# Good Harbor Marsh Assessment and Stewardship Project

**Friends of Good Harbor, Inc.**

**2012 and 2013**

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ACKNOWLEDGEMENTS

Salem Sound Coastwatch (SSCW) wants to thank the individuals that came together to form the Friends of Good Harbor. They reached out to SSCW with the wish to learn more about the Good Harbor marsh they see and live near. They were willing to give their time and money to fund this monitoring and reporting effort by SSCW. As the project leader, I was pleased to be assisted by three college interns: Jacob Chapman, Connor Hilfinger, and Vanessa Zendejas in 2012 and Anna Budrow, Peter Cottingham and Maritime Gloucester students and teachers in 2013. Also participating in the field work were FOGH members and volunteers: Tom Todd, John Knowlton, Ron Garry, and Collette Knowlton. Mary Sullivan was FOGH's marsh assessment project coordinator and Denton Crews supported the marsh assessment effort. Thank you all. It is a pleasure working with you.

**About Friends of Good Harbor** www.goodharbor.org/default.html

Friends of Good Harbor is 501 3(c) nonprofit organization of volunteers affiliated to foster environmental preservation, restoration, and enhancement of the Good Harbor beach and marsh and its watershed. FOGH is a citizen-based organization dedicated to the natural, recreational, and educational uses of the expanse of land and water located along the ocean front and traversed by Thatcher Road in Gloucester, Massachusetts.

**About Salem Sound Coastwatch** www.salemsound.org

Salem Sound Coastwatch is a non-profit coastal watershed organization that works with government agencies, businesses, other non-profit organizations and citizens from the communities on the north shore in Essex County, Massachusetts. The organization is focused primarily on the Salem Sound Watershed but extends its services to other towns along the coast. The mission of SSCW is to increase the public's knowledge and appreciation of the natural resources of the watershed and the threats to the ecological health of the watershed, to foster responsible and sustainable resource management practices, to conduct and facilitate environmental monitoring and scientific research, and to promote citizens' awareness and understanding of their connection and role in restoring and protecting the health of the coastal environment.

## INTRODUCTION

Salem Sound Coastwatch (SSCW) with the Friends of Good Harbor (FOGH) in Gloucester MA conducted an assessment of the Good Harbor marsh system from June through September in 2012 and 2013. The Good Harbor marsh system is in the North Coastal Watershed and fed by the Saratoga Creek. For this study, data were collected along the Northeast Creek branch of the Saratoga Creek, that is, the marsh areas north and south of Thatcher Road. Approximately 45 acres of the southerly marsh abuts the Good Harbor beach parking lot and is downstream of Thatcher Road, while the northerly marsh is about 20 acres upstream of Thatcher Road, bounded on the east by Witham Street, Beachcroft Road on the north and Old Nugent Farm on the west. SSCW completed five years of monitoring (2001 - 2005) at the southerly Good Harbor marsh in order to establish benchmarks for restoration efforts at the Eastern Point salt marsh in Gloucester. For consistency, the southerly marsh in this assessment is referred to as downstream. In 2012 and 2013, the focus was on the upstream marsh north of Thatcher Road. The upstream marsh along Thatcher Road was monitored in 2012. In 2013, monitoring took place even farther upstream, which is referred to as upper.

### Concern over Decline of the Salt Marsh

SSCW conducted monitoring at the downstream Good Harbor marsh as a reference for marsh restoration efforts at Eastern Point, Gloucester from 2001 - 2005. During SSCW's five years of monitoring at the downstream marsh, a three-year decline from not impaired (2002) to somewhat impaired (2003) to moderately impaired (2004) was observed based on the invertebrate parameter. A follow up study was recommended. Several other studies have been conducted which revealed problematic locations around the Good Harbor marsh system calling for further investigation and in some cases remediation (these studies are posted in the FOGH web site section, Marsh Resources). For these reasons, FOGH launched the Good Harbor Assessment and Stewardship Project.

**The objectives of this bio-monitoring project** were as follows:

a) Recruit and train volunteers to collect quantitative data on the ecological integrity of the Good Harbor salt marsh system using the WHAT Program monitoring protocols

b) Collect quantitative data for five parameters: salinity, vegetation, nektons, birds, and invertebrates from the Good Harbor marsh on both sides of Thatcher Road

c) Extend the wetlands monitoring to an area that has not been monitored in the past

d) Compare results with data collected from 2001 – 2005 at the Good Harbor downstream marsh to current conditions

e) Evaluate local land use impacts on the Good Harbor marsh ecosystem

f) Provide site-specific documentation regarding species diversity and abundance to FOGH, state agencies, local partners and municipal officials

g) Make recommendations for restoration and ecosystem management

h) Raise awareness and build stewardship of the Good Harbor marsh ecosystem through public education and outreach.

**MONITORING COMPONENTS:**

The project was organized around the collection of quantitative data using the methodology described in the manual, *A Volunteer Handbook for Monitoring New England Salt Marshes*[1] (referred to as the Wetland Health Assessment Toolbox, or WHAT), produced by the Massachusetts Office of Coastal Zone Management and the Executive Office of Environmental Affairs. SSCW and its volunteers, following WHAT protocols, studied the structural component – hydrology (pore water and creek salinity) and the functional components – nektons, vegetation, and invertebrates in marsh evaluation areas (EVA). An independent stewardship group documented birds in 2012.

**METHODOLOGY:**

- Photographic Monitoring – At pre-established stations, a photographic record of site conditions was documented at the macro-scale. Macro-scale photo monitoring included collecting landscape photographs from fixed points of landscape level and feature images, upstream and downstream of culverts.

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[1] **Wetland Health Assessment Toolbox** (WHAT)
WHAT is a set of scientific methods, developed by scientists from the Massachusetts Bays Program, UMass Extension and the Massachusetts Office of Coastal Zone Management, for the multi-metric assessment of wetland health. The program effectively measures the relative ecological integrity of a salt marsh (before and after local infrastructure improvements) by monitoring seven parameters. The WHAT Program manual, *A Volunteer's Handbook for Monitoring New England Salt Marshes,* may be viewed at http://www.mass.gov/czm/volunteermarshmonitoring.htm or hard copies are available from SSCW.

- Vegetation – SSCW worked with volunteer monitors to identify and determine percent cover of all plants present within a one-meter square quadrat along a series of randomly located linear transects during peak growing season on July 31, 2012 and in the upper EVA in August 14, 2013. *Phragmites australis*, an invasive species of concern, was assessed as an indicator species. Where appropriate, its percent cover and height was documented within the one-meter square plots. Photo documentation of each quadrat was taken along the vegetation transects.

- Salinity – Pore (within peat) and surface water (from the creek) were sampled for salinity concentrations at pre-existing stations using a hand-held refractometer. Pore water sippers were utilized to obtain pore water. Salinity measurements were taken once a month from June through September.

- Nekton – Fish, crabs and shrimp were collected using minnow traps. The contents were transferred to a bucket and sorted by species. Sub-sampling was done when the catch exceeded quantities of 40 per species. Three stations were sampled in each marsh evaluation area. Nektons were sampled once per month - June through September on an incoming high tide, which turned out to be in the morning for all sampling times.

- Invertebrates – Three types of samples were collected at three stations along the creek in each marsh evaluation area: quadrat samples at top of bank, d-net samples along the creek bank and auger samples in the creek bed. Samples were preserved with 70% alcohol, sorted and identified to family. D-net and bank quadrat sampling took place on September 14, 2012, while auger samples, needing a low tide, were collected on August 14, 2012. The upper marsh was sampled on August 14, 2013.

- Land Use – Maps and aerial photography along with field techniques to describe land use and the environmental characteristics of the landscape were used to gain an overall measure of human disturbance at each wetland site.

- Avifauna – Birds are often used as bio-indicators of salt marsh habitats. The presence/absence of certain bird species may provide clues about fish and invertebrate populations in a marsh.

More detailed description of these protocols is available from SSCW upon request or at http://www.mass.gov/czm/volunteermarshmonitoring.htm

**SITE LOCATION:**

The Good Harbor marsh system and beach watershed is 1060 acres (Figure 1) and consists of six subwatersheds. The immediate subwatershed 1 surrounds the entire marsh system and is 625 acres. In addition, the upstream marsh north of Thatcher Road receives water from Rockport and subwatershed 2 (101 acres ) – Pond Road, mainly industrial. The downstream marsh south of Thatcher Road receives water from the entire watershed, as well as subwatersheds 3 through 6. Subwatershed 4 – 30 acres of preserved open space in perpetuity, is northwest of Eastern Avenue and between Harrison Avenue and Pond Road. To the northwest, subwatershed 3 is mainly industrial (91 acres), while westerly subwatershed #5 includes Rt. 128 and high density residential (127 acres). The Bass Rock area is subwatershed 6 with its 86 acres draining directly to the mouth of Saratoga Creek.

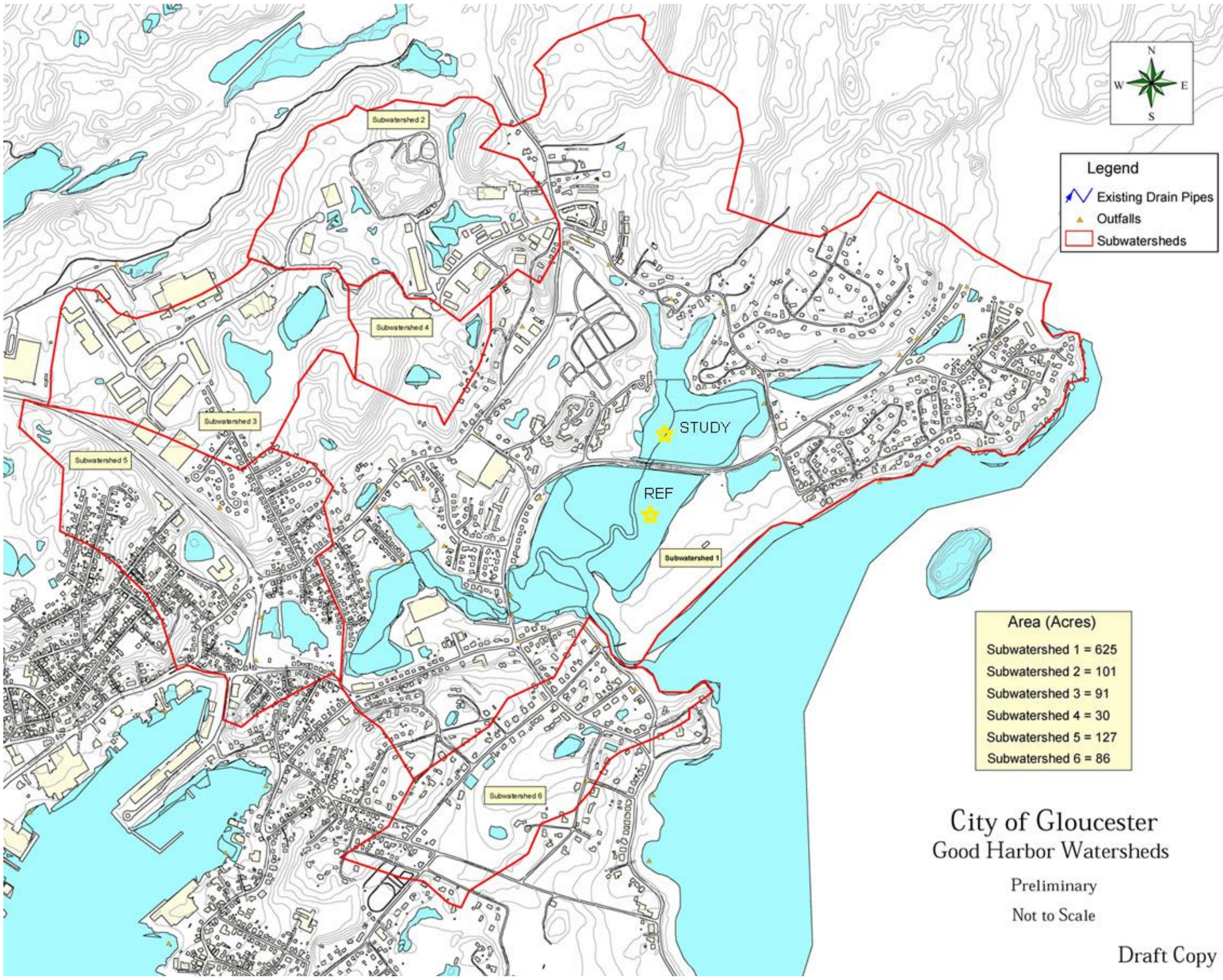


Figure 1. Good Harbor watersheds delineated for the Coastal Zone Management Coastal NPS Assessment Final Report: Assessment of Potential and Actual Sources of Nonpoint Source Pollution in the Good Harbor Drainage Area, 2005

The evaluation areas (EVA) for each marsh (Figure 2 & 3 - not to scale) are outlined below. Since the creek is narrower in the upstream EVA, vegetation transects were completed on both sides of the creek, but salinity was taken only on the west side (6 points on Figure 2). Sampling at the downstream EVA repeated the sampling locations used from 2001 – 2005. The upper marsh, outlined in green, was sampled in 2013 along the creek that goes over to Witham Street


Figure 2.  2012 Upstream marsh evaluation area (EVA) outlined in red; 2013 upper marsh EVA outlined in green. Stars mark nekton and creek salinity stations, red dots - pore water stations, yellow lines - the six vegetation transects in each area.


