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# Restoring Salt Marsh and Functions to Newly Acquired Shoreline in North Mill Pond, Portsmouth

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**Final Project Report**
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Ms. Heather Parker graciously allowed us to use her fresh water to help the plants survive following transplanting. Most of the plants were raised in a greenhouse at the UNH campus with the help of Evan Ehlrich, an undergraduate student at UNH. The Durham office of the Natural Resource Conservation Service harvested and transported rough cordgrass that was propagated at Big Flats Plants Materials Center in Corning New York. Jessica Whitmore created a wonderful workbook for the students as part of her Honors Project at UNH. Graduate students Alyson Eberhardt, Rob Vincent, Chris Peter and Jordan Mora all led student groups in field activities. David Price of the NH Department of Environmental Services' Wetlands Bureau helped with planning the project under DES Wetlands File # 2010-619.

**Summary:**
A berm of construction debris used to fill salt marsh and steepen the shoreline along North Mill Pond many decades ago was removed in 2010 after the land was deeded to the City. Removal of the berm reestablished regular tidal flooding to over 2,400 $ft^2$ of tidal marsh. From 2009 to 2011, the fifth grade classes at New Franklin School learned about the project and planted mussels, shrubs and marsh plants at the site. Plant survival was excellent in the low marsh (94%) and good in the high marsh (77%). By September 2011 (Year Two) plant cover increased to 42% in the low marsh and 13% in the high marsh. After the first growing season for the upper marsh (planted in May, 2011), cover reached 23%. Some fine-grained sediment was eroded from the surface of the high marsh due to low plant cover, but no linear features or erosion scours were observed. The site can be observed over time online, including construction and plant development at http://picturepost.unh.edu.

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## Project Description

An artificial berm was found covering salt marsh on a property recently acquired by the City of Portsmouth. The City Planning and Public Works Departments, Advocates for North Mill Pond, the fifth grade of the New Franklin School and UNH worked together to rehabilitate the shoreline. A low rip-rap wall was dismantled and fill materials were removed to restore the marsh and the transition from marsh to upland along the shoreline of the property at Mill Pond Way (Figure 1). This included re-grading the existing fill, replanting with native plants that typically grow in salt marshes (*Spartina* species) and the transition to upland (Seaside goldenrod and Marsh elder), and restoring ribbed mussels to the marsh. All aspects of the work were integrated into the spring science curriculum for fifth grade students at the New Franklin School (NFS) in 2010 and 2011. The site can be viewed over time online at http://picturepost.unh.edu.

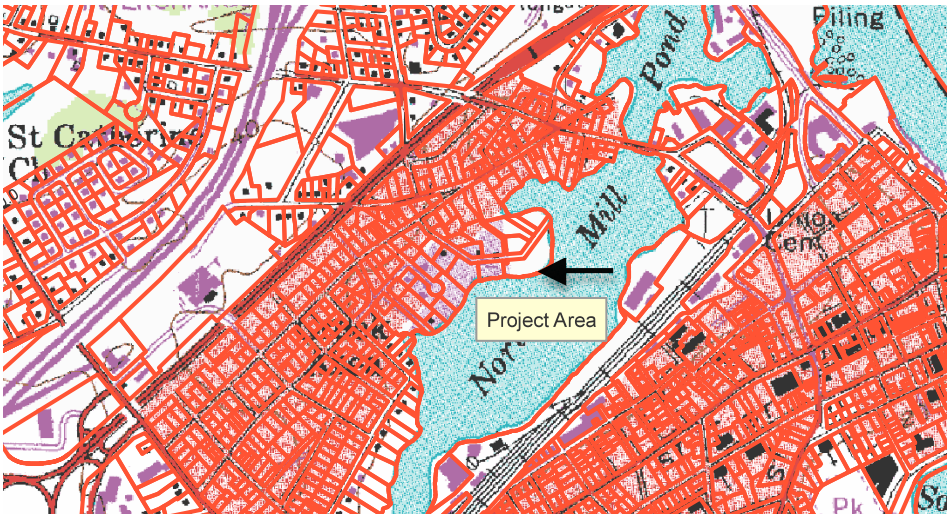



Figure 1. Locus map for property on Mill Pond Way, Portsmouth, NH.

