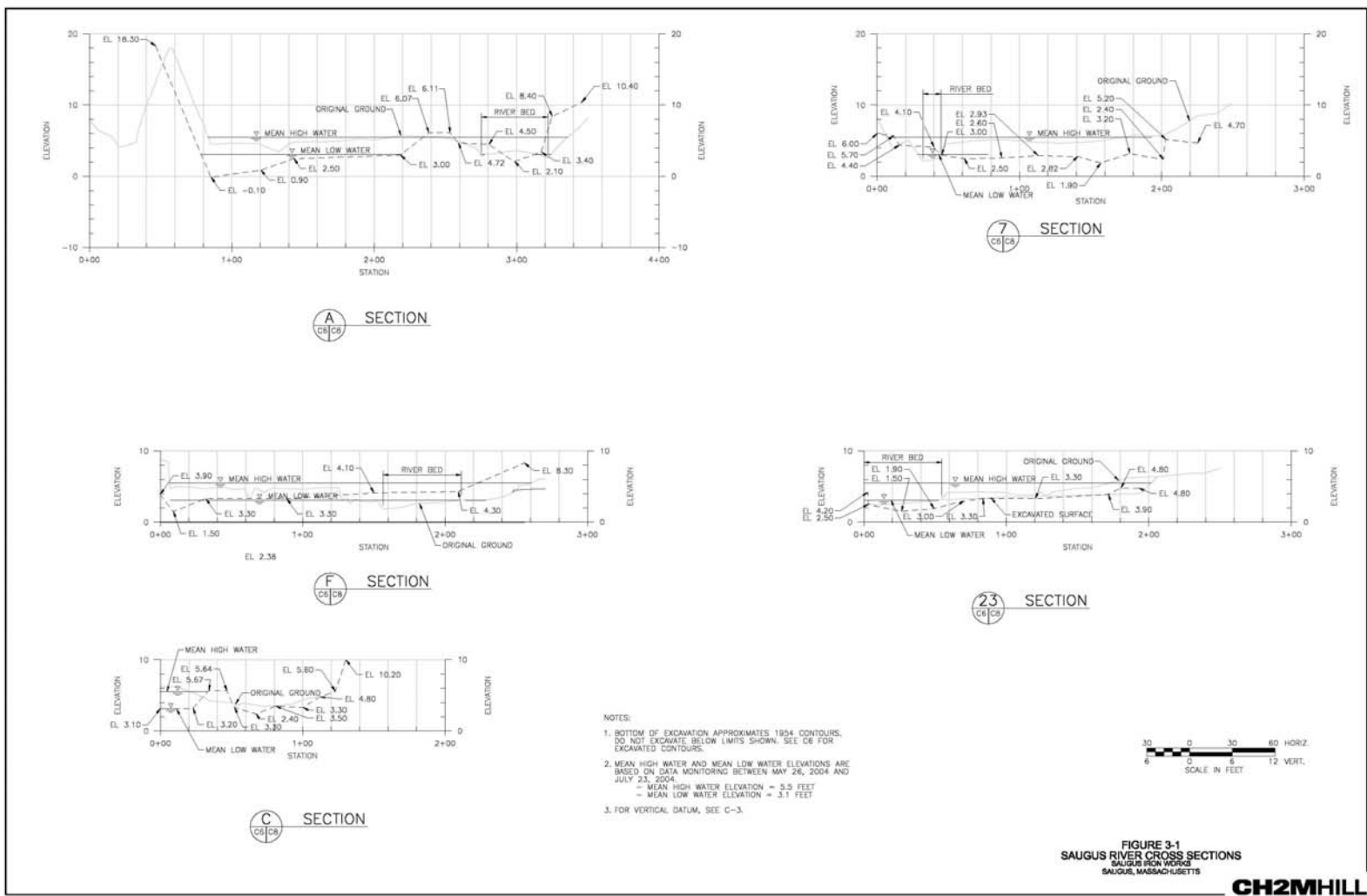


Figure 16. Cross-sections of river channel (figure excerpted from CH2MHill 2009).

Table 14. 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^{-1} . Only two PAH compounds (fluranthene and pyrene) were detected in sample S-A at concentrations of 204 and 207 ug kg^{-1} , 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 15).

One surface water sample was collected from the river channel and analyzed for PPMs in 2008. The only metal detected in the surface water sample was zinc at a concentration of 0.0271 mg l^{-1} , 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 15). Samples were collected from three cross-sections (7, 23, and F) 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 in^2 (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, commonly known as midges, were the most abundant organism in the 2008 benthic samples comprising 45% of the total number of organisms collected (Table 16). 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.

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 17). 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 (approximately 49% to 68%) in contrast to the subtidal samples where these organisms comprised only about 16% to 31% of the organisms present (Table 18). 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.

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 common organisms found in the sand substrate samples in 2004 were amphipods, which comprised more than 80% of the organisms in the samples (Table 18). 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 common 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

Table 15. 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).

Detected Metal	Average Concentration (mg kg ⁻¹)			
	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 16. Benthic invertebrate 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

Table 17. 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 18. Benthic invertebrate community at each of the sample stations, 2004 and 2008 sampling (data excerpted from CH2MHill 2009). Comparison with 2004 samples is only for the five common taxa (n/a notation).

Class or Order	Percent by Number of Organisms							
	2008 samples						2004 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	- ¹	-	-	-	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

¹“-” Indicates taxa not observed

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