memo

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Date | 9 March 2011

To | Chad Anderson

cc | Andrea Plevan; Jay Michels

From | Meghan Jacobson

Regarding | Green Lake Eurasian Watermilfoil Study

Data Collection:

Eurasian watermilfoil (EWM) and other macrophyte biomass data were collected by Chad and Sara (MFCRWD) at 30 total sites in Green Lake on 8 September 2010. Site selection was determined using the median depth of 81 EWM sites permitted by the DNR for treatment efforts by the Green Lake Property Owners Association (GLPOA) in 2010: 8 feet. Using a bathymetric map and GIS software, the first 8 foot deep site was chosen at random, and the 29 subsequent sites were selected by the GIS software based on equidistant points on the 8 foot contour around the lake (Figure 1).

Data Analysis:

Of 30 surveyed sites, EWM was present at only 8 sites representing 0.5% - 42.5% of the total macrophyte biomass. Low abundance and biomass of EWM may be due to treatment efforts of EWM by the GLPOA that same year. Therefore, survey sites in close proximity (i.e., less than 500 feet) to a treated site were also included in our analysis as a site with EWM present, assuming that treatment for EWM meant that EWM was present at that location prior to treatment (Figure 1).

Proximity of the 30 survey sites to nearby stormwater outfalls was calculated using GIS as distance to the single nearest stormwater outfall, disregarding proximity to other stormwater outfalls. Sediment samples were collected at each survey site and measured for total Kjeldahl nitrogen (TKN), total phosphorus (TP), total organic carbon (TOC), pH, and fraction of gravel, sand, silt, and clay. At the 8 sites where EWM was present, EWM and non-EWM vegetation was collected, dried, and weighed. The data are summarized in Table 1.

Major Findings:

Continued on the next page.

Hypothesis 1: Nutrient and sediment loading from stormwater inlets provide an environment more hospitable for EWM propagation.

To test this hypothesis we looked to see if nutrients and fine sediment fractions are higher at sites where EWM was present because higher nutrients and fine sediments may enhance EWM propagation. The **direction** of the relationships between sediment parameters or the proximity to stormwater inlets and the presence or absence of EWM supports this hypothesis, but **the relationships are not statistically significant**. Average sediment nutrient concentrations (TKN, TP, TOC) and the average fraction of sand, silt, and clay were greater at sites where EWM was present than at sites where EWM was not present (Table 2 and Figure 2). The average distance to the nearest stormwater inlet was lower at sites where EWM was present than at sites where EWM was not present. However, these relationships were not statistically significant ($P < 0.10$). The lack of statistical significance may be due to treatment of EWM that occurred prior in the same year as the sample collection for this study, or a sample size too small to determine statistical significance for the variability of data collected. While the statistical tests do not support the hypothesis, because the directions of the relationships between sediment parameters and the presence or absence of EWM were as predicted, the data do not reject the hypothesis either.

Hypothesis 2: Stormwater inlets increase nutrient and sediment loading.

Results from linear regressions between sediment and vegetation parameters with distance to the nearest inlet for **all sites** suggest that the fraction of sediment silt and clay increased with decreasing distance to the nearest stormwater inlet (statistical significance at $P < 0.05$). Sediment TKN and TP increased and the fraction of sediment gravel decreased with decreasing distance to the nearest stormwater inlet; however these relationships were not statistically significant (Table 3 and Figure 3). These data support the hypothesis that stormwater inlets increase nutrient and sediment loading. However, the dry weight of EWM and the total vegetative biomass both tended to increase with decreasing distance to the nearest stormwater inlet, with only total vegetative biomass statistically significant (P-value = 0.05). This suggests that increased nutrient loading from stormwater inlets may provide an environment more hospitable to all aquatic vegetation, and not necessarily just EWM.

However, the percent of EWM increased with decreasing distance to the nearest stormwater inlet, but this relationship was not statistically significant (Figure 3J). Therefore, to test whether increased nutrient and sediment loading from nearby stormwater inlets might increase the biomass of EWM as a percent of total vegetative biomass, linear regressions were performed between sediment parameters and the fraction of EWM as a percent of total biomass for **only the 8 sites where EWM was present** (Table 4 and Figure 4). The only statistically significant relationship was with sediment TP (P-value <0.05), with percent of EWM increasing as sediment TP increased (Figure 4B). The variability of the data around the linear regressions between other parameters and the percent of EWM were too great to make any ecologically relevant conclusions.

<u>Conclusions:</u>

- Treatment of EWM during the study season likely confounded the results.
- The results are not statistically conclusive, although the results do not reject the hypotheses.

- Potential additional study: Select a lake that has not been treated for EWM (or other aquatic plants) and in which EWM has recently invaded. Monitor over multiple years the relationship between stormwater outfall location (including stormwater flow), EWM propagation, and sediment characteristics.

