

Final Report

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

Final report for 2008 to 2012 monitoring

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Executive Summary

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 four years (2008 to 2012) after the restoration. Data summaries included in this report describe the status of biotic (e.g., vegetation, nekton, bird, and mammal communities) and abiotic parameters (e.g., water quality). This is final report in a series of annual data reports (2008 to 2011) summarizing the monitoring associated with the restoration of the turning basin and the wetlands adjacent to the Saugus River at Saugus Iron Work National Historical Site (SAIR). The purpose of the annual data reports are to inform stakeholders of the progress of the restoration monitoring, summarize monitoring data, document pertinent findings, and to assist with any adaptive management plans or actions associated with the restoration. This report represents the final report for the restoration monitoring conducted from 2008 to 2012 and contains the complete data analyses and interpretation for the monitoring conducted by the University of Rhode Island (e.g., marsh vegetation, aquatic vegetation, nekton sampling, marsh surface tidal inundation), and when appropriate includes brief summaries of data collected by the National Park Service (e.g. wildlife observations, water quality, smelt egg abundance), CH2MHill consultants (tidal hydrology, water quality, river geomorphology), and Massachusetts Division of Marine Fisheries (e.g., smelt sampling).

The restoration of the historic turning basin and wetlands succeeded in removing invasive vegetation and establishing a tidal mud flat/low marsh along the Saugus River. After restoration, the dominant plant on the restored marsh was dwarf spike rush (*Eleocharis parvula*) a native plant tolerant of fresh to brackish water conditions. The upland edge of the restored marsh had a diverse assemblage of wetland plants. The dominant aquatic plant in the river was horned pondweed (*Zannichella palustris*) which has gradually increased in cover since the restoration. This aquatic plant is also commonly found in the turning basin; however, other types of aquatic vegetation were also found in the restored turning basin. Some invasive plants have been observed in the restoration area since 2008, with the most notable being purple loosestrife (*Lythrum salicaria*).

Since the restoration, the nekton community in the Saugus River has transitioned from a mostly freshwater community to a brackish-estuarine community. Common nekton include four-spine stickleback (*Apeltus quadracus*), white sucker (*Catostomus commersoni*), and mummichog (*Fundulus heteroclitus*). In the turning basin, young-of-the-year American eel (*Anguilla rostrata*) were the dominant nekton. A few individuals of freshwater species were still sampled each year (e.g., largemouth bass [*Micropterus salmoides*], redbfin pickerel [*Esox americanus americanus*]). Upstream movement of tidal estuarine water has occurred since the restoration, especially during high tides and periods of low river flow. The intrusion of saline water to the upper reach of the Saugus River at SAIR is likely a primary factor responsible for the change from a primarily freshwater nekton community (before the restoration) to a brackish/estuarine community in the years following the restoration.

The restored turning basin and marsh increased the amount of open water and created extensive tidal mud flats that provide habitat for a variety of wildlife, including waterbirds which have increased dramatically since the restoration. Other wildlife observed in the restoration area included four amphibian/reptile and eight mammal species.

Water quality of the Saugus River at SAIR is generally within acceptable limits, although temperature occasionally exceeded recommended thresholds for warm water fisheries and elevated values for nutrients (nitrogen and phosphorus) have been observed. In general, the concentration of contaminants in the river sediments has decreased since the restoration, although the Hilsenhoff Biotic Index for benthic invertebrate communities ranged from fair to very poor and indicated significant organic pollution was present in the Saugus River at SAIR.

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). A few hundred meters downstream of the park a partial impediment to natural estuarine tidal flow was the Hamilton Street weir. The weir, built in 1954 as part of the parkland that was a precursor to the National Historical Site, artificially maintained water levels at the iron works. 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 restoration 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 and this area is referred to as the restored wetland throughout this report. The Hamilton Street weir was removed in the fall of 2009, as a mitigation permit condition for the restoration of the turning basin waterfront and wetland. 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 a consulting firm, CH2MHill, studied the restoration area for five years (2008 to 2012), with some monitoring continuing for the long-term. Research and monitoring followed protocols developed and utilized by the NPS Northeast Coastal and Barrier Network, NPS Northeast Temperate Network (James-Pirri et al. 2012, James-Pirri et al. In Review), and the environmental firm CH2MHill (2005). The monitoring program was conducted cooperatively by CH2MHill, NPS staff, and the University of Rhode Island.

This report summarizes the initial four years of post-restoration (2008 to 2012, Table 1) monitoring for vegetation and nekton and park wildlife observations. Information from other monitoring efforts by collected by CH2MHill was included where appropriate. The complete CH2MHill monitoring reports that summarize physical variables (tidal hydrology, river geomorphology, sediment, and water quality) and benthic invertebrate community, collected in 2008, 2010, and 2012, are available upon request (CH2MHill 2009, 2011, 2013).

Information from the 2004 monitoring report of salt marsh vegetation and riverine 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 wetland vegetation and riverine nekton. Also included in this report are data from the NPS Northeast Temperate Network Breeding Landbird monitoring and water quality monitoring and Massachusetts Division of Marine Fisheries annual smelt and eel sampling on the Saugus River.

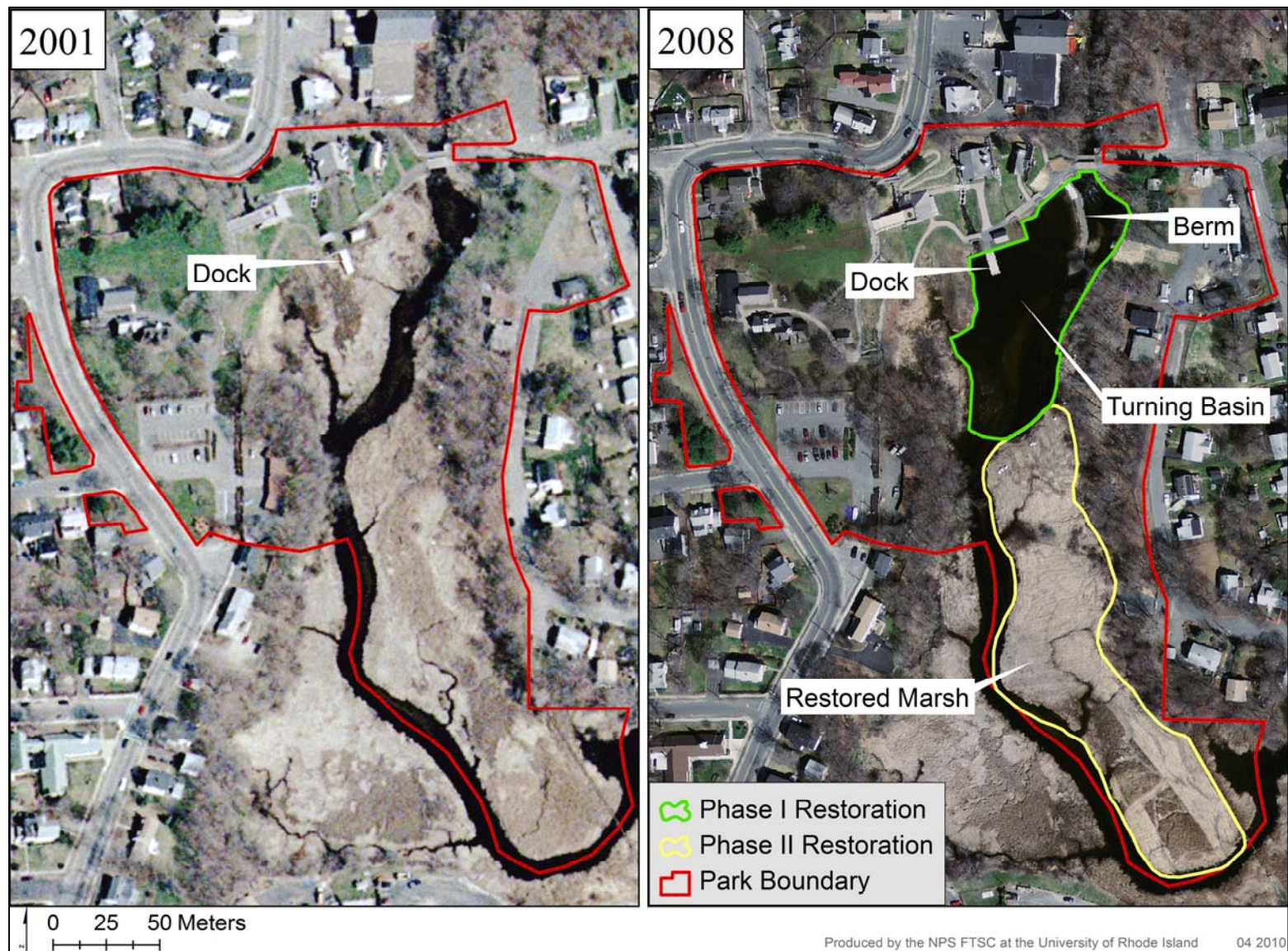


Figure 1. Aerial photographs before (left) and after (right) the Phase I of the restoration of the turning basin waterfront and wetland.

Table 1. Sampling dates and parameters for restoration monitoring at SAIR.

Sampling year and variable	Sampling date	Number of stations sampled
2004 (pre-restoration)		
Vegetation, turning basin	13 July 2004	16
Vegetation, southern marsh	13 July 2004	14
Aquatic vegetation, river	12 July 2004	12
Nekton, river throw traps	9 June & 4 August 2004	32 (16 stations on each date)
Nekton, river seine hauls	5, 11 August & 2 September 2004	7
2008		
Aquatic vegetation, turning basin	18 & 23 September 2008	11
Aquatic vegetation, river	18 & 23 September 2008	15
Nekton, river throw traps	23 September 2008	15
Nekton, river seine hauls	23 September 2008	6
Nekton, turning basin throw traps	18 September 2008	11
Nekton, turning basin seine hauls	18 September 2008	3
NETN avian monitoring	11 July 2008	3
NETN water quality monitoring	5 May & 20 Aug 2008	3
2009		
Vegetation, natural marsh	13 October 2009	17
Vegetation, restored wetland	11 September 2009	53
Aquatic vegetation, turning basin	15 July & 14-15 September 2009	21 (10-11 during each period)
Aquatic vegetation, river	15 July & 14-15 September 2009	27 (14 during each period)
Nekton, river throw traps	15 July & 14-15 September 2009	28 (14 during each period)
Nekton, river seine hauls	15 July & 14-15 September 2009	11 (5-6 during each period)
Nekton, turning basin throw traps	15 July & 14-15 September 2009	21 (10-11 during each period)
Nekton, turning basin seine hauls	15 July & 14-15 September 2009	6 (3 during each period)
NETN avian monitoring	4, 10, & 18 June 2009	3 (sampled each day)
NETN water quality monitoring	8 May & 20 Aug 2009	3
Park wildlife monitoring	June 3-Dec 26, 2009	48 observation days
2010		
Vegetation, natural marsh	19 September 2010	18
Vegetation, restored wetland	19 September 2010	48
Aquatic vegetation, turning basin	19 July & 1 September 2010	15 (7-8 during each period)
Aquatic vegetation, river	19 July & 1 September 2010	33 (16-17 during each period)
Nekton, river throw traps	19 July & 1 September 2010	33 (16-17 during each period)
Nekton, river seine hauls	19 July & 1 September 2010	12 (6 during each period)
Nekton, turning basin throw traps	19 July & 1 September 2010	15 (7-8 during each period)
Nekton, turning basin seine hauls	19 July & 1 September 2010	6 (3 during each period)
NETN avian monitoring	8 & 15 June 2010	3 (sampled each day)
NETN water quality monitoring	24 May & 10 Aug 2009	3
Park wildlife monitoring	May 1-Oct 3, 2010	19 observation days
2011		
Vegetation, natural marsh	8-9 September, 2011	18
Vegetation, restored wetland	8-9 September, 2011	47
Aquatic vegetation, turning basin	7-8 July & 6 September 2011	22 (10-12 during each period)
Aquatic vegetation, river	7-8 July & 6 September 2011	33 (16-17 during each period)
Nekton, river throw traps	7-8 July & 6 September 2011	33 (16-17 during each period)
Nekton, river seine hauls	7-8 July & 6 September 2011	12 (6 during each period)
Nekton, turning basin throw traps	7-8 July & 6 September 2011	22 (10-12 during each period)
Nekton, turning basin seine hauls	7-8 July & 6 September 2011	8 (4 during each period)
NETN avian monitoring	14 & 22 June, 2011	3 (sampled each day)
NETN water quality monitoring	Data not yet available	Data not yet available
Park wildlife monitoring	17 April-10 December, 2011	44 observations days & 89 incidental days

Table 1. Sampling dates and parameters for restoration monitoring at SAIR (continued).

Sampling year and variable	Sampling date	Number of stations sampled
2012		
Vegetation, natural marsh	5-6 September 2012	19
Vegetation, restored wetland	5-6 September 2012	54
Aquatic vegetation, turning basin	10-11 July & 6-7 September 2012	22 (9-13 during each period)
Aquatic vegetation, river	10-11 July & 6-7 September 2012	34 (17 during each period)
Nekton, river throw traps	10-11 July & 6-7 September 2012	34 (17 during each period)
Nekton, river seine hauls	10-11 July & 6-7 September 2012	11 (5-6 during each period)
Nekton, turning basin throw traps	10-11 July & 6-7 September 2012	22 (9-13 during each period)
Nekton, turning basin seine hauls	10-11 July & 6-7 September 2012	7 (3-4 during each period)
NETN avian monitoring	2012 (dates not given in annual report)	2 surveys
NETN water quality monitoring	16 May & 16 Aug, 2012	2
Park wildlife monitoring	18 February – 16 December 2012	56 observations days & 38 incidental days

Methods

Vegetation sampling

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 et al. In Review). According to the protocol, vegetation, including intertidal freshwater marsh and submerged aquatic vegetation, was 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 along transects throughout the restoration area and in the small natural marsh just south of the restored turning basin (James-Pirri et al. 2007). Species composition and species cover/abundance were recorded for each 1-m² plot. In addition to live vegetation, non-vegetative covers were also recorded (e.g., bare ground, open water, rock, wrack and litter). Estimates of percent cover were determined using a modified 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. The relative percent cover of each species was also calculated by converting Braun-Blanquet values to the midpoint of the percent range. Relative percent cover is the percentage of each species or cover type relative to all other species and cover types present in the marsh plots. The sum of the relative percent cover values for all species and cover types equals 100%. Conversion of the Braun-Blanquet values to their mid-point equivalent facilitates the interpretation of data summaries for natural resource staff.

Submerged aquatic vegetation cover in the river was estimated during nekton throw trap sampling. Percent cover of aquatic vegetation was estimated using a modified 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 in 2004 as part of the NPS Inventory and Monitoring Program (Table 1, Figure 2). Post-restoration vegetation monitoring occurred in the fall of 2009 to 2012 in the restored and planted wetland adjacent to the Saugus River and in two small natural wetland areas that were not part of the restored wetland (post-restoration vegetation monitoring did not occur in 2008 as the restored marsh was newly planted) (Figures 3 to 7).

Pre-restoration aquatic vegetation sampling was conducted in 2004 in the river (Table 1, Figure 2). Post-restoration monitoring of aquatic vegetation was conducted 2008 to 2012 with plots sampled in both the restored turning basin and the river (Table 1, Figures 3 to 7).

In 2011, at the request of NPS staff, a rapid survey was conducted to document plants observed on the streamside riparian berm (a previous survey was conducted by New

England Environmental Inc. in 2009). The berm area was surveyed in August 2011 by walking the area and recording observed plants with the aim of providing Park resource managers with a species list for the berm. The species list represents the majority of plants on the berm, but was not a complete list of all species that were present.

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. 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 (NPS 2005). 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 (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 because of its weak, floating stems. Due to low survivorship of all species from the 2008 planting, a full second round of 15,000 plantings was conducted in July 2010.

Nekton sampling

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. 2012). 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 and river system (Raposa et al. 2003). The sampling area was limited to locations with standing water present at ebbing tide conditions, but not higher than the top of the side walls of the trap (0.5-m high) (i.e., the deeper portions of the river channel and the deeper areas in the turning basin were excluded). The throw trap was an enclosure sampler that has excellent efficiency and provides quantitative, repeatable results (Kushlan 1981, Sogard and Able 1991, Rozas and Minello 1997). The trap had an open top and bottom, was 0.5-m in height and 1-m square, with sides covered by 3-mm wire mesh. The trap was thrown into water and captured 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 fitted snugly within the trap. The trap was considered empty when three successive attempts with the dip net produced no organisms (refer to James-Pirri et al. 2012 for complete details on gear and sampling protocol).

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 were not 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 were 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 and seine sampling was conducted in 2004 in the Saugus River (Table 1, Figure 2). Five of the seven seine hauls in 2004 were made immediately north of the Hamilton Street Bridge and these data were not included in the comparison of data from other years as they were further downstream than sampling occurred in later years. Post-restoration nekton sampling in the restored turning basin and Saugus River was conducted from 2008-2012 (Table 1, Figures 3 to 7).

Rainbow smelt and American eel sampling

The Massachusetts Division of Marine Fisheries (MA DMF), in conjunction with the Saugus River Watershed Council, has sampled rainbow smelt (*Osmerus mordax*) and young-of-year (YOY) American eel (*Anguilla rostrata*) at SAIR from 2005 to 2011. 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 (Figure 8). Nets were set overnight, facing upstream, three times per week from early March through late May (Chase et al. 2007). The smelt fyke net was located just south of the restored turning basin from 2005 to 2010. In 2011, the sampling location was re-located further south in the vicinity of the sewer pipe that crosses the Saugus River at the park's southern boundary (Figure 8). MA DMF moved the fyke net out of concerns that changes in the river's bottom topography from 2008 to 2010 decreased the gear's sampling efficiency and biased the data. MA DMF discontinued smelt sampling as of 2012.

In early spring of 2011 and 2012, the Saugus River at SAIR was monitored for the presence of smelt eggs (Welch and Albert 2011; LeBlanc 2012). The river was divided into sections and surveys were modeled after Chase (2006) (Figure 9). Briefly, the river bed substrate was sampled with mesh baskets and the substrate was examined for the presence of smelt eggs (Welch and Albert 2011; LeBlanc 2012). The presence or absence of eggs, viability (dead or viable eggs), and location were recorded. Once egg deposition was observed, sampling efforts were expanded both upstream and downstream until the limit of egg deposition was recorded. The objective of this sampling was to determine the extent of smelt egg deposition in the Saugus River, not to provide an estimate of egg densities.

American eel were sampled by the Saugus River Watershed Council annually using Sheldon elver traps from 2005 to 2011. Sampling occurred from the first week of April to the first week of June. These data have not been summarized as of June 2013.

