Site Specific Intensive Monitoring (SSIM) of a Raritan River tidal marsh

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Objective

The New Jersey Department of Environmental Protection, in partnership with the Mid-Atlantic Coastal Wetlands Assessment (MACWA), has developed a 4-tiered method to assess the health and status of coastal marshes and was designed to provide rigorous, comparable data across the Mid-Atlantic region. The objective of this project was to install a Tier 4 Station along the upper tidal reaches of the Raritan River in an area of *Phragmites australis*-dominated marsh. *Phragmites australis*-dominated marsh was selected as this type of tidal wetland is comparatively under-represented in the larger network of SSIM Tier 4 sites statewide. Tier 4 involves the installation of three surface elevation tables (SET) to measure rates of elevation change and vertical accretion of the marsh surface. Intensive monitoring of the condition and function of the marsh vegetation and broader biotic community will be conducted along a series of transects associated with the SETs.

Monitoring Network Design and Rationale

The spatial layout of the individual Tier 4 station is displayed in Figures 1 & 2. The sites are only accessible by boat from the south bank of the Raritan River. Due to the thickness of the *Phragmites australis* stand at these sites, it was difficult to traverse the site without first cutting a path through the reeds, which required some physical disturbance of the site. It is not expected that the trail will have a lasting effect on the SET measurements due to the 20+m distance from the riverbank to the SET and the narrow, winding nature of the path (Figure 3). The disturbed path was offset from the site of SET installation by ~ 5 m to create a straight line transect from the river edge perpendicular into the marsh. Systematic quadrats were sampled on one side of the path and biomass plots and soil cores were sampled from the other side of the path to minimize disturbance of the systematic quadrats (Figure 4). The establishment of only one vegetation transect deviates from the general MACWA SSIM protocol of a main transect and an additional two transects related to the Marker Horizons. This decision was made due to the difficulty navigating/traversing through the dense *Phragmites* and to minimize subsequent disturbance.

Figure 1. Location of Surface Elevation Tables (SETs) at the Raritan River Tier 4 Station on New Brunswick River Conservation Lands.

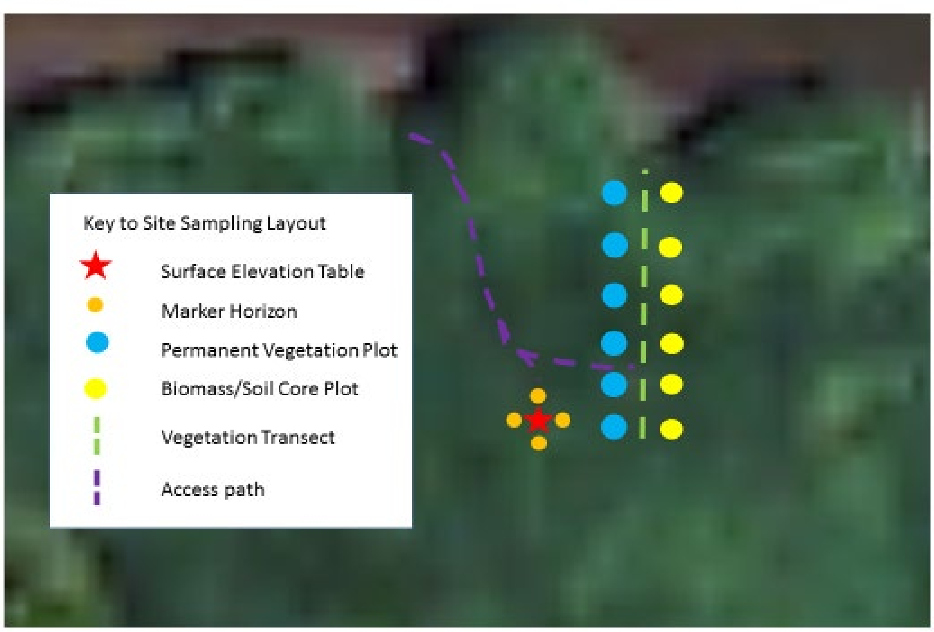

Figure 2. Layout of individual Raritan River Tier 4 Station on New Brunswick River Conservation Lands.