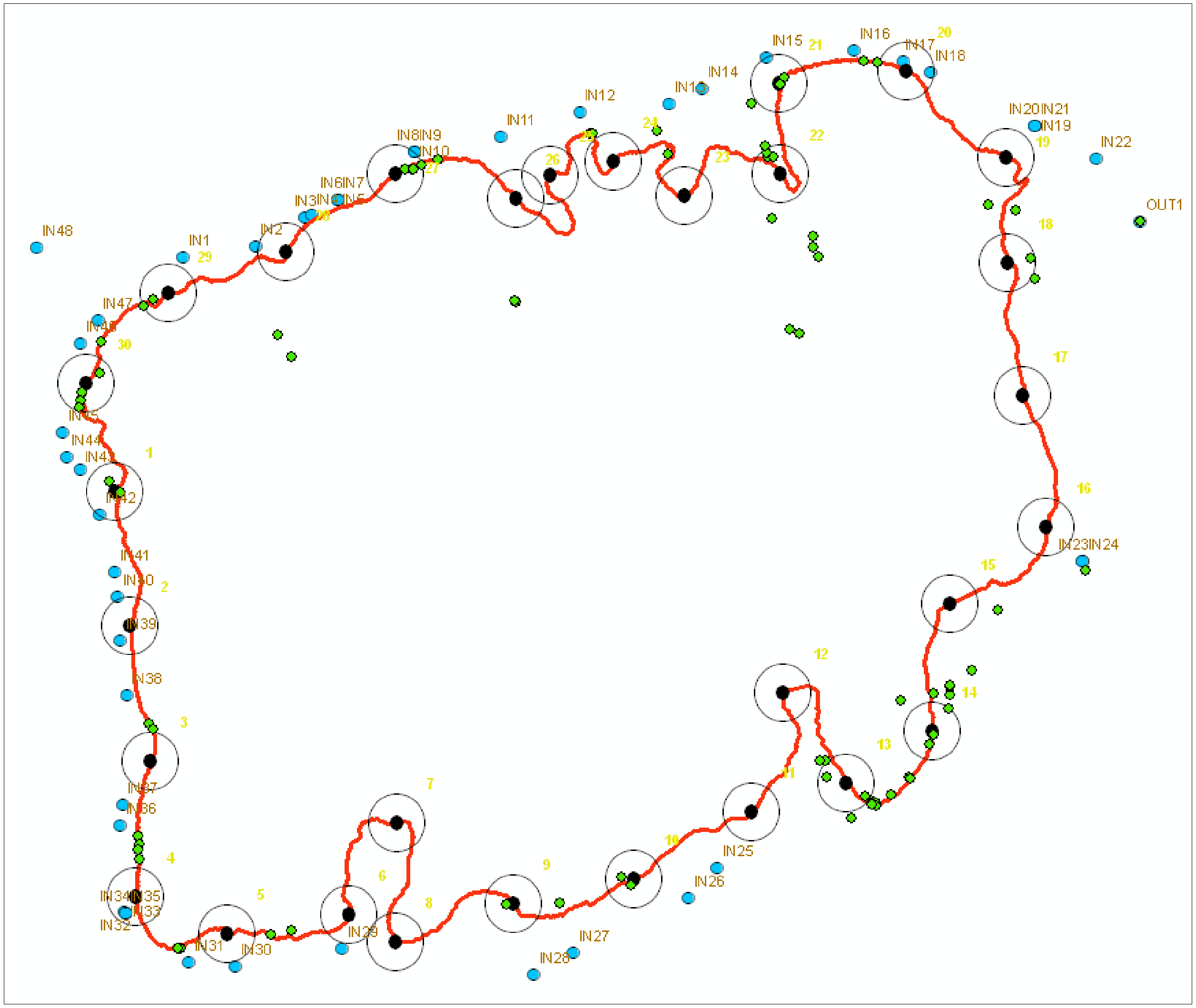


Figure 1. Location of EWM survey sites (black circles) showing 500 foot radius, treated sites for EWM (green circles), and stormwater outfalls (blue circles) in Green Lake

Table 1. Summary of sediment, inlet, and macrophyte data from 2010 survey, Green Lake.

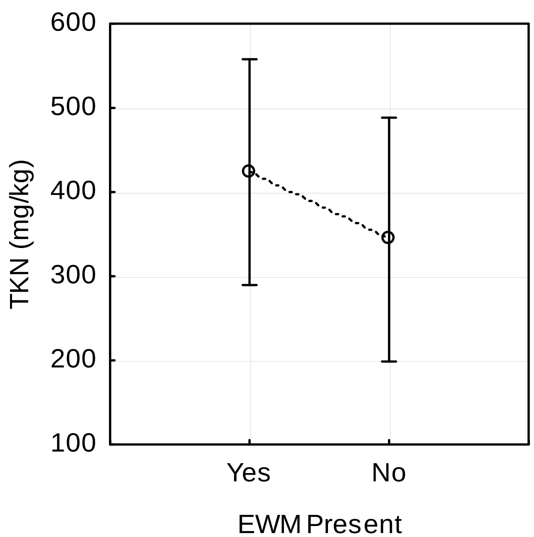
	Sediment								*Inlet*	*Vegetation*					
Site	**TKN (mg/kg)**	**TP (mg/kg)**	**TOC (mg/kg)**	**Gravel (%)**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**pH**	**Nearest inlet (feet)**	**EWM Present**	**EWM Weight (g)**	**Non-EWM Weight (g)**	**Total Biomass (g)**	**EWM (% Total Biomass)**	**Notes**
1	837	1,030	2,290	20.5	54.4	16.1	9.0	9.51	500	Y	82	111	193	42.5	
2	230	335	5,080	0.0	59.4	22.5	18.1	9.20	326	N					
3															No data
4	271	162	1,410	0.0	90.8	7.6	1.6	7.75	351	Y	48	234	282	17	
5	1,060	248	4,930	0.8	78.4	18.4	2.4	8.51	621	Y	1	205	205	0.5	
6	435	199	1,760	0.0	91.6	4.8	3.6	8.25	641	N					
7	180	163	1,140	60.7	37.6	0.9	0.8	8.93	2,527	N					
8	447	298	5,490	57.7	26.1	8.1	8.1	9.21	993	N					
9	334	*14,200*	3,190	4.0	56.0	23.6	16.4	9.34	1,339	Y	4	149	153	2.6	TP outlier excluded
10	268	289	1,500	43.3	54.1	1.4	1.2	8.34	1,028	Y	5	122	127	3.9	
11	250	219	1,090	33.6	63.9	1.3	1.3	8.72	1,208	N					
12	463	309	6,070	45.9	49.7	3.2	1.2	8.50	3,441	N					
13	330	185	2,580	18.5	75.4	4.9	1.2	7.93	2,864	Y					
14	331	118	3,120	3.1	94.2	1.1	1.6	8.04	4,140	Y					
15	321	95	2,100	34.6	59.4	3.1	2.9	8.23	2,524	N					
16	250	239	1,960	1.1	93.5	2.8	2.6	8.37	891	Y	1	202	202	0.5	
17	176	122	312	14.2	83.7	0.8	1.3	8.77	3,186	N					
18	128	225	1,750	40.5	42.5	11.4	5.6	8.74	2,463	Y					
19	911	309	4,600	0.0	48.8	40.6	10.6	7.71	767	N					
20	463	245	2,560	1.0	82.5	12.0	4.5	8.31	203	Y	41	200	241	17	
21	575	255	2,140	0.0	86.0	7.1	6.9	7.93	539	Y	7	310	317	2.2	
22															No data
23															No data
24	411	138	665	1.0	95.1	2.6	1.3	8.39	1,085	N					
25	220	101	629	0.6	95.2	2.9	1.3	7.67	1,136	N					
26	78	162	1,220	35.5	53.0	8.8	2.7	7.96	1,166	N					
27	598	241	5,700	45.1	26.5	20.9	7.5	7.98	525	Y					
28															No data
29	316	168	2,020	19.0	76.7	3.3	1.0	8.06	704	Y					
30	171	268	1,660	1.2	57.6	27.5	13.7	8.72	740	Y					