Avian community

Birds were monitored in the park by volunteers (coordinated by NPS staff) following the guidelines of the NPS Northeast Temperate Network (NETN) Breeding Landbird

Monitoring Protocol (Faccio et al. 2010). Birds were monitored using variable circular plot (VCP) point counts at three observation stations (Figure 3 to Figure 8). At each station, all birds seen or heard were recorded during 10-minute point counts. Birds were surveyed twice annually, with replicates occurring within 7-14 days of each other (Faccio et al. 2010). The NETN does not differentiate the specific locale (e.g., restoration area, manicured lawn, etc.) where birds were observed, so these data may include detections outside of the restoration area. 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, Albert and Bloch 2011, Welch and Albert 2012, Albert et al. in prep.). Observations of wildlife were conducted during all tide conditions, times of day, and locations in and adjacent to the restoration area. Briefly, wildlife observation data were collected at a range of stationary points at least once a day, three days a week for 30 to 90 minutes from summer through early fall, and incidental observations were collected throughout the year (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) are presented herein.

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; Albert and Bloch 2011; Welch and Albert 2012; Albert et al. in prep). Birds were the focus of the observations, and thus there were no searches conducted for mammals, reptiles or amphibians (Albert et al. In prep.). Only wildlife observed in the restoration area (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle zones, Figure 10) are reported herein.

Tidal Inundation of the Restored marsh Surface

To determine frequency and depth of tidal inundation of the restored marsh, four HOBO® water loggers were deployed on the surface of the restored marsh from 6 September to 2 October, 2012. Water level loggers were laid horizontal on the marsh surface, secured with lawn staples, and were located in proximity to vegetation transects in the northern and southern portions of the restored marsh, at ~ 10 m and 30 m from the river's edge (Figure 11). All water level data were corrected for atmospheric pressure from a fifth logger placed outside staff offices at SAIR. Elevation of the marsh surface where the water loggers were located was obtained from an RTK GPS unit. RTK data were relative to NAVD88 and were corrected to mean low water (1.678 m) height using the tidal datum from Boston Harbor, Boston, MA, tide gage (NOAA-NOS 2013).

Water Quality (monitored by NETN and CH2MHill)

Water-quality was 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). Samples were collected annually in May and August in the Saugus River (at the USGS stream gage 01102345, latitude 42.4693861, longitude - 71.0071722) and in the restored turning basin (latitude 42.4688833, longitude - 71.0077000). A YSI 600XL sonde was used in situ to measure temperature, pH, specific conductance, and dissolved oxygen. Water samples were analyzed for acid neutralizing capacity (ANC), color, and nutrients at the University of Maine's Sawyer Environmental Chemistry Research Laboratory (Gawley 2012). From 2007 through 2012 nutrient chemistry samples were taken from both sites, although YSI sonde measurements were collected only at the turning basin, likely due to misinterpretation of protocol instructions (Gawley 2012, W. Gawley personal communication, email 5 April 2013). The USGS has operated a continuous-record stream flow-gage just upstream of tidal influence on the Saugus River since 1994. Instantaneous discharge data are available on the USGS website and are summarized in annual USGS data reports (USGS 01102345 Saugus River at Saugus, MA available at:

http://waterdata.usgs.gov/ma/nwis/nwisman/?site_no=01102345).

CH2MHill has operated a YSI sonde in the tidal portion of the Saugus River just south of the turning basin (Figure 11). These data are part of the joint monitoring of the restoration project and are presented in the progress reports produced by CH2MHill (2009, 2011, 2013).

Data Collected by CH2MHill (consultant)

CH2MHill, a consulting company, was contracted by the NPS to monitor additional parameters during the post-restoration period. Those parameters were:

1. Tidal hydrology (water surface elevation and salinity);
2. River geomorphology (cross-sectional dimensions and substrate composition);
3. Sediment and water quality; and
4. Benthic invertebrate community.

CH2MHill collected data on these parameters in 2008, 2010, and 2012 and produced summary monitoring reports that were submitted to the NPS (CH2MHill 2009, 2013, 2013). Sampling methodology and other details were provided in the CH2MHill reports, and were not repeated herein. When appropriate, results from the CH2MHill monitoring were included in this report.



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 2008.
Note: vegetation was not sampled in 2008.



Figure 4. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2009.



Figure 5. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2010.



Figure 6. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2011.



Figure 7. Location of post-restoration sampling stations at Saugus Iron Works NHS in 2012.

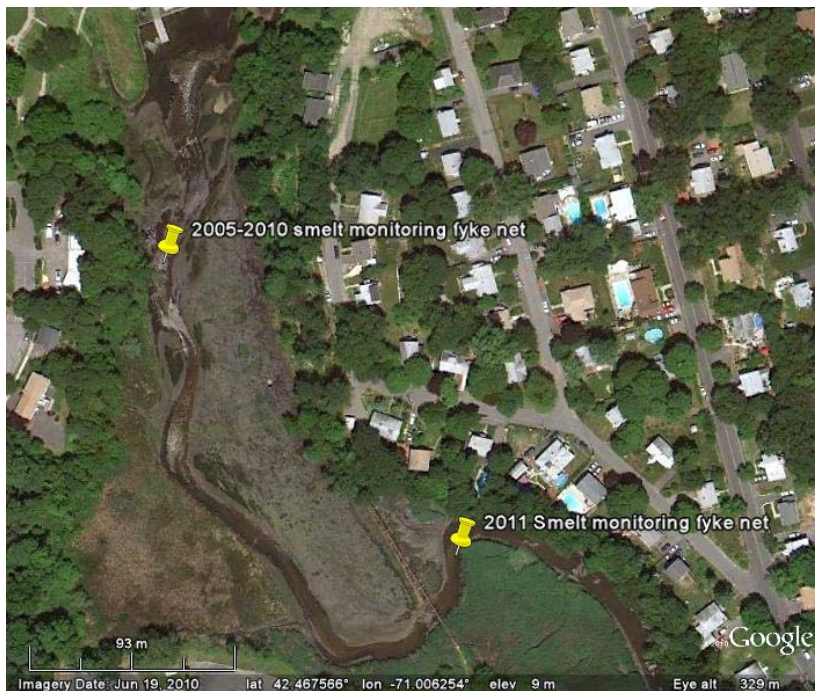


Figure 8. Locations of MA DMF smelt fyke net station.



Figure 9. Locations of smelt egg monitoring (map excerpted from Welch and Albert 2011).



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



Figure 11. Location of HOBO water level loggers (2012 deployment) and YSI water level and water quality sonde (CH2MHill deployment location in all years). Inset shows how HOBO loggers were deployed on marsh surface.

Statistical Analyses

Multivariate vegetation and nekton community data were analyzed using Analysis of Similarities (ANOSIM module, PRIMER version 6, Clarke and Gorley 2006) to evaluate responses of the communities to the restoration actions. ANOSIM is a non-parametric multivariate permutation analysis and was used to compare community composition and abundance between years. Pair-wise comparisons were defined *a priori* and a sequential Bonferroni¹ adjusted alpha of 0.05 (Rice 1989) was used to determine significance. Similarity percentages (SIMPER module) analysis was conducted for all significant pair-wise comparisons to determine individual species that contributed to dissimilarity in community structure. *A priori* comparisons included comparison of communities between sequential years (e.g., 2009 vs. 2010, 2010 vs. 2011, 2011 vs. 2012) and between the earliest year of data and the most recent year of data (e.g., 2008 vs. 2012) for each community.

¹ To test for significance using a sequential Bonferroni adjusted alpha, p-values are ranked from smallest to largest. Starting with the smallest p-value (P_1), significance is determined if $P_1 \leq \alpha/k$ where $\alpha=0.05$ and k is total number of comparisons, the significance for the second p-value (P_2) is evaluated as $P_2 \leq \alpha/(k-1)$, significance for the third smallest p-value (P_3) is evaluated at $P_3 \leq \alpha/(1+k-i)$, where i is the i^{th} comparison, or 3 in this example. This is continued for all comparisons until the inequality of $P_i \leq \alpha/(1+k-i)$ is not met (Rice 1989).

Results and Discussion

Vegetation in the restored wetland

Prior to restoration (2004 data) vegetation was present in the area of the former turning basin and 23 species were identified in this location. Narrowleaf cattail (*Typha angustifolia*) was the most common representing 21% of the vegetation community (Table 2). The southern wetland was dominated by common reed (*Phragmites australis*) and accounted for 61% of the vegetation community. Narrowleaf cattail was also abundant, comprising 12% of the vegetation. A total of 13 species were identified in southern wetland (Table 2). Several invasive plants were also observed during pre-restoration monitoring (refer to Invasive Vegetation section for more detail).

In 2009, the first year of post-restoration, 21 plant species were observed in the newly restored and planted southern wetland adjacent to the Saugus River; while in 2010, only 13 species were observed (Table 3). In 2011 and 2012, 26 and 38 species, respectively, were observed in this area. The differences in the number of observed species is likely due to the random placement of the vegetation plots in each year (as opposed to permanent plots). For example, the upland border of the restored wetland had high species diversity and the location and number of plots that randomly fell in this zone influenced the number of species recorded in each year (Figure 12).

The plant community in the restored wetland was different between all sequential years (e.g., 2009 vs. 2010, 2010 vs. 2011, and 2011 vs. 2012) and between the first year after restoration and the last year of data (2009 vs. 2012) (Table 4). Six cover types were primarily responsible for the differences among years: bare/algal mat, dwarf spikerush (*Eleocharis parvula*), horned pondweed (*Zannichella palustris*), wrack, and narrowleaf cattail. During the post-restoration monitoring period there was a general decrease in cover of bare/algal mat and narrowleaf cattail; while there was a concurrent increase in the cover of dwarf spike rush (Figure 13).

Since there was a dichotomy in the number of species observed in the restored wetland interior compared to the upland edge, the data were post-stratified into these groups and re-analyzed to determine if any trends could be elucidated. The analyses including only interior vegetation plots still indicated significant differences in the plant community among years (ANOSIM, Global R:0.30, $p < 0.0001$ for all sequential yearly comparisons). As in the previous analyses, differences in the communities between sequential years were due to slight changes in the cover of bare ground/algal mat, dwarf spikerush, narrowleaf cattail, and horned pondweed with the trends being similar to those observed in the analyses using all the plots (Figure 13).

The plant community was also different among sequential years in the upland edge of the restored wetland (ANOSIM, Global R: 0.19, $p < 0.05$). There were several species that contributed to the community differences between years with no dominant cover contributing a majority to the community dissimilarity, and it is likely that the observed differences were due to either 1) interannual variation; or 2) the random placement of plots in the different sampling years.

In all years the restored wetland was sparsely vegetated with a large amount of unvegetated bare/algal mat area (77% in 2009, 67% in 2010, 60% in 2011, and 49% in 2012) (Table 3, Figure 13, Figure 14). A common species in the restored wetland was dwarf spikerush that comprised ~11 to 25% of the total cover in 2010 to 2012. This is a native species with medium salinity tolerance, which has recruited to the restored wetland as it was not one of the planted species.

Vegetation in the natural marsh

The small natural wetland areas near the turning basin were a diverse community with 21 to 35 plant species present from 2009 to 2012 (Table 5). In general, the most common plant in these small natural wetlands was narrowleaf cattail (~35% cover) that was primarily located in the wetland on the western side of the river. Other common cover types were wrack (5-38% cover), bare ground (9-15% cover) and green arrow arum (*Peltandra virginica*) (~5% cover). In 2009, purple loosestrife (*Lythrum salicaria*), an invasive plant, comprised 6% of the total cover. Purple loosestrife was not observed in 2010, but was recorded in 2011 and 2012 (<1% and 2% of the total cover, respectively). The majority of other species had a percent of total cover of less than 5% (Table 5).

Vegetation in the riparian berm

The streamside riparian berm was planted in 2008. In 2009, five of the seven planted species were observed with another 26 species recorded (New England Environmental, Inc.) (Table 6). A storm event in April 2010, resulted in unusually high river flow, and washed out the majority of the berm plant community. In 2011, 69 species were recorded on the berm, including four that were on the 2008 planting list: speckled alder (*Alnus incana* spp. *rugosa*), tussock sedge (*Carex stricta*), silky dogwood (*Cornus amomum*), and swamp rose (*Rosa palustris*). Eight invasive species were observed on the berm in 2011 (Table 6) (refer to Invasive Vegetation section for more detail).

Table 2. Species, average Braun-Blanquet¹ score and relative percent cover (in parentheses) for vegetation sampled at Saugus Iron Works NHS in 2004 (pre-restoration). Invasive or potentially invasive plants are indicated in bold type.

Scientific Name	Common Name	2004 Turning Basin (n=16 plots)	2004 Southern marsh (n=14 plots)
<i>Bidens tripartita</i>	Estuary beggarticks	0.1 (0.1)	-
<i>Calamagrostis canadensis</i>	Bluejoint reedgrass	0.1 (0.2)	-
<i>Callitriche</i> species ²	Water starwort species	0.1 (<0.1)	-
<i>Calystegia sepium</i>	Hedge bindweed	1.3 (7.5)	0.4 (6.5)
<i>Eupatorium perfoliatum</i>	Common boneset	0.4 (3.8)	-
<i>Eupatorium purpureum</i>	Sweetscented joeypyeweed	0.3 (2.7)	-
<i>Impatiens capensis</i>	Jewelweed	1.3 (5.8)	0.1 (0.1)
<i>Juncus effusus</i>	Common rush	0.2 (1.1)	-
<i>Lythrum salicaria</i>	Purple loosestrife	0.6 (2.5)	0.8 (6.1)
<i>Mikania scandens</i>	Climbing hempvine	0.5 (0.9)	0.1 (0.2)
<i>Peltandra virginica</i>	Green arrow arum	1.1 (7.4)	0.6 (5.1)
<i>Phalaris arundinacea</i>	Reed canary grass	0.4 (3.0)	0.3 (2.8)
<i>Phragmites australis</i>	Common reed	0.2 (1.1)	4.1 (61.5)
<i>Polygonum punctatum</i>	Dotted smartweed	0.1 (0.2)	0.1 (0.2)
<i>Polygonum</i> species	<i>Polygonum</i> species	0.3 (0.5)	0.1 (0.2)
<i>Pontederia cordata</i>	Pickernelweed	0.3 (0.4)	0.1 (0.2)
<i>Robinia pseudoacacia</i>	Black locust	0.3 (4.5)	-
<i>Rosa multiflora</i>	Multiflora rose	1.0 (15.4)	-
<i>Rumex crispus</i>	Curly dock	0.1 (0.2)	-
<i>Solanum americanum</i>	American black nightshade	0.1 (<0.1)	-
<i>Sparganium americanum</i>	American bur-reed	0.3 (1.3)	0.1 (0.2)
<i>Toxicodendron radicans</i>	Poison ivy	0.1 (0.2)	0.3 (2.8)
<i>Typha angustifolia</i>	Narrowleaf cattail	2.4 (21.4)	1.6 (12.3)
Non-vegetative covers			
Bare ground/algal mat	Bare ground/algal mat	1.4 (13.3)	0.2 (1.1)
Litter/wrack	Litter/wrack	1.0 (6.3)	0.3 (0.4)

¹ Braun-Blanquet cover class scale (0: absent; 1: <1%; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%). “-” indicates species was not present.

² *Callitriche* species originally identified as *C. terrestris* (H. Leeson, Rhode Island Natural History Survey, October 2009), but was confirmed to be *C. stagnalis* in 2012 (identified by P. Sharpe and R. Baranowski, September 2012).

Table 3. Species, average Braun-Blanquet¹ score and relative percent cover (in parentheses) for vegetation sampled at Saugus Iron Works NHS from 2009-2012 (post-restoration) in the restored wetland. Also indicated are species planted in 2008 and planting zone² for the restored wetland, and presence in August 2009 during site visit by New England Environmental, Inc. Location where species were observed (wetland interior or upland edge) is also indicated. Invasive or potentially invasive plants are indicated in bold type.

Scientific Name	Common Name	Average Braun-Blanquet score (percent of total cover)	Zone ² (if planted) and presence in 2009 (V, +, or -)	Plots where observed (I: interior, E: edge)	Average Braun-Blanquet ¹ score (percent of total cover)			
					2009 (n=53 plots)	2010 (n=48 plots)	2011 (n=47 plots)	2012 (n=54 plots)
<i>Acorus americanus</i>	Sweet flag		HM (+)	E, I	<0.1 (0.06)	<0.1 (0.07)	0.1 (0.77)	0.2 (0.66)
<i>Alisma subcordatum</i>	American water plantain		-	E, I	-	-	0.1 (0.17)	<0.1 (0.06)
<i>Aster</i> species	Aster species		-	I	<0.1 (0.01)	-	-	-
<i>Atriplex cristata</i>	Crested saltbush		-	E	-	0.1 (0.44)	0.1 (0.29)	0.1 (0.32)
<i>Atriplex patula</i>	Spear saltbush		-	E	-	-	-	<0.1 (0.05)
<i>Butomus umbellatus</i>³	Flowering rush		-	E, I	-	-	0.1 (0.18)	-
<i>Callitriche</i> species ⁴	Water starwort species		(V)	E, I	0.9 (2.80)	-	2.0 (7.09)	4.4 (1.35)
<i>Carex lacustris</i>	Hairy sedge		-	E	-	<0.1 (0.07)	-	-
<i>Cicuta maculata</i>	Spotted water hemlock		-	E	-	-	<0.1 (0.05)	-
<i>Cyperus flavescens</i>	Yellow flatsedge		-	E, I	-	-	-	0.1 (0.17)
<i>Cyperus</i> species	Flatsedge species		-	E	-	-	-	0.1 (0.59)
<i>Eleocharis parvula</i>	Dwarf spikerush		-	E, I	0.1 (0.57)	1.8 (11.27)	2.6 (16.07)	3.6 (25.70)
<i>Eleocharis</i> species	<i>Eleocharis</i> species		-	E	<0.1 (0.07)	-	-	-
<i>Epilobium coloratum</i>	Purpleleaf willowherb		(V)	-	-	-	-	-
<i>Equisetum arvense</i>	Field horsetail		-	E	-	-	-	<0.1 (0.22)
<i>Geum canadense</i>	White flowered avens		(V)	-	-	-	-	-
<i>Hibiscus moscheutos</i>	Crimson-eyed rosemallow		HM (-)	E, I	<0.1 (0.30)	-	-	-
<i>Impatiens capensis</i>	Jewelweed		-	E	-	-	-	<0.1 (0.05)
<i>Iris versicolor</i>	Blue flag		HM (+)	-	-	-	-	-
<i>Iris</i> species	<i>Iris</i> species		-	E	-	<0.1 (0.07)	-	-
<i>Juncus effusus</i> ⁵	Common rush		HM (+)	E	-	-	0.1 (0.36)	-
<i>Juncus</i> species	<i>Juncus</i> species		-	E, I	0.2 (0.51)	-	-	-
<i>Leersia oryzoides</i>	Rice cut grass		(V)	E	-	-	<0.1 (0.05)	<0.1 (0.09)