Figure 3. Downstream marsh EVA outlined in red: stars mark nekton and creek salinity stations, yellow lines - six vegetation transects.

## RESULTS and DISCUSSION

### SALINITY

Salinity measurements were taken four times from June through September in the EVAs upstream and downstream of the culvert at Thatcher Road. In 2013, the creek at the upstream and upper EVAs was sampled once in July, twice in August and once in September. The upper pore water salinity was only sampled once during the August vegetation transect monitoring. The overall 2012 downstream average was 25 ppt (SD=9), compared to the upstream overall average of 20 ppt (SD=9) (Table 1), while the 2013 upper overall salinity was 24 ppt (SD=7). The overall lower average salinity from the 2012 upstream reflects the creek's proximity to fresh water input from the watershed. A lower reading would be expected from the upper EVA. The 2013 upper marsh overall salinity was higher than the 2012 upstream average, which may be due to the fact that salinity was not measured in June when there is generally more fresh water input to the system.

However, the pore water salinity samples from the 2012 downstream, upstream and the 2013 upper marsh areas were very similar, particularly in the marsh border areas (B, Table 1). Figure 4 visually displays the salinity averages for the creek and the marsh pore water salinity at mid-marsh (A) and marsh border (B) for the different EVAs and years.

Table 1. Average creek and pore water salinity (ppt) comparing downstream, upstream and upper for the Good Harbor Marsh System, Gloucester, MA.

| | Creek | A | B | Overall | St Dev | |
|---|---|---|---|---|---|---|
| Downstream 2005 | 17 | 28 | 29 | 24 | 7 | n= 16 |
| Downstream 2012 | 21 | 30 | 19 | 25 | 9 | n=31 |
| Upstream 2012 | 12 | 28 | 19 | 20 | 9 | n=15 |
| Upper 2013 | 24 | 25 | 20 | 24 | 7 | n=29 |

Error bars represent means ± Standard Deviation.

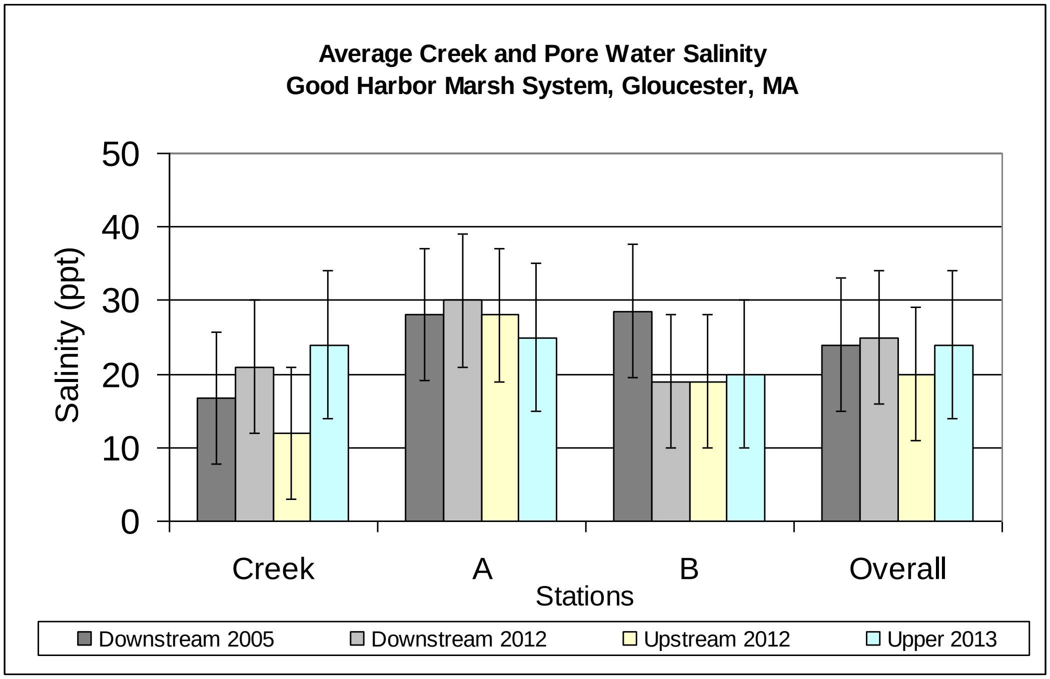


Figure 4. Average annual creek water and pore water salinity grouped by marsh areas: upper upstream and downstream of Thatcher Road, Gloucester MA and the year sampled.

Based on the NOAA salinity classification, [2] the marsh system experiences moderate to highest salinity.

The time of sampling and the tidal cycle influences the creek salinity. On an incoming high tide, the water in the creek in the downstream marsh, which is nearest the ocean, had an average salinity of 32 ppt (range 30 – 34 ppt) while the creek upstream of Thatcher Road averaged less at 19 ppt (range 15 – 23 ppt). In 2013, the upper marsh creek had a higher salinity at 31 ppt and a larger range 13 - 35 ppt. On an outgoing low tide, fresh water inputs were evidenced by lower salinity readings in the creek at both the downstream, upper and upstream EVAs, 19 ppt, 14 ppt and 5 ppt respectively (Figure 5).

[2] NOAA five-zone scheme: 1) 0-0.5 ppt (fresh water), 2) 0.5-5 ppt (low-salinity), 3) 5-15 ppt (moderate-salinity), 4) 15-25 ppt (high-salinity), and 5) >25 ppt (highest salinity).

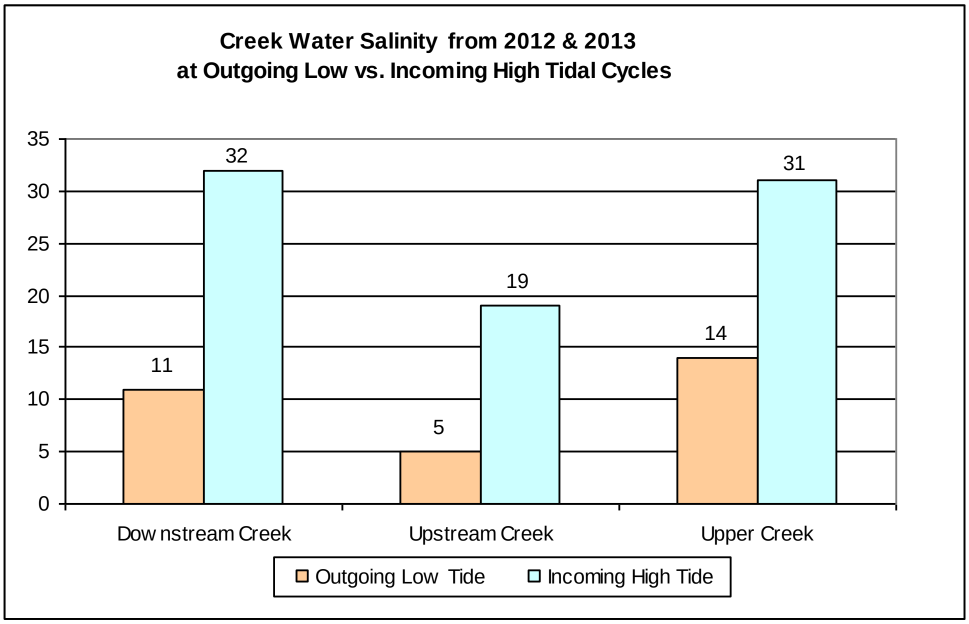


Figure 5. Average salinity in 2012 for the downstream and upstream creek and 2013 for the upper creek at different tidal cycles.

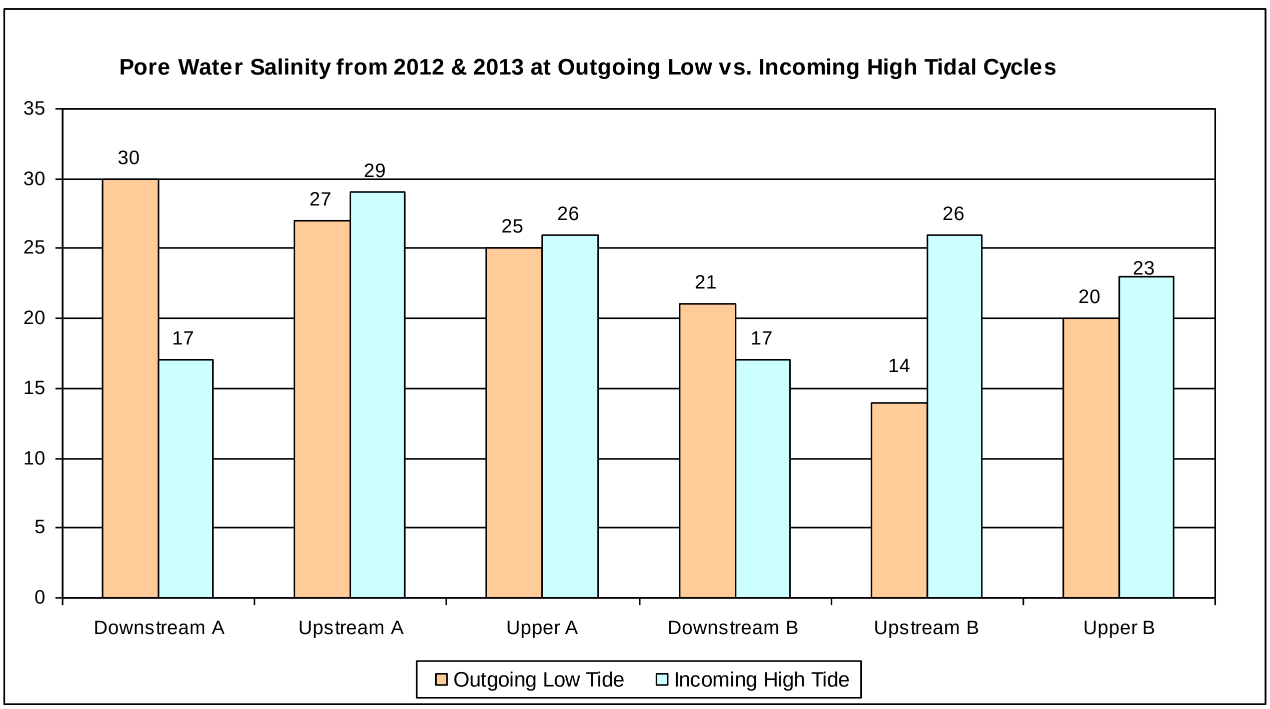


Figure 6. Average pore water salinity in 2012 for the downstream and upstream creek and 2013 for the upper creek at different tidal cycles.

When pore water salinities were examined at the two different tidal cycles (Figure 6), the pore water salinity readings in the downstream – Station A mid marsh sampling and Station B marsh border – were highest on the outgoing low tide and lower on the incoming high tide, as would be expected since the marsh had just been flooded before the outgoing tide. In contrast, the upstream's and upper's mid marsh sampling – Station A showed little variation in salinity for outgoing and incoming tides (upstream = 27 and 29 ppt; upper = 25 and 26 ppt respectively). However, the marsh border readings were reversed with the upstream and upper Station B salinity lower during the outgoing low tide. The upstream marsh border had an average 14 ppt on an outgoing tide, but an average 26 ppt on the incoming tide, while the upper marsh border in 2013 had an average 20 ppt on an outgoing tide and an average 23 ppt on the incoming tide. Evaporation may be playing a role in the higher pore water salinity. Also, inundation of upstream and upper marsh areas by seawater is dependent on fresh water inputs from precipitation events or the height of the tide, which varies throughout the monthly lunar cycle.

Because creek salinity varied so much with the tidal cycle (Figure 5), salinity readings from the creek were removed when examining for seasonal variability. Table 2 shows the average pore water salinity from the middle (A) and border marsh areas (B) for each month June through September in 2012. Salinity within estuaries is generally lowest from December to early spring and highest from late spring to early fall.[3] Often marshes will experience lower salinities in the spring due to fresh water input from increased rainfall. Salinities tend to rise in late summer with the higher temperatures and lower precipitation. However, in 2012, this trend is not clear.