## Activities and Results for 2010

**Year One Restoration:** On May 3, 2010 the City DPW removed the berm, re-graded the shoreline (Figure 2), and disposed of debris at the stump dump off Route 33. The removal was supervised by knowledgeable and experienced DPW staff, including Dave Allen. Some plants were removed from the debris and propagated at Jackson Estuarine Laboratory. Following fill removal, the entire

work area was covered with burlap staked to the exposed soils on May 4 (Figure 3). Natural wrack deposits were collected and bound by jute fabric and twine into rolls (4 to 6 inches in diameter, 4 feet long) and staked to the lower edge of the disturbed area to further reduce sediment movement into the pond. The berm removal area was approximately 15 by 160 feet (2,400 $ft^2$ or 223$m^2$).

Figure 2. Re-grading the shoreline. Note that two large rocks were replaced at the site.

Figure 3. Burlap covering exposed soils in work area; red cedar replanted on upland. Picture taken on May 5th, 2010.

Smooth cordgrass *(Spartina alterniflora*; 500 bare root seedlings) and 200 plugs of high marsh (Salt hay: *Spartina patens*, Salt grass: *Distichlis spicata*, Black grass: *Juncus gerardii*) were produced after removal from Adams Point Marsh and one month of growth at the JEL raised planting beds. The plants reserved from the berm site produced about 200 plugs and included: Salt hay, Black grass, Seashore alkali grass *(Puccinellia maritima)*, and Seaside goldenrod (*Solidago sempervirens)*.

In June of 2010 the fifth graders of NFS and community volunteers installed the plants at appropriate elevations. Soils disturbed by the berm removal were planted on two-foot centers with Smooth cordgrass (530 plants) at elevations appropriate for the low marsh and 450 plugs of high marsh plants in the upper intertidal zone (Figure 4). In addition, students planted coastal grass seed at the highest elevations rarely flooded by tides. On June 5th, community volunteers of ANMP planted marsh grasses as well as the coastal seed mix and completed the planting and site work (Figure 5). The marsh site and shrubs were watered with fresh water on this date and two more times in summer using Ms. Heather Parker's water.

Figure 4. New Franklin School students planting the new marsh, June 2, 2010. Photo Credit: Stephanie Parshall, Portsmouth Herald.

Figure 5. Planting and site work complete, June 5th, 2010.

**Monitoring:** Monitoring was done to document survival and development of cover by planted marsh grasses and upland shrubs as well as assess erosion control measures. Twenty plots were assessed in each marsh zone (low and high) for plant survival, cover and canopy height. Some soil winnowing was noted in the planting area in June of 2010 and minor amounts of sediment were observed collecting on the landward side of the jute baffles. Sediments were not apparent on the landward side of the sediment fence, which was removed on October 9th. No erosion features were observed in sediments on the site.

A coastal seed mix was scattered at upper elevations and covered with Jute (Figure 5), but the area may receive too much salt water flooding for these upper edge marsh plants to survive. A white layer of salt was observed on the soils of the upper areas covered with jute. Some seedlings were noted at the northern extreme of the site, but most new shoots at upper elevations were expanding from grasses along the upper edge of the work area (that is, not from the seeds).

Survival, cover and canopy height of planted plugs and bare root shoots were assessed on June 18th, soon after planting and on October 9th, after the first growing season to document survival and development of cover of planted marsh grasses and upland shrubs. The area was divided into

two linear zones or communities: low marsh where smooth cordgrass was planted, and high marsh where plugs of salt hay and other species were planted. Twenty plots were randomly selected using a random number table along each marsh zone (low and high) and located using a distance tape. Live and dead planting units were counted within a quadrat (0.71 by 1.41 m) placed perpendicular to the tape and ocular estimates of cover were made for each species. Canopy height, the height above the soil exceeded by 20% of the stems, was also recorded.

Survival and growth surpassed expectations for the student-planted marsh. The as-built assessment in June showed 89% survival of smooth cordgrass in the low marsh and 84% survival of salt hay and other perennials in the high marsh (Table 1). When revisited in October, survival rates were similar (94% in low marsh and 77% in the high marsh), but low marsh plants had grown substantially. Total cover of plants was 4% in June in the low marsh and by October cover had increased to 15%. Cover in the high marsh was 3% in June and 4% in October, but the increase was not significant. This may be because October was too late in the season to find many of the high marsh species (except salt hay) still alive.

