National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment for Saugus Iron Works National Historic Site

Natural Resource Report NPS/NER/NRR—2011/457

ON THE COVER

Top photo: Artist interpretation of Saugus Iron Works in 1650;
bottom photo: restored turning basin in 2009.
Photograph: M. J. James-Pirri.

Natural Resource Condition Assessment for Saugus Iron Works National Historic Site

Natural Resource Report NPS/NER/NRR—2011/457

Mary-Jane James-Pirri[1], Sarah J. Nelson[2], and Peter D. Vaux[2]

[1]Graduate School of Oceanography
University of Rhode Island
Narragansett, RI 02882

[2]Senator George J. Mitchell Center for
Environmental and Watershed Research
5710 Norman Smith Hall
University of Maine
Orono, ME 04469-5710

October 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science Office in Fort Collins, Colorado publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM).

Please cite this publication as:

James-Pirri, M. J., S. J. Nelson, and P. D. Vaux. June 2011. Natural Resource Condition Assessment for Saugus Iron Works National Historic Site. Natural Resource Report NPS/NER/NRR—2011/457. National Park Service. Fort Collins, Colorado.

NPS 444/111284, October 2011

Contents

Page

Figures

Tables

Page

Appendixes

Page

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xv) for more information.

Executive Summary

Saugus Iron Works National Historic Site (SAIR), a small, urban park located just outside of Boston, MA, preserves the site of America's first sustained, integrated, and successful iron works. The primary natural resources of the park are the tidally influenced turning basin and Saugus River, tidal wetlands bordering the river, and riparian woodlands. In 2007, the park initiated a restoration of the turning basin and southern wetlands along the river. The restoration excavated sediment and returned the turning basin to open water and mudflat, refurbished the wharf and dock area, removed invasive vegetation, began the restoration of the freshwater wetland and mudflat adjacent to the Saugus River, and made the river a more suitable nursery for aquatic and terrestrial organisms. This is one of the first tidal freshwater wetland restoration projects in New England.

The natural resources in the park are primarily associated with the Saugus River and its adjacent wetlands and the riparian forest that borders the eastern edge of the river. This Natural Resource Condition Assessment was organized by ecosystem resource, then grouped by the riverine-wetland environment and the terrestrial environment. Within each grouping, the natural resources were described, the condition and trend were evaluated based on selected metrics, and data gaps and threats were highlighted. Each natural resource section concludes with a table that summarizes the metrics and benchmarks used to assess conditions and provides estimates of condition and trend for the resource.

The natural resources of the riverine-wetland environment in the park were fish communities, aquatic benthic macroinvertebrates, water quality, riverbed and wetland sediments, river hydrology, wetland and aquatic vegetation, and amphibian and reptile communities. The fish community was historically and is currently dominated by pollution-tolerant and moderately tolerant species with very few intolerant species observed. In terms of trophic guilds, there were moderate proportions of generalist and omnivore species—usually considered a sign of a degraded fish community. Recent smelt abundance, as measured as catch-per-unit effort during spring fyke net surveys, was low and has declined in recent years; however, it was unknown if this a true decline in abundance or an artifact of gear performance. The overall quality of the smelt spawning habitat in the park rated in the lower 50th percentile when compared to other Massachusetts rivers. The aquatic benthic macroinvertebrate community was dominated by pollution-tolerant fauna and the community rated as very poor by the Hilsenhoff Biotic Index. The majority of the water quality (e.g., dissolved oxygen, nutrients, organic enrichment, pathogens, salt inputs, thermal modifications) parameters for the Saugus River at SAIR were impaired, with only pH and heavy metal concentrations meeting water quality standards. Recent analyses of riverbed sediments indicate that even though contaminants were present in the riverbed sediments, they were all below probable effect concentrations and were lower than observed prior to the restoration. The restoration of the turning basin waterfront and wetland likely removed the vast majority of contaminated wetland sediments. River discharge flow rates can be below recommended minimum flow rates, especially during the late spring. The restoration also removed invasive plants from the wetlands adjacent to the Saugus River and

created habitat that can be colonized by native wetland plants, improving the quality of the wetland areas. During recent surveys the number of reptile species was greater than 80% of the species richness historically observed in the park, but the number of amphibian species was less than 50% of the species richness historically present.

Prior to the restoration, the silted turning basin and wetlands along the Saugus River were extensively infiltrated with invasive vegetation. The restoration removed contaminated sediments and returned open water to the turning basin, thereby creating habitat for aquatic vegetation, foraging waterbirds, and fish, while providing the historical setting essential to the interpretation of the Iron Works. Native freshwater wetland plants were beginning to colonize the newly created wetlands, but some invasive vegetation (wetland and aquatic plants) were still present in the natural wetlands and were found in the newly restored wetlands and turning basin. These can threaten the establishment of native vegetation in the restoration area. The effects of the recent removal of the Hamilton Street weir, particularly its impact on the tidal inundation and salinity regime of the river and the tidal basin located just upstream, are unknown at this time. However, any significant changes in the tidal flooding and associated salinity regime within the tidal basin may have major influences on both the floral and faunal assemblages within the park.

The terrestrial natural resources of the park consist of terrestrial upland vegetation, mammal and avian communities, and air quality. The upland natural vegetation is limited to the narrow riparian woodlands along the eastern shore of the Saugus River. This mixed successional forest was co-dominated by invasive plants, most notably in the understory; however, the park has made substantial progress in reducing the abundance and distribution of invasive vegetation. There was limited information about the mammal community in the park, but there were several species that have been continuously observed in the park. The forest breeding bird community has consistently been rated as significant concern by the Northeast Temperate Network (NETN) guild rating system, with a lower-than-desired number of species in guilds representative of high-integrity ecological condition and a higher-than-desired number of generalist species considered indicative of low-integrity ecological condition. The number of waterbirds using the wetlands and tidal flats has increased since the restoration. Air quality of the park reflected the larger regional air quality of New England with total nitrogen wet deposition, total sulfur wet deposition, ozone, and visibility all exceeding acceptable values for air quality.

For a small historical park, there was a considerable amount of recent quantitative data on the park's natural resources, most of it related to the monitoring associated with the restoration of the turning basin and wetlands; however, there were areas where data gaps existed. For example, there was little information on smelt spawning habitat in the river. More comprehensive water quality and hydrological monitoring would be beneficial. There have only been a few standardized surveys of the terrestrial communities (e.g., amphibians, reptiles, and mammals), and more recent data would be beneficial to characterize these resources. Although the NETN monitors forest breeding birds in the park, the surveys were limited to two events per year and were oriented toward forest breeding birds. Standardized waterbird surveys would be beneficial to fully characterize waterbird use of the park, especially in light of the newly created wetland and tidal flat areas. Data on terrestrial vegetation was outdated and, in some cases. not applicable since the restoration dramatically changed areas that were previously surveyed.

Saugus Iron Works National Historic Site is located in a highly urbanized watershed and the surrounding landscape and the Saugus River exert great influence on the condition of the natural resources in the park. Stressors and threats associated with anthropogenic land use and human population that influence water quality parameters at SAIR include, but are not limited to, surface water runoff contaminated with road salt, non-point source pollution, sewage overflow and infiltration into groundwater, and alteration in river discharge flow rates. All of these anthropogenic influences threaten the park's riverine and wetland resources. Urbanization and habitat fragmentation in the larger watershed are threats to the terrestrial resources and may limit the type, diversity, and density of fauna present in the park. Climate change and accelerated sea-level rise are also threats to the park's flora and fauna as well as its riverine resources.

Acknowledgments

We are grateful to Charles Roman, Brian Mitchell, William Gawley, Marc Albert, and Christine McNiff who kindly provided invaluable assistance and access to several datasets. Many thanks go to Rebecca Bannon and Roland Duhaime of the National Park Service Field Technical Support Center at the University of Rhode Island for assistance with geospatial data collection, spatial analyses, and GIS mapping. Several reviewers provided helpful suggestions. Symbols are courtesy of the Integration and Application Network (http://ian.umces.edu/symbols/), University of Maryland, Center for Environmental Science.

Prologue

Publisher's Note: This was one of several projects used to demonstrate a variety of study approaches and reporting products for a new series of natural resource condition assessments in national park units. Projects such as this one, undertaken during initial development phases for the new series, contributed to revised project standards and guidelines issued in 2009 and 2010 (applicable to projects started in 2009 or later years). Some or all of the work done for this project preceded those revisions. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance and may differ in comparison to what is found in more recently published reports from this series.

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xv) for more information.

Introduction

The Park

Saugus Iron Works National Historic Site (SAIR) is a small (5.3 ha) park located 18 km north of Boston, MA. The park was established in 1968 to preserve archeological sites and features, historic and reconstructed structures and scenes, and museum collections associated with America's first sustained, integrated, and successful iron works. The iron works operated on site from 1646 to about 1670 and was critical to the development of iron manufacturing in America (NPS 2003).

The historic and reconstructed structures of the iron works, including the blast furnace, water wheel, and forge, are nestled along the banks of the Saugus River in the town of Saugus, MA. Intermixed with the historic structures are landscaped areas including shade trees, manicured lawns, flowerbeds, and herb gardens. The tidally influenced Saugus River and its associated wetlands and riparian woodlands are the principal natural resources in the park.

The turning basin and the Saugus River (Figure 1) are pivotal landscape features of the historic and cultural settings of the park. The Saugus River supplied power to operate waterwheels, while the tidal turning basin provided a shipping corridor for shallow draft boats bringing raw bog ore to the iron works and delivering finished goods (e.g., pots, kettles, skillets) to Boston and beyond (NPS 2006).

A working dock was a key element of the original iron works. As part of an effort to celebrate the American iron and steel industry within a historic park, the Saugus River turning basin was dredged in 1954 to approximate the colonial shipping lane, recreating the 17th century harbor and effectively communicating the fundamental role of the colonial iron works shipping operation (NPS 2006). The park was operated on site until the property became a national historic site in 1968.

In 1957, 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 (approx. 0.4 ha) was colonized by weedy plants and the southern wetland lining the Saugus River (approx. 1.1 ha) became choked with invasive vegetation such as *Phragmites australis* (common reed) and other exotic species (Agius 2003, CH2MHill 2005). In 2007, the park initiated a restoration of the turning basin waterfront and wetland along the banks of the Saugus River (refer to the Wetland Resources Section).

Figure 1. Newly restored turning basin and dock. (Photo courtesy of M. J. James-Pirri, 2008.)

The Landscape

The park itself is composed of three distinct natural zones. Surrounding the historic iron works structures is a manicured lawn area that includes ornamental and indigenous shrubs and trees. The manicured area slopes steeply towards the Saugus River. The river is narrow, with a mixture of riffle and tidal mudflat habitat, while the river floodplain supports a tidal wetland. A wooded area with a nature trail extends from the east bank of the Saugus River to the park's boundary (Refer to the Wetland and Terrestrial Resources sections for more detail). The U.S. Geological Survey (USGS) maintains a stream gage (Station 01102345, 42°28'10", 71°00'27") located a few meters north (upstream of tidal influence) of the Bridge Street crossing on the Saugus River.

The Saugus River watershed is 5,432 ha, of which the park is 5.3 ha (Table 1). Approximately one-quarter of the entire watershed is forested, whereas SAIR has 12% forest cover. SAIR has 32% wetland cover, whereas freshwater wetlands make up only 6% of the watershed as a whole (Table 1). The percent change in land use within SAIR over the past three decades (calculated from MassGIS landuse data from 1971 to 2005) has remained unchanged, whereas in the immediate surrounding area (within a 1-km buffer of the park) there has been a decrease in the amount of forest and open land and an increase in urban area. Slight increases in freshwater wetland and open water are due to inclusion of smaller hydrological features in the 2005 mapping effort and are not likely reflective of true increases (Table 1).

The watershed is highly urbanized, with 56% of land in urban cover types, and 65% of SAIR land is classified as urban (Table 1, Figure 2). Snook et al. (2007) proposed a value of <10% "urban" as a benchmark to characterize reference watersheds. The percent of urban area within SAIR exceeds this benchmark.

Coles et al. (2004) calculated an index of "Urban Intensity" related to the physical, biological, and chemical characteristics of coastal New England streams. The index ranged from 0 (low) to 100 (high) using 53 basin variables based on land cover, infrastructure, socioeconomic factors, and population density for 30 Massachusetts watersheds. Each watershed was assigned

Table 1. MassGIS Landuse for the Saugus River watershed and for Saugus Iron Works National Historic Site.

	Hectares (percent of area)[1]		
Land Cover Type	**Watershed (2005)**	**SAIR (2005)**	**Percent change (from 1971–2005) within 1km of SAIR**
Urban (residential, industrial, commercial, transportation)	3058 (56%)	2.6 (48%)	+5.4%
Water-based recreation (includes beaches)	1 (<0.5%)	0 (0%)	+0.03%
Agricultural, open land	280 (5%)	0 (0%)	-0.9%
Forest	1439 (27%)	0.6 (12%)	-7.7%
Non-forested freshwater wetland	310 (6%)	1.7 (32%)	+2.3%
Open water	344 (6%)	0.4 (8%)	+0.8%
Total	5432 ha	5.3 ha	419.2 ha

[1] Landuse statistics were generated using 1971 and 2005 MassGIS data (both years prior to the restoration of the turning basin waterfront and wetland) and do not include landuse inside the park.

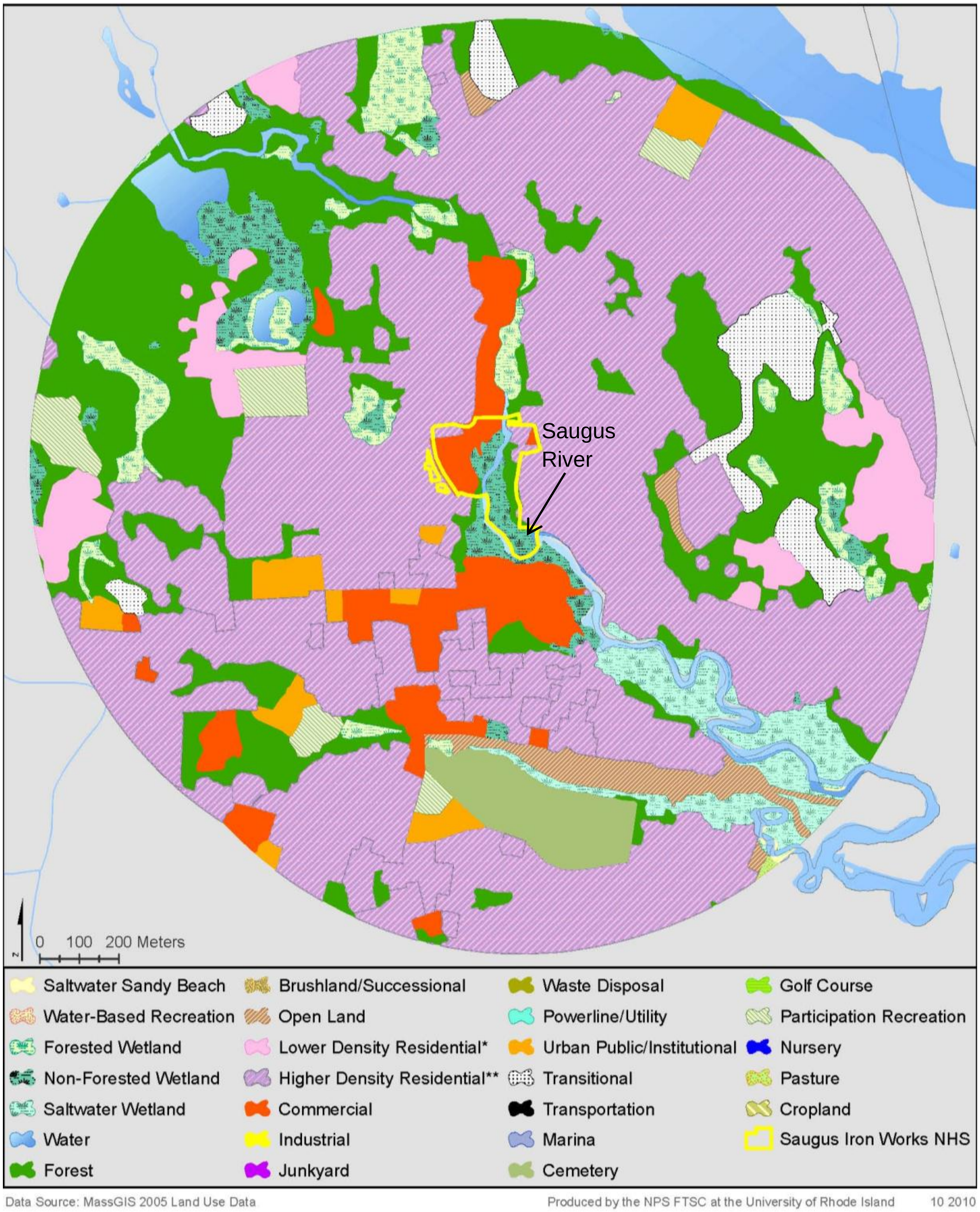


Figure 2. Landuse within a 1-km buffer of Saugus Iron Works National Historic Site.

an index value ranging from 0 (low) to 100 (high). Coles et al. (2004) documented declining fish abundance, aquatic macroinvertebrate and algal species richness, and water quality with increasing urbanization index value. The greatest change in aquatic health occurred at low to moderate levels of urban intensity (below an index value of 35, corresponding to an impervious surface cover of ~15%). The Saugus River's index value was 87.2, third highest among the watersheds, indicating an extremely urbanized watershed (Coles et al. 2004).

Turning Basin and Tidal Wetland

Restoration of the historic condition and ecological functions of the turning basin waterfront and southern wetland along the Saugus River was initiated in the fall of 2007 (Figure 3). This is one of the first tidal freshwater wetland restoration projects in New England. The restoration excavated sediment and returned the turning basin to open water, refurbished the wharf and dock area, removed invasive vegetation, and initiated restoration of the freshwater wetland and mudflat adjacent to the Saugus River. It is hoped that these improvements will make the river a more suitable habitat for aquatic and terrestrial organisms (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 weir was removed in the fall of 2009 as a mitigation permit condition for the restoration of the turning basin waterfront and wetland.

Phase I of the restoration (2007) restored the open water area of the turning basin, while Phase II (2008) removed invasive vegetation along the river in efforts to restore the native freshwater wetland along the river (Figure 4). The restoration removed vegetation and sediment from the turning basin and created about 3,330 m^2 of open water in the turning basin and adjacent river area (Figure 5). Currently, the depth of water in the basin varies from 0.1 m to 1.2 m depending on the tidal phase (CH2MHill 2009) (refer to River Hydrology Section for more detail). Cross-sectional transects through the turning basin are being monitored for five years following restoration to determine if the sedimentation rate in the basin threatens the newly restored open water habitat (refer to River Geomorphology Section).

Monitoring has recorded several fish species using the restored turning basin (James-Pirri et al. 2010a, 2010b [Refer to Fish Community Section]). Several native aquatic plant species have also colonized the turning basin, as well as the invasive curly pondweed (*Potamogeton crispus*), although monitoring in 2010 suggests that curly pondweed may no longer be present (James-Pirri et al. 2010a, 2010b [Refer to Aquatic Vegetation Section]).

Figure 3. Images of the turning basin over time: circa 1954 (top left), August 2007 (top right), October 2007 (bottom left), and September 2009 (bottom right). (Photos courtesy of NPS 2009a and M. J. James-Pirri.)

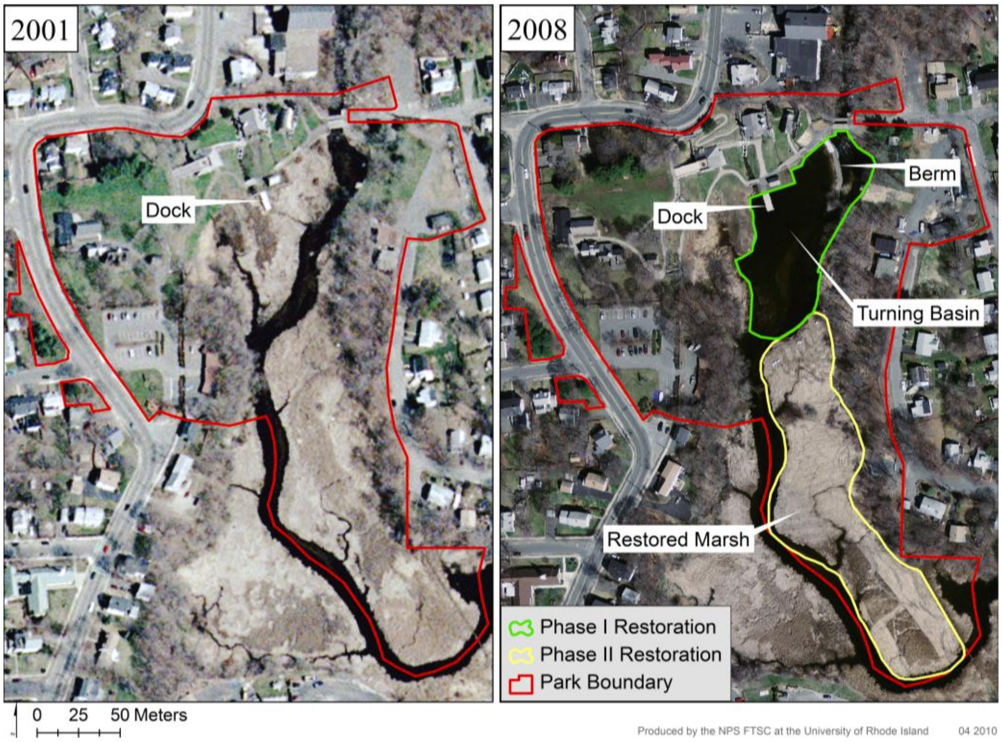


Figure 4. Aerial photographs of before (left) and after (right) Phase I of the restoration of the turning basin waterfront and wetland.

Figure 5. Phase I of the restoration (fall 2007): sediment excavation and creating open water in the turning basin. (Photo courtesy of MJ James-Pirri.)

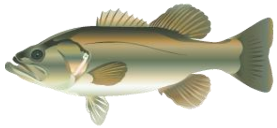
Natural Resource Condition Assessment Framework

This Natural Resource Condition Assessment is organized by ecosystem resource. Each section begins with a brief description of the resource and details any historical or current research and/or monitoring efforts. Results from these efforts are summarized and, if available, metrics are presented that have been used or could be used to assess the resource. Threats that may impact the resource are discussed and any data gaps are highlighted. At the conclusion of each section, an estimate of the condition (good, caution, significant concern, or unknown), trend (improving [moving towards a desirable condition], stable, declining [moving away from a desirable condition], or unknown), and justification for the estimate of condition for the resource are provided. A table is presented at the end of each section summarizing the metrics, benchmark values (if available), and estimates of condition and trend. Footnotes are provided in the table to identify data sources used for metrics and/or benchmarks.

Whenever possible, NPS vital sign parameters and benchmarks (e.g., NETN forest condition, NETN landbird community assessment points) or metrics from established monitoring programs (e.g., NPS air quality assessment, US EPA water quality monitoring) were used to estimate the condition of the park's natural resources. If available, data collected before and after the turning basin waterfront and wetland restoration were incorporated into the metrics used to assess condition. However, in many cases, metrics, benchmarks, and/or data to evaluate condition were not available. In these instances, metrics were based on the most recent, quantitative, and reliable data for the park or on best professional judgment.

The Riverine-Wetland Environment

Fish Community



Fish have been sampled in the Saugus River at SAIR since 1989 (Tashiro et al. 1991, USGS Water Resources 2010b), with several sampling events occurring since 2004. The recent survey efforts used a variety of gear types. Massachusetts Division of Marine Fisheries (MADMF) (Chase et al. 2006) uses a fyke net to monitor the rainbow smelt (*Osmerus mordax*) run at one location in the river. Young-of-the-year American eel (*Anguilla rostrata*) have been sampled annually from April to June since 2005 using elver traps monitored by MADMF and the Saugus River Watershed Council (SRWC). Monitoring associated with the restoration of the turning basin waterfront and wetland is conducted using throw traps and seines throughout the river and restored turning basin by the University of Rhode Island (URI) in cooperation with the NPS (James-Pirri et al. 2010a, 2010b).

Twenty-five fish species have been sampled at SAIR since 1989. White sucker (*Catostomus commersoni*), fourspine stickleback (*Apeltes quadracus*), and rainbow smelt dominate the fish community. None of the fish sampled during any survey were listed as species of concern in Massachusetts. Seven species were considered native transplants by the USGS-NAS database (USGS-NAS 2010) (Appendix A.). The Saugus River at SAIR has an active rainbow smelt run. A few individual brown trout (*Salmo trutta*), including sea-run brown trout, an exotic, have been observed during sampling. Other migratory fish species observed during smelt surveys were the diadromous alewife (*Alosa pseudoharengus*) and Atlantic tomcod (*Microgadus tomcod*), as well as the catadromous American eel (Chase 2006) (Appendix A.).

A baseline assessment (physical, chemical, and biological attributes) of the Saugus River conducted in 1989, which included one sampling station at SAIR, noted that the fish community was more depauperate (low numbers of species and individuals) than expected for a coastal plain stream (Tashiro et al. 1991). The Biotic Condition Index (BCI) from this study was quite low, ranging from 50 to 58 (a BCI of 100 indicates a “good” stream) for all sampling stations. The station at SAIR (Station 6) had a BCI of 50 (Tashiro et al. 1991). The Commonwealth of Massachusetts has developed Target Fish Community (TFC) models for several of the state’s mainstem freshwater rivers; however, the Northeast Coastal Basin, where the Saugus River is located, was not assessed. Rivers and streams in the Northeast Coastal Basin are small and require alternative assessment methodologies, such as Indices of Biotic Integrity (IBI) (Massachusetts Division of Fish and Wildlife 2007, Kashiwagi and Richards 2009); thus, there is no current TFC model for the Saugus River.

In a regional study of contaminants of the Northeast Coastal Basin, fish fillets from white suckers in the Saugus River at SAIR were assessed for total mercury (THg) in 1998–1999 (Chalmers 2002). The range for all sites was 0.24–2.71 $\mu g\ g^{-1}$ dry weight (dw), with the SAIR fillets having a THg concentration of 0.66 $\mu g\ g^{-1}$ dw. This THg value, equivalent to a wet weight (ww) value of 0.13 $\mu g\ g^{-1}$, exceeds the wildlife criterion of 0.077 $\mu g\ g^{-1}$ ww, suggesting that the current mercury burden may impact piscivorous wildlife.

Freshwater fish from throughout Massachusetts are under a statewide consumption advisory related to mercury contamination, but the Saugus white sucker samples did not exceed the 0.30 $\mu g\ g^{-1}$ EPA THg criterion for human consumption of fish.

The abundance of young-of-the-year American eel sampled from elver traps in 2006 was 0.40 catch per unit effort (CPUE) per set hour, a slight decrease from the 0.6 CPUE sampled in 2005 (Chase 2007). More recent data are currently being compiled by the SRWC and MADMF.

Smelt populations in Massachusetts have long been valued for supporting sport and small-scale commercial fisheries and as forage fish for many species of fish and wildlife (Chase 2006). The rainbow smelt run at SAIR, with greater than 1,000 m^2 of spawning habitat (Chase 2006), is one of the few active runs in the Northeast Coastal Basin of Massachusetts. A gravel berm was built to maintain the 175-m section of smelt spawning habitat in the river when the turning basin was restored (Figure 6).

Smelt spawn in a very specific type of riffle habitat characterized by turbulent water velocity (0.5–0.8 $m\ s^{-1}$), coarse cobble (10–20 cm diameter), and aquatic moss (*Fontinalis* spp.) (Chase 2009). This type of habitat is suitable for adult attraction, egg attachment, and egg survival. As of this writing these specific riffle habitat parameters have not been assessed at SAIR.

Figure 6. Gravel berm built during restoration to protect stream riffle habitat for rainbow smelt spawning, shown at spring high water, 2009 (photo courtesy of NPS).

Chase (2006) identified nine parameters (sedimentation, eutrophication, passage impediments, channel alterations, stream flow, stormwater flow, tidal influence, vegetative buffer, and water chemistry) that affect the quality of smelt spawning habitat. He qualitatively scored the condition of each parameter from 0 (no negative impact) to 3 (substantial negative impact) and summed the scores to estimate the condition of smelt spawning habitat (range of possible scores from 0 to 27). Scores for the 42 rivers in Massachusetts that were surveyed ranged from 7 to 22, with lower scores indicating a better condition. The smelt spawning habitat quality score for the Saugus River at SAIR was 15, falling between the 50th and 75th quartiles when compared to all the ranked rivers (Chase 2006). Stormwater flow was the only parameter that ranked as a "substantial" negative influence (score of 3) for the Saugus River at SAIR, while sedimentation, eutrophication, stream flow, and vegetative buffer ranked as "moderate" negative influences (score of 2). The remaining parameters ranked as "minor" impact (score of 1), with none of the parameters ranking as no impact (Chase 2006).

The smelt run at SAIR has been monitored during spring (March to May) by MADMF since 2005. Fish species richness at SAIR ranked third among MADMF smelt sampling stations (11 species observed), with a relatively high abundance of freshwater yellow perch (*Perca flavens*) and white sucker (Chase et al. 2006). In 2005, smelt were present in 56% of the fyke net hauls but at a low abundance (4.4 individuals $haul^{-1}$) compared to the other smelt sampling stations monitored by MADMF, where mean catch rates ranged from 0.2 to 71.0 individuals $haul^{-1}$ (Chase et al. 2006). The rainbow smelt run peaked in 2006 and 2007 (prior to the restoration of the turning basin waterfront and wetland) and declined in 2008 (after the restoration) (Figure 7). More recent data are currently being analyzed by MADMF (Chase unpublished data).

Smelt egg densities were periodically assessed at SAIR in the late 1980s and 1990s. Egg deposition was the highest in 1989, compared to 1988 and the 1990s. The low densities of smelt eggs observed in the 1990s relative to available spawning habitat and anecdotes of the local smelt sport fishery slowly declining raise concerns for the health of the Saugus River smelt population (Chase 2006).

Condition Metrics

TFC models and IBIs are often used to assess fish community condition (Karr 1981, Barbour et al. 1999, Legros and Parasiewicz 2007, Vile 2008, Kashiwagi and Richards 2009). Using several metrics, these methods compare fish communities of individual rivers to an expected or desired community based on data from reference sites; however, there is no TFC or IBI for the Saugus River. In the absence of these indices, some metrics (e.g., species pollution tolerance and trophic feeding guilds) from these models can be used describe general attributes of the SAIR fish community. Additionally, there are guidelines specific to smelt spawning that also can be used to evaluate conditions related to this species at SAIR. Therefore, to assess the SAIR fish community, several metrics are presented below, with the caveat that the metrics and their benchmarks are based on best professional judgment in the absence of established TFC models or IBIs for the Saugus River or comparable rivers.

The first metrics used to evaluate the overall fish community at SAIR were the percent species richness as related to pollution tolerance (intolerant, moderately tolerant, and tolerant) and trophic feeding guilds (generalist, insectivore, omnivore, piscivore, and planktivore). The fish community data from SAIR have been collected with several gear types focused on specific monitoring goals (e.g., fyke net sampling for smelt abundance, throw trap sampling for restoration monitoring [refer to Appendix A]), and since these methods have different biases it would not be appropriate to compare the individual datasets; however, to obtain a general description of the SAIR fish community, these datasets were combined into two time periods: before restoration of the turning basin waterfront and wetland (data collected from 1989 to 2007), and after restoration (data collected from 2008 and 2009), and the percent species richness was calculated for each category. More than 90% of the fish species at SAIR, both historically and currently, were pollution-tolerant to moderately pollution-tolerant fishes, with only one intolerant species (brown trout) observed in both time periods (Figure 8, Appendix A). Insectivores and piscivores, representing about 80% of the fish community both historically and currently, dominated the trophic guilds. Generalist species comprised about 20% of the community in both time periods, with few planktivorous or omnivorous species present (Figure 8, Appendix A).

Metrics used to evaluate the condition of rainbow smelt abundance and smelt spawning habitat were the smelt CPUE from fyke net data (Chase 2006, Chase unpublished data), the spawning habitat assessment score (Chase 2006), and favorable riffle habitat characteristics (Chase 2009).

