Restoring Tidal Flow to a New England Salt Marsh

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INTRODUCTION

Salt marshes have experienced the brunt of human civilization for eons as they were diked for pasture or producing salt hay and less saltwater-dependent crops, filled for port, commercial, and residential development, used as landfills and to dispose of dredged material, ditched in efforts to reduce mosquito populations in coastal communities, or have had their connection to estuaries simply reduced or severed by roads and railroads. This was largely done because they were viewed as unproductive wastelands, public health hazards, or because their location was important for accessing deep water or connecting two points of land, or simply providing a desirable location for homes.

In the 1960s scientists studying coastal habitats started writing about the ecological significance of these wetlands in the United States in terms the public could understand (e.g., Goodwin 1961, Odum 1961, and Teal and Teal 1969). Consequently the public was becoming more informed of the importance of these wetlands to coastal fisheries as well as to migratory birds as they witnessed accelerating destruction of salt marshes for residential and other development. In the 1960s, state legislatures began passing laws to restrict development of these wetlands, first in New England states then elsewhere (see Tiner 2013 for a comprehensive review of the history of tidal wetlands).

Today salt marshes are among America's most valued natural resources and government agencies and non-government organizations (NGOs) are both actively involved in restoring these wetlands. Most cases of this restoration involve bringing back tidal flow and more saline conditions in one way or another. Where the marshes have been crossed by a road or railroad, tidal flow has either been eliminated or restricted to varying degrees that has greatly affected soil salinities and promoted growth of brackish and freshwater species. In many cases in the northeastern U.S., these crossings have led to a drastic change in plant composition and vegetation structure – from a diverse salt marsh community dominated by low-growing halophytic plants to a virtual monoculture of common reed (*Phragmites australis*) – a non-native[2] that favors less saline habitats and grows to 3.7 m (12 feet) or more in height under the best circumstances. Some options for restoring tidal flow in these situations include: 1) reconnecting the marsh to the adjacent estuary (where tidal flow was eliminated), 2) removing tidal gates, and 3) expanding the size of the existing culverts. These may be some of the simplest restoration projects from a construction standpoint, although concerns about increased flooding on private property surrounding the marsh is often the major hurdle to overcome.

A small restoration project in Massachusetts serves as one example of the effectiveness of simply restoring tidal flow can bring about a return of salt marsh vegetation to an area that had been colonized by common reed. While some restoration projects are initiated as mitigation for destruction of wetland elsewhere, this project was a "pro-active project" – simply done for the benefit of the environment - to restore native halophytic vegetation and reduce the extent of non-native common reed.

STUDY AREA

Cow Yard Marsh is located along the Little River in the town of Dartmouth, Bristol County, Massachusetts. The 6.7 hectare (16.6acre) marsh occurs in two sections: the lower marsh (connected directly to the river) and the upper marsh (crossed by a private access road, dividing the marsh into two units) (Figure 1). Historically the area served as pasture for livestock and a holding area for cattle that would be transported from a nearby dock to markets (Anne Eades, pers. comm. September 2021).

Connection to the Estuary

A 15-inch[3] round culvert connected the lower marsh to the river (yellow dot in Figure 1), while two 24-inch pipes (blue dots) connected the upper marsh with the lower marsh. By the 1990s, the 15-inch culvert had been damaged and was in need of repair. Over time, a significant portion of the lower marsh unit had become infested with common reed which appeared to be advancing into marsh interior. Since a stream also supplies significant freshwater to the marsh and Teal Pond to the east supplies groundwater, the restricted tidal flow also likely retained more fresh water than prior to private road construction which would have further promoted the expansion of common reed. Many salt marshes in the southern New England have a fringe of common reed due to freshwater runoff or groundwater discharge.

Adjacent landowners were concerned about the broken culvert, the stagnant water conditions and frequent foul odors likely a result of stagnant water conditions. They also wanted to improve utility access to their properties which would require approval from the Dartmouth Conser-

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[2]There is a native species called American common reed (*Phragmites australis* ssp. *americanus*), but its distribution is limited in the Northeast.

[3] English measures are used in some of the text for culvert sizes and where data came from other sources (e.g., Figure 1).