Figure 3. Access path to SETs

Figure 4. Path adjacent to vegetation monitoring transect.

SET Monitoring

The SET and marker horizons were installed on June 24-25, 2019 using protocols established by the US Geological Survey, National Park Service and NOAA, as described in the document "The surface elevation tables and marker horizon technique: A protocol for monitoring wetland elevation dynamics" (https://pubs.er.usgs.gov/publication/70160049) (Lynch, 2015) (Figure 5). Four marker horizons were installed around each SET; one in each cardinal direction (N-E-S-W), ~2-3 m from the SET rod. To install the marker horizons, a ground area ~50 cm x 50 cm was scraped to bare earth and a PVC quadrat was laid out. White play sand was deposited and lightly tamped down to a depth of 2.4 cm above ground surface. On July 21, 2020, the locations of the SET stations were surveyed to a higher level of accuracy with a Leica RTK survey instrument (Datum WGS84).

Figure 5. SET immediately post installation.

The sites were revisited on 10/24/2019 to inspect the sites and collect an initial set of experimental readings to make sure everything was in proper working order. These data were not archived with the NJTWMN due to residual site disturbance from the installation. The SETs were revisited to collect readings on (7/24/2020, 8/26/2020, 10/27/2020, 5/6/2021, 10/5/2021, 6/28/2022, 5/23/2023 and 8/29/2023. SET data were read and collected by Dr. Richard Lathrop (Appendix A. Tables 1-5) with either postdoctoral researcher/graduate students Laura Reynolds, Emelie Einhorn, or Kendall Eldredge as notetakers. No Marker horizon data were collected until 2022, as there was not sufficient accretion of sediment consistently across all the sites. The whole lower Raritan River floodplain including the SET area had been severely inundated during Hurricane Ida. The phragmites marsh vegetation was blown over in large sections. The SETs were unharmed when checked on October 5, 2021. Large pieces of plant material or plastic debris were removed if they impeded the pins from resting on the marsh surface. Due to a limited number of

Falcon tubes which were used as coring devices, only two Marker Horizons were cored for each subplot.

Marsh Condition & Function Monitoring

Vegetation

We referred to the Site Specific Intensive Monitoring (SSIM) protocols established by MACWA in developing the marsh vegetation and soil sampling procedures. The SSIM protocols are described in the following documents: SSIM SOPs; MACWA QAPP Umbrella). The specific sampling procedures that were employed are outlined below.

One transect of permanent plots established in 2019 for each of the 3 SET study plots (1 for each SET) was revisited to monitor the vegetation community composition and status (Figure 2). Data were collected on the following parameters for a series of quadrats (0.25m x0.25m = 0.0625m2 in size) along the transects: plant species richness, percent cover, peak canopy height (Table 1), light intensity (Table 2) at the surface, and ribbed mussel density. Data were collected on August 26, 2020, at a period in the growing season where the *Phragmites* has reached its greatest height and flowering. Data was collected by Richard Lathrop, Laura Reynolds, and Emelie Einhorn. Vegetation data were collected in 2020. However, no vegetation data were collected in 2021, 2022 or 2023.

For all three SETS, the only vegetation species observed was *Phragmites australis*. No Ribbed mussels (*Geukensia demissa*) were observed.

Table 1. Vegetation monitoring data collected at permanent vegetation monitoring quadrats (0.25 x 0.25m = 0.0625m2). The transect is numbered with 0 starting close to the SET and then increasing towards the river. Live and dead stems were counted, vegetation cover percentage was determined and assigned a class (lowest 1-6 highest), and three individual *Phragmites australis* plants from outside the quadrat were cut at the base and measured for length.