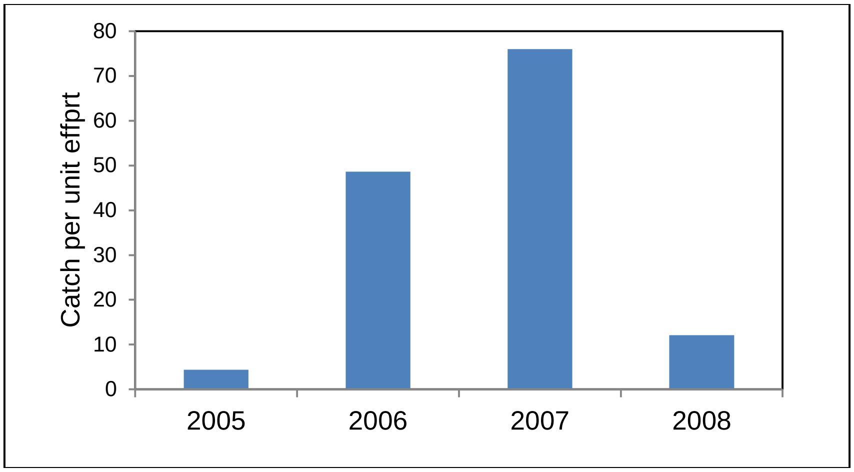


Figure 7. Catch per unit effort for rainbow smelt sampled during MADMF fyke net surveys.

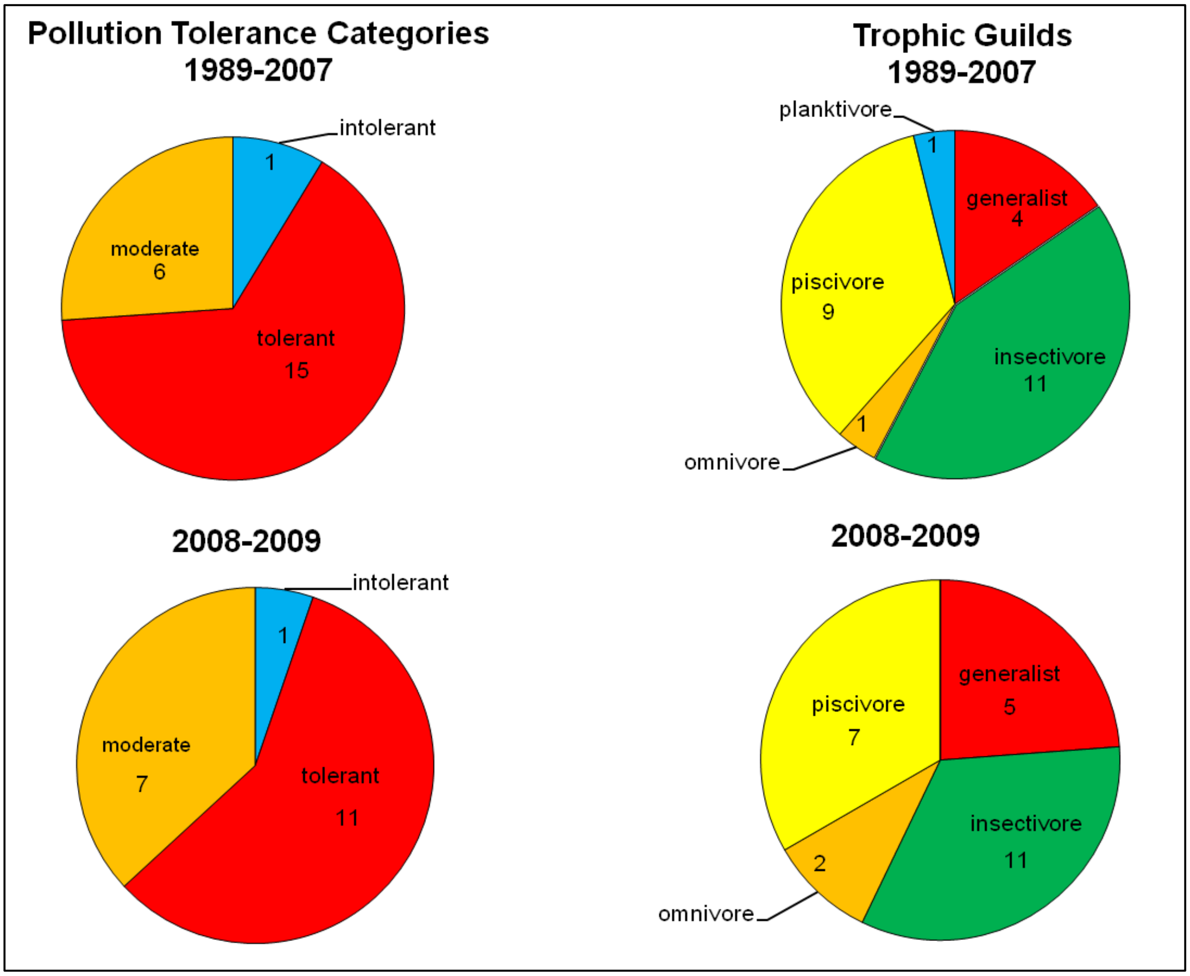


Figure 8. Proportion of species by pollution tolerance categories (left diagrams) and trophic guilds (right diagrams) for the fish community at Saugus Iron Works National Historic Site for historical (1989–2007) and recent (2008–2009) sampling events. Numbers indicate total species in each category.

Historical data from MADMF fyke net surveys were used to establish benchmarks for CPUE. The median CPUE, rather than the average, was used, as the median is less affected by extreme values. A percentile system was used to set benchmark condition values based on the best available data at the time of this assessment. Good condition was rated as a deviation of 20% or less from the median historical value, significant concern was rated as a deviation of 50% or more from the historical median value, and the caution rating fell in between these two values.

The median abundance of smelt from historic fyke net data was 30 CPUE (Chase 2006; Chase unpublished data), and decreases in smelt CPUE were viewed as undesirable. The benchmarks for smelt CPUE following the percentile system were:

Good: >24 smelt CPUE (>80th percentile compared to historic data)
Caution: 15–24 smelt CPUE (50th to 80th percentile compared to historic data)
Significant Concern: <15 smelt CPUE (<50th percentile compared to historic data)

Chase's (2006) smelt spawning habitat quality score for the Saugus River was 15 out of a possible range of 0 to 27, with lower values indicating better habitat. Based on the previously described percentile system, the benchmarks for smelt spawning habitat quality were:

Good: ≤6 (>80th percentile)
Caution: 7–12 (50th to 80th percentile)
Significant Concern: ≥13 (<50th percentile).

As previously described, the characteristics of ideal smelt spawning riffle habitat are: water velocity, 0.5–0.8 $m\ s^{-1}$; coarse cobble, 10–20 cm diameter; and the presence of aquatic moss (*Fontinalis* spp.) (Chase 2009). Based on these criteria, proposed benchmarks for assessing current and future condition of the riffle habitat at SAIR are:

Good: all parameters within ideal ranges
Caution: One parameter outside of ideal ranges
Significant Concern: Two or more parameters outside of ideal ranges.

Condition and Trend

Species Richness of Pollution-tolerance Categories and Trophic Guilds:

Condition: 😐 Caution

Trend: ⇔ Stable to ? Unknown.

Although there were no comparable benchmarks for the percent species richness for pollution-tolerance categories and trophic feeding guilds, these two metrics were evaluated as caution based on best professional judgment (Table 2). Both historically (1989–2007) and currently (2008–2009), the fish community at SAIR was/is dominated by either pollution-tolerant or moderately pollution-tolerant species with very few intolerant species present (Figure 8, Appendix A).

Table 2. Metrics, benchmark values, current condition, and trend for fish communities at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Fish Community: species pollution tolerance	No benchmarks exist for a small tidal river like the Saugus River at SAIR.	**Caution** High proportions of pollution tolerant species.	**Stable to Unknown** Historic and recent data are similar; influence of the weir removal is unknown.
Fish Community: species trophic guilds	No benchmarks exist for a small tidal river like the Saugus River at SAIR.	**Caution** Moderate proportions of generalist and omnivore species.	**Stable to Unknown** Historic and recent data are similar; influence of the weir removal is unknown.
Smelt abundance (CPUE) from MADMF fyke net sampling[1]	Good: ≥24 smelt CPUE (>80th percentile) Caution: 15–24 smelt CPUE (50th to 80th percentile) Significant concern: ≤15 smelt CPUE (< 50th percentile)	**Significant Concern** 2008 data:12.1 CPUE[1]	**Unknown** Recent data may be inaccurate due to gear performance. The influence of the restoration on smelt abundance is unknown.
Smelt spawning habitat score[2] range: 0 (ideal) to 27 (poor)	Good: ≤6 (>80th percentile) Caution: 7–12 (50th to 80th percentile) Significant concern: ≥13 (< 50th percentile)	**Significant Concern** 2006 habitat score: 15	**Unknown** Limited historical data. The influence of the restoration on smelt habitat is unknown.
Quality of smelt spawning riffle habitat[3]	Good: all within acceptable ranges Water velocity: 0.5–0.8 $m\ s^{-1}$ Cobble size: 10–20 cm Presence of aquatic moss Caution: One parameter outside of acceptable ranges Significant Concern: two or more parameters outside of acceptable ranges	**Unknown** No data are available on these parameters.	**Unknown** No data are available on these parameters.

[1] Smelt CPUE benchmarks and current CPUE based on historical data from MADMF fyke net sampling 2004 to 2008.
[2] Habitat assessment score for the Saugus River after Chase (2006).
[3] Riffle habitat characteristics after Chase (2009)

Species richness based on trophic guilds was also rated as caution based on best professional judgment. While there are currently no comparable benchmarks for a small tidal coastal river like the Saugus River at SAIR, in general, most TFC and IBI models consider moderate proportions of generalists (such as white suckers, Figure 9) and omnivore species as a sign of a degraded fish community.

The trend for these two metrics was evaluated as stable to unknown (Table 2), since there has been relatively little change in the proportion of either pollution-tolerance categories or trophic feeding guilds from earlier datasets (1989–2007) to current data (2008–2009), and the impact of the removal of the Hamilton Street weir is unknown. Recent data indicate that weir removal may have increased the abundance of estuarine fish species (e.g., mummichogs [*Fundulus heteroclitus*] and tidewater silversides [*Menidia beryllina*]) at SAIR, suggesting a possible change from a primarily freshwater fish community to an estuarine community (James-Pirri, unpublished data).

Figure 9. Juvenile white sucker, a dominant species in the SAIR fish community.
(Photo courtesy of M. J. James-Pirri, 2009.)

Smelt CPUE and Spawning Habitat Score:

Condition: ☹ Significant Concern

Trend: ? Unknown.

The most recent smelt sampling (2008) yielded a CPUE of 12.1 and was rated as significant concern based on the condition benchmarks for smelt CPUE (Table 2). The smelt spawning habitat score of 15 (Chase 2006) falls in the lower 50th percentile of the 42 evaluated rivers; therefore, the condition was evaluated as significant concern (Table 2).

The trend for smelt CPUE was rated as unknown. Even though there was a decrease in the 2008 smelt CPUE from previous years (Figure 7), there were concerns that the fyke net gear was not fishing as efficiently as it had been in previous years and the decrease in CPUE may be a sampling artifact (NPS, Marc Albert, Stewardship Program Manager, pers. comm., 5 November 2010). The trend for smelt habitat score was also evaluated as unknown, since a second survey of the habitat has not been done.

Quality of Smelt Spawning Riffle Habitat:

Condition: ? Unknown

Trend: ? Unknown.

The condition and trend for the quality of the smelt spawning riffle habitat, as described by Chase (2009), was evaluated as unknown, since there are no available data on these parameters for the smelt spawning habitat at SAIR (Table 2).

Data Gaps

The SWRC has sampled American eel elvers at SAIR for several years, but these data have not been summarized. An effort should be made to summarize and compare SAIR data to other elver sampling data in the state.

The smelt habitat at SAIR needs to be re-assessed. A re-survey of the smelt spawning habitat following the methodology of Chase (2006, 2009) would be beneficial to determine the quality of the smelt habitat at SAIR.

A re-assessment by the park for desired future conditions may be in order in light of the increase in estuarine connectivity resulting from the removal of the Hamilton Street weir.

Threats

Threats to the fish community at SAIR include degradation or loss of suitable habitat (e.g., smelt spawning habitat) coupled with degraded water quality (refer to Water Quality section for more detail). Low river flow (refer to River Hydrology section) can negatively impact the fish community at SAIR by altering water depth and water velocity during spawning periods and creating higher-than-desired water temperatures during the summer and fall. There is an overabundance of undesirable species (e.g., pollution tolerant) and moderate proportions of generalist and omnivore species that may compete with species that are more specialized.

Aquatic Benthic Macroinvertebrate Community

The aquatic benthic macroinvertebrate community of the Saugus River has been sampled several times over the past two decades. In 1989 and 1997–1998 the aquatic macroinvertebrate community was sampled as part of a baseline assessment of the Saugus River (Tashiro et al. 1991, Massachusetts Department of Environmental Management [MADEM] 2002). The macroinvertebrate community was again sampled in association with the restoration of the turning basin waterfront and wetland in 2004 and 2008 by CH2MHill (2004b, 2009).

In the late 1980s and late 1990s the macroinvertebrate community was dominated by amphipods and isopods (Tashiro et al. 1991, MADEM 2002). In 1989, Tashiro et al. (1991) noted that the Saugus River had a lack of pollution-intolerant species with insect taxa poorly represented. During sampling in 1997 and 1998, MADEM noted a dominance of filter-feeding *Hydropsychidae* (netspinning caddisflies) during its assessment at two sites (MA DEP-1 and MA DEP-3) upstream of SAIR (refer to Water Quality section for map of stations) (MADEM 2002). They suggested that the diversion dam upstream of SAIR, the upstream golf course, highway runoff, and erosion probably contributed heavy particulate loads which could be exploited by these organisms as a food source (MADEM 2002).

The Saugus River USGS stream gage site was included in a recent study examining the relationship between hydrological flow alteration and aquatic macroinvertebrate assemblages

(Kennen et al. 2010). These authors observed that streams with extreme low flows and more unpredictable high flows – often associated with urbanization – had declines in macroinvertebrate richness and sensitive taxa. The macroinvertebrate assemblage from the Saugus River had a moderate number of taxa tolerant of low or unpredictable stream flow, and no occurrences of more sensitive species (Kennen et al. 2010).

The benthic macroinvertebrate community of the river was surveyed in 2004 and 2008 at SAIR as part of restoration monitoring. Benthic sampling locations were co-located with sediment sampling locations (Figure 10) (CH2MHill 2009). A comparison of the data from Tashiro et al. (1991) with more recent CHM2Hill (2004b, 2009) monitoring data (2004, 2008) shows a community dominated by gammarid amphipods and isopods in 1989 and 2004, whereas in 2008 the community was dominated by Diptera (chironomid midges) and oligochaete worms (primarily of the family Tubificidae) (Figure 11, Appendix B). Eight other groups of organisms were also found in 2008, but together comprised less than 1% of the community (CH2MHill 2009, Appendix B). The benthic community in 1989–1991 and in 2008 was dominated by pollution-tolerant or moderately tolerant individuals, whereas in 2004 there was a high proportion of pollution-intolerant individuals due high numbers of gammarid amphipods (Figure 12); however, there was still a lack of other pollution-intolerant species such as mayflies and stoneflies (Ephemeroptera and Plecoptera, respectively) (Appendix B). In 2008, the dominance of oligochaetes, primarily tubificid worms, may be an indication of degraded benthic habitat. Dominance of tubificid worms can be a sign of an organically enriched or polluted environment because oligochaete worms of the family Tubificidae are generally classified as a contaminant-tolerant indicator species (CH2MHill 2009).

The differences observed in the benthic community among sampling events may be related to spatial heterogeneity of sampling locations at SAIR or seasonal differences in benthic macroinvertebrate abundance (samples in 2004 were collected in July and the 2008 samples were collected in late September). Or the changes in the dominant species might also be related to the disturbance created from the restoration project (CH2MHill 2009). Future sampling of the benthic community in 2010 and 2012 will provide more information to better characterize this resource at SAIR.

Condition Metrics

The metric used to evaluate the benthic macroinvertebrate community was the Hilsenhoff Biotic Index (HBI) (Hilsenhoff 1987, 1988) (Table 3). The HBI uses the composition of the benthic macroinvertebrate community as an indicator of water quality, with the premise that streams with good water quality will have healthy macroinvertebrate assemblages. This method assigns individual taxa pollution-tolerance values based on the taxon's tolerance to organic pollution. It produces a tolerance score that is weighted by the number of individuals in each taxon. The pollution-tolerance scores range from 0 to 10, where 0 applies to taxa that are least pollution tolerant and 10 applies to those taxa that are most pollution tolerant. The HBI score also ranges from 0 to 10, with lower values indicative of a healthier invertebrate community (Hilsenhoff 1987, Barbour et al. 1999). The HBI scores for sampling events at SAIR ranged from very good (sand and gravel stations sampled in 2004) to very poor (mud stations sampled in 2004 and 2008 data) (Table 3).

Figure 10. Aquatic benthic invertebrate and river sediment sample locations in 2004 and 2008 (CH2MHill 2009).

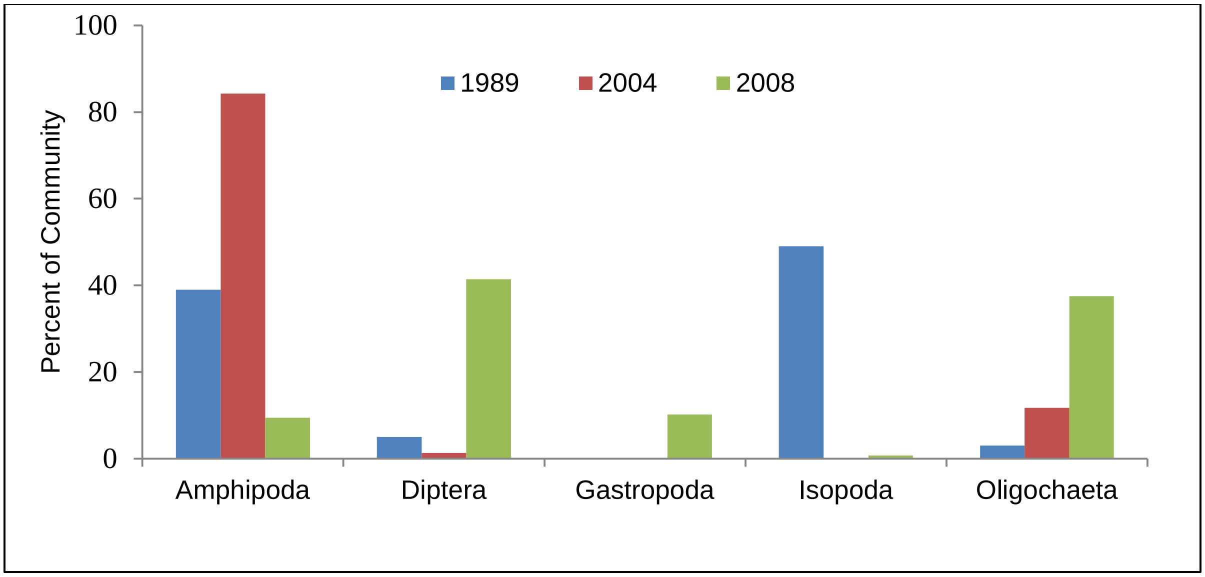


Figure 11. Benthic macroinvertebrate community composition at Saugus Iron Works National Historic Site (only dominant groups are shown). Note that sampling stations and times varied among sampling efforts.

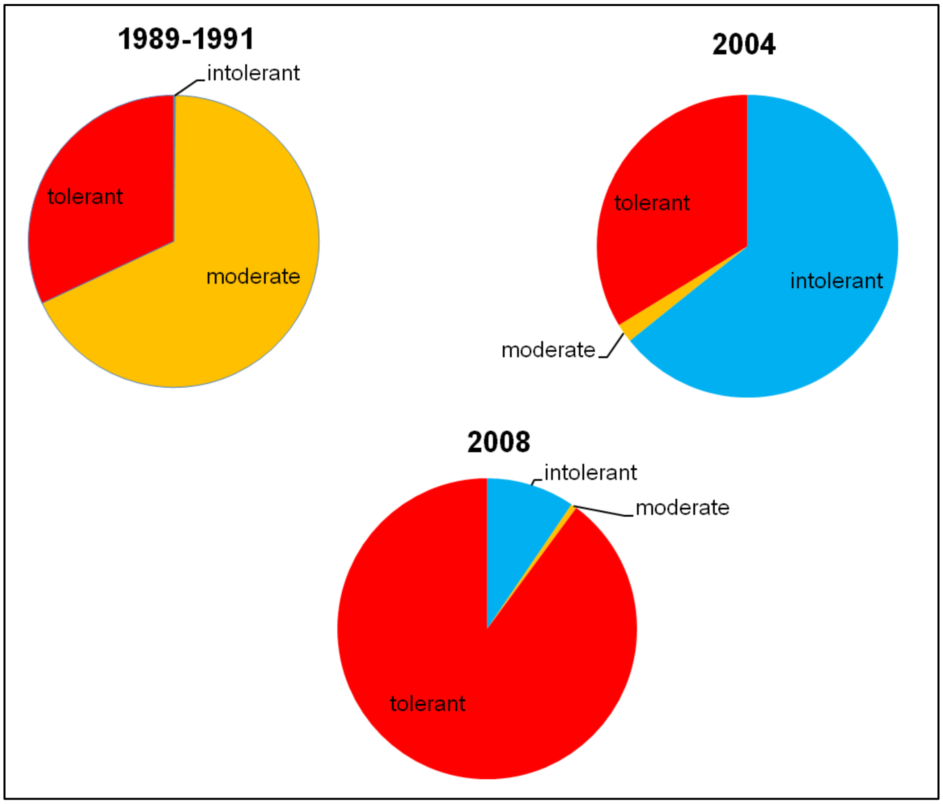


Figure 12. Proportion of individuals by pollution tolerance categories for the benthic macroinvertebrate community in Saugus Iron Works National Historic Site for historical (1989–1991) and recent (2004, 2008) sampling events.

Table 3. Hilsenhoff Biotic Index (HBI) for various benthic macroinvertebrate sampling events at Saugus Iron Works National Historic Site.

Sampling Period	Total individuals	Species richness (total taxa)	HBI score and rating[1]
1989–1991[2]	588	25	6.38 (fair)
2004 (sand/gravel stations)[3]	4,788	53[4]	3.75 (very good)
2004 (mud stations)[3]	10,276	18	9.12 (very poor)
2008 (all stations either sand or sand/gravel)[3]	10,568	29	8.99 (very poor)

[1] HBI ratings after Hilsenhoff 1987.
[2] Tashiro et al. (1991) data from samples collected at Saugus Iron Works and Hamilton Street Bridge.
[3] CH2MHill data (2004b, 2009) data from samples collected at Saugus Iron Works and Hamilton Street Bridge.
[4] Total taxa observed in 2004 (mud and sand/gravel stations combined) was 53 taxa.

The trend for the benthic macroinvertebrate community was rated as unknown (Table 4), as there is no clear pattern in the proportion of pollution-tolerant species or HBI scores over time (Figure 12, Table 3), and the impact of the restoration of the turning basin waterfront and wetland on the benthic community is not known.

Data Gaps

Benthic community sampling has been conducted in recent years (2004, 2008, and 2010 data pending analysis) and monitoring is planned for the future (2012). However, further long-term monitoring and a re-assessment by the park for desired future conditions may be required to fully characterize the community, especially in light of the recent removal of the Hamilton Street weir, which may impact the benthic community by altering tidal regimes and salinity of the river.

Threats

Threats to the benthic macroinvertebrate community at SAIR include degraded water quality, degraded habitat/sediment quality (organic enrichment and/or pollution, heavy particulate loads), erosion, and upstream impacts such as golf course and road runoff. Alterations in hydrologic flow, such as extreme high- and low-flow events, can be more frequent in a highly urbanized watershed and can negatively impact macroinvertebrate richness and sensitive taxa.

Condition and Trend

Benthic Macroinvertebrate Community:

Condition: ☹ Significant Concern

Trend: ? Unknown.

Recent sampling (2008 data) of the benthic macroinvertebrate community showed an abundance of pollution-tolerant fauna (Figure 12) and the HBI score was 8.99, rated as a very poor benthic community by Hilsenhoff (1987). Therefore, the current condition of the benthic macroinvertebrate community at SAIR was rated as significant concern (Table 4).

Table 4. Metrics, benchmarks, current condition, and trend for the aquatic benthic macroinvertebrate community at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Hilsenhoff Biotic Index (HBI)[1]	0.00–3.50: Excellent water quality, no apparent organic pollution 3.51–4.5: Very good water quality, possible slight organic pollution 4.51–5.50: Good water quality, some organic pollution 5.51–6.50: Fair water quality, fairly significant organic pollution 6.51–7.50:Fairly poor water quality, significant organic pollution 7.51–8.50: Poor water quality, very significant organic pollution 8.51–10.00: Very poor water quality, severe organic pollution	Significant Concern 2008 HBI score=8.99	Unknown No clear trend in the data.

[1]HBI benchmark values after Hilsenhoff (1987, 1988).

Water Quality

The Saugus River is classified as an inland Class B[1] freshwater river in its non-tidal portion upstream from Bridge Street (at the park's northern boundary). Downstream of Bridge Street, in its tidal portion within SAIR, it is designated as a coastal Class SB[2] coastal and marine waterbody (Commonwealth of Massachusetts 2007). Its official designation as a warm-water (Class BWWF) or cold-water (Class BCWF) fishery has never been completed (MADEM 2002). The Saugus River, including segments within SAIR (Segment ID MA93-35, MA93-43, and MA93-44, the latter two formerly part of MA93-14) (Figure 13), has several impairments, many related to urban influences, and is listed on the US Environmental Protection Agency's (EPA) impaired waters list (Table 5). State and federal agencies, non-profits, and researchers have assessed water quality in the Saugus River Watershed at several locations over the past two decades (Figure 13).

Condition Metrics

There are several well-established parameters used to evaluate water quality of inland and marine waters in Massachusetts. The parameters for Class SB marine waters and their associated assessment points are summarized below and in Appendix C.

Dissolved oxygen: In 1998, the river had dissolved oxygen (DO) levels below the 5 mg l^{-1} standard for Class SB marine and coastal waters (DeCesare et al. 2000, MADEM 2002, Appendix C). Organic enrichment and low DO were also listed as impairments for the river in 1998 to 2006 (Table 5). In more recent sampling at the USGS stream gage site, there were no DO values <5 mg l^{-1} (USGS-NAWQA 2010).

Heavy Metals: One surface water sample was collected from the river channel and analyzed for priority pollutant metals in 2008 during post-restoration monitoring. The only metal detected in the surface water was zinc at a concentration of 0.0271 mg l^{-1}, which was below the criteria for the protection of aquatic life for this metal. No other metals were detected above the reporting limits (CH2MHill 2009).

[1] Inland water quality Class B definition: These waters are designated as a habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated they shall be suitable as a source of water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value.

[2] Coastal and marine water quality Class SB definition: These waters are designated as a habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfishing Areas). These waters shall have consistently good aesthetic value.

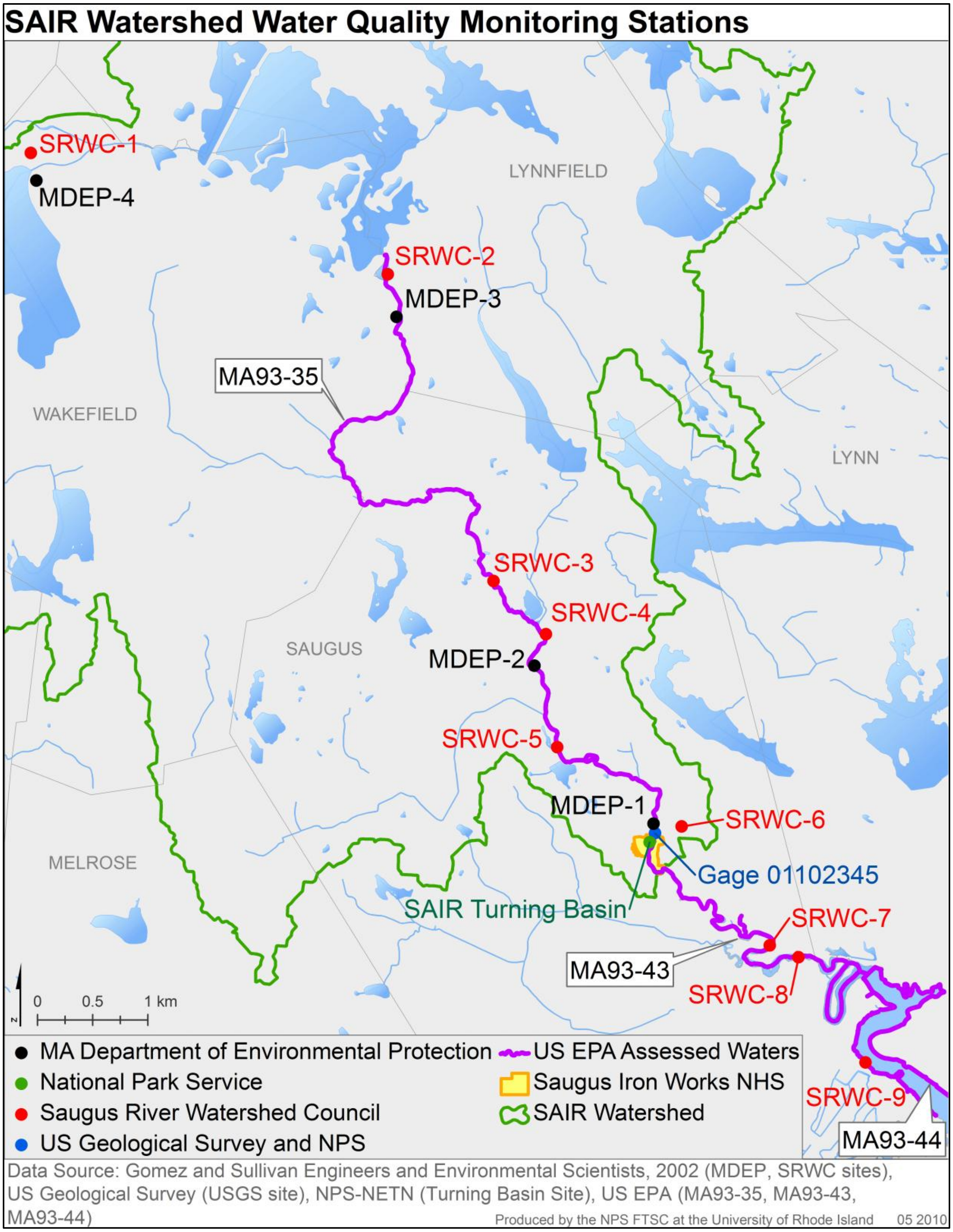


Figure 13. Water quality monitoring stations in the vicinity of Saugus Iron Works National Historic Site (SAIR).

Table 5. U.S. EPA water quality impairments from 1998 to 2010 in segments of the Saugus River at Saugus Iron Works National Historic Site.

Segment ID and Impairment	Assessment Year 1998[1]	2004[2]	2006[3]	2008[4]	2010[5]
MA93-35					
Organic enrichment/low DO	X	X	X		
Pathogens (fecal coliform)	X	X	X	X	X
Low flow alterations		X	X	X	X
Other habitat alterations		X	X		
Alteration in streamside or littoral vegetative covers				X	X
MA93-14[6]					
Pathogens (fecal coliform)	X	X	X	X	X
Thermal modifications/Water temperature	X	X	X	X	X
Oil and grease	X	X	X	X	X
Flow alterations/Other flow regime alterations		X	X	X	X

Data sources:
[1]Lombard et al. 2006
[2]Commonwealth of Massachusetts 2005
[3]Commonwealth of Massachusetts 2006
[4]Commonwealth of Massachusetts 2008
[5]Commonwealth of Massachusetts 2010
[6]Segments MA93-43 and MA93-44, both formerly part of MA93-14, are presented here for the 2008 and 2010 assessment years.