Table 1. Monitoring data for Year One of planted marsh at Mill Pond Way, Portsmouth.

| Marsh Zone | Date 2010 | Survival (%) | Canopy Height (cm) | Smooth Cordgrass (% cover) | Salt Hay (% cover) | Total Live Vascular plants (% cover) |
|---|---|---|---|---|---|---|
| Low | June | 89 | - | 3.5 | 0.55 | 4.15 |
| Low | October | 93.8 | 74 | 13.9 | 1.05 | 15.10 |
| High | June | 84 | - | 0.05 | 1.40 | 3.00 |
| High | October | 76.9 | 15 | 0.00 | 3.50 | 3.85 |

**Activities and Results for 2011**

**Year Two Restoration:** Smooth cordgrass *(Spartina alterniflora*) and a variety of high marsh species, including: Salt hay (*Spartina patens)*, Salt grass (*Distichlis spicata*), Black grass (*Juncus gerardii),* Seashore alkali grass *(Puccinellia maritima)*, Marsh orach (*Atriplex patula*), Sea Lavender (*Limonium nashii*), Stiff-leaf quackgrass (*Agropyron pungens*), Marsh elder (*Iva frutescens)*, and Seaside goldenrod (*Solidago sempervirens*) were grown at the JEL planting beds and the UNH greenhouses from March to May. The plants were collected as seeds, seedlings and culms from a variety of locations across coastal New Hampshire. In addition, Rough cordgrass

(*Spartina pectinata*) that was grown from New Hampshire seeds at the USDA Big Flats Plant Materials Center in Corning, New York was harvested and held in cold storage before planting.

On May 20th, students examined the site and measured the elevation of the salt marsh across a shore normal transect as part of their investigations of landforms. They also examined salt marsh plants and animals in detail and built simple food chains, then compared their chains to coastal food webs. Students were each given a workbook to record observations and ideas (Appendix A). On May 24th and 25th, the two fifth grade classes each spent half days at the restoration site (Figure 6). They planted in total: 30 Smooth cordgrass plugs in the low marsh; 350 plugs of various plants at appropriate elevations in the high and upper marsh zones; and 30 Rough cordgrass bare root culms at the upper edge of the marsh. In addition, 5 shrubs were planted above the high tide line.

While some students were planting grasses, others were learning about and installing ribbed mussels (Figure 6). These long-lived shellfish are oriented in the mud so their byssal threads can attach to the base of a smooth cordgrass culm. Over 800 ribbed mussels were planted in the previously existing low marsh seaward of the restoration area.

Figure 6. Fifth grade students from New Franklin School adding high marsh plants to upper marsh (right) and ribbed mussels previously existing to low marsh (left) in May 2011.

**Monitoring:** Monitoring was performed to document development of the planted vegetation and natural processes on the site. Following removal of the berm, students created a profile of the re-graded site on May 7, 2010. The new shoreline profile is shown in Figure 7 with a similar profile made in 2009 prior to restoration. Both show elevations relative to the highest observable tide (HOT), as estimated in the field. Berm excavation and re-grading occurred between 2 and 8 meters on the chart. The new profile should allow unhindered tidal flooding of the site and support of native marsh vegetation.

Over the course of the two years following the re-grading of the shoreline, the site was examined for evidence of erosion. Aside from soil winnowing associated with low plant cover in the high marsh, no erosion features were observed in sediments on the site. The jute baffles placed along the lower edge of the excavation continued to degrade as planned, and smooth cordgrass was seen growing through them.