Table 2. Sediment and stormwater inlet predictors of EWM Presence (ANOVA p-values and direction of relationship):

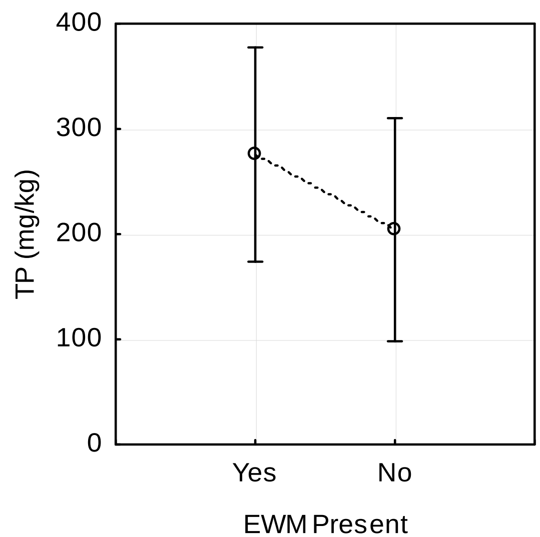
Predictor	ANOVA p-value	Greater when EMW is:
Sediment TKN (mg/kg)	0.41	present
Sediment TP (mg/kg)	0.32	present
Sediment TOC (mg/kg)	0.87	present
Sediment pH	0.75	not present
Sediment Gravel (%)	0.25	not present
Sediment Sand (%)	0.52	present
Sediment Silt (%)	0.46	present
Sediment Clay (%)	0.64	present
Distance to nearest inlet (feet)	0.39	not present

Figure 2. ANOVA LS Means statistical analyses of categorical variable EWM presence and the following dependent variables: A. Sediment TKN (mg/kg), **B.** Sediment TP (mg/kg), **C.** Sediment TOC (mg/kg), **D.** Sediment pH, **E.** Sediment Gravel (%), **F.** Sediment Sand (%), **G.** Sediment Silt (%), **H.** Sediment Clay (%), and **I.** Distance to nearest inlet (feet).

A.



B.



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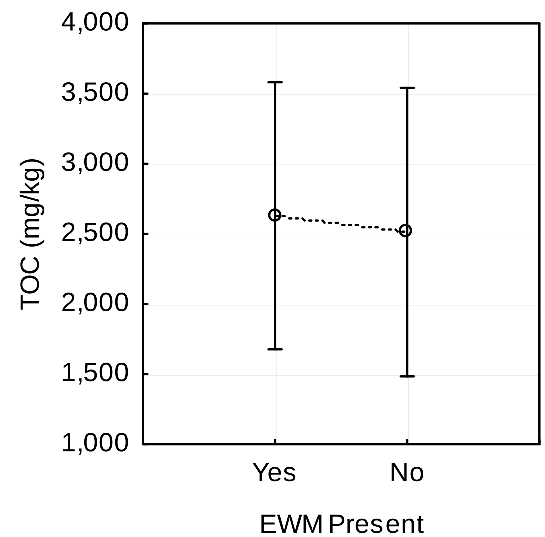

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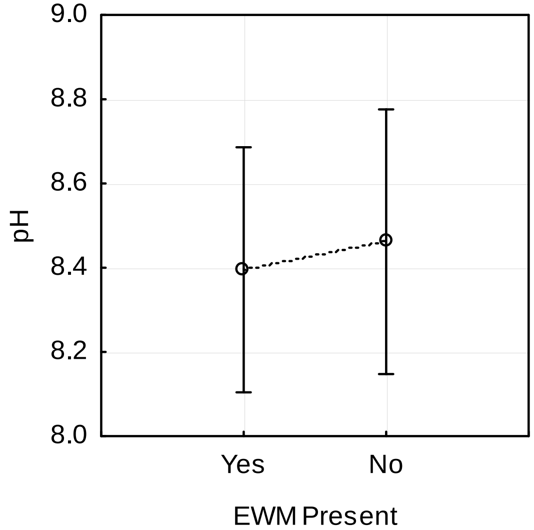
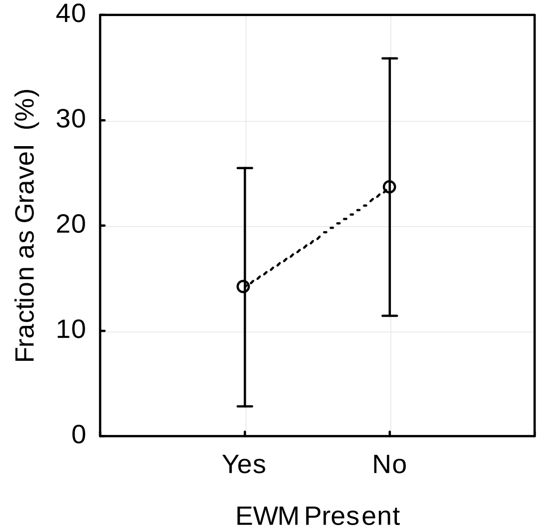
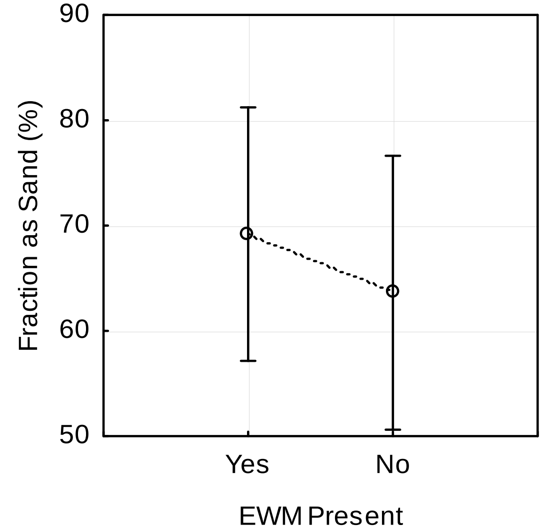