Mercury: Mercury (Hg) in streams can be affected by landscape factors (such as disturbance history and land-cover type) and hydrology. Often, high-discharge events are associated with high Hg flux in rivers and streams; dissolved organic carbon is also strongly correlated with Hg in many surface waters (Nelson et al. 2007). Mercury in its methylmercury form is toxic to wildlife and humans. Small amounts of mercury in atmospheric deposition (typically, parts per trillion values) to surface waters can translate to large body burdens in higher trophic level consumers (parts per million values) because it biomagnifies in food webs. In the Northeastern U.S., mercury is elevated in wildlife, resulting in statewide fish consumption advisories for mercury in Massachusetts (concentrations above 0.3 $\mu g\ g^{-1}$ in fish tissue are considered unsafe for human consumption [Commonwealth of Massachusetts 2010]). All waters in Massachusetts are also subject to the Northeast Regional Mercury Total Maximum Daily Load (TMDL).

At SAIR, total mercury (THg) and methylmercury (MeHg) in the river water were sampled twice during baseflow periods in 1998 and 2000. The values (~2.5 $\mu g\ l^{-1}$ THg) were below the benchmark proposed for “reference” streams across the Northeast (<7.5 $\mu g\ l^{-1}$), but values for THg and MeHg were greater than those proposed to be protective of wildlife (0.077 $\mu g\ g^{-1}$) (US EPA 1997). To more fully characterize Hg in streamwater, sampling during high-flow events would be necessary.

Nutrients: The Saugus River was characterized as “Moderately Impaired” with respect to nutrients in a study of the Northeast Coastal Basin that used 2001 USGS-NAWQA data (Riskin et al. 2003). The Massachusetts Department of Environmental Protection (MADEP) has assessed nutrient concentrations in the freshwater section of the Saugus River. At the MADEP site nearest to SAIR (site MDEP-1, refer to Figure 13), total phosphorus levels were near the 'widely accepted limit' (MADEM 2002) of <50 µg l^{-1}, with occasional exceedances. In subsequent sampling, exceedances occurred occasionally during 1999, 2000, 2003, and 2004, and in all but one sample collected in summer of 2001(USGS-NAWQA 2010, Appendix C). All USGS-NAWQA and NETN samples from the Saugus River and the turning basin (since 1998) have had higher total nitrogen values than the US Eco-regional nutrient criterion of 0.71 mg l^{-1}.

All values for chlorophyll-*a* from phytoplankton at the Saugus River USGS site were below the Eco-regional criteria of 3.75 µg $^{-1}$ in 2001 NAWQA sampling (USGS-NAWQA 2010 [Appendix C]).

Pathogens (fecal coliform/Escherichia coli): The Saugus River at SAIR has consistently been assessed as impaired by pathogens (fecal coliform/*Escherichia coli*) since 1998 (Table 5, Appendix C). Elevated bacteria levels typically observed after high-rainfall events are likely related to leakage from sanitary sewers and stormwater runoff from areas upstream of the park (MADEM 2002, CH2MHill 2008). During dry weather conditions, harmful bacteria levels can be a concern in both the river channel and pooled water in the marsh sediments (CH2MHill 2008). Water quality sampling (one station upstream of tidal influence and the other just below the turning basin) by CH2MHill (2008) immediately after the restoration (in 2008) observed that during storm events, when mean daily river-flow volumes were high (10 times above mean baseflow), secondary contact standards for *E. coli* were exceeded. During dry conditions, *E. coli* levels were generally below secondary contact levels but occasionally exceeded primary contact standards (CH2MHill 2008). Due to limitations in the dataset, it was not possible to model the relationships among stream rainfall, river discharge, and bacterial levels. Other sites on the Saugus River had high bacteria counts regardless of weather conditions (MADEM 2002). Additionally, changes in water chemistry associated with tidal fluctuation or freshwater discharge into the tidal portion of the river are likely to play an important but confounding role in the population dynamics of *E. coli* and other bacterial indices at SAIR (CH2MHill 2008).

pH (acid/base status): In freshwaters, acidity (measured and reported as pH) and acid neutralizing capacity (ANC, measured and reported as alkalinity or as Gran ANC) can be affected by acidic inputs from precipitation (especially sulfate, nitrate, and ammonium), natural organic acidity (often measured as dissolved organic carbon, or DOC), sea salt exchange in soils (typically affecting streams), and weathering rates of bedrock and soils. In turn, pH affects the mobility and toxicity of many metals, such as aluminum (Munson and Gherini 1991a, b), that can result in fish kills.

Fish are typically intolerant of very acidic conditions. The NETN uses a conservative ANC assessment point for freshwaters of >100 µeq l^{-1} (5 mg ^{1}, Lombard et al. 2006) as an indicator of systems where acidity may be a concern (others have stated that >40 µeq l^{-1} or >2 lmg l^{-1} is an adequate benchmark [Dupont et al. 2005 {Appendix C}]). Although the Northeast, in general, is strongly affected by acidic deposition (Figure 14), SAIR is located in an area not predicted to be sensitive to acidification (Dupont et al. 2005). During 1998–2001, the freshwater portion of the Saugus River had circumneutral pH averaging 7.28, alkalinity averaged 46 mg l^{-1}, and ANC (measured only during late 1998 to early 1999) averaged 45 mg l^{-1}, indicating acceptable levels and well above both criteria for fish tolerance (USGS-NAWQA 2010) (Appendix C).

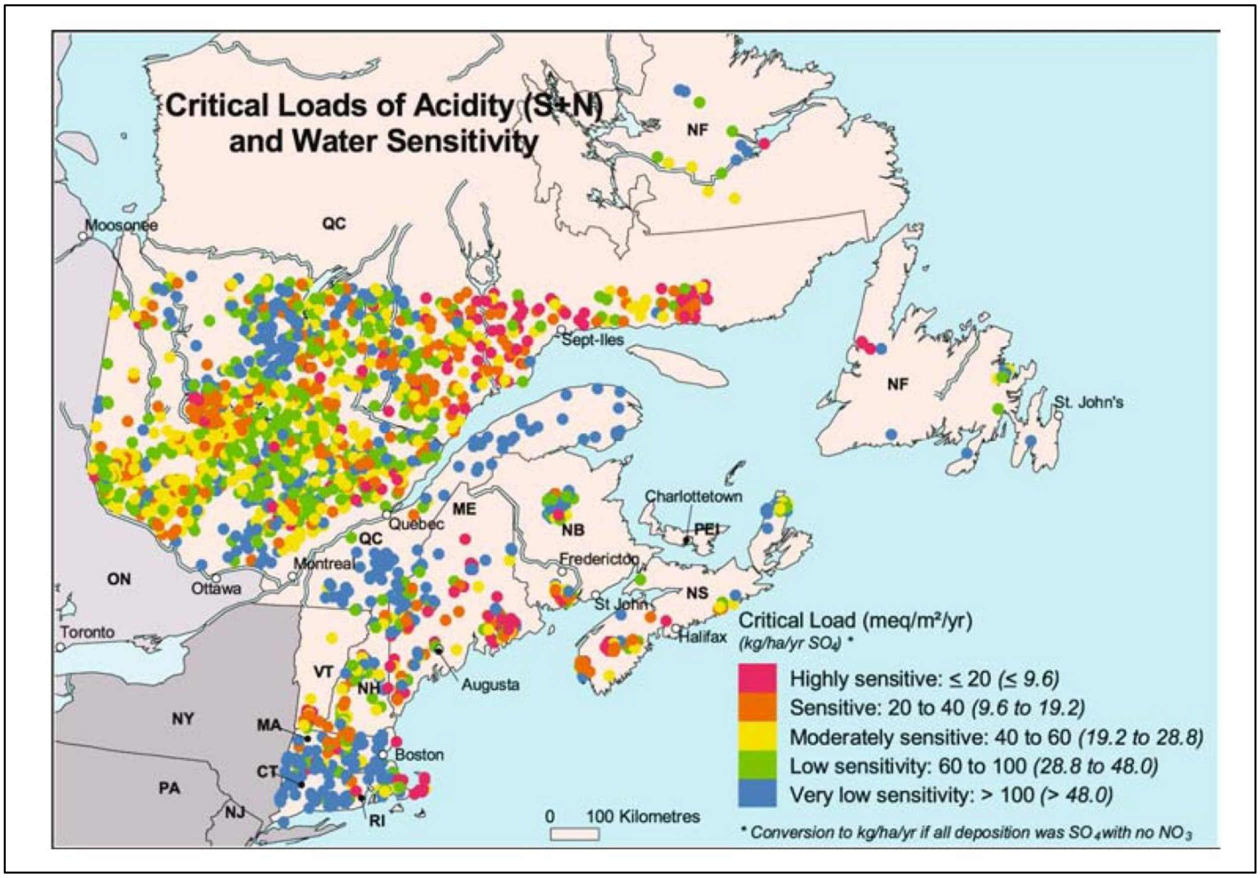


Figure 14. Critical loads of acidity (sulfur and nitrogen) and the relative sensitivity of surface waters to acidification. Saugus Iron Works National Historic Site area surface waters are in the "very low sensitivity" category. Figure excerpted from Dupont et al. 2005.

The Saugus River near the iron works may also have distinctive base cation chemistry that deviates from regional patterns due to its historic use. Comparison of the base cation magnesium (Mg) concentrations in NAWQA and research data collected at or near SAIR suggests elevated levels of Mg and a lack of correlation between Mg and calcium, as is typically seen across the Northeast (Andronache et al. 2008). Furnace bricks often contain magnesium oxide (MgO), and their use or disposal at the site could be contributing legacy Mg to the river (Andronache et al. 2008). However, Mg is also a marine-derived element and multiple sources could contribute to its relatively high concentration at SAIR.

Salt Inputs: Urbanization also affects salt (sodium [Na] and chloride [Cl]) budgets due to winter road salting. US EPA's National Aquatic Life Criteria has benchmark values for chloride of <230 mg l^{-1} for chronic exposure and <860 mg l^{-1} for acute exposure (Appendix C [US EPA 1988]). The Saugus River at SAIR had a mean Cl concentration of 103 mg l^{-1} (2905 μeq l^{-1}) from 1994–2004 (USGS NAWQA 2010 [Appendix C]). In a temporal study of Cl in Saugus River water, baseflow contained 100–150 ppm Cl; however, during the winter melt and runoff, values were in excess of 850 ppm (Coefer 2006). These values approach the benchmarks established by the US EPA.

SAIR is located at the marine-freshwater interface, and deposition of marine aerosols or tidal influences is probably the source of much of the Cl in the Saugus River in the park. The ratio of Na:Cl in the freshwater portion of the river at SAIR during regular USGS-NAWQA (2010) sampling was approximately 0.83, similar to that in seawater (0.86). Tidal saltwater intrusion can occur as far upstream as the turning basin during high-tide events (refer to River Hydrology Section for more detail). The USGS relocated a conductance probe to an area upstream of the tidal influence in 2008 and conducted over a year of continuous pilot sampling to estimate the amount of road salt that is entering the Saugus River at the iron works (data are currently being summarized, NPS 2010). The recent removal of the Hamilton Street weir has most likely influenced salt inputs, as the estuarine salt wedge from tidal flow may now extend further up into the Saugus River and turning basin.

Water temperature: The Commonwealth of Massachusetts (2007) water quality temperature standards for Class SB (coastal and marine surface waters) water temperature are not to exceed either a daily temperature of 29.4°C or a maximum daily mean of 26.7°C (Appendix C). Thermal modification has been listed as an impairment by the EPA since 1998 (Table 5).

Condition and Trend

Water Quality: Heavy Metals and pH:

Condition**:** ☺ Good.

Concentration of heavy metals and pH values are within acceptable ranges based on recent monitoring by the NPS and USGS (Table 6, Appendix C).

Water Quality: Dissolved Oxygen, Mercury, Nutrients, and Salts:

Condition**:** 😐 Caution.

Dissolved oxygen, mercury, nutrients, and salts can exceed benchmark criteria values (Table 6, Appendix C).

Water Quality: Temperature, Nutrients, Pathogens, and Water Temperature:

Condition**:** ☹ Significant Concern.

Temperature modifications and pathogens have been and are currently persistent impairments (Table 6).

Trend: ? Unknown.

It is not possible to assess trends in water quality at SAIR due to the recent restoration of the turning basin waterfront and wetland; therefore, trends for all water quality condition metrics were evaluated as unknown (Table 6). However, longer-term (~18 yr) data available for other sites in the Saugus River watershed suggest that there may be some improvements in water quality throughout the watershed, though water quality conditions for the Saugus River at SAIR still do not meet criteria for several parameters (e.g., Table 5).

Table 6. Metrics, benchmark values, current condition, and trend for water quality at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Dissolved oxygen (Class SB marine waters)[1]	Dissolved oxygen not less than 5 mg l^{-1}	**Caution** The segment upstream of SAIR has been listed as impaired by low DO in past years by the EPA.	**Unknown** The influence of the restoration on DO regimes is unknown.
Heavy metals	Refer to EPA water quality criteria[2]	**Good** Heavy metal concentrations are within acceptable ranges. Only detected metal was zinc (0.271 mg l^{-1}) which was below EPA standards[2].	**Unknown** The influence of the restoration on heavy metal concentrations is unknown.
Mercury[3]	<7.5 µg l^{-1} (reference stream value) <0.077 µg g^{-1} (wildlife protection criteria)	**Caution** Mercury concentrations in 1998–2000 (~2.5 µg g^{-1}) were below values of reference streams, but exceeded wildlife protection criteria.	**Unknown** The influence of the restoration on mercury concentrations is unknown.
Nutrients[4,5] and organic enrichment	Nitrogen: <0.71 mg l^{-1} Chl-a, phytoplankton: <3.75 spectrophotometric	**Caution** The segment upstream of SAIR has been listed as impaired by organic enrichment in past years by the EPA.	**Unknown** The influence of the restoration on nutrient and organic enrichment is unknown.
Pathogens (*Escherichia coli*) (Mean Probable Number, MPN) (Class SB marine waters)[1]	Shellfishing: Not to exceed a MPN of 88 organisms/100ml, or more than 10% of samples exceed an MPN of 260/100ml. Non-bathing beaches: No single sample shall exceed 104 colonies/100ml and the mean of 5 samples shall not exceed 35 colonies/100ml.	**Significant Concern** Currently and consistently listed as impaired by the EPA.	**Unknown** The influence of the restoration on pathogen concentrations is unknown.
pH[1]	Acceptable range: 6.5 to 8.5 and not more than 0.2 units outside of the natural background range.	**Good** pH (7.0-7.9)[7] is within acceptable ranges.	**Unknown** The influence of the restoration on pH is unknown.

Metric	Benchmarks	Current Condition	Trend
Salt inputs[6]	<230 mg l^{-1} (chronic exposure) <860 mg l^{-1} (acute exposure)	**Caution** Salt concentrations can approach EPA criteria for acute exposure during winter melt and runoff.	**Unknown** The influence of the restoration on salt concentrations is unknown.
Water temperature (Class SB marine waters)[1]	Temperature not to exceed 29.4ºC, or a maximum daily mean of 26.7ºC.	**Significant Concern** Currently and consistently listed by the EPA for thermal impairment.	**Unknown** The influence of the restoration on thermal regimes is unknown.

[1] Commonwealth of Massachusetts (2007), 314 CMR 4.00, Class SB marine and coastal waters water quality standards.
[2] National recommended water quality criteria (EPA 2009).
[3] EPA mercury criteria (EPA 1997).
[4] Massachusetts Department of Environmental Management (2002) water quality standard.
[5] NETN assessment point value (Lombard et al. 2006).
[6] EPA National Life Criteria assessment points (EPA 1988).
[7] Refer to Appendix C for details.

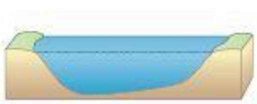
Data Gaps

Although the NETN monitors water quality at the park, it is limited to one or two sampling events per year. More comprehensive and/or continuous, site-specific data (e.g., turning basin, river channel) would be beneficial to the park to evaluate the influence of the restoration of the turning basin waterfront and wetland along the Saugus River and the recent removal of the Hamilton Street weir. For example, the weir removal has no doubt influenced the salinity regimes of the river, but comprehensive, detailed data are needed to fully understand any changes in SAIR water parameters. Continuous monitoring, as has been done recently with a YSI unit, will enhance the information about water quality in the park. A re-assessment by the park for desired future conditions may be in order in light of the increase in estuarine connectivity resulting from the removal of the weir.

Threats

Water quality at SAIR is greatly influenced by the surrounding watershed which is highly urbanized. Stressors associated with anthropogenic land use and human population that influence water quality parameters at SAIR include, but are not limited to: surface water runoff contaminated with road salt, fertilizers, and heavy metals; non-point source pollution; sewage overflow and infiltration into groundwater; and localized fecal coliform contamination. Alterations in water flow, particularly low-flow events, and loss of riparian buffers along the Saugus River can lead to increases in water temperature and decreases dissolved oxygen.

Riverbed and Wetland Sediments



Chalmers (2002) evaluated trace elements and organic pollutants in the Northeast Coastal Basin (NECB), which included samples from 1998–1999 collected at the Saugus River USGS stream gage site. As part of the restoration planning, implementation, and monitoring, cross-sectional transects of the turning basin and river were surveyed and river and marsh sediment contaminants were documented (CH2MHill 2004a, 2009). The CH2MHill (2009) sediment sampling locations in the river (Figure 11) were co-located with benthic invertebrate sampling stations. Additional surveys of riverbed sediments are planned for 2010 and 2012. Wetland sediment core sampling, which occurred prior to the restoration of the turning basin waterfront and wetland, were located in the turning basin's former degraded tidal wetland and former *Phragmites*-dominated wetland (Figure 15, CH2MHill 2004a).

In 2002, median riverbed sediment concentrations of organic carbon, lead, and mercury were elevated in the NECB compared to other study units across the U.S. Many contaminants were more strongly correlated with human population as compared to other watershed characteristics (Chalmers 2002).

There were several riverbed contaminants sampled from the USGS stream gage site in 1998–1999 that exceeded sediment quality guidelines (Chalmers 2002). The trace elements chromium, lead, and nickel (Table 7) exceeded sediment quality guidelines (MacDonald et al. 2000, Chalmers 2002). The organochlorine compounds (*p,p'*-DDD and *trans*-chlordane) and semivolatile compounds (benz[a]anthracene, benzo[a]pyrene, chrysene, flouroanthene,

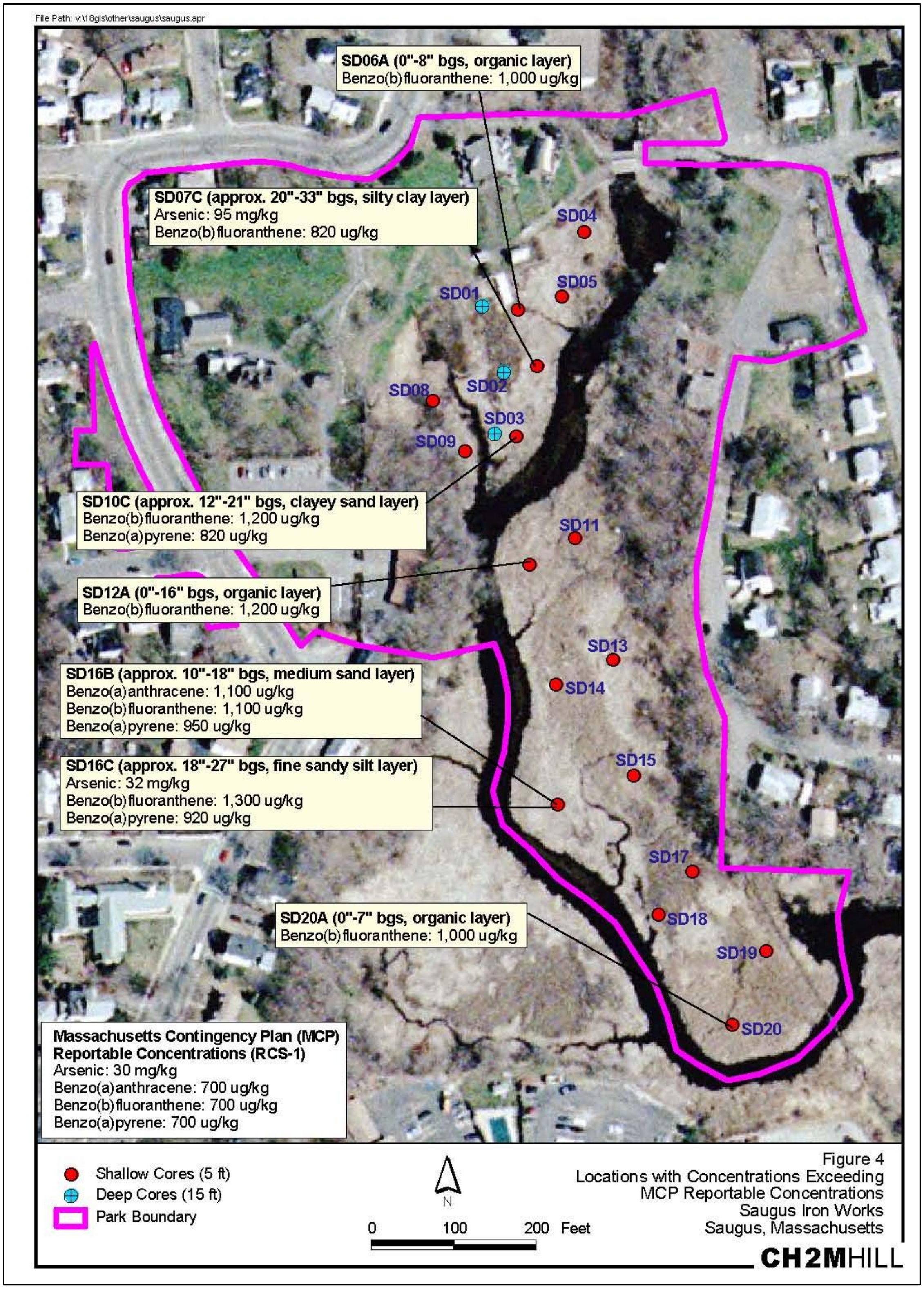


Figure 15. Marsh sediment sample locations and cores where specific contaminants exceeded Massachusetts guidelines (bgs: below ground surface). (Figure excerpted from CH2MHill 2004a.)

Table 7. Average concentration and probable effect concentration (mg kg^{-1}) of metals in riverbed sediments in and near Saugus Iron Works National Historic Site. Underlined and boldface values exceed sediment quality guidelines.

Detected Metal	Probable effect concentration[1]	1998–1999[2] (USGS gage site)	2004[3] (SAIR pre-restoration)	2008[3] (SAIR post-restoration)
Arsenic	33	29.0	14.3	2.36
Cadmium	5	2.0	1.5	0.589
Chromium	111	**<u>140.0</u>**	63.5	18.7
Copper	149	85.0	61.0	13.9
Lead	128	**<u>200.0</u>**	**<u>164.7</u>**	30.1
Mercury	1.06	0.540	0.316	0.057
Nickel	48.6	**<u>57.0</u>**	45.8	19.9
Zinc	459	380.0	263.7	68.7

[1] Probable effect concentrations from guidelines established by MacDonald et al. 2000.
[2] Data from Chalmers (2002) from samples taken at the USGS stream gage site.
[3] CH2MHill (2009) data from SAIR riverbed samples within SAIR.

phenanthrene, and pyrene) also exceeded sediment quality guidelines for samples collected in 1998–1999 (MacDonald et al. 2000, Chalmers 2002).

Breault et al. (2004) further assessed sediment quality across the Saugus River watershed and in other nearby streams in 2003. Their spatial study suggested that many trace metals (e.g., arsenic, chromium, lead) and organic contaminants across the Saugus River watershed were elevated as compared to probable background levels. Polycyclic aromatic hydrocarbons (PAH) in stream sediments at the Strawberry Brook site and dichlorodiphenyltrichloroethane (DDT) and its metabolites at the Vernon Street site (both sites ~8 km northwest of SAIR on the Saugus River) were the highest of those measured in the 2003 study (Breault et al. 2004).

As part of the pre-restoration monitoring, sediment core samples were collected in the wetlands prior to the restoration to characterize the nature and extent of sediment contamination. Sediment samples were collected and analyzed for priority pollutant metals (PPMs, e.g., antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc), PAHs, and total organic carbon (TOC) (Figure 15, CH2MHill 2004a). Seventeen shallow sediment cores (up to 5 ft) and three deep sediment cores (up to 16 ft) were collected in the wetland and former tidal basin to document sediment contamination in wetland sediments within the proposed restoration area. Most of the samples contained detectable concentrations of PPMs, with the most frequently detected metals being arsenic, chromium, lead, nickel, and zinc. Concentrations of most of the detected metals were generally higher in the upper, organically rich sediment layers. PAHs were detected less frequently than were metals. Only six of the 20 sampling locations contained concentrations of PPMs or PAHs greater than the recommended guidelines based on the Massachusetts Contingency Plan Reportable Concentrations for Soil Category 1 (MCP RCS-1) (CH2MHill 2004a, MADEP 1999, Figure 15). Generally, the locations with MCP RCS-1 exceedances were closest to the Saugus River. The least impacted areas of the wetlands were near the slag pile and the interior portion of the southern wetland, away from the river. This pattern of contamination would seem to be consistent with contaminant migration and deposition from an upstream release of PAHs. The concentrations of PPMs and PAHs detected in the marsh sediments are not unusually high for sediments in an urban river with a highly developed watershed, since these contaminants are common in surface water runoff from roadways and parking lots (CH2MHill 2004a).

Sediment characteristics and TOC analyses were conducted to discern the likely depth of the pre-1957 and post-1957 interface in the sediment profile (indicating the sedimentation event resulting from the breach of the Prankers Pond dam). Analyses indicated that in the former turning basin pre-1957 sediments were likely found at a depth greater than 3.5 ft below ground surface (bgs). In the *Phragmites*-dominated wetland evidence suggested that the pre-1957 sediments were likely found at a depth greater than 2 ft bgs over the majority of the area.

Condition Metrics

The metrics used to evaluate the condition of riverbed sediments were the concentrations of the contaminants arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc from recent sampling within the park.

The metrics used to evaluate the condition of wetland sediments were the concentrations of the PPMs and PAHs from pre-restoration sampling conducted in association with the restoration of the turning basin waterfront and wetland and the excavation of sediments in association with the restoration.

CH2MHill (2009) analyzed riverbed sediments for contaminants as part of the pre- and post-restoration monitoring. Arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc were detected in all sediment samples in both 2004 (before the restoration) and in 2008 (after the restoration). In 2004, only lead exceeded sediment quality guidelines. The average concentrations of all the detected metals in the 2008 samples were within sediment quality guidelines and were consistently lower than in the pre-restoration samples taken in 2004 (Table 7, MacDonald et al. 2000, CH2MHill 2009).

Prior to the restoration of the turning basin waterfront and wetland, PPMs and PAHs were present in the wetland sediments. The restoration excavated sediment down to the 1957 sediment line, equivalent to approximately 3.5 ft in the turning basin and 2 ft in the wetland. Based on comparison of the depth where contaminants were found (Figure 15) and the fact that the turning basin was excavated to an approximate 3.5-ft depth, it is very likely that the excavation of the turning basin removed all the contaminated sediment. However, excavation in the restored wetland was shallower than the proposed 2-ft excavation depth to allow for more emergent wetland rather than tidal flat habitat (John Burgess, CH2MHill, e-mail communication, 17 February 2011); therefore, there could still be contaminated sediments in the restored wetland, as some contaminants were observed at depths greater than the approximate 2-ft excavation depth (e.g., station SD16C, Figure 15).

Condition and Trend

Riverbed Sediments:

Condition: Good

Trend: ? Unknown to Possibly improving.

The condition of the SAIR riverbed sediment contaminants was evaluated as good and the trend was evaluated as unknown to possibly improving (Table 8). Recent analyses of sediments in 2004 and 2008 indicate that contaminants are present in the river sediments, albeit at lower levels than observed prior to the restoration, thus an improving trend. In 2004, only lead exceeded sediment concentration guidelines and there were no contaminants above recommended guidelines during the most recent sampling in 2008. Although some contaminant concentrations have declined since the restoration, long-term trends are unknown. The restoration of the turning basin waterfront and wetland was a major disturbance that could have re-suspended sediments or caused them to change oxidation states and bind with different compounds.

Wetland Sediments:

Condition: Good to Caution

Trend: improving.

The condition of the SAIR wetland sediment contaminants was evaluated as good to caution and the trend was evaluated as improving. The restoration of the turning basin waterfront and wetlands removed the contaminated sediments from these areas; however, a rating of caution was included, as the restoration may not have excavated out all the contaminated sediments in the restored wetland.

Data Gaps

CH2MHill will be sampling riverbed sediments in the future (2012) which will help further assess the impact of the restoration on riverbed sediments. Re-sampling of sediments in the restored turning basin and wetland may validate that the excavation removed all the contaminated sediments.

Threats

Threats to riverbed sediments at SAIR include alterations in stream flow that could change sediment dynamics in the river and possibly alter stream habitat characteristics (e.g., riffle habitat) and/or re-suspend or remobilize sediments and contaminants. Surface water runoff from nearby urbanized areas is also a source of contaminants to the sediments.

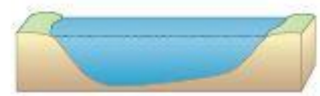
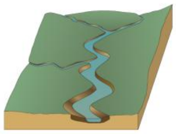


Table 8. Metrics, benchmark values, current condition, and trend for riverbed sediments at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend/Comments
Riverbed sediment contaminant concentration (probable effect concentration) [1]	Arsenic: <33 mg kg^{-1} Cadmium: <5 mg kg^{-1} Chromium: <111 mg kg^{-1} Copper: <149 mg kg^{-1} Lead: <128 mg kg^{-1} Mercury: <1.06 mg kg^{-1} Nickel: <48.6 mg kg^{-1} Zinc: <459 mg kg^{-1}	**Good** [2] All detected contaminants were below benchmark values for the most recent samples (2008): Arsenic: 2.4 mg kg^{-1} Cadmium: 0.6 mg kg^{-1} Chromium: 18.7 mg kg^{-1} Copper: 13.9 mg kg^{-1} Lead: 30.1 mg kg^{-1} Mercury: 0.06 mg kg^{-1} Nickel: 19.9 mg kg^{-1} Zinc: 68.7 mg kg^{-1}	**Unknown** to **Improving** All detected contaminants were lower than the previous sampling event.
Wetland sediment contaminant concentrations [3]	Refer to MADEP (1999) guidelines[3].	**Good to** **Caution** The majority of the contaminated sediments were removed by the restoration.	**Improving** The restoration removed contaminated wetland sediments.

[1] Probable effect concentration values after MacDonald et al. (2000).
[2] Current condition values from samples collected from SAIR riverbed sediments in 2008 (CH2MHill 2009).
[3] Refer to Massachusetts Contingency Plan Reportable Concentrations for Soil Category 1 guidelines (MADEP 1999).

River Hydrology



The Saugus River has been influenced by human activities for over 300 years. Dams and mills were the first activities to alter water flow, diverting water to impoundments and power textile factories (MADEM 2002). Currently, flow is regulated upstream of SAIR by the Lynn Water and Sewer Commission (LWSC) Diversion Dam which controls flows from the upper watershed into the main stem of the Saugus River (Gomez and Sullivan Engineers 2006). A partial impediment to natural estuarine tidal flow at SAIR was the Hamilton Street weir, which was removed in the fall of 2009. Anecdotal observations indicate a more extensive draining of the estuary at SAIR after the weir was removed. Hydrologic monitoring conducted annually by CH2MHill for five years following the restoration of the turning basin waterfront and wetland will provide data on how the weir removal affects hydrology and water chemistry in the park (National Park Service, Marc Albert, Stewardship Program Manager, pers. comm., 29 June 2010).

Currently, several public water supply sources are located in the Saugus River basin. Most of the water is removed directly from the river or indirectly from groundwater sources and ponds. The water does not return to the basin, but is discharged out of the basin to wastewater treatment facilities (MADEM 2002). Historically, during the summer and fall low-flow periods the majority of the water was diverted from the river at the LWSC Diversion Dam, leaving minimal flow below the dam. In recent years the LWSC has worked closely with conservation organizations to maintain continuous flows below the Diversion Dam to protect aquatic resources and facilitate upstream fish passage (Gomez and Sullivan 2006).