SET 1					
Stem Count *Phragmites australis*			8/26/2020		
Transect Length	Living	Dead		Cover Class	Flower
0m	1	0m	3	5	Yes
5m	7	5m	19	5	Yes
10m	11	10m	20	5	Yes
15m	5	15m	11	4	Yes
Height of 3 tallest plants (cm)					
0m	344	330	337		
5m	330	339	334		
10m	359	362	345		
15m	342	343	340		
SET 2					
Stem Count *Phragmites australis*			8/26/2020		
Transect	Living	Dead		Cover Class	Flower
0m	3	0m	14	4	Yes
5m	9	5m	23	6	Yes
10m	7	10m	3	4	Yes
15m	3	15m	10	5	Yes
20m	10	20m	3	5	Yes
25m	10	25m	15	6	Yes
30m	7	30m	17	6	Yes
Height of 3 tallest plants (cm)					
0m	383	372	406		
5m	353	355	394		
10m	351	371	382		
15m	363	374	366		
20m	370	377	389		
25m	422	411	400		
30m	380	393	402		

Table 1 continued.

SET 3					
Stem Count *Phragmites australis*			8/26/2020		
Transect	Living	Dead		Cover Class	Flower
0m	14	0m	18	6	Yes
5m	13	5m	12	4	Yes
10m	8	10m	21	4	Yes
15m	11	15m	25	4	Yes
20m	6	20m	13	5	Yes
25m	17	25m	30	5	Yes
30m	9	30m	27	4	Yes
35m	5	35m	22	4	Yes
40m	10	40m	17	5	Yes
45m	8	45m	14	4	Yes
Height of 3 tallest plants (cm)					
0m	322	340	345		
5m	350	360	374		
10m	340	342	355		
15m	328	332	358		
20m	324	332	374		
25m	352	366	367		
30m	343	354	370		
35m	340	343	403		
40m	396	409	412		
45m	375	389	401		

Table 2. Light Intensity. Using a LI-191R Line Quantum Sensor, light intensity penetrating the base of the quadrat was collected at each cardinal direction (North, South, East, and West). Initial measurements were taken before taking 15, 30, 45, and 60 second averages. Calibration measurements were collected in an open canopy setting. All results are reported in µmol s^{-1} m^{-2}. All measurements were collected on August 26, 2020; conditions were sunny with no cloud cover.

SET 1					
LICOR	8/26/2020				
time (AM)	plot #	15s (umol)	30s (umol)	45s (umol)	60s (umol)
9:21	open	851.9	863.4	862.7	867.8
9:25	0m	10.05	10.42	10.65	10.31
9:27	5m	18.05	18.99	16.64	18.92
9:29	10m	12.26	13.87	11.8	11.85
9:33	15m	9.29	8.8	8.86	9.24
SET 2					
LICOR	8/26/2020				
time (AM)	plot #	15s (umol)	30s (umol)	45s (umol)	60s (umol)
9:44	open	1081	1084.9	1097	1114.7
9:53	0m	27.05	25.37	25.39	26.84
9:57	5m	62.12	59.43	60.07	56.62
10:00	10m	20.98	23.81	24.98	19.94
10:03	15m	8.82	8.82	8.12	7.17
10:06	20m	26.41	22.14	21.62	18.44
10:09	25m	5.16	7.43	6.3	8.35
10:12	30m	3.83	4.11	4.08	4.15
SET 3					
LICOR	8/26/2020				
time (AM)	plot #	15s (umol)	30s (umol)	45s (umol)	60s (umol)
10:53	open	1386.3	1383.8	1394	1412.7
11:00	0m	187.92	166.97	199.72	221.6
11:03	5m	87.52	93.59	92.53	90.26
11:06	10m	136.76	180.84	178.87	185.4
11:09	15m	64.83	68.5	74.93	72.91
11:12	20m	80.82	92.7	130.08	118.08
11:15	25m	85.28	87.1	88.41	88.46
11:18	30m	67.79	70.89	68.55	69.61
11:20	35m	200.9	197.21	213.4	216.6
11:23	40m	278	228.6	172.74	209.3
11:27	45m	56.72	56.89	64.33	55.64

Water

A continuous water quality monitoring station had provided data on temperature, turbidity, pH, salinity, dissolved oxygen and chlorophyll at a water quality monitoring station 2.5 km upstream (Latitude: 40.488701, Longitude: -74.433651). A technical malfunction took the station out of commission in mid-August 2020. Due to COVID, we were unable to access the site to service the station for the remainder of 2020. The mooring and sensors were retrieved but were badly damaged and need to be replaced. In the interim, replicate 1 liter grab samples were collected 10m offshore from the end of the SET monitoring transect (Table 3) and brought to the Rutgers Soil Testing Lab for chemical analysis (Table 4).