9.0
8.8
8.6
8.4
8.2
8.0
pH
Yes
No
EWM Present

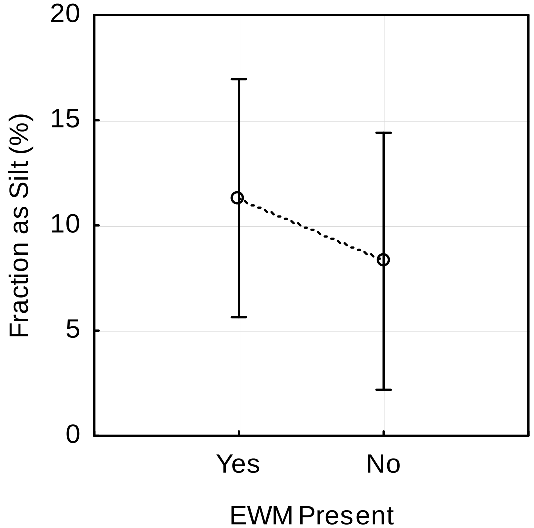
E.


40
30
20
10
0
Fraction as Gravel (%)
Yes
No
EWM Present

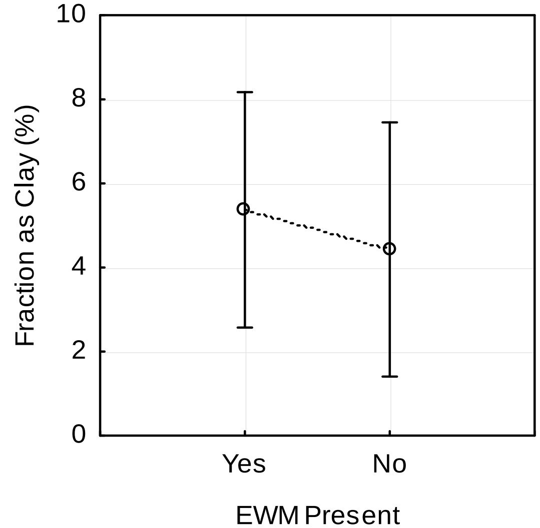
F.


90
80
70
60
50
Fraction as Sand (%)
Yes
No
EWM Present

G.


20
15
10
5
0
Fraction as Silt (%)
Yes
No
EWM Present

H.


10
8
6
4
2
0
Fraction as Clay (%)
Yes
No
EWM Present

I.

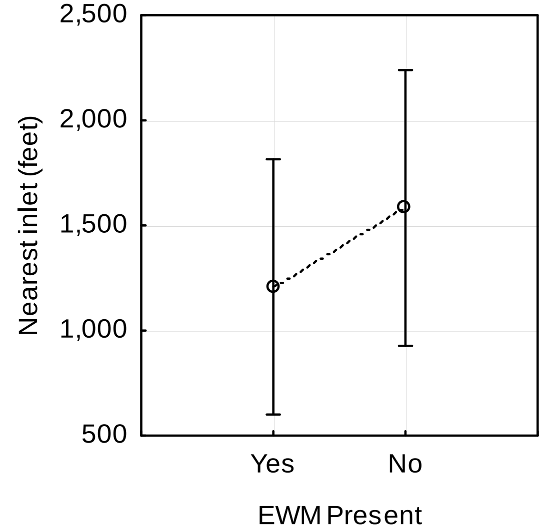
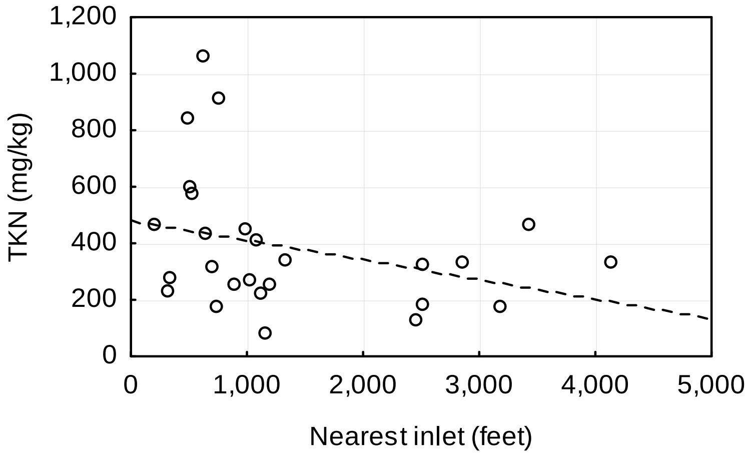

2,500
2,000
1,500
1,000
500
Nearest inlet (feet)
Yes
No
EWM Present

Table 3. Linear regression statistics between sediment and vegetation parameters with distance to nearest inlet (feet).