Table 3. Species, average Braun-Blanquet¹ score and relative percent cover (in parentheses) for vegetation sampled at Saugus Iron Works NHS from 2009-2012 (post-restoration) in the restored wetland. Also indicated are the planted native species and planting zone², for species planted in the restored wetland in 2008, and presence in August 2009 during site visit by New England Environmental, Inc. Location where species was observed (wetland interior or upland edge) is also indicated. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	Average Braun-Blanquet score (percent of total cover)	Zone ² (if planted) and presence in 2009 (V, +, or -)	Plots where observed (I: interior, E: edge)	Average Braun-Blanquet ¹ score (percent of total cover)			
					2009 (n=53 plots)	2010 (n=48 plots)	2011 (n=47 plots)	2012 (n=54 plots)
<i>Lythrum salicaria</i>	Purple loosestrife		(V)	E	<0.1 (0.29)	-	0.1 (0.41)	0.2 (0.53)
<i>Morus rubra</i>	Red mulberry		-	E	-	-	-	<0.1 (0.22)
<i>Panicum dichotomiflorum</i>	Fall panicgrass		-	E	-	<0.1 (0.07)	0.1 (0.29)	0.2 (0.86)
<i>Panicum virgatum</i>	Switchgrass		HM (-)	-	-	-	-	-
<i>Peltandra virginica</i>	Green arrow arum		LM (+)	E, I	<0.1 (0.02)	-	<0.1 (0.05)	-
<i>Persicaria amphibia</i>	Water knotweed		-	E	-	-	0.1 (0.29)	-
<i>Persicaria hydropiperoides</i>	Swamp smartweed		-	E, I	<0.1 (0.12)	-	-	<0.1 (0.05)
<i>Persicaria maculosa</i>	Spotted ladythumb		-	E	-	-	-	0.1 (0.09)
<i>Phragmites australis</i>	Common reed		(V)	E	-	-	-	<0.1 (0.05)
<i>Plantago major</i>	Common plantain		-	E	-	-	-	0.1 (0.26)
<i>Plantago virginica</i>	Virginia plantain		-	E	-	-	<0.1 (0.05)	-
<i>Pluchea odorata</i> var. <i>succulenta</i>	Saltmarsh fleabane		(V)	E, I	-	-	-	0.2 (0.46)
<i>Poa pratensis</i>	Kentucky bluegrass		-	E	-	-	-	0.1 (0.22)
<i>Polygonum</i> species	<i>Polygonum</i> species		(V)	-	-	-	-	-
<i>Pontederia cordata</i>	Pickerselweed		HM (-)	E, I	0.3 (0.26)	-	-	0.2 (1.52)
<i>Potamogeton crispus</i>	Curly pondweed		-	I	<0.1 (0.70)	-	-	-
<i>Ranunculus sceleratus</i>	Cursed buttercup		(V)	-	-	-	-	-
<i>Rorippa palustris</i> var. <i>hispida</i>	Hispid yellowcress		(V)	-	-	-	-	-
<i>Rumex crispus</i>	Curly dock		-	E	-	-	<0.1 (0.05)	0.1 (0.05)
<i>Sagittaria graminea</i>	Grassy arrowhead		HM (-)	-	-	-	-	-
<i>Sagittaria latifolia</i>	Broadleaf arrowhead		HM (+)	E, I	<0.1 (0.34)	-	<0.1 (0.05)	<0.1 (0.05)
<i>Sagittaria rigida</i>	Deep water duck potato		LM (+)	-	-	-	-	-

Table 3. Species, average Braun-Blanquet¹ score and relative percent cover (in parentheses) for vegetation sampled at Saugus Iron Works NHS from 2009-2012 (post-restoration) in the restored wetland. Also indicated are the planted native species and planting zone², for species planted in the restored wetland in 2008, and presence in August 2009 during site visit by New England Environmental, Inc. Location where species was observed (wetland interior or upland edge) is also indicated. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	Average Braun-Blanquet score (percent of total cover)	Zone ² (if planted) and presence in 2009 (V, +, or -)	Plots where observed (I: interior, E: edge)	Average Braun-Blanquet ¹ score (percent of total cover)			
					2009 (n=53 plots)	2010 (n=48 plots)	2011 (n=47 plots)	2012 (n=54 plots)
<i>Sambucus nigra</i> spp. <i>canadensis</i>	American black elderberry	-	-	E	-	-	-	0.1 (0.22)
<i>Samolus valerandi</i> ,	Water-pimpernel	-	-	E	-	-	<0.1 (0.06)	0.4 (2.19)
<i>Schoenoplectus acutus</i>	Hardstem bulrush	LM (+)	E, I		0.4 (0.37)	-	-	-
<i>Schoenoplectus pungens</i>	Common threesquare	HM (+)	E, I		0.2 (0.41)	0.3 (1.47)	0.2 (0.43)	0.4 (1.80)
<i>Schoenoplectus tabernaemontani</i>	Softstem bulrush	HM (-)	I		-	-	0.1 (0.12)	-
<i>Scirpus cyperinus</i>	Woolgrass	-	E		-	-	-	0.1 (0.54)
<i>Sium suave</i>	Hemlock waterparsnip	HM (+)	E		<0.1 (0.02)	-	-	-
<i>Solanum dulcamara</i>	Climbing nightshade	(V)	-		-	-	-	<0.1 (0.05)
<i>Solidago patula</i>	Roundleaf goldenrod	-	E		-	-	-	0.1 (0.22)
<i>Sonchus oleraceus</i>	Common sowthistle	-	E		-	-	-	<0.1 (0.05)
<i>Spartina pectinata</i>	Prairie cordgrass	HM (+)	I		-	0.1 (0.36)	-	-
<i>Symphyotrichum puniceum</i>	Purplestem aster	-	E		-	-	-	<0.1 (0.05)
<i>Symphyotrichum subulatum</i>	Eastern annual saltmarsh aster	-	E		-	-	0.1 (0.29)	0.2 (0.86)
<i>Trifolium repens</i>	White clover	(V)	-		-	-	-	-
<i>Toxicodendron radicans</i>	Poison Ivy	-	E		-	-	-	<0.1 (0.05)
<i>Typha angustifolia</i>	Narrowleaf cattail	-	E, I		1.5 (7.24)	0.1 (0.47)	0.9 (2.04)	0.3 (0.26)
Unknown forb seedling	Unknown forb seedling	-	E		<0.1 (0.02)	<0.1 (0.01)	-	-
Unknown grass	Unknown grass	-	E, I		0.2 (1.6)	-	-	-
Unknown rush	Unknown rush	-	E		-	<0.1 (0.01)	-	-
Unknown sedge	Unknown sedge	-	E		-	0.1 (0.51)	-	-
<i>Verbena hastata</i>	Blue vervain	(V)	-		-	-	-	-
<i>Viburnum dentatum</i>	Arrow-wood viburnum	-	E		-	-	<0.1 (0.05)	<0.1 (0.05)

Table 3. Species, average Braun-Blanquet¹ score and relative percent cover (in parentheses) for vegetation sampled at Saugus Iron Works NHS from 2009-2012 (post-restoration) in the restored wetland. Also indicated are the planted native species and planting zone², for species planted in the restored wetland in 2008, and presence in August 2009 during site visit by New England Environmental, Inc. Location where species was observed (wetland interior or upland edge) is also indicated. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	Average Braun-Blanquet score (percent of total cover)	Zone ² (if planted) and presence in 2009 (V, +, or -)	Plots where observed (I: interior, E: edge)	Average Braun-Blanquet ¹ score (percent of total cover)			
					2009 (n=53 plots)	2010 (n=48 plots)	2011 (n=47 plots)	2012 (n=54 plots)
<i>Zannichella palustris</i>	Horned pondweed		(V)	E, I	1.3 (6.35)	1.2 (10.61)	1.3 (5.81)	1.3 (4.40)
<i>Zizania aquatica</i>	Wild rice		LM (-)	-	-	-	-	-
Total species					21	13	23	37
Non vegetative covers								
Algal mat only ⁶	Algal mat only		-	E, I	Not defined as a cover	3.3 (58.55) ⁷	3.9 (50.73) ⁷	4.0 (42.13) ⁷
Bare ground/algal mat ⁶	Bare ground and algal mat		-	E, I	5.6 (77.31)	4.0 (66.55) ⁸	4.6 (59.66) ⁸	4.4 (48.47) ⁸
Bare ground only ⁶	Bare ground only		-	E, I	Not defined as a cover	3.5 (56.26) ⁷	3.3 (41.85) ⁷	2.9 (29.40) ⁷
Dead, <i>Carex lacustris</i>	Dead hairy sedge		-	E	-	0.1 (0.36)	-	-
Dead, woody plant	Dead woody plant		-		-	<0.1 (0.01)	-	-
Filamentous algae	Filamentous algae		-	I	-	0.1 (0.97)	-	-
Litter/wrack	Litter/wrack		-	E, I	0.6 (2.03)	1.4 (5.29)	1.5 (3.34)	1.9 (6.60)
Rock	Rock		-	E	-	0.4 (1.39)	0.2 (1.95)	0.2 (0.53)
Water	Water			I	-	-	-	1.0 (0.22)

¹ Braun-Blanquet cover class scale (0; 1: <1; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%). "-" indicates species was not present.

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 *Butomus umbellatus* is listed as potentially invasive in CT.

⁴ *Callitriche* species originally identified as *C. terrestris* (H. Leeson, Rhode Island Natural History Survey, October 2009), but was confirmed to be *C. stagnalis* in 2012 (identified by P. Sharpe and R. Baranowski, September 2012).

⁵ 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.).

⁶ In 2009, bare ground and algal mat were recorded as one cover type. In 2010 to 2012, at the request of NPS staff, the cover of only algal mat and only bare ground in addition to the combined cover of bare ground and algal mat were recorded.

⁷ Percent calculated after excluding the combined cover of bare ground/algal mat.

⁸ Percent calculated after excluding the covers of algal mat only and bare ground only.

Table 4. ANOSIM results comparing the vegetation community in the restored marsh among years (2009 to 2012). Only comparisons of interest (e.g., comparison of sequential years and the first year data vs. last year of data are shown).

Comparison	R Statistic	p-value	Significant
Restored marsh, all areas¹			
2012 vs. 2011	0.0800	0.00020	Yes
2011 vs. 2010	0.150	0.00001	Yes
2010 vs. 2009	0.280	0.00001	Yes
2009 vs. 2012	0.376	0.00001	Yes
Restored marsh, interior area¹			
2012 vs. 2011	0.147	0.00001	Yes
2011 vs. 2010	0.211	0.00001	Yes
2010 vs. 2009	0.359	0.00001	Yes
2009 vs. 2012	0.549	0.00001	Yes
Restored marsh, upland edge area¹			
2012 vs. 2011	0.260	0.0050	Yes
2011 vs. 2010	0.149	0.0140	Yes
2010 vs. 2009	0.251	0.0006	Yes
2009 vs. 2012	0.644	0.00003	Yes

¹ Significance based on sequential Bonferroni adjusted alpha (Rice 1989) at $\alpha = 0.05$ for four pair-wise comparisons.

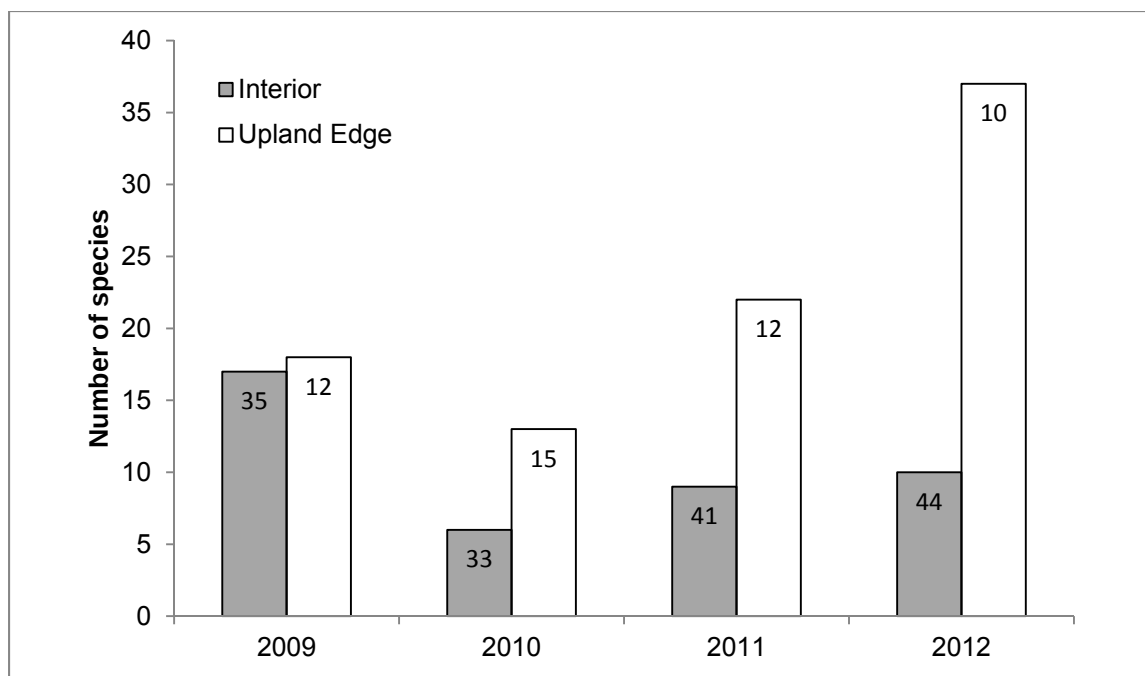


Figure 12. Number of species observed in the restored wetland interior and along the upland edge. The number of plots sampled in each area is indicated inside the bars.

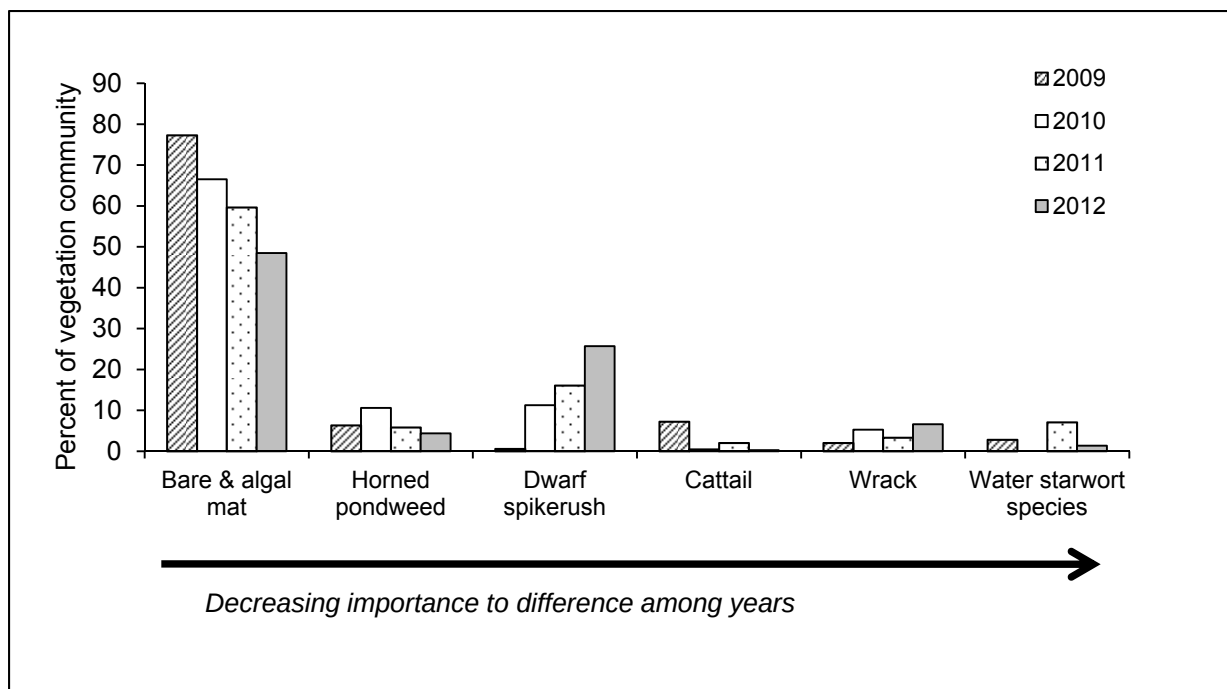


Figure 13. Species contributing to more than 70% of the community dissimilarity among years in the restored wetland.



Figure 14. Photos of the restored wetland in 2009 to 2012.

Table 5. Species, average Braun-Blanquet score and relative percent cover (in parentheses) for vegetation sampled in the natural marsh at Saugus Iron Works NHS from 2009-2012. Invasive or potentially invasive plants are indicated in bold type.