Table 2. Monthly pore water salinity averages (ppt) for 2012 at the downstream and upstream for Good Harbor marsh system, Gloucester MA.

| **Monthly Average for All Pore Water Salinity Readings** | | |
|---|---|---|
| Date sampled | Downstream | Upstream |
| 06/28/12 | 23.2 | 16.6 |
| 07/17/12 | 24.8 | 27 |
| 08/14/12 | 31.2 | 24 |
| 09/14/12 | 25.8 | 28.5 |

[3] Orlando, S.p.Jr., C.K.P.H. Wendt, M.E. Pattillo, K.C. Dennis, and G.H.Ward. 1994. Salinity characteristics of south Atlantic estuaries. NOAA, Office of Ocean Conservaion and Assessment, Silver Springs, MD 117p.

Yearly average ranged from 32 to 20 ppt when the 2012 salinity averages were compared to the averages obtained from 2002 to 2005 at the downstream marsh (Figure 6). The upstream had the lowest at 20 ppt in 2012, but in 2003, the average was 22 ppt, which is closer to the 2012 upstream EVA. In 2013, creek salinity ranged from 35 to 13 ppt in the upstream and upper EVAs, which is more in line with 2002 and 2004 salinity averages from the downstream creek.

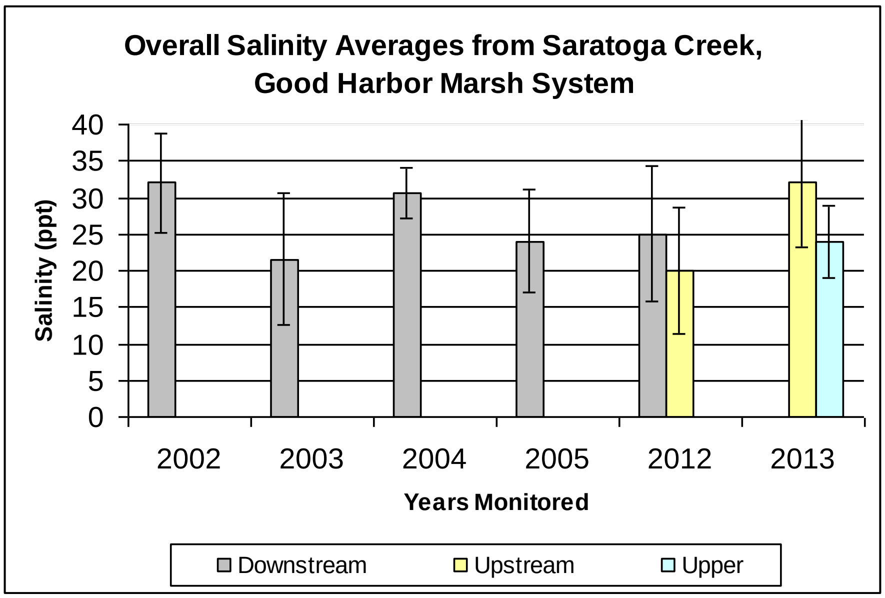


Figure 7. Average creek and pore water salinity per year for the downstream (2002 –2012), upstream (2012) and upper (2013) for Good Harbor Marsh System, Gloucester MA.

## VEGETATION

Six transects in each marsh EVA were sampled for vegetation on 8/14/2013 (upper), 7/31/12 (upstream) and 8/7/12 (downstream). Compass bearings and location of transects are in appendix, page 43.

**Species richness** was highest in the upstream marsh at 16 different plants, while the downstream had 11 species (2005 n=12) and the upper marsh had 12 species. All marsh EVAs shared ten plants in common (Table 3).

Table 3. Plant species relative percent cover averaged for the 2013 upper, 2012 upstream, 2012 and 2005 downstream marsh evaluation areas. "Other" includes bare ground, mud, water, wrack, algae, and debris.

| **Common Name** | **Species** | **2013 Upper - North Upstream** | **2012 North-Upstream** | **2012 South - Downstream** | **2005 South - Downstream** |
|---|---|---|---|---|---|
| Seaside gerardia | *Agalinis maritima* | | 0.54 | | |
| Stiff-leaf quackgrass | *Agropyron pungens* | | 2.84 | | 5.07 |
| Creeping bentgrass | *Agrostis stolonifera* | | 0.15 | | |
| Marsh orach | *Atriplex patula* | 0.21 | 0.17 | 0.34 | 0.64 |
| Spike grass | *Distichlis spicata* | 27.14 | 13.28 | 20.11 | 5.79 |
| Sea milkwort | *Glaux maritima* | | 1.86 | | |
| Marsh elder | *Iva frutescens* | 7.30 | 5.01 | 2.45 | 0.64 |
| Black grass | *Juncus gerardii* | 20.02 | 11.65 | 2.98 | 3.22 |
| Sea lavender | *Limonium nashii* | 0.43 | 0.04 | 0.11 | 0.23 |
| Eged's silverweed | *Argentina egedii* | 0.05 | | | |
| Seaside plaintain | *Plantago maritima* | | | 0.09 | |
| Alkali grass | *Puccinellia maritima* | | | | 0.08 |
| Common glasswort | *Salicornia europaea* | 2.01 | 3.40 | 1.50 | 1.06 |
| Saltmarsh bullrush | *Schoenoplectus robustus* | 1.73 | | | |
| Seaside goldenrod | *Solidago sempirvirens* | 1.03 | 1.15 | 0.18 | 0.13 |
| Smooth cordgrass | *Spartina alterniflora* | 6.85 | 6.91 | 8.57 | 8.55 |
| Salt hay grass | *Spartina patens* | 28.01 | 38.68 | 49.01 | 54.44 |
| Sea blite | *Suaeda linearis* | 0.46 | 0.48 | 2.09 | 2.60 |
| Shore arrowgrass | *Triglochin maritimum* | | 0.73 | | |
| Common reed | *Phragmites australis* | | 1.02 | | |
| Other | | 4.77 | 12.08 | 12.23 | 17.54 |

*Plantago maritima* was a unique species in the 2012 downstream, while *Puccinellia maritima* was unique in 2005. *Triglochin maritimum* (seaside arrow grass) was unique to the 2012 upstream EVA. *Plantago maritima* (seaside plantain) and *Triglochin maritimum* (seaside arrow grass) are very similar, but the *Plantago maritima w*as near the creek in the downstream EVA while *Triglochin maritimum* was found as expected in shallow panes on the upstream high marsh. The upper marsh had two unique species in 2013, *Argentina egedii* (Eged's silverweed) and *Schoenoplectus robustus* (saltmarsh bulrush). Both are salt tolerant and found in brackish and irregularly flooded areas, marsh border and upland edges.

The upstream EVA had the most species diversity. The four unique plants, *Agalinis maritima, Thinopyrum pungens, Glaux maritima, Triglochin maritimum*, found in the upstream EVA grow in irregularly flooded areas of the high marsh near salt pannes.[4] These high marsh shallow pools are only within reach of the highest tides and thus, are flooded infrequently, so salt levels become very high as water evaporates between flood cycles. Few plant species can tolerate these extremes of salinity. *Agalinis maritima* (salt marsh gerardia) and *Glaux maritime* (sea milkwort), a succulent like *Salicornia europaea*, were located in the southeast corner of the upstream marsh. *Phragmites australis* was found only in the upstream transects.

Figure 8. *Agalinis maritime, Glaux maritima* and *Plantago maritima*

[4] Tiner, R.W. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. The University of Massachusetts Press, Amherst, MA.
New England Wild Flower Society. Go Botany project is supported in part by the National Science Foundation. accessed 2013. http://gobotany.newenglandwild.org/species/agalinis/maritima/

*Agropyron pungens* (stiff-leaf quackgrass) is often found at the upper edges of salt marshes usually in sandy areas. Sand has been deposited along the creek banks in the upstream marsh where much of the *Agropyron pungens* was found. *Agrostis stolonifera* (creeping bent grass) and *Puccinellia maritima* (seashore alkali grass), both in the grass family and commonly found in irregularly flooded brackish and tidal fresh marshes, were also found in the upstream EVA.

Figure 9. *Agropyron pungens* (stiff-leaf quackgrass) along the sandy bank of the upstream EVA, Good Harbor marsh, north of Thatcher Road, Gloucester.

**Community similarity**[5] refers to the similarity or difference in species between two different communities. When 2012 upstream vegetation data were compared to the downstream site, the upstream site had a 63% community similarity with the 2012 downstream. The 2012 and 2005 species comparison from the downstream EVA resulted in a community similarity of 83% between the two years. The upper marsh had an 88% similarity to the vegetation in the upstream area sampled in 2012.

All plant species were halophytic or salt tolerant except *Phragmites australis*, which was found in the upstream border marsh. The invasive species, *Phragmites australis* (common reed) is an aggressive colonizer of natural and disturbed areas, often forming extensive monoculture stands. It has colonized much of the upstream marsh border.  Phragmites has not established itself in the downstream EVA although it is in the marsh along the south side of Thatcher Road, and one

[5] The ratio of similarity or difference in species between the two different communities is calculated by dividing the number of species that the study site(upstream) and reference site (downstream) shared by the number of species at the reference site.

patch is expanding at the edge of the beach parking lot. There is *Phragmites* along the upland border in the upper marsh, but there was none present in the six upper vegetation transects.

Figure 10. Phragmites bordering the Briarneck Crossing filled marsh in the southeasterly corner of the upstream marsh, Good Harbor marsh, north of Thatcher Road, Gloucester.

The graph displaying relative percent coverage of the most common plant species shows that high marsh plants dominate the entire Good Harbor marsh system (Figure 11). *Spartina patens* was consistently the most abundant followed by *Distichlis spicata,* then *Juncus gerardii. Juncus gerardii* was more abundant in the upstream EVA in 2012 than in the downstream EVA in either 2005 or 2012. In the upper EVA, *Spartina patens* (28%) and *Distichlis spicata* (27%) are equal distributed with *Juncus gerardii* following at 20%.

*Spartina alterniflora* abundance was very similar across all marsh EVAs and years, just under ten percent. Able to withstand inundation by salt water for up to 20 hours per day, *Spartina alterniflora* thrives in anoxic, low marsh habitats due to its ability to oxygenate its roots and rhizosphere.  It can grow as a short version in high marsh where there is less frequent inundation but is more common in the low marsh because it is outcompeted by *Spartina patens* in the high marsh.[6]

[6] http://www.fs.fed.us/database/feis/plants/graminoid/spaalt/all.html USDA Forest Service Fire Effects Information System (FEIS) for Spartina alterniflora

The high marsh shrub or marsh elder, *Iva frutescens,* was found to be twice as abundant in the upstream EVA compared to the downstream (5% to 2.5%) and increased to 7.3% in the upper EVA. It was found along the high sections of the creek bank and at other elevated areas across the marsh.

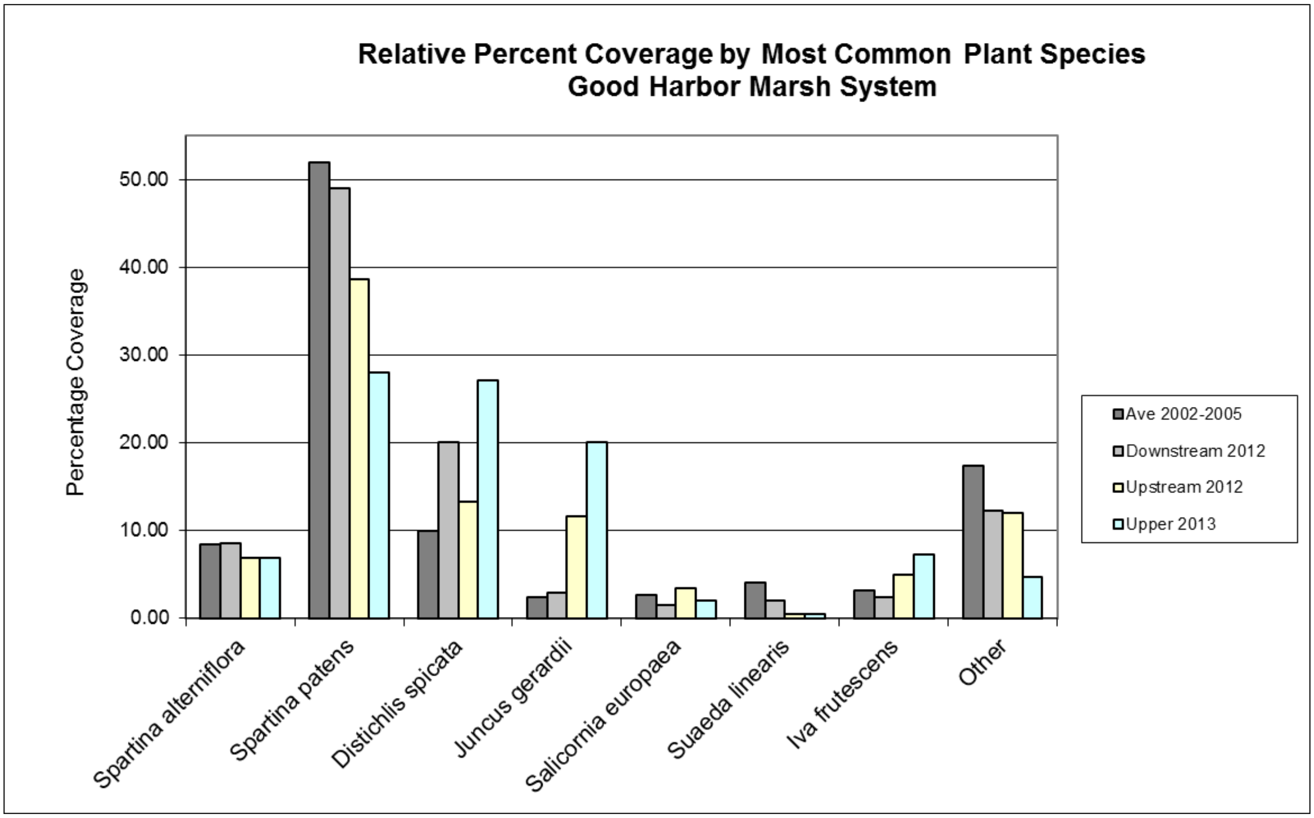


Figure 11. Yearly average of relative percent cover for the most common plant species from 2013 upper, 2012 upstream and the downstream marsh for 2012 and the total average for years 2002 through 2005.