Table 3. Water quality sampling locations for May 6, 2021.

	Lat	Long
Raritan #1	40.491138	-74.407281
Raritan #2	40.490580	-74.405441
Raritan #3	40.489964	-74.402737

Table 4. Lower Raritan River water quality data (May 6, 2021). The minimum detectable limit for ammonium was rated at 0.003 mg/L ammonium-N (ND = non-detects).

5/6/2021 Sample ID	pH	P mg/L	K mg/L	Ca mg/L	Mg mg/L	Fe mg/L	Ammonium -N mg/L	Nitrate-N mg/L	Electrical conductivity mmho/cm
Raritan #1	7.35	0.1	2.9	27.1	9.8	0.25	ND	1.2	0.40
Raritan #2	7.37	0.2	2.9	27.5	9.9	0.26	ND	1.2	0.41
Raritan #3	7.35	0.2	2.9	28.0	10.0	0.28	ND	1.2	0.41
10/5/2021									
Raritan #1	7.08	0.25	4.04	34.06	15.27	0.67	0.4	1.2	0.68
Raritan#2	7.08	0.14	3.97	33.87	15.18	0.52	0.2	1.1	0.68
ND = not detected									

No water samples were collected in 2022 or 2023.

Data Organization and Archiving

The data collected above were organized into a series of data tables along with accompanying documentation on field collection and subsequent laboratory protocols and archived at the Center for Remote Sensing and Spatial Analysis (CRSSA). The SET data were also sent to the New Jersey Tidal Wetland Monitoring Network (NJTWMN) for archiving.

Appendix A: SET data for Lower Raritan for 2021-2023

Table A1. SET Data Collection: 5/6/2021

5/6/2021		Rick Lathrop	Units= mm	
SET1				
Bearing	North	West	South	East
Pin	1	3	5	7
1	130	131	128	131
2	136	135	124	129
3	139	129	123	137
4	129	128	125	113
5	133	128	123	139
6	137	127	114	135
7	143	128	112	137
8	148	122	120	137
9	136	129	122	156

5/6/2021		Rick Lathrop	Units= mm	
SET2				
Bearing	North	West	South	East
Pin	1	3	5	7
1	135	145	120	130
2	132	130	123	119
3	122	133	121	128
4	137	126	136	129
5	115	137	116	124
6	115	122	111	114
7	131	141	102	105
8	141	133	116	110
9	139	118	111	113

5/6/2021		Rick Lathrop	Units= mm	
SET3				
Bearing	North	West	South	East
Pin	1	3	5	7
1	143	157	155	157
2	135	158	153	154
3	146	149	139	144

4	119	155	145	134
5	125	133	153	144
6	129	149	122	146
7	143	149	143	135
8	132	140	137	130
9	143	142	142	172

Table A2. SET Data Collection: 10/5/2021

10/5/2021		Rick Lathrop	Units= mm	
SET1				
Bearing	North	West	South	East
Pin	1	3	5	7
1	141	140	130	133
2	132	140	125	142
3	138	138	127	132
4	143	128	135	133
5	136	128	127	148
6	142	129	107	154
7	148	124	127	145
8	146	130	125	140
9	141	125	129	143

10/5/2021		Rick Lathrop	Units= mm	
SET2				
Bearing	North	West	South	East
Pin	1	3	5	7
1	146	122	136	120
2	145	112	108	125
3	123	114	120	130
4	122	121	117	131
5	119	129	106	130
6	119	135	100	116
7	126	115	109	117
8	105	103	113	128
9	116	122	118	126

10/5/2021		Rick Lathrop	Units= mm	
SET3				
Bearing	North	West	South	East
Pin	1	3	5	7
1	135	145	147	149
2	132	151	148	144
3	133	146	147	143
4	128	155	146	139
5	126	146	140	141