Scientific Name	Common Name	Average Braun-Blanquet ¹ score (percent of total cover)			
		2009 Natural marsh (n=17 plots)	2010 Natural marsh (n=18 plots)	2011 Natural marsh (n=18 plots)	2012 Natural marsh (n=19 plots)
<i>Acalypha virginica</i>	Three-seeded mercury	-	-	-	0.1 (0.12)
<i>Acer negundo</i>	Boxelder	0.1 (0.16)	-	-	-
<i>Acorus americanus</i>	Sweet flag	0.1 (0.16)	0.7 (3.82)	1.1 (5.93)	0.5 (2.24)
<i>Alisma subcordatum</i>	American water plantain	-	-	0.4 (2.47)	0.2 (0.06)
<i>Alliaria petiolata</i>	Garlic mustard	-	-	0.1 (0.02)	-
<i>Alnus incana</i>	Gray alder	-	-	-	0.3 (3.50)
<i>Alnus serrulata</i>	Hazel alder	-	0.4 (2.99)	-	-
<i>Apios americana</i>	Groundnut	0.4 (2.18)	-	0.5 (1.13)	0.2 (0.62)
<i>Aster lanceolatus</i> var. <i>lanceolatus</i>	White panicle aster	0.1 (0.16)	-	-	-
<i>Aster novi-belgii</i>	New York aster	0.2 (0.32)	0.1 (0.14)	-	-
<i>Aster</i> species	<i>Aster</i> species	0.2 (0.32)	0.2 (1.72)	-	-
<i>Bidens frondosa</i>	Devil's beggartick	0.5 (1.81)	-	-	-
<i>Callitriche</i> species ²	Water starwort species	-	-	0.4 (0.44)	-
<i>Calystegia sepium</i>	Hedge bindweed	0.1 (0.16)	-	0.1 (0.14)	-
<i>Carex lacustris</i>	Hairy sedge	-	0.1 (0.14)	0.3 (1.43)	-
<i>Cicuta maculata</i>	Spotted water hemlock	-	-	0.1 (0.14)	-
<i>Dulichium arundinaceum</i>	Threeway sedge	-	-	0.1 (0.14)	-
<i>Dysphania ambrosioides</i>	Mexican tea	-	0.3 (2.88)	-	0.1 (0.02)
<i>Echinochloa muricata</i>	Rough barnyardgrass	0.1 (0.03)	-	--	-
<i>Eleocharis parvula</i>	Dwarf spikerush	-	-	0.1 (0.14)	0.1 (0.12)
<i>Eutrochium dubium</i>	Coastal plain joeypyeweed	-	-	-	0.2 (1.51)
<i>Eutrochium maculatum</i>	Spotted joeypyeweed	0.2 (0.19)	-	-	-
<i>Geum macrophyllum</i>	Largeleaf avens	0.1 (0.16)	-	-	-
<i>Iris</i> species	<i>Iris</i> species	-	-	0.1 (0.14)	-
<i>Juncus effusus</i>	Common rush	-	-	0.1 (0.02)	-
<i>Leersia oryzoides</i>	Rice cut grass	-	-	0.1 (0.14)	0.1 (0.12)
<i>Lycopus americanus</i>	American water horehound	-	0.4 (2.42)	-	<0.1 (0.02)
<i>Lycopus europaeus</i>	Gypsywort	0.5 (3.00)	-	-	-
<i>Lythrum salicaria</i>	Purple loosestrife	1.1 (6.57)	-	0.2 (0.71)	0.5 (2.27)
<i>Mikania scandens</i>	Climbing hempvine	0.6 (2.5)	-	-	0.4 (1.75)
<i>Nasturtium officinale</i> ³	Watercress	0.2 (0.32)	-	-	-
<i>Oenothera biennis</i>	Common evening primrose	0.4 (1.65)	-	-	-
<i>Oxalis stricta</i>	Common yellow oxalis	0.4 (1.14)	-	-	-
<i>Panicum dichotomiflorum</i>	Fall panicgrass	-	-	-	0.1 (0.12)

Table 5. Species, average Braun-Blanquet score and relative percent cover (in parentheses) for vegetation sampled in the natural marsh at Saugus Iron Works NHS from 2009-2012. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	Average Braun-Blanquet ¹ score (percent of total cover)			
		2009 Natural marsh (n=17 plots)	2010 Natural marsh (n=18 plots)	2011 Natural marsh (n=18 plots)	2012 Natural marsh (n=19 plots)
<i>Panicum flexile</i>	Wiry panicgrass	0.1 (0.16)	-	-	-
<i>Parthenocissus quinquefolia</i>	Virginia creeper	-	0.2 (0.70)	-	0.2 (0.62)
<i>Peltandra virginica</i>	Green arrow arum	1.2 (4.47)	1.2 (4.83)	1.4 (6.76)	1.3 (6.22)
<i>Persicaria amphibia</i>	Water smartweed	-	-	-	0.1 (0.12)
<i>Persicaria hydropiper</i>	Marshpepper knotweed	0.3 (0.99)	-	-	-
<i>Persicaria hydropiperoides</i>	Swamp smartweed	-	-	0.4 (0.99)	0.4 (0.85)
<i>Persicaria maculosa</i>	Spotted ladysthumb	0.4 (2.21)	-	0.2 (0.27)	0.2 (1.51)
<i>Persicaria pennsylvanicum</i>	Pennsylvania smartweed	0.2 (0.85)	-	-	-
<i>Persicaria</i> species	Smartweed species	-	0.1(0.02)	-	-
<i>Phalaris arundinacea</i>	Reed canary grass	0.1 (0.16)	0.3 (2.47)	0.9 (7.83)	0.3 (1.23)
<i>Phragmites australis</i>	Common reed	-	0.2 (0.27)	0.2 (0.71)	-
<i>Phytolacca americana</i>	Pokeweed	0.2 (0.32)	-	-	-
<i>Plantago major</i>	Common plantain	-	-	-	0.1 (0.12)
Poaceae species	Unknown grass (Poaceae)	0.1 (0.16)	-	-	0.1 (0.12)
<i>Rorippa palustris</i> var. <i>hispida</i>	Hispid yellowcress	0.1 (0.16)	-	-	-
<i>Rosa multiflora</i>	Multiflora rose	0.3 (0.99)	0.2 (1.72)	0.1 (0.14)	-
<i>Rumex</i> species	Water hemp species	0.1 (0.16)	-	-	-
<i>Schoenoplectus/Scirpus</i> species	<i>Schoenoplectus/Scirpus</i> species	0.1 (0.16)	-	-	-
<i>Sciyo angulatus</i>	Oneseed bur cucumber	0.2 (0.82)	0.2 (0.70)	-	-
<i>Smilax rotundifolia</i>	Roundleaf greenbrier	-	0.3 (2.85)	0.1 (0.14)	-
<i>Sium suave</i>	Water parsnip	-	-	0.2 (0.27)	0.2 (0.24)
<i>Solidago speciosa</i>	Showy goldenrod	-	-	0.4 (3.05)	-
<i>Symphyotrichum pilosum</i>	Hairy white oldfield aster	-	-	-	0.2 (0.62)
<i>Symphyotrichum prenanthoides</i>	Crookedstem aster	-	-	-	0.1 (0.12)
<i>Symphyotrichum subulatum</i>	Eastern annual saltmarsh aster	-	-	0.3 (1.43)	0.1 (0.12)
<i>Typha angustifolia</i>	Narrowleaf cattail	3.6 (36.48)	3.7 (30.05)	3.6 (36.88)	3.8 (35.77)
Unknown grass	Unknown grass	0.3 (0.34)	0.1 (0.02)	-	-
Unknown panic grass	Unknown panic grass	-	0.2 (0.07)	-	-
<i>Verbena hastata</i>	Swamp verberna	-	-	-	0.1 (0.12)
<i>Veronica serpyllifolia</i>	Thymeleaf speedwell	0.1 (0.03)	-	-	-
<i>Viburnum dentatum</i>	Arrow-wood viburnum	-	3.3 (3.99)	-	-
<i>Zannichella palustris</i>	Horned pondweed	0.1 (0.03)	0.1 (0.14)	0.3 (1.89)	0.2 (1.51)
Total species		35	21	26	29
Non-vegetative covers					
Bare ground/algal mat	Bare ground/algal mat	1.6 (9.7)	2.8 (17.0)	2.7 (15.7)	-

Table 5. Species, average Braun-Blanquet score, and average percent of total cover (in parentheses) for vegetation sampled in the natural marsh at Saugus Iron Works NHS from 2009-2012. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	Average Braun-Blanquet ¹ score (percent of total cover)			
		2009 Natural marsh (n=17 plots)	2010 Natural marsh (n=18 plots)	2011 Natural marsh (n=18 plots)	2012 Natural marsh (n=19 plots)
Dead, <i>Persicaria</i> species	Dead, smartweed species	-	0.4 (1.54)	-	-
Dead, <i>Typha angustifolia</i>	Dead, narrowleaf cattail	-	0.3 (0.14)	-	-
Dead, woody plant	Dead, woody plant	0.3 (1.65)	-	-	-
Litter/wrack	Litter/wrack	2.0 (14.34)	2.9 (15.44)	2.1 (5.13)	4.5 (38.23)
Rock	Rock	-	-	0.2 (1.75)	-
Water	Water	-	0.3 (2.85)	0.2 (1.75)	-

¹ Braun-Blanquet cover class scale (0; 1: <1; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%). "-" indicates species was not present.

² *Callitriche* species was originally identified as *C. terrestris* (H. Leeson, Rhode Island Natural History Survey, October 2009), but was confirmed to be *C. stagnalis* in 2012 (identified by P. Sharpe and R. Baranowski, September 2012).

³ *Nasturtium officinale* is listed as potentially invasive in CT.

Table 6. Plants observed on the streamside riparian berm in 2009 and 2011. Invasive or potentially invasive plants are indicated in bold type.

Scientific Name	Common Name	2009 ¹	2011
<i>Acalypha virginica</i>	Three-seeded mercury		X
<i>Achillea millefolium</i>	Common yarrow		X
<i>Agalinis tenuifolia</i>	Slenderleaf false foxglove		X
<i>Alisma lantago-aquatica</i>	Water plantain	X	
<i>Alnus incana</i> spp. <i>rugosa</i>	Speckled alder	P (+)	X
<i>Ambrosia artemisiifolia</i>	Common ragweed	X	X
<i>Artemisia vulgaris</i>	Mugwort		X
<i>Atriplex patula</i>	Spear saltbush		X
<i>Bidens cernua</i>	Nodding beggar tick	X	
<i>Bidens frondosa</i>	Devil's beggartick	X	X
<i>Brassica nigra</i>	Black mustard	X	
<i>Calystegia sepium</i>	Hedge bindweed	X	X
<i>Carex lacustris</i>	Lake sedge	P (-)	
<i>Carex stricta</i>	Tussock sedge	P (-)	X
<i>Carex</i> species	<i>Carex</i> species	P/X (+)	
<i>Commelina communis</i>	Asiatic dayflower	X	X
<i>Conyza canadensis</i>	Horseweed		X
<i>Cornus amomum</i>	Silky dogwood	P (+)	X
<i>Cornus sericea</i>	Redosier dogwood	P (+)	
<i>Cyperus grayoides</i>	Umbrella sedge		X
<i>Daucus carota</i>	Queen Anne's lace		X
<i>Dysphania ambrosioides</i>	Mexican tea		X
<i>Echinochloa crus-galli</i>	Barnyard grass		X
<i>Echinochloa walteri</i>	Coast cockspur		X
<i>Echinocystis lobata</i>	Wild cucumber		X
<i>Eleocharis obtusa</i>	Soft-stem spikerush	X	
<i>Epilobium coloratum</i>	Purpleleaf willowherb	X	
<i>Erigeron strigosus</i>	Daisy fleabane		X
<i>Eupatorium perfoliatum</i>	Common boneset	X	X
<i>Eutrochium maculatum</i>	Spotted joeypyeweed		X
<i>Fraxinus</i> species	Ash species		X
<i>Glyceria grandis</i>	Tall mannagrass	X	
<i>Helianthus</i> species	Sunflower species		X
<i>Hieracium</i> species	Hawkweed species		X
<i>Humulus japonicus</i>	Japanese hops	X	X
<i>Impatiens capensis</i>	Spotted jewelweed	X	X
<i>Iris</i> species	Iris species		X
<i>Juncus effusus</i>	Common rush	X	X
<i>Lepidium virginicum</i>	Wild peppergrass	X	
<i>Lotus corniculatus</i>	Birdsfoot trefoil		X
<i>Lycopus americanus</i>	American water horehound	X	X
<i>Lythrum salicaria</i>	Purple loosestrife		X
<i>Medicago lupulina</i>	Black medic		X
<i>Mikania scandens</i>	Climbing hempweed		X
<i>Mimulus ringens</i>	Monkey flower	X	
<i>Nasturtium officinale</i> ²	Watercress		X
<i>Polygonum cuspidatum</i>	Japanese knotweed		X
<i>Oenothera biennis</i>	Common evening primrose	X	X
<i>Oxalis stricta</i>	Yellow woodsorrel		X

Table 6. Species list for plants observed on the berm (streamside riparian buffer zone) in 2009 and 2011. Invasive or potentially invasive plants are indicated in bold type (continued).

Scientific Name	Common Name	2009 ¹	2011
<i>Panicum dichotomiflorum</i>	Fall panicgrass		X
<i>Panicum virgatum</i>	Switchgrass		X
<i>Persicaria hydropiper</i>	Marshpepper knotweed		X
<i>Persicaria hydropiperoides</i>	Swamp smartweed		X
<i>Persicaria maculosa</i>	Spotted ladythumb		X
<i>Pilea pumila</i>	Canada clearweed		X
<i>Plantago lanceolata</i>	Narrowleaf plantain	X	X
<i>Plantago major</i>	Common plantain		X
<i>Poa pratensis</i>	Kentucky bluegrass		X
<i>Polygonum persicaria</i>	Spotted ladythumb	X	
<i>Pontederia cordata</i>	Pickerelweed		X
<i>Populus deltoides</i>	Eastern cottonwood		X
<i>Potentilla norvegica</i>	Rough cinquefoil	X	
<i>Potentilla simplex</i>	Old field cinquefoil	X	
<i>Rorippa species</i>	Yellowcress species	X	
<i>Rosa multiflora</i>	Multiflora rose	X	X
<i>Rosa palustris</i>	Swamp rose	P (+)	X
<i>Rumex crispus</i>	Curly dock		X
<i>Salix bebbiana</i>	Bebb willow		X
<i>Sambucus nigra</i>	Common elderberry		X
<i>Setaria viridis</i>	Green foxtail		X
<i>Sium suave</i>	Water parsnip	X	X
<i>Solanum nigrum</i>	Black nightshade		X
<i>Solidago odora</i>	Fragrant goldenrod		X
<i>Sonchus oleraceus</i>	Annual sowthistle		X
<i>Symphyotrichum novi-belgii</i>	New York aster		X
<i>Symphyotrichum subulatum</i>	Eastern annual saltmarsh aster		X
<i>Taraxacum officinale</i>	Common dandelion		X
<i>Thlaspi arvense</i>	Field pennycress		X
<i>Trifolium hybridum</i>	Alsike clover	X	
<i>Trifolium pratense</i>	Red clover		X
<i>Trifolium repens</i>	White clover		X
<i>Ulmus rubra</i>	Slippery elm		X
<i>Verbascum thapsus</i>	Common mullein		X
<i>Verbena hastata</i>	Blue vervain		X
<i>Viola species</i>	Violet species		X

¹ P(+): Planted in 2008 and present in 2009; P(-): Planted in 2008, but absent in 2009; X: Species was present.

Aquatic vegetation

Several types of aquatic vegetation have been observed in both the river and turning basin at SAIR since 2004. Horned pondweed has been observed in all years (2004, 2008-2012) in both the river and the turning basin (after its conversion to open water) and has increased in abundance especially in the turning basin, since the restoration (Table 7, Figure 15). Horned pondweed is tolerant of fresh to moderately brackish conditions, is eaten by waterfowl, and provides good habitat for small aquatic animals (Washington State Department of Ecology 2012). Curly pondweed (*Potamogeton crispus*), an invasive plant (Massachusetts Invasive Plant Advisory Group [MIPAG] 2005), was observed in both 2004 and 2009, but was not found after 2010.

A comparison among years indicated that the aquatic vegetation community in the river has changed since the restoration. Differences in the river's aquatic vegetation were observed between all sequential years, except between 2011 and 2012 (Table 8). In all significant yearly comparisons, horned pondweed accounted for 80% to 100% of the dissimilarity among years. The abundance of horned pondweed was highest in the river in 2009, and was also observed at 96% of the samples in this year (Figure 15, Table 7).

Differences in the aquatic vegetation were observed in the turning basin between 2012 and 2011, and between 2011 and 2010 (Table 8). Horned pondweed contributed 80-100% dissimilarity between these years and was highest in abundance in the turning basin in 2011 (Figure 15).

Differences in the aquatic vegetation community were also observed within years between the river and turning basin habitats in 2012, 2009, and 2008 (Table 8). Generally, in these years, only horned pondweed was observed in the river; whereas, in the turning basin other types of aquatic vegetation were observed (Table 7).

Invasive vegetation

Nine invasive and/or introduced plants have been encountered at SAIR during pre- and post-restoration monitoring (USDA 2012, MIPAG 2005, New England Environmental, Inc. 2009) (Table 9). 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 (curly pondweed), but only aquatic vegetation was monitored in 2008 (the newly restored wetland was not sampled). In 2009, eight invasive plant species were observed, including three new ones (flowering rush [*Butomus umbellatus*], watercress [*Nasturtium officinale*], and Japanese hop [*Humulus japonicus*]). The majority of these (five species) were found either on the riparian berm or in the natural marsh. In 2010, only three invasive plants (common reed, multiflora rose [*Rosa multiflora*], and reed canary grass [*Phalaris arundinacea*]) were observed and all were observed in the natural marsh. In 2011, nine invasive species were recorded, the majority of which (eight species) were found either on the streamside riparian berm (four species) or the natural marsh (four species). The only potentially invasive plant found in the restored wetland in 2011 was flowering rush (considered potentially invasive in CT, USDA 2012).

Curly pondweed was found in the restored turning basin and the restored wetland in 2008 and 2009, but was not observed in either area in 2010 to 2012. This plant is a freshwater pondweed species, and increased salt water intrusion into the river (CH2MHill 2011) maybe partially responsible for its absence in later sampling years. Purple loosestrife, which was fairly abundant in the natural marsh (representing 7% of the total cover in 2009) and was also present in the restored wetland in 2009, was not observed in 2010. The park initiated a focused effort in 2010 to manually eradicate purple loosestrife from these areas and this effort appears to have been successful in 2010; however, purple loosestrife was again observed in both the natural and restored wetland in 2011 and 2012, indicating that a continuing effort to remove this species might be required to prevent it from becoming overly abundant.

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. Invasive plants have consistently been found on the streamside riparian berm and in the small natural marsh, and control/eradication efforts could be focused on these areas to limit the spread of these plants within the park.

Table 7. Aquatic vegetation species list, average Braun-Blanquet score, and percent of sampling stations where observed at Saugus Iron Works NHS in 2004 (pre-restoration) and 2008 to 2012 (post-restoration). Invasive species are indicated in bold type.

Location & Common Name	Scientific Name	Average Braun-Blanquet ¹ score (percent of plots observed)					
		2004 ²	2008 (n=11)	2009 (n=21)	2010 (n=15)	2011 (n=22)	2012 (n=25)
Turning Basin							
<i>Elodea</i> species	<i>Elodea</i> species	n/a	1.8 (55%)	0.3 (14%)	-	-	-
<i>Potamogeton crispus</i>	Curly pondweed	n/a	1.0 (27%)	1.0 (38%)	-	-	-
<i>Potamogeton epihydrus</i>	Ribbonleaf pondweed	n/a	-	0.4 (19%)	-	-	-
<i>Potamogeton gramineus</i>	Variableleaf pondweed	n/a	-	Present	-	-	-
<i>Potamogeton perfoliatus</i>	Claspingleaf pondweed	n/a	-	-	-	-	0.08 (4%)
Unknown pondweed ³	Unknown pondweed	n/a	0.2 (9%)	-	-	-	-
Unknown filamentous green algae	Unknown filamentous green algae	-	-	-	-	-	0.7 (24%)
<i>Vallisneria americana</i>	Wild celery	n/a	-	-	-	0.05 (5%)	-
<i>Zannichella palustris</i>	Horned pondweed	n/a	1.2 (45%)	1.5 (52%)	2.3 (87%)	4.2 (86%)	1.8 (48%)
River							
		2004 (n=12)	2008 (n=15)	2009 (n=27)	2010 (n=33)	2011 (n=33)	2012 (n=49)
<i>Callitriche</i> species ⁴	Water starwort species	0.3 (17%)	-	-	-	0.03 (3%)	-
<i>Elodea</i> species	<i>Elodea</i> species	-	-	-	-	-	-
<i>Potamogeton crispus</i>	Curly pondweed	0.6 (33%)	-	-	-	-	-
<i>Potamogeton epihydrus</i>	Ribbonleaf pondweed	-	-	-	-	-	-
<i>Potamogeton gramineus</i>	Variableleaf pondweed	-	-	-	-	-	-
Unknown filamentous green algae	Unknown filamentous green algae	-	-	-	0.2 (9%)	0.03 (3%)	0.02 (2%)
Unknown green algae	Unknown green algae	0.7 (17%)	-	-	-	-	-
<i>Vallisneria americana</i>	Wild celery	-	-	-	-	0.05 (6%)	-
Unknown pondweed ³	Unknown pondweed	-	-	-	-	-	-
<i>Zannichella palustris</i>	Horned pondweed	1.5 (42%)	0.9 (20%)	4.0 (96%)	1.7 (55%)	3.4 (82%)	2.6 (65%)

¹ Braun Blanquet cover class scale (0; 1: <1; 2: 1%- 5%; 3: 6-25%; 4: 26-50%; 5: 51-75%; 6: 76-100%). "-" indicates species was not present.