The US Geological Survey monitors stream stage and discharge at Station 01102345 on the Saugus River (upstream of tidal influence, Figure 16) at SAIR (USGS Water Resources 2010a). Stream discharge (ft^3sec^{-1} [cfs]) rates fluctuate seasonally with evidence of pulses likely caused by rainfall events and regulations by ponds upstream (CH2MHill 2009, USGS Water Resources 2010a). During 1995–2009, years for which data are available, annual mean discharge ranged from 14.5 cfs (2002, a drought year) to 56.5 cfs (2006), with a 15-yr (1995–2009) annual mean discharge of 33.6 cfs (USGS Water Resources 2010a). Peak flows have usually occurred during April and May since 2000, and range up approximately 20 times average mean discharge (Figure 17).

Figure 16. Location of USGS stream gage at Saugus Iron Works National Historic Site. (Photo courtesy of USGS, date unknown.)

Water surface elevation and salinity data were collected as part of the monitoring associated with the restoration monitoring. Water level in the restored turning basin fluctuated between approximately 0.1 m and 1.2 m between low and high tides, mirroring the lunar trends of high and low tide fluctuations (CH2MHill 2009). Saltwater intrusion occurred as far upstream as the turning basin during high tide events, with recorded salinities exceeding 15 ppt during these events (Figure 18). The upstream movement of saltwater

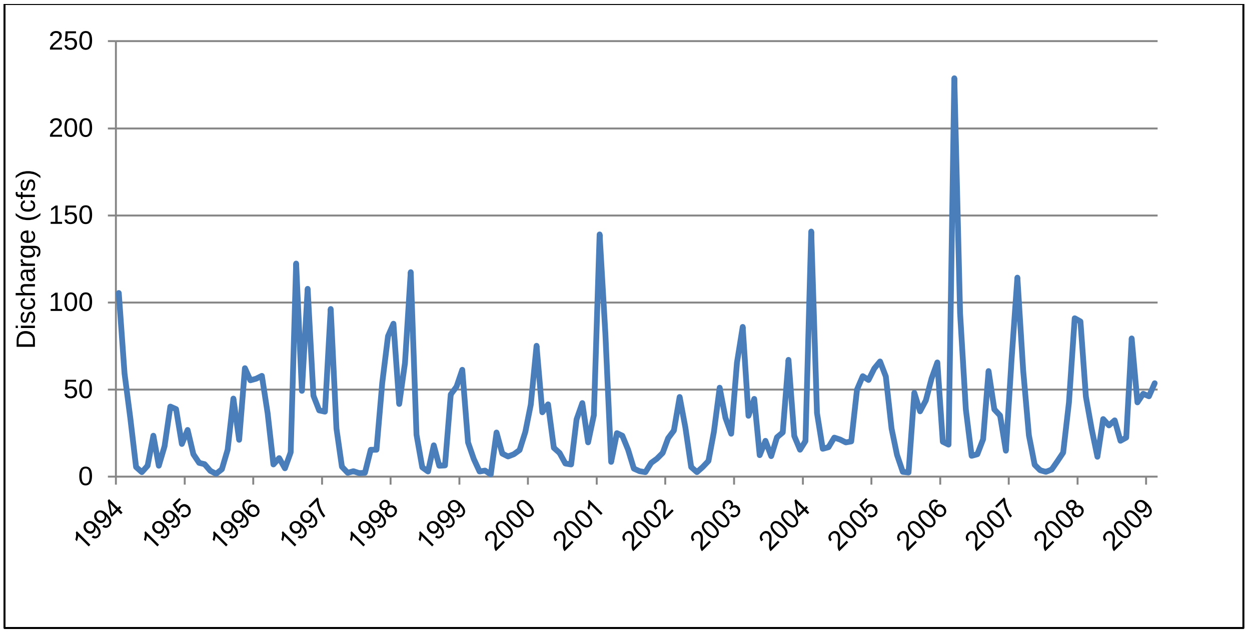


Figure 17. Mean monthly water discharge (cfs) recorded at the USGS stream flow gage, Station 01102345, at Saugust Iron Works National Historic Site (USGS 2010a).

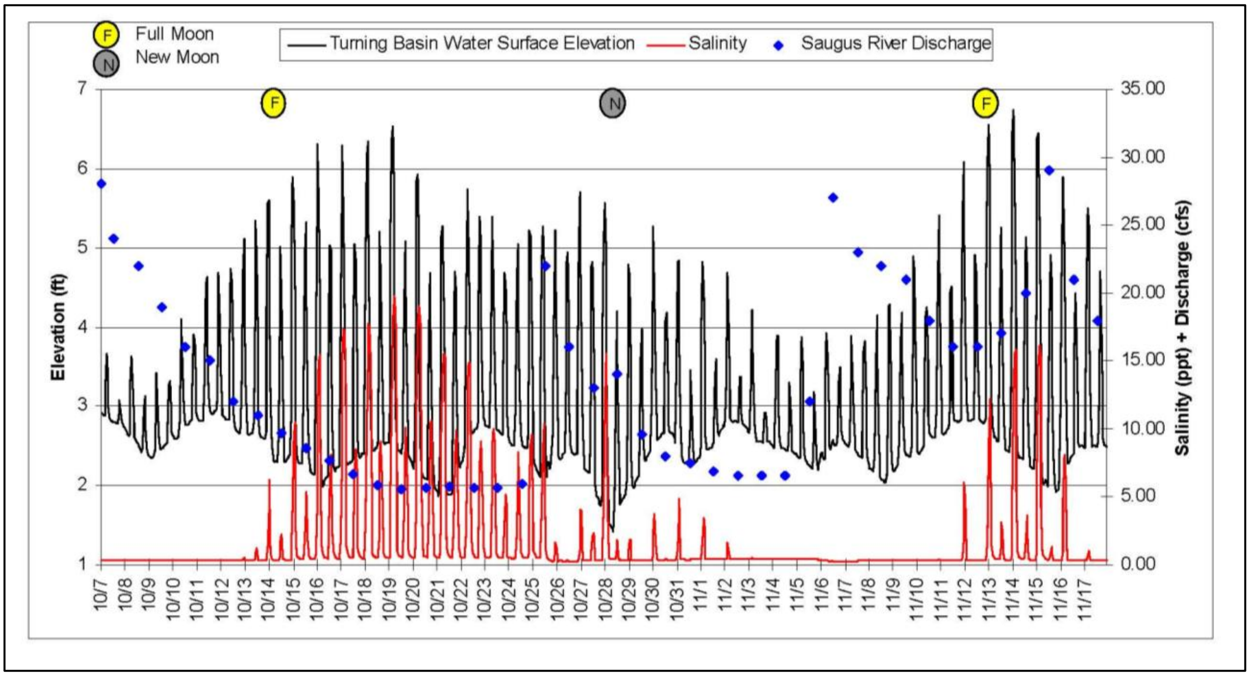


Figure 18. Surface water elevation and salinity in the turning basin, October and November, 2008. (Figure excerpted from CH2MHill 2009.)

was strongly influenced by stream flow from upstream as salinity values tended to be lower during periods of high stream flow. At stream flows higher than 10 cfs, limited amounts of saltwater would reach the turning basin; if stream flow was less than 10 cfs, saltwater would move upstream to the turning basin, except during neap tides when the high tide was at its lowest magnitude (CH2MHill 2009). The removal of the Hamilton Street weir will likely increase the extent and duration of these saltwater intrusion events and the turning basin may be trending away from a freshwater environment (<0.5 ppt) towards a more oligohaline (0.5–3.0 ppt) or even mesohaline (3.0–18 ppt) environment.

Condition Metrics

The metrics for evaluating river hydrology were average daily flow rates (cfs) (Figure 19) and the percent of days when river flow was below the recommended rates (Figure 20) for the Saugus River at SAIR. Recommended average minimum flows established by MADEM (2002) for the Saugus River are: 3 cfs for summer (June 1–September 30) based on the natural flow conditions in the basin; 6 cfs for fall (October 1–Febuary 28) based on instream flow studies; 12 cfs for spring (March 1–April 30); and 10 cfs for late spring (May 1–30) based on spring flows necessary to maintain a river herring run (Table 9). The magnitude, timing, duration, and rate of change of water flow can have an effect on the quality and quantity of fish habitat present in the Saugus River. Maintaining minimum flows during summer could help to provide and protect suitable habitat for fish in the river (MADEM 2002).

Additional potential metrics to assess river hydrology are river water depth and the extent and duration of salinity of tidal estuarine water intrusion. As with water flow, water depth and salinity are two important factors that will influence the types of communities (e.g., smelt spawning, benthic invertebrates, wetland vegetation) that are found in and adjacent to the river. Anecdotal observations suggest that removal of the weir has facilitated increased estuarine tidal exchange in the river and turning basin. No benchmarks are provided for these metrics, as the system is still in transition and data are needed to characterize the new tidal regime. Continuous monitoring of water depth, salinity, and temperature as has recently been done in the river (e.g., YSI monitoring) and these data will provide baseline information.

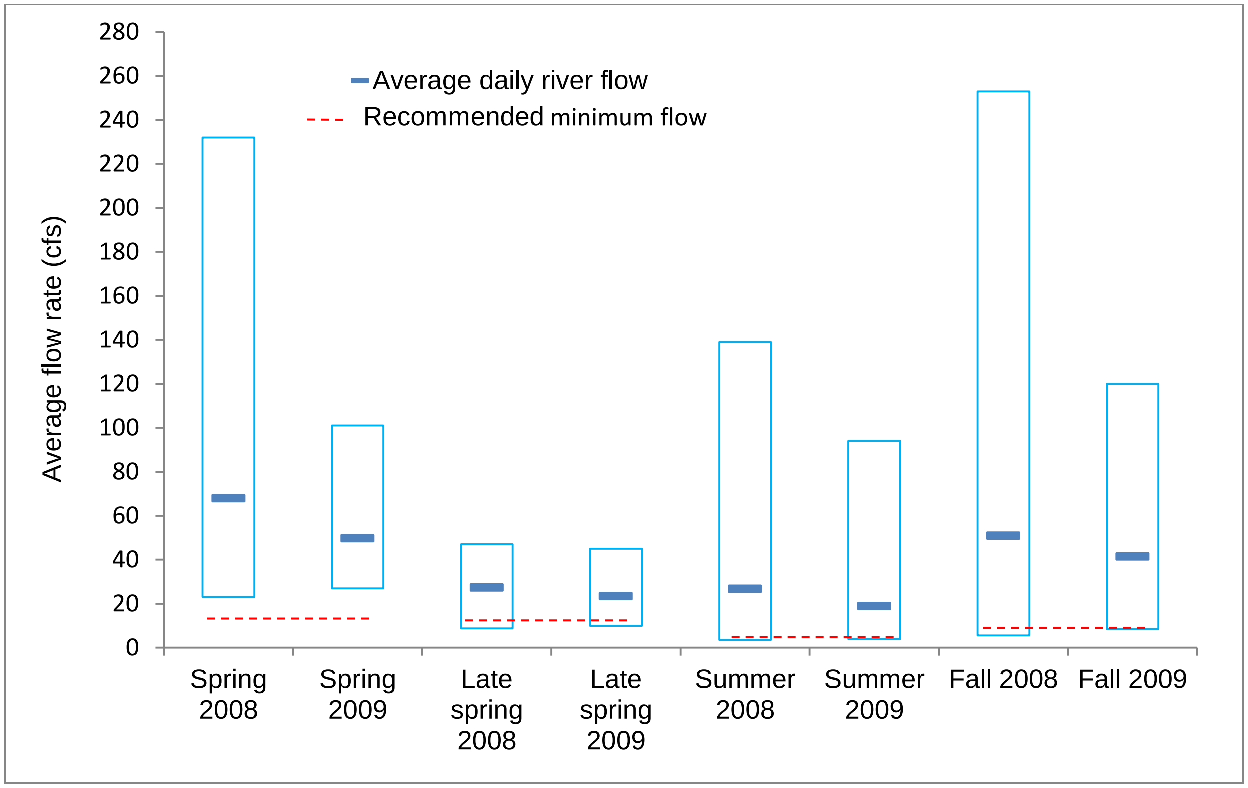


Figure 19. Seasonal minimum, maximum, and average daily flow rates (cfs) for the Saugus River for 2008 and 2009.

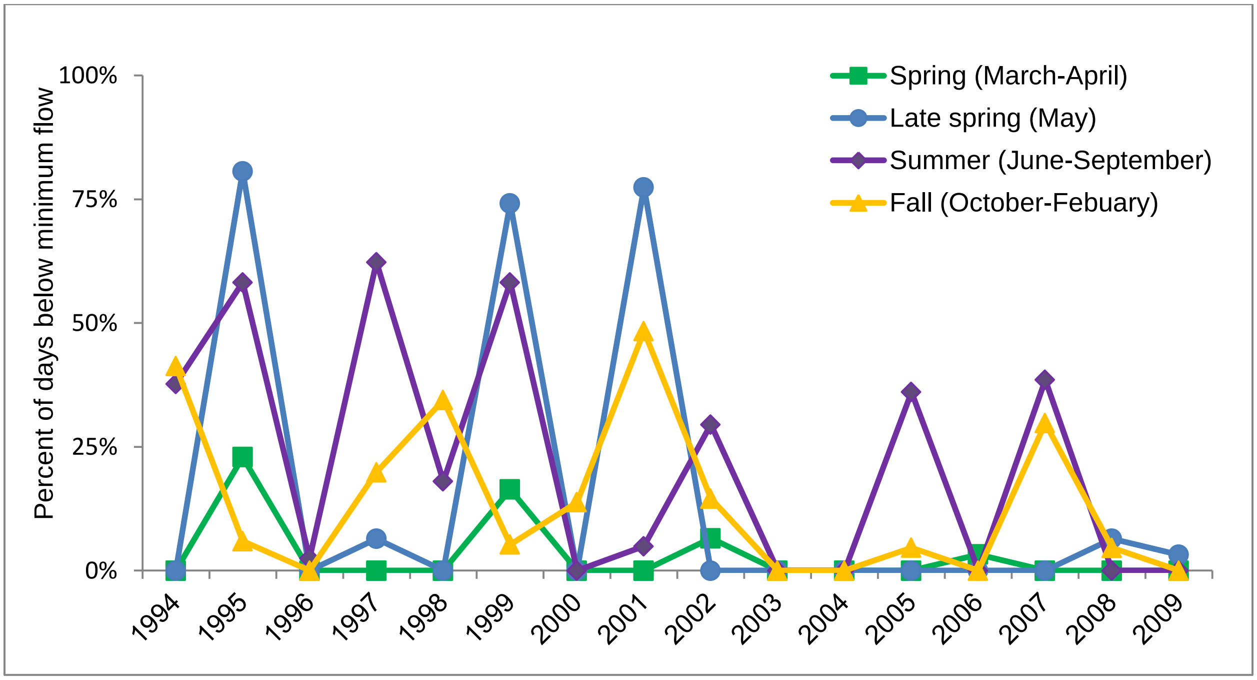


Figure 20. Percent of days in each seasonal period when average daily river discharge was below the minimum recommended flow in the Saugus River, 1994–2009.

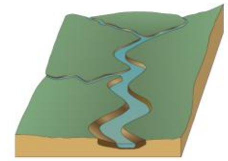


Table 9. Metrics, benchmark values, current condition, and trend for river hydrology at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend/Comments
River discharge minimum flow rates (ft^{3}sec^{-1} [cfs])[1]	Spring: Mar 1–Apr 30: ≥ 12 cfs Late spring: May 1–31: ≥ 10 cfs Summer: June 1–Sept 20: ≥ 3 cfs Fall: Oct 1–Feb 28: ≥ 6 cfs	**Caution** Recent data (2008 and 2009) indicated that river discharge rates can be below minimum recommended flow rates in the late spring (2008: 9.2 cfs, 2009: 9.9cfs) and fall (2008: 5.6 cfs).	**Improving** The percent of days when river discharge was below suggested minimum flow rates has decreased in recent years, resulting in improved river discharge rates.
River water depth	None available, current monitoring will provide data to characterize this metric.	**Unknown**	**Unknown**
Extent of salinity intrusion	None available, current monitoring will provide data to characterize this metric.	**Unknown**	**Unknown**

[1]Recommended minimum flow discharge rates from MADEM (2002).

Condition and Trend

River Flow Discharge:

Condition: 😐 Caution

Trend: ⇧ Improving.

The current condition of river hydrology based on flow discharge rates was evaluated as caution (Table 9). Recent data indicate that minimum average daily flow for the Saugus River at the USGS stream gage can be below the recommended flow rates (Figure 19). In late spring and fall of 2008 minimum discharge rates were below suggested levels. In 2009, flow rates were at or only slightly above minimum suggested flows during the late spring and summer periods.

Overall river flow rates appear to be improving within the park based on the percent of days when minimum flows were below the recommended discharge rate (Table 9). The percent of days when river flow was below the minimum flow rate has decreased in recent years (since about 2000, Figure 20), especially during spring and late spring. Flow rates have improved for the fall in recent years, with the percent of days when flow was below the minimum recommended discharge rate generally falling below 5% of the time over the past ten years. Summer flow rates can still fall below the minimum recommended discharge rate more than 30% of the time (Figure 20).

River Depth and Extent of Salinity Intrusion:

Condition: ? Unknown

Trend: ? Unknown.

The current condition of river water depth and extent of salinity intrusion is unknown (Table 9). Both the wetland and turning basin waterfront restoration and the recent removal of the Hamilton Street weir will influence these parameters. Recent continuous monitoring in 2010 with YSI equipment placed in the river channel will provide baseline data to characterize these parameters.

Data Gaps

Data are needed to characterize the tidal regime of the Saugus River and turning basin since the restoration and the removal of the Hamilton Street weir. Currently, there is YSI equipment in place in the river that continuously records temperature, salinity, dissolved oxygen, and water depth. Continued monitoring using this equipment would be beneficial to determine hydrological conditions in the park.

Threats

Threats to river hydrology include water withdrawals in upstream portions of the watershed, especially at the LWSC Diversion Dam. Extreme flow events, both low flows caused by drought and water regulation and high flows caused by spring flooding, can negatively affect critical river habitat (e.g., smelt spawning riffle habitat), buffer, and riparian zones along the river. Climate change and accelerated sea-level rise can also impact river hydrology and may result in more frequent extreme events (e.g., flooding, drought), changes in the proportion of snow to rain in winter, and seasonal shifts in hydrology (e.g., changes in the extent and duration of salinity intrusion). Although most of the area of the watershed is already developed, changes in impervious surface cover in the watershed can result in flow alteration; specifically, increased and more variable stormwater runoff.

Wetland Vegetation

Prior to restoration of the turning basin waterfront and wetland along the Saugus River, the park was infested with multiple invasive species. Based on a systematic grid (50×50m) survey of the park, it was estimated that 72% of the available natural habitat of the park in 2003 was covered with terrestrial and wetland invasive plants (Agius 2003). Roughly half of the wetland area was dominated by common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), with the rest dominated by the native narrow-leaved cattail (*Typha angustifolia*). *Phragmites* was most abundant in the wetland adjacent to the river, while purple loosestrife dominated the area of the turning basin prior to restoration (Agius 2003). The restoration removed all vegetation from the turning basin when it was restored to open water. The restoration also physically removed the *Phragmites*-dominated wetland along the river and the wetland surface was re-graded to support high and low marsh vegetation and tidal mudflat habitat. The newly created wetland adjacent to the river was planted in the fall of 2008 with native freshwater wetland plants (e.g., arrow arum [*Peltandra virginica*], hardstem bulrush [*Schoenoplectus acutus*], Northern arrowhead [*Sagittaria latifolia*], wild rice [*Zizania aquatic*], NPS 2005).

In September 2009, vegetation of the planted marsh was surveyed (New England Environmental, Inc. 2009, James-Pirri et al. 2010a, Figure 21). Very few of the species planted in the fall of 2008 were present in 2009 (New England Environmental, Inc. 2009) and the planting was deemed largely unsuccessful by the NPS. In 2009, twenty-one plant species were present in the sparsely vegetated newly created wetland, but bare ground dominated the area (47% of the area). Dominant vegetative covers included narrowleaf cattail at 12% of total cover, horned pondweed (*Zannichella palustris*) at 11% of total cover, and waterwort species (*Callitriche* species, James-Pirri et al. 2010a, Figure 22). Although the newly created wetland was sparsely vegetated, there were several desirable native species that were present in 10% or more of the monitoring plots (Figure 22). Several invasive plants were also observed in 2009 in the small natural wetland areas just south of the restored turning basin and a few invasive plants already had colonized the newly created wetland along the river (James-Pirri et al. 2010a, Figure 23). These species present a threat to the establishment of native wetland plants in the restored marsh.

A second round of planting, including replacement of failed plantings, was conducted in early June of 2010; however, few of these plants were observed during vegetation monitoring in the fall of 2010 (NPS, Marc Albert, Stewardship Program Manager, pers. comm., 29 June 2010; James-Pirri, unpublished data). Possible causes of the low survivorship of the plantings include goose herbivory (observed by park staff), salinity stress, and/or anoxic conditions in the root zone. NPS staff members are working to assess the causes contributing to the failed plantings.

Figure 21. Sampling vegetation in the newly restored wetland in 2009. (Photo courtesy of MJ James- Pirri.)

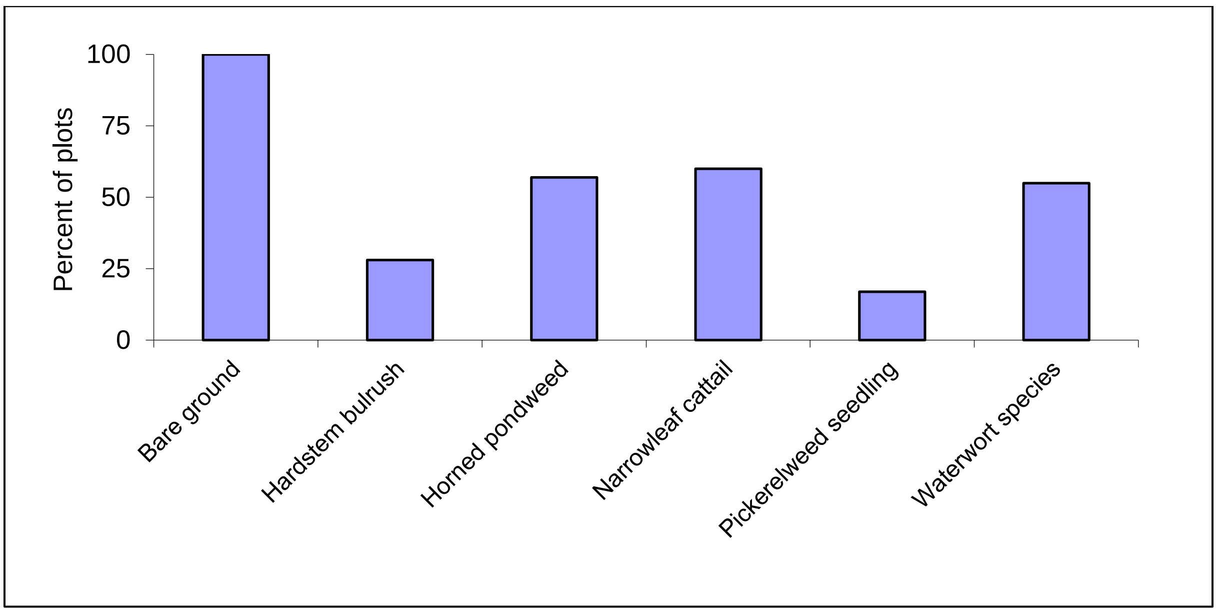


Figure 22. Common cover types observed in the restored wetland in 2009.

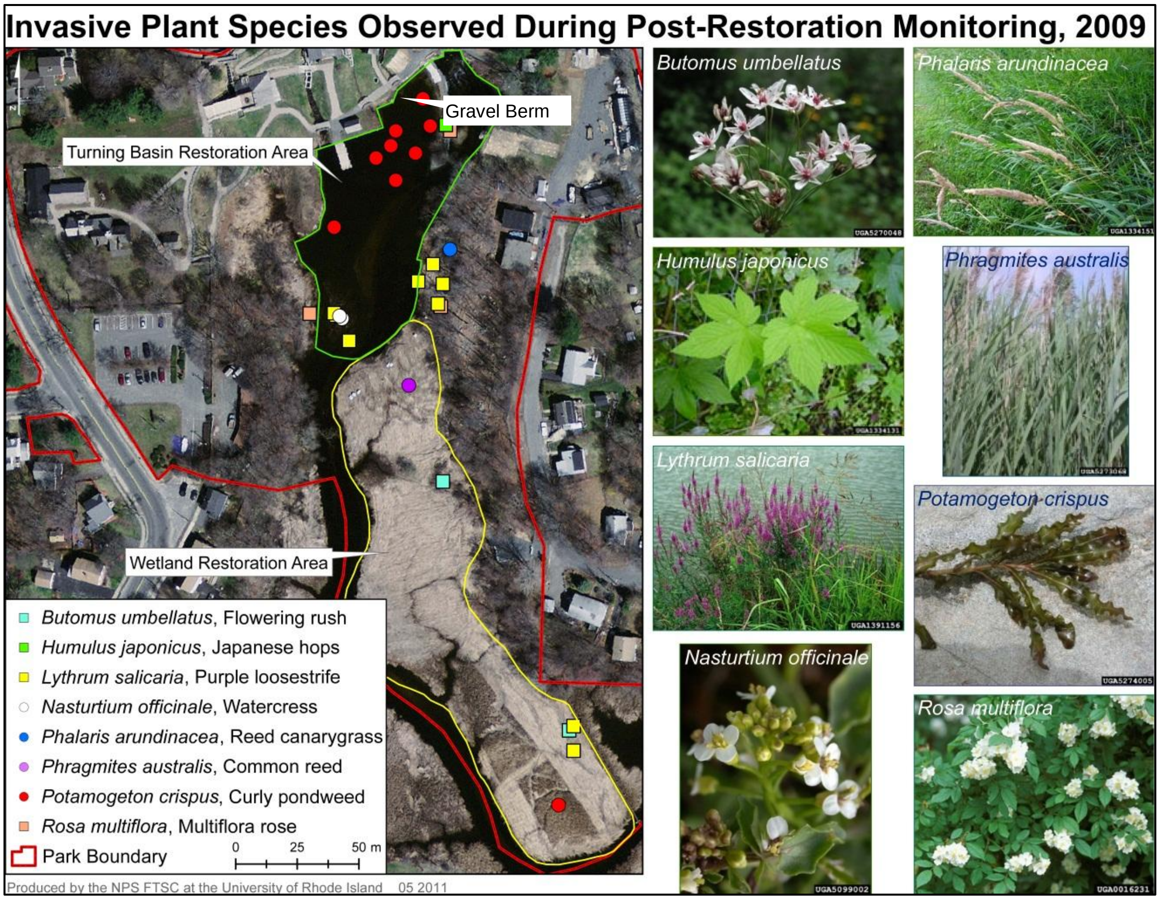


Figure 23. Invasive vegetation observed in 2009.

As part of the restoration, a streamside riparian buffer zone or berm was built between the river channel and the restored turning basin. This 0.01 ha gravel and cobble area was planted in the fall of 2008 with native shrubs and sedges (NPS 2005). Unlike the wetland planting, the berm shrub planting was more successful, with 38 of 51 planted shrubs surviving. The sedge planting was not as successful, with only a few of the 350 planted sedges observed in 2009 (New England Environmental, Inc. 2009). Heavy rains and high water in March of 2010 washed out many of the planted shrubs on the berm that were observed in 2009; replanting was done in June of 2010 (NPS, Marc Albert, Stewardship Program Manager, pers. comm., 29 June 2010).

Restoration of the turning basin waterfront and wetland along the river physically removed the majority of invasive plants in these areas. Some invasive vegetation (e.g., purple loosestrife) did regrow in the restored wetland (James-Pirri, personal observation), but the park worked aggressively to remove these and other invasive plants and great progress has been made in limiting the extent of these species in the wetlands.

Aquatic Vegetation

Several species of aquatic vegetation were present in the restored turning basin and the Saugus River during recent sampling (Table 10). Invasive curly pondweed (*Potamogeton crispus*) was observed in 2003 at about 1–5% cover in the river (Agius 2003) and was present in about 30% of the samples taken in the river and turning basin in 2008 (James-Pirri et al. 2010a). This plant was also observed in 2009 in the newly created wetland area adjacent to the river, indicating a recent colonization of a low intertidal portion of the wetland (James-Pirri et al. 2010b, Figure 23), but was not observed in 2010 (James-Pirri, unpublished data). Curly pondweed is a threat to the establishment and persistence of native pondweed species. American waterwort (*Elatine americana*), a Massachusetts state-listed endangered species (Massachusetts Division of Fisheries and Wildlife 2010), was recorded on a plant list made by SAIR staff (S. Wignot) in 1988 (Appendix D). Attempts to re-locate this species during a vascular plant survey of the park in the late 1990s were unsuccessful (Clemants 1997); later surveys also did not observe this species. Vernal water-starwort (*Callitriche palustris*), which is very similar in appearance, is present in the park (Table 10, Appendix D).

Condition Metrics

There are no established metrics available to evaluate the condition of the wetland and aquatic plant communities at SAIR; therefore, the condition of the upland vegetation at SAIR was based on best professional judgment. Factors that were considered in the evaluation of the condition were the composition of the plant community that was colonizing the restored wetland and the presence of invasive species.

Condition and Trend

Wetland Plant Community:

Condition: Caution

Trend: Improving to Unknown.

The condition of the wetland plant community was evaluated as caution (Table 11). Although the restored wetland was sparsely vegetated, the majority of plants colonizing the restored wetland were desirable, native plants. Invasive plants were still present in the small natural wetland areas and these may spread to the restored wetland.

Table 10. Aquatic plants observed in 2009 at Saugus Iron Works National Historic Site.

Scientific name	Common name	Location
Callitriche spp., likely *C. palustris*	Water starwort spp.	River, Wetland marsh
Elodea spp.	Elodea spp.	Turning basin
Potamogeton crispus [1]	Curly pond weed	Turning basin, Wetland marsh
Potamogeton epihydrus	Ribbonleaf pondweed	Turning basin
Potamogeton gramineus	Variableleaf pondweed	Turning basin
Unknown green algae	Unknown green algae	River
Zannichella palustris	Horned pondweed	River, Turning basin

[1] Invasive species.

The trend for wetland vegetation was evaluated as improving to unknown (Table 11). Prior to the restoration, the wetland areas along the Saugus River were dominated by invasive species (e.g., *Phragmites*). The restoration removed a vast majority of the invasive plants and created habitat that can be colonized by native wetland plants, improving the quality of the wetland areas. It is not known how the removal of the Hamilton Street weir will affect the salinity and tidal regimes of the river. Salinity and periodicity of tidal inundation are major factors that will determine the type of wetland vegetation that can colonize and persist in the restored wetland areas.

Aquatic Plant Community:

Condition: Caution

Trend: Unknown.

The condition of the aquatic plant community was evaluated as caution (Table 11). Surveys in 2008 and 2009 noted that the invasive curly pondweed was present in moderate amounts in the river and turning basin, but this plant was not observed in 2010. The trend for the aquatic plant community was evaluated as unknown (Table 11). The removal of the Hamilton Street weir and its effect on the salinity regime of the river will be a major factor in determining the type of aquatic vegetation that can colonize and persist in the river and turning basin.

Data Gaps

Information on soil chemistry characteristics and periodicity of tidal inundation in the restored wetland would provide further information to help understand why the wetland is sparsely vegetated.

Threats

Although SAIR has made great progress in removing invasive vegetation from the wetland and riparian forest along the river, invasive plants are still present and can potentially recolonize these areas if they are not kept under control. Possible anoxic soil conditions and high sulfide levels in sediments may be a factor in the slow re-vegetation of the restored wetland. High stream flow events can erode wetland areas, but can also be beneficial to the marsh surface by increasing sediment accretion. Climate change and accelerated sea-level rise can also impact wetland and aquatic vegetation by altering the extent and duration of estuarine tidal inundation.

Table 11. Metrics, benchmark values, current condition, and trend for wetland and aquatic vegetation at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Wetland vegetation, community composition	None available, condition evaluated based on best professional judgment.	**Caution** Restored wetland was sparsely vegetated, but some native plants were colonizing the area.	**Improving to Unknown** Native species were present in the restored wetland, but the impact of the weir removal on tidal inundation of the wetland is unknown.
Aquatic vegetation community composition	None available, condition evaluated based on best professional judgment.	**Caution** Invasive aquatic plants were observed during recent surveys.	**Unknown** The effect of the weir removal on the salinity regime of the river will be a major factor in determining the type of aquatic vegetation in the river.