6	121	144	145	136
7	114	145	147	143
8	117	143	144	140
9	115	148	145	137

Table A3. SET Data Collection: June 28, 2022

6/28/2022		Rick Lathrop	Units= mm	
SET1				
Bearing	North	West	South	East
Pin	1	3	5	7
1	131	130	117	136
2	136	128	111	140
3	127	129	103	137
4	125	110	116	123
5	130	110	121	155
6	140	117	120	131
7	131	115	124	127
8	147	127	122	134
9	133	125	119	127
Marker Horizons (Cut Plugs)				
	18	17	15	15
	18	18	14	22

6/28/2022		Rick Lathrop	Units= mm	
SET2				
Bearing	North	West	South	East
Pin	1	3	5	7
1	140	120	116	113
2	148	118	101	124
3	111	124	100	127
4	111	119	106	125
5	117	127	76	120
6	118	125	114	109
7	130	133	101	112
8	127	128	109	111
9	119	127	121	95
Marker Horizons (Cut Plugs)				
	10	15	10	--
	11	14	9	--

6/28/2022		Rick Lathrop	Units= mm	
SET3				
Bearing	North	West	South	East

Pin	1	3	5	7
1	153	147	147	140
2	146	143	149	138
3	143	131	140	134
4	187	137	149	132
5	156	147	140	139
6	115	144	144	135
7	131	144	148	144
8	126	143	150	137
9	122	141	145	127
Marker Horizons (Cut Plugs)				
	8	8	8	15
	11	8	12	14

Table A4. SET Data Collection: 5/23/2023

5/23/2023		Rick Lathrop	Units= mm	
SET1				
Bearing	North	West	South	East
Pin	1	3	5	7
1	125	134	117	141
2	128	129	114	158
3	115	125	119	151
4	127	125	118	140
5	126	113	126	133
6	146	120	127	125
7	140	114	126	137
8	147	121	130	125
9	142	122	116	134
Marker Horizons (Cut Plugs) (Units = mm)				
	LRR1MHN	LRR1MHW	LRR1MHS	LRR1MHE
	18	20	18	15
	Missing	19	11	17

5/23/2023		Rick Lathrop	Units= mm	
SET2				
Bearing	North	West	South	East
Pin	1	3	5	7
1	139	127	122	115
2	122	130	115	117
3	109	133	115	128
4	120	121	120	121
5	142	118	116	140
6	131	130	115	139
7	114	136	109	124
8	130	128	110	104
9	106	119	116	125
Marker Horizons (Cut Plugs) (Units = mm)				
	LRR2MHN	LRR2MHW	LRR2MHS	LRR2MHE
	16	17	15	**
	18	15	16	**

** This marker horizon could not be located after repeated attempts.

5/23/2023		Rick Lathrop	Units= mm	
SET3				
Bearing	North	West	South	East
Pin	1	3	5	7
1	154	152	150	147
2	133	145	150	132
3	132	140	150	143
4	142	155	153	144
5	140	152	144	154
6	143	151	151	142
7	149	151	134	149
8	117	147	154	142
9	119	137	148	150
Marker Horizons (Cut Plugs) (Units = mm)				
	LRR3MHN	LRR3MHW	LRR3MHS	LRR3MHE
	5	5	8	10
	5	10	8	13

Table A5. SET Data Collection: 8/29/2023

8/29/2023		Rick Lathrop	Units= mm	
SET1				
Bearing	North	West	South	East
Pin	1	3	5	7
1	134	138	122	134
2	142	137	123	139
3	137	137	121	131
4	135	127	125	122
5	137	131	120	130
6	141	126	121	133
7	145	130	129	132
8	145	125	124	141
9	145	128	117	134

8/29/2023		Rick Lathrop	Units= mm	
SET2				
Bearing	North	West	South	East
Pin	1	3	5	7
1	125	126	114	113
2	123	121	117	115
3	116	132	113	121
4	109	124	116	127
5	106	122	119	128
6	121	130	118	124
7	128	123	113	120
8	129	123	117	113
9	130	113	118	99

8/29/2023		Rick Lathrop	Units= mm	
SET3				
Bearing	North	West	South	East
Pin	1	3	5	7
1	149	147	145	143
2	156	146	147	145
3	153	146	146	145
4	139	154	150	132

5	146	151	149	151
6	145	150	148	144
7	136	145	145	144
8	136	141	143	134
9	134	145	142	135