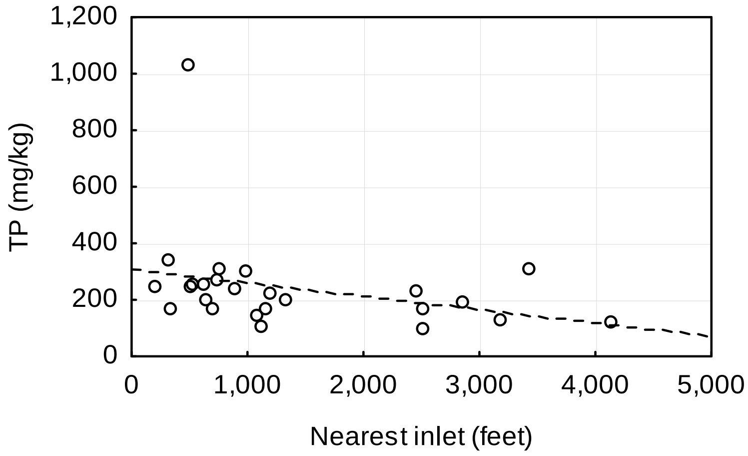
Parameter	r^2	P-value
Sediment TKN (mg/kg)	0.10	0.12
Sediment TP (mg/kg)	0.09	0.15
Sediment TOC (mg/kg)	<0.01	0.81
Sediment pH	<0.01	0.99
Sediment Gravel (%)	0.11	0.10
Sediment Sand (%)	<0.01	0.92
Sediment Silt (%)	0.19	0.03
Sediment Clay (%)	0.15	0.05
EWM Weight (g)	0.36	0.12
EWM (% of Total Biomass)	0.24	0.22
Total Biomass (g)	0.51	0.05

Figure 3. Linear regression with distance to nearest inlet (feet) as the dependent variable and the following independent variables: A. Sediment TKN (mg/kg), **B.** Sediment TP (mg/kg), **C.** Sediment TOC (mg/kg), **D.** Sediment pH, **E.** Sediment Gravel (%), **F.** Sediment Sand (%), **G.** Sediment Silt (%), **H.** Sediment Clay (%), **I.** EWM Weight (g), **J.** EWM (% of Total Biomass), and **K.** Total Biomass (g).

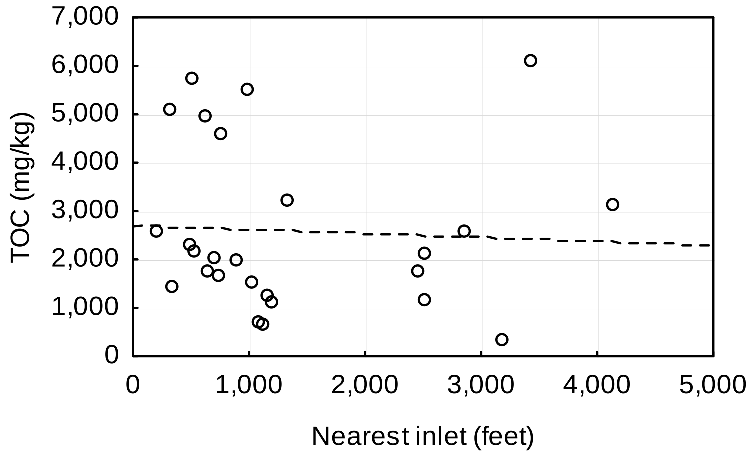
A.



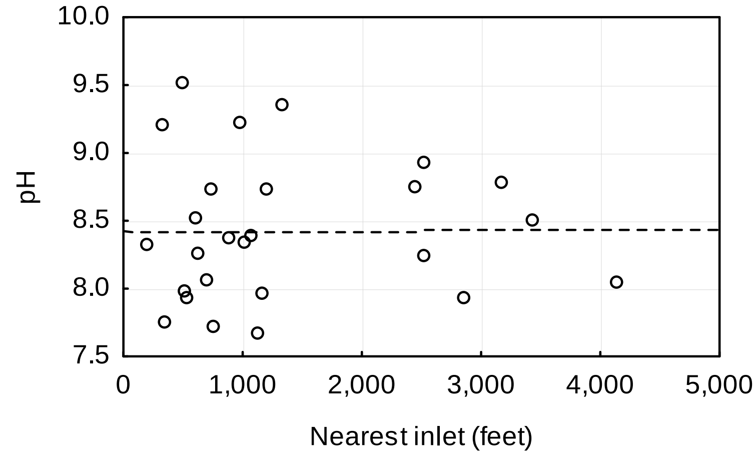
B.



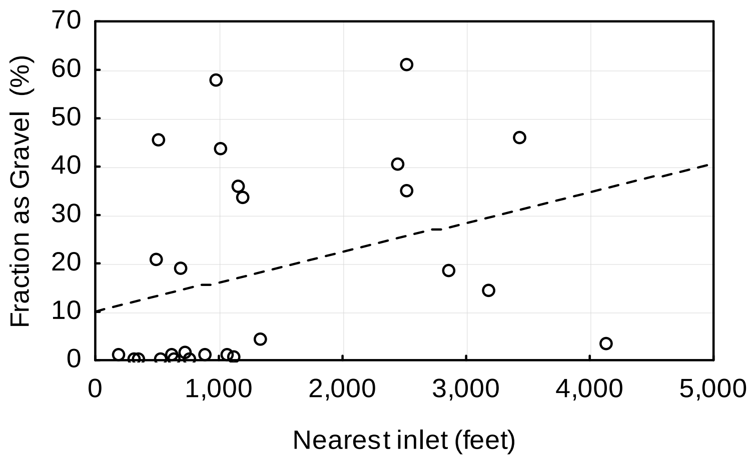
C.


7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
TOC (mg/kg)
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

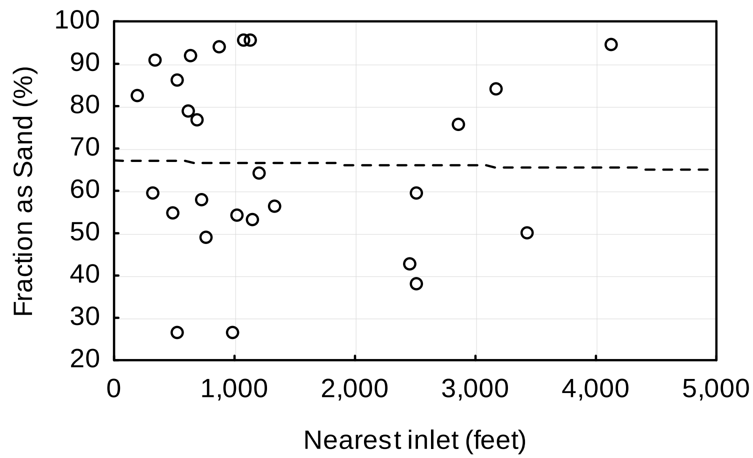
D.