² Turning basin was a vegetated wetland in 2004 and therefore no aquatic vegetation samples were taken.

³ Possibly *P. gramineus*, *P. gramineus* was present but was not observed in plots in 2009.

⁴ *Callitriche* species was originally identified as *C. terrestris* (H. Leeson, Rhode Island Natural History Survey, October 2009), but was confirmed to be *C. stagnalis* in 2012 (identified by P. Sharpe and R. Baranowski, September 2012).

Table 8. ANOSIM results comparing aquatic vegetation communities among years and between habitats. Only comparisons of interest (e.g., sequential years within the same habitat or between habitats in the same year are shown).

Comparison	R Statistic	p-value	Significant
River comparisons between years¹			
2012 river, 2011 river	0.002	0.34400	No
2011 river, 2010 river	0.112	0.00300	Yes
2010 river, 2009 river	0.213	0.00010	Yes
2009 river, 2008 river	0.630	0.00001	Yes
2012 river, 2004 river	0.407	0.0001	Yes
Basin comparisons between years²			
2012 basin, 2011 basin	0.168	0.00600	Yes
2011 basin, 2010 basin	0.243	0.00100	Yes
2010 basin, 2009 basin	0.063	0.09300	No
2009 basin, 2008 basin	0.097	0.06200	No
River-basin comparisons within year¹			
2012 river, 2012 basin	0.161	0.01000	Yes
2011 river, 2011 basin	-0.029	0.80300	No
2010 river, 2010 basin	-0.042	0.78700	No
2008 river, 2008 basin	0.430	0.00010	Yes
2009 river, 2009 basin	0.372	0.00001	Yes

¹ Significance based on sequential Bonferroni adjusted alpha (Rice 1989) at $\alpha = 0.05$ for five pair-wise comparisons.

² Significance based on sequential Bonferroni adjusted alpha (Rice 1989) at $\alpha = 0.05$ for four pair-wise comparisons.

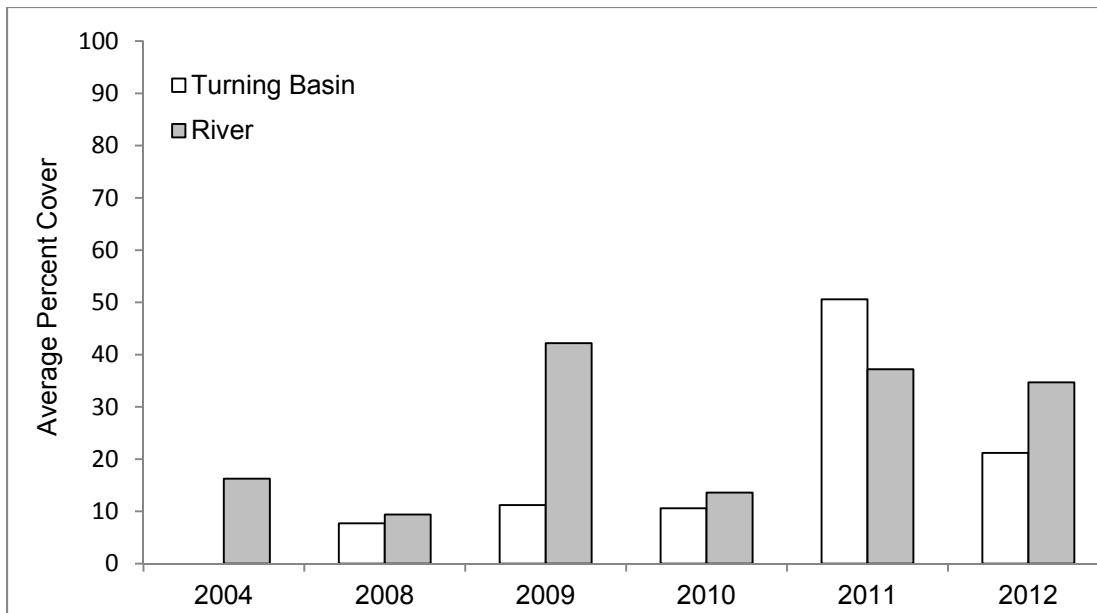


Figure 15. Abundance of horned pondweed (*Zannichella palustris*) at Saugus Iron Works NHS. Note: Aquatic vegetation was not sampled in the tuning basin in 2004 because it was a vegetated area.

Table 9. List of Massachusetts state-listed invasive plants observed during vegetation sampling at SAIR. Also listed are plants not listed in MA, but listed in neighboring states.

Scientific Name	Common Name	Status ¹	Years observed and Location ²
<i>Alliaria petiolata</i>	Garlic mustard	Invasive (MA)	2011 (NM)
<i>Butomus umbellatus</i>	Flowering rush	potentially invasive (CT)	2009 (RW), 2011 (RW)
<i>Polygonum cuspidatum</i>	Japanese knotweed	Invasive (MA)	2011 (B)
<i>Humulus japonicus</i>	Japanese hop	Invasive (MA)	2009 (B), 2011 (B)
<i>Lythrum salicaria</i>	Purple loosestrife	Invasive (MA)	2004 (FTB, SM), 2009 (NM, RW), 2011 (B, NM, RW), 2012 (RW)
<i>Nasturtium officinale</i>	Watercress	potentially invasive (CT)	2009 (B, NM), 2011 (B)
<i>Phalaris arundinacea</i>	Reed canary grass	Invasive (MA)	2004 (SM, FTB), 2009 (NM), 2010 (NM), 2011 (NM), 2012 (NM)
<i>Phragmites australis</i>	Common reed	Invasive (MA)	2004 (SM, FTB), 2009 (RW), 2010 (NM), 2011 (NM), 2012 (RW)
<i>Potamogeton crispus</i>	Curly pondweed	Invasive (MA)	2004 (R), 2008 (TB), 2009 (TB, RW)
<i>Robinia pseudoacacia</i>	Black locust	Invasive (MA)	2004 (FTB)
<i>Rosa multiflora</i>	Multiflora rose	Invasive (MA)	2004 (FTB), 2009 (B, NM), 2010 (NM), 2011 (B, NM)

¹ Status information is from USDA Plants Database (2012).

² Locations where invasive species were observed: B: riparian berm; FTB: former turning basin (pre-restoration); NM: natural marsh; R: river; RW: restored wetland (post-restoration); SM: southern marsh (pre-restoration); TB: turning basin (post-restoration).

Nekton community

Since nekton sampling has been conducted at SAIR, at least 25 species (18 fishes and four decapods, one amphibian, and two odonates [dragonfly and damselfly larvae]) (Table 10 to Table 14) have been recorded. In 2004, it is possible that the brook sticklebacks may have been mis-identified and were really nine-spine sticklebacks, unfortunately voucher specimens were not available for verification.

A juvenile jack (*Caranx* species), possibly a blue runner (*C. crysos*) or crevalle jack (*C. hippos*) was caught in a minnow trap off the turning basin dock in September 2010. The identification was based on photographic record (Figure 17) as the specimen was released and positive identification was not possible. Both jack species are found in the Western Atlantic from Nova Scotia to the Gulf of Mexico, although the blue runner is more likely to round Cape Cod than the crevalle jack (Collette and Klein-MacPhee 2002). Discussion with several experts indicated that the observation of a juvenile jack far upstream in the Saugus River was an unusual and interesting occurrence.

In the river, common nekton included nine-spine stickleback (*Pungitius pungitius*) (in 2008 only), four-spine stickleback (*Apeltes quadracus*), white sucker (*Catostomus commersoni*), and mummichog (*Fundulus heteroclitus*) (since 2009) (Figure 16). In the restored turning basin, common nekton included four-spine stickleback, American eel (*Anguilla rostrata*), and mummichog (since 2009) (Figure 16). The high incidence of American eels in 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 the river there was a shift from a freshwater to estuarine fish community, with differences observed among years for three of the ten yearly comparisons (2009 vs. 2008, 2010 vs. 2009, and 2010 vs. 2004; ANOSIM, sequentially adjusted α of 0.05, Table 15). In 2009, the densities of all species sampled in the river (e.g., American eel, four-spine stickleback, mummichog, white sucker) were higher compared to 2008 (Table 11). In 2010, majority (80% or more) of the community dissimilarity between this year and 2009 and 2004 was due to an increase of mummichogs and a decrease in American eel, four-spine sticklebacks, white suckers in 2010 (Table 11). The percent catch also mirrored this same trend, and it appears that the nekton community in the river may be transitioning from a freshwater-brackish water community to a more estuarine nekton community in more recent years (2009 and later) (Figure 16). This is consistent with data collected by CH2MHill's continuous YSI recorder that showed salinity in the turning basin and river exceeded 20 ppt on several occasions in 2010, whereas 20 ppt was never exceeded in 2008 (CH2MHill 2011).

In the restored turning basin, the only difference in the nekton community was between 2011 and 2010 (ANOSIM, sequentially adjusted α of 0.05, Table 15). In 2011, American eel and four-spine stickleback were more abundant, whereas in 2010 mummichogs were more abundant in the turning basin (Table 12).

A comparison of nekton among habitats and within years, indicated significant differences in the nekton community sampled with the throw trap between the river and

the basin in 2008 and 2011 (ANOSIM, sequentially adjusted α of 0.05, Table 15). In 2011 and 2008, American eel and four-spine stickleback were more abundant in the basin than in the river (comprising 67 to 75% of the dissimilarity between the habitats). In the river in 2011, mummichogs and white suckers were more abundant in the river than in the basin; whereas in 2008, bluegills were only sampled in the basin, while white suckers were only found in the river (Table 11, Table 12).

The catch consisted of young-of-the-year or juveniles for most of the nekton species in all years (Figure 18).

Water temperature, salinity, and dissolved oxygen collected in conjunction with the nekton sampling events are summarized in Table 16. Thresholds established for acceptable habitat for warm water fisheries were exceeded for water temperature in 2009, 2010, and 2012, and for dissolved oxygen in 2009 to 2012 (Lombard et al. 2006).

Invasive nekton

One exotic crustacean (green crab, *Carcinus maenas*) was found in 2004. Two nonindigenous (non-native) fish, largemouth bass (*Micropterus salmoides*, observed in all years except 2012) and the bluegill (*Lepomis macrochirus*, observed in 2008, 2009, 2011, and 2012) were collected during sampling (Table 17). 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).

Rainbow smelt and American eel monitoring

In 2005 (prior to restoration), rainbow smelt were present in 56% of the Saugus River fyke net samples collected by MA DMF (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 to 2011 (after the restoration of the turning basin) (Brad Chase, Massachusetts Division of Marine Fisheries, unpublished data) (Figure 19). Changes in the river bed topography after the restoration may be responsible for the low smelt catches, as the fyke net may not be fishing as efficiently (Marc Albert, National Park Service, personal communication).

Smelt egg surveys in 2011 and 2012 observed the presence of viable smelt eggs at several locations in the Saugus River SAIR, with an estimated 2104 m² of spawning habitat of (LeBlanc 2012). The areal extent of suitable smelt habitat in the Saugus River in 2012 was larger than identified by surveys in 1988 and 1990 (Chase 2006). The most active spawning areas for smelt in the Saugus River were adjacent to the Saugus Iron Works

historic waterfront. The berm, constructed during the restoration of the Saugus River wetlands and turning basin, was successful in protecting valuable riffle spawning habitat (LeBlanc 2012).

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 (Chase 2007). Historically, the Saugus River was noted for large catches of American eel, but recent catches have been small (Chase 2007). Juvenile American eel (< 100 mm total length) are frequently observed in the throw trap samples (University of Rhode Island monitoring program), particularly in the restored turning basin (Figure 18, Table 13).

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

Table 10. Nekton sampled during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2012) at Saugus Iron Works NHS. Life cycle/habitat preference is given after scientific name¹.

Scientific Name	Common Name	2004 River only		2008 River & Basin		2009 River & Basin		2010 River & Basin		2011 River & Basin		2012 River & Basin	
		Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap
<i>Alosa pseudoharengus</i> (A, E, F)	Alewife	X										X	
<i>Ameiurus natalis</i> (F)	Yellow bullhead									X			
<i>Anguilla rostrata</i> (C, E, F)	American eel	X	X	X		X	X	X	X	X	X	X	X
<i>Apeltes quadracus</i> (E, F)	Four-spine stickleback	X	X	X	X	X	X	X	X	X	X	X	X
<i>Carcinus maenas</i> (E)	Green crab		X										
<i>Catostomus commersoni</i> (F)	White sucker	X	X	X	X	X	X	X	X	X	X	X	
<i>Culaea inconstans</i> ² (F)	Brook stickleback	X	X										
<i>Esox americanus americanus</i> (F)	Redfin pickerel	X				X		X		X			
<i>Esox americanus vermiculatus</i> (F)	Grass pickerel					X							
<i>Fundulus heteroclitus</i> (E, F)	Mummichog	X				X	X	X	X	X	X	X	X
<i>Gasterosteus aculeatus</i> (E, F)	Three-spine stickleback		X										
<i>Lepomis gibbosus</i> (F)	Pumpkinseed					X	X						
<i>Lepomis macrochirus</i> (F)	Bluegill			X	X	X				X	X	X	
<i>Micropterus salmoides</i> (F)	Largemouth bass	X		X		X		X	X	X			
<i>Menidia beryllina</i> (E, F)	Tidewater silverside							X	X	X		X	
<i>Morone americana</i> (E, F)	White perch	X		X						X			
<i>Morone saxatilis</i> (A, E, F)	Striped bass											X	
<i>Notemigonus crysoleucas</i>	Golden shiner									X		X	

Table 10. Nekton sampled during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2011) at Saugus Iron Works NHS. Life cycle/habitat preference is given after scientific name¹ (continued).

Scientific Name	Common Name	2004 River only		2008 River & Basin		2009 River & Basin		2010 River & Basin		2011 River & Basin		2012 River & Basin	
		Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap	Seine	Throw trap
<i>Odonata</i> spp. (F)	Dragonfly/Damselfly larvae							X	X	X	X	X	X
<i>Orconectes</i> spp. (F) ³	Crayfish species										X		
<i>Palaemonetes pugio</i> (E)	Daggerblade grass shrimp							X	X				
<i>Pimephales promelas</i> ⁴ (F)	Fathead minnow					X							
<i>Pungitius pungitius</i> (E, F)	Nine-spine stickleback	X			X	X		X	X	X	X	X	
<i>Lithobates</i> spp. (F) ⁵	Tadpole species									X			
<i>Rhithropanopeus harrisii</i> (E, F)	Harris mud crab	X							X			X	X
Total species caught		11	6	5	5	11	5	10	10	14	8	11	5

¹ A: anadromous; C: catadromous E: estuarine; F: freshwater;

² Possibly nine-spine stickleback (voucher specimen not available for verification). Brook sticklebacks have not been verified east of the Connecticut River.

³ Specimen was a juvenile, likely either *Orconectes virilis* or *O. immunis*.

⁴ Identification of fathead minnow (*Pimephales promelas*) was verified by Karsten Hartel of the Harvard Museum of Comparative Zoology (MCZ). The specimen is vouchered at MCZ (voucher # MCZ 168881).

⁵ Likely either bull frog (*L. catesbeianus*) or green frog (*L. clamitans*), as tadpoles of these species are present in the fall and can overwinter as tadpoles (R. Cook, Wildlife Ecologist, National Park Service, e-mail 7 Nov 2011).

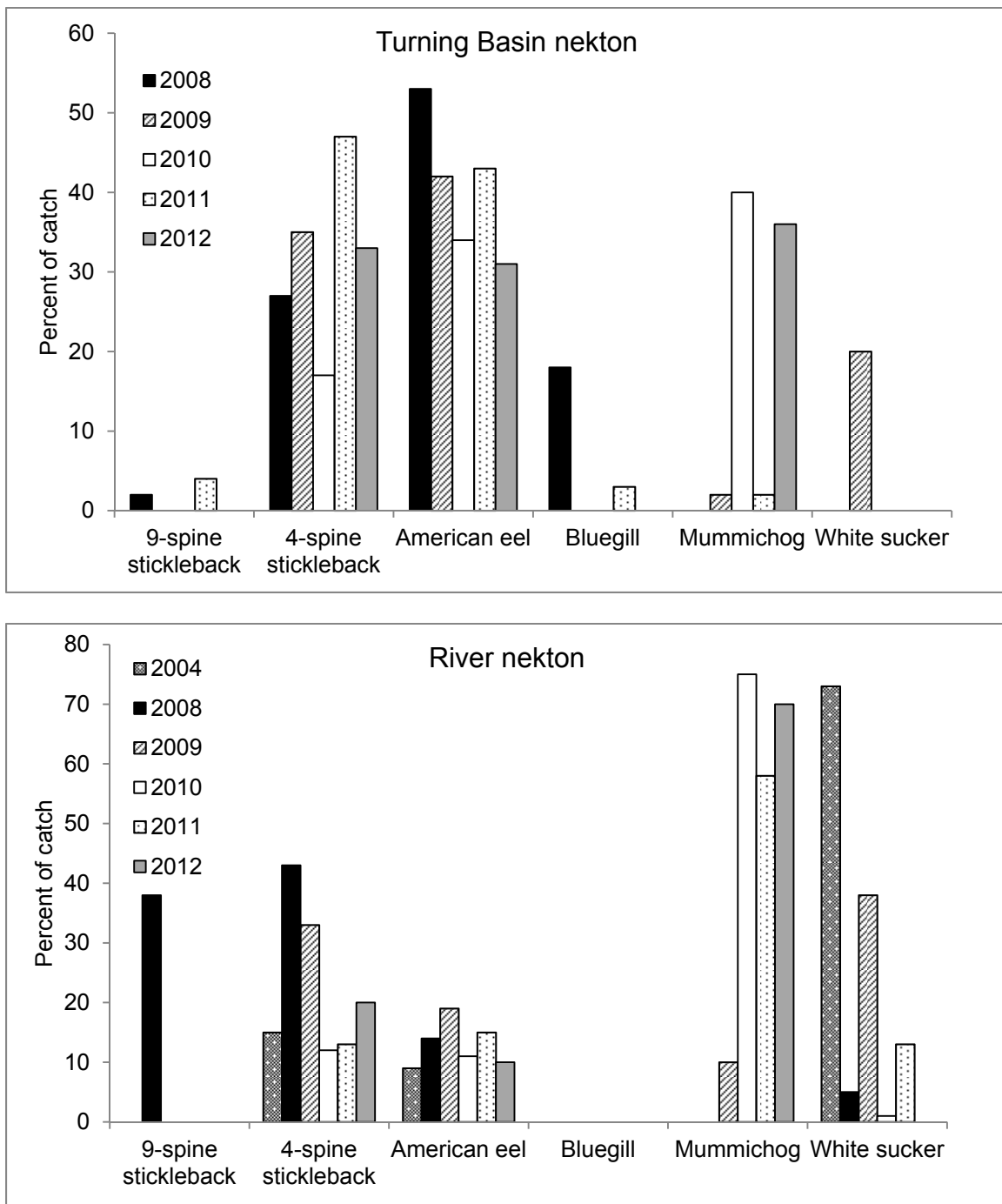


Figure 16. Percent of catch for nekton sampled with a throw trap from the turning basin (top graph) and river (bottom graph) at Saugus Iron Works NHS.