*Salicornia europaea* (common glasswort) and *Suaeda linearis* (sea blite) are early colonizers and are generally found in low percentages unless there has been a major disruption of vegetation coverage in the marsh by events such as heavy ice or ponding of water. Relative percent abundance for *Salicornia europaea* ranged from 1.5 to 3.4 and 0.5 to 4 for *Suaeda linearis*. They are less abundant in the upper EVA.

Other (bare ground, debris, algae, mud, water) relative percent coverage (Table 3) was relatively the same between the upstream and downstream EVAs in 2012 at about 12%, while slightly more bare ground or water was observed in 2005 at the downstream - 17.5%. Once again the upper EVA in 2013 had less "Other" coverage.

**Vegetation Attribute Metrics** values - wetness, salinity tolerance and nutrient regime - have been established for each plant species. For each species, the attributes were weighted to reflect the total abundance of that species. The total wetland abundance value for every plant in each marsh EVA was multiplied by these attribute values and then averaged to derive a weighted value for each metric.

Table 4. Vegetation Metrics by year

| METRIC by Year | Good Harbor Marsh South of Thatcher Road - Downstream | | | | | | North of Thatcher Road - Upstream | North of Thatcher Road - Upper |
|---|---|---|---|---|---|---|---|---|
| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2012 | 2012 | 2013 |
| Taxa Richness | 13 | 18 | 17 | 16 | 12 | 11 | 16 | 12 |
| Abundance Invasive | 0.00 | 0.09 | 0 | 0 | 0 | 0 | 1 | 0 |
| Weighted Wetness | 92.17 | 91.49 | 90.54 | 79.74 | 90.24 | 80.59 | 80.42 | 87.55 |
| Weighted Salinity Tolerance | 97.57 | 96.67 | 94.12 | 84.04 | 95.78 | 84.71 | 86.39 | 93.07 |
| Weighted Nutrient Regime | 34.41 | 34.22 | 34.34 | 29.70 | 34.09 | 30.54 | 29.80 | 32.42 |

The adjusted weighted wetness[7] value was 80.42 at the upstream EVA, very similar to the downstream 80.59. Although the wetness value was 79.74 in 2004 at the downstream, it was above 90 for the other four years as was the upper EVA in 2013.

The adjusted weighted salinity tolerance[8] value was 86.39 at the upstream EVA and slightly lower at the downstream 84.71. Once again except for 2004 (84), salinity tolerance was above 94

[7] **Wetness:** This attribute was taken directly from the U.S. Fish and Wildlife Service National List. Wetness values rank a species relative affinity to hydric (wet) conditions. Attributes range from obligate (wetland dependent) to upland, and are based on the median probability of a particular species occurring in a wetland. Wetness scores were assigned according to this scale: Obligate = 1.00; FacWet+ = 0.91; FacWet = 0.82; FacWet- = 0.71; Fac+ = 0.60; Fac = 0.50; Fac- = 0.40; FacUp+ = 0.29; FacUp = 0.18; FacUp- = 0.09; Upland = 0.00.

[8] **Salinity Tolerance:** This attribute ranks a species' tolerance to saline conditions. The attributes range from intolerant to very high tolerance. Intolerant species will not survive saltwater exposure, including the occasional ocean spray. Species with very high tolerance will survive in tidal areas with twice-daily inundation of saltwater. Salinity tolerance scores were assigned according to this scale: Very High = 1.00; High = 0.80; Medium = 0.60; Low = 0.40; Intolerant = 0.20. The values for this attribute were adapted from the New England Institute for Environmental Studies Plant Community Indicator Database (Michner, 1990).

for the other four years. In 2013, the upper EVA had a salinity (93) more consistent with the downstream marsh in all the years but 2004.

The adjusted weighted nutrient regime[9] value was 29.8 at the upstream EVA and slightly higher at the downstream 30.54 in 2012. The 2004 nutrient regime value (29.7) was similar to the 2012 upstream (29.8), while the rest of the years values from the downstream marsh were between 34.09 and 34.41. Once again the 2013 upper EVA nutrient value of 32.42 was closer to the downstream marsh in all years except 2004.

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[9] **Nutrient Regime:** This attribute ranks a species affinity for certain habitats associated with a corresponding nutrient availability. Attributes range from species generally occurring in areas with low nutrient availability (as in bogs and isolated wetlands) to those species occurring in areas with disturbances or enrichment from fertilizer or wastewater. Nutrient scores were assigned according to this scale: Bogs, lowest nutrients = 0.12; Sands, low nutrients = 0.23; Acid woods, till, and sandy loam = 0.34; Alluvial acid soils, enriched by flood deposits = 0.45; Sweet soils in calcareous areas = 0.56; Alluvial sweet soils = 0.67; Somewhat disturbed or partly enriched soils = 0.78; Disturbed or enriched soils = 0.89; Very disturbed and heavily enriched = 1.00. The values for this attribute were adapted from the New England Institute for Environmental Studies Plant Community Indicator Database (Michner, 1990).

**NEKTON**

Three minnow traps were set once a month in the main creek of the upstream and downstream EVAs – June through September. At the June 2912 sampling, no nektons were captured in any of the six traps. Conditions appeared not ideal because the tide was going out and salinity in the creek was measured at 5 – 6 ppt. The following three sampling times were scheduled for a morning incoming tide. Creek water salinity was measured each time, and it ranged from 10 – 30 ppt in the downstream creek and 4 – 25 ppt in the upstream creek. On August 14, 2012, nine mummichogs were caught in the farthest upstream station when the salinity was 4 ppt so drawing the conclusion that the empty traps in June were due to low salinity is not advisable.

Fish species richness was the same in both EVAs. Four resident fish species -*Fundulus species, Pungitius pungitius, Apeltes quadracus, Gasterosteus aculeatus* - were caught (Table 5). The most dominant species in terms of abundance was *Fundulus* species commonly called mummichogs. *Fundulus heteroclitus* and *Fundulus majalis* occupy a similar ecological niche and can be difficult for volunteer monitors to distinguish so these two species have been combined and are referred to as *Fundulus* species.

Figure 12. *Fundulus* species were measured and weighed by SSCW and FOGH volunteers, 8/12/2012.

In 2012, all fishes caught in the upstream and downstream EVAs were resident species. Good Harbor marsh system receives good tidal flushing from Saratoga Creek, which has direct access to the ocean. Therefore, the expectation is that transient fish species will access this system. In 2005, the downstream EVA had the same resident species but also a small numbers of transient fishes: blueback herring (*Alosa aestivalis*) and cunner (*Tautogolabrus adspersus*).  On July 17, 2012, five striped bass (*Moronee saxatilis*) were observed on the second sampling day in the downstream section of the creek.

Table 5. The species and number of nektons collected on the monitoring dates for 2005 and 2012 in the downstream and upstream creeks.

| Nekton Species - Good Harbor Marsh System, Gloucester, MA | | | | | |
|---|---|---|---|---|---|
| | **Scientific Name** | **Common Name** | **6/22/2005** | **7/20/2005** | **8/19/2005** |
| **2005 Downstream - South of Thatcher Road** | *Fundulus heteroclitus & Fundulus majalis* | Mummichog & Striped killifish | 28 | 99 | 254 |
| | *Pungitius pungitius* | Ninespine stickleback | 20 | 7 | 0 |
| | *Apeltes quadracus* | Fourspine stickleback | 3 | 1 | 0 |
| | *Tautogolabrus adspersus* | Cunner | 0 | 1 | 0 |
| | **Scientific Name** | **Common Name** | **7/17/2012** | **8/14/2012** | **9/14/2012** |
| **2012 Downstream - South of Thatcher Road** | *Fundulus heteroclitus & Fundulus majalis* | Mummichog & Striped killifish | 215 | 464 | 632 |
| | *Pungitius pungitius* | Ninespine stickleback | 2 | 0 | 0 |
| | *Apeltes quadracus* | Fourspine stickleback | 2 | 0 | 0 |
| | *Palaemon elegans* | European Rock Shrimp | 0 | 0 | 3 |
| **2012 Upstream - North of Thatcher Road** | *Fundulus heteroclitus & Fundulus majalis* | Mummichog & Striped killifish | 7 | 141 | 34 |
| | *Pungitius pungitius* | Ninespine stickleback | 0 | 0 | 1 |
| | *Apeltes quadracus* | Fourspine stickleback | 7 | 0 | 0 |
| | *Gasterosteus aculeatus* | Threespine stickleback | 0 | 2 | 7 |
| | *Palaemonetes species* | Grass Shrimp | 2 | 0 | 0 |
| | *Palaemon elegans* | European Rock Shrimp | 0 | 0 | 8 |

Total species richness was slightly higher in the upstream creek than the downstream, n = 6, while downstream n = 4. Although many European green crabs (*Carcinus maenas)* were observed walking along the creek bed, none entered the traps. However, shrimp were collected. The upstream had two native grass shrimp (*Palaemonetes* species) in July and eight European rock shrimp (*Palaemon elegans*) in September, while the downstream had three *P elegans*. Northern comb jellies, Ctenophores – free swimming or floating animals with clear gelatinous body that has 8 rows of comblike plates, were caught in September.

Table 6. Total *Fundulus* species abundance and average for all sampling days for 2005 and 2012 in the downstream and upstream creeks.

| | **2005 Downstream** | **2012 Downstream** | **2012 Upstream** |
|---|---|---|---|
| **Total - All Dates** | 414 | 1311 | 182 |
| **Average - All Dates** | 46 | 146 | 20 |
| **Standard Deviation** | 54.6 | 158.3 | 40.6 |

The average number of *Fundulus* species in the upstream creek was 20, while the downstream had an average of 146 for 2012, compared to 46 in 2005 (Table 6). Comparing the average catch for all the years monitored found variation from year to year with a standard deviation that varied from 33 to 158 (Figure 13).

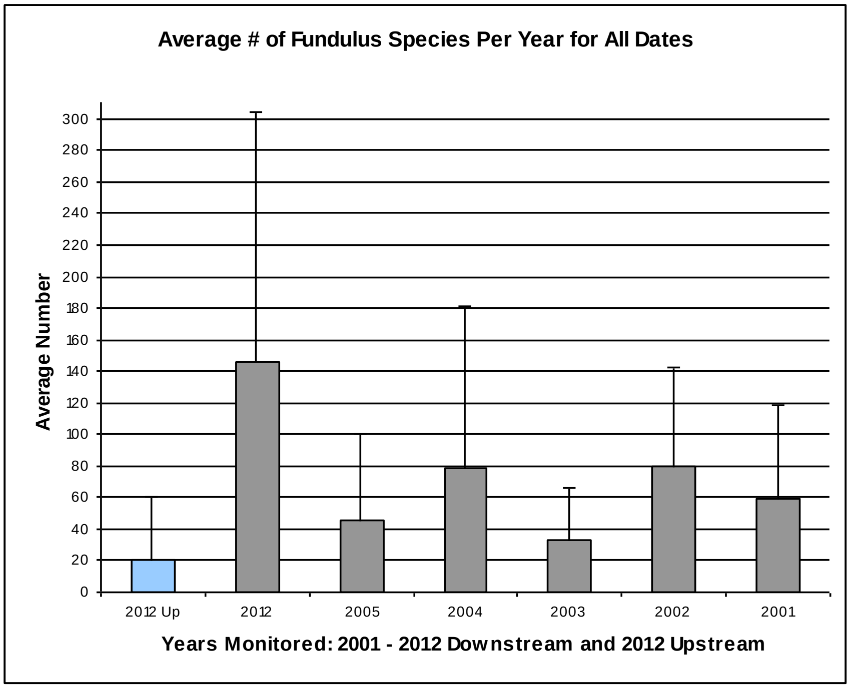


Figure 13. Average number of *Fundulus* species grouped by year for all years of monitoring at the downstream and upstream creeks, Good Harbor marsh, Gloucester, MA.