10.0
9.5
9.0
8.5
8.0
7.5
pH
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

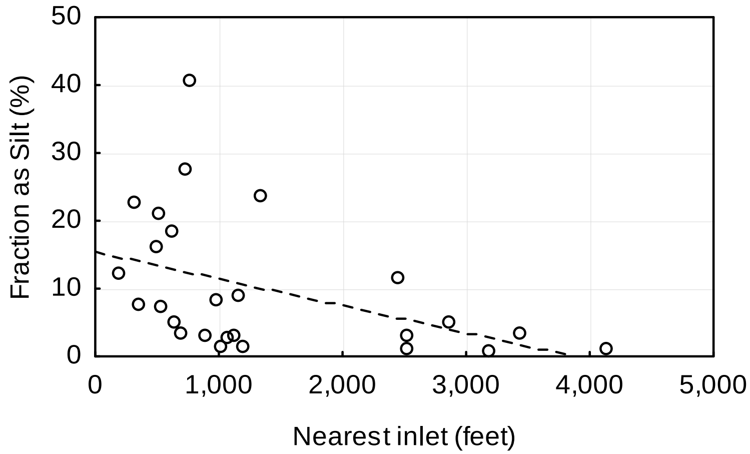
E.


70
60
50
40
30
20
10
0
Fraction as Gravel (%)
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

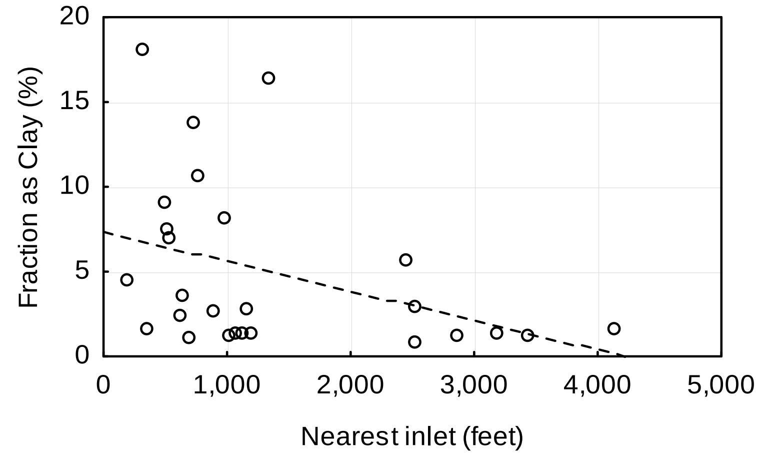
F.


100
90
80
70
60
50
40
30
20
Fraction as Sand (%)
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

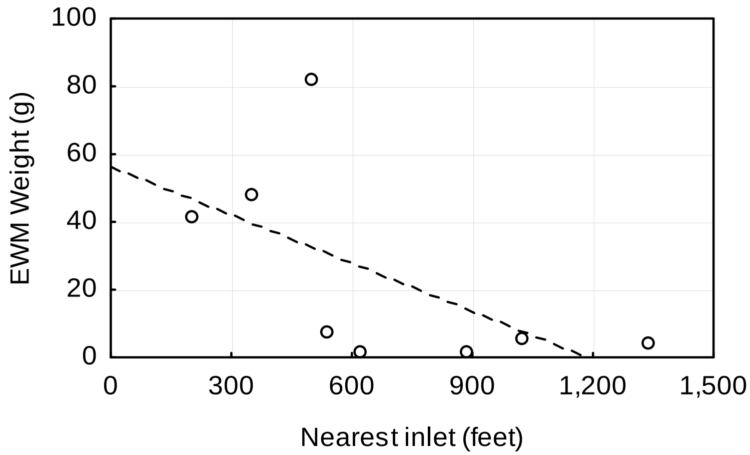
G.


Fraction as Silt (%)
50
40
30
20
10
0
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

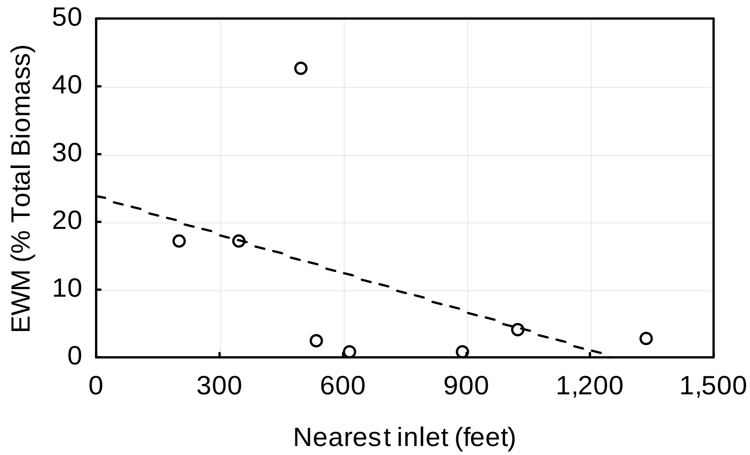
H.


Fraction as Clay (%)
20
15
10
5
0
0
1,000
2,000
3,000
4,000
5,000
Nearest inlet (feet)

I.


EWM Weight (g)
100
80
60
40
20
0
0
300
600
900
1,200
1,500
Nearest inlet (feet)

J.


EWM (% Total Biomass)
50
40
30
20
10
0
0
300
600
900
1,200
1,500
Nearest inlet (feet)

K.