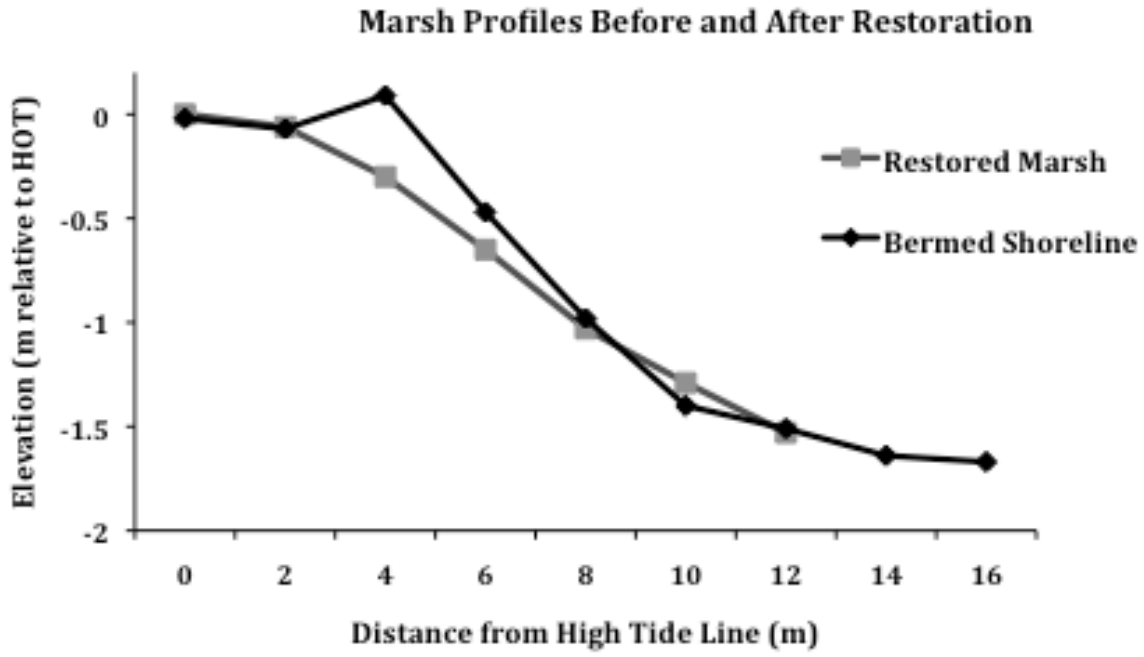



Figure 7. Shore normal profiles measured with a lazar level from the highest observable tide to the edge of the low marsh in 2009 (Bermed Shoreline) and in 2010 (Restored Shoreline).

Overall, the high survival of plants in Year One carried over to Year Two, but could not be quantitatively assessed because underground rhizomes produced new shoots indistinguishable from planting units (Figures 8 and 9). Figure 10 shows the planted low marsh on the left. In most areas it is indistinguishable from existing marsh, forming a continuous band along the pond shoreline. Note the position of the boulder with respect to the Smooth cordgrass over time by comparing Figure 10 with Figures 2 and 6).

Tufts of grasses and forbs in the high marsh are also shown to be expanding (Figures 9 and 10). The upper marsh shows clearly in Figure 10, as indicated by the lighter surface of the degrading burlap cover installed in 2010. It had been planted with plugs in 2011 (Figure 6) and these plugs are growing and expanding.

In the low marsh, development of the planted vegetation proceeded rapidly, increasing from 4% cover in June 2010 to over 40% cover at the close of Year Two in September 2011 (Table 2).

Figure 8. Low marsh with Smooth cordgrass and Salt hay. Note the multiple new shoots of cordgrass between planting units.

Figure 9. High marsh with Marsh orach, Sea blite (*Sueada linearis*) and Salt hay in the foreground. Note the coarse surface sediments.

Figure 10. Mill Pond Way restoration site after two growing seasons (September 2011). Low marsh cordgrass has expanded to surround boulder (see Figure 2). High marsh plants are established and expanding, but spread rates are slow in the stressful high marsh zone. The burlap from June 2010 can be seen in the upper marsh zone at right as a lighter band; it continues to decompose under the new high marsh plants that were added in 2011.

Algae in the low marsh were primarily Marsh felt (*Vaucherria* spp.), which can be seen as a dark green film on the soil surface among the cordgrass in Figure 8. *Vaucherria* increased to 3% cover in the high light of the exposed soil during the first growing season, but then fell by the second year as the cordgrass canopy closed. By the end of Year Two, canopy heights increased to 93 cm, shoots produced seed heads, and many plots appeared similar to existing marsh (Figure 10).

In the high marsh zone, drier conditions and rocky soil (Figure 8) may have led to lower survival than in the low marsh (Table 2). However, survival was greater than 75% in Year One and most plants appeared to survive the winter and expand during Year Two. At the end of the second growing season, cover had increased from 3% to 12.8% and that trend is expected to continue to about 80% cover by Year Four. Canopy heights increased from 15 to 17 cm in Year Two, but these high marsh plants typically do not grow much taller than 20 cm.

Table 2. Summary of monitoring data for planted marsh at Mill Pond Way, Portsmouth. Values represent averages of 20 randomly located plots.

| Marsh Zone | Monitoring Period | Sample Date | Survival | Canopy Height (cm) | Total live vascular plants | Algae | Bare/Rock/ Wrack |
|---|---|---|---|---|---|---|---|
| Low | As-Built | June, 2010 | 89 | - | 4.2 | 0.3 | 95.8 |
| Low | Year One | October, 2010 | 94 | 74.3 | 15.1 | 3.1 | 82.0 |
| Low | Year Two | September, 2011 | - | 93.0 | 42.1 | 1.2 | 55.5 |
| | | | | | | | |
| High | As-Built | June, 2010 | 84 | - | 3.0 | 0.0 | 96.2 |
| High | Year One | October, 2010 | 77 | 15.0 | 3.9 | 0.0 | 96.2 |
| High | Year Two | September, 2011 | - | 16.9 | 12.8 | 0.1 | 86.9 |
| | | | | | | | |
| Upper | Year Two | September, 2011 | - | 18.0 | 23.3 | 0.0 | 76.3 |

Failure of the coastal seed mix to sprout and grow led to planting a variety of species along the upper marsh zone in May 2011 (Figures 11 and 12). This zone is typically inhabited by a mixture of high marsh grasses and forbs as well as a few species typically found only here (e.g., Marsh elder, Rough cordgrass) or even higher in elevation (e.g., Stiff-leaf quackgrass). Cover of planted and existing vegetation in the upper marsh zone reached 23% in fall 2011 (Table 2).