Table 11. Nekton composition, average abundance $\pm$ SD per throw trap (m^{-2}), and total number of individuals collected (in parentheses) with a throw trap in the river at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2012). Sample size is given after year.

Scientific Name	Common Name	2004 River n=32	2008 River n=15	2009 River n=27	2010 River n=33	2011 River n=33	2012 River n=38
<i>Anguilla rostrata</i>	American eel	0.9 $\pm$ 2.0 (30)	0.2 $\pm$ 0.4 (3)	2.4 $\pm$ 3.2 (66)	1.0 $\pm$ 1.5 (34)	1.4 $\pm$ 2.1 (45)	1.4 $\pm$ 2.0 (55)
<i>Apeltes quadracus</i>	Four-spine stickleback	1.6 $\pm$ 3.6 (50)	0.6 $\pm$ 1.5 (9)	4.2 $\pm$ 6.1 (114)	1.2 $\pm$ 2.9 (39)	1.2 $\pm$ 3.1 (39)	2.9 $\pm$ 5.9 (112)
<i>Carcinus maenas</i>	Green crab	0.03 $\pm$ 0.2 (1)	0	0	0	0	0
<i>Catostomus commersoni</i>	White sucker	7.4 $\pm$ 16.1 (236)	0.1 $\pm$ 0.3 (1)	5.0 $\pm$ 8.4 (134)	0.1 $\pm$ 0.5 (3)	1.2 $\pm$ 2.9 (40)	0
<i>Culaea inconstans</i> ¹	Brook stickleback	0.03 $\pm$ 0.2 (1)	0	0	0	0	0
<i>Fundulus heteroclitus</i>	Mummichog	0	0	1.3 $\pm$ 2.2 (35)	7.1 $\pm$ 20.5 (234)	5.3 $\pm$ 19.1 (175)	10.5 $\pm$ 32.6 (400)
<i>Gasterosteus aculeatus</i>	Three-spine stickleback	0.2 $\pm$ 1.1 (6)	0	0	0	0	0
<i>Micropterus salmoides</i>	Largemouth bass	0	0	0	0.03 $\pm$ 0.2 (1)	0	0
<i>Palaemonetes pugio</i>	Daggerblade grass shrimp	0	0	0	0.03 $\pm$ 0.2 (1)	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0	0.5 $\pm$ 2.1 (8)	0	0	0.03 $\pm$ 0.2 (1)	0
<i>Rhithropanopeus harrisi</i>	Harris mud crab	0	0	0	0.03 $\pm$ 0.2 (1)	0	0.03 $\pm$ 0.1 (1)

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

Table 12. Nekton composition, average abundance $\pm$ SD per throw trap, and total number of individuals collected (in parentheses) with a throw trap (m^{-2}) in the turning basin at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2012). Sample size is given after year.

Scientific Name	Common Name	2008 Basin n=11	2009 Basin n=21	2010 Basin n=15	2011 Basin n=22	2012 Basin n=18
<i>Anguilla rostrata</i>	American eel	2.6 $\pm$ 3.3 (29)	5.3 $\pm$ 9.3 (112)	4.9 $\pm$ 8.1 (73)	5.1 $\pm$ 4.9 (112)	5.6 $\pm$ 8.4 (101)
<i>Apeltes quadracus</i>	Four-spine stickleback	1.4 $\pm$ 1.9 (15)	4.4 $\pm$ 10.2 (93)	2.5 $\pm$ 5.6 (37)	5.5 $\pm$ 8.4 (120)	5.8 $\pm$ 9.4 (105)
<i>Catostomus commersoni</i>	White sucker	0	2.6 $\pm$ 10.0 (54)	0.5 $\pm$ 1.5 (8)	0.05 $\pm$ 0.2 (1)	0
<i>Fundulus heteroclitus</i>	Mummichog	0	0.3 $\pm$ 0.9 (6)	5.7 $\pm$ 12.0 (85)	0.2 $\pm$ 0.5 (4)	6.4 $\pm$ 22.7 (116)
<i>Lepomis gibbosus</i>	Pumpkinseed	0	0.0 $\pm$ 0.2 (1)	0	0	0
<i>Lepomis macrochirus</i>	Bluegill	0.9 $\pm$ 1.4 (10)	0	0	0.4 $\pm$ 0.9 (9)	0
<i>Menidia beryllina</i>	Tidewater silverside	0	0	0.1 $\pm$ 0.4 (2)	0	0
<i>Micropterus salmoides</i>	Largemouth bass	0	0	0.2 $\pm$ 0.4 (3)	0	0
<i>Morone americana</i>	White perch	0	0	0	0.05 $\pm$ 0.2 (1)	0
<i>Orconectes species</i> ¹	Crayfish species	0	0	0	0.05 $\pm$ 0.2 (1)	0
<i>Palaemonetes pugio</i>	Daggerblade grass shrimp	0	0	0.2 $\pm$ 0.4 (3)	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0.1 $\pm$ 0.3 (1)	0	0.1 $\pm$ 0.3 (1)	0.5 $\pm$ 1.2 (10)	0
<i>Rhithropanopeus harrisi</i>	Harris mud crab	0	0	0.2 $\pm$ 0.4 (3)	0	0

¹ Specimen was a juvenile, likely either *Orconectes virilis* or *O. immunis*.

Table 13. Nekton composition, average abundance per seine haul, and total number of individuals collected (in parentheses) with a seine in the river at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2012). Sample size is given after year.

Common Name	Scientific Name Average abundance per haul (total catch)	2004 Upper river n = 2	2004 Hamilton St. Bridge n=5	2008 River n=6	2009 River n=11	2010 River n=12	2011 River n=12	2012 River n=11
<i>Alosa pseudoharengus</i>	Alewife	2.5 (5)	0.2 (1)	0	0	0	0	0.3 (3)
<i>Anguilla rostrata</i>	American eel	0.5 (1)	0	0	0.1 (1)	0	0	0
<i>Apeltes quadracus</i>	Four-spine stickleback	4.0 (8)	23.4 (117)	2.2 (13)	74.5 (820)	1.3 (16)	30.1 (361)	9.4 (104)
<i>Catostomus commersoni</i>	White sucker	1.0 (2)	168.2 (841)	0	71.7 (189)	37.8 (453)	56.4 (677)	6.4 (71)
<i>Culaea inconstans</i> ¹	Brook stickleback	1.5 (3)	15.2 (76)	0	0	0	0	0
<i>Esox americanus americanus</i>	Redfin pickerel	0	0.2 (1)	0	0.3 (3)	0.1 (1)	0.3 (3)	0
<i>Esox americanus vermiculatus</i>	Grass pickerel	0	0	0	0.2 (2)	0	0	0
<i>Fundulus heteroclitus</i>	Mummichog	0	1.2 (6)	0	18.1 (199)	340.4 (4085)	162.2 (1946)	239.9 (2639)
<i>Lepomis macrochirus</i>	Bluegill	0	0	0.2 (1)	0	0	0	0
<i>Menidia beryllina</i>	Tidewater silverside	0	0	0	0	29.2 (350)	1.3 (16)	1.1 (12)
<i>Micropterus salmoides</i>	Largemouth bass	0	0.8 (4)	0.3 (2)	0	3.3 (39)	0.2 (2)	0
<i>Morone americana</i>	White perch	0	0.6 (3)	0	0	0	0	0
<i>Morone saxatilis</i>	Striped bass	0	0	0	0	0	0	0
<i>Notemigonus crysoleucas</i>	Golden shiner	0	0	0	0	0	0	0
<i>Odonata</i> species	Dragonfly larvae	0	0	0	0	0	0.1 (1)	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0	0.4 (2)	0	0.2 (2)	0.1(1)	1.2 (14)	0.1 (1)
<i>Rhithropanopeus harrisii</i>	Harris mud crab	0	0.2 (1)	0	0	0	0	0.1 (1)
Average abundance per haul		9.5 (19)	210.4 (1052)	2.6 (16)	165.1 (1816)	412.1 (4945)	251.8 (3020)	257.6 (2834)

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

Table 14. Nekton composition, average abundance per seine haul, and total number of individuals collected (in parentheses) with a seine in the turning basin at Saugus Iron Works NHS during pre-restoration monitoring (2004) and post-restoration monitoring (2008 to 2012). Sample size is given after year.

Common Name	Scientific Name	Average abundance per haul (total catch)				
		2008 Turning Basin n=3	2009 Turning Basin n=6	2010 Turning Basin n=6	2011 Turning Basin n=8	2012 Turning Basin n=7
<i>Ameiurus natalis</i>	Yellow bullhead	0	0	0	0.3 (2)	0
<i>Anguilla rostrata</i>	American eel	0	0.8 (5)	0.2 (1)	0.5 (4)	1.0 (7)
<i>Apeltes quadracus</i>	Four-spine stickleback	5.7 (17)	150.5 (903)	6.7 (40)	30.6 (245)	25.5 (178)
<i>Catostomus commersoni</i>	White sucker	15.7 (47)	92.3 (554)	14.2 (85)	0.6 (5)	0
<i>Esox americanus americanus</i>	Redfin pickerel	0	0.2 (1)	0	0.4 (3)	0
<i>Fundulus heteroclitus</i>	Mummichog	0	15.7 (94)	99.0 (594)	7.0 (56)	342.7 (2399)
<i>Lepomis gibbosus</i>	Pumpkinseed	0	0.2 (1)	0	0	00
<i>Lepomis macrochirus</i>	Bluegill	14.0 (42)	5.2 (31)	0	8.5 (68)	5.7 (40)
<i>Menidia beryllina</i>	Tidewater silverside	0	0	0.7 (4)	0	0
<i>Micropterus salmoides</i>	Largemouth bass	2.0 (6)	9.0 (54)	2.7 (16)	3.8 (30)	0
<i>Morone americana</i>	White perch	0.3 (1)	0	0	0.7 (5)	0
<i>Morone saxatilis</i>	Striped bass	0	0	0	0	0.1 (1)
<i>Notemigonus crysoleucas</i>	Golden shiner	0	0	0	0.3 (2)	0.1 (1)
<i>Palaemonetes pugio</i>	Daggerblade grass shrimp	0	0	0.2 (1)	0	0
<i>Pimephales promelas</i>	Fathead minnow	0	0.2 (1)	0	0	0
<i>Pungitius pungitius</i>	Nine-spine stickleback	0	0.3 (2)	1.0 (6)	4.4 (35)	0.3(2)
<i>Lithobates species</i> ¹	Tadpole species	0	0	0	0.1 (1)	
Average total abundance per haul		37.7 (113)	274.3 (1646)	125.0 (750)	57.0 (456)	376.3 (2634)

¹ Likely either bull frog (*L. catesbeianus*) or green frog (*L. clamitans*), as tadpoles of these species are present in the fall and can overwinter as tadpoles (R. Cook, Wildlife Ecologist, National Park Service, email communication 7 Nov 2011).



Figure 17. Photographs of a juvenile jack (*Caranx* species) caught in a minnow trap off the turning basin dock in September 2010.

Table 15. ANOSIM results comparing nekton communities among years (2004, 2008 to 2012) and between habitats (river or basin). Only comparisons of interest (e.g., between sequential years within the same habitat or between habitats in the same year) are shown).

Comparison (sample 1, sample 2)	R Statistic	p-value	Significant
River comparisons between years¹			
2011 river, 2012 river	0.014	0.181	No
2011 river, 2010 river	-0.002	0.424	No
2010 river, 2009 river	0.120	0.004	Yes
2009 river, 2008 river	0.287	0.0003	Yes
2008 river, 2004 river	-0.016	0.539	No
Basin comparisons between years²			
2011 basin, 2012 basin	0.055	0.075	No
2011 basin, 2010 basin	0.164	0.009	Yes
2010 basin, 2009 basin	0.051	0.120	No
2009 basin, 2008 basin	-0.043	0.720	No
River-basin comparisons within year¹			
2012 basin, 2012 river	0.045	0.118	No
2011 basin, 2011 river	0.129	0.005	Yes
2010 basin, 2010 river	0.051	0.119	No
2009 basin, 2009 river	0.016	0.244	No
2008 basin, 2008 river	0.295	0.004	Yes

¹ Significance based on sequential Bonferroni adjusted alpha (Rice 1989) at $\alpha = 0.05$ for five pair-wise comparisons.

² Significance based on sequential Bonferroni adjusted alpha (Rice 1989) at $\alpha = 0.05$ for four pair-wise comparisons.

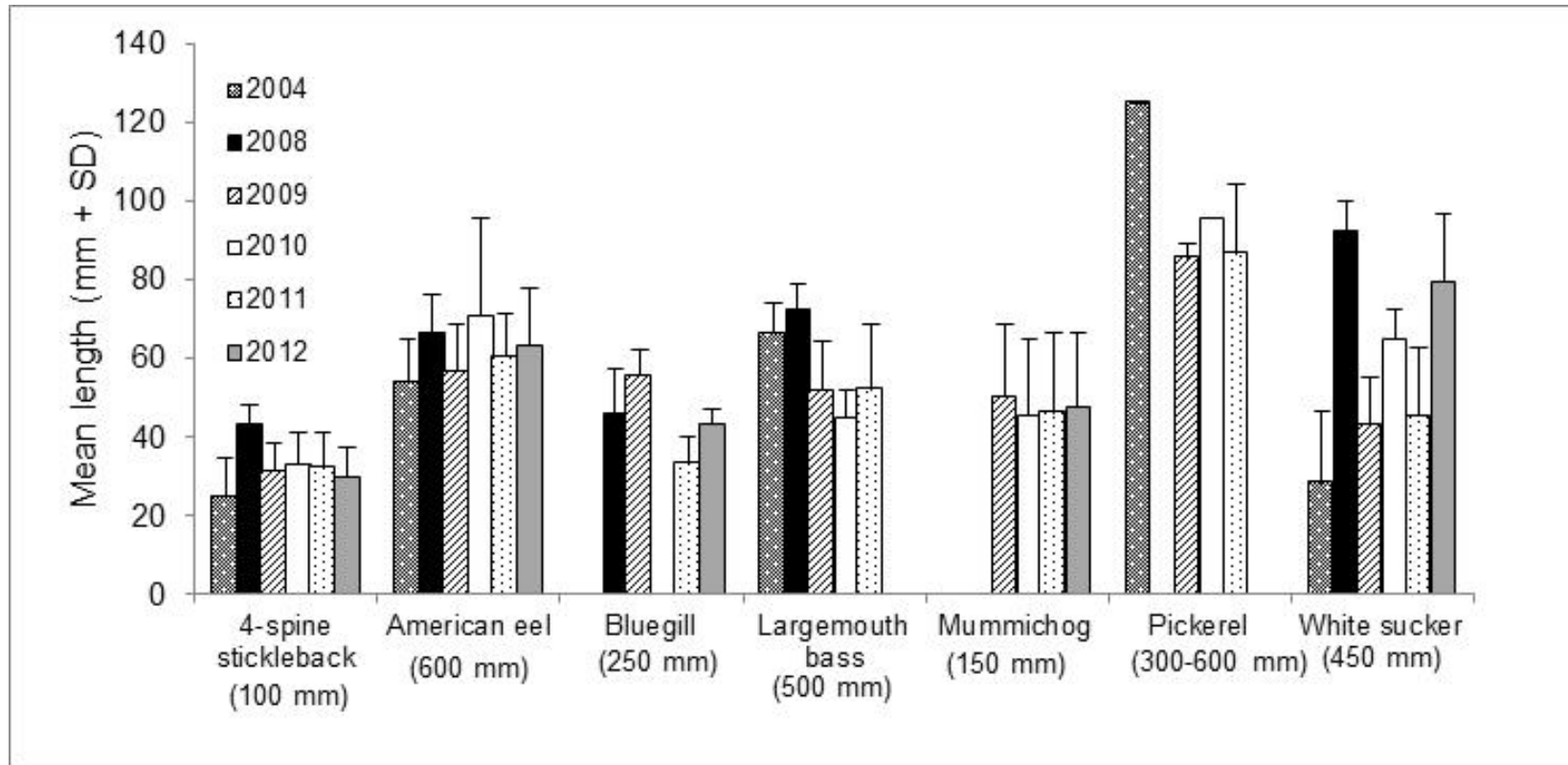


Figure 18. Mean length (mm ± SD) of nekton sampled at Saugus Iron Works NHS with throw traps and seines during pre-restoration (2004) and post-restoration (2008 to 2012) monitoring. Mean adult length (mm) is given under each species name for reference. Only nekton where more than five individuals were collected (all years combined) are shown.

Table 16. 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}.

Sampling date	Water Temperature ¹ °C (maximum)	Salinity ppt	Dissolved Oxygen ² mg l ⁻¹ (minimum)
9 June 2004 (n=16) (river)	21.5 $\pm$ 1.4 (23.9)	0.3 $\pm$ 0.04	7.4 $\pm$ 0.5 (6.3)
5 Aug 2004 (n=16) (river)	19.9 $\pm$ 0.8 (20.9)	0.1 $\pm$ 0.1	7.5 $\pm$ 0.5 (6.3)
18 Sept 2008 (n=11, basin)	18.4 $\pm$ 0.8 (20.1)	0.5 $\pm$ 0.8	8.3 $\pm$ 1.3 (7.5)
23 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)
15 July 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>)
15 July 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>)
14 & 15 Sept 2009 (n=13, basin)	18.6 $\pm$ 1.0 (21.0)	0.7 $\pm$ 0.1	7.2 ³ $\pm$ 0.2 (7.0)
14 & 15 Sept 2009 (n=20, river)	18.6 $\pm$ 0.7 (19.9)	0.3 $\pm$ 0.1	8.6 $\pm$ 0.4 (7.2)
19 July 2010 (n=10, basin)	28.4 $\pm$ 0.8 (<u>30.0</u>)	3.5 $\pm$ 2.8	8.5 $\pm$ 2.4 (<u>5.5</u>)
19 July 2010 (n=22, river)	25.9 $\pm$ 1.5 (<u>28.7</u>)	0.4 $\pm$ 0.5	9.6 $\pm$ 3.1 (<u>1.9</u>)
1 Sept 2010 (n=11, basin)	23.2 $\pm$ 1.0 (25.0)	2.1 $\pm$ 2.6	10.5 $\pm$ 2.8 (7.2)
1 Sept 2010 (n=23, river)	23.9 $\pm$ 0.8 (26.1)	0.4 $\pm$ 0.2	11.7 $\pm$ 0.6 (9.9)
7 July 2011 (n=14, basin)	23.0 $\pm$ 1.6 (27.6)	0.4 $\pm$ 0.4	8.1 ⁴ $\pm$ 0.7 (6.9)
7 July 2011 (n=22, river)	24.1 $\pm$ 1.2 (27.0)	0.4 $\pm$ 0.4	8.6 $\pm$ 0.6 (6.9)
6 Sept 2011 (n=16, basin)	21.1 $\pm$ 0.9 (22.0)	0 $\pm$ 0	6.4 $\pm$ 1.3 (<u>4.6</u>)
6 Sept 2011 (n=22, river)	19.7 $\pm$ 0.5 (20.8)	0.2 $\pm$ 0.1	7.3 $\pm$ 0.4 (6.4)
10 July 2012 (n=17, basin)	23.5 $\pm$ 2.4 (<u>28.6</u>)	0.4 $\pm$ 0.3	6.5 $\pm$ 2.1 (<u>1.0</u>)
10 July 2012 (n=22, creek)	21.6 $\pm$ 0.9 (23.2)	0.4 $\pm$ 0.3	8.3 $\pm$ 0.5 (7.3)
6 & 7 Sept 2012 (n=7, basin)	21.7 $\pm$ 0.8 (23.0)	0.5 $\pm$ 0.8	7.1 ⁴ $\pm$ 1.8 (<u>3.2</u>)
6 & 7 Sept 2012 (n=21, creek)	21.8 $\pm$ 0.5 (23.0)	0.2 $\pm$ 0.1	9.7 $\pm$ 0.6 (8.1)

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.