The catch at the downstream increased as the summer season progressed in both 2012 and 2005. The upstream creek catch peaked in August in 2012 (Figure 14).

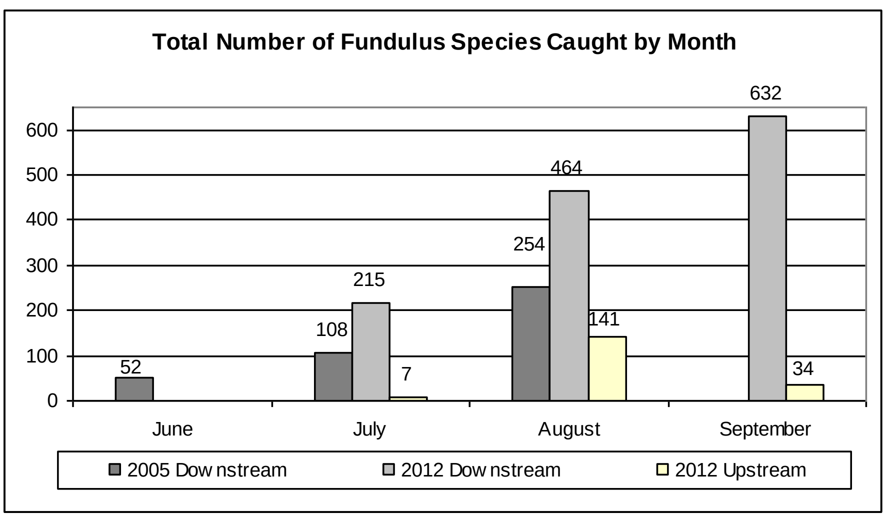


Figure 14. Total number of *Fundulus* species by month for 2005 and 2012 in the downstream and upstream creeks.

The sticklebacks, *Pungitius pungitius*, *Apeltes quadracus* and *Gasterosteus aculeatus*, were not included in the biomass analysis since they are very small and were caught in low numbers (1-4) so their biomass was below the measurable limit of 1gram.

Table 7. Average biomass of *Fundulus* species by month for 2005 and 2012 in the downstream and upstream creeks.

| Average Weight of Fundulus Species per Month Sampled in grams | | | |
|---|---|---|---|
| | 2005-Downstream | 2012-Downstream | 2012-Upstream |
| June | 1.61 | 0* | 0* |
| July | 0* | Not weighed | 0.21 |
| August | 1.87 | 0.56 | 0.53 |
| September | Not sampled | 1.27 | 0.57 |
| | | | |
| 0* | No fish caught | | |

Although slightly more than three times the number of *Fundulus* were caught in 2012 in the downstream, the average weight was lower in 2012 than in 2005 regardless of the month (Table 7). The smallest *Fundulus* species were found in the upstream creek. In 2012, the average total weight did increase from July to September. The upstream creek had an increase of 108% from August to September while the 2012 downstream increased 227% in average biomass from July to August/September.

The nekton sampling in 2013 concentrated on the upstream EVA monitored in 2012 and the new sampling area in the upper marsh. Although the sampling methods used were the same and traps were set in July, August and September, very few nektons were caught in 2013. The average creek temperature was 18 degrees C. (ranging from 16.5 to 24) and creek salinity averaged 32 ppt (range of 25 to 35) for both upstream and upper EVAs at the time of nekton sampling.

No *Fundulus* species were caught in the upstream traps just north of Thatcher Road and only 7 were trapped in the upper marsh (Table 8). Sticklebacks were the most common fish species with a total of 18 in the upstream EVA and 27 in the upper EVA. In 2012 (Table 5.), 182 mummichogs and 17 sticklebacks were caught. Four invasive European Rock Shrimp were collected in September, fewer than the eleven trapped in 2012.

Table 8. The species and number of nektons collected on the monitoring dates for 2013 in the upstream and upper creek EVAs.

| | Scientific Name | Common Name | 7/24/2013 | 8/20/2013 | 9/17/2013 |
|---|---|---|---|---|---|
| **2013 Study - North of Thatcher Road** | *Pungitius pungitius* | Ninespine stickleback | | 1 | |
| | *Apeltes quadracus* | Fourspine stickleback | 3 | 3 | |
| | *Gasterosteus aculeatus* | Threespine stickleback | 1 | | 10 |
| | *Palaemon elegans* | European Rock Shrimp | | | 4 |
| | **Scientific Name** | **Common Name** | **7/24/2013** | **8/20/2013** | **9/17/2013** |
| **2013 Study - Upstream of North of Thatcher Road** | *Fundulus heteroclitus & Fundulus majalis* | Mummichog & Striped killifish | 4 | 3 | |
| | *Apeltes quadracus* | Fourspine stickleback | 2 | 7 | |
| | *Gasterosteus aculeatus* | Threespine stickleback | | | 18 |

On possible explanation for the reduction in nektons, in particular the lack of Mummichogs, could be the presence of a large flock of Mallards (Figure 15) that took up residence in the upstream creek during the summer of 2013. Mallards are omnivores so while they are often thought of eating pond vegetation and grain, they may have indulged or at least scared off the resident marsh creek fish and shrimp.

Figure 15. Mallards were seen in the upstream EVA at the time of nekton sampling in 2013.

## AQUATIC INVERTEBRATES

Invertebrate sampling was conducted in August from 2001 to 2005 at the downstream EVA and then again in 2012 at both the downstream and upstream EVAs. The upper EVA was sampled in 2013. The results are a composite of three sets of d-net, auger, and creek bank quadrat samplings. The average number of organisms was 73 downstream in 2012 compared to the upstream average of 40 organisms. In 2013, the average number of organisms in the upper creek and from the bank was 38. The average total number of organisms for the combined years 2001 to 2005 sampling in the downstream EVA was 94.

Figure 16. Jake Chapman, FOGH volunteer, taking an auger sample from the downstream creek, 2012.

The following analysis to determine the Salt Marsh – Invertebrate Community Index (ICI) used the same metric that was deployed in 2005 data analysis. It was calculated based on pre-restoration study and reference marsh analysis on the North Shore from 2001 – 2005. The Biological Condition Score (BCS) criteria table (Table 9) for the selected metrics was determined using the reference average value to mark a maximum score of 6, and the Standard Deviation was used to set the breaks for the other scores 4, 2, and 0. Metric scores for each site were summed, and the sum converted to a percentage for the final ICI (Table 9).

Table 9. Invertebrate Biological Condition Scoring Criteria 2005 - used in the 2012 and 2013 analysis.

| Selected Metrics for 2005 | Impact Trend | Ref. Avg. | 0 | 2 | 4 | 6 | Factor | Represents | Stnd. Dev. |
|---|---|---|---|---|---|---|---|---|---|
| Total Taxa Richness | Decline | 14.00 | <6 | 6-12 | 12-18 | >18 | 6 | .5 sd | 5 |
| % Predators | Rise | 12.32 | >9 | 6 - 9 | 3-6 | <3 | 3 | 0.33 sd | 7 |
| % Deposit Feeders | Decline | 41.66 | <6 | 7-13 | 14-20 | >20 | 6 | .75 sd | 24 |
| % Contribution Dominant Taxa Group | Rise | 54.48 | >85 | 66-85 | 46-65 | <46 | 19 | sd | 19 |
| % Rare | Rise | 34.44 | >63 | 51-62 | 39-50 | <39 | 11 | .5 sd | 13 |
| % Phyllodocida | Decline | 26.99 | <7 | 7-13 | 14-18 | >18 | 6 | .33 sd | 20 |
| % Amphipoda | Decline | 23.77 | <21 | 21-32 | 33-44 | >25 | 11 | sd | 11 |
| % Tanaidacea | Decline | 0.54 | <1 | 1-3 | 4-6 | >6 | 2 | sd | 0 |
| % Other Groups | Rise | 38.28 | >74 | 44-73 | 14-43 | <13 | 29 | sd | 29 |
| % Insects, Spiders and Mites | Rise | 20.25 | >85 | 51-84 | 17-50 | <17 | 33 | sd | 33 |

Table 10. 2005, 2012 & 2013 Invertebrate Metric Table for Good Harbor Marsh EVAs, Gloucester MA.

| METRIC/INDEX | Downstream 2005 | Downstream 2012 | Upstream 2012 | Upper 2013 |
|---|---|---|---|---|
| **Total Taxa Richness** | 13 | 18 | 11 | 12 |
| **Score** | *4* | *4* | *2* | *4* |
| **% Predators** | 7.4 | 29.7 | 7.5 | 13.8 |
| **Score** | *2* | *0* | *2* | *0* |
| **% Deposit Feeders** | 45.8 | 49 | 5.8 | 44 |
| **Score** | *6* | *6* | *0* | *6* |
| **% Contribution Dominant Taxa Group** | 41.75 | 46.3 | 32.5 | 55.2 |
| **Score** | *6* | *4* | *6* | *4* |
| **% Rare** | 38.5 | 66.67 | 45.45 | 42 |
| **Score** | *6* | *0* | *4* | *4* |
| **% Contribution Phyllodocida** | 7.4 | 12.8 | 13.33 | 10.3 |
| **Score** | *2* | *2* | *2* | *2* |
| **% Contribution Amphipoda** | 41.75 | 33 | 5.8 | 17.2 |
| **Score** | *6* | *6* | *0* | *0* |
| **% Contribution Tanaidacea** | 31.65 | 0 | 9 | 7.8 |
| **Score** | *6* | *0* | *0* | *6* |
| **% Contribution Other Groups** | 17.5 | 46.33 | 30.8 | 55.1 |
| **Score** | *4* | *2* | *4* | *2* |
| **% Insects, Spiders and Mites** | 14.14 | 30.28 | 30.8 | 38.7 |
| **Score** | *6* | *4* | *4* | *4* |
| **Raw Score for Selected 10 Metrics** | 46 | 28 | 24 | 32 |
| **Adjusted as Scale of 100** | 80 | 47 | 40 | 53 |
| | | | | |
| **INVERTEBRATE COMMUNITY INDEX** | **80** | **47** | **40** | **53** |
| BIOLOGICAL CONDITION | NI / SWI | MI | MI / SI | MI |

| Invertebrate Community Index | |
|---|---|
| 80-100 | Not Impaired (NI) |
| 60-80 | Somewhat Impaired (SWI) |
| 40-60 | Moderately Impaired (MI) |
| 0-40 | Severely Impaired (SI) |

The average Total Taxa Richness was 18 in 2012 at the downstream (n = 219) and 13 in 2005 (n = 294), while the 2012 upstream had 11 (n = 120) and the 2013 upper had 12 (n= 115). The 2012 and 2005 downstream and the upper received Biological Condition Scores (BCS) of 4; upstream received a BCS of 2 in the Total Taxa Richness metric.

The % Predators was highest at the 2012 downstream at 29.7%, receiving a BCS of 0. The 2005 downstream and 2012 upstream were similar with values of 7.4 and 7.5, respectively, and received BCS of 2 in the % Predators metric. The 2013 upper was at 13.8%, receiving a BCS of 0. Predators include Polychaete worms, crabs, Aranea (spiders), Acari (mites).

The % Deposit Feeders was 45.8% at the 2005 downstream and 49% in 2012. The 2013 upper was similar with 44%. Deposit feeders are amphipods, isopods, oligochaetes and most polychaetes. All three received BCS of 6 in the % Deposit Feeders metric, while the 2012 upstream was 5.8% and received a 0.

The % Contribution Dominant Taxa Group was 41.8% at the 2005 downstream site for Amphipoda. The 2012 upstream had 32.5% Gastropoda (Melampodidae – marsh snails). The "Other" category (oligochaetes, spiders, insects) was the Dominant Taxa Group for the 2012 downstream, 46.3%, and the 2013 upper, 55%. The 2005 downstream and 2012 upstream received BC scores of 6 in the % Contribution Dominant Taxa Group metric, while the 2012 downstream and 2013 upper received scores of 4.

The % Rare was 38.5% at the 2005 downstream and increased to 66.7% in 2012. A rise in rare indicates an impact. The 2012 upstream was 45.5% and the 2013 upper was 42%. A BCS of 6 was given to the 2005 downstream; 2012 downstream received a 0, and the 2012 upstream and 2013 upper received 4 in the % Rare metric.

The % Contribution Order Phyllodocida was 7.4% at the 2005 downstream, 10% for the 2013 upper and 13% for both the 2012 downstream and upstream. All received BC scores of 2 in the % Contribution Phyllodocida metric. Nephytidae and Nereidae are the two families of Phyllodocida found in 2012. Omnivores, Neiridae (clam worms) made up 6% of the yearly total organisms collected in the 2005, 8% of the 2012 downstream, 10% of the 2013 upper, and 12%

of the 2012 upstream. Another type of polychaete worm, Syllidae, was also found in 2005. Spionidae and Terebillidae were found in the upper.