Amphibian and Reptile Community

The principal habitats for amphibians and reptiles at SAIR are the Saugus River, a small unnamed seep/stream that flows into the west side of the Saugus River down slope of the maintenance building, small patches of riparian forest on both sides of the river, marshes on both sides of the river, and fields, lawns, and landscape plantings of the historic/administrative zone (Cook et al. 2010). Based on surveys of the entire Saugus River watershed (Nyman 1991), data from the Massachusetts Herpetological Atlas (Jackson et al. 2010), wildlife observations (McNiff and Albert 2010), consideration of the habitats present, and species' life history, Cook et al. (2010) considered 10 species of amphibians and reptiles as known or potentially occurring at SAIR (Table 12).

Surveys conducted in 2000–2001 as part of the NPS Inventory and Monitoring Program (Cook et al. 2010) and the 2009 wildlife observations as part of the post-restoration turning basin and wetland monitoring program (McNiff and Albert 2010) collectively recorded two amphibian and five reptile species in the park, including one species, Eastern milksnake (*Lampropeltis t. triangulum*), not previously considered as potentially occurring (Table 12). This represents 45% (six of 11) of the species known or believed to occur at SAIR. Robert Cook (NPS, Biologist, pers. comm.) visited SAIR in July 2010 and is currently compiling data from that visit. None of the species observed were officially designated as threatened, endangered, or of special concern (Massachusetts Division of Fisheries and Wildlife 2010), and most were urban-tolerant and widespread species (Cook et al. 2010).

The diversity of herpetofauna at SAIR is restricted by the small size of the park and lack of habitat for pond-breeding amphibians. Amphibians and reptiles at SAIR are largely limited to species that do not breed in ponds, have small home ranges and are capable of maintaining a population in a small habitat patch, or are mobile species that disperse along the river or across the adjacent uplands. Many of the species that occur or potentially occur at SAIR would use the habitats present at SAIR as a small part of their use of the broader landscape and watershed (Cook et al. 2010). For example, it is likely that the northern green frogs (*Rana clamitans melanota*) observed at SAIR are non-breeding individuals using the Saugus River as a dispersal

Table 12. Amphibian and reptile community of Saugus Iron Works National Historic Site.

Scientific Name	Common Name	Year Observed
Chelydra serpentina	Snapping turtle	2000, 2001, 2009
Chrysemys picta	Painted turtle	2009
Eurycea bislineata	Northern two-lined salamander	2000, 2001
Lampropeltis trangulum	Milk snake	2009[1]
Nerodia sipedon	Northern watersnake	Possibly present
Plethodon cinereus	Eastern red-backed salamander	Possibly present
Pseudacris crucifer	Spring peeper	Possibly present
Rana catesbeiana	American bullfrog	Possibly present
Rana clamitans melanota	Northern green frog	2000, 2001, 2009
Storeria dekayii	Northern brownsnake	2001
Thamnophis sirtalis sirtalis	Eastern gartersnake	2001, 2009[1]

[1] Positive identification was not possible and these should be treated as unconfirmed observations.

corridor and juvenile habitat, and the snapping turtles (*Chelydra serpentina*) and painted turtles (*Chrysemys picta*) undoubtedly move up and down the river and riparian habitats through SAIR (Cook et al. 2010). However, the slag pile at SAIR is an important and rare habitat feature in an urban area. It provides turtle nesting habitat immediately adjacent to the river, which spares females a risky nesting foray across roads and through urban neighborhoods (a major source of mortality for urban turtles). The long history of its use for turtle nesting suggests that the female turtles using this stretch of river return to use it repeatedly over the years (Cook et al. 2010). Potentially occurring species such as American bullfrog (*Rana catesbeiana*) or northern watersnake (*Nerodia sipedon)* would use SAIR similarly and the mostly terrestrial spring peeper could range into SAIR outside of breeding season from other nearby habitat patches (Cook et al. 2010). Although it is unlikely that SAIR will ever support an extensive herpetofauna, it is an important part of a larger system of protected "greenspace" along the Saugus River and provides regionally important habitat. It is likely that, over time, additional species will be recorded at SAIR, particularly as environmental conditions improve (Cook et al. 2010).

It was noted in the 2001 inventory that, in spite of the history of disturbance and the parks' presence in an urban landscape, there was an abundant population of northern two-lined salamander (*Eurycea bislineata*) in the small seep/stream east of the SAIR maintenance building (Figure 24). On 21 July 2010, an individual was also found under rocks in a seep on the east side of the Saugus River, indicating that this urban-tolerant species occurs elsewhere at SAIR (Cook et al. 2010). Other herpetofauna that are urban-tolerant with relatively small area requirements observed at SAIR are the Eastern gartersnake (*Thamnophis sirtalis sirtalis*) and northern brownsnake (*Storeria dekayii*). A site the size of SAIR is capable of supporting populations of these three species. In contrast, Eastern milksnakes generally require much larger habitat patches than present at SAIR (Cook et al. 2010), and the origins of the individual observed in 2009 (McNiff and Albert 2010) are uncertain. Since the park contains some of the only relatively undisturbed habitats in the area, these areas may be important for herpetofauna. Even if little breeding occurs, they still may serve as important travel corridor, refuge, and forage/hunting locations.

Figure 24. Location (yellow circle) of stream where breeding population of northern two-lined salamanders was observed.

Condition Metrics

There are no established metrics to evaluate condition of herpetofauna in an urban setting. In the absence of these metrics, species richness of the amphibian and reptile communities could be used with the caveat that it is not known how many species would be appropriate for a small urban park such as SAIR. Therefore, lower species richness and/or a decreasing trend in species richness could be viewed as an undesirable condition.

Possible benchmarks for amphibian and reptile species richness at SAIR were estimated based on previous surveys. Five amphibian and six reptile species occur or could potentially occur in the park.

A percentile system was used to set benchmark condition values with a good condition rated as a deviation of 20% or less of the occurring or potentially occurring species. Significant concern was rated as a deviation of 50% or more, with the caution rating falling in between these two values. These ratings are based on the best available data and best professional judgment.

Amphibians:

Good: ≥4 species present (>80th percentile)
Caution: 3 species present (50th to 80th percentile)
Significant concern: ≤2 species present (<50th percentile).

Reptiles:

Good: ≥5 species present (>80th percentile)
Caution: 3–4 species present (50th to 80th percentile)
Significant concern: <3 species present (<50th percentile).

Condition and Trend

Amphibian and Reptile Community:

Condition: Amphibians: ☹ Significant Concern, Reptiles: ☺ Good

Trend: Amphibians and Reptiles: ? Unknown.

Recent surveys (2000–2001 and 2009) recorded two amphibian and five reptile species in the park. The condition for the amphibian community was rated as significant concern, since only two of five potentially occurring species have been observed in the park over the past decade. The condition of the reptile community was rated as good, since five of six potentially occurring species have been observed in recent surveys. The trend for the herpetofaunal community was evaluated as unknown, as there were limited historical data (Table 13).

The recent restoration of the turning basin waterfront and wetland is unlikely to have much effect on the herpetofauna of the park. The lack of habitat for pond-breeding and pond-dwelling species, plus the site's relatively small size, will continue to be the primary limitations to herpetofaunal diversity (Cook et al. 2010).

Data Gaps

There have only been a few surveys of herpetofauna at SAIR and more data on this community are needed. Verification of the breeding population of northern two-lined salamanders would be beneficial, as they were last detected in 2001. A standardized, systematic, long-term monitoring program is required to more fully evaluate the herpetofauna at SAIR. Such a program could include coverboard surveys, searches of the marshes and stream, surveys of the Saugus River with minnow traps and turtle traps, and general searching of the park to monitor changes, assess any influence of the recent restoration, and better understand the herpetofauna in the park (Cook et al. 2010).

Table 13. Metrics, benchmark values, current condition, and trend for amphibian and reptile communities at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Amphibian community	Good: ≥4 species (>80th percentile) Caution: 3 species (50th to 80th percentile) Significant concern: ≤2 species (<50th percentile)	Significant Concern Two of five species observed.	Unknown Not enough data to determine trends.
Reptile community	Good: ≥5 species (>80th percentile) Caution: 3–4 species (50th to 80th percentile) Significant concern: ≤3 species (<50th percentile)	Good Five of six species observed.	Unknown Not enough data to determine trends.

Threats

SAIR is located in a highly urbanized area and any herpetofauna in the park are influenced by a variety of anthropogenic impacts associated with urbanization. For example, habitat fragmentation can limit breeding success and spatial distribution of many herpetofauna. Motor vehicle traffic can be a leading cause of mortality for many reptile and amphibian species in urban areas as they migrate to and from breeding and nesting areas (Petranka 1998, Glista et al. 2007, Massachusetts Audubon 2008). Other localized stressors that could negatively impact the herpetofauna at SAIR include pesticides, fertilizers, road runoff, degraded water quality, habitat degradation, disease, introduced species, and predation by feral and domestic cats. Regional and global stressors include atmospherically transported pollutants, acid precipitation, and ultraviolet-B radiation (Massachusetts Audubon 2008; Cook et al. 2010). There is a limited amount of herpetofaunal habitat at SAIR, and the presence of invasive, nonnative plants is a threat to this habitat (Cook et al. 2010). While the restoration of the turning basin waterfront and wetland along the Saugus River removed much of the invasive vegetation, invasive plants are still present in the park.

The Terrestrial Environment

Upland Vegetation

The upland vegetation was surveyed and mapped at SAIR in 2003 to 2004. This survey produced a detailed map of both invasive plants and major vegetation communities as identified by the National Vegetation Classification (NVC) system (Agius 2003, Largay and Sneddon 2008).

The woodland habitat at SAIR is a Northeastern Modified Successional Forest, a forest type characterized by early successional species and an herbaceous layer supporting many exotic species. This forest type reflects the altered composition caused by the historic land uses of the area (Largay and Sneddon 2008). At the time of the NVC survey, the forest area was extremely fragmented and heavily invaded by invasive species such as Norway maple (*Acer platanoides*). The forest area covers approximately 12% of the park and has inclusions of skunk cabbage (*Symplocarpus foetidus*) and orange jewelweed (*Impatiens capensis*) under the canopy. Developed areas, including the lawn, landscaping, and historic structures, cover 50% of the park, while the tidal marsh and river make up the remainder of the park (Figure 25, Largay and Sneddon 2008).

The forest is moderately dense (70% tree canopy cover) and is dominated by Norway maple, mockernut hickory (*Carya alba*), American beech (*Fagus grandifolia*), black cherry (*Prunus serotina*), and northern red oak (*Quercus rubra*) (Largay and Sneddon 2008). There are several native shrub species, and the herbaceous layer is weedy, dominated by Kentucky bluegrass (*Poa pratensis*). Vines, including the invasive oriental bittersweet (*Celastrus orbiculatus*), make up about 10% of the understory (Appendix D, vegetation species list; Largay and Sneddon 2008).

Several invasive plants were observed in the forest (Appendix D; Agius 2003, Largay and Sneddon 2008). In 2003, multiflora rose (*Rosa multiflora*) was the dominant invasive plant in this area, having invaded nearly the entire understory of the forest (Agius 2003). Norway maple was the second most dominant invasive species in the forest. Other invasive species present in the forested area were oriental bittersweet, common buckthorn (*Rhamnus cathartica*), and purple loosestrife (Agius 2003). Agius (2003) observed that 72% of the available natural habitat was inhabited by 11 invasive species (Figure 26); however, this estimate, as well as the vegetation mapping conducted in 2004 to 2007 (Largay and Sneddon 2008), were performed prior to the restoration of the turning basin waterfront and wetland along the river.

In 2002, park management removed multiflora rose and Norway maple from the slag pile area, and oriental bittersweet from the stone wall along the river (NPS 2003). The NPS Northeast Exotic Plant Management Team (NE EPMT) visited SAIR in 2009, again removing invasive plants from the slag pile and along the nature trail in the riparian woodland adjacent to the Saugus River. Plants that were removed in 2009 were alder buckthorn (*Frangula alnus*), Japanese knotweed (*Polygonum cuspidatum*), multiflora rose, select Norway maples, oriental bittersweet, and *Phragmites*. Not all Norway maples were treated, as most of the remaining trees at SAIR were beyond the ability of the NE EPMT to cut and remove safely (NE EPMT 2009). The park continues to actively remove invasive plants.

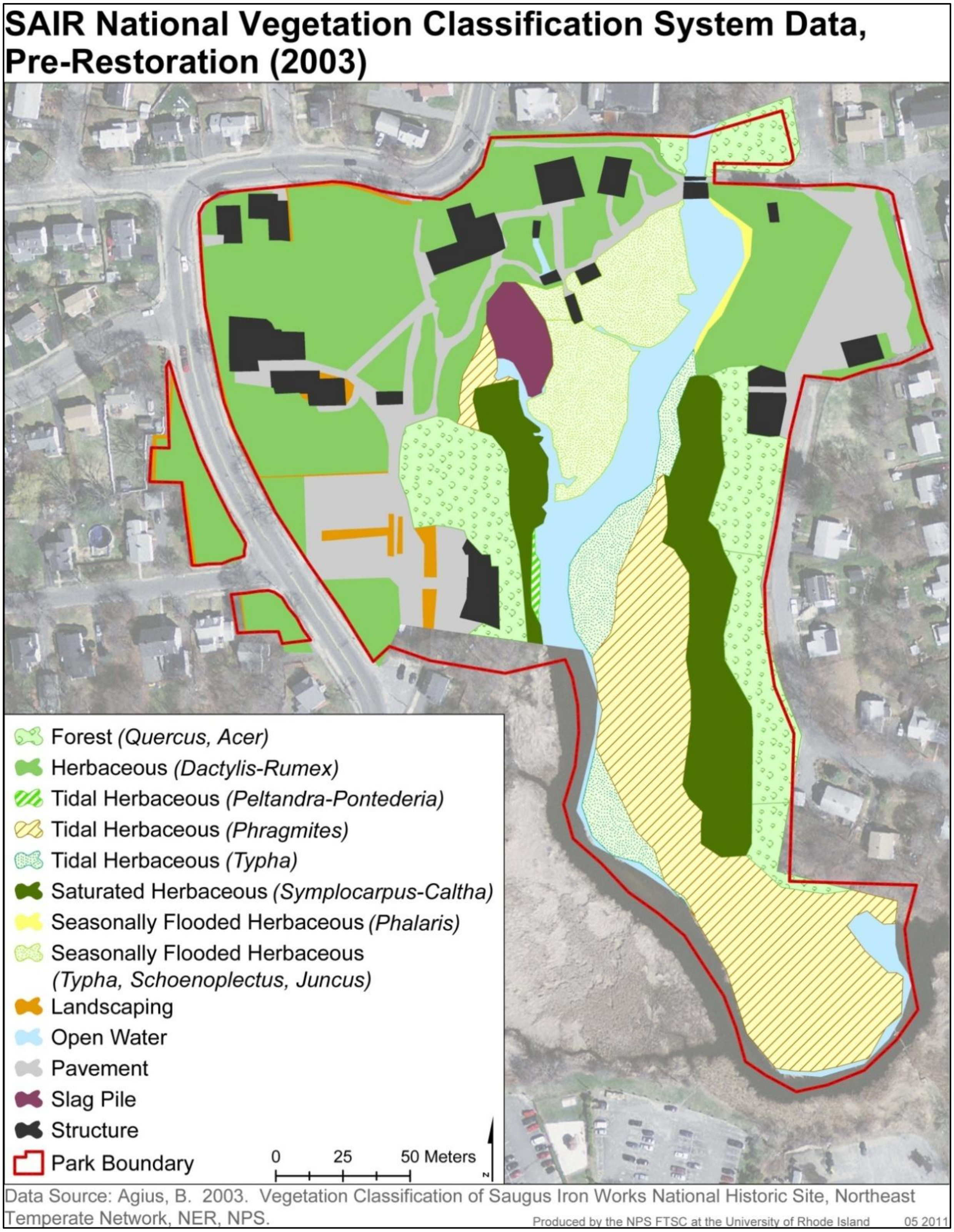


Figure 25. Vegetation mapped in 2003 at Saugus Iron Works National Historic Site (SAIR).

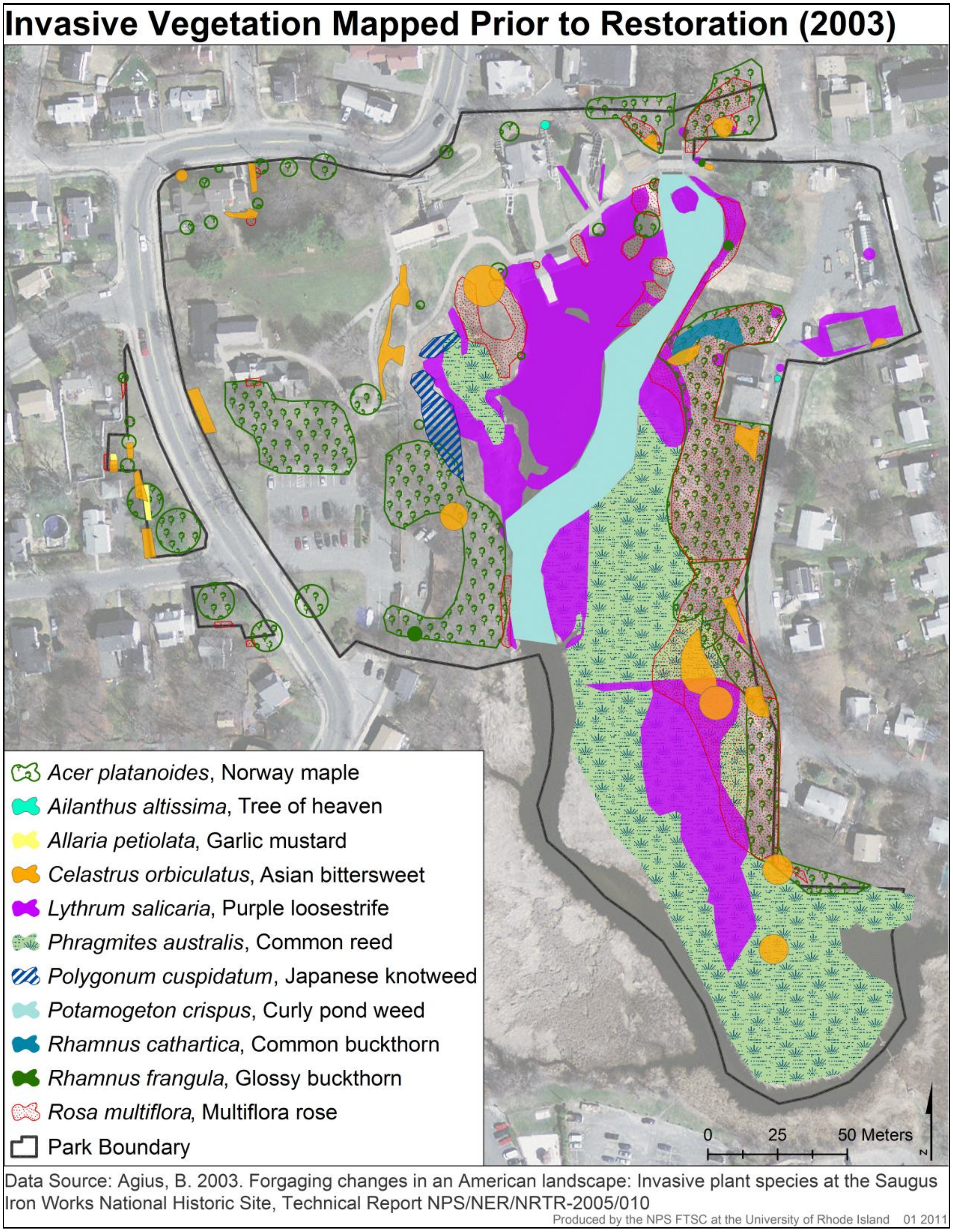


Figure 26. Invasive vegetation mapped in 2003 at Saugus Iron Works National Historic Site (SAIR).

Approximately 1.4 ha of the park is grassy lawn habitat (Figures 25 and 26; Agius 2003). Even though the landscaped area of the park was not systematically quantified during the invasive species inventory, it was noted that the lawns were comprised mostly of nonnative grasses with numerous exotic and invasive plant species, further increasing the area of invasive species within the park (Agius 2003).

The US Forest Service maps the distribution and susceptibility of forests to infestation by a variety of non-indigenous forest pest species (USDA Forest Service 2010). Susceptibility of forests is based on the basal area of preferred host species (tree and shrubs). Several of these insect pests have distribution ranges that include Essex County, MA, where SAIR is located (Table 14, Appendix E). Essex County forests have a high or medium susceptibility to infestation by several additional pest species. If these species expand their distributions to Essex County, these insects could become potential threats to the forest at SAIR (Table 14, Appendix E).

Non-indigenous pests that are currently present in Essex County and pose an extreme risk to the forest at SAIR are: Asiatic oak weevil, birch leafminer, black vine weevil, calico scale, European pine sawfly, Japanese beetle, oystershell scale, phytophthora root rot, pine false webworm, and white pine blister rust. Essex County forests are also at an extreme risk of infestation from ambermarked birch leafminer, Asian longhorned beetle, and circular hemlock scale if these species expand their ranges into the county. All three of these species have been found in the New England region (Connecticut or Rhode Island) with the Asian longhorned beetle found in Worcester County, MA (in 2009), and in Boston (in July of 2010) (Appendix E).

Condition Metrics

There are no established metrics available to evaluate the condition of the upland vegetation at SAIR. The NPS does have a forest health monitoring program (Miller et al. 2010); however, the forest at SAIR was not monitored by the NETN, presumably due to its small size. Therefore, the condition of the upland vegetation at SAIR was based on best professional judgment. A factor that was considered in the evaluation of the condition was the presence of invasive species.

Table 14. Number of non-indigenous insect pests and diseases by forest susceptibility rating for Saugus Iron Works National Historic Site as tracked by the USDA.

Forest Susceptibility[1]	Number of species or disease	
	Present in Essex County	Not currently present in Essex County
Extreme	11	3
High	8	6
Medium	4	7
Low	2	1

[1] Data source, USDA Forest Service (2010).

Current Condition

Upland Vegetation:

Condition: Caution

Trend: Stable to Improving**.**

The condition of upland vegetation was rated as caution because invasive plants are still present in the forest. The trend was rated as stable to improving, as recent efforts have substantially reduced the extent and abundance of invasive species (Table 15).

Data Gaps

The park's NVC survey was conducted in 2003 to 2004 and three of the four NVC plots were located in the area that was recent restored. NVC plots SAIR 001 and 002 were located in the newly restored wetland along the Saugus River, while plot SAIR 004 was located immediately off the dock in what is now the open water of the restored turning basin (plot SAIR 003 was located in the *Typha*-dominated marsh on the western side of the river, Largay and Sneddon 2008). These areas have changed dramatically as a result of the restoration and the vegetation classifications associated with these plots are no longer current.

While the wetlands in SAIR have been and will continue to be extensively surveyed, there are few recent data on the plant community of the forest (none of the NVC plots were located in the forest). The park may want to consider a survey of this area to document species' presence and/or changes in the plant community (e.g., document decrease in invasive vegetation as a result of NE EPMT efforts).

Threats

The terrestrial vegetation at SAIR is threatened by habitat fragmentation, invasive plants, and surrounding land uses (e.g., composting of invasive plants on adjacent private properties). There were several forest pests that are present in the county that have the potential to infest and possibly damage the SAIR forest. Climate change is also a threat to the native plants in the park.

Table 15. Metrics, potential benchmark values, current condition, and trend for upland vegetation at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Upland Vegetation	None available, condition evaluated based on best professional judgment.	**Caution** Invasive species are still present in upland vegetation communities.	**Stable** **Improving** Invasive plants have been consistently observed in the forest, but have been substantially reduced due to focused removal efforts.

Mammalian Community

The only mammalian survey at SAIR was conducted by NETN in 2004. Nine species were identified and another three were likely present (representing an estimated 25% of the potential mammal species, 48 possible species that could occur in the park; Gilbert et al. 2008). Wildlife observations in 2009 (part of the turning basin waterfront and wetland post-restoration monitoring program, McNiff and Albert 2010) identified two additional mammal species. It is estimated that at least 14 mammal species are currently present at SAIR (Table 16). None of the species detected were considered threatened, endangered, or species of special concern (Massachusetts Division of Fisheries and Wildlife 2010).

Raccoons (*Procyon lotor*), domestic cats (*Felis catus*), and Virginia opossums (*Didelphis virginiana*) were the most often detected medium-sized mammals at SAIR during 2004 survey (Gilbert et al. 2008). In 2009, the most frequently observed mammals were Eastern chipmunks (*Tamias striatus*), Eastern gray squirrels (*Sciurus carolinensis*), and groundhogs (*Marmota monax.*), which maintain burrows in the slag pile on the west side of the river. The small size of the park and fencing may have reduced mammal use of the area, thus reducing species richness. Low species diversity may also be explained by the low number of traps used during the NETN survey at SAIR (although trap density was comparable to that at other study parks; Gilbert et al. 2008).

Bats were not specifically surveyed during the NETN mammal survey, but they have been reported to roost in the blast furnace and were observed in 2009 (Gilbert et al. 2008, McNiff and Albert 2010). In the Northeastern U.S., hibernating bats are dying at an alarming rate due to white-nose syndrome (first identified in New York in 2006; US Fish and Wildlife Service [USFWS] 2010). White-nose syndrome is linked to a fungus (*Geomyces* sp.) that thrives in the cold, humid conditions of caves and mines where bats hibernate. White-nose syndrome has been confirmed in three western counties of Massachusetts and is likely present in Middlesex and Suffolk counties (USFWS 2010). It is not known if the bats observed at SAIR hibernate in the park or if they are infected with white-nose syndrome.

Condition Metrics

There are no established metrics to evaluate the condition of mammal communities in urban parks. In the absence of these metrics, species richness could be used with the caveat that it is not known how many species would be appropriate for a small urban park such as SAIR. In a study examining mammal communities of suburban and urban parks in Pennsylvania, lower species richness was associated with parks containing manicured habitats and surrounded by human-modified landscapes, whereas higher species richness was observed in parks with mature riparian forests (Mahan and O'Connell 2005). Therefore, lower species richness and/or a decreasing trend in species richness could be viewed as an undesirable condition.

Table 16. Mammal species observed or potentially present at Saugus Iron Works National Historic Site.

Scientific Name	Common Name	Year Observed[1]
Blarina brevicauda	northern short-tailed shrew	2004, 2009
Castor canadensis	beaver	likely present
Condylura cristata	star-nosed mole	likely present
Didelphis virginiana	Virginia opossum	2004
Felis catus	domestic cat	2004, 2009
Lontra canadensis	North American river otter	2009
Marmota monax	groundhog	2004, 2009
Ondatra zibethicus	muskrat	2004
Parascalops breweri	hairy-tailed mole	likely present
Peromyscus leucopus	white-footed mouse	2004, 2009
Procyon lotor	raccoon	2004, 2009
Sciurus carolinensis	Eastern gray squirrel	2004, 2009
Tamias striatus	Eastern chipmunk	2004, 2009
Unknown bat spp.	unknown bat spp.	2009
Unknown mouse or vole	mouse/vole spp.	2004
Unknown mouse spp.	deer or white-footed mouse	2004, 2009

[1] Data sources: 2004: Gilbert et al. 2008, 2009: McNiff and Albert 2010.

Possible benchmarks for mammal species richness at SAIR were estimated based on previous surveys. During the 2004 NETN mammal inventory nine species were directly observed. A percentile system was used to set benchmark condition values with a good condition rated as a deviation of 20% or less from the species richness observed during the 2004 surveys. Significant concern was rated as a deviation of 50% or more, with the caution rating falling in between these two values. These ratings are based on the best available data and best professional judgment.

Good: >7 species present (>80^{th} percentile
Caution: 5–7 species present (50^{th} to 80^{th} percentile)
Significant concern: ≤4 species present (<50^{th} percentile).

Condition and Trend

Condition: Good to Caution

Trend: Stable to Unknown.

The condition of the mammal community at SAIR was rated as good to caution (Table 17). In 2009, the same number of species (nine) were directly observed as recorded in 2004 (Table 17), equivalent to a good rating based on the presented percentile system. A caution rating was also included to indicate that it is not known how many mammal species would be appropriate for a small urban park and further study is warranted to fully evaluate the mammal community at SAIR.

The trend for the mammal community was rated as stable to unknown (Table 17). Eight of the same species observed in 2004 were also seen in 2009. The trend of unknown was included, as further study is warranted to further determine the status of mammals at SAIR (i.e., the presence of breeding populations or transient species, increasing or decreasing population densities).

Data Gaps

Bats should be surveyed at SAIR to determine their status (e.g., do they hibernate in the park) and health (e.g., presence of white-nose syndrome). Standardized mammal surveys conducted at regular intervals (e.g., annually) would provide better information on the status of mammals in the park.

Threats

Attributes associated with the urban setting of the park, such as habitat fragmentation and road mortality, threaten the mammal population of the park. If hibernating bats are present, white-nose syndrome could be a threat to the bats at SAIR.

Table 17. Metrics, benchmark values, current condition, and trend for the mammal community at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Mammal species richness	Good: >7 (>80th percentile) Caution: 5–7 (50th to 80th percentile) Significant concern: ≤4 (<50th percentile)	**Good to Caution** Nine species were observed in 2009, but it is unknown how many species are appropriate for SAIR.	**Stable to Unknown** Seven of the same species were observed in 2004 and in 2009.

Avian Community

The avian community at SAIR was surveyed in 2002 and 2003 by the NETN (Trocki and Paton 2005). Long-term forest breeding bird monitoring was conducted in 2008 and 2009 by the NETN (Faccio and Mitchell 2010). Park staff also recorded bird sightings during wildlife observation monitoring in 2009 as part of the turning basin waterfront and wetland restoration monitoring program (James-Pirri et al. 2010b, McNiff and Albert 2010). Altogether, 66 species, including 16 waterbird species (shorebirds, waders, and waterfowl), have been observed at SAIR since 2002 (Appendix F).

Nine species observed at SAIR are listed as priority species by Partners in Flight (PIF) for the Southern New England area (Dettmers and Rosenberg 2000). The Baltimore oriole (*Icterus galbula*) and scarlet tanager (*Pitanga olivacea*) have a PIF status as IA: High Continental Priority, High Regional Responsibility, indicating that conservation of these species in southern New England is critical to the overall health of the species. The chimney swift (*Chaetura pelagica*) is listed as IIA: High Regional Priority, High Regional Concern, indicating that the species is experiencing declines in the core of its range, requiring short-term conservation action to reverse or stabilize trends.

Six species, American bittern (*Botaurus lentiginosus*), black-crowned night heron (*Nycticorax nycticorax*), great blue heron (*Ardea herodias*), great egret (*Ardea alba*), Savannah sparrow (*Passerculus sandwichensis*), and snowy egret (*Egretta thula*), are listed as PIF V: Additional State Listed Species, indicating that the species is of special interest locally (Dettmers and Rosenberg 2000). Three nonnative species, European starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), and rock dove (*Columba livia*), were also detected (Appendix F). Trocki and Paton (2005) estimated that 29 of the 37 species (78%) observed in 2002 and 2003 were breeding within the park (Appendix F). Three of the PIF species that likely breed in the park are the Baltimore oriole, chimney swift, and rose-breasted grosbeak (Appendix F).

Condition Metrics

The first metric used to evaluate avian community condition was the NETN guild-based species richness scoring system for evaluating the biotic integrity of the forest avian community (Table 18; Faccio et al. 2010). The NETN protocol is focused on breeding birds and only considers landbirds (small terrestrial birds); it does not include raptors, upland game birds, waterbirds, or waterfowl in its condition estimate (with the exception of including all species observed in the estimation of species richness percentages). Since the guild-based system of the NETN breeding landbird monitoring is focused on interior forest conditions, SAIR will never rate well in these analyses; however, the NETN guild-based system was used with this caveat.