Of the 16 upland shrubs that were planted in 2009 and 2011, two Beach plum (*Prunus maritima*) and one Bayberry (*Myrica pensylvanica*) appear to be dead; two Beach plum, three Bayberry, two chokecherry (*Prunus virginiana*), and six shadbush (*Amelanchier canadensis*) survive.

Figure 11. Marsh Elder in upper marsh.

Figure 12. Seaside goldenrod and Rough cordgrass (in flower) in the upper marsh.

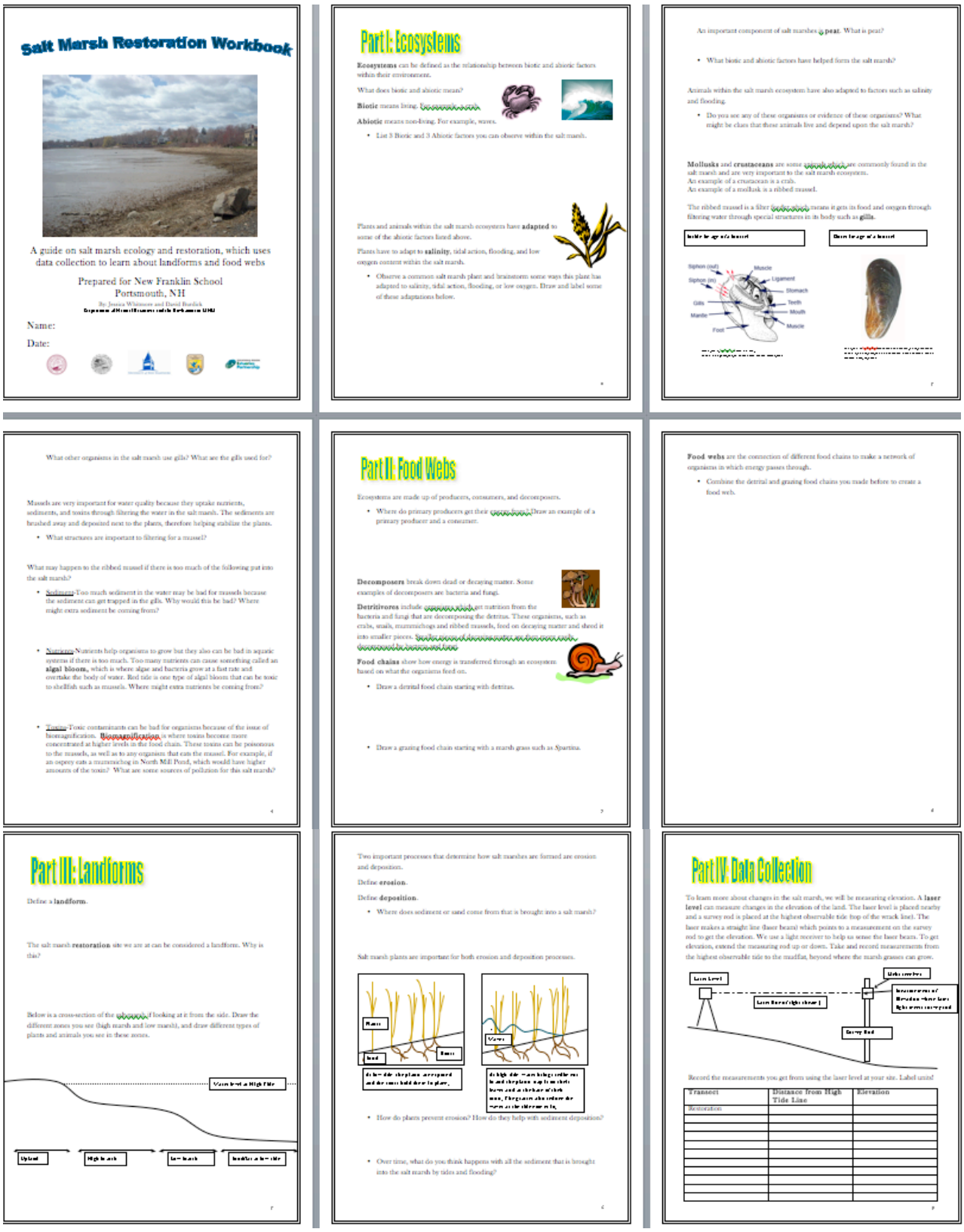
## Conclusions

Salt marshes degraded by fill along protected shorelines can be restored by simply removing the fill and replanting species tolerant of saltwater flooding at appropriate elevations. In this case, the restored area (over 2,400 $ft^2$) is greater than the area of sediment removal (2,240 $ft^2$) because the berm blocked tides from reaching the upper marsh. The degree of exposure will help dictate the scale and complexity of erosion control measures: a sediment fence and jute baffles did a good job controlling erosion and preventing mobilized sediments from leaving the site. The rapid canopy development within the low marsh further reduced erosion, but tidal action and rainfall removed fine-grained particles from the surface of the exposed sediment in the high marsh. In the upper marsh zone, a layer of jute fabric helped to hold fine sediment in place.

With instruction, fifth grade students can work together to successfully plant delicate grasses as well as hardy shrubs. Instructional aids like the workbook and PicturePost helped to formalize lessons and provide a broader context for the student experience. Plant survival in the low marsh surpassed expectations for a student-planted marsh. Survival of plants in the high marsh was lower, but exceeded 75%. The dry salty soils of the high and upper marsh zones reduced plant survival and prevented seeding success over the first summer. Low and high marsh zones were fortified with new plants and a variety of plants were added to the upper marsh in May 2011, followed by periodic watering to enhance survival. Plant cover increased in all marsh zones (low: 44%; high: 13%; and upper 23%) through the final Year Two monitoring in September 2011. Plant cover is expected to continue increasing for the next several years and the site should be able to maintain itself as a functioning tidal marsh into the future.

Over 2,000 ribbed mussels have been placed in the marsh since 2009. Not much is known about this long-lived species (annual growth patterns suggest many can reach 14 years or older) that filters pond water to obtain its food of plankton and detritus. Mussels from 2011 and earlier plantings were observed in fall 2011, but survival and growth rates were not measured.

Appendix A. Fifth grade workbook developed by Jessica Whitmore.