The % Contribution Amphipoda was 41.8% at the 2005 downstream, 33% in 2012. Both sites received BC scores of 6 in the % Contribution Amphipoda metric, while the 2012 upstream received a 0 for a 5.8% Amphipoda as did the 2013 upper for a 17% Amphipoda.

The % Contribution Tanaidacea was 31.7% at the 2005 downstream and 0% in 2012. The 2012 upstream and 2013 upper were also low at 9% and 8%, respectively. Both 2012 sites received a BCS of 0, while the 2005 downstream received a BCS of 6 in the % Contribution Tanaidacea metric.

The % Contribution Other Groups was 17.5% at the 2005 downstream and 46.3% in 2012 while the upstream had 30.8% and the 2013 upper 55%. The 2005 downstream and the 2012 upstream received BCS of 4; the 2012 downstream and 2013 upper received a BCS of 2 in the % Contribution Other Groups metric. Other consists of oligochaete worms, spiders and insects.

The % Insects, Spiders and Mites was 14% at the 2005 downstream, while the 2012 sites were very similar: 30% - downstream and 31% upstream, while the 2013 upper was higher at 39%. The 2005 downstream received a BCS of 6; the 2012 and 2013 EVAs received scores of 4 in the % Insects, Spiders and Mites metric.

The final Salt Marsh – Invertebrate Community Index (ICI) for the downstream dropped from 80 (not impaired) in 2005 to 47 in 2012, while the 2012 upstream was lower at 40. This number was higher in 2013 for the upper EVA at 52. The marsh condition index for the 2012 and 2013 falls into the “moderately impaired” range based on the invertebrate community.

Table 11 and Figure 17 take a closer look at the distribution of each feeding group per EVA. Grazers (32%) dominated the 2012 upstream EVA, followed by the mixed feeding groups (*i.e.*, insects) (25%), then scavengers (16 %). The 2012 downstream EVA was dominated by the mixed feeding groups (55%), followed by deposit feeders (49%). The dominance of these two groups was reversed in the downstream in 2005. Omnivores in both the 2012 upstream (12.5%) and downstream (14%) were higher than the 2005 downstream (6%). The percent of predators was the highest in the 2012 downstream by 21 points, as was the mixed feeding groups by 30 points.

Table 11. The Invertebrate Community Trophic Similarity Index metric showing feeding groups and the total average percent for each EVA for a given year.

| COMMUNITY TROPHIC SIMILARITY INDICES | | | | |
|---|---|---|---|---|
| **FEEDING GROUP** | **Upper 2013** | **Upstream 2012** | **Downstream 2012** | **Downstream 2005** |
| % Predators | 14 | 8 | 30 | 7 |
| % Deposit Feeders | 44 | 6 | 49 | 46 |
| % Grazers | 0 | 32 | 3 | 0 |
| % Omnivores | 16 | 13 | 14 | 6 |
| % Scavengers | 0 | 16 | 1 | 1 |
| % Suspension Feeders | 0 | 2 | 1 | 1 |
| % Mixed Feeding Groups | 26 | 25 | 55 | 24 |

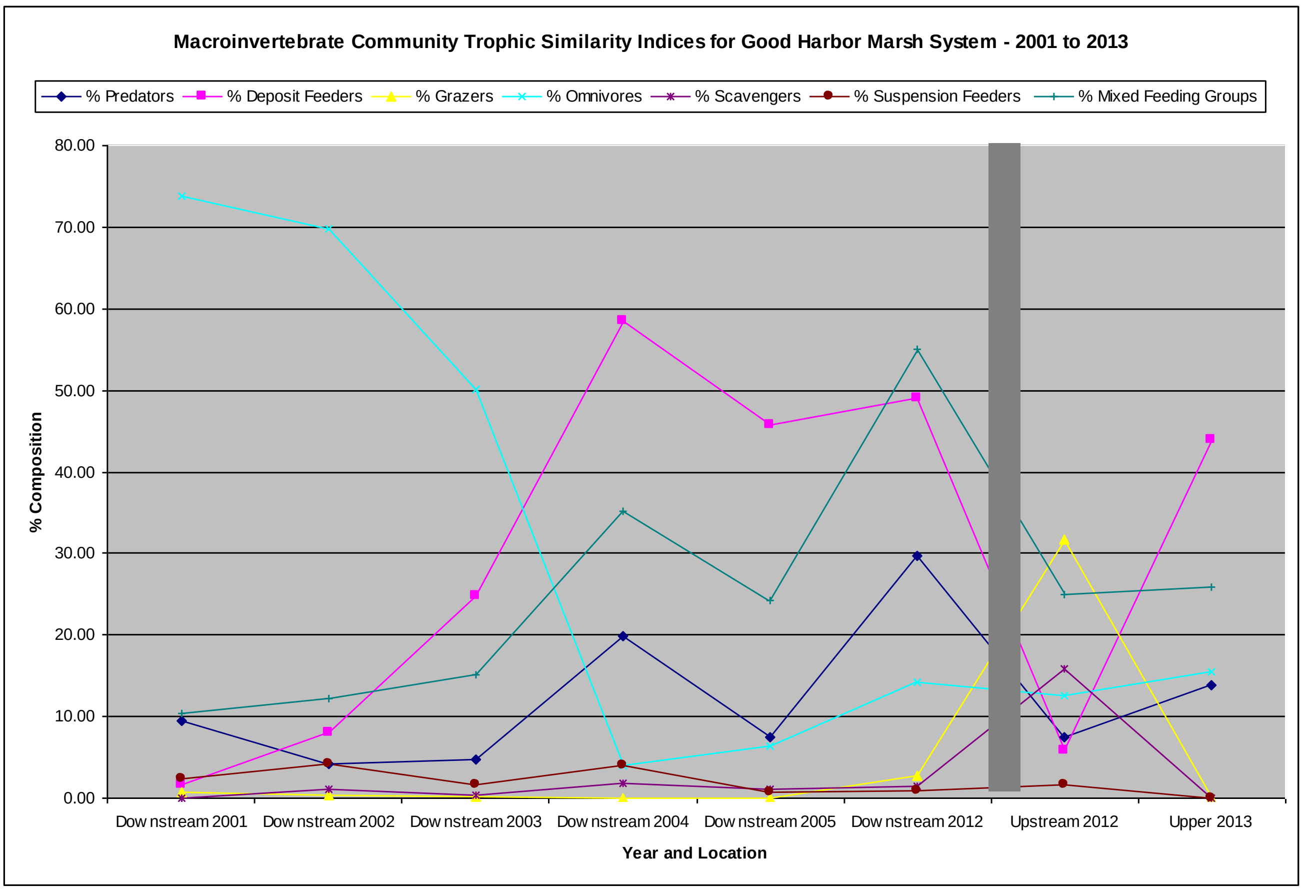


Figure 17. Yearly total average percent for each feeding group for the downstream 2001-2012, and the 2012 upstream and 2013. Gray bar separates upstream and upper EVA results from downstream EVA. Invertebrate community health is reliant on both habitat conditions and water quality.

The monitoring handbook, *A Volunteer's Handbook for Monitoring New England Salt Marshes,* http://www.mass.gov/czm/volunteermarshmonitoring.htm, provides a way of expressing habitat and water quality that is comparable to the invertebrate community metrics and ICI. Habitat conditions are based on best judgment visual assessment using ten variables to compute a Habitat Assessment Score (HAS). The scoring sheet is located in the Appendix page 44. The 2012 upstream HAS (74), 2012 downstream HAS (72) and 2013 upper HAS (70) were similar – "somewhat impaired". The upstream had a slightly higher score because more of the upstream marsh has more vegetative buffer than the downstream. The Salt Marsh Status Summary Graph (Figure 18) provides a visual representation of the invertebrate community condition (ICI) and the assessed habitat quality (HAS). The biological condition of the invertebrate community is "moderately impaired" for the Good Harbor marsh system, but the upstream in 2012 was on the edge of slipping in a "severely impaired" status. The comparison of ICI to HAS placed the Good Harbor Beach marsh system in the category of being "moderately impaired ecological integrity" due to poor habitat and other stressors.

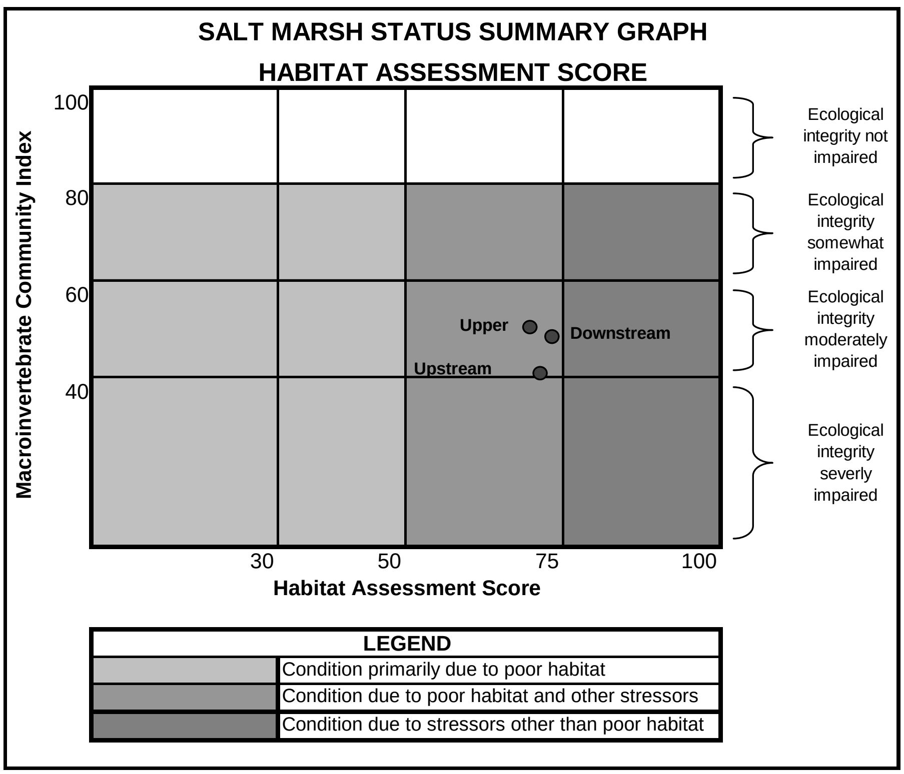


Figure 18. Salt Marsh Status Summary Graph for the Good Harbor marsh system in 2012 and 2013, Gloucester

| Invertebrate Community Index | |
|---|---|
| 80-100 | Not Impaired (NI) |
| 60-80 | Somewhat Impaired (SWI) |
| 40-60 | Moderately Impaired (MI) |
| 0-40 | Severely Impaired (SI) |

| Habitat Assessment Score Criteria | |
|---|---|
| 75% and above | Not Impaired |
| 50-74% | Somewhat Impaired |
| 30-49% | Moderately Impaired |
| <30% | Severely Impaired |

**BIRDS**

FOGH Volunteers made observations on September 14, 2012 with John Nelson, an experienced birder. The combined viewing from #1 Witham Street near Thatcher Road and #2 the upstream marsh and lawn at Old Nugent Farm reported 226 birds consisting of 23 species. From 2001 to 2005, five surveys were conducted at each of the salt marshes over the season with twenty-minute observation session conducted upstream and downstream. All species seen and heard were recorded including birds located in the wetland and a 50-100 foot wetland buffer. Formal bird observations were not conducted in 2013.

The most common was European Starling as it was in 2005 when observations were made in both the downstream and upstream marsh. Every year that birds have been monitored at the Good Harbor marsh system, a Red-tailed Hawk has been seen. Other interesting birds seen this past September were Pine Siskin, Bobolink and Carolina Wren. A migrating Bobolink was also seen in 2004.

In 2012, six wetland dependent species were present: American Black Duck, Double-crested Cormorant, Great Blue Heron, Herring Gull, Mallard, and Snowy Egret. There were 10 Wetland Dependent Species observed at the downstream in 2005: Black Duck, Double-crested Cormorant, Eastern Kingbird, Greater Yellowlegs, Herring Gull, Killdeer, Least Sandpiper, Mallard, Red-winged Blackbird and Snowy Egret. Over the years, the ten other wetland dependent birds have also been seen using the Good Harbor marsh system: Black-Bellied Plover, Cliff Swallow, Common Yellowthroat, Great Black-backed Gull, Green Heron, Northern Rough-winged Swallow, Salt Marsh Sharp-tailed Sparrow, Semipalmated Plover, Semipalmated Sandpiper, and Yellow Warbler. Two Saltmarsh Sharp-tailed Sparrows were sighted at the Good Harbor marsh system in 2001 and 2005.

