



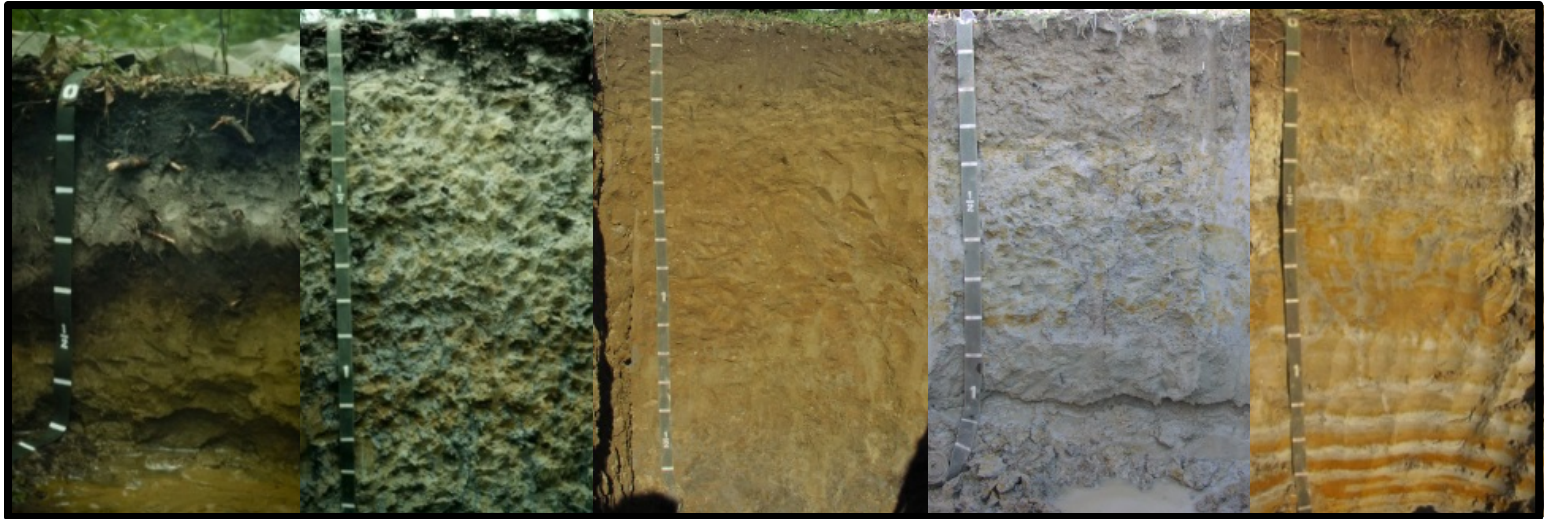
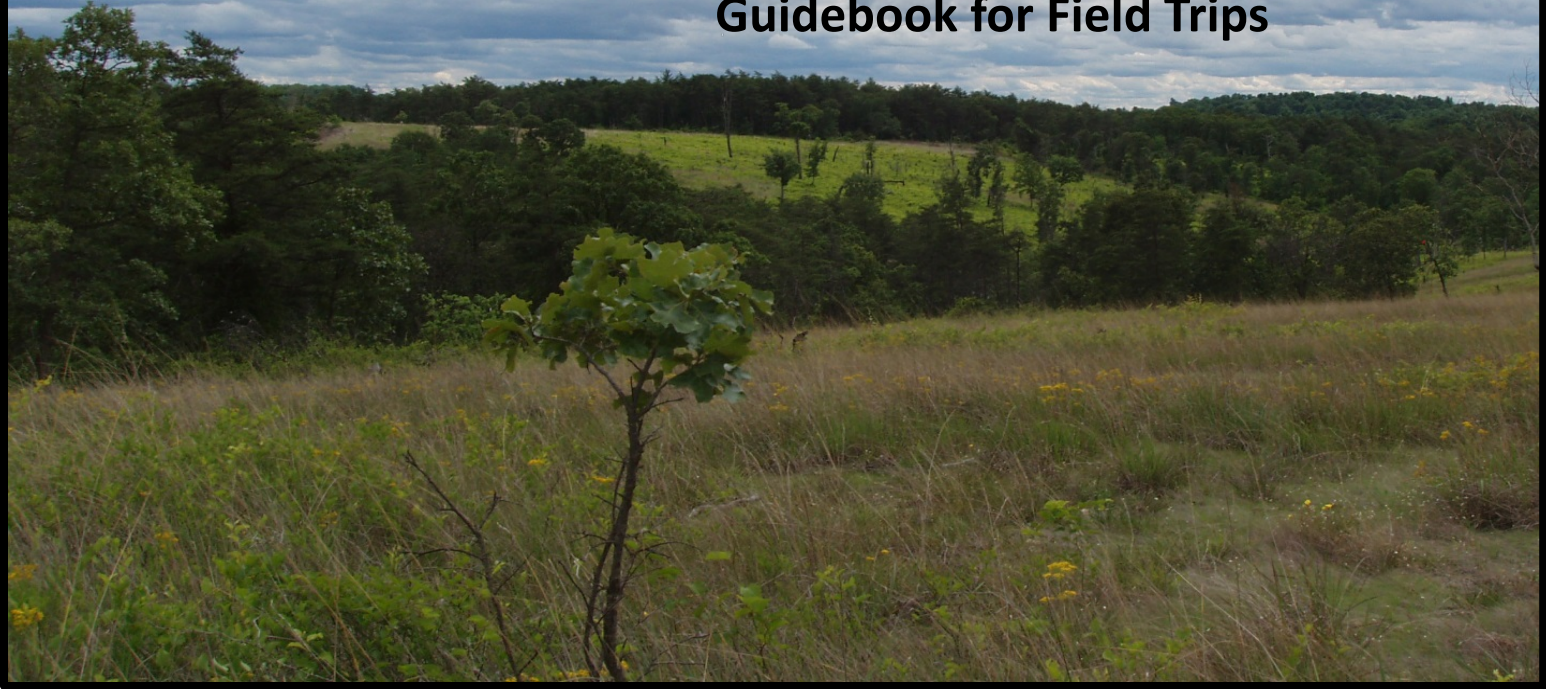
National  
Cooperative  
Soil  
Survey

# National Cooperative Soil Survey Conference

June 16-20, 2013

Annapolis, Maryland

## Guidebook for Field Trips



University of Maryland, Dept. Environ. Sci. & Tech.



USDA, Natural Resources Conservation Service



Mid-Atlantic Association of Professional Soil Scientists



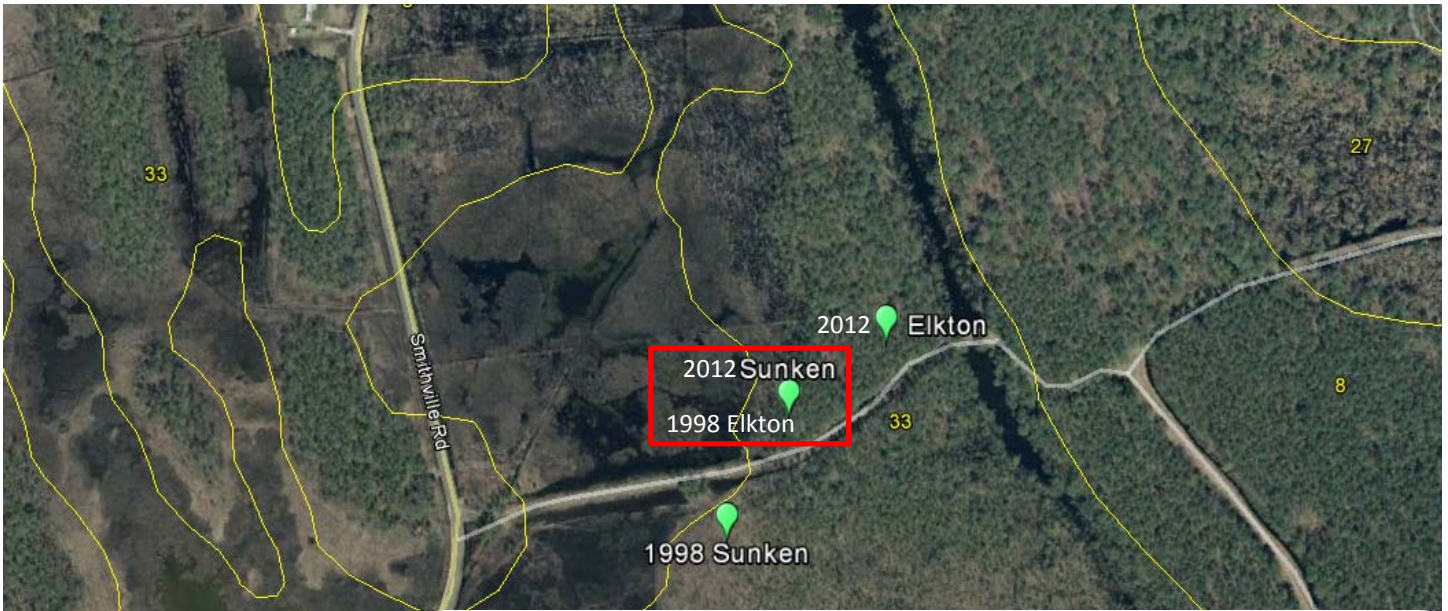
**Blackwater National Wildlife Refuge, Moneystump Swamp Area E**  
**Dorchester County, MD**  
**Sea Level Rise and Submerging Coastal Environments**

At this stop we will examine a series of soils which transition between the upland and the coastal marsh. A MacCaulay sampler will be used to extract cores from the Honga soil series in the marsh (Terric Sulphemist). The official series description for the Honga series is included, although it was not described at this site. Two pits are also open for examination representing the Elkton series (fine silty mixed mesic, Typic Endoaquults) and the Sunken Series (fine silty mixed mesic, Typic Endoaqualfs). The profile descriptions are given for these two pits and the official series description (OSD) for the Sunken series is also provided. Data from the two pits are restricted to pH and EC measurements, which are presented in the following figure. Additional data from other studies in the general area are provided and discussed briefly below. Waterproof footwear is recommended at this stop.

**Background and Supporting Information**

At the time of the glacial maximum, sea level is reported to have been 150 m lower than at present. Subsequently, as a result of glacial melting and ocean warming, sea level has been rising to the present levels. Initially, the rates of sea level rise were too high to permit establishment of vegetation in the intertidal zone. As the rates of sea level rise slowed, marsh vegetation was able to become established. Sea level has continued to rise over the last few thousand years, and long term rates of sea level rise in the vicinity of Chesapeake Bay are estimated to have been approximately 0.5 to 1 mm per year. Rates during the last century are higher and have been estimated to range from 2-4 mm/year, or in some locations as great as 7 mm/yr.

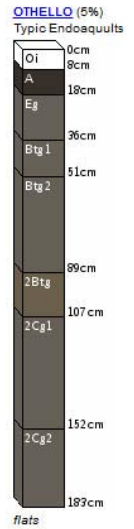
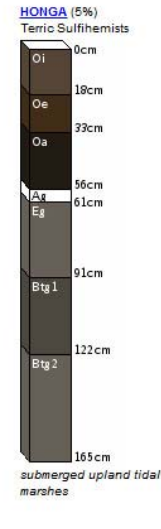
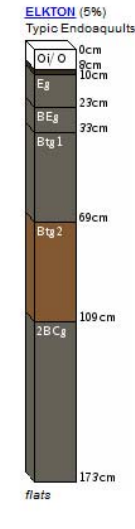
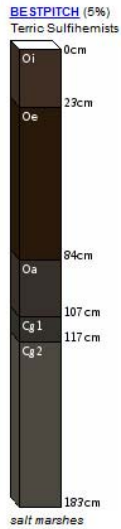
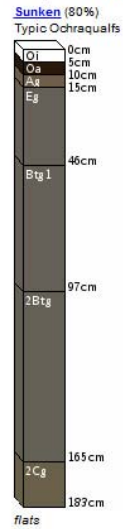
As sea level continues to rise (partially accentuated by coastal subsidence) low-lying upland areas are gradually inundated by estuarine waters. Initially, this might occur as rare or occasional instances of inundation by storm tides. Eventually, however, marsh grasses such as *Spartina patens* can be seen encroaching upon stands of loblolly pine. With rising sea level, the pines become adversely affected by high water and brackish conditions, and eventually forests give way to a dominance of marsh vegetation. Within the marsh, high rates of primary productivity and slow rates of organic matter decomposition (caused by anaerobic conditions) joined with the trapping of mineral sediment, allows the organic horizons in marsh soils to accrete vertically.



**Sunken mucky silt loam**

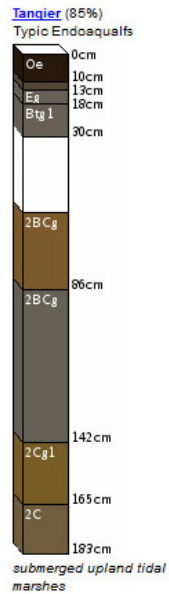
**MU33**

Components within map unit 128966



**Tangier mucky peat, very frequently flooded, tidal**

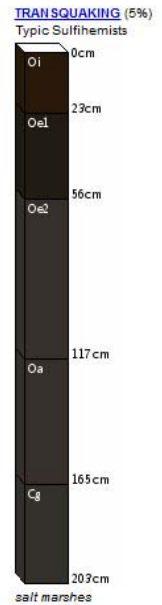
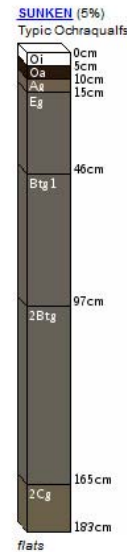
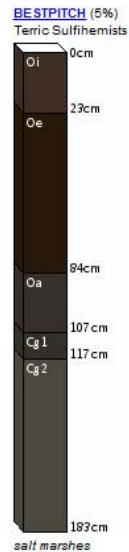
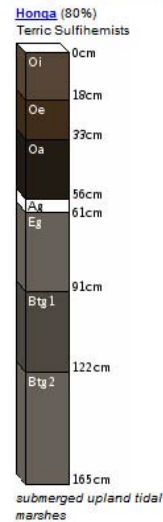
Components within map unit 1408005