## Salt Marsh Restoration Workbook

A guide on salt marsh ecology and restoration, which uses data collection to learn about landforms and food webs

Prepared for New Franklin School
Portsmouth, NH

Name:

Date:

## Part I: Ecosystems

**Ecosystems** can be defined as the relationship between biotic and abiotic factors within their environment.

What does biotic and abiotic mean?

**Biotic** means living.

**Abiotic** means non-living. For example, waves.

- List 3 Biotic and 3 Abiotic factors you can observe within the salt marsh.

Plants and animals within the salt marsh ecosystem have **adapted** to some of the abiotic factors listed above.

Plants have to adapt to **salinity**, tidal action, flooding, and low oxygen content within the salt marsh.

- Observe a common salt marsh plant and brainstorm some ways this plant has adapted to salinity, tidal action, flooding, or low oxygen. Draw and label some of these adaptations below.

An important component of salt marshes is **peat**. What is peat?

- What biotic and abiotic factors have helped form the salt marsh?

Animals within the salt marsh ecosystem have also adapted to factors such as salinity and flooding.

- Do you see any of these organisms or evidence of these organisms? What might be clues that these animals live and depend upon the salt marsh?

**Mollusks** and **crustaceans** are some animals are commonly found in the salt marsh and are very important to the salt marsh ecosystem.
An example of a crustacean is a crab.
An example of a mollusk is a ribbed mussel.

The ribbed mussel is a filter feeder, means it gets its food and oxygen through filtering water through special structures in its body such as **gills**.

Inside image of a mussel

Outer image of a mussel

Siphon (out)
Siphon (in)
Gills
Mantle
Foot
Muscle
Ligament
Stomach
Teeth
Mouth
Muscle

What other organisms in the salt marsh use gills? What are the gills used for?

Mussels are very important for water quality because they uptake nutrients, sediments, and toxins through filtering the water in the salt marsh. The sediments are brushed away and deposited next to the plants, therefore helping stabilize the plants.

- What structures are important to filtering for a mussel?

What may happen to the ribbed mussel if there is too much of the following put into the salt marsh?

- Sediment: Too much sediment in the water may be bad for mussels because the sediment can get trapped in the gills. Why would this be bad? Where might extra sediment be coming from?

- Nutrients: Nutrients help organisms to grow but they also can be bad in aquatic systems if there is too much. Too many nutrients can cause something called an **algal bloom**, which is where algae and bacteria grow at a fast rate and overtake the body of water. Red tide is one type of algal bloom that can be toxic to shellfish such as mussels. Where might extra nutrients be coming from?