## CONCLUSION

### SALINITY

The Saratoga Creek and its tributaries drain 1,060 acres before exiting at Good Harbor Beach. The Good Harbor marsh system occupies the transition zone between freshwater and marine systems and is also a part of a very dynamic barrier beach system. Salinity zones change within the marsh in response to water flow, time of year, weather conditions, prevailing winds and tidal fluctuations. Salinity levels in the marsh averaged between 20 - 25 ppt, placing it in the moderate to high salinity range. The upstream overall lower average salinity reflected the creek's proximity to fresh water inputs from the watershed. However, the upstream and upper pore water salinity were similar to salinity levels at the downstream and probably explain the similarities in the upstream and downstream marshes since aquatic and vegetation community compositions in a marsh are driven by salinity.

### VEGETATION

Except for the invasive *Phragmites australis*, all plant species were halophytic or salt tolerant. When the Vegetation Attribute Metrics were compared over the seven years of assessment, the metric values were fairly similar for the 2012 upstream EVA and the years 2004 and 2012 at the downstream EVA (Table 12). The upper EVA in 2013 was more similar to the other years of sampling at the Good Harbor downstream marsh.

Table 12. Vegetation Metrics for all years sampled at Good Marsh system, Gloucester MA.

| METRIC by Year | North of Thatcher Road - Upper | North of Thatcher Road - Upstream | Good Harbor Marsh South of Thatcher Road - Downstream | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 2013 | 2012 | 2001 | 2002 | 2003 | 2004 | 2005 | 2012 |
| Taxa Richness | 12 | 16 | 13 | 18 | 17 | 16 | 12 | 11 |
| Abundance Invasive | 0 | 1 | 0.00 | 0.09 | 0 | 0 | 0 | 0 |
| Weighted Wetness | 87.55 | 80.42 | 92.17 | 91.49 | 90.54 | 79.74 | 90.24 | 80.59 |
| Weighted Salinity Tolerance | 93.07 | 86.39 | 97.57 | 96.67 | 94.12 | 84.04 | 95.78 | 84.71 |
| Weighted Nutrient Regime | 32.42 | 29.80 | 34.41 | 34.22 | 34.34 | 29.70 | 34.09 | 30.54 |

The adjusted weighted salinity tolerance values were high for the 2012 upstream, 2012 downstream and 2004 downstream, while all the other four years had very high salinity tolerances - above 94. In 2013 the upper EVA adjusted weighted salinity tolerance value was 93.07.

Wetness values are based on the probability of occurring in a wetland. The wetness values for 2012 upstream, 2012 downstream and 2004 downstream are Facultative Wetland, which is defined as "usually a hydrophyte but occasionally found in uplands," while the other four years had values above 90, making them Facultative Wetland + to Obligate, i.e. "almost always is a hydrophyte, rarely in uplands." In 2013 the upper EVA adjusted weighted wetness value was closer to the downstream values in 2001-2003 and 2005.

The nutrient regime ranks a species affinity for certain habitats associated with a corresponding nutrient availability. The adjusted weighted nutrient regime value of the 2012 upstream was similar to the 2004 downstream nutrient regime value. The 2012 downstream result was slightly higher, while the downstream EVA was higher between for the rest of the years. In 2013 the upper EVA adjusted weighted nutrient tolerance value was in between the two. The nutrient regime rankings categorize the marsh system as "Sands, low nutrients = 0.23 and Acid woods, till, and sandy loam = 0.34." Marsh vegetation can survive in a low nutrient availability environment. If the marsh was being nutrient enriched or disturbed, the adjusted weighted nutrient regime value would be above 0.78.

The consistency and similarity in the Good Harbor Marsh vegetation is evidenced by the seven years of assessment. The drop in values in 2004 and 2012 are interesting and may be due to annual precipitation and temperature variations. This slight shift in vegetation attributes is reflected also in the macroinvertebrate assessments.

## INVERTEBRATES and NEKTONS

Invertebrates are another key indicator of marsh system condition. When Community Taxa and Trophic metrics were compared to the 2012 downstream marsh to establish community similarity, once again the highest similarity was with the 2004 downstream (Table 13).

Table 13. Invertebrate Community Taxa and Trophic Similarity Scores for 2001-2005, 2012 upstream and 2013 upper EVAs, using 2012 downstream for the community comparison.

| Community Similarity Indices when compared to 2012 Downstream Site, Good Harbor | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Downstream | | | | |
| | Upper 2013 | Upstream 2012 | 2005 | 2004 | 2003 | 2002 | 2001 |
| Community Taxa Similarity | 78 | 55 | 59 | 82 | 52 | 39 | 52 |
| Community Trophic Similarity | 72 | 29 | 66 | 72 | 35 | 15 | 12 |

Good Harbor marsh system's ecological integrity appears to be moderately impaired due poor habitat and other stressors for three of the six years. Table 14 shows the invertebrate community condition (ICI), the Biological Condition and the assessed habitat quality (HAS) for all assessment years.

Table 14. Invertebrate Community Index, Biological Condition and Habitat Assessment Scores for all years at the Good Harbor marsh system.

| | Upper 2013 | Upstream 2012 | Downstream 2012 | Downstream 2005 | Downstream 2004 | Downstream 2003 | Downstream 2002 | Downstream 2001 |
|---|---|---|---|---|---|---|---|---|
| Macroinvertebrate Community Index | 50 | 40 | 47 | 80 | 47 | 80 | 86 | 53 |
| Biological Condition | MI | MI | MI | NI | MI | NI | NI | MI |
| Habitat Assessment Score | 70 | 74 | 72 | 77 | 88 | 65 | 65 | 68 |

In past SSCW reports, it was noted that the downstream EVA had experienced a three-year decline from not impaired (2002) to somewhat impaired (2003) to moderately impaired (2004). In 2005, there was improvement in the ICI, but by 2012, the ICI value was back to the 2004 level. Two possible stressors that affect invertebrate community health are water quality and prey-predator relationship. Water quality was not a monitored parameter and so water quality degradation can not be ruled out. An increase in predator populations can also affect invertebrate abundance. The Good Harbor Beach marsh system has good tidal flushing, productive vegetative salt marsh community and a well-established bank edge along a wide creek that provides habitat and food to support a healthy invertebrate community but that may mean competition from larger predators. The average number of invertebrate organisms collected increased in 2005 at the downstream site over the previous year. Upon examination of the fish count at the downstream, the total fish trapped increased from 301 (ave. inverts = 154) in 2003 to 742 (ave. inverts = 57) in 2004, then returned to a lower count of 414 (ave. inverts = 130) in 2005. In 2012, the total count was back up to 1311 (ave. inverts = 73).

## INVASIVE INVERTEBRATE SPECIES

Invasive non-native invertebrate species were found in the Good Harbor marsh. *Hemigrapsus sanguineus*, the invasive Asian shore crab, was collected at the downstream site in 2005. European green crabs, *Carcinus maenas*, were common at both the downstream and upstream but not caught in minnow traps in 2012. However, some were retrieved with invertebrate sampling. *Palaemon elegans*, the European rock shrimp, was found in Gloucester in the Eastern

Point marsh in 2010 in a D-net sample. The summer of 2010 was the first observation of this species in North America. During that summer, this new invasive was first sighted at Hawthorne Cove Marina, Salem MA at the end of July and then consequently found in August during SSCW's salt marsh monitoring, one at Eastern Point, Gloucester and the other at the Salem State University's Old Creek marsh, Salem. In 2012, *Palaemon elegans* were caught in minnow traps and in the d-nets, and many more were seen swimming along the banks of the creek in September. However, in 2013, the numbers of *Palaemon elegans* observed and caught in traps were fewer.

**BIRDS**

The Good Harbor marsh system and surrounding buffer does provide habitat diversity for resident and migrating birds. Twenty-six wetland dependent birds were seen over the six years of observation. Of particular interest is the Saltmarsh Sharp-tailed Sparrow, which nests in salt marshes. Although not listed on the Endangered Species List, the Saltmarsh Sharp-tailed Sparrow is a species of greatest conservation need according Massachusetts Division of Fisheries & Wildlife Comprehensive Wildlife Conservation Strategy.[10] The American Black Duck and Snowy Egret are also listed as species of conservation need in the Comprehensive Wildlife Conservation Strategy report.

[10] Revised September 2006. pg. 294. http://www.mass.gov/dfwele/dfw/habitat/cwcs/cwcs_home.htm

## SUMMARY

The Good Harbor marsh assessment funded by FOGH and conducted SSCW provides baseline data for the marsh system north of Thatcher Road and expands to six years of comparative data collected from the downstream marsh system abutting Good Harbor Beach. Salt marsh estuaries are a balancing act with coarser-grained sediments, saline water and migrating organisms entering the system on flood tides and finer-grained sediment, fresh water, nutrients, and organic matter coming in on the ebb tide (SAFMC 1998a).[11] These dynamic marsh ecosystems are also influenced by natural conditions such as weather, storms, species population variation, and prey dynamics. Land use, water quality and stormwater non-point source pollution are human-induced stressors that impact the marsh system. Despite this variability, with long-term data collection, it is possible to establish the general condition of the marsh and identify trends and issues that are worth further investigation.

The seven years of data allows comparisons of metric evaluations by year. Both the downstream and upstream EVAs were more similar to the results collected for the downstream in 2004 than any of the other years monitored. The marsh system had moderate to high salinity and typical halophytic salt marsh vegetation found in high saline, low nutrient, sandy soils. Habitat and species diversity was reflected in the number and type of species found. Fish species were the typical residents of marsh/estuarine environments with some transient larger fish coming into the estuary to feed. Twenty-six wetland dependent birds were seen over the six years of observation, in addition to many more species of resident and migrating birds. The Saltmarsh Sharp-tailed Sparrows, a species of greatest conservation need, have nested in the marsh system. Red-tailed Hawks made use of the marsh and vegetated buffers in all years of monitoring. The average number of invertebrates for 2012 and 2013 led to a habitat assessment condition of moderately impaired due to poor habitat and other stressors.

[11] SAFMC (South Atlantic Fisheries Management Council). 1998a. Final Amendment 9 to fishery management plan for the snapper groper fishery of the South Atlantic region. SAFMC, Charleston, SC, 246 p.
Street, M.W., A.S. Deaton, W.S. Chappell, and P.D. Mooreside. *2005*. North Carolina Coastal Habitat Protection Plan 2005 - http://ncfisheries.net/habitat/chppdocs/C_Water Column.pdf

## RECOMMENDATIONS FROM PREVIOUS STUDIES[12]

The City of Gloucester Comprehensive River and Stream Habitat Restoration Report, 2003 identified eight sites in need of restoration in the Saratoga Creek watershed, five of which were along Thatcher Road. They included restoration opportunities to reduce Phragmites, improve vegetated buffers and reduce encroachment into the high marsh. The possibility of an eel run at Old Nugent Farm and alewife potential in the pond east of Witham Street and north of Rt. 127A were identified. This 8.5 acre pond and its fringing wetland were also identified for restoration potential in The Great Marsh Coastal Wetlands Restoration Plan, 2007 (see Figure 19), developed by the state's Wetland Restoration Program (now Division of Ecological Restoration). This historically diked impoundment now has a culvert at Witham Street (Site ID 179) that continues to impound water in an area that was once intertidal habitat. A tidal survey and assessment project would be needed to evaluate culvert height and size, ecological condition and potential tidal flow re-conversion.

Another potential restored tidal flow project would be the conversion of the 2.8 acres of impounded wetland just north of Good Harbor Beach and south of Rt. 127A (Site ID 205). Once part of the tidally-influenced Good Harbor marsh system, the access drive to the Good Harbor beach parking lot impounds water in this upstream area.

Two potential fill removal projects were identified: 1.5 acres of historically-filled salt marsh north of Rt. 127A and west of Witham Street (Site ID 177), known as Briarneck Crossing, and the historically-filled 2-acres of salt marsh on the western edge of municipal parking lot for Good Harbor Beach. Fill removal assessments would be needed to determine appropriate marsh grades to restore wetland soils, hydrology and marsh vegetation at these two priority projects sites.