⁴ Values based on 8-10 readings taken throughout turning basin.

Table 17. List of exotic and native transplant nekton (species native to the U.S. that have been introduced to areas outside of their original range) recorded during sampling. Status information is from the USGS Nonindigenous Aquatic Species Database.

Scientific Name	Common Name	Status	Year(s) Observed
<i>Carcinus maenas</i>	Green crab	Exotic	2004
<i>Lepomis macrochirus</i>	Bluegill	Native transplant	2008, 2009, 2011, 2012
<i>Micropterus salmoides</i>	Largemouth bass	Native transplant	2004, 2008, 2009, 2010, 2011

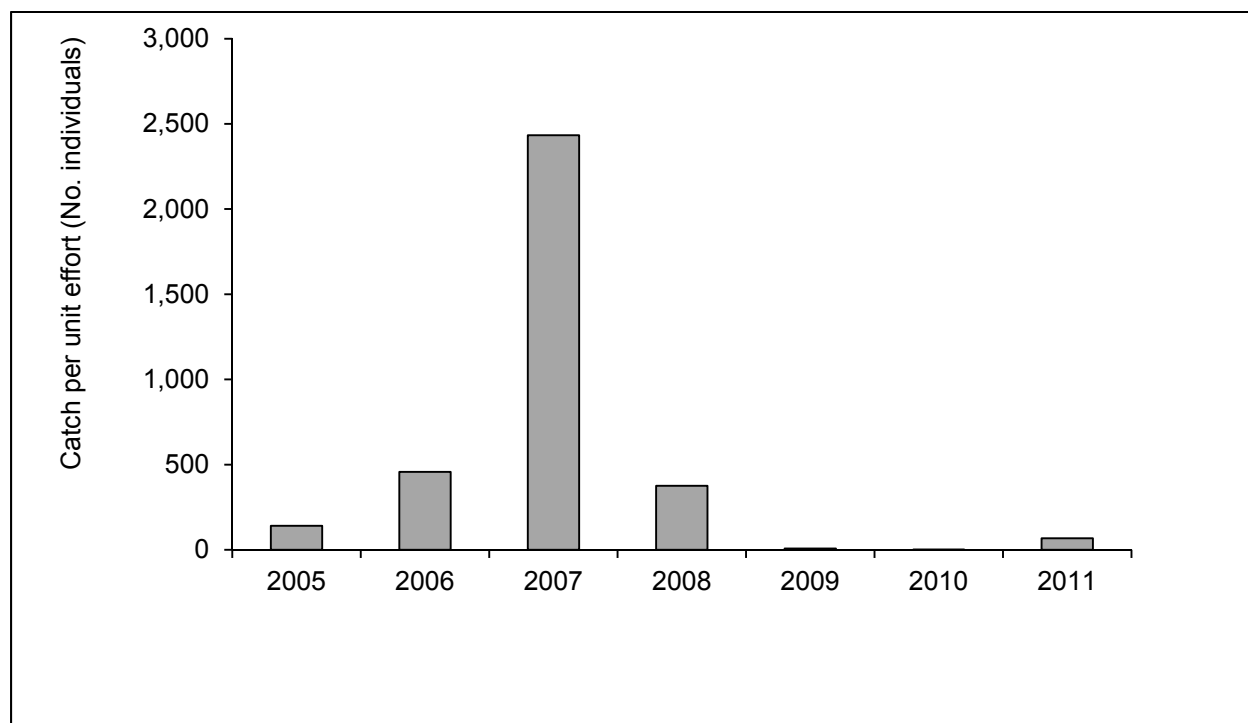


Figure 19. Rainbow smelt catch (number of individuals collected) at SAIR from 2005-2011 (data from MA DMF).

Avian community

NETN avian monitoring was initiated in 2008. Twenty-one to 33 species have been detected annually by Network monitoring, for a net total of 42 species detected in the park including areas outside of the restoration area (Table 18) (Faccio and Mitchell 2009). During park wildlife observations in the restoration area, 31 to 68 species have been detected from 2009 to 2012 (excluding five taxa that were only identified as duck, heron, gull, shorebird, or sparrow), for a net total of 87 species observed during wildlife observations (McNiff and Albert 2010, Albert and Bloch 2011, Welch and Albert 2012, Albert et al. In Prep., Table 18). Together both monitoring programs have been 88 species of birds at SAIR since 2008.

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 20). 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.

Seven species observed in the restoration area during park wildlife monitoring are listed as priority species by Partners in Flight (PIF) for the Southern New England area (Dettmers and Rosenberg 2000) (Table 18). The Baltimore oriole (*Icterus galbula*) has a PIF status of 1A: High Continental Priority-High Regional Responsibility indicating that conservation of these species is of concern throughout their range and that conservation in the region is critical to the overall health of the species. The American black duck (*Anas rubripes*) has a PIF status of IIC: High Regional Priority, High Regional Threat, indicating that it is of moderate continental priority and is uncommon in the region and whose remaining populations are threatened, usually because of extreme threats to sensitive habitats. The other five species: American bittern (*Botaurus lentiginosus*), black-crowned night heron (*Nycticorax nycticorax*), great blue heron (*Ardea Herodias*), great egret (*Ardea alba*), osprey (*Pandion haliaetus*), and snowy egret (*Egretta thula*) are PIF status of V: Additional State Listed Species, indicating that the species is of special interest locally (Dettmers and Rosenberg 2000).

Mammals and other Wildlife

Twelve species (four amphibians/reptiles and eight mammals) were observed in the restoration area (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle zones) from 2008 to 2012 (McNiff and Albert 2010, Albert and Bloch 2011, Welch and Albert 2012; Albert et al. In Prep.) (Table 19). The Eastern gray squirrel (*Sciurus carolinensis*) was observed in all years. All mammals, with the exception of the while the Northern American river otter (observed in 2009), were also observed during the parkwide 2004 NETN Mammal Inventory at SAIR (Gilbert et al. 2008).

The common snapping turtle (*Chelydra serpentine*) resides and breeds in the park. Snapping turtle nests are laid on the slag pile, along the bulkhead, and adjacent to the blacksmith shop (Albert et al. In Prep.). The Northern two-lined salamander (*Eurycea bislineata*) has been observed in freshwater seeps on both sides of the Saugus River (Albert et al. In Prep.). In 2012, a female painted turtle was caught (and released unharmed) in a seine haul in in the deep hole near

the berm in the turning basin. None of the observed wildlife species were designated as threatened, endangered, or of special concern by the Commonwealth of Massachusetts (Massachusetts Division of Fisheries and Wildlife 2010).

Tidal Inundation

Water level data from the HOBO loggers on the marsh surface indicate that the restored marsh is inundated twice daily by tidal waters. Loggers in both the lower marsh zone near the river (HOBO #1 and #3) and those in the zone closer to the upland (HOBO #2 and #4) exhibited similar tidal and lunar signals (Figure 21). The surface of the restored marsh is flooded approximately 4 hr per tidal cycle, or approximately 25% of the time, and can be flooded to a 1 m depth on lunar tides.

NETN Water Quality monitoring

The NETN has monitored water quality following the protocols in NETN Lakes and Streams Water Quality Protocol (Lombard et al. 2006) at SAIR since 2006. Based on the NETN water quality monitoring, temperature, dissolved oxygen, and pH of the restored turning basin are within acceptable ranges, except for temperature in 2009 (Table 20). 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 2007) (Table 20).

CH2MHill (consultant) Data Summary

Tidal hydrology

Data from CH2MHill (2013) indicate that salinity in the Saugus River and turning basin (data from “Turning Basin” YSI sonde (refer to Figure 11) indicated that higher salinity values (~20 ppt) were associated with lunar high tides and low river flow events (CH2MHill 2103). Salinity values generally fluctuated between 0 and 16 ppt (Figure 22) with values >20 ppt most often observed in 2010, which was a dry year, while in other years (2008 and 2012) salinity rarely, if at all, exceeded 20 ppt (CH2MHill 2013). Salinity of water inundating the marsh surface can reach 10-15ppt, especially during new and full moon high tides; however, there are also extended periods of freshwater inundation in between lunar cycles (Figure 23).

River geomorphology

Cross-dimensional transects of the Saugus River indicated that some redistribution of sediment has occurred in the riverbed. The most notable change was erosion of the berm elevation likely due to a storm in April 2010. The berm elevation remained stable from 2010 to 2012. There has been some accretion of sediment at the south western end of the turning basin from 2010 to 2012; however, this area lost elevation from 2008 to 2010 and its elevation in 2012 was similar to that observed in 2008 (CH2MHill 2013). Changes in the elevation of the restored marsh surface were also noted. In 2010, the marsh surface was slightly scoured resulting in a decrease in elevation of approximately 9 cm, but this area has since accumulated sediment and was approximately 15 cm higher in elevation than it was in 2008 (CH2MHill 2013).

Sediment and water quality

Prior to the restoration, elevated concentrations of metals (arsenic, chromium, lead, nickel, and zinc) and polycyclic aromatic hydrocarbons (PAHs) were found in the marsh sediments. In general, metal concentrations were lower in 2012 compared to 2010, except for arsenic which has shown a consistent increase in concentration over time since the completion of the restoration in 2008. None of the metals or PAHs detected in 2012 exceeded the probable effect concentration, indicating that none of these contaminants likely pose a risk to sediment dwelling organisms (CH2MHill 2013). No metals were detected in the one surface water quality sample collected in May 2012.

Benthic invertebrate community

The benthic invertebrate community sampled in May 2012 was primarily composed of Dipteran chironomids (non-biting midges) (35% of the community). The second most abundant invertebrates were oligochaete worms (34% of the community). Ostracods were the third most abundant comprising 19% of the benthic invertebrate community. Other invertebrates present included amphipods and polychaete worms (CH2MHill 2013). The Hilsenhoff Biotic Index (HBI), an index that scored the degree of organic pollution based on the macroinvertebrate community tolerance to water quality, ranged between 6.31 and 9.06. This HBI score suggested that water quality ranged from fair to very poor and indicated significant organic pollution was present in the Saugus River at SAIR. The benthic community in 2008 and 2012 was dominated by dipteran insects and oligochaete worms, whereas in 2008 these taxa declined in abundance. The shift in the benthic community in 2010 could be related to the unusually high salinity recorded in 2010, a result of low river flow that allowed the tidal salinity wedge to penetrate further upstream (CH2MHill 2013)

Table 18. Birds observed in the restoration area from 2008 to 2012 during NETN monitoring and park wildlife observations. Partners in Flight status¹, if applicable, is indicated in parentheses after name. Non-native species are indicated in bold type.

Scientific name ¹	Common name	Category	Number of detections								
			NETN 2008	NETN 2009	2009 Park ²	2010 NETN	2010 Park ²	2011 NETN	2011 Park ²	2012 NETN	2012 Park ²
<i>Accipter cooperii</i>	Cooper's hawk	Non-waterbird									x
<i>Actitis macularia</i>	Spotted sandpiper	Shorebird			x	x	x		x	x	x
<i>Agelaius phoeniceus</i>	Red-winged blackbird	Non-waterbird	x	x	x	x	x	x	x	x	x
<i>Anas crecca</i>	Green-winged teal	Waterfowl							x		x
<i>Anas discors</i>	Blue-winged teal	Waterfowl									x
<i>Anas platyrhynchos</i>	Mallard	Waterfowl	x	x	x	x	x	x	x	x	x
<i>Anas rubripes</i> (IIC)	American black duck	Waterfowl			x		x		x		
<i>Anas rubripes x platyrhynchos</i>	American black duck x mallard hybrid	Waterfowl							x		
<i>Anatidae</i> species	Muscovy duck hybrid	Waterfowl							x		
<i>Ardea alba</i> (V)	Great egret	Wader		x	x				x		x
<i>Ardea herodias</i> (V)	Great blue heron	Wader		x	x		x	x	x		x
<i>Baeolophus bicolor</i>	Tufted titmouse	Non-waterbird	x	x							x
<i>Bombycilla cedrorum</i>	Cedar waxwing	Non-waterbird									x
<i>Botaurus lentiginosus</i> (V)	American bittern	Wader			x		x				
<i>Branta canadensis</i>	Canada goose	Waterfowl		x	x	x	x		x	x	x
<i>Bucephala albeola</i>	Bufflehead	Waterfowl							x		
<i>Buteo jamaicensis</i>	Red-tailed hawk	Non-waterbird			x	x			x		x
<i>Buteo lineatus</i>	Red-shouldered hawk	Non-waterbird									x
<i>Butorides virescens</i>	Green heron	Wader			x		x		x		x
<i>Calidris alba</i>	Sanderling	Shorebird					x		x		
<i>Calidris melanotos</i>	Pectoral Sandpiper	Shorebird							x		
<i>Calidris minutilla</i>	Least sandpiper	Shorebird			x		x				x
<i>Calidris pusilla</i>	Semipalmated sandpiper	Shorebird			x		x				x
<i>Calidris</i> species	Sandpiper species	Shorebird							x		x
<i>Cardinalis cardinalis</i>	Northern cardinal	Non-waterbird	x	x	x	x			x	x	x
<i>Carduelis tristis</i>	American goldfinch	Non-waterbird		x	x	x	x	x	x		
<i>Carpodacus mexicanus</i>	House finch	Non-waterbird							x		
<i>Chaetura pelagica</i> (IIA)	Chimney swift	Non-waterbird		x		x		x	x	x	x

Table 18. Birds observed in the restoration area from 2008 to 2012 during NETN monitoring and park wildlife observations. Partners in Flight status¹, if applicable, is indicated in parentheses after name. Non-native species are indicated in bold type (continued).

[illegible]

Table 18. Birds observed in the restoration area from 2008 to 2012 during NETN monitoring and park wildlife observations. Partners in Flight status¹, if applicable, is indicated in parentheses after name. Non-native species are indicated in bold type (continued).

[illegible]

Table 18. Birds observed in the restoration area from 2008 to 2012 during NETN monitoring and park wildlife observations. Partners in Flight status¹, if applicable, is indicated in parentheses after name. Non-native species are indicated in bold type (continued).

Scientific name ¹	Common name	Category	Number of detections								
			NETN 2008	NETN 2009	2009 Park ²	2010 NETN	2010 Park ²	2011 NETN	2011 Park ²	2012 NETN	2012 Park ²
<i>Turdus migratorius</i>	American robin	Non-waterbird	x	x	x	x	x	x	x	x	x
<i>Tyrannus tyrannus</i>	Eastern kingbird	Non-waterbird				x		x	x	x	x
<i>Vireo gilvus</i>	Warbling vireo	Non-waterbird				x		x		x	x
<i>Vireo olivaceus</i>	Red-eyed vireo	Non-waterbird		x							x
<i>Zenaida macroura</i>	Mourning dove	Non-waterbird	x	x				x			x
<i>Zonotricha albicollis</i>	White-throated sparrow	Non-waterbird									x
n/a	Unknown duck	n/a			x						
n/a	Unknown gull	n/a			x		x		x		x
n/a	Unknown heron	n/a			x						
n/a	Unknown shorebird	n/a			x						
n/a	Unknown sparrow	n/a			x						x
Total species detected			21	33	31	29	32	24	43	26	68

¹ Partners in Flight status: IA: High Continental Priority, High Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIC: High Regional Priority, High Regional Threat; V: Additional State Listed (Dettmers and Rosenberg 2000).

² Only data for birds observed in the six restoration zones (high marsh, low marsh, mudflat, turning basin, river channel, and berm/riffle area) in 2009 to 2012 are presented.

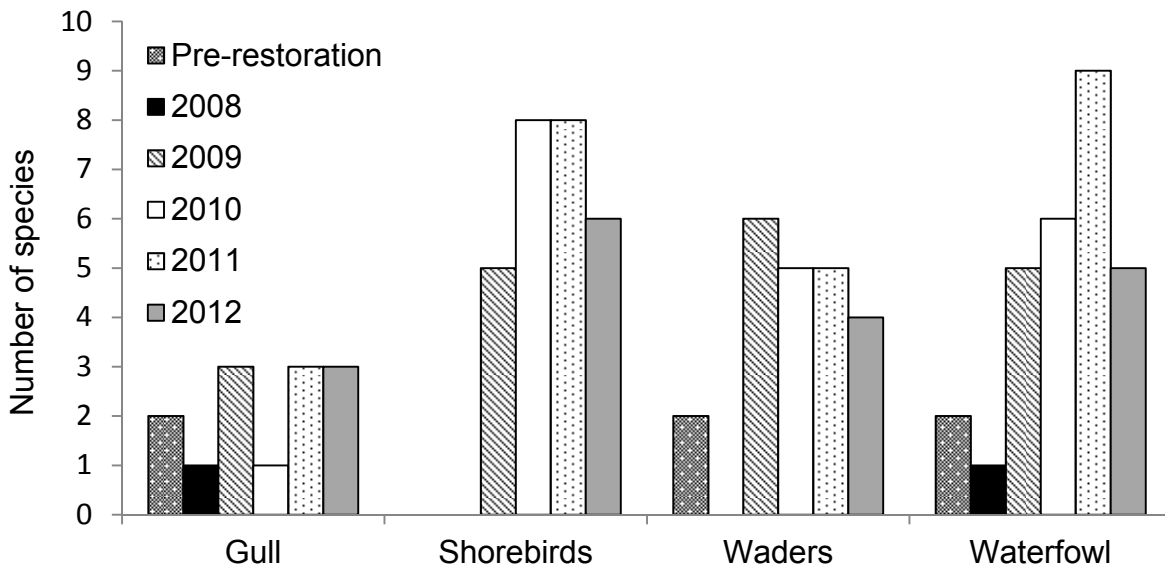


Figure 20. Number of waterbird species observed before restoration (2002-2003) and after (2008-2012, NETN and Park Wildlife data combined) the restoration of the turning basin and restored wetland.