- Toxins: Toxic contaminants can be bad for organisms because of the issue of bioaccumulation. **Bioaccumulation** is where toxins become more concentrated at higher levels in the food chain. These toxins can be poisonous to the mussels, as well as to any organism that eats the mussel. For example, if an osprey eats a mummichog in North Mill Pond, which would have higher amounts of the toxin? What are some sources of pollution for this salt marsh?

## Part II: Food Webs

Ecosystems are made up of producers, consumers, and decomposers.

- Where do primary producers get their energy from? Draw an example of a primary producer and a consumer.

**Decomposers** break down dead or decaying matter. Some examples of decomposers are bacteria and fungi.

**Detritivores** include animals that get nutrition from the bacteria and fungi that are decomposing the detritus. These organisms, such as crabs, snails, mummichogs and ribbed mussels, feed on decaying matter and shred it into smaller pieces. Scientists call these smaller pieces detritus.

**Food chains** show how energy is transferred through an ecosystem based on what the organisms feed on.

- Draw a detrital food chain starting with detritus.

- Draw a grazing food chain starting with a marsh grass such as *Spartina*.

**Food webs** are the connection of different food chains to make a network of organisms in which energy passes through.

- Combine the detrital and grazing food chains you made before to create a food web.

## Part III: Landforms

Define a **landform**.

The salt marsh **restoration** site we are at can be considered a landform. Why is this?

Below is a cross-section of the marsh if looking at it from the side. Draw the different zones you see (high marsh and low marsh), and draw different types of plants and animals you see in these zones.

Water level at High Tide

Upland
High marsh
Low marsh
Intertidal zone below HT

Two important processes that determine how salt marshes are formed are erosion and deposition.

Define **erosion**.

Define **deposition**.

- Where does sediment or sand come from that is brought into a salt marsh?

Salt marsh plants are important for both erosion and deposition processes.

Roots
Soil
Roots

Water

- How do plants prevent erosion? How do they help with sediment deposition?

- Over time, what do you think happens with all the sediment that is brought into the salt marsh by tides and flooding?

## Part IV: Data Collection

To learn more about changes in the salt marsh, we will be measuring elevation. A **laser level** can measure changes in the elevation of the land. The laser level is placed nearby and a survey rod is placed at the highest observable tide (top of the wrack line). The laser makes a straight line (laser beam) which points to a measurement on the survey rod to get the elevation. We use a light receiver to help us sense the laser beam. To get elevation, extend the measuring rod up or down. Take and record measurements from the highest observable tide to the mudflat, beyond where the marsh grasses can grow.

Laser Level
Light receiver
Laser Beam (light shown)
Measurement of Elevation (how low light sensor is surveyed)
Survey Rod

Record the measurements you get from using the laser level at your site. Label units!

| Transect Restoration | Distance from High Tide Line | Elevation |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Scientists can see changes in ecosystems and landforms by using graphs. Graphs of elevation can show if the land is growing or getting smaller.

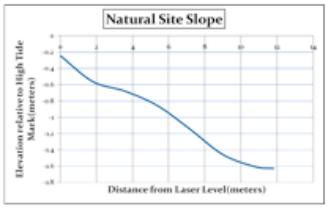
We will use the 2 sets of elevation data below and the data you collected to make our own graphs:

1. Elevation data for the Salt Marsh in its Natural state (Natural)
2. Elevation data for Salt Marsh before restoration (Berm)
3. Elevation data for Salt Marsh after restoration which you collected today (Restoration)

| Transect | Distance from High Tide Line | Elevation (relative to High Tide) |
|---|---|---|
| Natural | 0 | -0.25 |
| Natural | 1.8 | -0.56 |
| Natural | 3.6 | -0.68 |
| Natural | 5.4 | -0.86 |
| Natural | 7.2 | -1.13 |
| Natural | 9 | -1.66 |
| Natural | 10.8 | -1.81 |
| Natural | 12.6 | -1.83 |
| Berm | 0 | -0.02 |
| Berm | 2 | -0.07 |
| Berm | 4 | -0.09 |
| Berm | 5 | 0.09 |
| Berm | 6 | -0.67 |
| Berm | 7.2 | -0.98 |
| Berm | 9 | -1.6 |
| Berm | 11 | -1.81 |
| Berm | 13 | -1.84 |
| Berm | 13.2 | -1.87 |

To graph this data, we will put Distance on the x-axis and Elevation (Height) on the y-axis. X-axis means moving in the horizontal direction (left-to right) and Y-axis means moving in the vertical direction (up and down).