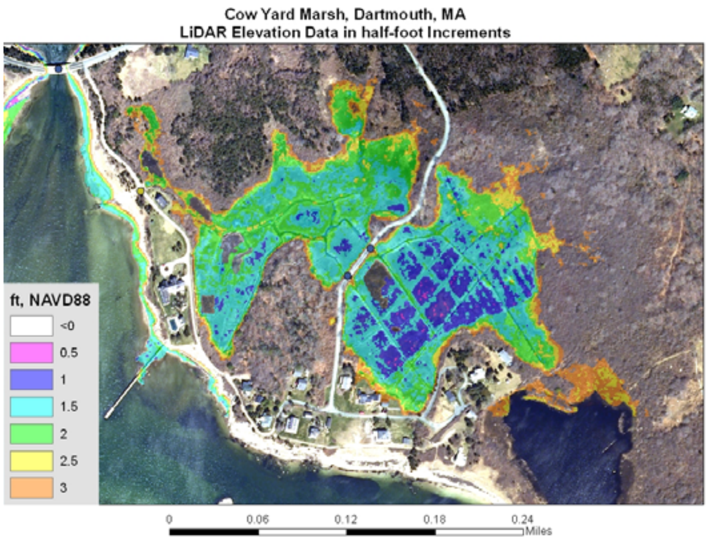

Figure 1. Aerial view of Cow Yard Marsh and relative elevations. Elevations above the North American Vertical Datum of 1988 give a perspective of the elevation differences within the Cow Yard Marsh. Higher elevations along the creek in the lower marsh likely resulted from mosquito ditch work. The dark blue areas represent salt pannes or pools in the marsh. The round yellow dot along the private road (Beach Lane) on the upper left shows the location of the main culvert connecting the marsh with Little River. Another road (Cow Yard Lane) divides the marsh into two units – lower marsh on the left and upper marsh on the right. (Note: The lower marsh is the subject of this paper.) The two blue dots on Cow Yard Lane represent culverts connecting the two units. Teal Pond is on lower right. (Source: Massachusetts Division of Ecological Restoration)

vation Commission, so the Commission became involved with the work and added its perspective – salt marsh restoration to the project. While residents were mostly worried about odors, the Commission was concerned about marsh health and reducing the spread of common reed and restoring native salt marsh vegetation as much as possible.

INITIAL ACTION TAKEN – FIRST PHASE OF RESTORATION

In 1992, the broken culvert for the lower marsh was replaced with a 19” x 30” elliptical pipe while the culverts for the upper unit were replaced by two 24” x 36” elliptical pipes. This was done without any serious analysis of the restriction. Simply expanding the connection should have a beneficial effect. Sometime later, co-author Mike O’Reilly (the Conservation Commission agent at the time) recognized that the *Phragmites* was beginning to show signs of dieback as evidenced by a “gray haze” produced by the stems of dead reeds and decided it might be useful to document the process.

Baseline Vegetation

In 1995, we established 15 study areas in the lower marsh to document the baseline conditions for informal monitoring of future changes. Sampling locations were chosen to represent areas with varying amounts of common reed, ranging from sparse cover to virtual monocultures (Figures 2-5). No sampling was done in areas solely represented by native species. At each site 2-4 nested plots (0.46m x 0.46m or 1.5ft x 1.5ft each) were evaluated for plant species, cover, and number and average height of *Phragmites* stems. Four plots were examined at the first two locations but due to time considerations sampling was reduced to two plots per site. Results are shown in Tables 1 and 2. Six species were recorded in the plots: *Phragmites australis*, salt hay grass (*Spartina patens*), salt grass (*Distichlis spicata*), smooth cordgrass-short form (*Spartina alterniflora*), common three-square (*Schoenoplectus pungens*), and Olney’s three-square (*Schoenoplectus americanus*). *Phragmites* cover varied from 5 to 100%, while the other species occurred in significant amounts depending on location with *Schoenoplectus* more abundant in areas of strong freshwater influence (Table 1). *Phragmites* density ranged from 8 to 348 stems/m^2 (Table 2; Figures 2-4). In addition to the plots, a few photographs were taken to document the 1995 conditions (Figures 2-5). Informal monitoring over the next few years revealed some dieback of common reed and the return of some salt marsh but it was not considered as significant a response as the Commission had hoped for. Further work would be required.

NEXT STEPS – SECOND PHASE OF RESTORATION

The Commission then worked with the Dartmouth Natural Resources Trust (DNRT) and others to better evaluate the degree of tidal restriction and determine what additional measures needed to be taken.