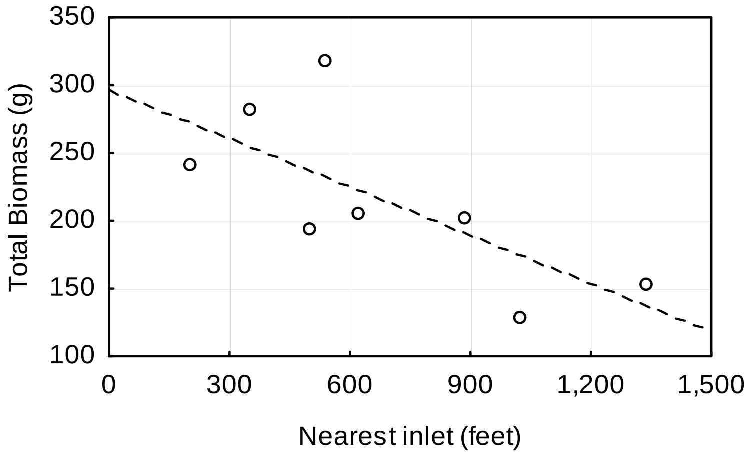
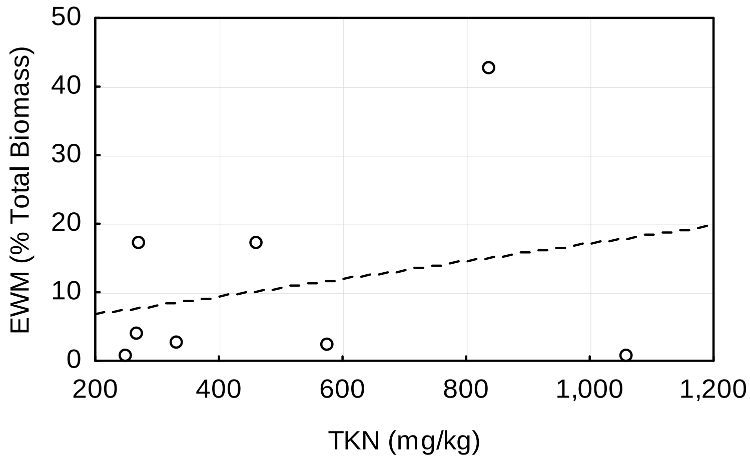

350
300
250
200
150
100
Total Biomass (g)
0
300
600
900
1,200
1,500
Nearest inlet (feet)

Table 4. Linear regression statistics between sediment parameters and EWM (% Total Biomass).

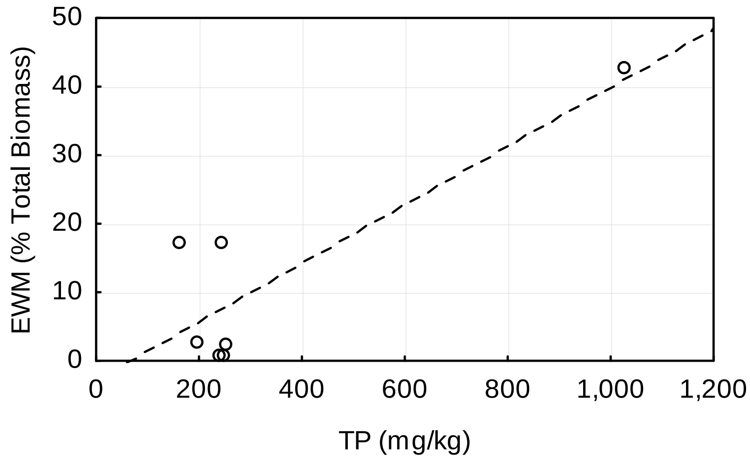
Parameter	r^2	P-value
Sediment TKN (mg/kg)	0.07	0.52
Sediment TP (mg/kg)	0.72	0.02
Sediment TOC (mg/kg)	0.06	0.56
Sediment pH	0.18	0.30
Sediment Gravel (%)	0.04	0.65
Sediment Sand (%)	0.09	0.46
Sediment Silt (%)	0.04	0.65
Sediment Clay (%)	0.02	0.75
Distance to nearest inlet (feet)	0.24	0.22

Figure 4. Linear regression with EWM (% Total Biomass) as the dependent variable and the following independent variables: A. Sediment TKN (mg/kg), **B.** Sediment TP (mg/kg), **C.** Sediment TOC (mg/kg), **D.** Sediment pH, **E.** Sediment Gravel (%), **F.** Sediment Sand (%), **G.** Sediment Silt (%), **H.** Sediment Clay (%), and **I.** Distance to nearest inlet (feet).

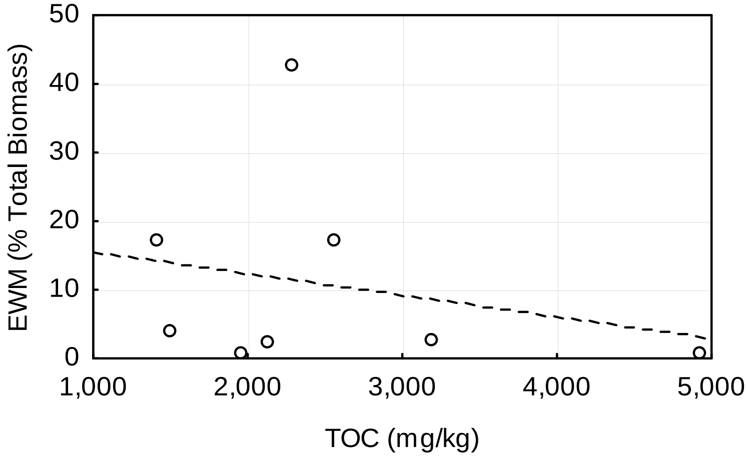
A.