Table 19. Species observed in the restoration area during the wildlife observation program at Saugus Iron Works.

Scientific Name	Common Name	2009 ¹	2010 ²	2011 ³	2012 ⁴
Amphibians and reptiles					
<i>Chelydra serpentina</i>	Common snapping turtle	X	X	X	
<i>Chrysemys picta</i>	Painted turtle	X	X		X
<i>Eurycea bislineata</i>	Northern two-lined salamander		X		
<i>Thamnophis sirtalis sirtalis</i>	Eastern garter snake				X
Mammals					
<i>Blarina brevicauda</i>	Northern short-tailed shrew				X
<i>Felis catus</i>	Domestic cat				X
<i>Lontra canadensis</i>	North American river otter	X			
<i>Marmota monax</i>	Woodchuck				X
<i>Ondatra zibethicus</i>	Muskrat		X		X
<i>Procyon lotor</i>	Raccoon	X	X		
<i>Sciurus carolinensis</i>	Eastern gray squirrel	X	X	X	X
<i>Tamias striatus</i>	Eastern chipmunk			X	X

² Data from McNiff and Albert 2010.

³ Data from Albert and Bloch 2011.

⁴ Data from Welch and Albert 2012.

⁵ Data from Albert et al. In Prep.

Table 20. Water quality measurements from NETN monitoring. Bold values indicate parameters that exceeded acceptable standards.

Parameter ¹	Acceptable value or range ²	2006	2007	2008	2009	2010	2011	2012
Turning Basin ³								
Temperature (°C) (warm water fishery)	<28.3	- ⁴	14.0	16.5	20.7	23.1	16.3	17.3
Dissolved oxygen (mg l ⁻¹)	>6	-	9.01	9.05	5.05	7.42	9.15	8.04
pH	6.5-8.3	-	7.44	7.54	7.23	7.73	7.39	7.20
Specific conductance (uS cm ⁻¹)	None given	-	1000	644	13721	12272	636.5	382.5
Total nitrogen (mg l ⁻¹)	<0.71	-	-	0.95	1.00	0.94	0.98	0.91
Total phosphorus (ug l ⁻¹)	<31.25	-	-	45.0	51.0	51.0	50.0	84.0
Saugus River (at USGS stream gage)								
Total nitrogen (mg l ⁻¹)	<0.71	0.91	1.05	0.95	1.14	0.93	0.99	0.99
Total phosphorus (ug l ⁻¹)	<31.25	36.0	27.5	41.5	99.50	59.0	50.5	84.0

¹ Values given are average annual readings from May and August.

² Acceptable range or value after Lombard et al. 2006.

³ The turning basin was restored in the fall of 2007, prior to that it was vegetated wetland.

⁴ “-” indicates data were not available.

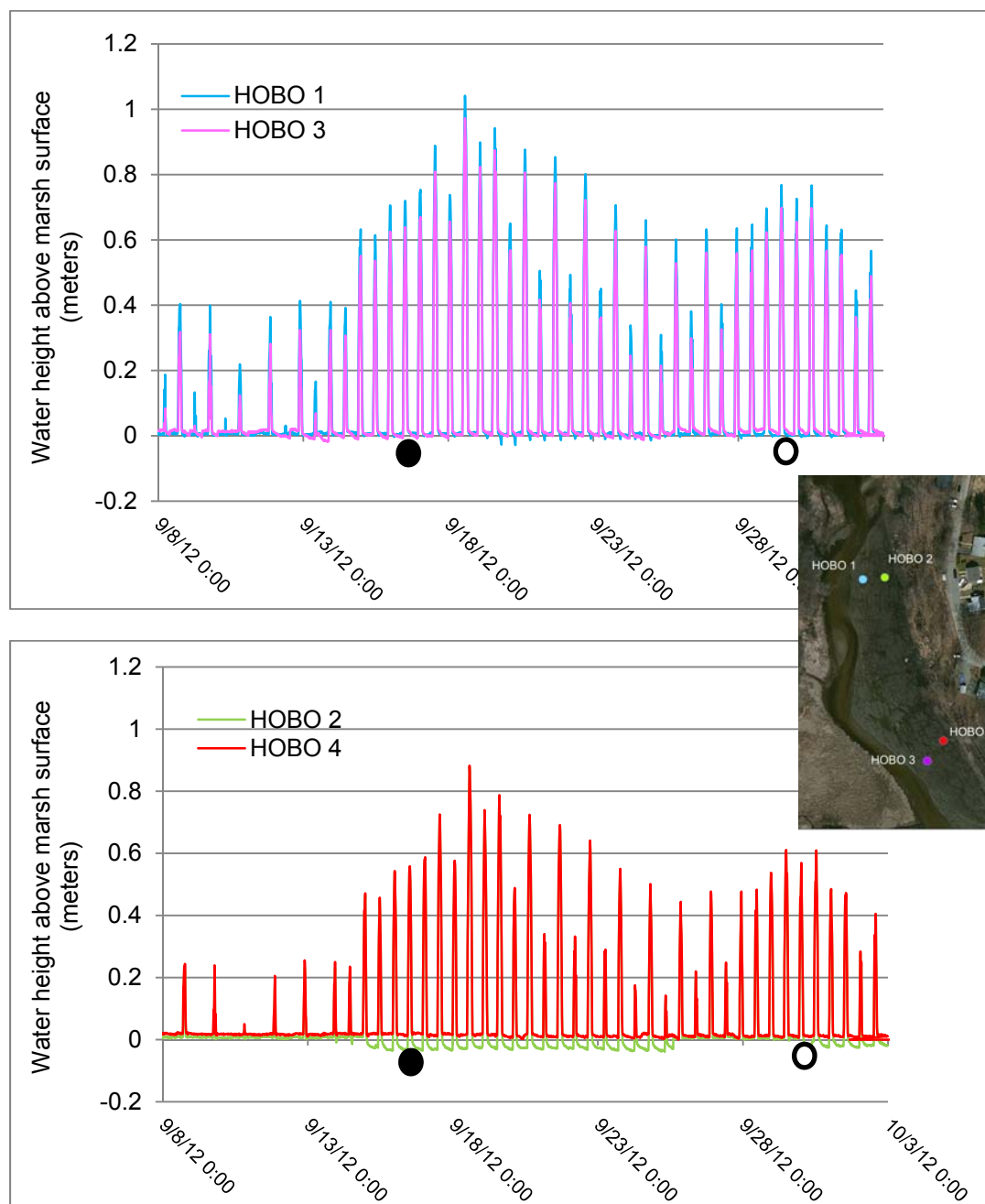


Figure 21. Tidal water inundation on the restored marsh surface for low marsh areas (top graph) and areas closer to the upland edge (bottom graph). Circles indicate dates of new moon (filled circles) and full moon (open circles). Inset shows location of HOBO loggers.

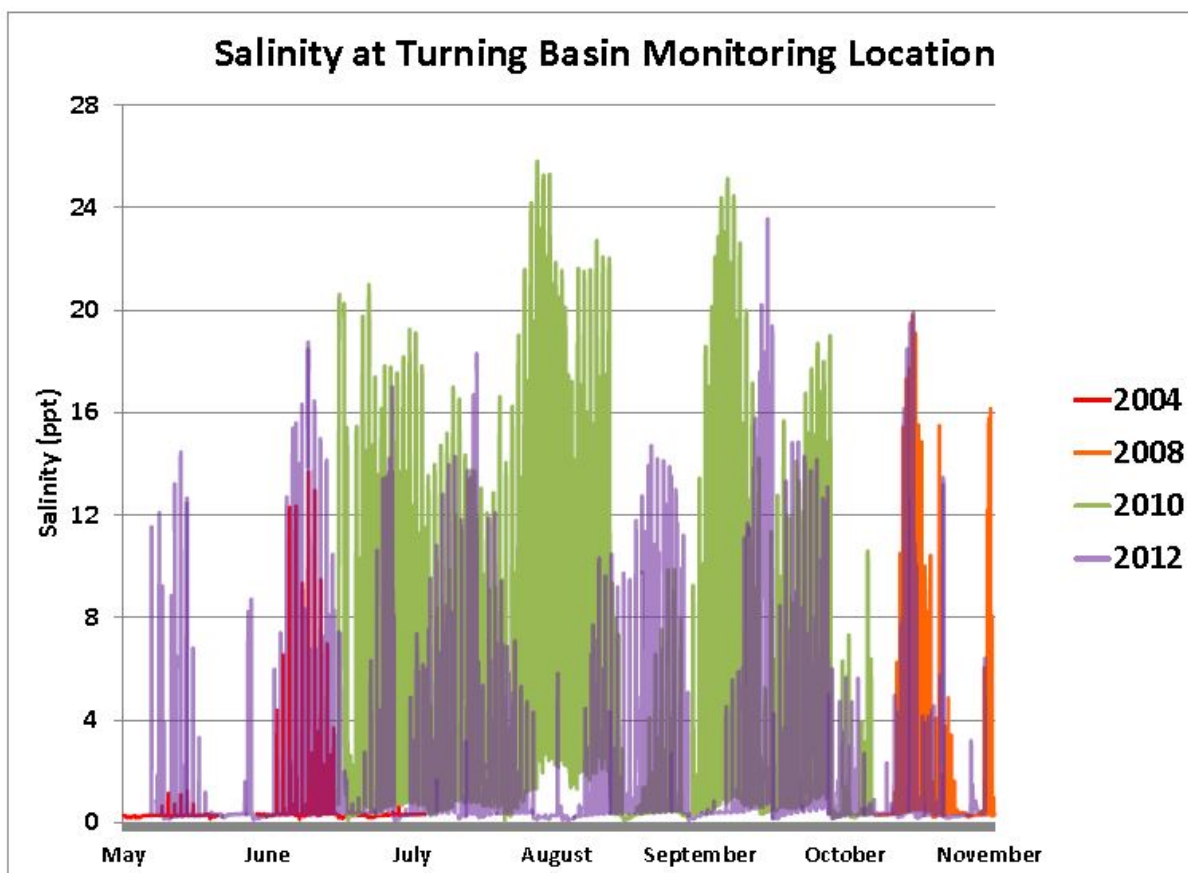


Figure 22. Salinity recorded by YSI sonde (graph excerpted from CH2MHill 2013).

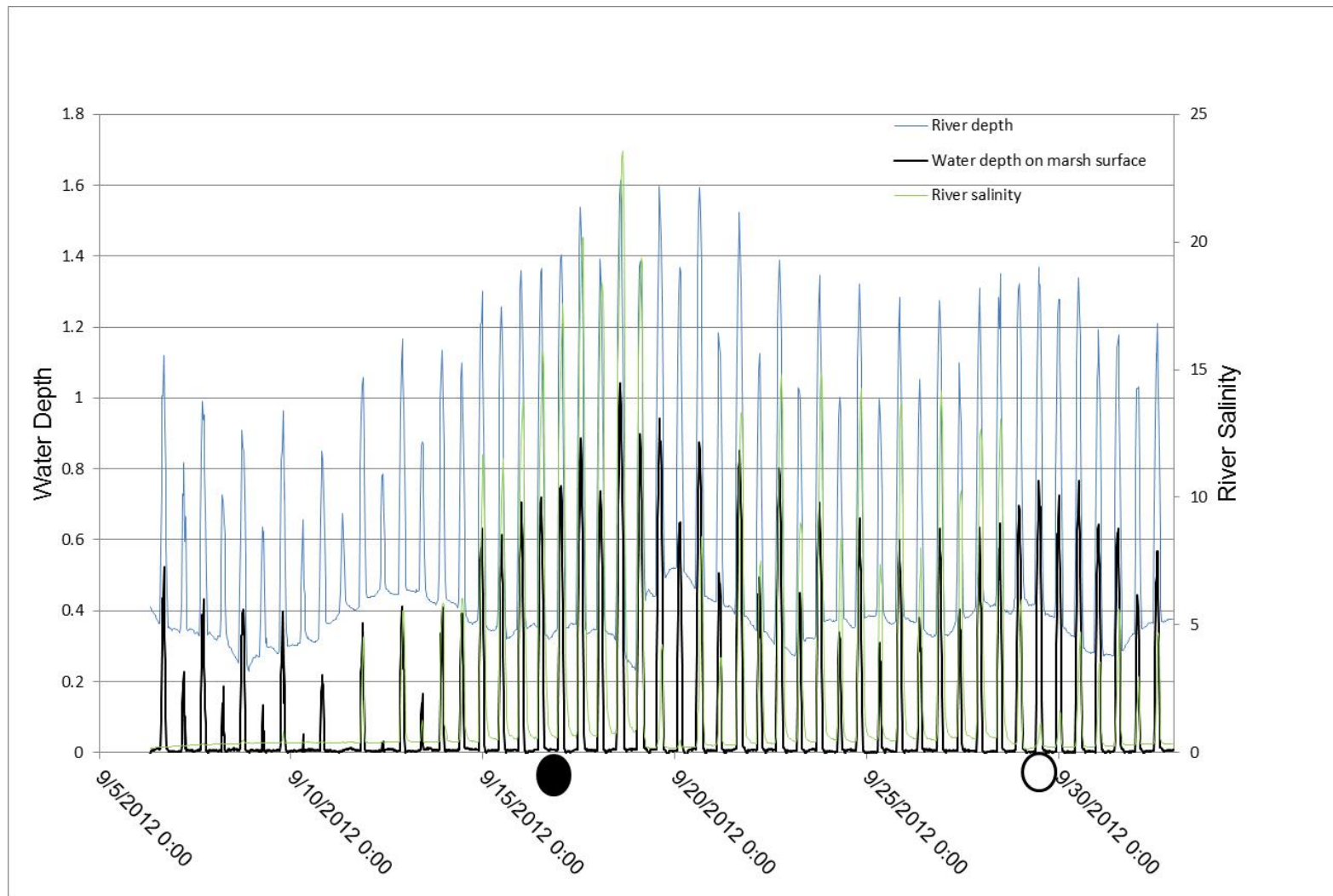


Figure 23. Tidal water inundation on the restored marsh surface (Data from HOB0 1) overlaid on CH2MHill YSI water level and salinity data for the Saugus River. Circles indicate dates of new moon (filled circles) and full moon (open circles).

Summary

Vegetation monitoring of the restored wetland indicated that the restoration was successful in eradicating the invasive common reed (*Phragmites australis*) from the restored wetland adjacent to the Saugus River. Prior to the restoration (2004) this wetland was a monoculture of dense common reed. Since 2008, a small native spike sedge, dwarf spike rush (*Eleocharis parvula*), has slowly colonized the restored marsh and has generally increased in cover from 2008 to 2012. Although the NPS plantings were not very successful in the marsh interior, a few other species native species have begun to colonize the restored area (e.g., water starwort [*Callitriche* species], horned pondweed [*Zannichella palustris*]). Bare ground and algal mat were abundant in all sampling years and although these areas were not colonized by vascular plants, they provide foraging areas for many species of shorebirds that have frequented the marsh since the restoration. A diverse assemblage of vegetation was present along the upland edge (~2 m edge) of the restored marsh between the restored marsh and the riparian woodland. More than thirty species of plants were observed in this zone during the restoration monitoring (compared to ~12 species observed in the marsh interior). Some of the species along the upland edge could be from the NPS plantings (e.g., sweet flag [*Acorus americanus*], pickerelweed [*Pontederia cordata*], and common threesquare [*Schoenoplectus pungens*]); however, most were likely native volunteer plants that have recruited to the upland edge. A few invasive plants were present in the restored marsh, with purple loosestrife (*Lythrum salicaria*) presenting the greatest threat since it has re-appeared after eradication efforts in 2010. The vegetated natural areas within the restoration zone (the small natural marshes just south of the turning basin and the riparian berm adjacent to the turning basin) had a diverse vegetation community with several invasive plants present.

Aquatic vegetation in the river is dominated by horned pondweed, which has gradually increased in abundance since 2008. Several other types of pondweed have been observed in the turning basin since 2008; however, horned pondweed is also the most common aquatic plant in the turning basin.

The nekton community in the Saugus River has transitioned from a mostly freshwater community to a brackish-estuarine community in later years. The catch of fresh to brackish water species such as four-spine stickleback (*Apeltus quadracus*) and white sucker (*Catostomus commersoni*) has declined while more estuarine tolerant species has increased in later years, with mummichogs (*Fundulus heteroclitus*) becoming the dominant nekton in the river in later sampling years. In the turning basin, young-of-the-year American eel (*Anguilla rostrata*) were the dominant nekton in all sampling years. A few individuals of freshwater species were still sampled each year (e.g., largemouth bass [*Micropterus salmoides*] and redfin pickerel [*Esox americanus americanus*], although all species (with the exception of mummichogs and tidewater silversides [*Menidia beryllina*]), were juveniles or young-of-the-year and it is not known if these freshwater species survive in the river to adulthood. Although smelt catch has declined since the restoration, viable smelt eggs were still found in over a large area in the Saugus River at SAIR, indicating that suitable spawning habitat was still present in the river.

Prior to restoration (2004) very little tidal salt water reached the turning basin. After the restoration (YSI data from 2008, 2010, 2012) there was an upstream movement of the tidal salt water wedge during high tides and periods of low river flow, especially after the removal of the Hamilton Street Bridge. The upstream movement of tidal water after the restoration is likely the primary factor influencing the transition of the nekton community from a primarily freshwater

community (before the restoration) to a brackish/estuarine community in the years following the restoration. The restored marsh and mud flats are inundated on a daily basis by tidal flow traveling up the Saugus River. The salinity of tidal waters inundating the marsh surface ranged from 0 ppt to 20 ppt. During new and full moons, salinity of the tidal waters on the marsh surface can range between 10-15ppt; whereas in between moons tidal waters are closer to 0 ppt.

The restored turning basin and marsh increased the amount of open water and created extensive tidal mud flats that provide habitat for a variety of wildlife. The number of waterbirds (shorebirds, waders, and waterfowl) observed in the restoration area has dramatically increased since 2008. Other wildlife observed in the restoration area included four amphibian/reptile and eight mammal species.

Water quality of the Saugus River at SAIR is generally within acceptable limits, although temperature occasionally exceeded recommended thresholds for warm water fisheries. Elevated values for nutrients (nitrogen and phosphorus) have been observed in both the Saugus River and restored turning basin. In general, the concentration of contaminants in the river sediments has decreased since the restoration with none of the metals or PAHs detected in 2012 exceeding the probable effect concentration, indicating that none of these contaminants likely pose a risk to sediment dwelling organisms. The Hilsenhoff Biotic Index for benthic invertebrate communities ranged from fair to very poor and indicated significant organic pollution was present in the Saugus River at SAIR.

Sources of Expertise

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