Here's an example using the Natural site data.




- Draw a new curve using the data you collected from the laser level today onto the same graph shown above.
- Are the curves similar or different?
- Why do you think they are similar or different between the Natural and the Restored site?

- To compare if there have been changes before and after restoration, we can draw two curves. Draw one curve using the Berm data and another curve using the Restoration data you collected today on the same graph below. Label your axes (x and y) with titles and numbers. The title of the graph is given for you.

Comparison of Berm vs. Restored Elevation Data at Mill Pond

- Are the curves similar or different?
- Why do you think they are similar or different between the Berm and the Restored site?

## Part V. Observation Section

This section is for any observations, definitions, or drawings you would like to remember from today.

## Glossary

**Abiotic**: non-living

**Adapt**: to change characteristics due to the environment or stresses

**Algal bloom**: when there are too many nutrients in a body of water, algae grow at a very fast rate and can be toxic

**Biomagnification**: the higher up in the food chain an organism is, the more toxins build up in their body

**Biotic**: living

**Consumer**: gets energy from eating other organisms

**Crustacean**: a group of organisms found in water and on land that have an exoskeleton, or a hard outer shell. An example is a crab.

**Deposition**: the process where sediment or sand is moved from one area to another and builds up

**Detritivore**: an organism that feeds on dead or decaying matter

**Detritus**: dead or decaying matter

**Ecology**: the study of the relationships between organisms in a community and their environment

**Ecosystem**: the relationship between biotic and abiotic factors within their environment

**Elevation**: the height of a landscape

**Erosion**: the wearing away of land due to wind, water, or ice

**Filter Feeder**: an organism that gets its food from straining water through their gills

**Food Chain**: shows how energy is transferred through an ecosystem based on prey and predator relationships

**Food Web**: a connection of food chains which shows how energy is transferred through the system based on prey and predator relationships

**Gills**: special organs found in many aquatic or semi-aquatic organisms to filter oxygen, food, and sediment from water

**Laser level**: a tool used to measure elevation in a landscape

**Mollusk**: a group of organisms that usually have hard outer shells but not always. They also are known as shellfish.

**Peat**: dead or decaying matter and sediment, found in the salt marsh and very good at absorbing water like a sponge

**Photosynthesis**: the process where plants make their own food in the form of sugars from water, sunlight, and carbon dioxide

**Primary Producer**: creates its own food using photosynthesis

**Restoration**: making changes to an altered landscape to bring it back to its natural conditions

**Salinity**: the concentration of salts in water

**Sea Level Rise**: the process where ocean levels around the world increase in height over the land on the coast

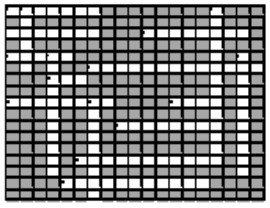
## Salt Marsh Word Find

- Use the given words and clues to solve these puzzles!

C B S C D S D M E R O S I O N
S E A L E V E L R I S E W S K
S F C U C X C B F T V R B L J
B U K B P J O E J X Q M L N T
R C T E P E M N R S X E G S L
L E A I K W P D X G Z O A Y B
R T S J R E D O R M H L C K G
D J J C R T S O R M T Y R T X
O I M G O F E F O M C D A F S
X O F G A R R D A E N S B D H
P O N W Y R A R E A C A S Q A
U O I A O C S T L I O Y J E K
U W Y Y P E H T I D A N H E L
D Y D N W D E M R O F D N A L
U N E A Q N K P A K N G T L J

CRAB
DECOMPOSER
DETRITUS
EROSION
FOODWEB
LANDFORM
MUSSEL
PEAT
RESTORATION
SALTMARSH
SEALEVELRISE
WETLAND

## Salt Marsh Crossword Puzzle



## Wetlands around the World

Mangrove wetlands are very similar to salt marshes in that they have many of the same functions and have a similar ecological community based on the detrital food web. Mangroves can be found on the coasts in the Caribbean, as well as other tropical parts of the world. Mangroves help to build land through trapping sediment and preventing erosion, just like the grasses do in a salt marsh. Instead of grasses, mangrove wetlands are comprised of trees and shrubs, which have special roots for getting oxygen. These roots are an example of how mangroves have adapted to their environment. Mangroves are also important habitat for many birds, fish, and shellfish. The mangrove oyster is similar to the ribbed mussel found in salt marshes in that it is a filter feeder and performs some of the same functions as a mussel. How do filter feeders help mangrove and salt marsh ecosystems?