[12] Studies available at the Friends of Good Harbor website: www.goodharbor.org/Resources/resources_marsh.html

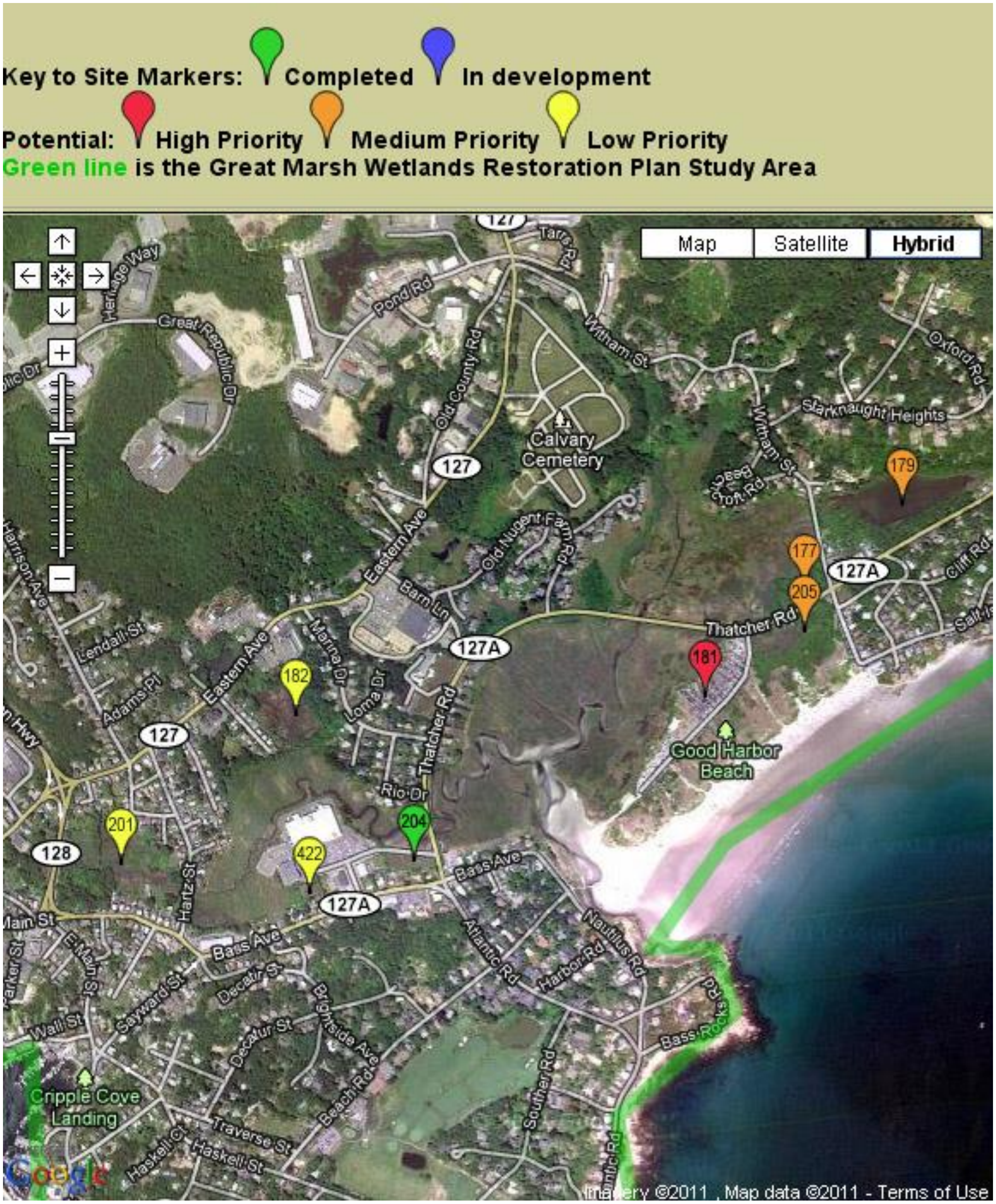


Figure 19. Good Harbor Beach section from The Great Marsh Coastal Wetlands Restoration Plan, 2007

Human-induced stressors were examined in 2005 by the City of Gloucester under a MA Coastal Zone Management Coastal NPS (Nonpoint Source Pollution ) grant. The Final Report, Assessment of Potential and Actual Sources of Nonpoint Source Pollution in the Good Harbor

Drainage Area, was seen as a critical first step in providing long term protection for the Good Harbor Drainage Area and Good Harbor Beach. The study was in response to documented water quality problems in association with stormwater runoff and non-point source pollution. The Massachusetts Division of Marine Fisheries has closed Saratoga Creek and part of Good Harbor beach to shellfishing, and the beach and creek have historically been closed to swimming by the Gloucester Health Department. Evaluation of historic data revealed 13 hazardous waste releases reported to MA Department of Environmental Protection and 4 properties reported sewer overflow incidents. Water testing found evidence of bacterial levels transported through stormwater runoff with fecal coliform and salinity inversely correlated and incidences of low pH, high total suspended solids (TSS) concentrations, high nitrate concentrations, and volatile organic compounds (VOC) contamination. City of Gloucester Project Staff observed outfalls and catch basins and potential NPS sources: golf course, industrial parks, roads, homeowners, and landscapers.

The Project Staff made fourteen recommendations[13] that included the following: no increase and mitigation of freshwater flow to the marsh, develop a beach management plan, improve wetland mapping, assess sewer system capacity and impact of any unsewered homes including homes in Rockport that are in the Good Harbor Watershed, institute a catch basin cleaning and street sweeping maintenance program, develop a stormwater ordinance pertaining to new construction to increase infiltration of runoff, implement best management practices for nitrate, TSS and VOC contaminants, and lastly, increase public education and outreach.

## RECOMMENDATIONS FOR FUTURE STUDY AND ACTIONS

Given that Good Harbor marsh system's ecological integrity is moderately impaired due to poor habitat and other stressors, further study and actions should be undertaken. Examining the results of the monitoring assessment completed by Salem Sound Coastwatch (SSCW) and the recommendations of the previously discussed studies, there are many opportunities for education, assessment and restoration in the Good Harbor Watershed.

[13] www.goodharbor.org/Resources/PDF%20Docs/GOOD%20HARBOR%20WATERSHED%20STUDY%20-%202005.pdf

SSCW recommends the following new parameters be added to any future monitoring of the marsh system:

- Sea level rise – document marsh elevation, vertical accretion or subsidence
- Bank erosion – begin measuring creek and selected ditch widths
- Invasive *Phragmites australis* assessment – map areas of Phragmites and assess removal strategies
- Anadromous fish assessment in the spring – evaluate potential for herring, eels and rainbow smelt fish runs.

Human-induced stressors from land use practices such as filling of wetlands, reducing vegetated buffers around wetland borders, restricting seawater flow or increasing fresh water have negative impacts on wetland systems. Strategies for addressing the following restoration projects should be developed for the Good Harbor marsh system with the goal of alleviating the physical stressors to wetland functions:

1. Assess culvert at Witham Street (Site ID 179) to evaluate culvert height and size, ecological condition and potential for tidal flow restoration
2. Begin a Good Harbor Beach Management Plan with the City that would address the 2.8 acres of impounded wetland and the 2 acres of filled salt marsh on the western edge of municipal parking lot.

Stormwater management in the Good Harbor watershed should also be revisited. The 2005 CZM Coastal NPS report identified particular hotspots having water quality issues of bacteria, nutrients, TSS, and VOC. It would be valuable to find out if any of the recommendations were enacted and if any of the hotspots were remediated. Field reconnaissance should be conducted to update the report's watershed survey.

Citizens of Gloucester, the North Shore and visitors appreciate the tremendous beauty and natural resource of the Good Harbor Beach. Often the marsh is the just the backdrop for beach activities. Few people understand the importance of the watershed to a healthy marsh and productive ocean and even fewer people have experienced a marsh up close. Knowledge and personal experiences lead people to stewardship. In 2012, the Friends of Good Harbor formed to support the preservation and enhancement of the beach, salt marsh and wetlands, with the overarching goal to create a Good Harbor Conservancy, a contiguous sanctuary of over 100 acres. Friends of Good Harbor and Salem Sound Coastwatch have set as a high priority public outreach and education of homeowners and business owners in the watershed and the City. Educational programming should address the role of property owners in reducing the harmful impacts of stormwater runoff and low impact development techniques owners can implement to cleanse and reduce runoff. Improving vegetation in the buffer zones to wetlands and creeks needs to be addressed and someone or group needs to initiate revegetation of buffers to set the example. Public presentations, stormwater stenciling events, marsh walk and talks, biodiversity assessments, and marsh monitoring with citizen volunteers being trained to become citizen scientists will all lead to greater public knowledge, appreciation and commitment to environmental stewardship.

With a moderately impaired ecological integrity due to poor habitat and other stressors, there is room for improvement in the Good Harbor marsh system and several studies over the last ten years have made recommendations and identified actions that lead to improvements at the beach and marsh. SSCW looks forward to working with the Friends of Good Harbor (FOGH) and citizen volunteers from the community to study and restore the Good Harbor Marsh.

APPENDIX

Compass bearings and location of the vegetation transects, nekton and pore water sampling sites.

| Vegetation Transect Locations | | | | | | Pore Water Locations | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Good Harbor Marsh - Reference - beach side** | | | | | | | | | |
| **Gloucester, MA** | **Reference Site** | | | **Date: 8/7/12** | | | **WELLS** | **Pore Salinity** | |
| **Compass Bearing: 120** | | | | | | | | | |
| 1A 26' | 1B 36' | 2A 151' | 2B 171' | 3A 240' | 3B 285' | **Transects** | **1** | **2** | **3** |
| 0 | 0 | 0 | 0 | 0 | 0 | | 0 m | 0 m | 0 m |
| 60 | 60 | 60 | 60 | 60 | 60 | | 60 m | 49 m | 38.5 m |
| 120 | 120 | 120 | 120 | 120 | 120 | | 140 m | 98 m | 77 m |
| 180 | 180 | 180 | 180 | 180 | 180 | | | | |
| 240 | 240 | 240 | 240 | 240 | 240 | | closest | | |
| 300 | 300 | 300 | 300 | 285 | 300 | | to culvert | | |
| 360 | 360 | | | | | | | | |
| 377 | 373 | | | | | | | | |
| **Good Harbor Marsh - Study - Thatcher Road side** | | | | | | | | | |
| **Gloucester, MA** | **Study Site** | | | **Date: 7/31/2012** | | | **WELLS** | **Pore Salinity** | |
| **Compass Bearing: 140** | | | | | | | | | |
| 1A 100' W | 1B 200' w | 1C | 2A 100' E | 2B 200' E | 2C | **Transects** | **1** | **2** | **3** |
| 0 | 0 | 0 | 0 | 0 | 0 | | 0 m | 0 m | 0 m |
| 60 | 60 | 60 | 60 | 60 | 60 | | 41.5 m | 37 m | |
| 120 | 120 | 120 | 120 | 120 | 120 | | 83 m | 74 m | |
| 180 | 180 | 180 | 180 | 180 | 180 | | | | |
| 240 | 240 | 240 | 240 | 240 | 240 | | | | |
| 275 | | not done | 300 | 300 | 300 | | | | |
| | | | 360 | 360 | 360 | | | | |
| | | | 382 | 420 | 420 | | | | |
| | | | | 480 | 480 | | | | |
| | | | | | 540 | | | | |
| | | | | | 573 | at sites of nekton sampling | | | |
| 1A at 2nd nekton sampling | | | | 1B at 3rd Nekton | | | | | |

| Vegetation Transect Locations | | | | | |
|---|---|---|---|---|---|
| **Good Harbor Marsh - Upper Study - North of Thatcher Road** | | | | | |
| **Gloucester, MA** | | **Upper Study Site** | | **Date: 8/14/13** | |
| **Compass Bearing: 22** | | | | | |
| 1A 32' | 1B 150' | 2A 65' | 2B 180' | 3A 215' | 3B 245' |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 30 | 30 | 30 | 30 | 30 |
| 60 | 60 | 60 | 60 | 60 | 60 |
| 90 | 90 | 90 | 90 | 90 | 90 |
| 120 | 120 | 120 | 120 | 120 | 120 |
| 150 | 150 | 150 | 150 | 150 | |
| 180 | | | | | |
| **Pore Water Locations along Vegetation Transects** | | | | | |
| 1A 32' | 1B 150' | 2A 65' | 2B 180' | 3A 215' | 3B 245' |
| 0' (creek) | 0' | 0' | 0' | 0' | 0' |
| 88' | 79' | 76' | 75' | 80' | 72' |
| 180' | 158' | 151' | 150' | 160' | 144' |
| **Nekton sampled** | | | | | |
| Upper 1: at creek divide | | | | | |
| Upper 2: 100' from Upper 1 towards Witham Street | | | | | |
| Upper 3: 200' from Upper 1 towards Witham Street | | | | | |

**Habitat Assessment Score (HAS)**

Form 1 and Form 5 (Appendix) were used to express habitat and water quality in a way comparable to the invertebrate community metrics and the ICI. Ten variables of habitat condition were used to compute an overall score, called the HAS. The HAS is expressed as a percentage of a theoretical optimal condition. The following procedures are used to compute the HAS:

1. The Form 1 information and best judgment were used to determine a score for each of the variables on Form 5. Scores ranged from zero to five, with zero = poor and five = excellent. Partial numbers were allowed to be used (i.e. 3.5). The score was then recorded in the appropriate column on Form 5.

2. The scores for each variable were summed and converted the total to a percentage. Conversion to % = total score for attributes/50 x 100

**Summary of ICI and HAS**

The Salt Marsh Invertebrate and Habitat Summary Graph were used as a graphical representation of the HAS and the ICI. The vertical axis of the graph represented the ICI and the horizontal axis represented the HAS. The graph provided a visual representation of salt marsh invertebrate community condition and provided some indication about the relative importance of habitat quality when marshes were plotted against the two axes.