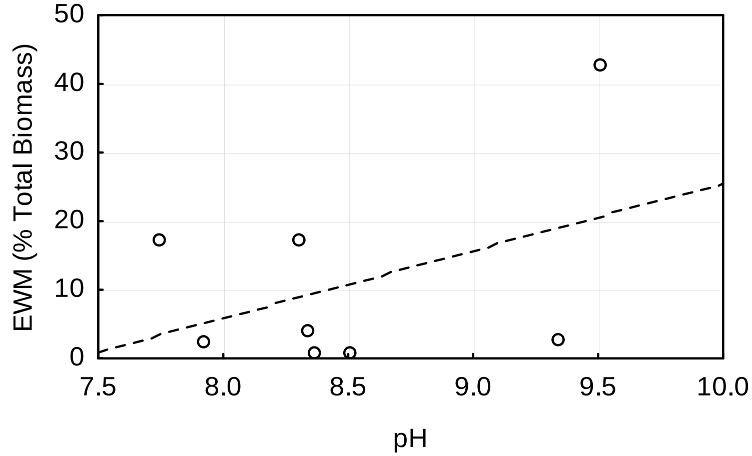
B.



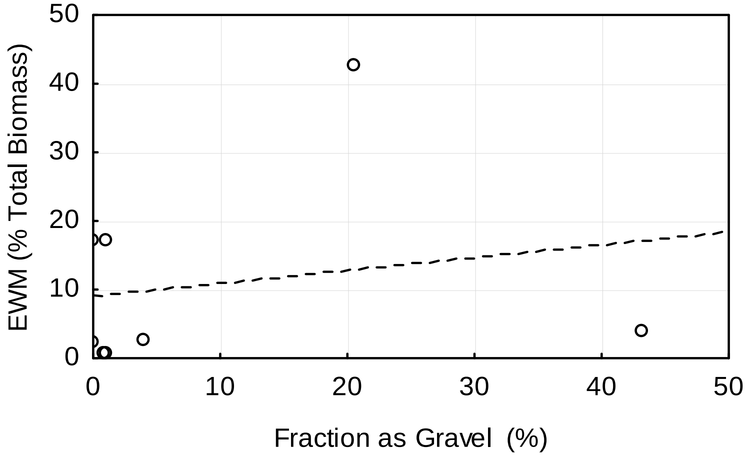
C.


EWM (% Total Biomass)
50
40
30
20
10
0
1,000
2,000
3,000
4,000
5,000
TOC (mg/kg)

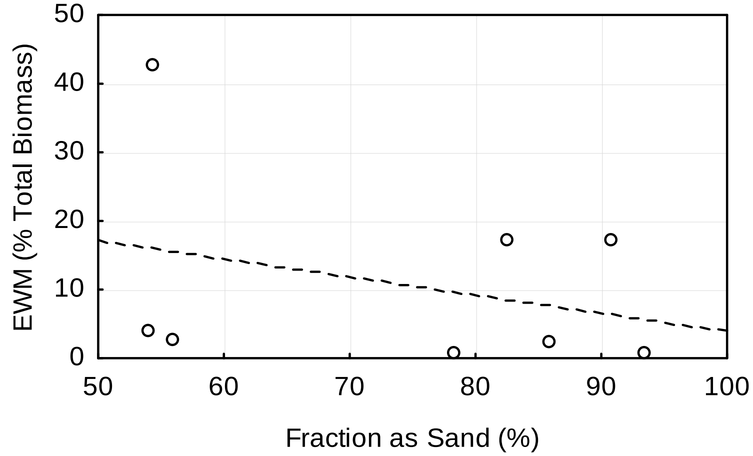
D.


EWM (% Total Biomass)
50
40
30
20
10
0
7.5
8.0
8.5
9.0
9.5
10.0
pH

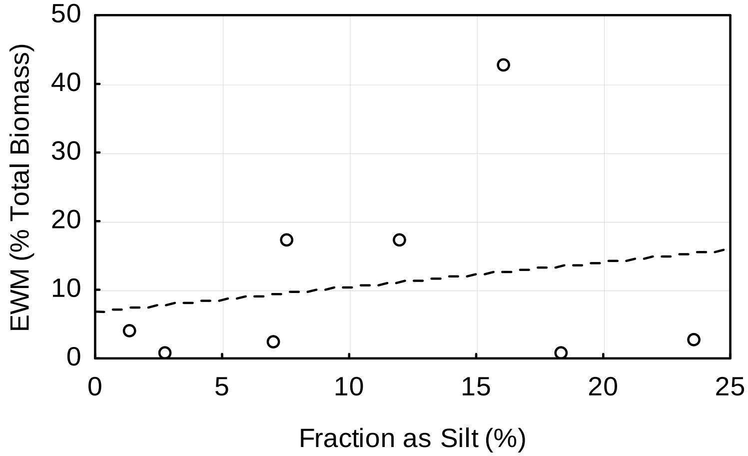
E.


EWM (% Total Biomass)
50
40
30
20
10
0
0
10
20
30
40
50
Fraction as Gravel (%)

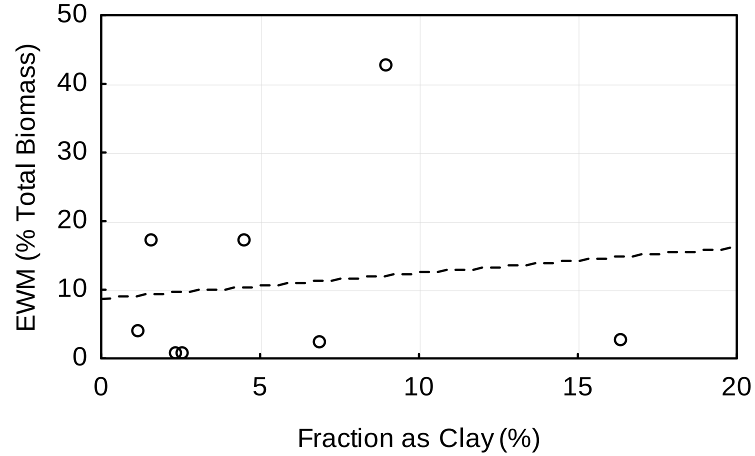
F.


EWM (% Total Biomass)
50
40
30
20
10
0
50
60
70
80
90
100
Fraction as Sand (%)

G.


50
40
30
20
10
0
EWM (% Total Biomass)
0
5
10
15
20
25
Fraction as Silt (%)

H.


50
40
30
20
10
0
EWM (% Total Biomass)
0
5
10
15
20
Fraction as Clay (%)