The second metric used to evaluate the condition of the avian community was the number of waterbird species (shorebirds, waders, and waterfowl) observed in the park (Figure 27, Appendix F). This second metric is not an established method to estimate avian community condition, but was considered important in light of the recent observations of waterbirds using the SAIR wetlands and tidal flats. The benchmarks, based on best professional judgment, for the number of species in each waterbird category (shorebirds, waders, and waterfowl) were:

Table 18. Percent species richness for avian guilds and NETN guild-based scoring for avian surveys. Arrows after guilds indicate the desired direction of species richness to improve condition.

Biotic Element & Guild	Guild type	Percent Richness (NETN rating)[1]			
		2002–2003	2008 NETN	2009 NETN	2009 Wildlife
Compositional					
Exotic ↓	G	11% (SC)	14% (SC)	6% (C)	6% (C)
Nest predator ↓	G	8% (G)	14% (C)	12% (C)	8% (G)
Resident ↓	G	41% (C)	38% (C)[3]	30% (C)[3]	26% (G)
Single brooder ↑	S	30% (SC)	14% (SC)[3]	21% (SC)[3]	22% (SC)
Functional					
Bark Prober ↑	S	8% (C)	5% (C)	3% (SC)	4% (SC)
Ground gleaner ↑	S	5% (C)	5% (C)	3% (SC)	2% (SC)
High canopy forager ↑	S	0% (SC)	0% (SC)	3% (SC)	2% (SC)
Low canopy forager ↑	S	11% (SC)	5% (SC)[3]	12% (SC)[3]	6% (SC)
Omnivore ↓	G	41% (C)	52% (SC)	39% (C)	30% (C)
Structural					
Canopy nester ↑	S	14% (SC)	19% (SC)	12% (SC)	14% (SC)
Forest ground nester ↑	S	3% (SC)	0% (SC)	0% (SC)	0% (SC)
Interior forest nester ↑	S	5% (SC)	0% (SC)	0% (SC)	4% (SC)
Shrub nester ↓	G	24% (C)	24% (C)	21% (SC)	14% (G)

[1] NETN guild ratings: G: Good, C: Caution, SC: Significant concern.
[2] Guild type: G: generalist, S: specialist.
[3] Percentages differ slightly NETN 2009 annual report (Faccio et al. 2010) because the NETN report mistakenly omitted Eastern tufted titmouse from guild calculations (National Park Service, Brian Mitchell, Inventory and Monitoring Program Manager, Northeast Temperate Network, e-mail communication, 19 March 2010).

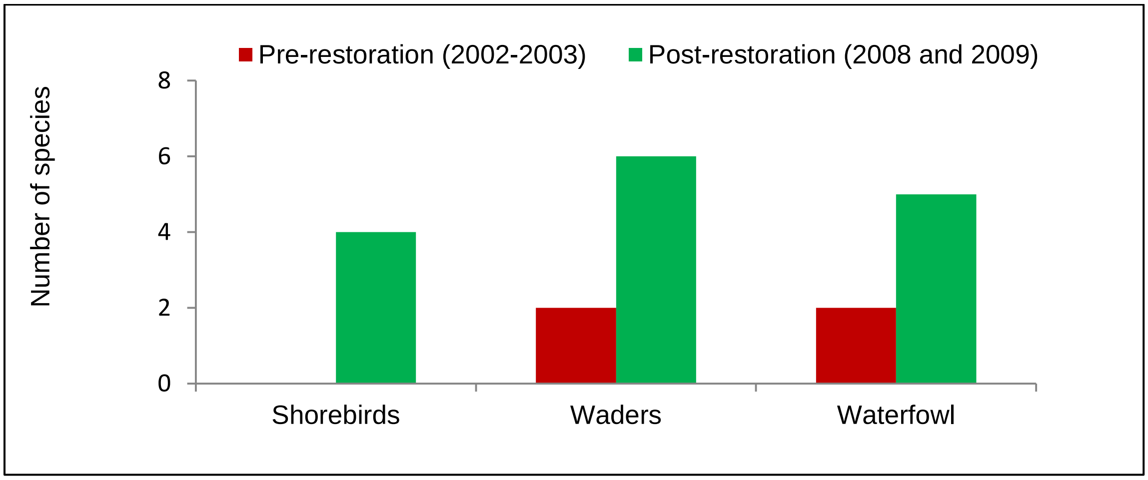


Figure 27. Number of waterbird species observed in wetland areas before and after the restoration of the turning basin waterfront and wetland.

Good: 4 or more species in each category (80th percentile or better);
Caution: 2–3 species in each category (50th to 80th percentile);
Significant concern: <2 species in each category (50th percentile or lower).

The benchmark for good condition was based on the recent (2008 and 2009) number of shorebirds (five species), waders (six species), and waterfowl (five species) species observed using the SAIR wetlands (Figure 27), with decreasing numbers of species richness in each category indicative of less desirable conditions. As more data are collected on waterbird use these benchmarks could change, as it is not known how many waterbird species would be considered appropriate for a small urban park such as SAIR.

Condition and Trend

Avian Forest Community:

Condition**:** Significant Concern

Trend: Stable.

The majority of the NETN guild-based indicators for the avian forest community rated as significant concern (Table 18). Avian surveys over the past decade have consistently observed a lower-than-desired number of specialist species, considered indicative of a high-integrity ecological condition (e.g., bark prober, ground gleaner, forest canopy foragers and nesters; Appendix F), and a higher-than-desired number of generalist species, considered indicative of a low-integrity ecological condition (e.g., exotic, resident, omnivore, and shrub nester species; Appendix F; Faccio et al. 2010). Based on the NETN rating system, the overall condition of the forest avian community was rated as significant concern and the trend was rated as stable (Table 19), since the NETN guild ratings did not change from 2003 to 2008 (Table 18).

Waterbirds:

Condition: Good

Improving: Trend**.**

The condition of the waterbird community appears to be improving based on professional judgment of the existing data (Table 19). In recent years (2008 and 2009) there have been at least four species each of shorebirds, waders, and waterfowl observed in the park (Figure 27, Appendix F). The trend for waterbirds was evaluated as improving as the number of shorebirds, waders, and waterfowl observed in the park’s wetland areas since the restoration of the turning basin waterfront and wetland has increased. Prior to the restoration, no shorebirds (e.g., sandpipers, plovers) and only a few waders (e.g., egrets, herons) and waterfowl (e.g., ducks), were observed. After the restoration, several waterbird species were observed, particularly shorebirds, dozens of which visited the mudflat areas daily in the late summer of 2009 and 2010 (McNiff and Albert 2010). This is likely a result of the newly created wetland, open water, and tidal flats.

Table 19. Metrics, benchmark values, current condition, and trend for the avian community at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Forest birds	NETN guild-based species richness assessment points for forest birds.	**Significant Concern** The majority of NETN guild ratings for forest birds were rated as significant concern.	**Stable** NETN guild ratings have been similar for several years.
Waterbirds- shorebirds, waders, and waterfowl	Good: 4 or more species per category; Caution: 2–3 species per category; Significant Concern: <2 species per category.	**Good** There are several species of waterbirds (4 shorebirds, 5 waterfowl, 6 waders) using the newly restored wetland, open water, and tidal flats.	**Improving** Since the restoration, the number of waterbirds in the park has increased.

Data Gaps

The NETN surveys of forest breeding birds at SAIR are limited to two events per year and may miss some species using the park, although over several years is it likely that these surveys will detect the majority of species in the park. The wildlife observations, while not a statistically robust method, do produce many more detections, and were the only surveys to regularly detect waterbirds (Appendix F). Standardized waterbird surveys to assess the use of SAIR wetland areas would be beneficial to fully evaluate the waterbirds in the park.

Threats

The avian community at SAIR is influenced by the urban setting of the park. Habitat loss due to urban development is a major threat to landbird populations, with neo-tropical migrants (e.g., single brooders such as flycatchers, warblers, orioles, and vireos) particularly vulnerable to habitat fragmentation. Forest fragmentation leads to increases in edge habitat, an ideal habitat for non-migratory resident species, and results in higher rates of brood parasitism and nest predation in the remaining forest habitat (Faccio et al. 2010). While small parks like SAIR may have some control over forest fragmentation within their boundaries, habitat loss and fragmentation are widespread throughout much of the Northeast region (Faccio et al. 2010).

Air Quality

The National Park Service Air Resources Division (NPS ARD) oversees the national air resource management program for the NPS. The NPS ARD has developed park-specific estimates and rated the condition of air quality from interpolated data for ozone, atmospheric deposition, and visibility. These estimates are from the most recent air quality data (2003 to 2007) and the condition is rated as good, moderate, or significant concern (NPS ARD 2010a, 2010b).

Condition Metrics

The NPS ARD (2010a, 2010b) uses four metrics, ozone, total nitrogen (N) wet deposition, total sulfur (S) wet deposition, and visibility, to evaluate air quality in NPS units.

Regionally, ozone levels have consistently exceeded the 8-hour average ozone standard. All 14 Massachusetts counties have a non-attainment status (Figure 28), indicating they have persistently exceeded the national air quality standard as set by the Clean Air Act (US EPA 2010). In Essex County, where SAIR is located, the 8-hour average ozone has consistently exceeded EPA air quality standards in ten of the 11 years where data are available (1998 to 2008) (US EPA 2010) (Figure 29).

In the Northeast, nitrogen deposition has declined at some sites, but only by a small amount (Kahl et al. 2004). Sulfate concentrations in wet deposition declined in the Northeast (as well as in other parts of the country) from 1980–2000 (Kahl et al. 2004).

Although not a metric used by the NPS ARD to evaluate air quality, mercury is an air quality concern. The Mercury Deposition Network (MDN) of the National Atmospheric Deposition Program (NADP) measures wet-only deposition of total Hg at a network of sites in North America (NADP/NTN 2010). There is no MDN site at or near SAIR, but regional values for Hg wet-only deposition are typically 6–8 $\mu g\ m^{-2}\ yr^{-1}$, based on spatial interpolation of data from other sites in the Northeast.

Mercury is atmospherically deposited in regions remote to its origin. Atmospheric Hg is delivered to ecosystems by rain, snow, dry, and occult (cloud and fog) deposition. In the Northeast, approximately 75% of mercury deposition from the atmosphere is from anthropogenic sources (Perry et al. 2005, Roos-Barraclough et al. 2006, Northeast States and New England Interstate Water Pollution Control Commission [NEIWPCC] 2007). Lake sediment data for the Northeast indicate that atmospheric deposition of Hg has increased since 1875, with a peak after 1970 (Perry et al. 2005).

Where total deposition of Hg has been measured, dry deposition (particles and gases) equals or exceeds wet deposition (Hg in rain and snow) and is likely the largest vector of Hg input from the atmosphere to terrestrial ecosystems (Miller et al. 2005, Lindberg et al. 2007). The Northeast states have reduced mercury deposition by approximately 74% between 1998 and 2002 and will likely achieve Phase II goals (75% reduction by 2010; NEIWPCC 2007).

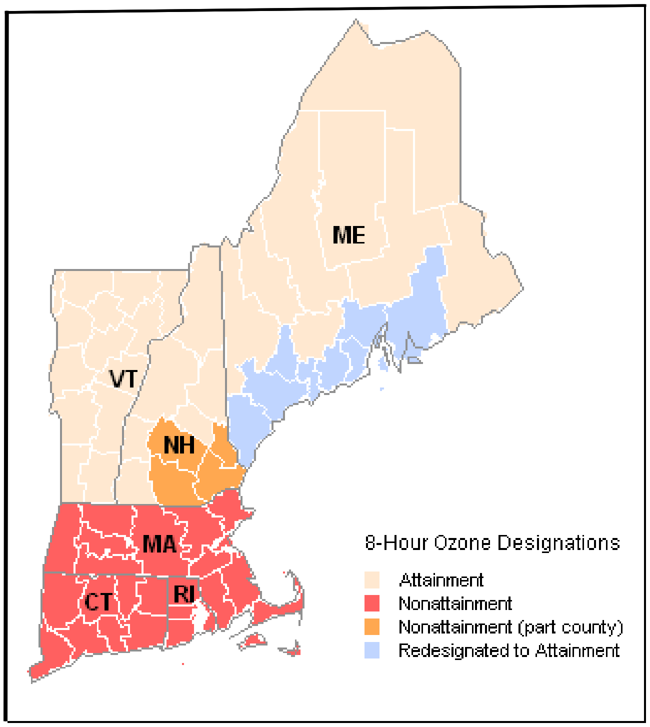


Figure 28. Attainment status for 8-hour average ground level ozone (1997 standard of 0.08ppm) for U.S. EPA Region 1. (Map from USEPA Air Data website.)

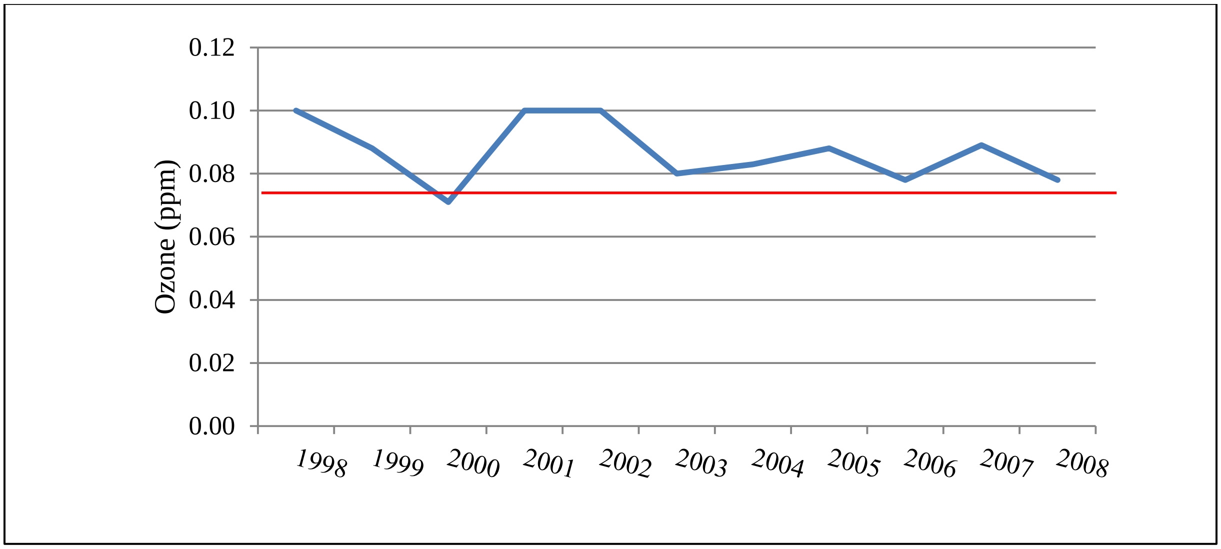


Figure 29. Ozone trends (8-hour average) for Essex County, MA from 1996 to 2008. US EPA standard for 8-hour ozone is <0.075 ppm (red line). (Data from USEPA Air Data website.)

Condition and Trend

Total N Wet Deposition, Total S Wet Deposition, and Ozone:

Condition: Significant Concern.

Total N wet deposition, total S wet deposition, and ozone were all evaluated as significant concern by NPS ARD (Table 20).

Visibility:

Condition: Caution.

Visibility was rated as moderate by the by NPS ARD, therefore, the condition was rated as caution by this assessment (Table 20).

Trend: No Trend.

Ozone, Total N Wet Deposition, Total S Wet Deposition, and Visibility:

The NPS ARD lists “no trend” for ozone, total N wet deposition, total S wet deposition, and visibility for SAIR (NPS ARD 2010b; Table 20). Ozone concentrations remained relatively unchanged (Figure 29), albeit exceeding air quality standards (>0.075ppm), in Essex County as well as all MA counties.

Data Gaps

Air quality data are regularly collected by state and federal agencies and there are no apparent data gaps for this resource.

Threats

Local air quality is influenced by both local and regional emissions from automobile traffic and industries.

Table 20. Metrics, benchmark values, current condition, and trend for air quality at Saugus Iron Works National Historic Site.

Metric	Benchmarks	Current Condition	Trend
Ozone[1]	Good: ≤ 60 ppb Moderate: 61–75 ppb Significant Concern: 76 ppb	**Significant Concern** (77.4 ppb)	**No Trend**
Total N wet deposition[1]	Good: < 1 kg ha^{-1} yr^{-1} Moderate: 1–3 kg ha^{-1} yr^{-1} Significant Concern: > 3 kg ha^{-1} yr^{-1}	**Significant Concern** (3.7 kg ha^{-1} yr^{-1})	**No Trend**
Total S wet deposition[1]	Good: < 1 kg ha^{-1} yr^{-1} Moderate: 1–3 kg ha^{-1} yr^{-1} Significant Concern: > 3 kg ha^{-1} yr^{-1}	**Significant Concern** (4.7 kg ha^{-1} yr^{-1})	**No Trend**
Visibility[1]	Good: > 8 dv Moderate: 2–8 dv Significant Concern: < 2 dv	**Caution** (7.2 dv)	**No Trend**

[1] Benchmarks, current condition, and trend from NPS-ARD (2010a, 2010b) interpolated values for 2004 to 2008, 5-year air quality estimates.

Summary

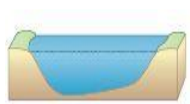
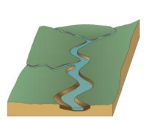
The natural resources at Saugus Iron Works NHS are primarily associated with the Saugus River, the adjacent wetlands, and the forest that borders the eastern edge of the river. This Natural Resource Condition Assessment was organized by ecosystem resources, and grouped by riverine-wetland and terrestrial environments. Within each grouping, the natural resources were described, the condition and trend were evaluated based on selected metrics, and data gaps and threats were highlighted. Each natural resource section concludes with a table summarizing the metrics and benchmarks used to assess condition and estimates of current condition and trend for the resource. A summary table for the all assessed resources is presented at the end of this Summary section (Table 21).

Only seven metrics for natural resources for SAIR were evaluated as “good,” with the majority of the metrics evaluated as either as “caution” or “significant concern.” Two metrics were evaluated as “unknown” (Table 21). The majority of the metrics were evaluated as having either “improving” or “stable” trends, although some metrics had “unknown” trends or “no trends.” No metrics were evaluated as a “declining” trend.

Metrics that were evaluated as “good” were water quality parameters of heavy metal and pH, riverbed and wetland sediments (wetland sediments were evaluated as good to caution), reptile species richness, mammal species richness (rated good to caution), and waterbird species richness (Table 21). Water quality parameters of heavy metal and pH were within acceptable ranges and riverbed sediment contaminant concentrations were all below probable effect concentrations (Tables 6 and 8). The restoration of the turning basin waterfront and wetland excavated the majority of the contaminated wetland sediments in these areas, but a condition of caution was also included, as some contaminants may have been below the excavated sediment depth and could still be present (Table 8). In the absence of established benchmarks, best professional judgment was used to estimate the condition of the reptile, mammal, and water bird communities based on species richness. During recent surveys, numbers of reptile, mammal, and waterbird species were greater or equal to 80% of the species richness historically observed in the park (Tables 13, 17, and 19). The mammal community was also rated as caution as it was not known what would be an appropriate number of mammals for a small urban park like SAIR.

Metrics that were evaluated as “caution” were: fish community guilds (pollution tolerance and trophic guilds); the water quality metrics of dissolved oxygen, mercury, nutrient and organic enrichment, and salts; river discharge rates; wetland and aquatic plant communities; upland vegetation; and the air quality parameter of visibility (Table 21). The fish community was dominated by pollution-tolerant and moderately pollution-tolerant species with very few intolerant species observed. In terms of trophic guilds, there were moderate proportions of generalist and omnivore species, usually considered a sign of a degraded fish community (Table 2). Saugus River water quality parameters of dissolved oxygen, mercury, nutrient and organic enrichment, and salts can exceed benchmark values and impair water quality (Table 6). River discharge flow rates at the USGS stream gage can be below recommended minimum flow rates, especially during late spring (Table 9). The newly restored wetland, although sparsely vegetated, was being colonized by desirable native wetland plants; however, invasive plants were still present in small natural wetland areas. Invasive curly pondweed has been observed in the turning basin and intertidal areas of the restored wetland (Table 11). Invasive vegetation is also still

Table 21. Summary of condition and trends for natural resources at Saugus Iron Works National Historic Site.

Resource	Condition and key points	Trend and key points
Riverine-Wetland Resources		
 Fish Community	Caution: High proportions of pollution tolerant species and moderate proportions of omnivore and generalist species. Significant Concern: Smelt abundance is low. The smelt spawning habitat score indicated a degraded habitat. Unknown: Quality of smelt riffle habitat is unknown.	Stable to Unknown: Historic and recent fish community data indicate similar communities, but the influence of the weir removal is unknown. The influence of the restoration and high water in 2009 are unknown. Unknown: Recent data on smelt abundance may be inaccurate. The influence of the restoration and weir removal on smelt abundance and spawning habitat quality is unknown.
 Aquatic Benthic Macroinvertebrate Community	Significant Concern: The Hilsenhoff Biotic Index indicated a degraded community primarily due to an abundance of pollution tolerant aquatic macroinvertebrates.	Unknown: There were no clear trends in the data.
 Water Quality	Good: Heavy metal concentrations and pH were within acceptable ranges. Caution: Dissolved oxygen, mercury, nutrients, organic enrichment, and salt inputs were all impairments to water quality. Significant Concern: Pathogens (*fecal coliform*) and temperature modifications were persistent threats to water quality.	Unknown: The influence of the restoration on water quality is unknown.
 Riverbed and Wetland Sediments	Good, riverbed sediments: All detected sediment contaminants were below probable effect concentrations. Good to Caution, wetland sediments: The restoration removed likely removed the vast majority of contaminated sediments.	Improving: All detected contaminants were lower that previous sampling year (2004) in riverbed sediments. The restoration removed likely removed the vast majority of contaminated wetland sediments
 River Hydrology	Caution, river discharge rate: Flow rates can fall below minimum recommended flow rates in late spring and fall. Unknown, river water depth and salinity intrusion: There were no data available to assess these metrics.	Improving: The percent of days when river discharge was below suggested minimum flow rates has decreased in recent years. Unknown: There are no data available to assess trends in river water depth or extent of salinity intrusion.

Resource		Condition and key points	Trend and key points
	Wetland Vegetation	Caution, wetland vegetation: The restored wetland was sparsely vegetated, but some native plants were colonizing the area.	Improving to Unknown, wetland vegetation : Native species were present in the restored wetland, but the impact of the weir removal on tidal inundation of the wetland is unknown.
	Aquatic Vegetation	Caution, aquatic vegetation: Invasive aquatic vegetation has been observed recently in the river and turning basin.	Unknown, aquatic vegetation: Salinity regime will determine the type of aquatic vegetation and the effect of the weir removal on the salinity regime of the river is unknown.
	Amphibians & Reptiles	Good, Reptiles: Five of six probable species have been observed in recent years. Significant Concern: Amphibians: Two of five probable species have been observed in recent years.	Unknown: There were not enough long-term data to evaluate trends for either amphibians or reptiles.
Terrestrial Resources			
	Upland Vegetation	Caution: Invasive plant species were still present in upland vegetation communities.	Stable to Improving: Invasive plants have been consistently observed in the riparian forest, but have been substantially reduced.
	Mammal Community	Good to Caution: Nine species were observed in 2009, but it is not known how many species are appropriate for SAIR.	Stable to Unknown: Seven species observed in 2004 have been recorded in 2009.
	Avian Community	Significant Concern, forest birds: The condition of the majority of forest breeding avian guilds was rated as significant concern using the NETN guild-based scoring system. Good, waterbirds: There are several species of waterbirds using the newly restored wetland, open water, and tidal flats.	Stable, forest birds: NETN guild ratings have been similar for several years. Improving: There has been an increase in the number of waterbirds in the park.
	Air Quality	Significant Concern: Ozone, total N wet deposition, and total S wet deposition were all rated as significant concern by the NPS ARD. Caution: Visibility was rated as caution by the NPS ARD.	The NPS ARD rated the four air quality metrics as no trend.

present in the riparian forest, although great progress has been made to reduce the abundance of exotic plants (Table 15). Lastly, the air quality metric of visibility was rated as moderate by the NPS ARD (Table 20).

Metrics that were evaluated as "significant concern" were: smelt abundance; overall smelt spawning habitat quality; benthic macroinvertebrate community; water quality as related to temperature modifications and pathogens; amphibian species richness; avian forest community guilds; and the air quality parameters of ozone, total nitrogen wet deposition and total sulfur wet deposition (Table 21). Recent smelt abundance, measured as catch per unit effort during spring fyke net surveys, was low and has declined in recent years (Table 2), although it was unknown if this was true decline in abundance or an artifact of gear performance. The overall quality of the smelt spawning habitat in the park as assessed by Chase (2006) rated in the lower 50^{th} percentile when compared to other Massachusetts rivers (Table 2). The aquatic benthic macroinvertebrate community was dominated by pollution-tolerant fauna and the community rated as very poor by the Hilsenhoff Biotic Index (Table 4). Temperature modifications and pathogens (e.g., fecal coliform bacteria) have been and are currently persistent water quality impairments (Table 6). Only two of five potentially occurring amphibian species have been observed in the park over the past decade (Table 13). The forest breeding bird community has consistently been rated as significant concern by the NETN guild rating system, with a lower-than-desired number of species in guilds representative of high-integrity ecological condition (e.g., bark prober, ground gleaner, forest canopy foragers and nesters), and a higher-than-desired number of generalist species considered indicative of low-integrity ecological condition (e.g., exotic, resident, omnivore, and shrub nester species) (Table 18). Air quality metrics of total nitrogen wet deposition, total sulfur wet deposition, and ozone were all evaluated by the NPS Air Resources Division as significant concern (Table 20).

Metrics that were evaluated as "unknown" (Table 21) were: the quality of specific smelt spawning riffle habitat characteristics as described by Chase (2009) and river hydrology as related to river water depth and extent of salinity intrusion (Tables 2 and 9). Current and planned future monitoring at the park should provide data to evaluate these parameters.

Metrics that were viewed as having "improving trends" were riverbed (evaluated as unknown to possibly improving trend), wetland sediments, river discharge rates, wetland plant community (evaluated as improving to unknown), upland vegetation (evaluated as stable to improving), and waterbird species richness (Table 21). Riverbed sediment contaminant concentrations were lower in recent sampling than in previous years, possibly indicating an improvement in sediment habitat quality, and the excavation associated with the restoration removed the majority of contaminated wetland sediments (Table 8). Although river discharge rates can fall below minimum recommended values, the percent of days when river flow was below the minimum flow rate has decreased in recent years (Table 9). The restoration of the turning basin and wetlands removed the vast majority of the invasive plants from the wetlands adjacent to the Saugus River and created habitat that can be colonized by native wetland plants, thus improving the quality of the wetland areas. Although the impact of the weir removal on tidal inundation and salinity regimes was unknown, these factors will dictate the type of wetland and aquatic vegetation that can persist in the restored wetland and river (Table 11) over time. While invasive plants were still present in the riparian forest, the park has made substantial progress in removing and reducing the abundance of invasive vegetation in this area (Table 15). Since the restoration of the turning basin and wetlands there has been an increase in the number of waterbirds (e.g., waterfowl, waders, and shorebirds) using the Saugus River, tidal flats, and wetland areas (Table 19).

Metrics that were evaluated as having “stable trends” were fish community species pollution tolerance and trophic guilds (both evaluated as stable to unknown), mammal community (evaluated as stable to unknown), and avian forest community (Table 21). There has been little change in the proportion of either pollution-tolerant or trophic feeding guilds of the fish community (both rated as caution) based on examination of recent and historic data, and the removal of the Hamilton Street weir on the fish community was unknown (Table 2). Similar numbers of mammalian species have been observed during past and recent surveys; however, further information is needed to determine status (e.g., the presence of breeding populations or transient species, increasing or decreasing population densities) of mammals at SAIR (Table 17). The NETN avian forest guild ratings have remained similar, albeit evaluated as significant concern, over time (Table 19).

The trends for several metrics were evaluated as “unknown” (Table 21), related to possibly inaccurate data (e.g., recent abundance data for smelt, Table 2), the lack of long-term data (e.g., smelt spawning habitat, amphibian and reptile communities, Tables 2 and 13), no clear trends in the data (e.g., aquatic benthic macroinvertebrates, air quality metrics, all evaluated as “no trend” by the NPS ARD; Tables 4 and 20), or absence of data (e.g., smelt riffle habitat; Table 2). The recent restoration of the turning basin and wetlands has no doubt influenced some of the aquatic (e.g., water quality, extent of salinity intrusion, Tables 6 and 9) and wetland (e.g., wetland and aquatic plant communities) natural resources at SAIR; only future monitoring will elucidate any associated impacts or trends.

For a small historical park, there was a considerable amount of recent, quantitative data on the park’s natural resources, most of it related to the monitoring associated with the restoration of the turning basin and wetlands. However, there were areas where data gaps existed. For example, the smelt spawning habitat was only surveyed once; a re-survey would be beneficial, especially since the influence of the restoration and removal of the Hamilton Street weir on smelt abundance and habitat was unknown. Water quality monitoring could be improved. Although the NETN monitors water quality at the park, it was limited to one or two sampling events per year. More comprehensive information on the periodicity of tidal inundation, water chemistry, salinity regimes, and extent of salinity intrusion would greatly enhance understanding of the hydrology of the river and its impact on the wetland and aquatic vegetation and the fish and aquatic benthic macroinvertebrate communities in the river. The park is making strides in collecting these types of data with the recent installation of a YSI unit in the river channel. There have only been a few standardized surveys of the terrestrial communities (e.g., amphibians, reptiles, and mammals) and more recent data would be beneficial to characterize these resources. Although the NETN monitors forest breeding birds in the park, the surveys were limited to two events per year and were oriented toward forest breeding birds. Standardized waterbird surveys would be beneficial to fully characterize waterbird use of the park, especially in light of the newly created wetland and tidal flat areas. The NVC data of the park’s vegetation was outdated and not applicable, since three of the four NVC plots were located in the restoration area that has now been dramatically changed. There were no recent data on the vegetation of the riparian forest.

Saugus Iron Works NHS is a small historical park located in a highly urbanized watershed; therefore, the surrounding watershed and the Saugus River exert great influence on the condition of the natural resources in the park. The majority of park's natural resources are associated with the Saugus River and the adjacent wetlands. River water quality influences many of the park's resources and the water quality of the river is, in turn, influenced by the surrounding watershed. For example, chronic water quality impairments influence the quality of the river habitat and the organisms that reside in the river. Stressors and threats associated with anthropogenic land use and human population that influence water quality parameters at SAIR include, but are not limited to, surface water runoff contaminated with road salt, non-point source pollution, sewage overflow and infiltration into groundwater, and alteration in river discharge flow. Urbanization and habitat fragmentation of the larger watershed are threats to the terrestrial resources and may limit the type, diversity, and density of fauna that are present in the park. Although SAIR has made great progress in removing invasive vegetation from the wetland and riparian forest along the river, invasive plants are still present and can detrimentally impact other resources. Climate change and accelerated sea-level rise are also threats to the park's flora and fauna as well as its riverine resources.

Literature Cited

Agius, B. 2003. Forging changes in an American landscape: Invasive plant species at the Saugus Iron Works National Historic Site. Technical Report NPS/NER/NRTR – 2005/010. National Park Service, Woodstock, VT.

Andronache, C., R. Hon, N. Tedder, Q. Xian, and B. Schaudt. 2008. Analysis of possible anthropogenic impact in surface water quality in eastern Massachusetts. Geological Society of America Abstracts with Programs, Northeastern Section - 43rd Annual Meeting Buffalo, NY, March 2008.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Breault, R. F., M. S. Ashman, and D. Heath. 2004. Sediment quality in the North Coastal Basin of Massachusetts, 2003: U.S. Geological Survey Scientific Investigations Report 2004-5110, Reston, VA.

CH2MHill. 2004a. Restore Saugus River turning basin and dock – marsh characterization, Saugus Iron Works National Historic Site Saugus, Massachusetts. Report prepared for National Park Service, Denver Service Center, Denver, CO.

CH2MHill. 2004b. Saugus River aquatic habitat and benthic invertebrate survey. Addendum to the marsh characterization report: Restore Saugus River turning basin and dock-marsh characterization, Saugus Iron Works National Historic Site Saugus, Massachusetts. Report prepared for National Park Service, Denver Service Center, Denver, CO.

CH2MHill. 2005. Restore Saugus River turning basin and dock – monitoring plan. Technical Report, prepared for National Park Service, Denver Service Center, Denver, CO.