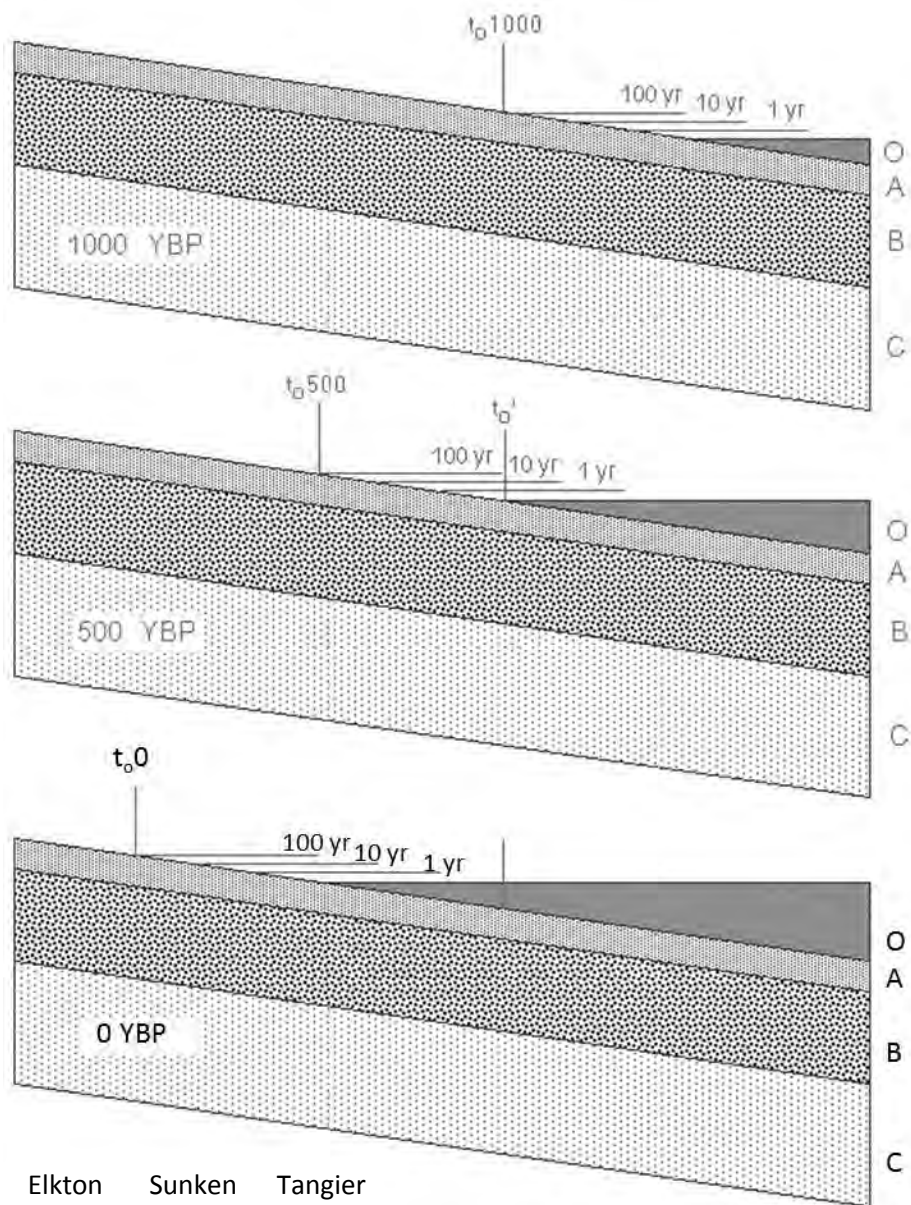


**Honga peat**

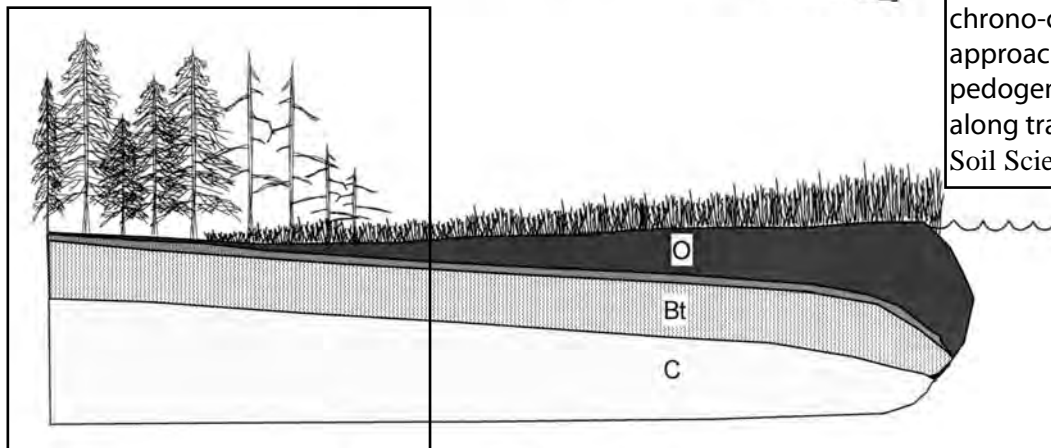
**MU17**

Components within map unit 128944

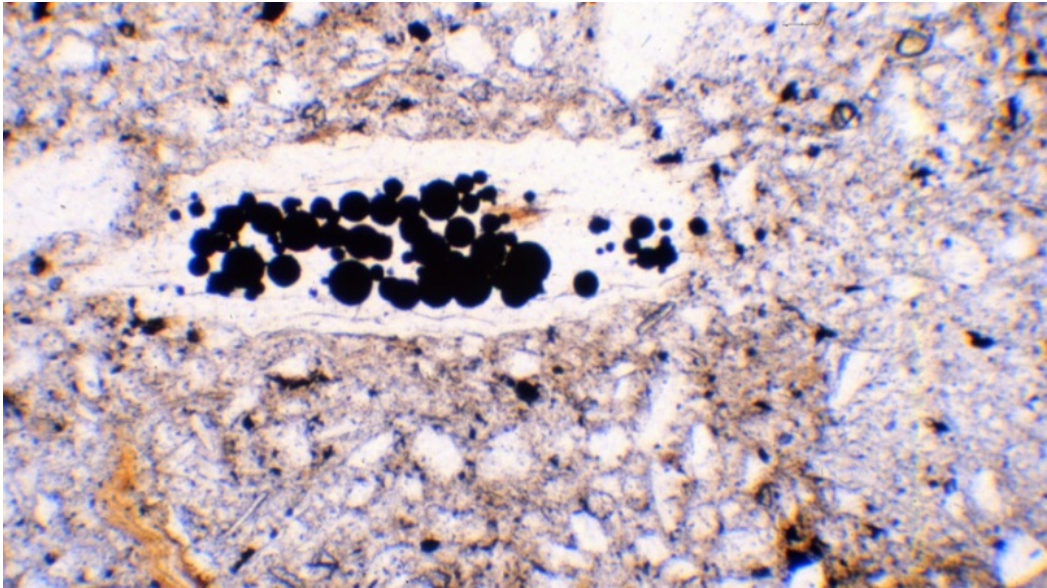




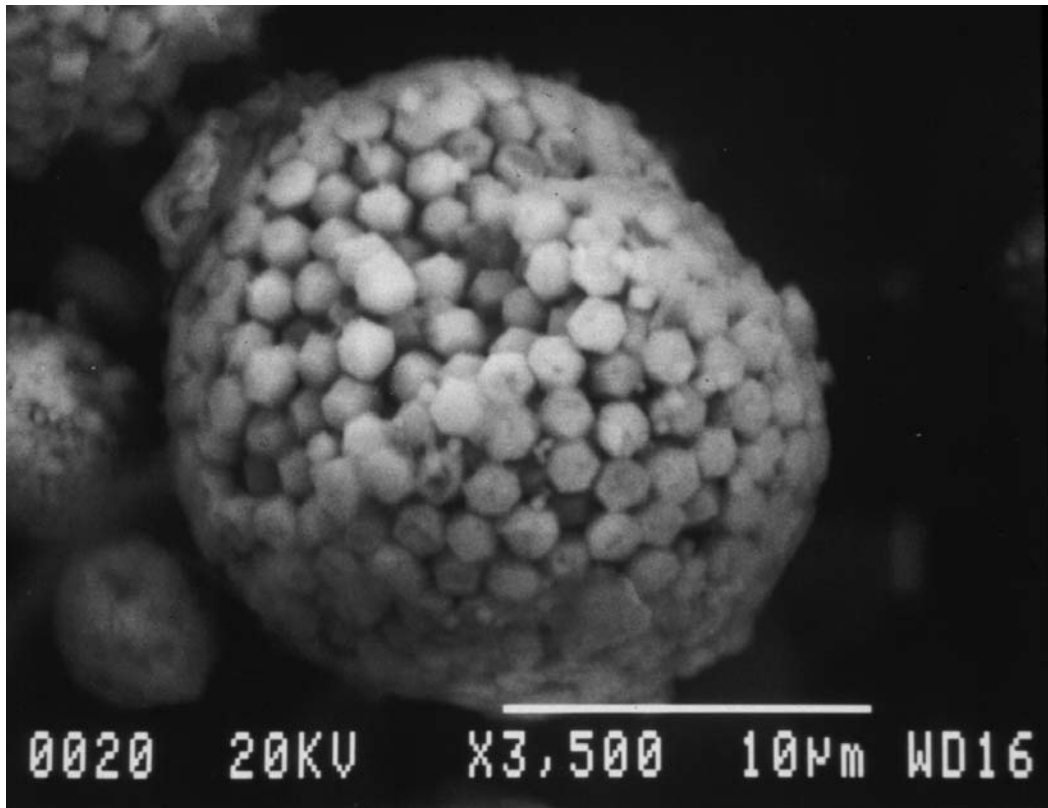
Elkton Sunken Tangier



Rabenhorst, M. C. 1997. The chrono-continuum: An approach to modeling pedogenesis in marsh soils along transgressive coastlines. Soil Science 162: 2-9.

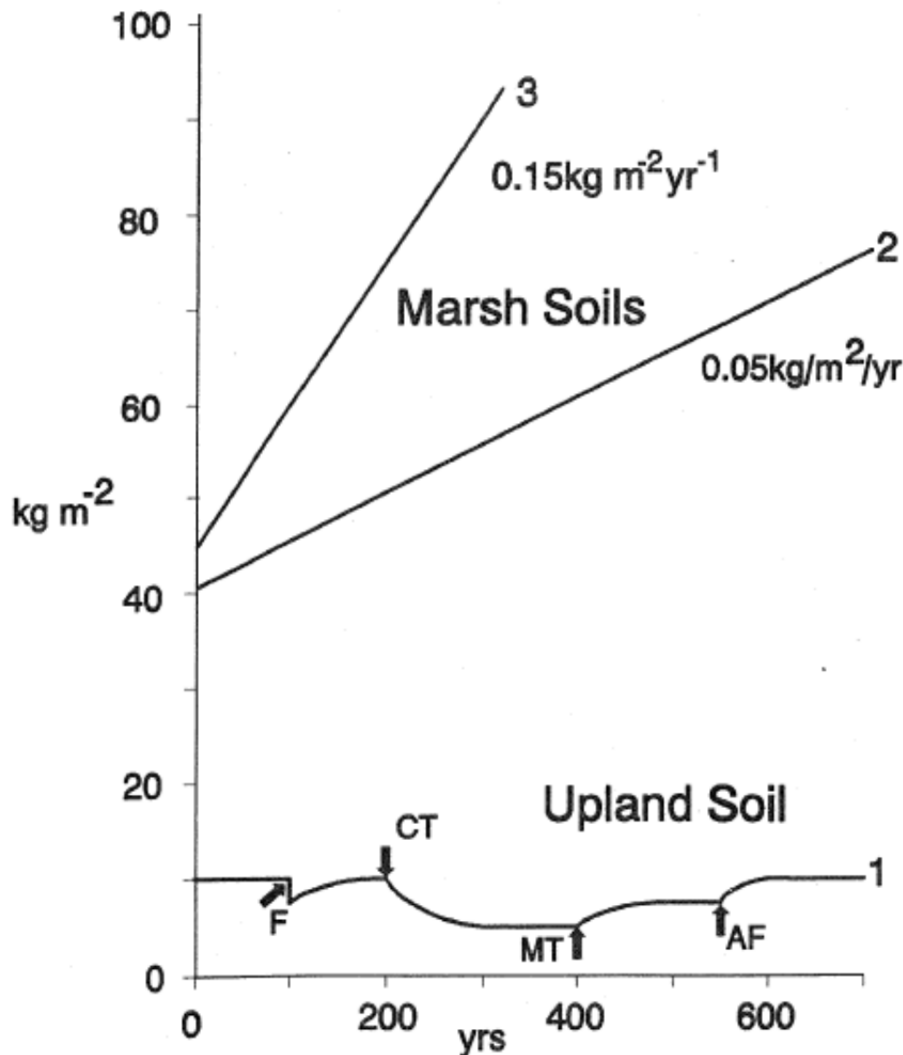


Thin section showing pyrite framboids forming in a vacant root channel in a submerged Btg horizons. Iron comes from the soil and sulfide is generated in the immediate vicinity due to the availability of oxidizable carbon from senesced plant roots. The framboids are mostly silt sized (plane light).



Scanning electron micrograph (SEM) of pyrite framboid collected from a tidal marsh soil.

There are two distinct periods during the gradual tidal submergence. The first period occurs while the upland soils become progressively affected by occasional tidal inundation with increasing frequency as sea level rises. This period continues until mhw is approximately at the level of the soil surface. As sea level continues to rise, the second period begins during which progressively thickening organic horizons develop which are permanently saturated with tidal water. In these soils histic epipedons will initially develop, and as the organic materials continue to thicken, they will eventually develop into Histosols. If these organic soils are sampled and studied, properties of better drained upland soils are preserved, such as the presence of argillic horizons. At the same time, properties reflecting the current conditions are also evident.



**Figure 5.** Carbon storage and sequestration in an upland soil (1) under various natural and managed conditions, and in marsh soils (2 and 3) under two rates of carbon sequestration, 0.05 and 0.15 kg C m<sup>-2</sup> yr<sup>-1</sup>, respectively. F indicates fire; CT indicates conventional tillage agriculture; MT indicates minimum tillage agriculture; AF indicates agro-forestry.

Rabenhorst, M. C. 1995. Carbon storage in tidal marsh soils. pp 93-103. In R. Lal, J. Kimble, E. Levine, and B.A. Stewart (eds.) *Soils and Global Change*. Proceedings of the International Soil Symposium on Greenhouse Gases and Carbon Sequestration. Columbus, Ohio. April 5-9, 1993. Lewis Publishers, CRC, Boca Raton.

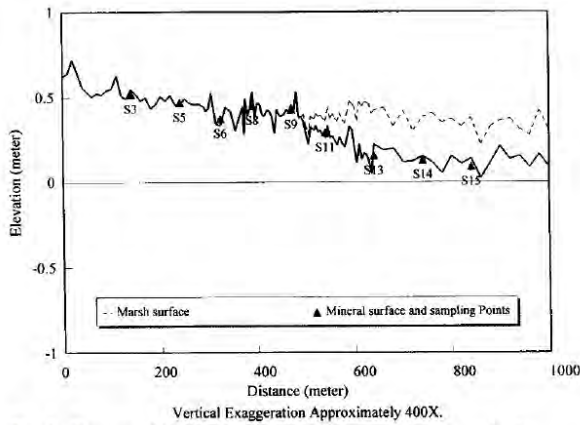


Fig. 1. Topographic cross section of Cedar Creek research site.

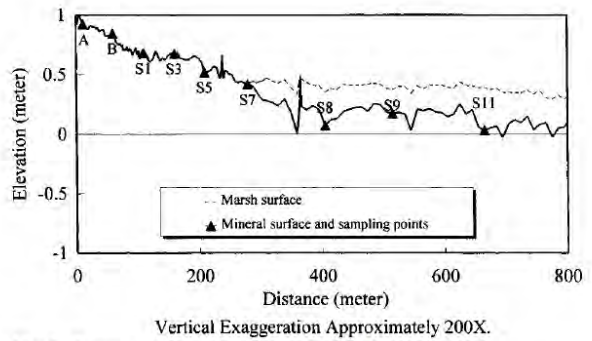


Fig. 2. Topographic cross section of Hell Hook research site.