A preliminary site inspection was conducted by the Commission on February 15, 2001 and determined that the initial assessment would focus on the culvert that linked the marsh to the Little River. On that day the predicted tide should have flooded the marsh, but no flooding was observed. Further observations and measurements on April 9, 2001 showed that the flow into the marsh failed to attain

Figure 2. Plot 2A on October 31, 1995: mostly *Spartina patens* with some *Phragmites*. (R. Tiner photo)

Figure 3. Mike at Plot 9B (a virtual monoculture of *Phragmites)* on October 31, 1995. (R. Tiner photo)

Figure 4. General location of Plot 15B in late summer of 1995 (just before initiating study), looking west from Cow Yard Lane – a robust stand of *Phragmites* (R. Tiner photo)

Figure 5. View of eastern section of Cow Yard Marsh on October 31, 1995, looking toward Plots 9 through 12. (R. Tiner photo)

Plot #	Pa	Sp	Ds	SaS	Schp	Scha	April 2018 Observations
1A	10	100					No Pa; SaS and Sp
1B	25	100					No Pa; SaS and Sp
1C	50	100					No Pa; SaS and Sp
1D	10	100					No Pa; SaS and Sp
2Aa	25	95					No Pa; SaS and Sp
2Ab	25	95					No Pa; SaS and Sp
2Ac	10	100					No Pa; SaS and Sp
2Ad	25	100					No Pa; SaS and Sp
2Ba	75	30					No Pa; SaS and Sp
2Bb	75	30					No Pa; SaS and Sp
3A	20	2	90				Sp, SaS, and Ds
3B	25	10	80				Sp, SaS, and Ds
4A	15	100			1		No Pa; SaS and Sp and Geukensia
4B	25	85			20		No Pa and Sphp; SaS and Sp and Geukensia
5A	30	100					No Pa; SaS and Sp
5B	30	95					No Pa; SaS and Sp
6A	30			80			No Pa; SaS and Sp
6B	60	30		30			No Pa; SaS and Sp
7A	25	60	25	1			No Pa or Ds; SaS and Sp
7B	5	100	40		t		No Pa, Ds and Schp; SaS and Sp
8A	10	100					-----
8B	80	100					-----
9Aa	10		40		40		No Pa, Ds and Schp; SaS and Sp
9Ab	25		20		60		No Pa, Ds and Schp; SaS and Sp
9Ba	25	5				50	No Pa; Scha – 60% Sp – 20%
9Bb	100	t				20	No Pa; Scha – 90% Sp = 5%
10Aa	5	t	90		5		No Pa, Ds and Schp; SaS and Sp
10Ab	20		70		20		No Pa, Ds and Schp; SaS and Sp
10Ba	50	t				60	No Pa and Scha; SaS and Sp
10Bb	50	5				50	No Pa and Scha; SaS and Sp
10Ca	40					80	No Pa and Scha; SaS and Sp
10Cb	70					70	No Pa and Scha; SaS and Sp
11A	20	75				40	No Pa and Scha; SaS and Sp
11B	40	50			50		No Pa and Scha; SaS and Sp
12Aa	15	100		5			No Pa; SaS and Sp
12Ab	5	100		5			No Pa; SaS and Sp
12Ba	100					t	No Pa; SaS and Sp
12Bb	100					5	No Pa; SaS and Sp
13A	90	t		5			-----
13B	100			15			-----
14Aa	50	100					No Pa; SaS and Sp
14Ab	30	100			t		No Pa; SaS and Sp
14Ba	60	25				60	No Pa; SaS and Sp
14Bb	90	25				40	No Pa; SaS and Sp
15Aa	75	50		20			No Pa; SaS and Sp
15Ab	75	20		25			No Pa; SaS and Sp
15Ba	100	40					No Pa; SaS and Sp
15Bb	100	25					No Pa; SaS and Sp

Table 1. Percent cover for study plots in October 1995 and general observations in April 2018. Each plot was 0.46m x 0.46m. Pa – *Phragmites australis*, Sp – *Spartina patens*, Ds – *Distichlis spicata,* SaS – *Spartina alterniflora* (short form), Schp – *Schoenoplectus pungens*, and Scha – *Schoenoplectus americanus.*

Plot #	# of Stems per plot	Density per m²	Average Height (m)
1A	6	29	1.04
1B	15	71	0.91
1C*	18	86	0.97
1D	10	48	0.66
2Aa	19	90	0.76
2Ab	11	52	0.97
2Ac	7	33	0.83
2Ad	9	43	0.91
2Ba*	59	281	0.84
2Bb*	73	348	1.14
3A	12	57	0.84
3B	12	57	1.19
4A	1	8	1.63
4B	7	33	1.37
5A	9	43	1.35
5B	17	81	0.84
6A	13	62	1.37
6B*	16	76	1.35
7A	20	95	0.81
7B	2	10	1.22
8A	4	19	1.04
8B*	14	67	1.98
9Aa	1	8	1.35
9Ab	6	29	1.32
9Ba	4	19	2.01
9Bb*	23	110	2.03
10Aa	4	19	1.45
10Ab	9	43	1.27
10Ba*	18	86	1.12
10Bb*	24	114	1.22
10Ca	7	33	1.63
10Cb*	27	129	1.75
11A	12	57	0.91
11B	17	81	1.07
12Aa	21	100	1.63
12Ab	11	52	0.99
12Ba*	68	324	1.17
12Bb*	60	286	1.37
13A*	18	62	2.08
13B*	24	114	2.64
14Aa*	22	105	1.27
14Ab	13	62	1.45
14Ba*	21	100	2.36
14Bb*	19	90	2.36
15Aa*	39	186	1.12
15Ab*	55	262	1.55
15Ba*	62	295	2.31
15Bb*	67	319	1.27

Table 2. Density and height of *Phragmites* at sampling locations in October 1995. Density is rounded off to nearest whole number. Plots marked by asterisk (*) had 50% cover or more by *Phragmites.* Plot size was 0.46m x 0.46m.

the expected height and that the outflow was also restricted producing a damming effect that failed to allow sufficient drawdown at low tide (Figure 6). Scouring at the culvert was also observed, providing further evidence of restriction – a 4.6 m (15-ft) wide scour depression on the marsh side of the culvert demonstrated restricted outflow. This reduced flushing would continue the retention of freshwater and maintain common reed, thereby limiting the re-establishment of salt marsh vegetation. There were minimal effects at the other culverts, so the focus of the restoration project would be on restoring full tidal flow via the marsh's connection to Little River.

REVISITING THE SITE – VEGETATION RESPONSE

On April 24, 2018, we revisited the site. While we were able to locate a few of the wooden stakes most were gone. Nonetheless when we walked through the marsh, virtually all of the *Phragmites* was gone (Table 1). Almost all of the study plots are now occupied by a combination of *Spartina alterniflora*–short form and *Spartina patens.* In addition, the presence of the Atlantic ribbed mussel (*Geukensia demissa*) was conspicuous at Plot 4. All this provides evidence of more frequently flooded and more saline conditions.

This restoration has allowed the marsh to follow vegetation patterns similar to other southern New England salt marshes where smooth cordgrass is becoming more abundant in former upper high marsh zones in response to rising sea-levels (e.g., Warren and Niering 1993; Donnelly and Bertness 2001). Figures 7 and 8 show what the marsh looks like today. Without question, the project was successful at bringing back salt marsh vegetation to portions of the lower unit that were invaded by common reed and pushing common reed back to the marsh fringes and where the stream empties into the marsh (Figure 9).

LESSONS LEARNED

The monitoring we considered was not part of a permit requirement so follow-up was delayed until we decided to take time to revisit the site. Having witnessed the before-after scenes, upon reflection, it would have been better if we had established a formal plan for monitoring that would have directed us to track the changes in vegetation at some frequency. Annual visits, for example, would have allowed us to ensure that the stakes were still in place. It would have been worthwhile to re-evaluate the plots in 2001

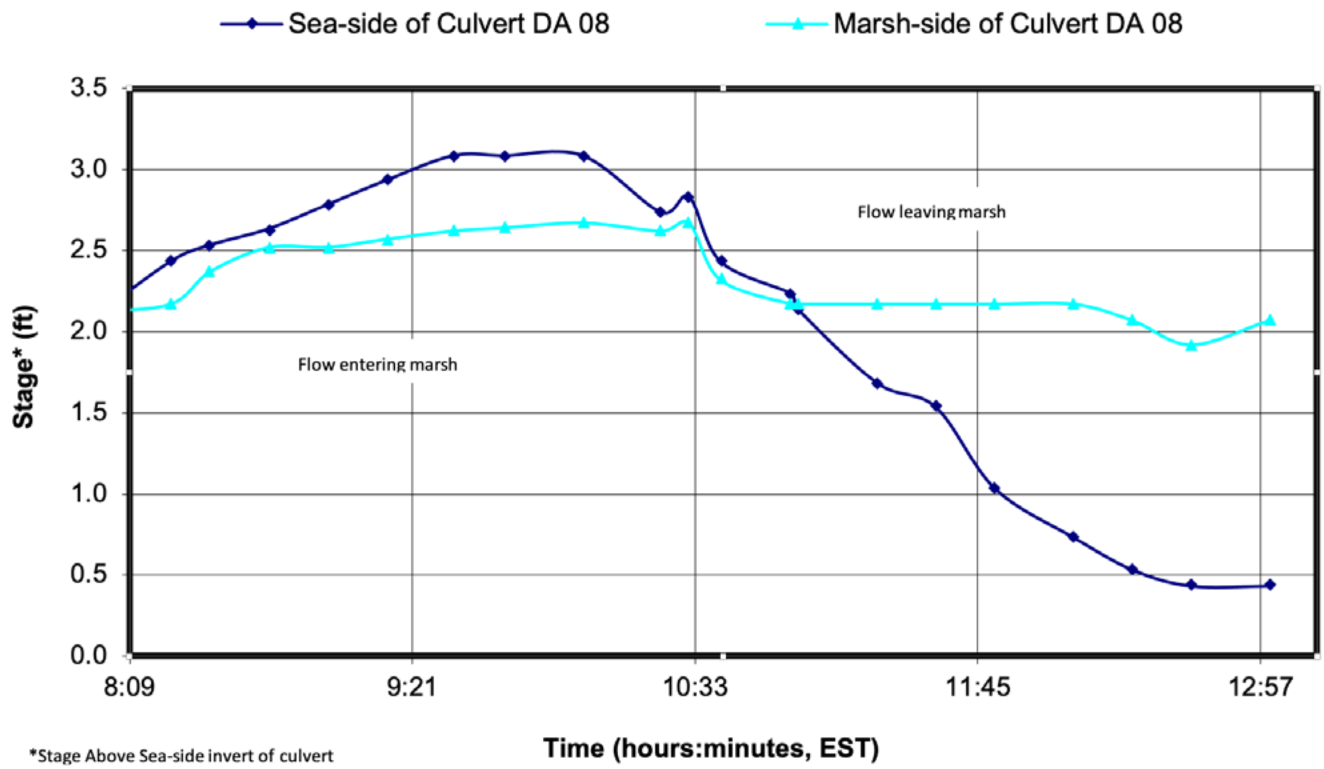

Figure 6. Tidal hydrograph showing water levels on both sides of the culvert connecting the lower marsh to Little River. (Source: Earth Tech 2001) At this point, the Dartmouth Conservation Commission secured cooperation and support from a number of public and NGO entities: Bristol County Mosquito Control, Dartmouth Natural Resources Trust, Buzzards Bay Coalition, Massachusetts Division of Ecological Restoration, and the Buzzards Bay National Estuary Program. With funding from the Fish America Program (NOAA Restoration Center) and DNRT, permitting was done to replace the 19" x 30"" pipe with a 3' x 4' box culvert to increase tidal flow to the marsh complex. In March 2004, the box culvert was installed.

when the second phase of restoration was being planned. We should have also GPSed the stake locations. (Note: Subsequent studies for other projects that were designed to monitor long-term changes in coastal vegetation in response to rising sea level have included GPS locations; see Tiner and Veneman 2014.) With today's technology, a time series of aerial images captured by drones could visually capture gross vegetation changes at the site (e.g., Madden et al. 2015). Also on-the-ground photos should have been captured at plot locations and other key locations to document visual changes in the marsh landscape over time. All this takes time and commitment, so plan accordingly.

THE FUTURE – NEED FOR MONITORING?

Restoring tidal flow to the Cow Yard Marsh has eliminated much of the *Phragmites* from the high marsh zone of the lower marsh unit and has allowed the marsh to function more like a typical New England salt marsh. Native salt marsh vegetation has replaced *Phragmites* in much of the high marsh within two decades. Common reed, however, is still present along the fringes and also in the easternmost portion of the lower marsh unit but this was expected due to strong freshwater influence from an entering stream, local groundwater discharge, and runoff from higher ground.

While the restoration project has been a success, it will be interesting to see what happens to this marsh in the future. With rising sea-level, many questions arise. Will smooth cordgrass replace the existing salt hay grass? Will "high marsh" become "low marsh"? If so, how long will it take? Will the high marsh migrate into areas dominated by the *Phragmites* on the eastern end of the lower marsh unit and eventually into any lowland forest? Will pannes and pools continue to increase, creating more open water in the marsh interior? Will the lower marsh unit eventually be converted to mud flat? What is happening in the upper unit of Cow Yard Marsh? And finally will there be a call for action to reverse the process initiated by the restoration to maintain a salt marsh community?

Ironically, the persistence of this salt marsh like oth-

Figure 7. Panoramic view of same scene shown in Figure 5 as of October 2021. *Phragmites* has been pushed back to the east but remains where fresh water enters the marsh. (M. O'Reilly photo)

Figure 8. View of Plots 15A and B (stakes visible) looking northwest from Cow Yard Lane, in September 2021 – no Phragmites. (Note: This is the same area shown in Figure 4 but view is to northwest rather than to west.) (M. O'Reilly photo)

Figure 9. Aerial view of Cow Yard Marsh in the fall of 2021. A few scattered patches of *Phragmites* (coarse-textured whitish areas) remain in the eastern marsh unit with the most extensive reed marsh occurring along the woodland border (lower right). It also appears that there is some dieback of woody vegetation along the northern edge of the marsh (on middle right of image) plus an increase in the number of pannes dominated by glassworts (Salicornia; red areas) and pools (open water) when compared to a 2001 aerial photograph (Figure 10). (Source: Dartmouth Natural Resources Trust)

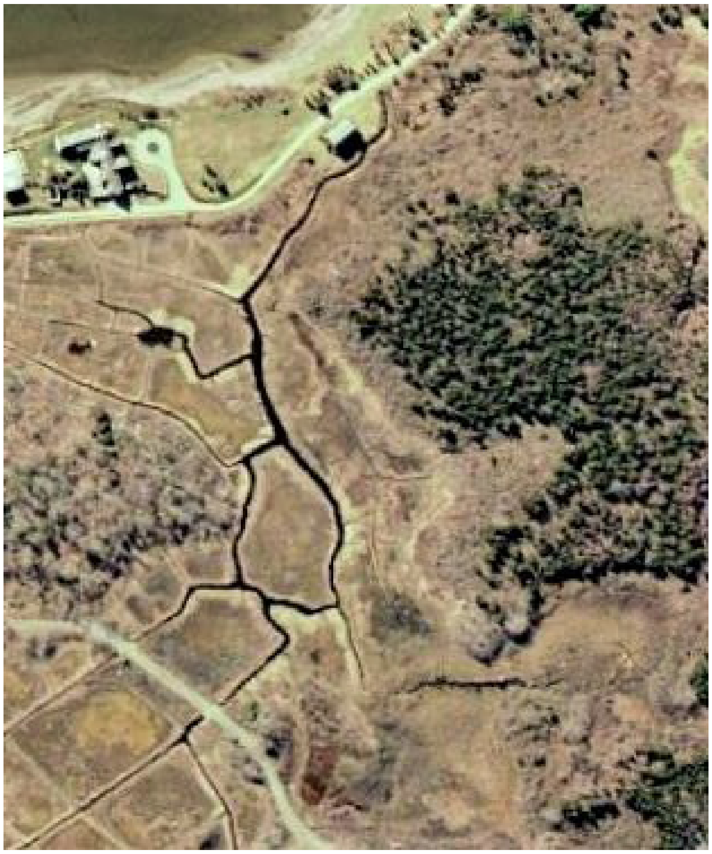

Figure 10. April 2001 image of the lower unit of Cow Yard Marsh. (Source: Mass GIS OLIVER)

ers may be in jeopardy due to rising sea-level (e.g., Crosby et al. 2016). This presents an interesting situation for the Dartmouth Conservation Commission and others – one that should require close attention. Perhaps a more formal monitoring program should be established to track future changes in the plant communities in both units of Cow Yard Marsh.

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