CH2MHill. 2008. Saugus bacterial monitoring report. Technical memorandum to the National Park Service, Dated 18 November 2008.

CH2MHill 2009. Draft Report – 2008 Monitoring data report- restore Saugus River turning basin and dock – Saugus Iron Works National Historic Site, Saugus Massachusetts, January 2009. Report prepared for National Park Service, Denver Service Center, Denver, CO.

Chalmers, A. 2002. Trace elements and organic compounds in streambed sediment and fish tissue of coastal New England streams, 1998–99. USGS Water-Resources Investigations Report 02-4179, Pembroke, NH.

Chase B. C. 2006. Rainbow smelt (*Osmerus mordax*) spawning habitat on the Gulf of Maine coast of Massachusetts Technical Report TR-30, 2006. Massachusetts Division of Marine Fisheries, Gloucester, MA.

Chase B. C. 2007. American eel compliance report to the Atlantic States Marine Fisheries Commission. Massachusetts Division of Marine Fisheries, Gloucester, MA.

Chase B. C. 2009. The spawning habitat of anadromous rainbow smelt: Trouble at the tidal interface. American Fisheries Symposium 69:859–862.

Chase B. C., M. H. Ayer, K. J. MacGowan, and K. Taylor. 2006. Population indices of rainbow smelt spawning runs in Massachusetts. Massachusetts Division of Marine Fisheries, Gloucester, MA.

Clemants, S. 1997. Saugus Iron Works National Historic Site, vascular plant survey 1996–1997.

Coefer, J., 2006. Road salt contamination of urban spring and river water. Geological Society of America Abstracts with Programs, Northeastern Section – 41st Annual Meeting, Camp Hill/Harrisburg, PA, March 2006.

Coles, J.F., T.F Cuffney, G. McMahon, and K.M. Beaulieu. 2004. The effects of urbanization on the biological, physical, and chemical characteristics of coastal New England streams: U.S. Geological Survey Professional Paper 1695. U.S. Geological Survey, Reston, VA.

Commonwealth of Massachusetts. 2005. Massachusetts Year 2004 Integrated list of waters. Division of Watershed Management Watershed Planning Program, Worcester, MA.

Commonwealth of Massachusetts. 2006. Massachusetts Year 2006 Integrated list of waters. Division of Watershed Management Watershed Planning Program, Worcester, MA.

Commonwealth of Massachusetts. 2007. Department of Environmental Protection, Massachusetts surface water quality standards 314 CMR 4.00: Division of water pollution control, Worcester, MA. http://www.mass.gov/dep/water/laws/regulati.htm. Accessed 3 December 2010

Commonwealth of Massachusetts. 2008. Massachusetts Year 2008 Integrated list of waters. Division of Watershed Management Watershed Planning Program, Worcester, MA.

Commonwealth of Massachusetts. 2010. Massachusetts Year 2010 Integrated list of waters. Division of Watershed Management Watershed Planning Program, Worcester, MA.

Cook, R. P., D. K. Brotherton, and J. L. Behler. 2010. Saugus Iron Works National Historic Site, amphibian and reptile inventory, March–September 2001. Natural Resources Report NPS/NETN/NRR-2010-248. National Park Service, Fort Collins, CO.

DeCesare, G. J., L. E. Kennedy, and M. J. Weinstein. 2000. North Coastal Watershed 1997/1998 water quality assessment report. DWM Control Number: 17.0, Report Number: 93-AC-1. Department of Environmental Protection, Division of Watershed Management, Worcester, MA.

Dettmers R. and K. Rosenburg. 2000. Draft Partners in Flight landbird conservation plan: Physiographic Area 9: Southern New England. Version 1.0, October 2000. American Bird Conservancy, Ithaca, NY.

Dupont, J., T. A. Clair, C. Gagnon, D. D. Jeffries, J. S. Kahl, S. J. Nelson, and J. M. Peckenham. 2005. Estimation of critical loads of acidity for lakes in Northeastern United States and Eastern Canada. Environmental Monitoring and Assessment 109:275–292.

Faccio, S. D. and B. R. Mitchell. 2010. Northeast Temperate Network breeding landbird monitoring report: 2009 annual report. Natural Resource Report NPS/NETN/NRR—2010/190. National Park Service, Fort Collins, CO.

Faccio, S., B. R. Mitchell, and P. S. Pooler. 2010. Breeding landbird monitoring protocol: Northeast Temperate Network. Natural Resource Report NPS/NETN/NRR—2010/198. National Park Service, Fort Collins, CO.

Gilbert A. T., A. F. O'Connell, Jr., E. M. Annand, N. W. Talancy, J. R. Sauer, and J. D. Nichols. 2008. An inventory of terrestrial mammals at National Parks in the Northeast Temperate Network and Sagamore Hill National Historic Site. Scientific Investigations Report 2007-5245. US Geological Survey, Reston, VA.

Glista, D. J., T. L. DeVauly, and J. A. DeWoody. 2007. Vertebrate road mortality predominantly impacts amphibians. Herpetological Conservation and Biology 3:77–87.

Gomez and Sullivan Engineers. 2006. Evaluation of Saugus River fish passage and hydrology. Weare, NH.

Hilsenhoff, W. L. 1987. An improved biotic index of organic stream pollution: The Great Lakes Entomologist 20:31–39.

Hilsenhoff, W. L. 1988. Rapid field assessment of organic pollution with a family-level biotic index, Journal of the North American Benthological Society 7:65–68.

Jackson, S. D., R. M. Richmond, T. F. Tyning, and C. W. Leahy (editors). 2010. Massachusetts Herpetological Atlas 1992–1998, Massachusetts Audubon Society and University of Massachusetts www.massherpatlas.org. Accessed 1 July 2010.

James-Pirri M.-J., J. Burgess, C. T. Roman, and M. Albert. 2010a. Restoration of the turning basin and tidal wetlands at Saugus Iron Works National Historic Site: 2008 post-restoration monitoring data report. Natural Resource Data Series NPS/NERO/NRDS-2010/054. National Park Service, Fort Collins, CO. http://www.nature.nps.gov/publications/nrpm/nrds.cfm

James-Pirri M.-J., J. Burgess, C. T. Roman, and M. Albert. 2010b. Restoration of the turning basin and tidal wetlands at Saugus Iron Works National Historic Site: 2009 post-restoration monitoring data report. Natural Resource Data Series NPS/NERO/NRDS-2010/093. National Park Service, Philadelphia, PA. http://www.nature.nps.gov/publications/nrpm/nrds.cfm

Kahl, J. S., J. L. Stoddard, R. Haeuber, S. G. Paulsen, F. A. Deviney, J. R. Webb, D. R. DeWalle, W. Sharpe, C. T. Driscoll, A. T. Herlihy, J. H. Kellogg, P. S. Murdoch, K. Roy, K. E. Webster, and N. S. Urquhart. 2004. Have U.S. surface waters responded to the 1990 Clean Air Act Amendments? Environmental Science and Technology 38:484A-490A.

Karr, J. R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21–27.

Kashiwagi, M. and T. Richards. 2009. Development of target fish community models for Massachusetts mainstem rivers. Technical Report. Commonwealth of Massachusetts, Department of Fish and Game, Division of Fisheries and Wildlife, Worcester, MA.

Kennen, J. G., K. Riva-Murray, and K. M. Beaulieu. 2010. Determining hydrologic factors that influence stream macroinvertebrate assemblages in the Northeastern US. Ecohydrology 3:88–106.

Largay, E. F. and L. A. Sneddon. 2008. Vegetation classification and mapping at Saugus Iron Works National Historic Site. Technical Report NPS/NER/NRTR – 2008/123. Philadelphia, PA.

Legros, J. D. and P. Parasiewicz. 2007. Development and analysis of a Target Fish Community model to assess the biological integrity of the Lamprey Designated River, New Hampshire and to identify indicator fish species for a MesoHABSIM model. New Hampshire Department of Environmental Services, Concord, NH.

Lindberg, S., R. Bullock, R. Ebinghaus, D. Engstrom, X. Feng, W. Fitzgerald, N. Pirrone, E. Prestbo, and C. Seigneur. 2007. A synthesis of progress and uncertainties in attributing the sources of mercury in deposition. Ambio 36:19–32.

Lombard, P., W. Gawley, and J. Caldwell. 2006. Freshwater vital-signs monitoring plan for National Parks in the Northeast Temperate Network (NETN) PHASE III: water-quality monitoring protocols in lakes, ponds and streams. USGS, Augusta, ME.

MacDonald, D. D., C. G Ingersoll, and T. A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems: Archives of Environmental Contamination and Toxicology 39:20–31.

Mahan, C. G. and T. J. O'Connell. 2005. Small mammal use of suburban and urban parks in central Pennsylvania. Northeastern Naturalist 12:307–314.

Massachusetts Audubon. 2008. Salamander migration. http://www.massaudubon.org/Nature_Connection/wildlife/index.php?subject=Reptiles%20and%20Amphibians&id=58. Accessed 10 July 2010.

Massachusetts Department of Environmental Protection (MADEP). 1999. Massachusetts contingency plan, 310 CMR 40.000. Boston, MA.

Massachusetts Department of Environmental Management (MADEM). 2002. Saugus River water budget and instream flow study. Final Report, June 2002. Gomez and Sullivan Engineers and Environmental Scientists, Weare, NH.

Massachusetts Division of Fisheries and Wildlife. 2010. Massachusetts list of endangered, threatened and special concern species http://www.mass.gov/dfwele/dfw/nhesp/species_info/mesa_list/mesa_list.htm Accessed 27 April 2010.

Massachusetts Division of Fisheries and Wildlife. 2007. Annual report. Westborough, MA. http://www.mass.gov/dfwele/dfw/publications/annual_reports/annual_report_fy07.pdf Accessed 1 July 2010.

Massachusetts Invasive Plant Advisory Group (MIPAG). 2005. The evaluation of nonnative plant species for invasiveness in Massachusetts (with annotated list). (http://www.massnrc.org/MIPAG/) Accessed 6 April 2010.

McNiff, C. and M. Albert. 2010. Saugus Iron Works wildlife observation summary: Summer 2009. National Park Service. Saugus Iron Works National Historic Site, Saugus, MA.

Miller, K. M., G. L. Tierney, and B. R. Mitchell. 2010. Northeast Temperate Network forest health monitoring report: 2006–2009. Natural Resource Report NPS/NETN/NRR—2010/206. National Park Service, Fort Collins, CO.

Miller, E., A. Vanarsdale, G. Keeler, A. Chalmers, L. Poissant, N. Kamman, and R. Brulotte. 2005. Estimation and mapping of wet and dry mercury deposition across Northeastern North America. Ecotoxicology 14:53–70.

Munson, R. K. and S. A. Gherini. 1991a. Processes influencing the acid-base chemistry of surface waters. Pages 3–34 *in* D.F. Charles, editor. Acidic Deposition and Aquatic Ecosystems: Regional Case Studies. Springer-Verlag, New York, NY.

Munson, R.K. and S.A. Gherini. 1991b. Hydrochemical assessment methods for analyzing the effects of acidic deposition on surface waters. Pages 35–63 *in* D.F. Charles, editor. Acidic Deposition and Aquatic Ecosystems: Regional Case Studies. Springer-Verlag, New York, NY.

National Atmospheric Deposition Program/National Trends Network (NADP/NTN). 2010. NADP Program Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL. http://nadp.sws.uiuc.edu/ Accessed 7 April 2010.

National Park Service (NPS). 2003. Annual performance plan for Salem Maritime and Saugus Iron Work National Historic Sites. National Park Service, Denver, CO.

National Park Service (NPS). 2005. 100% design development drawings for Restore Saugus River turning basin and dock, sub-sheet C11, sheet 12, June 2005. National Park Service, Denver Service Center. Denver, CO.

National Park Service (NPS). 2006. Restore Saugus River turning basin and dock: Summary of historic and natural resource values. Project synopsis July 14, 2006. Saugus Iron Works National Historic Site, Saugus, MA. Report prepared for National Park Service, Denver Service Center, Denver, CO.

National Park Service (NPS). 2009a. Restore Saugus River turning basin and dock 2009 photo monitoring report, National Park Service. Saugus, MA.

National Park Service (NPS). 2009b. NPSpecies database. Accessed 1 December 2009.

National Park Service (NPS). 2010. New projects for Saugus Iron Works National Historic Site. http://home.nps.gov/nero/science/NEW/newprojSAIR.htm. Accessed 11 May 2010.

National Park Service, Air Resources Division (NPS ARD). 2010a. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, CO. http://www.nature.nps.gov/air/Pubs/pdf/gpra/AQ_Trends_In_Parks_2009_Final_Web.pdf

National Park Service. Air Resources Division (NPS ARD). 2010b. National Park Service. Fort Collins, CO. http://www.nature.nps.gov/air/planning/docs/NPS_AQC_0408_values_web.pdf. Accessed 6 December 2010.

Nelson, S. J., K. B. Johnson, J. S. Kahl, T. A. Haines, and I. J. Fernandez, 2007. Mass balances of mercury and nitrogen in burned and unburned forested watersheds at Acadia National Park, Maine, USA. Environmental Monitoring and Assessment 126:69–80.

New England Environmental, Inc. 2009. Site visit results. Memo dated 31 July 2009. Amherst, MA.

Northeast Exotic Plant Management Team (NE EMPT). 2009. NE EMPT report to the park. National Park Service, Saugus, MA.

Northeast States and New England Interstate Water Pollution Control Commission (NEIWPCC). 2007. Northeast regional mercury total maximum daily load. http://www.neiwpcc.org/mercury/MercuryTMDL.asp. Accessed 12 January 2009.

Nyman, S. 1991. Report on the amphibian and reptile fauna of the Saugus River. Pages F1 to F10 *in* J. S. Tashiro, R. E. Schmidt, E. Kiviat, and D. R. Roeder, editors. Baseline assessment of the Saugus River system Massachusetts, appendices. Report prepared for New England Natural Resources Research Center and Massachusetts Public Interest Research Group by Hudsonia Limited, Bard College Field Station, Annadale-On-Hudson, NY.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press. Washington, DC.

Perry, E., S. A. Norton, N. C. Kamman, P. M. Lorey, and C. T. Driscoll. 2005. Deconstruction of historic mercury accumulation in lake sediments, Northeastern United States. Ecotoxicology 14:85–99.

Riskin, M. L., J. R. Deacon, M. L. Liebman, and K. W. Robinson. 2003. Nutrient and chlorophyll relations in selected streams of the New England Coastal Basins in Massachusetts and New Hampshire, June–September 2001. U.S. Geological Survey Water-Resources Investigations Report 03-4191. National Water Quality Assessment Program, Pembroke, NH.

Roos-Barraclough, F., N. Givelet, A. K. Cheburkin, W. Shotyk, and S. A. Norton. 2006. Use of Br and Se in peat to reconstruct the natural and anthropogenic fluxes of atmospheric Hg: A 10000-year record from Caribou Bog, Maine. Environmental Science and Technology 40: 3188–3194.

Snook, H., S. P. Davies, J. Gerritsen, B. K. Jessup, R. Langdon, D. Neils, and E. Pizutto. 2007. The New England Wadeable Stream Survey (NEWS): Development of common assessments in the framework of the biological condition gradient. USEPA Office of Science and Technology and Office of Watersheds Oceans and Wetlands, Washington, D.C.

Tashiro J. S. R. E. Schmidt, E. Kiviat, and D. R. Roeder. 1991. Baseline assessment of the Saugus River system Massachusetts, appendices. Report prepared for New England Natural Resources Research Center and Massachusetts Public Interest Research Group by Hudsonia Limited, Bard College Field Station, Annadale-On-Hudson, NY.

Trocki C., and P. Paton. 2005. Avian surveys in Northeast Temperate Network Parks. Technical Report NPS/NER/NRTR--2005/004. National Park Service, Woodstock, VT.

USDA Forest Service. 2010. Alien forest pest explorer static maps and links. http://www.fs.fed.us/ne/morgantown/4557/AFPE/links.html. Accessed 2 Febuary 2010.

US Environmental Protection Agency (US EPA). 1988. Ambient water quality criteria for chloride. Office of Water, Regulations and Standards Criteria and Standards Division, Washington, DC.

US Environmental Protection Agency (US EPA). 1997. Mercury study report to Congress. EPA-452/R-97-003. Washington, DC.

US Environmental Protection Agency (US EPA). 2009. National recommended water quality criteria. Office of Water and Office of Science and Technology. Washington, DC. http://www.epa.gov/ost/criteria/wqctable/. Accessed 3 February 2011.

US Environmental Protection Agency (US EPA). 2010. Air data website. http://www.epa.gov/air/data/info.html. Accessed 11 May 2010.

US Fish and Wildlife Service. 2009 (USFWS). White-nose syndrome in bats frequently asked questions. http://www.fws.gov/northeast/white_nose.html. Accessed 10 January 2011.

USGS-NAS. 2010. Nonindigenous Aquatic Species (NAS) – http://nas3.er.usgs.gov/. Accessed 10 January 2010.

USGS-NAWQA. 2010. National Water-Quality Assessment (NAWQA) Program. http://water.usgs.gov/nawqa, accessed 30 March 2010.

USGS Water Resources. 2010a. National Water Information System USGS 01102345 Saugus River at Saugus Ironworks at Saugus, MA. http://waterdata.usgs.gov/usa/nwis/uv?01102345 Accessed 24 April 2010.

USGS Water Resources. 2010b. Fixed-site network data for Saugus River. http://nh.water.usgs.gov/projects/nawqa/sw_saugu.htm Accessed 24 April 2010.

Vile J. 2008. Fish IBI report, 2006 sampling, round 2, year 2 of 5. Volume 1. New Jersey Department of Environmental Protection, Trenton, NJ. http://www.state.nj.us/dep/wms/bfbm/download/ibi2006Vol1.pdf.

Appendix A. Species, pollution tolerance, trophic guild, and nativity status for fish observed at Saugus Iron Work National Historic Site.

Scientific Name	Common Name	Nativity status	Pollution Tolerance[1]	Trophic Guild[1]	1989[2]	2000 (USGS)[3]	2004 (URI)[4]	2005 (DMF)[5]	2006 (DMF)[5]	2007 (DMF)[5]	2008 (DMF)[5]	2008 (URI)[4]	2009 (URI)[6]
Alosa aestivalis	blueback herring	native	M	PL					X	X			
Alosa pseudoharengus	alewife	native	M	PL			X	X	X	X			
Ameiurus natalis	yellow bullhead	transplant	T	G						X			
Ameiurus nebulosus	brown bullhead	native	T	G							X		
Anguilla rostrata	American eel	native	T	P	X	X	X	X	X	X	X	X	X
Apeltes quadracus	four spine stickleback	native	M	I	X		X	X	X	X	X	X	X
Catostomus commersoni	white sucker	native	T	G	X	X	X	X	X	X	X	X	X
Culaea inconstans	brook stickleback[7]	transplant	M	I			X						
Enneacanthus obesus	banded sunfish	native	M	I						X	X		
Esox americanus americanus	redfin pickerel	native	M	P			X	X	X	X	X		X
Esox americanus vermiculatus	grass pickerel	native	M	P									X
Esox niger	chain pickerel	native	M	P		X			X				
Fundulus heteroclitus	mummichog	native	T	G	X		X	X	X	X	X		X
Gasterosteus aculeatus	threespine stickleback	transplant	M	I			X	X	X	X	X		
Lepomis macrochirus	bluegill	transplant	T	G					X		X	X	X
Microgadus tomcod	Atlantic tomcod	native	-	-					X				
Micropterus salmoides	largemouth bass	transplant	M	P			X					X	X
Morone americana	white perch	native	M	I, P			X	X	X	X	X	X	
Notemigonus crysoleucas	golden shiner	native	T	O					X	X	X		
Osmerus mordax	rainbow smelt	transplant	M	I				X	X	X	X		
Perca flavens	yellow perch	native	M	P				X	X	X	X		
Pimephales promelas	fathead minnow	native	T	O								X	
Pomoxis nigromaculatus	black crappie	transplant	M	I, P						X			
Pungitius pungitius	ninespine stickleback	native	M	I			X					X	X
Salmo trutta	brown trout	exotic	I	I, P		X			X[8]		X		
		Total species			4	5	11	10	16	15	14	7	12

[1] Pollution tolerance and trophic guild designations after Barbour et al. 1999: Pollution tolerance: I: intolerant, M: moderately tolerance, T: tolerant; Trophic guilds: G: generalist, I: insectivore, P: piscivore, PL: planktivore, O: omnivore, "-" not assigne.
[2] Data source: Tashiro et al. 1991.
[3] Data source: USGS 2010b.
[4] Data source: James-Pirri et al. 2010a.
[5] Data source: Massachusetts Division of Marine Fisheries, B. Chase unpublished data.
[6] Data source: James-Pirri et al. 2010b
[7] May be nine spine stickleback.
[8] Sea-run brown trout

Appendix B. Benthic macroinvertebrates (listed by phylogentic order) observed at Saugus Iron Works National Historic Site.

Taxa	Pollution tolerance value[1]	Functional feeding group[2]	Number of individuals and year observed[3]		
			1989–1991	2004	2008
PLATYHELMINTHES					
Turbellaria	4	PR	17	-	-
Tricladida					
Planariidae					
Cura sp.	4.97	n/a	-	2	-
Girardia (*Dugesia*) *tigrina*	n/a	n/a	-	-	2
Dugesia sp.	7.23	n/a	-	5	-
Phagocata sp.	n/a	n/a	-	8	1
NEMATODA	6.02	n/a	-	7	-
MOLLUSCA					
Bivalvia					
Veneroida					
Sphaeriidae	8	FC	-	-	-
Pisidium sp.	5	FC	-	2	22
Sphaerium sp.	5	FC	-	71	-
Gastropoda					
Mesogastropoda					
Hydrobiidae	8	SC	-	-	-
Amnicola limosa	8	SC	-	-	339
Amnicola sp.	8	SC	-	22	-
Basommatophora					
Physidae					
Physella sp.	8	CG	-	12	23
Planorbidae	6	SC	-	-	-
Gyraulus sp.	8	SC	-	1	-
Menetus dilatatus	8.23	SC	-	-	2

Taxa	Pollution tolerance value[1]	Functional feeding group[2]	Number of individuals and year observed[3]		
			1989–1991	2004	2008
ANNELIDA					
Oligochaeta	10	CG	41	-	-
Haplotaxida					
Naididae	8	CG	4	-	-
Tubificida	10	CG	29	-	-
Bothrioneurum vejdovskyanum	9	n/a	96	-	-
Tubificidae w.h.c.	10	CG	-	46	118
Tubificidae w.o.h.c.	10	CG	-	3675	3320
Limnodrilus hoffmeisteri	10	CG	-	-	942
Limnodrilus sp.	10	CG	-	713	-
Lumbriculida					
Lumbriculidae	8	CG	-	14	14
Polychaeta	n/a	n/a	-	1	-
Terebellida					
Ampharetidae					
Hobsonia sp.	n/a	n/a	-	7	-
Laeonereis culveri	n/a	n/a	-	-	3
Spionidae					
Hobsonia florida	n/a	n/a	-	-	6
Hirudinea	8	PR	-	-	3
Erpobdellidae	8	PR	-	3	-
Erpobdella sp.	8.33	PR	-	17	-
Mooreobdella melanostoma	7.8	PR	1	-	-
Mooreobdella sp.	7.8	PR	4	-	-
Rhynchobdellida					
Glossiphoniidae	8	PR	-	-	-
Helobdella stagnalis	6.7	PR	4	-	-
Helobdella sp.	6	PA	-	1	-
Placobdella sp.	6	PR	-	1	-

Taxa	Pollution tolerance value[1]	Functional feeding group[2]	Number of individuals and year observed[3] 1989–1991	2004	2008
ARTHROPODA					
Arachnoidea					
Acariformes	5.53	n/a	-	1	-
Crustacea					
Ostracoda	n/a	n/a	-	1	19
Isopoda					
Anthuridae					
Cyathura sp.	n/a	n/a	-	17	-
Cyathura polita	n/a	n/a	-	-	8
Asellidae	8	SH	-	-	-
Caecidotea r. racovitzai	6	CG	120	-	-
Caecidotea sp.	6	CG	2	21	-
Amphipoda					
Corophiidae					
Corophium sp.	n/a	n/a	-	1	-
Gammaridae	4	n/a	-	-	-
Gammarus tigrinus	3	SH	-	-	1001
Gammarus fasciatus	6	CG	155	-	-
Gammarus sp.	3	SH	-	9637	-
Decapoda					
Panopeidae					
Rhithropanopeus sp.	n/a	n/a	-	1	-

Taxa	Pollution tolerance value[1]	Functional feeding group[2]	Number of individuals and year observed[3]		
			1989–1991	2004	2008
ARTHROPODA (continued)					
Insecta					
Ephemeroptera					
Baetidae					
Baetis flavistriga	4.5	CG	1	-	-
Hemiptera					
Veliidae	n/a	PR	-	-	-
Rhagovelia obesa	6	PR	1	-	-
Rhagovelia sp.	n/a	PR	-	1	-
Trichoptera					
Hydropsychidae	4	FC	-	-	-
Ceratopsyche sp.	1	FC	-	1	-
Cheumatopsyche sp.	6	FC	4	15	-
Hydropsyche betteni	4	FC	11	-	-
Hydropsyche sp.	5	FC	-	4	-
Leptoceridae	4	CG	-	-	-
Mystacides sepulchralis	2	CG	-	-	3
Polycentropodidae	6	FC	-	-	-
Phylocentropus sp.	5	FC	-	11	-
Uenoidae					
Neophylax sp.	3	SC	-	1	-
Coleoptera					
Elmidae	5	CG	-	-	-
Dubiraphia quadrinotata	3.2	OM	1	-	-
Dubiraphia sp.	5	SC	-	10	7
Macronychus sp.	2	SH	-	1	-
Optioservus sp.	4	SC	-	16	-
Stenelmis sp.	7	SC	-	65	2
Collembola					
Entomobryidae	n/a	CG	1	-	-
Diptera	7	n/a	2	-	-
Chironomidae	n/a	n/a	-	7	-
Ablabesmyia mallochi	6	PR	-	-	3
Cardiocladius sp.	5	PR	-	2	-
Chironomus sp.	10	CG	-	442	4428

Taxa	Pollution tolerance value[1]	Functional feeding group[2]	Number of individuals and year observed[3]		
			1989–1991	2004	2008
ARTHROPODA (continued)					
Chironomidae (continued)	n/a	n/a	-	7	-
Cladotanytarsus sp.	7	FC	-	-	7
Clinotanypus sp.	6	PR	-	-	15
Conchapelopia sp.	6	PR	-	1	-
Cricotopus sp.	7	CG	7	40	88
Cricotopus bicinctus	10	CG	-	-	29
Cricotopus sylvestris	n/a	n/a	-	-	13
Diamesa sp.	4	CG	-	2	-
Dicrotendipes neomodestus	6.4	FC	9	-	-
Dicrotendipes sp.	6	CG	-	6	-
Endochironomus sp.	6	SH	-	1	-
Eukiefferiella sp.	8	CG	-	4	-
Microtendipes sp.	6	CG	-	2	-
Orthocladiinae	5	CG	74	-	-
Parasmittia sp.	n/a	n/a	-	1	-
Paratanytarsus sp.	6	CG	2	-	-
Polypedilum halterale sp.	4	SH	-	-	18
Polypedilum sp.	4	SH	1	36	-
Procladius sp.	8	PR	-	2	9
Prodiamesa sp.	3	CG	-	2	-
Rheotanytarsus sp.	6	FC	-	3	-
Tanytarsus sp.	7	FC	-	6	175
Thienmannimyia group	n/a	n/a	6	-	-
Tribelos sp.	5	CG	-	6	-
Dolichopodidae	5	PR	-	1	-
Empididae					
Hemerodromia sp.	6	PR	2	-	-
Tipulidae	3	SH	-	7	-
Antocha sp.	5	CG	-	81	-

[1] Tolerance values (range: 0=pollution intolerant to 10=pollution tolerant) and functional feeding groups from CH2MHill (2004, 2009) and Barbour et al. (1999). n/a = not available.

[2] Functional feeding groups (if known): CG=collector/gatherer, FC=filter/collector, OM=omnivore, PA=parasite, PR=predator, SC=scraper, SH=shredder, PI=piercer. n/a = not available.

[3] Data sources: 1989–1991: Tashiro et al. 1991, 2004 and 2008: CH2MHill 2004, 2009.

Appendix C. Water chemistry at Saugus Iron Works National Historic Site taken at USGS stream gage #01102345 and the Turning Basin. Sample size (N), mean, minimum (Min), maximum (Max), and standard deviation (SD) for samples are presented. If available, benchmark values from regulatory standards or from the literature are provided.

Variable	Site	Agency[1]	Year(s)	S	Min	Max	Mean	SD	Benchmarks
Water temperature (C)	River	USGS	1994–2004	54	0.1	22.1	11.5	7.7	<29.4°C or max daily mean <26.7°C (Class SB water)[2]
	Turning Basin	NPS-NETN	2006–2009	6	12.0	26.7	17.1	5.1	
Dissolved Oxygen (mg l^{-1})	River	USGS	1994–2004	50	6.6	14.0	9.7	2.2	>5 mg l^{-1} (Class SB water)[2]
	Turning Basin	NPS-NETN	2006–2009	6	0.7	10.4	7.7	3.6	
Dissolved Oxygen (%)	River	USGS	1994–2004	50	72.0	100.0	87.6	5.8	>75% (Class SB water)[2]
	Turning Basin	NPS-NETN	2006–2009	6	9.9	102.7	77.0	33.7	
Pathogens (Most Probable Number, MPN)	River	EPA		Consistently listed as exceeding water quality standards					Shellfishing[2]: mean MPN <88 organisms per 100ml, no more than 10% of samples exceeding 260 per 100ml Bathing[2]: MPN <104 colonies per 100ml, mean of 5 samples not to exceed 35 colonies per 100ml
Total Phosphorus (µg l^{-1})	River	USGS	1994–2004	48	<4	84	44.5	20.9	As naturally occurs[2] <31.25µg l^{-1} [2], <50µg l^{-1} [3]
	River	NPS-NETN	2006–2009	7	24	158	52.4	47.1	
	Turning Basin	NPS-NETN	2006–2009	4	39	58	48.0	8.3	
Total Nitrogen (mgl^{-1})	River	USGS	1994–2004	47	0.72	1.8	1.10	0.20	As naturally occurs[2] <0.71 mgl^{-1} [2]
	River	NPS-NETN	2006–2009	7	0.866	1.41	1.03	0.19	
	Turning Basin	NPS-NETN	2006–2009	4	0.906	1.09	0.98	0.08	
Chl-a, phytoplankton (mg l^{-1})	River	USGS	2001	5	1.1	1.7	1.3	0.3	<3.75 spectrophotometric[2]
Lab pH	River	USGS	1994–2004	44	6.7	7.8	7.3	0.3	Acceptable range[2]: 6.5–8.5
Field pH	Turning Basin	NPS-NETN	2006–2009	6	7.0	7.9	7.4	0.3	
ANC (µeq l^{-1})	River	USGS	1994–2004	5	400	1320	904	406	>100 µeq l^{-1} (5 mg l^{-1})[2]

Variable	Site	Agency[1]	Year(s)	S	Min	Max	Mean	SD	Benchmarks
Alkalinity (mg l^{-1})	River	USGS	1994–2004	29	19	70	46	14	
ANC (µeq l^{-1})	River	NPS-NETN	2006–2009	7	880	1600	1181	242	
ANC (µeq l^{-1})	Turning Basin	NPS-NETN	2006–2009	4	1098	1590	1267	232	
Sodium (mg $^{-1}$)	River	USGS	1994–2004	44	19.5	107.0	55.3	18.3	n/a
Chloride (mg l^{-1})	River	USGS	1994–2004	44	32.4	197.0	102.6	35.3	230 (chronic), 860 (acute)[2]
Lab Conductivity, µs cm^{-1}	River	USGS	1994–2004	48	174	797	472	134	n/a
Field Conductivity, µs cm^{-1}	Turning Basin	NPS-NETN	2006–2009	5	639	1174	786*	231.0	n/a
Apparent Color	River	NPS-NETN	2006–2009	7	30	139	84	43	Free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any assigned use.[2]
	Turning Basin	NPS-NETN	2006–2009	4	85	195	125	49	
Diss. Organic Carbon (mg l^{-1})	River	USGS	1994–2004	37	4.3	11.1	7.0	1.9	n/a
Calcium (mg l^{-1})	River	USGS	1994–2004	44	7.4	28.8	19.6	5.6	n/a
Magnesium (mg l^{-1})	River	USGS	1994–2004	44	2.3	11.3	7.1	2.4	n/a
Potassium (mg l^{-1})	River	USGS	1994–2004	44	1.4	4.1	2.8	0.6	n/a
Sulfate (mg l^{-1})	River	USGS	1994–2004	46	6.3	22.9	13.3	3.7	n/a
Nitrate-nitrogen (mg l^{-1})	River	USGS	1994–2004	20	0.3	0.9	0.6	0.2	n/a
Ammonium (mg l^{-1})	River	USGS	1994–2004	44	<0.02	0.16	0.05	0.04	n/a
Silica (as SiO_2) (mg l^{-1})	River	USGS	1994–2004	44	3.34	13.90	9.16	2.91	n/a
Iron (µg l^{-1})	River	USGS	1994–2004	44	64	562	256	132	n/a
Dissolved Solids (mg l^{-1})	River	USGS	1994–2004	44	93	428	268	76	n/a
Turbidity (NTU)	River	USGS	1994–2004	4	4.4	7.4	5.5	1.4	n/a

[1] USGS NAWQA 2010 and NPS NETN data (National Park Service, Brian Mitchell, Inventory and Monitoring Program Manager, Northeast Temperate Network, e-mail communication, 26 March 2010).
[2] Commonwealth of Massachusetts (2007) surface water quality standards.
[3] MADEM 2002.
[4] US Environmental Protection Agency 1988
* A conductivity value of 26,801 µS cm^{-1} was excluded from statistical analyses, although NPS staff indicate this could be a real value (National Park Service, William Gawley, Biologist-Air/Water/Data Manager, e-mail communication, 26 March 2010).