Increased salinity and ESP over time (with increased frequency of inundation)

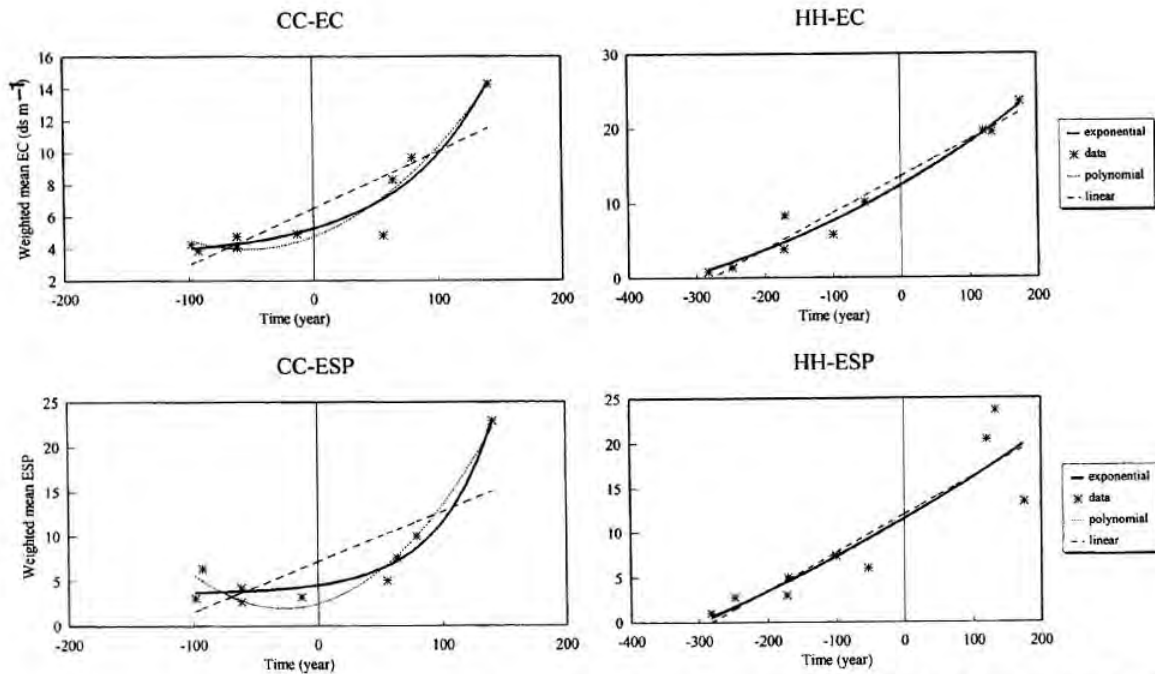


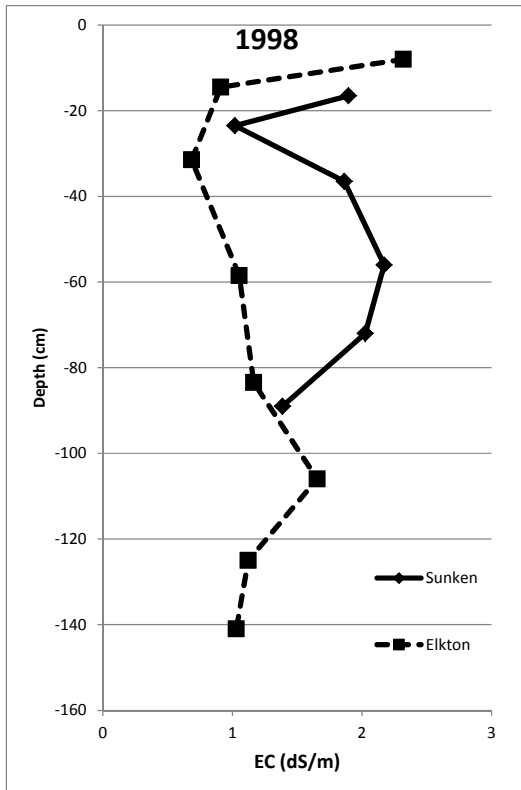
Fig. 5. Chronofunctions for electrical conductivity (EC) and exchangeable sodium percentage (ESP) for the Hell Hook (HH) and Cedar Creek (CC) research sites, constructed using the weighted mean values for the upper 50 cm of the soil.

Hussein, A. H., and M. C. Rabenhorst. 2001. Modeling the Impact of Tidal Inundation on Submerging Coastal Landscapes of the Chesapeake Bay. Soil Sci. Soc. Am J. 65:932-941.

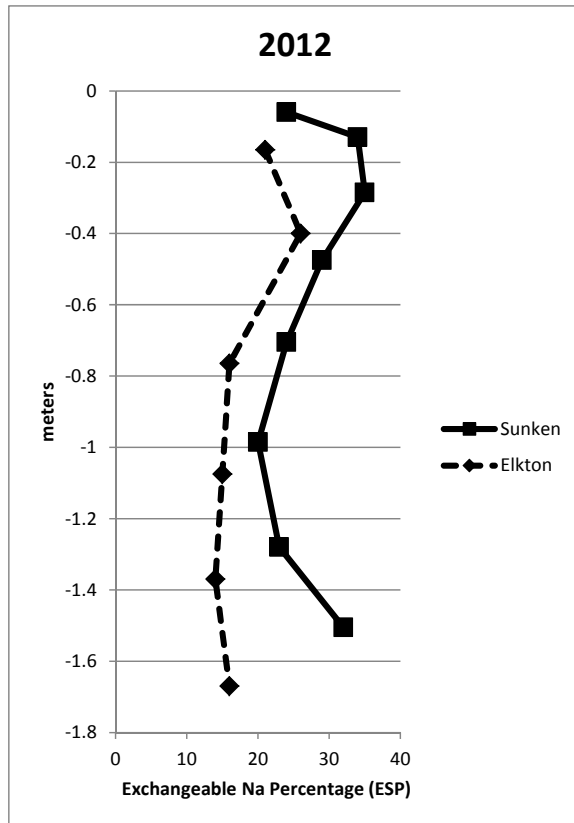
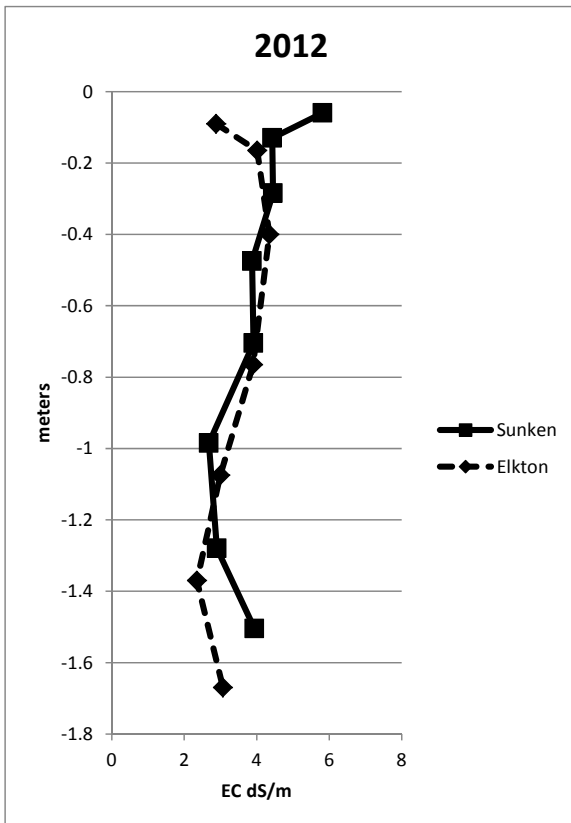
In these systems, as one moves seaward, and downward elevationally, one also is moving along a chronological continuum. Given the rates of sea level rise, *any increment along the geomorphic surface could be translated into an increment in time, with regard to marsh pedogenesis*. The geomorphic surface itself becomes equivalent to a ***chrono-continuum*** (Rabenhorst, 1997).

Two theses have been completed at the Univ. of Maryland over the last couple of years which have focused on marsh pedogenesis in submerging landscapes. Dr. Ahmed Hussein addressed the impact of occasional periodic tidal inundation on mineral soil in his dissertation entitled “Soil chronofunctions in submerging coastal areas of Chesapeake Bay.” Some data from his dissertation showing the effects of tidal inundation AT ANOTHER SITE are presented. The work by Melvin Tucker focused on the storage of organic carbon in these transgressive systems. Because these systems are transgressive and O horizons are accreting vertically and laterally, coastal marshes are thought to be important sinks for organic carbon

EC and ESP in pairs of pedons sampled in 1998 and in 2012 . The Elkton is slightly higher on the landscape than Sunken. The pedon called Elkton in 1998 was sampled as the Sunken pedon in 2012.



Note that the 1998 data were run in the UMD Pedology lab on a 1:5 soil:water extract; The 2012 data were run through the lab in Lincoln. The pedon sampled as "Elkton" in 1998, was sampled as "Sunken" in 2012.



Soil type *Elkton?*

FILE NO.

Area <i>Blackwater - "Money stump"</i>		Date <i>11-15-12</i>	Stop No.
Classification			
Location <i>38°26'00.2" N 76°13'53.7"</i>			
N. veg. (or crop) <i>loblolly, red maple, willow oak</i>		Climate	
Parent material			
Physiography			
Relief	Drainage	Salt or alkali	
Elevation	Gr. water	Stoniness	
Slope	Moisture		
Aspect	Root distrib.	% Clay *	
Erosion	% Coarse fragments *	% Coarser than V.F.S. *	
Permeability			
Additional notes			

*M. Rabenhorst, P. King, J. Brewer, D. Shields*

*Subsamples for X Ray Fluorescence*

\* Control section average

Horizon	Depth cm	Color		Texture	Structure	Consistence			Reaction	Boundary
		Dry	Moist			Dry	Moist	Wet		
<i>Oe</i>	<i>0-6.5</i>		<i>2.5YR 2.5/1</i>							
<i>A</i>	<i>6.5-11</i>		<i>7.5YR 2.5/1</i>	<i>sil</i>						
<i>Eg</i>	<i>11-22</i>	<i>20% fi 5YR 3/3 + root channels 3/4</i>	<i>2.5Y 4/2</i>	<i>12% c sil</i>		<i>7.5YR 4/3 soft masses</i>				
<i>* Btg1</i>	<i>22-58</i>	<i>40% 10YR 4/4</i>	<i>2.5Y 5.5/1.5</i>	<i>23% c sil</i>						<i>* auger starting from 51 cm</i>
<i>Btg2</i>	<i>58-95</i>	<i>35% 7.5YR 5/6 fi 5YR 4/6-5/6 root channels</i>	<i>2.5Y 5/1</i>	<i>37% c silt</i>						
<i>Bt</i>	<i>95-120</i>	<i>30% 7.5YR 5/6 10% 2.5Y 5/2</i>	<i>10YR 5/4</i>	<i>hvy ~ 36% c silt</i>						
<i>B'tg1</i>	<i>120-154</i>	<i>25% 10YR 5/6 1% fi 5YR 3/4</i>	<i>2.5Y 5/1.5</i>	<i>28% c silt</i>						
<i>B'tg2</i>	<i>154-178</i>	<i>10YR 5/3</i>	<i>10Y 6/0.5</i>	<i>25% c sil</i>						

Pedon ID: S2012MD019002

Sampled As : Elkton

USDA-NRCS-NSSC-National Soil Survey Laboratory

\*\*\* Primary Characterization Data \*\*\*

(Dorchester County, Maryland)

Fine-silty, mixed, active, mesic Typic Endoaquult

; Pedon No. 13N0422

Print Date: Apr 26 2013 8:23AM

PSDA & Rock Fragments	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
Layer	Horz	Prep	3A1a1a1a3A1a1a3A1a1a3A1a1a3A1a1a														
13N01705	Oe	S	3A1a1a														
13N01706	A	S	3A1a1a														
13N01707	11-22	S	3A1a1a														
13N01708	22-58	S	3A1a1a														
13N01709	58-95	S	3A1a1a														
13N01710	95-120	S	3A1a1a														
13N01711	120-154	S	3A1a1a														
13N01712	154-180	S	3A1a1a														

Bulk Density & Moisture	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
Layer	Horz	Prep	3D1										
13N01705	Oe	S	3D1										
13N01706	A	S	3D1										
13N01707	11-22	S	3D1										
13N01708	22-58	S	3D1										
13N01709	58-95	S	3D1										
13N01710	95-120	S	3D1										
13N01711	120-154	S	3D1										
13N01712	154-180	S	3D1										

Stop 2 - Blackwater NWR  
Elkton

Depth (cm)	Horz	Prep	(Bulk Density)	33 kPa	Oven Dry	Cole	Whole	Soil	Water Content	1500 kPa	1500 kPa	Moist	AD/OD	Ratio	WRD	Whole	Soil	Aggst	Stabl	2-0.5mm	CEC7	1500 kPa	(- Ratio/Clay -)	
0-7	Oe	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
7-11	A	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
11-22	Eg	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
22-58	Btg1	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
58-95	Btg2	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
95-120	Bt	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
120-154	B'tg1	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
154-180	B'tg2	S	33	6	10	33	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500



\*\*\* Primary Characterization Data \*\*\*

Pedon ID: S2012MD019002  
 Sampled As : Elkton  
 USDA-NRCS-NSSC-National Soil Survey Laboratory

(Dorchester County, Maryland)  
 Fine-silty, mixed, active, mesic Typic Endoaquult  
 ; Pedon No. 13N0422

Layer	Depth (cm)	Horz	Prep	CEC & Bases													
				Ca 4B1a1a	Mg 4B1a1a	Na 4B1a1a	K 4B1a1a	Sum Bases 4B1a1a	Acidity 4B2b1a14B3a1a	Extr Al 4B3a1a	KCl Mn 4B3a1a	CEC8 Sum Cats 4B1a1a	CEC7 NH <sub>4</sub> OAC 4B1a1a	ECEC Bases +Al 4B1a1a	AI Sat 4B1a1a	(- Saturation -) Sum NH <sub>4</sub> OAC 4B1a1a	
13N01705	0-7	Oe	S	9.2	10.5	6.1	1.4	166.2	5.8	3.1	96.2						
13N01707	11-22	Eg	S	0.5	1.6	1.8	0.1	13.4	3.4	0.1	8.5						47
13N01708	22-58	Btg1	S	0.8	2.5	2.5	0.1	12.6	4.0	0.1	9.5						62
13N01709	58-95	Btg2	S	1.8	4.5	2.6	0.1	21.3	9.8	0.4	17.0						53
13N01710	95-120	Bt	S	2.4	4.7	2.8	0.1	26.4	10.3	0.5	36.4	18.3	20.3	51	27		55
13N01711	120-154	B'tg1	S	2.3	3.3	1.8	0.1	14.5	6.9	0.5	13.0						58
13N01712	154-180	B'tg2	S	2.5	2.4	1.7	0.1	10.9	5.0	0.6	10.8						62

Layer	Depth (cm)	Horz	Prep	D <sub>s</sub> Salt Water Extracted From Saturated Paste																	
				Ca 4F2	Mg 4F2	Na 4F2	K 4F2	CO <sub>3</sub> 4F2	HCO <sub>3</sub> 4F2	F 4F2	Cl 4F2	PO <sub>4</sub> 4F2	Br 4F2	OAC 4F2	SO <sub>4</sub> 4F2	NO <sub>2</sub> 4F2	NO <sub>3</sub> 4F2	H <sub>2</sub> O 4F2	Total Salts 4F2	Pred Elec Cond 4F2	Exch Na % 4F2
13N01706	7-11	A	S	2.0	7.5	14.3	0.6	-	-	21.7	-	0.1	-	4.6	-	0.1	115.4	2.88	4.01	1.20	21
13N01707	11-22	Eg	S	3.9	12.5	22.7	0.2	-	-	28.1	-	0.1	-	14.0	-	0.1	45.2	4.01	1.20	21	
13N01708	22-58	Btg1	S	4.4	13.6	25.8	0.1	-	-	30.8	-	-	-	16.7	-	0.2	57.6	4.35	1.63	26	
13N01709	58-95	Btg2	S	5.2	13.6	21.5	0.1	-	-	21.5	-	-	-	22.9	-	0.3	70.6	3.90	1.73	16	
13N01710	95-120	Bt	S	4.7	9.8	16.0	0.1	-	-	16.0	-	-	-	16.5	-	0.2	105.2	2.99	1.84	15	
13N01711	120-154	B'tg1	S	4.2	6.3	12.4	0.1	-	-	11.4	-	-	-	13.3	-	0.1	79.1	2.35	1.16	14	
13N01712	154-180	B'tg2	S	7.7	8.4	15.5	0.2	-	-	15.8	-	-	-	18.6	-	0.2	56.7	3.07	1.11	16	

Stop 2 - Blackwater NWR  
 Elkton

\*\*\* Primary Characterization Data \*\*\*

Pedon ID: S2012MD019002 (Dorchester County, Maryland) ; Elkton  
 Sampled As : Elkton  
 USDA-NRCS-NSSC-National Soil Survey Laboratory ; Pedon No. 13N0422  
 Print Date: Apr 26 2013 8:23AM  
 Fine-silty, mixed, active, mesic Typic Endoaquult

PSDA & Rock Fragments	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
Layer	Horz	Prep	3A1a1a1a3A1a1a3A1a1a3A1a1a3A1a1a														
13N01705	Oe	S	3A1a1a														
13N01706	A	S	3A1a1a														
13N01707	11-22	S	3A1a1a														
13N01708	22-58	S	3A1a1a														
13N01709	58-95	S	3A1a1a														
13N01710	95-120	S	3A1a1a														
13N01711	120-154	S	3A1a1a														
13N01712	154-180	S	3A1a1a														

Bulk Density & Moisture	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
Layer	Horz	Prep	3D1										
13N01705	Oe	S	3D1										
13N01706	A	S	3D1										
13N01707	11-22	S	3D1										
13N01708	22-58	S	3D1										
13N01709	58-95	S	3D1										
13N01710	95-120	S	3D1										
13N01711	120-154	S	3D1										
13N01712	154-180	S	3D1										

Stop 2 - Blackwater NWR  
Elkton





Stop 2 - Blackwater NWR  
Sunken 2012

Soil type *Sunken*

Area *Blackwater - Moneystump*

Date *11-15-12*

Stop No.

Classification

Location *38°25'58.3" N 76°13'56.5" W.*

N. veg. (or crop) *loblolly pine, bayberry, willow oak (1)*

Climate

Parent material

Physiography

Relief Drainage Salt or alkali

Elevation Gr. water Stoniness

Slope Moisture

Aspect Root distrib. % Clay \*

Erosion % Coarse fragments \* % Coarser than V.F.S. \*

Permeability

Additional notes

*M. Rabenhorst, J Brewer, P King,  
D. Shields*

\* Control section average

Horizon	Depth cm	Color		Texture	Structure	Consistence			Reac- tion	Bound- ary					
		Dry	Moist			Dry	Moist	Wet							
<i>Oe</i>	<i>0-5</i>		<i>5YR 2.5/2</i>												
<i>A</i>	<i>5-7</i>		<i>7.5YR 2.5/1</i>	<i>sil</i>											
<i>Eg</i>	<i>7-19</i>	<i>10% f 10YR 4/4 root chann</i>	<i>2.5Y 5/1</i>	<i>20% sil</i>											
<i>BEg</i>	<i>19-38</i>	<i>100% 10YR 5/4, 5/6 masses f 7.5YR 3/4 - 3% root channels</i>	<i>2.5Y 5/1</i>	<i>sil</i>											
<i>* Btg1</i>	<i>38-57</i>	<i>17% 10YR 5/4 3% 7.5YR 4/6 root channels</i>	<i>2.5Y 5/1 - 40% " 5/2 - 40%</i>	<i>sil</i>											<i>* auger samples start 50 cm; above from small pit</i>
<i>Btg2</i>	<i>57-84</i>	<i>10YR 5/4 7.5YR 4/6</i>	<i>2.5Y 5/1 - 50% 5/2 - 30%</i>	<i>sil - 30% c</i>											
<i>Btg3</i>	<i>84-113</i>	<i>2.5Y 5/3 - 30% 10YR 5/6 - 25%</i>	<i>2.5Y 5/1 - 45% 5Y 6/1 - 65% 18% c</i>	<i>sil - 38% c</i>											
<i>2BCg1</i>	<i>113-143</i>	<i>5% 10YR 5/6 43% 2.5Y 5/4</i>	<i>2.5Y 6/2 - 30% 5Y 6/0.5 - 55%</i>	<i>l</i>											
<i>2BCg2</i>	<i>143-158</i>	<i>2% 7.5YR 3/4</i>													

**Soil Series: Elkton** Map Unit Name: Elkton mucky silt loam, very wet  
Site Identification #: 98MD019001 Lab Pedon #: 98MD019002  
Soil Survey Area #: 019 MLRA: 153D County FIPS Code: 019  
Soil Survey Area Name: Dorchester Co.

Described as Elkton in 1998;  
(Maybe Sunken in 2012)

Location Description: Moneystump Swamp, Area E, 2100 ft. NE of Beaverdam Ck.

Geographically Associated Soils: Honga, Sunken, Othello, Kentuck, Keyport

Classification: fine-silty, mixed, mesic, Typic Endoaquults

Natural Drainage Class: poorly drained

Vegetative Information: Loblolly Pine, wax myrtle, white grass, sweet gum, willow oak, blackgum, holly

**Described by: M. Rabenhorst, J. Brewer , 10/07/1998**

Oe--0 to 6 cm; dark reddish brown (5YR 3/2), rubbed, hemic material; common medium and fine roots throughout; abrupt smooth boundary.

A--6 to 10 cm; very dark grayish brown (10YR 3/2), broken face, silt loam; moderate fine granular structure; very friable; common medium and fine roots throughout; 10.0 percent clay; abrupt wavy boundary.

Eg--10 to 19 cm; gray (5Y 6/1), broken face, silt loam; weak coarse platy structure; friable; common coarse, medium, fine and very fine roots throughout; 12.0 percent clay; common fine threads yellowish brown (10YR 5/4) soft masses of pedogenic iron accumulation throughout; clear smooth boundary. Iron accumulations occur in channels and pores of live roots (oxidized rhizospheres).

BEG--19 to 44 cm; gray (5Y 6/1), broken face, silt loam; weak medium and coarse subangular blocky structure; friable; common medium, fine and very fine roots throughout; 16.0 percent clay; many medium irregular light olive brown (2.5Y 5/4) soft masses of iron accumulation pedogenic throughout and common fine irregular yellowish brown (10YR 5/6) soft masses of pedogenic iron accumulation throughout; clear smooth boundary. 10YR 5/6 iron accumulations occur in channels and pores of live roots (oxidized rhizospheres).

Btg1--44 to 73 cm; gray (2.5Y 5/1), broken face, silty clay loam; weak medium subangular blocky structure; friable; common coarse, medium, fine, and very fine roots throughout; 28.0 percent clay; few faint continuous gray (2.5Y 5/1), moist, clay films on faces of peds; common medium and coarse irregular light yellowish brown (2.5Y 6/4) soft masses of iron accumulation pedogenic throughout and common medium irregular strong brown (7.5YR 5/6) soft masses of pedogenic iron accumulation throughout; gradual smooth boundary.

Btg2--73 to 94 cm; 30 percent grayish brown (2.5Y 5/2), broken face, and 30 percent grayish brown (10YR 5/2), broken face, silty clay; moderate coarse prismatic structure parting to moderate coarse subangular blocky; firm; common medium, fine and very fine roots throughout; 41.0 percent clay; common distinct continuous gray (2.5Y 5/1), moist, clay films on faces of peds; many coarse irregular yellowish brown (10YR 5/8) soft masses of pedogenic iron accumulation throughout and common fine irregular dark yellowish brown (10YR 4/6) soft masses of iron accumulation pedogenic throughout; gradual wavy boundary. 10YR 4/6 iron accumulations occur in root channels.

Btg3--94 to 118 cm; 30 percent yellowish brown (10YR 5/6), broken face, and 30 percent light olive gray (5Y 6/2), broken face, and 30 percent yellowish brown (10YR 5/8), broken face, silty clay; moderate coarse prismatic structure parting to moderate medium and coarse subangular blocky; firm; common very fine, fine, and medium roots; 45.0 percent clay; few prominent continuous gray (5Y 5/1), moist, clay films on faces of peds; common fine irregular strong brown (7.5YR 5/8) soft masses of pedogenic iron accumulation throughout; clear smooth boundary. Iron accumulations occur in root channels.

Btg4--118 to 132 cm; 40 percent pale olive (5Y 6/4), broken face, and 40 percent greenish gray (10Y 6/1), broken face, silty clay; moderate coarse prismatic structure; very firm; 45.0 percent clay; few prominent continuous gray (5Y 5/1), moist, clay films on faces of peds; common fine irregular strong brown (7.5YR 5/8) soft masses of pedogenic iron accumulation throughout; gradual smooth boundary.

BCg--132 to 150 cm; 40 percent greenish gray (10Y 6/1), broken face, and 30 percent pale olive (5Y 6/3), broken face, silt loam; weak coarse subangular blocky structure; firm; 25.0 percent clay; common medium irregular light olive brown (2.5Y 5/6) soft masses of iron accumulation pedogenic throughout and common fine irregular yellowish brown (10YR 5/8) soft masses of pedogenic iron accumulation throughout.

**Soil Series: Sunken** Map Unit Name: Sunken mucky silt loam  
Site Identification #: 98MD019000 Lab Pedon #: 98MD019001  
Soil Survey Area #: 019 MLRA: 153D County FIPS Code: 019  
Soil Survey Area Name: Dorchester Co.

Stop 2 - Blackwater NWR  
Described as Sunken in 1998

Location Description: Moneystump Swamp, Area E, 2100 ft. NE of Beaverdam Ck.

Geographically Associated Soils: Honga, Elkton, Othello, Kentuck

Classification: fine-silty, mixed, mesic, Typic Endoaqualfs

Natural Drainage Class: Very poorly drained

Vegetative Information: Loblolly Pine, Marsh Hay grass, wax myrtle, 3-square

**Described by: M. Rabenhorst, J. Brewer, 10/07/1998**

Notes: The clay films and structure of this soil has been dispersed and degraded due to the salts from the inundation of brackish waters.

Oi--0 to 8 cm; very dark brown (7.5YR 2/2), rubbed, peat; abrupt smooth boundary. Material made up of partially decomposed pine needles and grass leaves.

Oe--8 to 13 cm; very dark brown (7.5YR 2/2), rubbed, mucky peat; abrupt smooth boundary.

A--13 to 20 cm; very dark grayish brown (10YR 3/2), broken face, silt loam; massive; 15.0 percent clay; clear wavy boundary.

Eg--20 to 27 cm; gray (2.5Y 5/1), broken face, silt loam; massive; common very fine and fine roots throughout; 20.0 percent clay; common fine threads reddish yellow (7.5YR 6/8) soft masses of iron accumulation pedogenic throughout; clear wavy boundary. Iron accumulations occur in channels and pores of live roots (oxidized rhizospheres).

BEg--27 to 46 cm; gray (N 5/0), broken face, silt loam; weak very fine subangular blocky structure; common very fine and fine roots in cracks; 26.0 percent clay; many medium irregular yellowish brown (10YR 5/8) soft masses of iron accumulation pedogenic throughout and common fine threads yellowish red (5YR 4/6) soft masses of iron accumulation pedogenic throughout; gradual smooth boundary. Thread shaped iron accumulations occur in channels and pores of live roots (oxidized rhizospheres).

Btg1--46 to 66 cm; gray (N 5/0), broken face, silty clay loam; weak fine subangular blocky structure; common very fine and fine roots throughout; 37.0 percent clay; few distinct continuous gray (N 6/0) clay films on faces of peds; common medium irregular yellowish brown (10YR 5/6) soft masses of iron accumulation pedogenic throughout and common medium irregular light gray (N 7/0) soft iron depletions pedogenic throughout; gradual smooth boundary.

Btg2--66 to 78 cm; gray (N 6/0), broken face, silty clay loam; weak coarse prismatic structure; common very fine and fine roots in mat at top of horizon; 33.0 percent clay; common prominent patchy gray (N 5/0) clay films; many medium and coarse irregular brownish yellow (10YR 6/8) soft masses of iron accumulation pedogenic throughout and many coarse irregular light gray (N 7/0) soft iron depletions pedogenic throughout; gradual wavy boundary.

Btg3--78 to 100 cm; 40 percent gray (N 6/0), broken face, and 20 percent gray (2.5Y 5/1), broken face, silty clay loam; moderate coarse prismatic structure parting to weak very thick platy; common very fine and fine roots in mat at top of horizon; 34.0 percent clay; common distinct continuous dark gray (N 4/0) clay films on faces of peds and in pores; many coarse irregular dark yellowish brown (10YR 4/6) soft masses of iron accumulation pedogenic throughout and common fine irregular yellowish red (5YR 4/6) soft masses of iron accumulation pedogenic throughout. This horizon contains silt loam material (2.5Y 4/2) associated in the interior of verticle iron accumulations which are 5 to 15 cm. across. This material also includes iron accumulations of 5YR 4/4 (10%).

Pedon ID: S2012MD019001

Sampled As : Sunken

USDA-NRCS-NSSC-National Soil Survey Laboratory

\*\*\* Primary Characterization Data \*\*\*

(Dorchester County, Maryland)

Fine-silty, mixed, active, mesic Typic Endoaqualf

; Pedon No. 13N0421

Print Date: Apr 26 2013 8:23AM

PSDA & Rock Fragments	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
	(-----Total-----) (---Clay---) (----Silt-----) (-----Sand-----) (Rock Fragments (mm))																
Layer	Clay	Silt	Sand	Fine	CO <sub>3</sub>	Fine	Coarse	VF	F	M	C	VC	(-----Weight-----)	(-----Weight-----)	(-----Weight-----)	(-----Weight-----)	(-----Weight-----)
Depth (cm)	< .002	.002	< .05	< .0002	<	.002	.02	.05	.10	.25	.5	1	2	5	20	75	>2 mm wt % whole soil
Horz	3A1a1a																
Prep	3A1a1a3A1a1a3A1a1a3A1a1a3A1a1a																
13N01696 0-5	S																
13N01697 5-7	S	13.4	78.6	8.0		46.7	31.9	4.4	3.2	0.2	0.2	tr	--	--	--	--	--
13N01698 7-19	S	21.8	73.2	5.0		43.5	29.7	4.0	0.9	0.1	tr	tr	--	--	--	--	4
13N01699 19-38	S	26.4	67.5	6.1		39.7	27.8	4.8	1.2	0.1	tr	--	--	--	--	--	1
13N01700 38-57	S	31.0	59.4	9.6		35.5	23.9	6.1	3.3	0.1	0.1	--	--	--	--	--	4
13N01701 57-84	S	31.1	59.3	9.6		36.2	23.1	7.2	2.3	0.1	--	--	--	--	--	--	2
13N01702 84-113	S	41.6	45.3	13.1		30.1	15.2	10.4	2.6	0.1	tr	--	--	--	--	--	3
13N01703 113-143	S	24.7	50.7	24.6		26.9	23.8	19.4	5.1	0.1	tr	tr	--	--	--	--	5
13N01704 143-158	S	15.9	45.1	39.0		21.1	24.0	26.8	12.0	0.2	tr	tr	--	--	--	--	12

Bulk Density & Moisture	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-
	(Bulk Density) (-----Water Content-----) (-----Ratio-----)												
Layer	33	6	10	33	1500	1500	1500	AD/OD	Moist	Ratio	Whole	Soil	Aggst
Depth (cm)	kPa	kPa	kPa	kPa	kPa	kPa	kPa	AD/OD	Moist	Ratio	Whole	Soil	Stabl
Horz	3C2a1a												
Prep	3D1												
13N01696 0-5	S												
13N01697 5-7	S	21.7	10.6	10.13	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
13N01698 7-19	S	13.7	17.8	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020	1.020
13N01699 19-38	S	20.7	26.7	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
13N01700 38-57	S	10.6	7.6	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013	1.013
13N01701 57-84	S	2.70	0.55	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
13N01702 84-113	S	1.62	0.49	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
13N01703 113-143	S	0.48	0.57	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
13N01704 143-158	S	0.42	0.64	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43

Stop 2 - Blackwater NWR  
Sunken



\*\*\* Primary Characterization Data \*\*\*

Pedon ID: S2012MD019001  
 Sampled As : Sunken  
 USDA-NRCS-NSSC-National Soil Survey Laboratory

(Dorchester County, Maryland)  
 Fine-silty, mixed, active, mesic Typic Endoaqualf  
 ; Pedon No. 13N0421

CEC & Bases	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-
	(- - - - - NH <sub>4</sub> OAC Extractable Bases - - - - -)													
Depth (cm)	Ca	Mg	Na	K	Sum Bases	Acidity	Extr Al	KCl Mn	CEC8 Sum Cats	CEC7 NH <sub>4</sub> OAC	ECEC Bases +Al	AI Sat	(- - - - - Base - - - - -)	
Layer	(- - - - - cmol(+) kg <sup>-1</sup> - - - - -)													
	4B1a1a 4B1a1a 4B1a1a 4B1a1a 4B2b1a14B3a1a 4B3a1a 4B1a1a													
13N01696 0-5	11.7	13.9	27.8	1.8	166.8	2.1	0.1	99.7						
13N01697 5-7	4.0	5.4	8.7	0.3	18.4	5.6	0.1	36.2	24.0	23	51			
13N01698 7-19	1.5	3.3	4.0	0.2	9.0	14.2	3.0	23.2	12.0	25	39	75		
13N01699 19-38	1.3	2.9	4.2	0.2	8.6	14.9	4.0	12.1			71			
13N01700 38-57	1.5	2.5	4.2	0.1	8.3	20.8	8.1	29.1	14.8	49	29	56		
13N01701 57-84	2.2	2.7	3.6	0.1	8.6	22.2	8.1	14.8			58			
13N01702 84-113	4.5	3.9	3.5	0.1	12.0	24.3	7.7	17.6			88			
13N01703 113-143	3.9	2.8	2.4	0.1	9.2	9.5	2.6	10.5			88			
13N01704 143-158	4.4*	2.6	2.1	0.1	9.2	4.1	0.4	6.6			100			

\*Extractable Ca may contain Ca from calcium carbonate or gypsum. CEC7 base saturation set to 100.

Salt	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-	-18-	-19-	-20-	
	(- - - - - Water Extracted From Saturated Paste - - - - -)																				
Depth (cm)	Ca	Mg	Na	K	CO <sub>3</sub>	HCO <sub>3</sub>	F	Cl	PO <sub>4</sub>	Br	OAC	SO <sub>4</sub>	NO <sub>2</sub>	NO <sub>3</sub>	H <sub>2</sub> O	Total Salts	Elec Cond	Elec Cond	Exch Na	SAR	
Layer	(- - - - - mmol(+) L <sup>-1</sup> - - - - -)																				
	4F2 4F2																				
13N01697 5-7	3.8	10.9	40.6	0.7	-	-	-	49.0	-	0.2	-	7.4	-	0.3	117.0	5.82	3.77	24			
13N01698 7-19	2.4	6.1	33.5	0.3	-	-	36.8	-	0.3	-	4.8	-	-	0.7	51.1	4.43	1.45	34			
13N01699 19-38	2.3	5.8	33.2	0.3	-	-	38.0	-	0.3	-	4.3	-	-	0.4	53.4	4.45	1.50	35			
13N01700 38-57	2.5	4.7	27.6	0.2	-	-	31.4	-	0.2	-	4.5	-	-	0.1	62.2	3.87	1.49	29			
13N01701 57-84	3.8	5.6	27.3	0.1	-	-	31.1	-	0.1	-	5.9	-	-	0.1	59.6	3.91	1.43	24			
13N01702 84-113	4.9	4.8	15.4	tr	-	-	17.8	-	0.3	-	8.7	-	-	0.1	92.6	2.68	1.46	20			
13N01703 113-143	6.0	5.2	16.3	0.1	-	-	19.5	-	0.1	-	9.4	-	-	-	63.8	2.90	1.13	23			
13N01704 143-158	10.4	7.9	21.3	0.1	-	-	28.2	-	0.1	-	11.7	-	-	0.1	46.8	3.94	1.19	32			

Stop 2 - Blackwater NWR  
Sunken

\*\*\* Primary Characterization Data \*\*\*

Pedon ID: S2012MD019001  
 Sampled As : Sunken  
 USDA-NRCS-NSSC-National Soil Survey Laboratory

(Dorchester County, Maryland)  
 Fine-silty, mixed, active, mesic Typic Endoaqualf  
 ; Pedon No. 13N0421

pH & Carbonates	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	
	CaCl <sub>2</sub> 0.01M H <sub>2</sub> O Sat											
	pH-----											
	(- - - - - Carbonate - -) (- - Gypsum - - -)											
	AsCaCO <sub>3</sub> AsCaSO <sub>4</sub> *2H <sub>2</sub> O Resist											
Depth	Horz	Prep	KCl	NaF	Oxid	NaF	<2mm	<2mm	<2mm	<20mm	<20mm	ohms
Layer	(cm)		1:2	4C1a2a	4C1a2a	4F2	4E1a1a1a1	4E2a1a1a1	cm <sup>-1</sup>			
13N01697	5-7	S										
13N01698	7-19	S	4.3	4.7	4.5							
13N01699	19-38	S	4.2	4.5	4.3		tr					
13N01700	38-57	S	3.9	4.2	4.1							
13N01701	57-84	S	3.9	4.2	4.1		tr					
13N01702	84-113	S	3.9	4.0	4.2		tr					
13N01703	113-143	S	4.1	4.3	4.3		tr					
13N01704	143-158	S	4.5	4.7	4.6		tr					

Organic	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
Mineral Est	Min + Est	Est	OC	OC	Total	Est OC	Fiber Content	NaPyro	Decomp Limnic	(---- pH ----)	(--- Bulk Density ---)	Proj					
ContentOM	Est OM	OC	N	N	N	/N	Unrub	Color	State	Matter	CaCl <sub>2</sub>	H <sub>2</sub> O	33 kPa	33 kPa	OD	Subs	
(----- % -----)	(----- % -----)	(----- % -----)	4H2a	ratio	5C	5C	5C	5C	5C	5C	5C	4C1a2a	g cm <sup>-3</sup>	rewet	g cm <sup>-3</sup>	cm cm <sup>-1</sup>	
5A	5A	5A	5A	5A	5A	5A	5C	5C	5C	5C	5C	5C	5C	5C	5C	5C	5C
13N01696	0-5	MW	16	82	98		48	38	10YR 7/4		3.8						
13N01696	0-5	S			47.3	1.74	27										
13N01697	5-7	S			14.0	0.59	24										
13N01698	7-19	S			1.4	0.11	13										
13N01699	19-38	S			0.5	0.10	5										
13N01700	38-57	S			0.4	0.02	15										
13N01701	57-84	S			0.4	0.08	5										
13N01702	84-113	S			0.3	0.11	3										
13N01703	113-143	S			0.2	0.07	2										
13N01704	143-158	S			0.1	0.06	2										

Stop 2 - Blackwater NWR  
 Sunken

Pedon ID: S2012MD019001

Sampled As : Sunken

USDA-NRCS-NSSC-National Soil Survey Laboratory

\*\*\* Primary Characterization Data \*\*\*

(Dorchester County, Maryland)

Fine-silty, mixed, active, mesic Typic Endoaqualf

; Pedon No. 13N0421

Print Date: Apr 26 2013 8:23AM

Layer	Depth (cm)	Horz	Fract ion	-1- X-Ray	-2- 7A1b1	-3- peak size	-4- 7A1b1	-5- 7A4a	-6- Thermal	-7- 7A4a	-8- 7A4a	-9- 7A4a	-10- SiO <sub>2</sub>	-11- Al <sub>2</sub> O <sub>3</sub>	-12- Fe <sub>2</sub> O <sub>3</sub>	-13- MgO	-14- CaO	-15- K <sub>2</sub> O	-16- Na <sub>2</sub> O	-17- EGME Retn	-18- Inter preta tion	
13N01700	38-57	Btg1	tcl	VR 3	MT 2	KK 2	MI 1	GE 1	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	VERM
13N01701	57-84	Btg2	tcl	VR 2	KK 2	MT 2	MI 1	GE 1	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	VERM
13N01702	84-113	Btg3	tcl	KK 2	GE 1	VR 1	MT 1	MI 1	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	(-----%-----)	CMIX

FRACTION INTERPRETATION:

tcl - Total Clay, <0.002 mm

MINERAL INTERPRETATION:

GE - Goethite

VR - Vermiculite

GI - Gibbsite

KK - Kaolinite

MI - Mica

MT - Montmorillonite

RELATIVE PEAK SIZE:

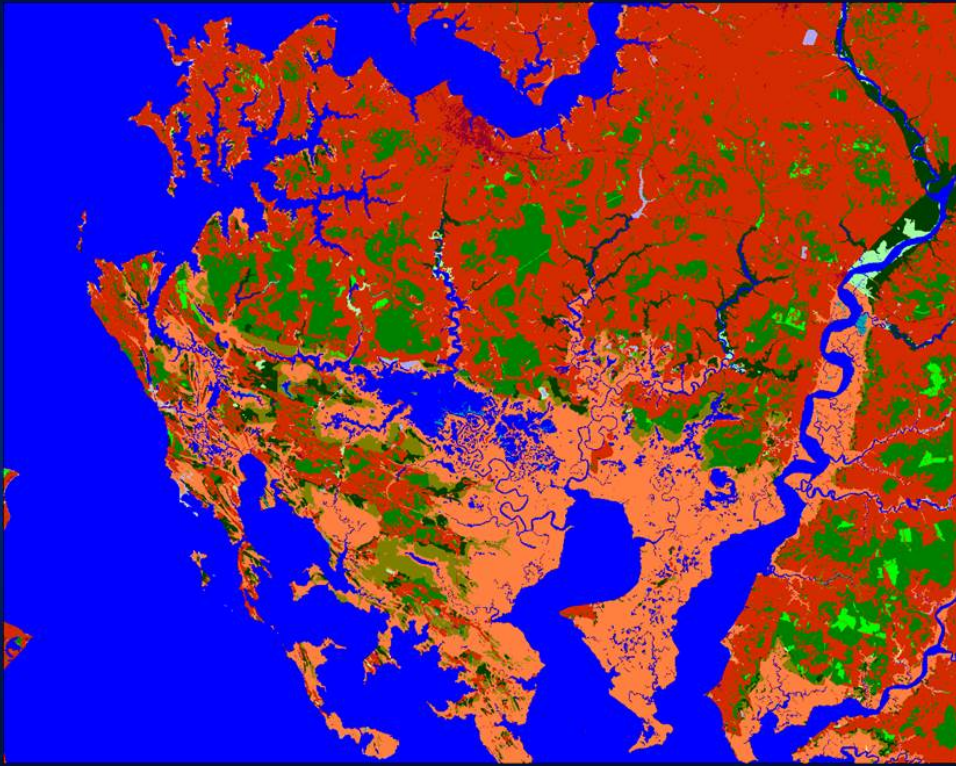
5 Very Large    4 Large    3 Medium    2 Small    1 Very Small    6 No Peaks

Stop 2 - Blackwater NWR  
Sunken

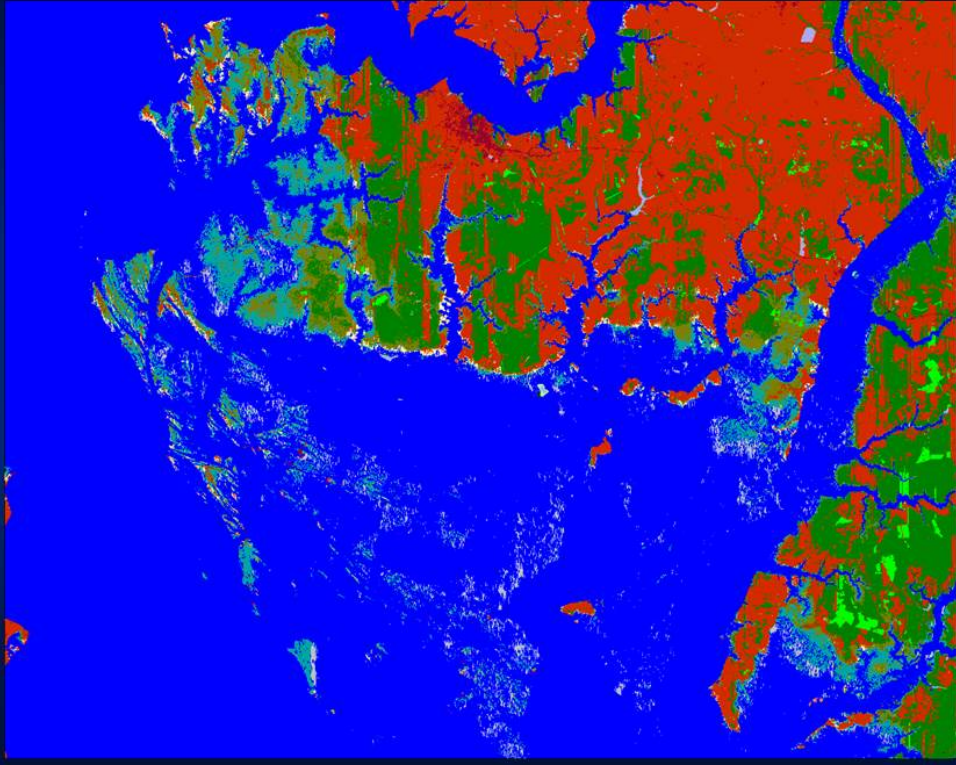
Predicted effect on Chesapeake Bay Tidal Marshes of approximately 1 meter rise in sea level.

***Sea Level Affecting Marshes Model (SLAMM)***

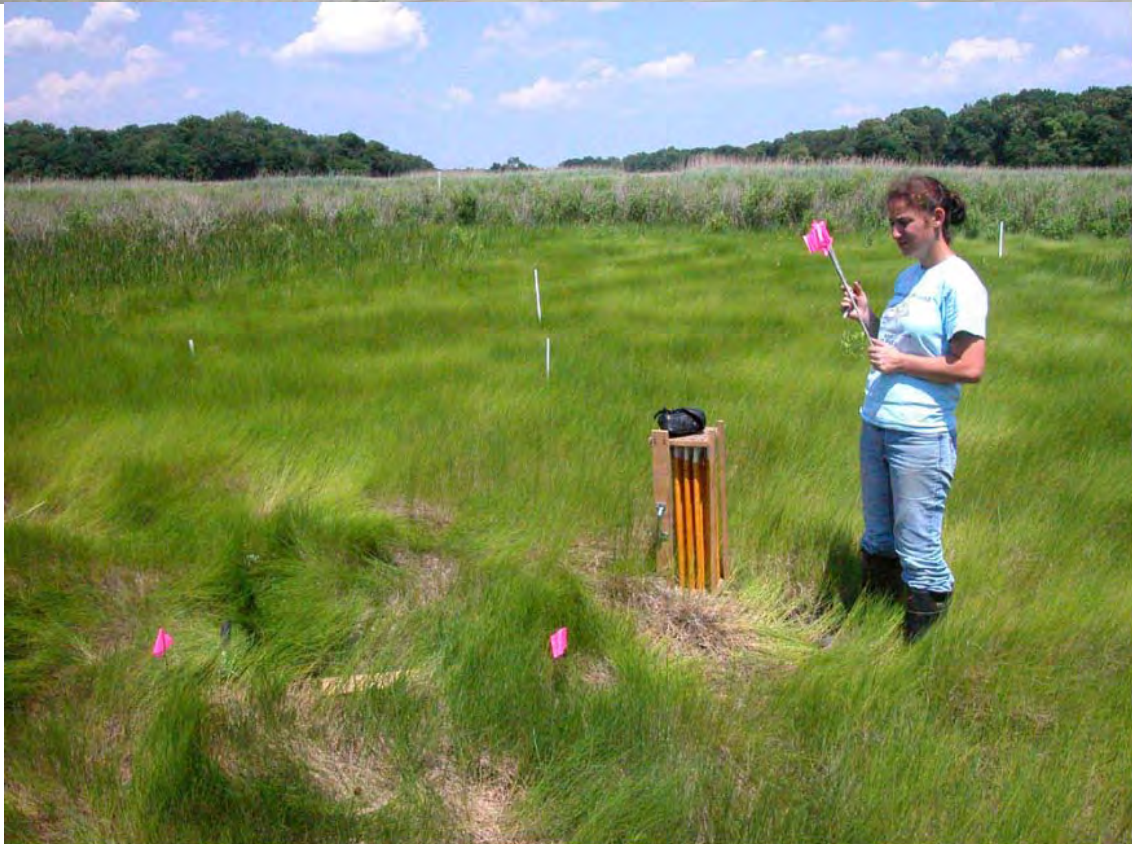
Initial Condition Cambridge MD, & Surrounding Peninsula



Year 2100, 1 meter of global sea level rise

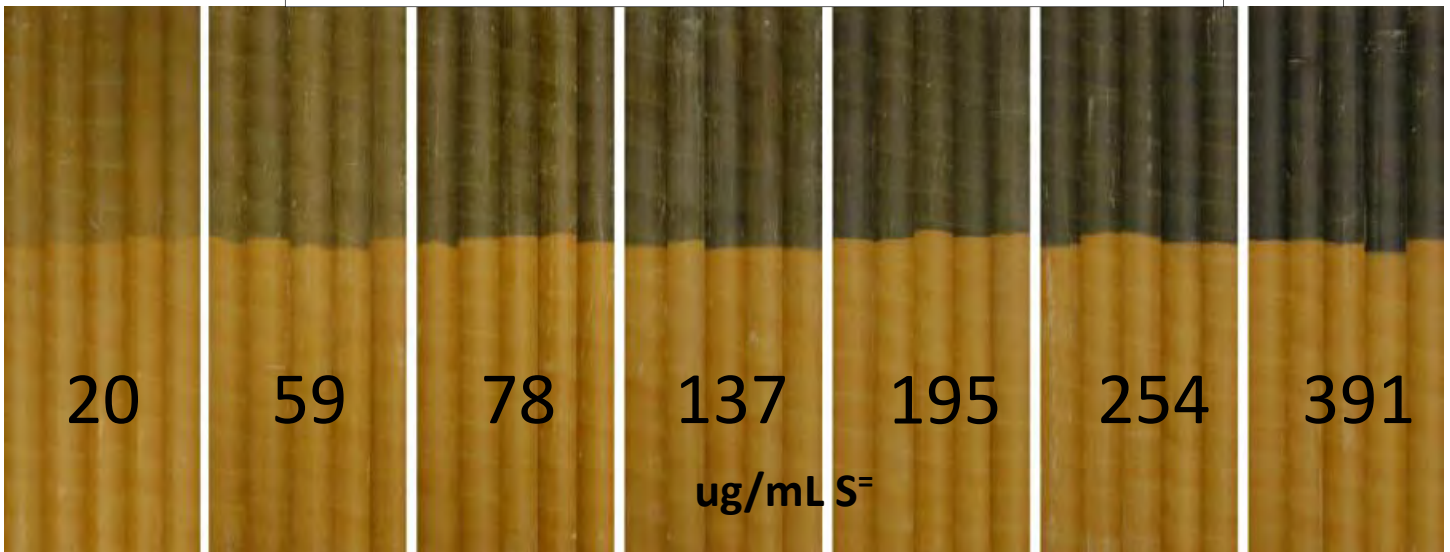
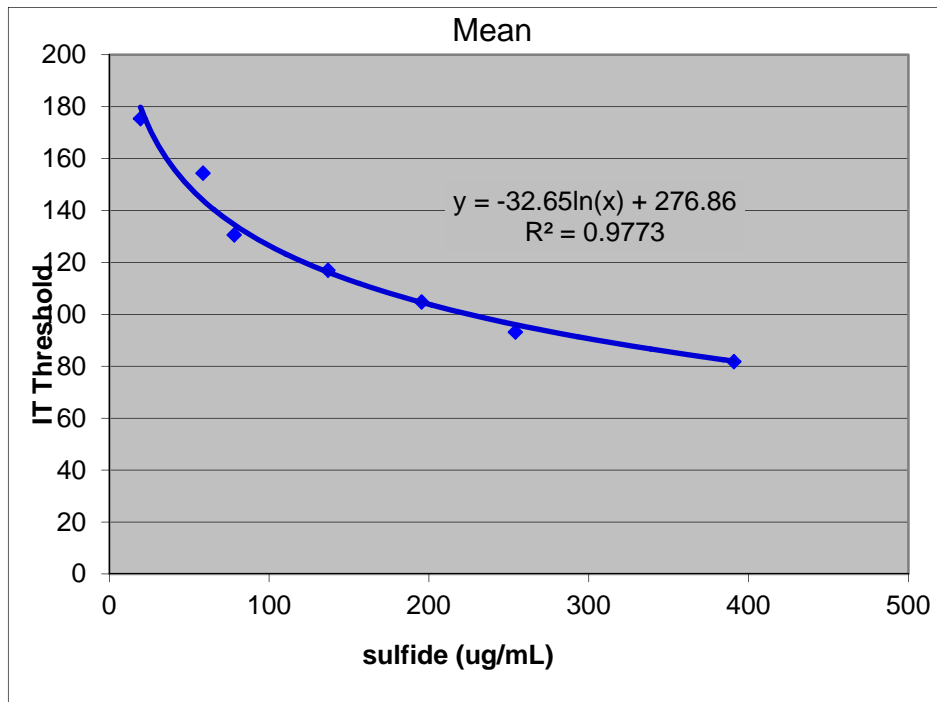


IRIS (Indicator of Reduction In Soils) tubes inserted into a tidal marsh for 5 minutes. The black color is from the formation of iron monosulfides ( $\text{FeS}$ ) by soluble sulfide reacting with the iron oxide coatings on the tubes.



# Standards

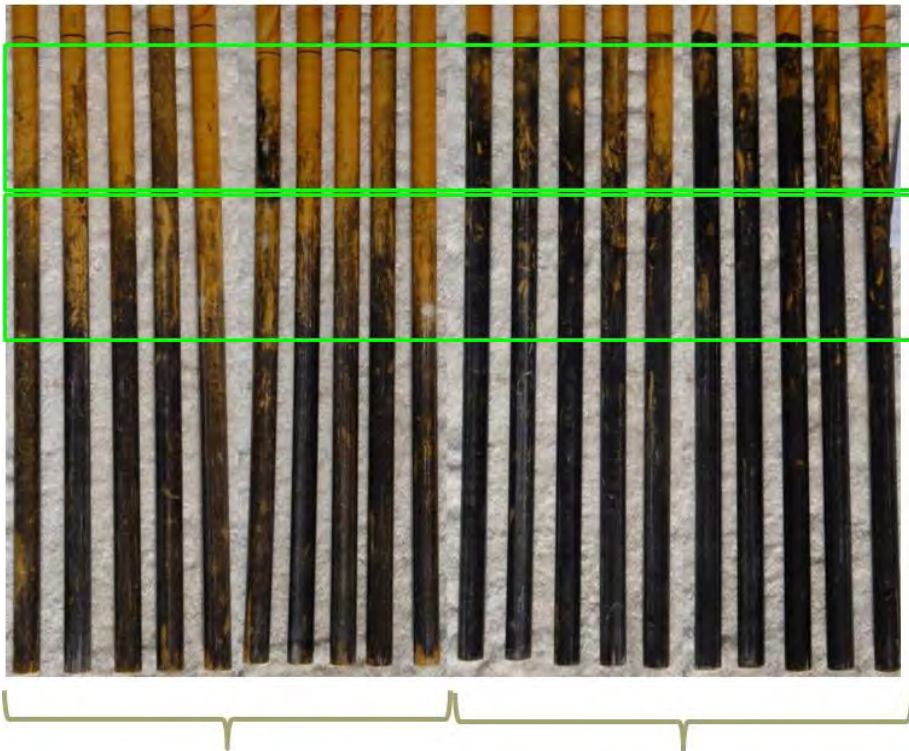
- IRIS tubes were exposed to known concentrations of sulfide for fixed time (5 min) and photographed
- Identical to field methods
- Image Tool 3.0 software



Stop 2 - Blackwater NWR

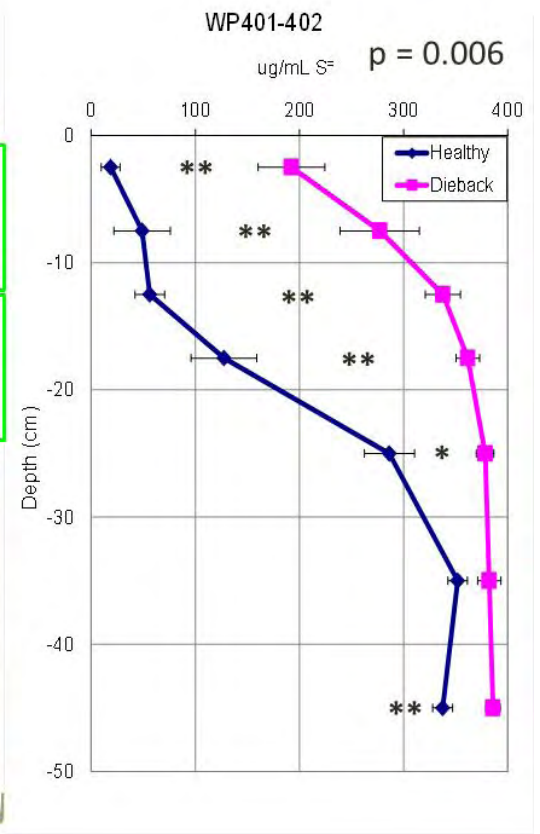


IRIS tubes used to quantify soluble porewater sulfide in tidal marsh soils. Using IRIS tubes, it was shown that the porewater sulfide concentration was significantly higher in areas where marsh grasses (*Spartina alterniflora*) had suffered dieback, than in areas where the *S. alterniflora* had healthy growth.



Healthy

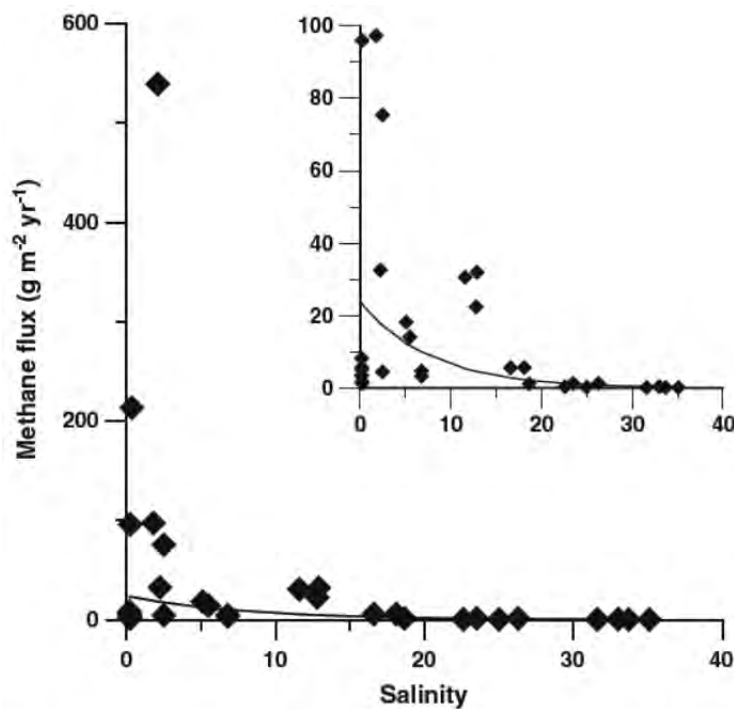
Dieback



# Salinity Influence on Methane Emissions from Tidal Marshes

Hanna J. Poffenbarger & Brian A. Needelman & J. Patrick Megonigal

**Abstract** The relationship between methane emissions and salinity is not well understood in tidal marshes, leading to uncertainty about the net effect of marsh conservation and restoration on greenhouse gas balance. We used published and unpublished field data to investigate the relationships between tidal marsh methane emissions, salinity, and porewater concentrations of methane and sulfate, then used these relationships to consider the balance between methane emissions and soil carbon sequestration. Polyhaline tidal marshes (salinity >18) had significantly lower methane emissions (mean ± sd=1±2 gm<sup>-2</sup> yr<sup>-1</sup>) than other marshes, and can be expected to decrease radiative forcing when created or restored. There was no significant difference in methane emissions from fresh (salinity=0–0.5) and mesohaline (5–18) marshes (42±76 and 16±11 gm<sup>-2</sup> yr<sup>-1</sup>, respectively), while oligohaline (0.5–5) marshes had the highest and most variable methane emissions (150±221 gm<sup>-2</sup> yr<sup>-1</sup>). Annual methane emissions were modeled using a linear fit of salinity against log-transformed methane flux ( $\log_{10} \text{CH}_4 \text{P} \frac{1}{4} - 0.056 - \text{salinity} \text{p} 1:38; r^2 = 0.52; p < 0.0001$ ). Managers interested in using marshes as greenhouse gas sinks can assume negligible methane emissions in polyhaline systems, but need to estimate or monitor methane emissions in lower-salinity marshes.



**Fig. 1** Tidal marsh methane emissions versus salinity from published sources and field sites in Maryland, USA (Table 1). The black-line curve is the linear fit of the salinity data against the log-transformed methane flux data. The inset presents the same data and curve, but does not show points with emissions above 100 g CH<sub>4</sub> m<sup>-2</sup> yr<sup>-1</sup>

**Table 2** Statistical summary and carbon dioxide equivalents of methane emissions by salinity class from tidal marshes based on published and new field data

Salinity Class	Salinity range	N	Methane emissions (g m <sup>-2</sup> yr <sup>-1</sup> )					Carbon dioxide equivalent of methane emissions (Mg CO <sub>2</sub> ha <sup>-1</sup> yr <sup>-1</sup> ) <sup>a</sup>			
			Mean	Median	Min	Max	Standard deviation	Mean	Median	Min	Max
Fresh	<0.5	8	41.9 <sup>a</sup>	5.4	1.3	213	76	10.5	1.4	0.33	53
Oligohaline	0.5–5	5	150 <sup>b</sup>	75.4	4.5	539	221	37.5	18.9	1.1	135
Mesohaline	5–18	8	16.4 <sup>a</sup>	16.2	3.3	32.0	11	4.1	4.0	0.83	8.0
Polyhaline	>18	10	1.12 <sup>c</sup>	0.40	0.2	5.7	2	0.3	0.10	0.10	1.4

<sup>a</sup> Calculated based on a methane global warming potential of 25 (100-yr time horizon)

## Vegetation Response to Prescribed Fire in Mid-Atlantic Brackish Marshes

Wesley A. Bickford, Brian A. Needelman, Raymond R. Weil, and Andrew H. Baldwin

**Abstract** Prescribed fire management generally stimulates plant biomass production in coastal marsh systems. This study was conducted to understand the interactive effects of the mechanisms of fire on vegetation production. The effects of canopy removal and ash deposition on biomass production were investigated in two manipulative experiments at the Blackwater National Wildlife Refuge, Dorchester County, MD. On non-burned sites, canopy removal increased biomass production above and belowground (40 and 260 %, respectively), while ash deposition showed no effect on production. On burned sites, post-burn canopy replacement decreased biomass production above and belowground (41 and 40 %, respectively). Production increased more in response to canopy removal at sites dominated by *Schoenoplectus americanus* than at sites dominated by *Spartina patens* and *Distichlis spicata*. Canopy removal was the dominant mechanism through which fire affected biomass production in this study. If increased biomass production is a desirable outcome, prescribed fire programs may benefit by maximizing canopy removal.

Fig. 2 Photos of canopy replacement construction over burned marsh

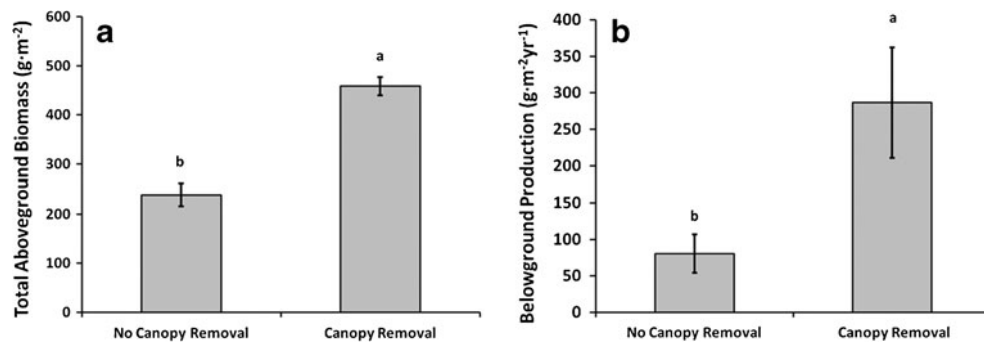


Fig. 5 Biomass production from sedge-dominated sites (2D and 7D) of No-Burn study. a Total aboveground biomass production, values represent the mean of 24 replicates ( $\pm$ standard error of the mean). Letters indicate the results of an ANOVA; means with the same letter were not significantly different from each other ( $\alpha$ 0.05). b Belowground

production, values represent the mean production to a depth of 30 cm of 24 replicates ( $\pm$ standard error of the mean). Letters indicate the results of an ANOVA; means with the same letter were not significantly different from each other ( $\alpha$ 0.05)

# Why do prescribed burns stimulate tidal marsh plant growth?

## Burn Study Fact Sheet

*The results of a University of Maryland study conducted at the Blackwater National Wildlife Refuge are summarized in this fact sheet. The study was a field-based manipulative experiment designed to better understand the mechanisms controlling plant response to prescribed burns in this region.*



### ***Prescribed burns***

A prescribed burn is a management technique whereby fire is strategically set with the intent to benefit an ecosystem. This technique is also called a “controlled burn”, and wildlife managers often employ it in marshlands during the winter, when marsh vegetation is dormant and the water table is just above the soil surface. The result is a burn that moves very quickly, removing only aboveground biomass and avoiding detrimental deeper burns that could combust marsh peat or affect living roots or rhizomes. Fire is used in coastal marshes as an aid in hunting and trapping, to reduce fuel load build-up, to encourage plant species and structures that are favorable for target wildlife, and to stimulate the growth of marsh plants.

### ***Possible reasons for the stimulation of marsh growth with prescribed burns***

Land managers have long-recognized that prescribed burns stimulate marsh plant growth and research has provided data supporting this observation. However, the mechanism is not clear: is this stimulation due to the deposition of ash, the removal of the plant canopy, or other mechanisms? Some people think the deposition of ash provides a fertilization effect, by making nutrients important to plant growth immediately available. Others believe that the removal of the canopy and/or accumulated litter increases light availability and soil temperatures early in the growing season. We conducted a manipulative, one-year experiment to test these possible mechanisms.

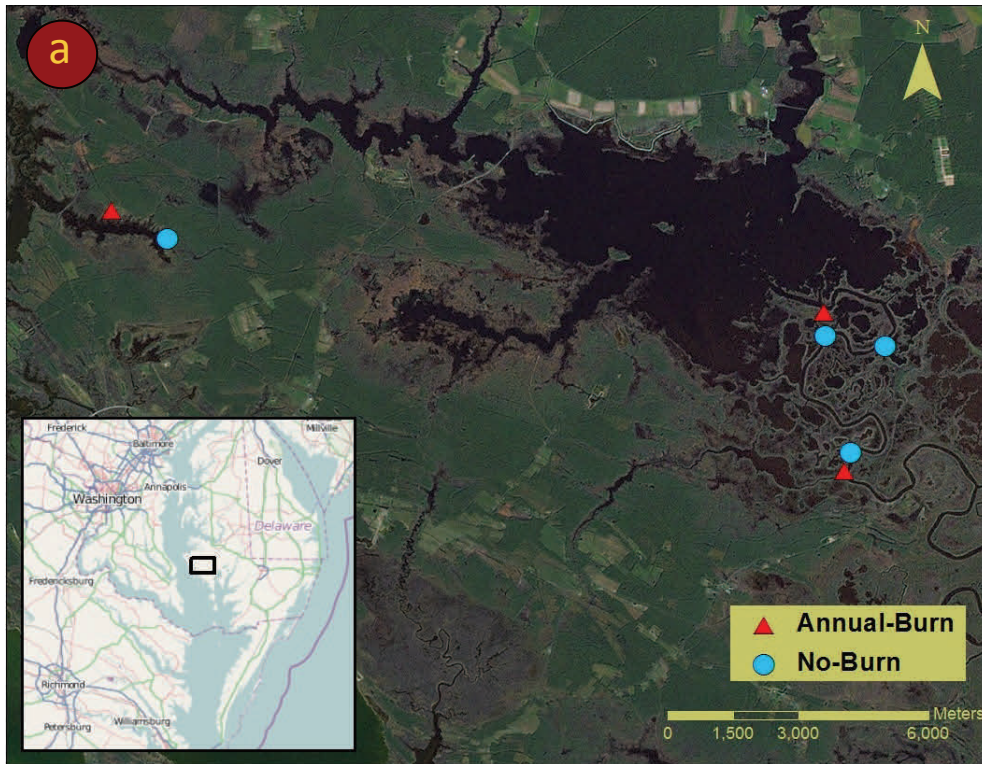
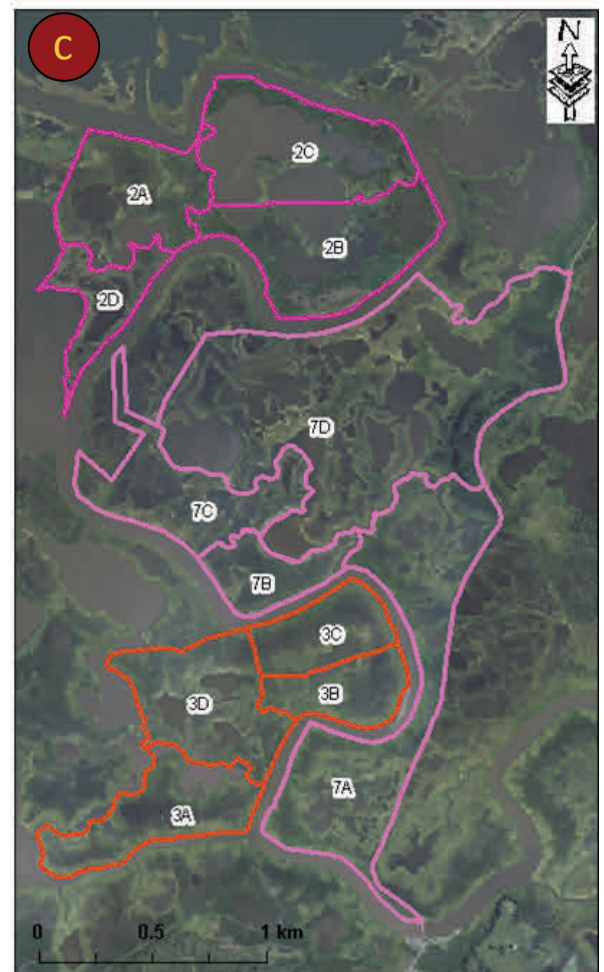
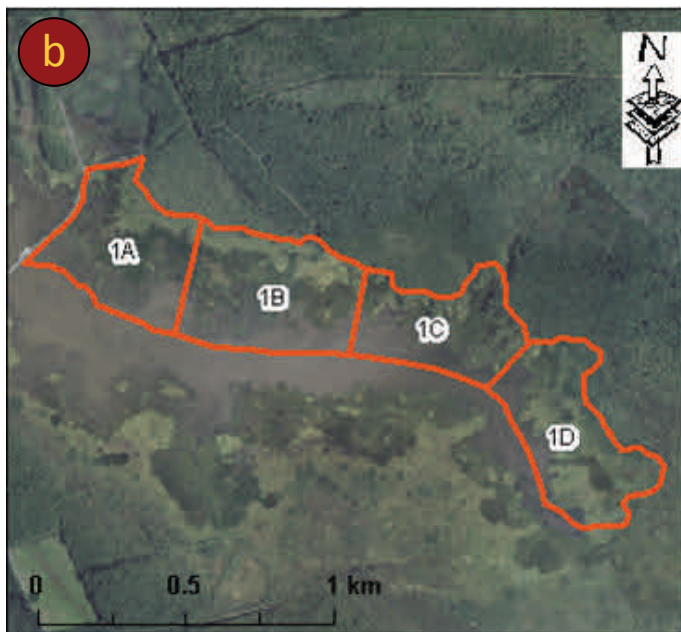


Fig. 1 The study was conducted at three annual-burn cells and four no-burn cells in the Blackwater National Wildlife Refuge on the Eastern Shore of Maryland (a). Close-ups provide more detail of the cells (b) (c).

**Experimental design and methods**

We conducted our study within the U.S. Fish and Wildlife Service’s long-term burn rotation plots at the Blackwater National Wildlife Refuge in Dorchester County Maryland. We conducted two experiments—one within four No-Burn cells (1D, 2D, 3D, 7D) and one within three Annual-Burn cells (1A, 2A, 3A) (Fig. 1a, 1b, 1c).



Within each burn treatment cell, we established 3X4 meter treatment plots that were monitored and sampled for a range of environmental variables such as: plant species composition, cover, height, and aboveground biomass; belowground production; soil temperature; light availability at the soil surface; water level and chemistry; nutrient availability; and organic matter decomposition (Fig. 2). We had three replications per cell for each treatment (described on next two pages). The plots were located adjacent to plots established by the U.S. Geological Survey, who are conducting a long-term study on prescribed burns and marsh elevation change (Cahoon et al. 2010).

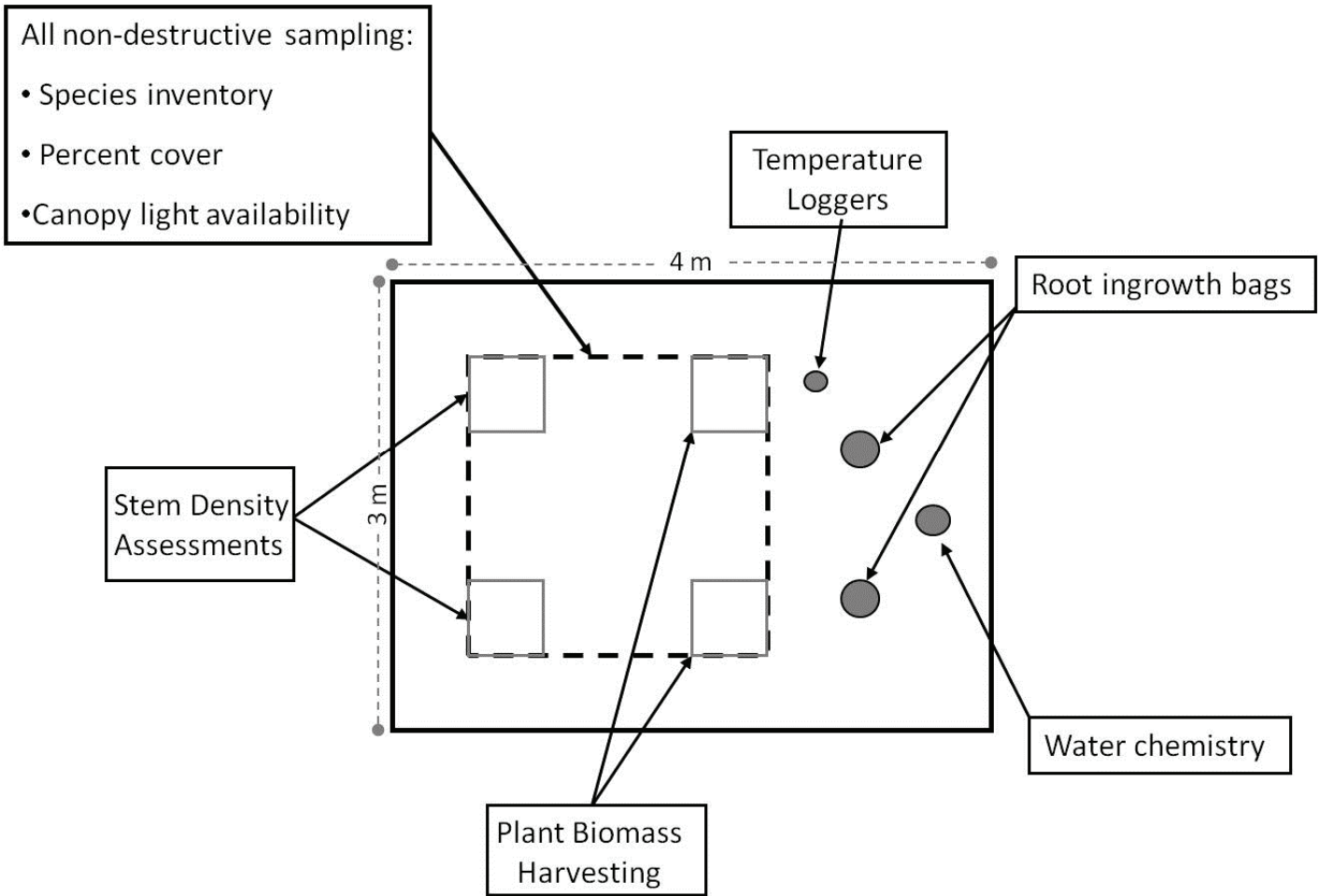


Fig. 2. Schematic of plot set-up. A temperature logger was installed at a depth of 5 cm. One of the three replicate plots per site was also equipped with a second logger at 20 cm. Each plot had a non-destructive and a destructive sampling area. All non-invasive data collection, such as the species composition assessment, was performed in non-destructive area while all invasive data collection, such as biomass harvest or installing instruments into the soil, was performed outside of the non-destructive zone. At the conclusion of the study, final biomass harvest was collected from the non-destructive zone, as this area remained relatively undisturbed throughout the field season. There was a 50-cm buffer around the perimeter where no sampling occurred. A well was established at each plot where water chemistry and water table height data were collected. Plots were identical in Annual-Burn and No-Burn experiments.

Our treatments at the No-Burn cells were: a control, canopy removal (using a hedge clippers), ash deposition (senesced plant materials removed, combusted, and re-applied), and canopy removal plus ash deposition (Fig. 3 and 4).

(Right) Fig. 3. Canopy removal at a No-Burn cell

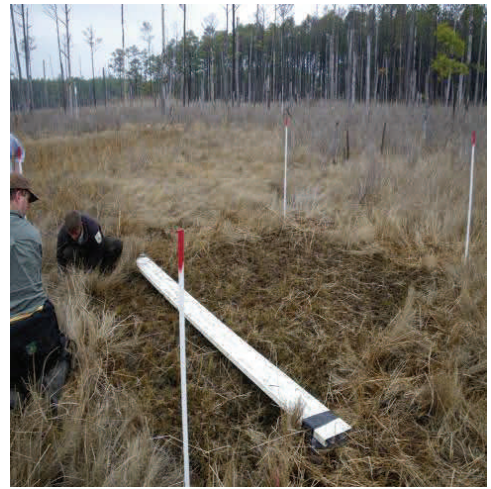


Fig. 4. Biomass was dried at 40°C for 24 hours and ignited in galvanized steel bins (a) (b) (c); After combustion, the ash was homogenized and spread evenly over the Ash Deposition plots using a 1-mm mesh sifter. This ash was deposited on the soil surface of the Ash Deposition and Canopy Removal + Ash Deposition plots in April 2009 (d).

Our treatments at the Annual-Burn cells were a control and canopy replacement. For canopy replacement, we used poultry fencing and nearby senesced vegetation to recreate the plant canopy following the burn. The idea behind this treatment was to determine if we could cancel out the positive effects of burning on plant growth solely by putting the canopy back (Fig. 5).



Fig. 5. Photos of canopy replacement treatment applied at annually burned sites. Poultry fencing was stapled to a wooden frame (a); artificial canopies were set ~15 cm above of the soil surface (b); senesced plant shoots were placed in mesh hardware cloth (c); new growth was able to grow through the artificial canopy (d).



## Overall Results

We found that our ash deposition treatment had no effect on plant growth while our canopy removal and replacement treatments had very strong effects on plant growth. The canopy removal treatment yielded results that were comparable to the positive effects often observed on plant growth by prescribed burns, increasing aboveground biomass 40% and belowground production 160% (Fig. 6a and 6b). In contrast, canopy replacement decreased aboveground biomass 41% (Fig. 7).



Canopy replacement treatment at high tide

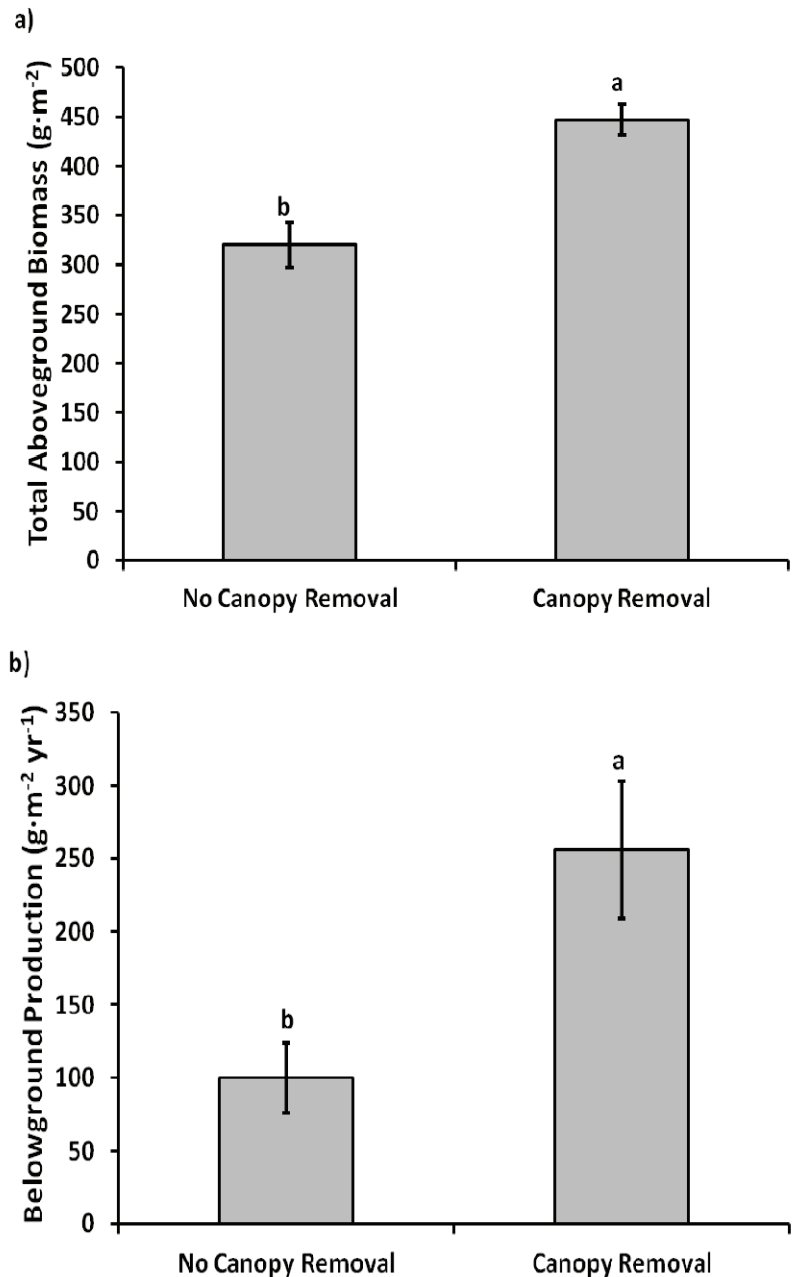


Fig. 6. Biomass production from No-Burn sites. a) Total aboveground biomass production, values represent the mean of 48 replicates ( $\pm$  standard error of the mean). b) Belowground production, values represent the mean production to a depth of 30 cm of 48 replicates ( $\pm$  standard error of the mean). Letters indicate the results of an ANOVA; means with different letters were significantly different from each other ( $\alpha=0.05$ ).

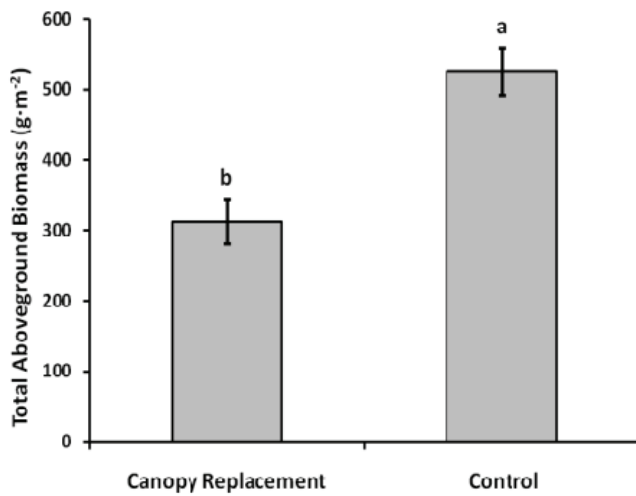


Fig. 7. Canopy replacement at annual-burn sites lowered total aboveground biomass. Different letters indicate significant differences ( $\alpha=0.05$ ).

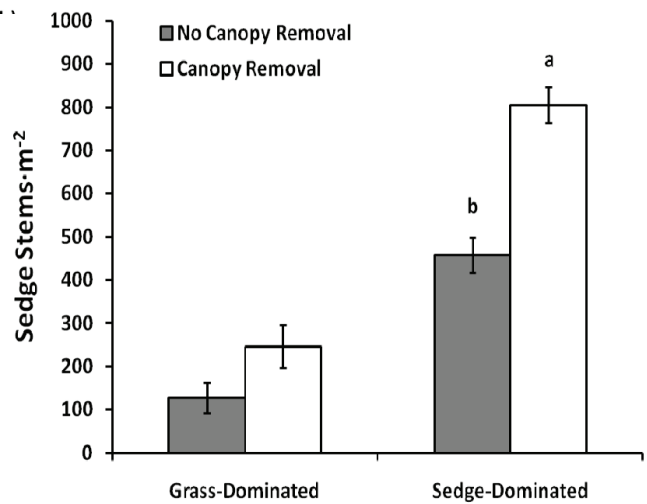


Fig. 8. Canopy removal increased sedge stem density at both grass and sedge-dominated sites. Different letters indicate significant differences ( $\alpha=0.05$ ).

## Results by species

Our statistical analysis indicated that the effects of canopy removal were not consistent across our four study sites in the No-Burn experiment. Two of these sites were dominated by the sedge *Schoenoplectus americanus* while the other two were dominated by the grasses *Distichlis spicata* and *Spartina patens*. When we analyzed just the grass-dominated sites, we found that canopy removal had relatively minor or no effects on plant growth (the average biomass production at these sites was 457 g / m<sup>2</sup>). When we looked at the sedge-dominated sites, the effects of canopy removal were dramatic, including a 92% increase in aboveground biomass and a 250% increase in belowground production (Fig. 9). We also observed dramatic increases in the density of the sedges (Fig. 8), but not the grasses.

## Sedge-dominated sites

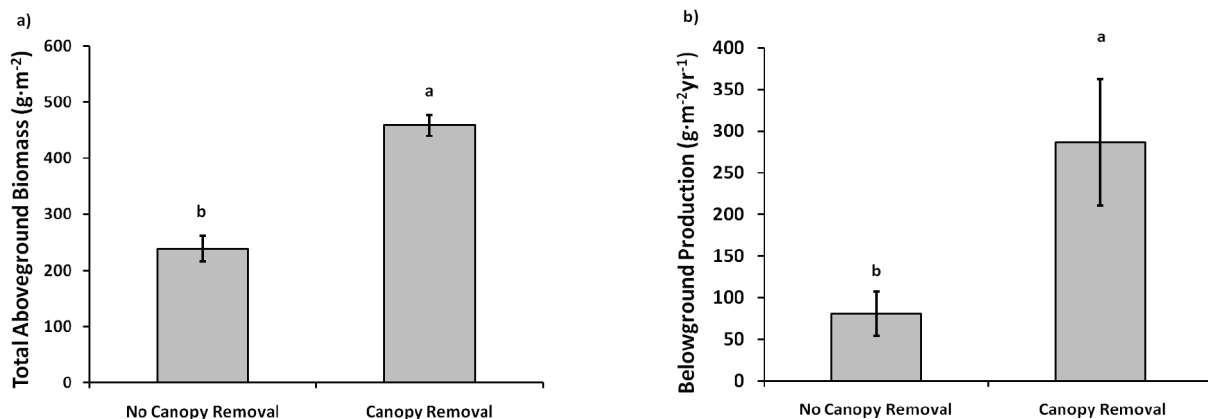


Fig. 9. Biomass production from sedge-dominated sites (2D and 7D) of No-Burn study. a) Total aboveground biomass production, values represent the mean of 24 replicates ( $\pm$  standard error of the mean). b) Belowground production, values represent the mean production to a depth of 30 cm of 24 replicates ( $\pm$  standard error of the mean). Letters indicate the results of an ANOVA; means with different letters were significantly different from each other ( $\alpha=0.05$ ).

## Mechanisms

There are two explanations for why canopy removal may increase plant growth—increased light availability and increased soil temperatures. Both of these mechanisms are thought to be most important early in the growing season. We monitored light availability and did find that it increased dramatically following canopy removal. This effect diminished as the plant canopy was re-established, but it was present throughout that growing season. We also found that soil temperatures increased with canopy removals at depths of both 5 and 20 cm. The greatest increase in soil temperatures actually wasn't very early in the growing season (March to mid-April), which was probably because the marsh water levels were high during this period. Rather, we found that the greatest soil temperature increases were from mid-April to mid-June, when temperatures were about 0.5 to 2 °C warmer at 5 cm with canopy removal.

## Why not nutrients?

We measured nutrient availability using four different methods – porewater, soils, resin capsules, and plant nutrient content – and found no increases in nutrients in our ash deposition treatment. Blackwater is a nitrogen limited system. As it turns out, the ash only contained 0.22 g nitrogen / m<sup>2</sup> (Table 1). This is probably not a sufficient fertilizer dose to generate a plant response when applied in the winter or early spring (plants are generally most nutrient-limited at their peak growth rate). Our combustion method generated relatively high burn temperatures (at least 320°C), which means that we had relatively low nitrogen in our samples. However, based on published models (Qian et al. 2009), even at lower burn temperatures the nitrogen content of our ash would likely have been in the range of 1 g Nitrogen / m<sup>2</sup>; which based on our literature review probably still would not have generated a plant response (see Geatz, 2012). In general, we found that canopy removal by itself generated the type of plant growth stimulation that is commonly observed. We were able to reverse this effect with our canopy replacement treatment (which did have natural ash deposition). Overall, we found little support for nutrients as an important mechanism controlling plant response to fire in these systems.

Table 1. Elemental standing stocks of senesced vegetation and ash constituents applied to no-burn study sites along with percent volatilization. Standard error bars shown as well.

Element	Pre-Burn Biomass Constituents (g/m <sup>2</sup> )	Percent Volatilized	Ash Constituents (g/m <sup>2</sup> )
C	137.05 ± 11.73	93.87 ± 1.43	6.12 ± 0.67
N	3.46 ± 0.37	90.57 ± 2.14	0.22 ± 0.02
P	0.34 ± 0.03	50.55 ± 6.70	0.16 ± 0.02
K	5.13 ± 0.81	6.35 ± 4.51	4.96 ± 0.05
Ca	0.75 ± 0.08	4.67 ± 3.86	0.71 ± 0.06
Mg	1.20 ± 0.12	6.80 ± 7.36	1.10 ± 0.06
S	4.06 ± 0.60	84.82 ± 4.10	0.31 ± 0.03

## Summary and implications

In a one-year manipulative study, we found that prescribed fire increased aboveground and belowground biomass production primarily through canopy removal, and not through fertilization by deposited ash. Biomass increases were greatest and most consistent following canopy removal in *S. americanus*-dominated communities. If increased biomass production is a desirable outcome, prescribed fire programs may benefit by maximizing canopy removal, particularly in *S. americanus*-dominated areas.

## **The data, figures, and tables in this fact sheet come from the following publications:**

- Bickford, W. A. 2011. Plant productivity and competitive response to prescribed fire in mid-Atlantic brackish marshes. M.S. Thesis, University of Maryland, College Park, MD, USA. 229p.
- Bickford, W.A., A.H. Baldwin, B.A. Needelman, and R.R. Weil. 2012. Canopy disturbance alters competitive outcomes between two brackish marsh plant species. *Aquatic Botany*. doi:10.1016/j.aquabot.2012.05.006
- Bickford, W. A., B. A. Needelman, R. R. Weil, and A. H. Baldwin. 2012. Vegetation response to prescribed fire in Mid-Atlantic brackish marshes. *Estuaries and Coasts* 2012, DOI: 10.1007/s12237-012-9538-3
- Geatz, G.W. 2012. Nutrient levels and organic matter decomposition in response to prescribed burns in Mid-Atlantic coastal marshes. M.S. Thesis. University of Maryland.
- Geatz, G.W., B.A. Needelman, R.R. Weil, J.P. Megonigal. Nutrient Availability and Soil Organic Matter Decomposition Response to Prescribed Burns in Mid-Atlantic Brackish Marshes. (in review)

## **Citations**

- Cahoon D. R., G. Guntenspergen, S. Baird, J. Nagel, P. Hensel, J. Lynch, D. Bishara, P. Brennan, J. Jones, and C. Otto. 2010. Do annual prescribed fires enhance or slow the loss of coastal marsh habitat at Blackwater National Wildlife Refuge? Final Project Report (JFSP Number: 06-2-1-35). March 31, 2010. Beltsville, MD.
- Qian, Y., S.L. Miao, B. Gu, and Y.C. Li. 2009. Estimation of postfire nutrient loss in the Florida everglades. *J. Environ. Qual.* 38:1812–1820.

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**Some results presented in this fact sheet have not yet been peer-reviewed and should be interpreted as preliminary.**

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