Appendix D. Plants (invasive species indicated in bold type [MIPAG 2005]) observed at Saugus Iron Works National Historic Site.

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Acer negundo	boxelder	X	X			X
Acer platanoides	**Norway maple**	**X**	**X**	**X**	**X**	
Acer rubrum	red maple	X	X			
Acer saccharinum	silver maple	X	X			
Achillea millefolium	common yarrow	X	X	X		
Achillea ptarmica [6]	sneezeweed	X				
Acorus americanus	sweet flag					X
Aesculus hippocastanum	horse chestnut	X	X	X	X	
Agrimonia eupatoria [6]	churchsteeples	X				
Agrimonia gryposepala	tall hairy agrimony	X	X			
Agrostis capillaris	colonial bentgrass	X	X			
Agrostis stolonifera	**creeping bentgrass**				**X**	
Ailanthus altissima	**tree of heaven**	**X**	**X**	**X**		
Ajuga reptans [6]	common bugle	X				
Alchemilla vulgaris [6]	hairy lady's mantle	X				
Alisma plantago-aquatica	European water plantain	X	X			X
Alliaria petiolata	**garlic mustard**	**X**		**X**	**X**	
Allium sativum [6]	cultivated garlic	X				
Allium schoenoprasum [6]	wild chives	X				
Alnus incana spp. *rugosa*	speckled alder	X	X			X
Amaranthus hybridus	slim amaranth	X	X			
Ambrosia artemisiifolia	common ragweed			X		X
Anaphalis margaritacea	Western pearly everlasting	X	X			
Angelica archangelica [6]	Norwegian angelica	X				
Anthemis nobilis [6]	Roman chamomile	X				
Anthemis tinctoria [6]	golden chamomile	X				
Anthriscus cerefolium [6]	garden chervil	X				
Apios americana	groundnut	X			X	X
Aquilegia canadensis [6]	red columbine	X				
Aquilegia vulgaris [6]	European columbine	X				
Arctium minus	lesser burrdock	X	X			
Arisaema triphyllum	Jack in the pulpit	X	X		X	

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Artemisia abrotanum [6]	Southernwood	X				
Artemisia absinthium [6]	absinthium	X				
Artemisia dracunculus [6]	tarragon	X				
Artemisia pontica [6]	Roman wormwood	X				
Artemisia vulgaris	common wormwood	X	X	X		
Asclepias incarnata	swamp milkweed	X	X			
Asclepias syriaca	common milkweed	X	X			
Athyrium filix-femina (Athyrium) *angustum*	Subarctic lady fern	X	X			
Athyrium filix-femina	common ladyfern	X			X	
Berberis thunbergii	**Japanese barberry**	**X**	**X**	**X**		
Betula spp.	birch spp.		X			
Bidens cernua	nodding beggartick					X
Bidens frondosa	Devil's beggartick					X
Bidens tripartita	threelobe beggarticks	X	X		X	
Boehmeria cylindrica	smallspike false nettle	X	X			
Borago officinalis [6]	common borage	X				
Brassica nigra	black mustard					X
Calamagrostis canadensis	bluejoint	X			X	
Calendula officinalis [6]	pot marigold	X				
Callitriche palustris	vernal water-starwort	X	X		X	X
Calystegia sepium	hedge false bindweed	X	X		X	X
Campanula rapunculoides	rampion bellflower	X	X			
Cardamine pensylvanica	Pennsylvania bittercress	X	X			
Carex lupulina	hop sedge	X	X			
Carex spp.	rush spp.					X
Carex stricta	upright sedge	X			X	
Carex vulpinoidea	fox sedge	X	X			
Carya alba	mockernut hickory	X			X	
Carya ovata	shagbark hickory	X	X			
Celastrus orbiculatus	**oriental bittersweet**	**X**	**X**	**X**	**X**	
Cephalanthus occidentalis	common buttonbush	X	X			
Chelidonium majus	celandine	X	X	X	X	
Chelone glabra	white turtlehead	X	X			

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Chenopodium album	lambsquarters	X	X	X		
Cichorium intybus	chicory	X	X	X		
Cinna arundinacea	sweet woodreed	X	X			
Circaea lutetiana ssp. *canadensis*	broadleaf enchanter's nightshade	X	X		X	
Cirsium vulgare	bull thistle			X		
Clausena (Clausen) spp.	clausena		X			
Clethra alnifolia	Coastal sweetpepperbush	X	X			
Commelina communis	Asiatic dayflower					X
Convallaria majalis [6]	European lily of the valley	X				
Cornus amomum	silky dogwood	X				X
Cornus sericea	redosier dogwood			X		X
Cyperus spp.	flatsedge spp.		X			
Daucus carota	Queen Anne's lace	X	X	X		
Dianthus armeria	deptford pink	X	X			
Dianthus caryophyllus [6]	carnation	X				
Dipsacus fullonum	Fuller's teasel	X	X			
Dipsacus spp.	teasel spp.			X		
Echinochloa muricata	rough barnyardgrass					X
Echinocystis lobata	wild cucumber	X	X		X	
Elatine americana [8]	American waterwort	X	X[9]			
Eleocharis acicularis	needle spikerush					X
Eleocharis obtusa	blunt spikerush					X
Eleocharis spp.	eleocharis spp.					X
Elyhordeum montanense	mountain barley	X	X			
Epilobium coloratum	purpleleaf willowherb					X
Equisetum arvense	field horsetail	X	X			
Equisetum hyemale [6]	scouringrush horsetail	X				
Erigeron annuus	Eastern daisy fleabane	X	X		X	
Euonymus alata	**burningbush**			**X**		
Eupatorium maculatum	spotted joe pye weed					X
Eupatorium perfoliatum	common boneset	X	X		X	X
Eupatorium purpureum	sweetscented joe pye weed	X	X		X	
Euphorbia esula	leafy spurge	X	X			

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Fagus grandifolia	American beech	X	X		X	
Fragaria vesca	woodland strawberry	X	X			
Fragaria virginiana [6]	Virginia strawberry	X				
Fraxinus pennsylvanica	green ash	X			X	
Fraxinus spp.	ash spp.		X			
Galium (*Asperula*) *odorata* [6]	sweetscented bedstraw	X				
Galium palustre	common marsh bedstraw	X	X			
Galium tinctorium	stiff marsh bedstraw	X	X			
Galium verum [6]	yellow spring bedstraw	X				
Geum canadense	white avens	X	X		X	X
Geum macrophyllum	largeleaf avens					X
Glechoma hederacea	ground ivy			X		
Glyceria grandis	American mannagrass					X
Glyceria maxima	reed mannagrass	X	X			
Hamamelis virginiana	American witchhazel	X	X			
Hedeoma pulegioides [6]	American false pennyroyal	X				
Hemerocallis fulva	orange daylily			X		
Hesperis matronalis	**dames rocket**	**X**	**X**			
Hibiscus moscheutos	crimsoneyed rosemallow				X	X
Hieracium pilosella	mouseear hawkweed	X	X			
Holcus lanatus	common velvetgrass	X	X			
Humulus japonicus	**Japanese hop**					**X**
Hypericum boreale (*Hypericum mutilum* ssp. *boreale*)	northern St. Johnswort	X	X			
Hypericum perforatum	common St. Johnswort			X		
Hypericum punctatum	spotted St. Johnswort	X	X			
Hyssopus officinalis [6]	hyssop	X				
Impatiens capensis	jewelweed	X	X		X	X
Inula helenium [6]	elecampane inula	X				
Ipomoea cairica	mile a minute vine	X			X	
Iris versicolor	harlequin Blueflag					X
Isatis tinctoria [6]	Dyer’s woad	X				
Juglans nigra	black walnut	X	X			
Juncus acuminatus	tapertip rush	X	X			

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Juncus effusus	common rush	X	X		X	X
Juncus spp.	juncus spp.					X
Juncus tenuis	poverty rush	X	X			
Lamium album	white deadnettle	X	X			
Lamium galeobdolon [6]	yellow archangel	X				
Lavandula vera [6]	English lavender	X				
Leersia oryzoides	rice cut grass					X
Leonurus cardiaca	common motherwort	X	X			
Lepidium spp.	pepperweed spp.		X			
Lepidium virginicum	Virginia peppergrass					X
Leucanthemum vulgare (Chrysanthemum) *leucanthemum*)	oxeye daisy	X	X	X		
Levisticum officinale [6]	garden lovage	X				
Ligustrum spp.	privet			X		
Lilium candidum [6]	Madonna lily	X				
Linaria vulgaris	butter and eggs	X	X	X		
Linum perenne [6]	blue flax	X				
Lolium perenne	perennial ryegrass	X	X			
Lotus corniculatus	bird's-foot trefoil	X	X			
Lycopus americanus	American water horehound					X
Lycopus europaeus	gypsywort					X
Lycopus virginicus	Virginia water horehound	X	X			
Lythrum salicaria	**purple loosestrife**	**X**	**X**	**X**	**X**	**X**
Malus pumila	Paradise apple	X	X			
Malus spp.	crab apple spp.			X		
Marrubium vulgare [6]	horehound	X				
Matricaria spp.	mayweed		X			
Medicago lupulina	black medick	X	X			
Melissa officinalis [6]	common balm	X				
Mentha arvensis	wild mint	X	X			
Mikania scandens	climbing hempvine	X	X		X	X
Mimulus ringens	Allegheny monkeyflower					X
Mollugo verticillata	green carpetweed	X	X			
Monarda didyma [6]	scarlet beebalm	X				

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Monarda fistulosa [6]	wild bergamot	X				
Morus alba	white mulberry	X	X			
Myosotis scorpioides	true forget-me-not	X	X			
Myrrhis odorata [6]	anise	X				
Nasturtium officinale	**watercress**					**X**
Oenothera biennis	common evening primrose	X	X			X
Onoclea sensibilis	sensitive fern	X	X			
Origanum vulgare [6]	oregano	X				
Osmunda cinnamomea	cinnamon fern	X	X		X	
Oxalis spp.	woodsorrel spp.		X		X	
Oxalis stricta	common yellow oxalis					X
Panicum flexile	wiry panicgrass					X
Parthenocissus quinquefolia	Virginia creeper	X	X		X	
Paspalum spp.	crowngrass spp.		X			
Peltandra virginica	green arrow arum	X	X		X	X
Petroselinum hortense [6]	parsley	X				
Phalaris arundinacea	**reed canary grass**	**X**	**X**		**X**	**X**
Phragmites australis	**common reed**	**X**	**X**	**X**	**X**	**X**
Phytolacca americana	American pokeweed	X	X			X
Plantago lanceolata	narrowleaf plantain	X	X	X		X
Plantago major	common plantain	X	X			
Pluchea odorata var. *succulenta*	sweetscent					X
Poa pratensis	Kentucky bluegrass	X	X		X	
Poaceae spp.	unknown grass (Poaceae)					X
Polygonum amphibium var. *emersum*	longroot smartweed	X	X			
Polygonum cuspidatum	**Japanese knotweed**	**X**	**X**			
Polygonum hydropiper	marshpepper knotweed					X
Polygonum hydropiperoides	swamp smartweed	X			X	X
Polygonum pensylvanicum	Pennsylvania smartweed					X
Polygonum persicaria	spotted ladysthumb	X				X
Polygonum punctatum	dotted smartweed	X			X	
Polygonum sagittatum	arrowleaf tearthumb	X	X			
Polygonum spp.	polygonum spp.				X	X

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Pontederia cordata	pickerelweed	X	X		X	X
Potamogeton crispus	**curly pondweed**	**X**	**X**	**X**	**X**	**X**
Potamogeton pectinatus	sago pondweed	X	X			
Potentilla argentea	silver cinquefoil	X	X			
Potentilla norvegica	Norwegian cinquefoil					X
Potentilla recta	sulphur cinquefoil	X	X			
Potentilla simplex	common cinquefoil					X
Prunella vulgaris	common selfheal	X	X			
Prunus americana	American plum	X	X			
Prunus serotina	black Cherry	X	X		X	
Prunus virginiana	chokecherry	X			X	
Pulmonaria officinalis [6]	common lungwort	X				
Quercus alba	white oak	X	X			
Quercus coccinea	scarlet oak	X	X			
Quercus rubra	Northern red oak	X			X	
Ranunculus sceleratus	cursed buttercup					X
Rhamnus cathartica	**common buckthorn**			**X**		
Rhamnus frangula	**glossy buckthorn**	**X**	**X**	**X**		
Rhus typhina	staghorn sumac	X	X			
Robinia pseudoacacia	**black locust**	**X**		**X**	**X**	
Rorippa palustris var. *hispida*	hispid yellowcress					X
Rorippa spp. [7]	watercress spp.					X
Rosa multiflora	**multiflora rose**	**X**	**X**	**X**	**X**	**X**
Rosa palustris	swamp rose	X	X		X	X
Rosa X *alba* [6]	white rose of New York	X				
Rosa X *damascene* [6]	damask rose	X				
Rosmarinus officinalis [6]	Rosemary	X				
Rubia tinctorum [6]	Dyer's madder	X				
Rubus pensilvanicus	Pennsylvania blackberry	X	X			
Rumex acetosella	common sheep sorrel	X	X			
Rumex crispus	curly dock	X	X		X	
Rumex obtusifolius	bitter dock	X	X			
Rumex spp.	water hemp spp.					X

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Ruta graveolens [6]	common rue	X				
Sagittaria latifolia	broadleaf arrowhead	X	X			X
Sagittaria rigida	sessilefruit arrowhead					X
Salix nigra	black willow	X	X			
Salvia officinalis [6]	kitchen sage	X				
Salvia sclarea [6]	Europe sage	X				
Sanguisorba minor [6]	small burnet	X				
Santolina chamaecyparissus [6]	lavender cotton	X				
Saponaria officinalis [6]	bouncingbet	X				
Satureja montana [6]	winter savory	X				
Schoenoplectus acutus	hardstem bulrush	X	X		X	X
Schoenoplectus pungens	common threesquare					X
Schoenoplectus/Scirpus spp.	scirpus spp.				X	
Sempervivum tectorum [6]	common houseleek	X				
Setaria spp.	bristlegrass spp.					
Sicyos angulatus	oneseed bur cucumber				X	
Silene vulgaris	maidenstears	X	X			
Sisymbrium officinale	hedgemustard	X				
Sium suave	hemlock waterparsnip	X	X		X	X
Smilacina spp.	lily of the valley spp.		X			
Smilax rotundifolia	roundleaf greenbrier	X	X		X	
Solanum americanum	American black nightshade	X			X	
Solanum dulcamara	climbing nightshade	X	X	X	X	X
Solidago caesia	wreath goldenrod	X	X			
Solidago canadensis	Canada goldenrod	X	X			
Solidago rugosa	wrinkleleaf goldenrod	X	X		X	
Sorbus aucuparia	European mountain ash	X	X		X	
Sparganium americanum	American bur-reed	X			X	
Sparganium eurycarpum	broadfruit bur-reed	X	X			
Spartina pectinata	prairie cordgrass	X	X			X
Stachys byzantine [6]	woolly hedgenettle	X				
Stachys officinalis [6]	common hedgenettle	X				
Symphyotrichum novae-angliae	New England aster	X			X	

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Symphyotrichum novi-belgii	New York aster					X
Symphyotrichum cordifolium (Aster *cordifolius*)	common blue wood aster	X	X			
Symphyotrichum (*Aster*) *lanceolatus* var. *lanceolatus*	white panicle aster	X	X			X
Symphyotrichum (*Aster*) *patens*	late purple aster	X	X			
Symphyotrichum (*Aster*) *pilosum* var. *pilosum*	hairy white oldfield aster	X	X			
Symphyotrichum (*Aster*) spp.	aster spp.					X
Symphytum officinale [6]	common comfrey	X				
Symplocarpus foetidus	skunk cabbage	X	X		X	
Syringa vulgaris	common lilac	X	X	X		
Tanacetum (*Chrysanthemum*) *balsamita* [6]	costmary	X				
Tanacetum (*Chrysanthemum*) *parthenium* [6]	feverfew	X				
Tanacetum vulgare [6]	common tansy	X		X		
Taraxacum officinale	common dandelion	X	X			
Thalictrum pubescens	king of the meadow	X	X		X	
Thymus serpyllum [6]	creeping thyme	X				
Thymus vulgaris [6]	garden thyme	X				
Toxicodendron radicans	Eastern poison ivy	X	X		X	
Trifolium arvense	rabbitfoot clover	X	X			
Trifolium hybridum	alsike clover	X	X			X
Trifolium pratense	red clover	X	X	X		
Trifolium repens	white clover	X	X	X		X
Typha angustifolia	narrowleaf cattail	X	X		X	X
Ulmus rubra	slippery elm	X	X		X	
Unknown forb seedling	unknown forb seedling					X
Unknown grass	unknown grass					X
Valeriana officinalis [6]	garden valerian	X				
Verbascum thapsus	common mullien	X	X	X		
Verbena hastata	swamp verbena					X
Veronica serpyllifolia	thymeleaf speedwell					X
Viburnum dentatum	Southern arrowwood	X				
Viburnum lentago	nannyberry	X	X			
Viburnum recognitum	Southern arrowwood	X	X			
Vicia cracca	bird vetch	X	X			

Scientific Name	Common Name	Data Source or Year Observed				
		NPS [1]	1997 [2]	2003 [3]	2004 [4]	2009 [5]
Vicia spp. [7]	vetch spp.			X		
Vinca minor [6]	common periwinkle	X		X		
Viola odorata [6]	sweet violet	X				
Viola tricolor [6]	Johnny jumpup	X				
Vitis labrusca	fox grape	X	X		X	
Vitis spp. [7]	grape spp.			X		
Zannichellia palustris	horned pondweed					X
Zizania aquatica	annual wildrice	X	X			
	Total number of species	**232**	**155**	**51**	**77**	**95**
	Total number of invasive or potentially invasive species	**14**	**12**	**15**	**9**	**7**

[1] Data source: NPSpecies Database (NPS 2009b).
[2] Data source: Clemants 1997.
[3] Data source: Agius 2003.
[4] Data sources: Largay and Sneddon 2008, James-Pirri et al. 2010a.
[5] Data sources: New England Environmental, Inc. 2009, James-Pirri et al. 2010b.
[6] Species present within Iron Works House seventeenth century herb garden.
[7] Indicates a cryptogenic species (may be either native or exotic).
[8] *Elatine americana* is listed as an endangered species by the state of Massachusetts, it was reported on a list compiled by SAIR staff (Sandy Wignot in 1998) but could not be re-located by Clemants during his surveys (Clemants 1997).
Invasive species indicated in bold type.

Appendix E. Current and potential emerging threats to the forest at Saugus Iron Works National Historic Site from non-indigenous insect pests and diseases.

Scientific Name	Common Name	Presence in Essex Cty (State present in, if not in Essex Cty)[1]	Forest susceptibility in Essex Cty[1]
Insects that are Threats			
Acantholyda erythrocephala	pine false webworm	Yes	Extreme
Adelges abietis	Eastern spruce gall adelgid	Yes	None
Adelges tsugae	hemlock woolly adelgid	Yes	Extreme
Carulaspis juniperi	juniper scale	Yes	None
Cronartium ribicola	white pine blister rust	Yes	Extreme
Cryphonectria parasitica	chestnut blight	Yes	None
Cryptoccocus fagisuga Lind.	beech bark disease	Yes	None
Cryptodiaporthe populea	cryptodiaporthe canker	Yes	None
Cryptorhynchus lapathi	poplar and willow borer	Yes	Medium
Cyrtepistomus castaneus	Asiatic oak weevil	Yes	Extreme
Diprion similis	introduced pine sawfly	Yes	High
Discula destructiva	dogwood anthracnose	Yes	None
Epinotia nanana	European spruce needleminer	Yes	None
Eulecanium cerasorum	calico scale	Yes	Extreme
Fenusa pumila	birch leafminer	Yes	Extreme
Fenusa ulmi	elm leafminer	Yes	Medium
Fiorinia externa	elongate hemlock scale	Yes	High
Lepidosaphes ulmi	oystershell scale	Yes	Extreme
Leucoma salicis	satin moth-added	Yes	High
Lymantria dispar	gypsy moth	Yes	High
Neodiprion sertifer	European pine sawfly	Yes	Extreme
Operophtera brumata	winter moth	Yes	High
Ophiostoma novo-ulmi	Dutch elm disease	Yes	Low
Otiorhynchus sulcatus	black vine weevil	Yes	Extreme
Phytophthora cinnamomi	phytophthora root rot	Yes	Extreme
Popillia japonica	Japanese beetle	Yes	Extreme
Pristiphora erichsonii	larch sawfly	Yes	None
Pristiphora geniculata	mountain ash sawfly	Yes	None
Rhyacionia buoliana	European pine shoot moth	Yes	None
Scolytus multistriatus	smaller European elm bark beetle	Yes	Low
Taeniothrips inconsequens	pear thrips	Yes	Medium

Scientific Name	Common Name	Presence in Essex Cty (State present in, if not in Essex Cty)[1]	Forest susceptibility in Essex Cty[1]
Tomicus piniperda	pine shoot beetle	Yes	High
Trichiocampus viminalis	poplar sawfly-added	Yes	High
Venturia saliciperda	willow scab	Yes	High
Xanthogaleruca (Pyrrhalta) luteola	elm leafbeetle	Yes	Medium
Potential emerging insect threats			
Agrilus planipennis	emerald ash borer	No (NY, PA)	Medium
Anoplophora glabripennis	Asian longhorned beetle	No (Worcester Cty, MA)	Extreme
Callidiellum rufipenne	Japanese cedar longhorn beetle	No (CT)	Medium
Caulocampus acericaulis	maple petiole borer	No (CT,VT)	Medium
Ceratocystis fagacearum	oak wilt	No (PA)	Medium
Enarmonia formosana	cherry bark tortrix	No (OR)	Medium
Euproctis chrysorrhoea	browntail moth	No (Barnstable Cty, MA)	High
Hylurgus ligniperda	red-haired pine bark beetle	No (NY)	High
Nuculaspis tsugae	circular hemlock scale	No (CT, RI)	Extreme
Orchestes alni	elm flea weevil	No (MI)	Low
Orthotomicus erosus	Mediterranean pine engraver beetle	No (CA)	High
Phytophthora ramorum	sudden oak death	No (CA)	Medium
Plagiodera versicolora	imported willow leaf beetle	No (ME, NY)	High
Profenusa thomsoni	ambermarked birch leafminer	No (CT)	Extreme
Scolytus schevyrewi	banded elm bark beetle	No (PA)	Medium
Sirex noctilio	sirex woodwasp	No (NY)	High
Viscum album	European mistletoe	No (CA)	High

[1] Insect pest distribution and forest susceptibility based on host tree species volume as of October 2008 (last date of website update) (USDA Forest Service 2010).

Appendix F. Birds observed at Saugus Iron Works National Historic Site. Partners in Flight Priority Species, breeding status, category, and NETN forest guild designations.

Scientific Name[1, 2]	Common Name	Category	Forest Guild[3]	2002–2003 NETN	2008 NETN	2009 NETN	2009 Park
Actitis macularia	spotted sandpiper	Shorebird	n/a				X
Agelaius phoeniceus	**red-winged blackbird**	**Non-waterbird**	**O, S**	**X**	**X**	**X**	**X**
Anas platyrhynchos	**mallard**	**Waterfowl**	**n/a**	**X**	**X**	**X**	**X**
Anas rubripes	American black duck	Waterfowl	n/a				X
Ardea alba (V)	great egret	Wader	n/a			X	X
Ardea herodias (V)	great blue heron	Wader	n/a	X		X	X
Ardea herodias	green heron	Wader	n/a				X
Baeolophus bicolor	**tufted titmouse**	**Non-waterbird**	**LC, R, SB**	**X**	**X**	**X**	
Bombycilla cedrorum	cedar waxwing	Non-waterbird	C, R, SB				X
Botaurus lentiginosus (V)	American bittern	Wader	n/a				X
Branta canadensis	**Canada goose**	**Waterfowl**	**n/a**	**X**		**X**	**X**
Buteo jamaicensis	red-tailed hawk	Non-waterbird	n/a				X
Calidris minutilla	least sandpiper	Shorebird	n/a				X
Calidris pusilla	semipalmated sandpiper	Shorebird	n/a				X
Cardinalis cardinalis	**Northern cardinal**	**Non-waterbird**	**O, R, S**	**X**	**X**	**X**	**X**
Carduelis tristis	**American goldfinch**	**Non-waterbird**	**O, R, S, SB**	**X**		**X**	**X**
Carpodacus mexicanus	**house finch**	**Non-waterbird**	**E, R**	**X**			
Ceryle alcyon	belted kingfisher	Non-waterbird	n/a	X	X		X
***Chaetura pelagica* (IIA)**	**chimney swift**	**Non-waterbird**	**SB**	**X**		**X**	
Charadrius vociferus	killdeer	Shorebird	n/a			X	X
Cistothorus palustris	marsh wren	Non-waterbird	n/a				X
Colaptes auratus	**Northern flicker/yellow shafted flicker**	**Non-waterbird**	**GG**	**X**	**X**	**X**	**X**
***Columba livia* ***	**rock dove**	**Non-waterbird**	**E, O, R**	**X**	**X**	**X**	**X**
Corvus brachyrhynchos	**American crow**	**Non-waterbird**	**C, NP, O, R, SB**	**X**	**X**	**X**	**X**
Corvus ossifragus	fish crow	Non-waterbird	C, NP, O, R, SB				X
Cyanocitta cristata	**blue jay**	Non-waterbird	**C, NP, O, R**	**X**	**X**	**X**	**X**
Dendroica petechia	**yellow warbler**	**Non-waterbird**	**LC, S, SB**	**X**	**X**		**X**
Dumetella carolinensis	**gray catbird**	**Non-waterbird**	**O, S**	**X**	**X**	**X**	**X**
Egretta thula (V)	snowy egret	Wader	n/a				X
Geothlypis trichas	**common yellowthroat**	**Non-waterbird**	**LC, S**	**X**	**X**	**X**	
Hirundo rustica	barn swallow	Non-waterbird	SB	X	X	X	X
***Icterus galbula* (IA)**	**Baltimore oriole**	**Non-waterbird**	**C, O, SB**	**X**	**X**	**X**	**X**
Larus argentatus	herring gull	Gull	n/a	X	X	X	

Scientific Name[1, 2]	Common Name	Category	Forest Guild[3]	2002–2003 NETN	2008 NETN	2009 NETN	2009 Park
Larus delawarensis	ringed-billed gull	Gull	n/a				X
Larus marinus	great black-backed gull	Gull	n/a	X		X	
Melanerpes carolinus	red-bellied woodpecker	Non-waterbird	BP, R	X		X	
Melospiza melodia	**song sparrow**	**Non-waterbird**	**O**	**X**	**X**	**X**	**X**
Mergus serrator	red-breasted merganser	Waterfowl	n/a				X
Mimus polyglottos	**Northern mockingbird**	**Non-waterbird**	**O, R, S**	**X**			
Molothrus ater	brown-headed cowbird	Non-waterbird	NP, O			X	
Nycticorax nycticorax (V)	black-crowned night-heron	Wader	n/a	X		X	X
Passer domesticus *	house sparrow	Non-waterbird	E, R	X	X	X	X
Passerculus sandwichensis (V)	Savannah sparrow	Non-waterbird	O				X
Passerina cyanea	**indigo bunting**	**Non-waterbird**	**O, S**	**X**			
Phalacrocorax auritus	double-crested cormorant	Waterfowl	n/a				X
***Pheucticus ludovicianus* (IIA)**	**rose-breasted grosbeak**	**Non-waterbird**	**C, O, SB**	**X**			
Picoides pubescens	**downy woodpecker**	**Non-waterbird**	**BP, R**	**X**	**X**	**X**	**X**
Pinicola enucleator	pine grosbeak	Non-waterbird	n/a				X
Pitanga olivacea (IA)	scarlet tanager	Non-waterbird	C, HC, IF, SB				X
Pluvialis squatarola	black-bellied plover	Shorebird	n/a				X
Poecile atricapilla	**black-capped chickadee**	**Non-waterbird**	**LC, R, SB**	**X**		**X**	**X**
Progne subis	purple martin	Non-waterbird	n/a				X
Quiscalus quiscula	**common grackle**	**Non-waterbird**	**O**	**X**	**X**	**X**	**X**
Sayornis phoebe	**Eastern phoebe**	**Non-waterbird**	**n/a**	**X**		**X**	**X**
Seiurus aurocapillus	ovenbird	Non-waterbird	FG, GG, IF, SB	X			
Sitta carolinensis	**white-breasted nuthatch**	**Non-waterbird**	**BP, IF, R, SB**	**X**			**X**
Spizella passerina	chipping sparrow	Non-waterbird	O, S				X
***Sturnus vulgaris* ***	**European starling**	**Non-waterbird**	**E, NP, O, R**	**X**	**X**	**X**	**X**
Tachycineata bicolor	tree swallow	Non-waterbird	SB				X
Thryothorus ludovicianus	Carolina wren	Non-waterbird	LC, R			X	
Troglodytes aedon	house wren	Non-waterbird	LC			X	X
Turdus migratorius	**American robin**	**Non-waterbird**	**O, S**	**X**	**X**	**X**	**X**
Unknown duck	unknown duck	n/a	n/a				X
Unknown gull	unknown gull	n/a	n/a				X
Unknown heron	unknown heron	n/a	n/a				X
Unknown sparrow	unknown sparrow	n/a	n/a				X
Unknown swift	unknown swift	n/a	n/a				X
Vireo olivaceus	red-eyed vireo	Non-waterbird	S, SB, HC			X	

Scientific Name[1, 2]	Common Name	Category	Forest Guild[3]	2002–2003 NETN	2008 NETN	2009 NETN	2009 Park
Zenaida macroura	**mourning dove**	**Non-waterbird**	**C, R**	**X**	**X**	**X**	**X**
			Total species observed	37	21	33	50

[1] PIF Priority species status designations: IA: High Continental Priority, High Regional Responsibility; IIA: High Regional Priority, High Regional Concern; V: State Listed (after Deetmers and Rosenberg 2000).
[2] Bold type Indicates birds that likely breed in the park (after Trocki and Paton 2005).
[3] NETN Forest Guilds: BP: bark prober forager, C: canopy nester, E: exotic; FG: forest-ground nester, GG: ground gleaner forager, HC: high canopy forager, IF: interior forest obligate nester, LC: low canopy forager, NP: nest predator, O: omnivore, R: resident, S: shrub nester, SB: single brooded, n/a: not assigned (not a forest breeding bird) (after Faccio et al. 2010).
"*" Indicates exotic species

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS 444/111284, October 2011

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov