Three Topics

- Influence of Climate Change on Wetlands and Water Quality
- Influence of Submerged Aquatic Vegetation on Nutrient Budgets and Water Quality
- Plans for Future Model Development

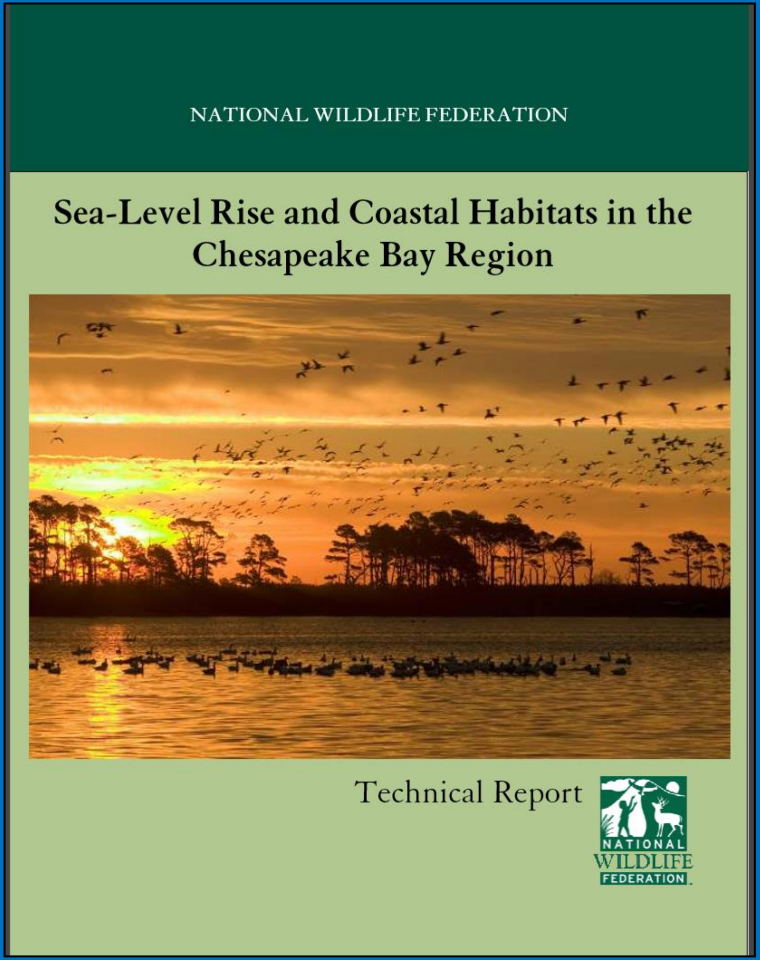
Influence of Climate Change on Wetlands and Water Quality

We need projections of wetlands location and area as a function of sea-level.

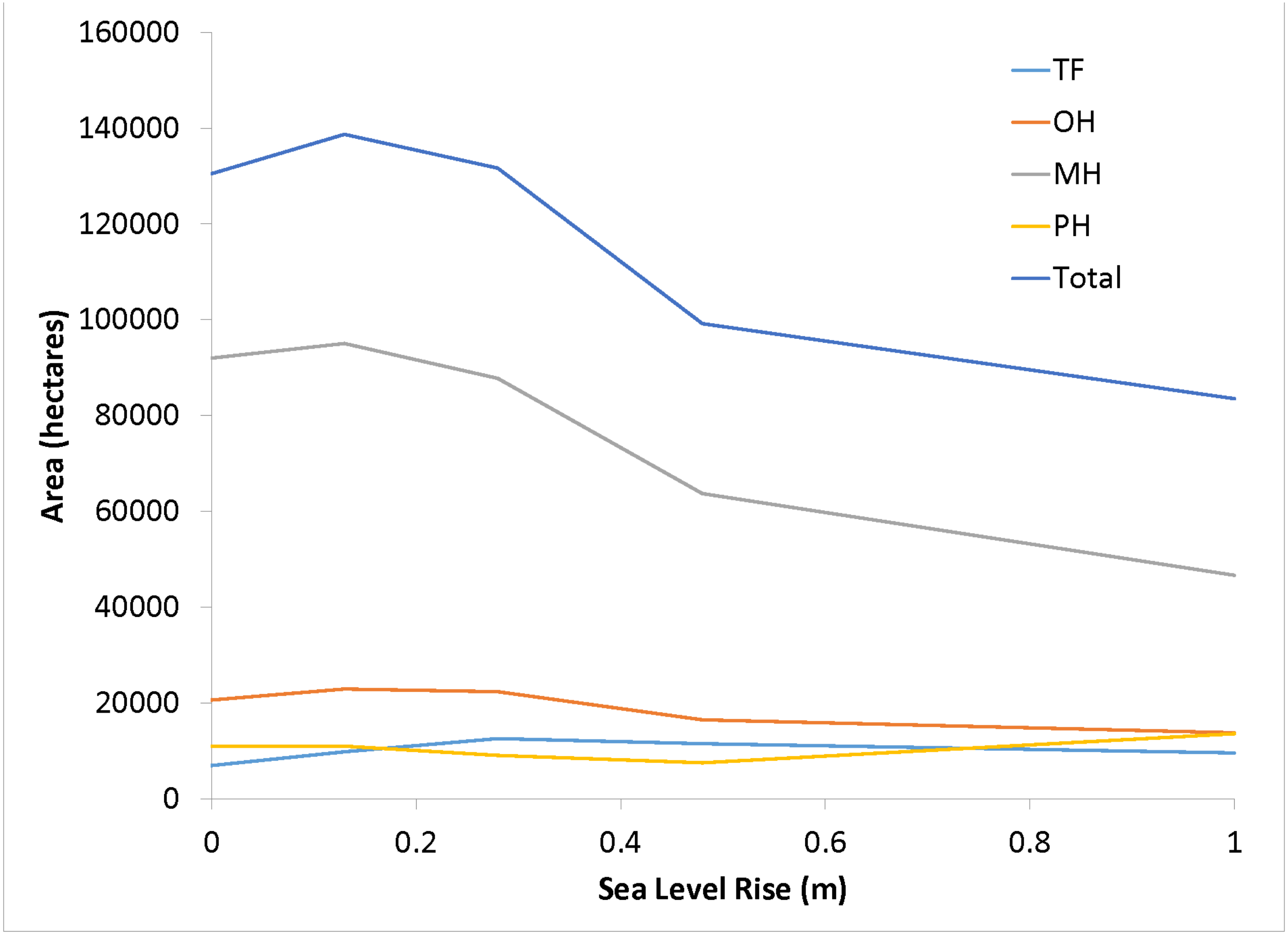
We need to quantify materials fluxes between wetlands and adjacent open waters.

Cerco, C., and Tian, R. (2021) "Impact of Wetlands Loss and Migration, Induced by Climate Change, on Chesapeake Bay DO Standards," Journal of the American Water Resources Association.

Sea-Level Rise and Tidal Wetlands



- Our estimates of effect of sea-level rise on tidal wetlands come from the Sea-Level Affecting Marshes Model (SLAMM).
- Study conducted for the national Wildlife Federation by Glick et al. (2008).
- SLAMM scenarios:
  - IPCC B1: 0.31 m sea-level rise, broken into four increments.
  - 1 Meter: 1 m sea-level rise, broken into four increments.


Area (hectares)
160000
140000
120000
100000
80000
60000
40000
20000
0
0
0.2
0.4
0.6
0.8
1
Sea Level Rise (m)
TF
OH
MH
PH
Total

Wetlands Module

- We don’t want to develop a complete wetlands biogeochemical model.
- We do want to develop a simplified module that includes:
  - Particle burial (organic and inorganic)
  - Respiration
  - Denitrification
  - Primary production
  - Others?

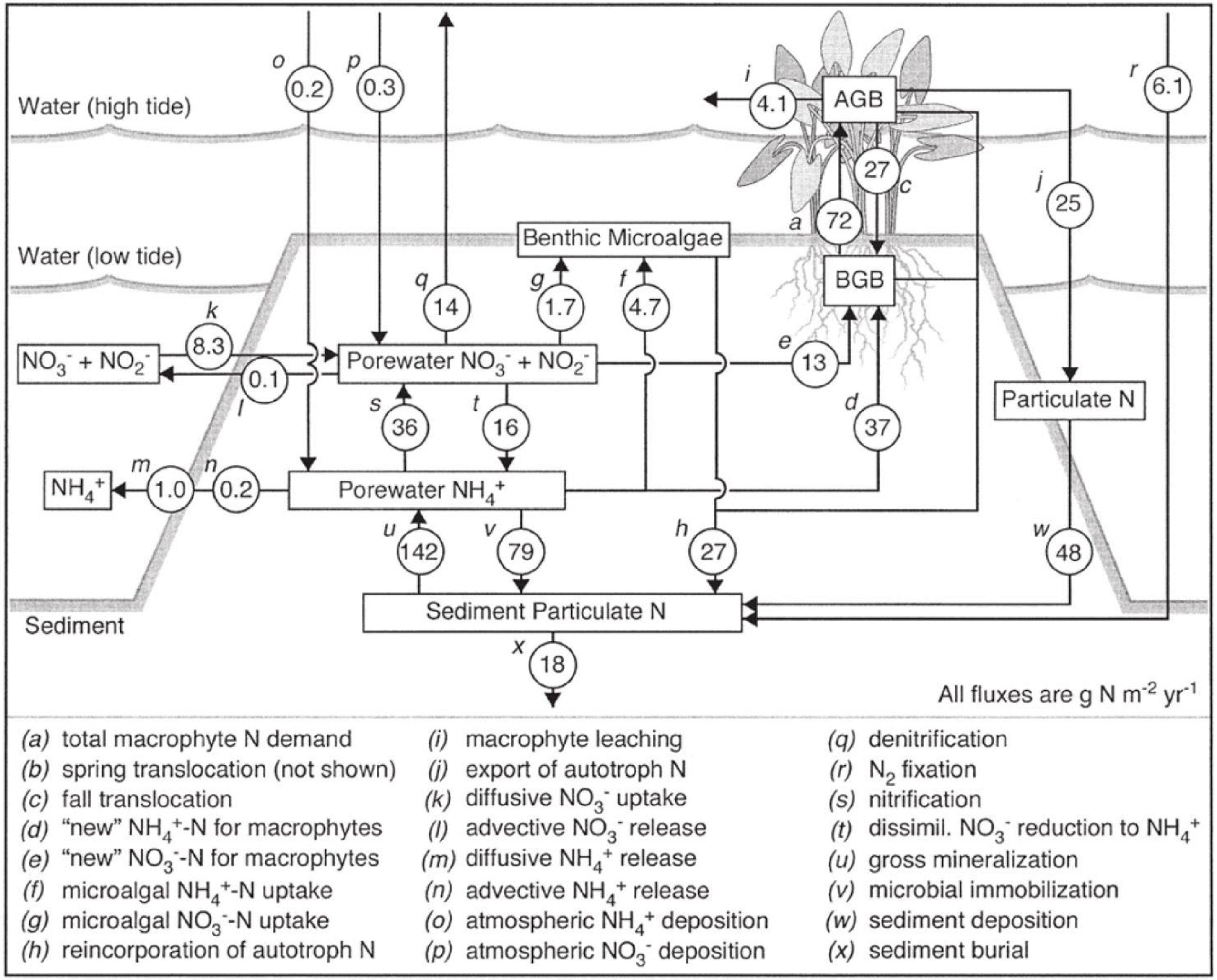


Fig. 3. Nitrogen mass balance for Sweet Hall marsh. All fluxes are in g N m^{-2} yr^{-1} and are based on measured rates, literature values, or calculated by difference (assuming steady state) as detailed in the text. Standard deviations for each flux are omitted for visual clarity but can be found in Table 1 and in the text. AGB = aboveground macrophyte biomass; BGB = belowground macrophyte biomass.

Estuaries Vol. 28, No. 6, p. 909–922 December 2005

Nitrogen Cycling and Ecosystem Exchanges in a Virginia Tidal Freshwater Marsh

Scott C. Neubauer[1,2,*], Iris C. Anderson[1], and Betty B. Neikirk[1]

Particle Settling

$$V \cdot \frac{dC}{dt} = Transport \ + Kinetics \ - WSw \cdot C \cdot Aw$$

V = volume of WQM cell adjacent to wetlands
C = concentration
WSw = wetland settling velocity
Aw = area of wetland adjacent to WQM cell

This applies to all particles, organic and inorganic. Present settling rates 0.05 m/d for most particles, 0.005 m/d for phytoplankton.

Respiration

$$V \cdot \frac{dC}{dt} = Transport\ + Kinetics\ - f(DO) \cdot f(T) \cdot WOC \cdot Aw$$

V = volume of WQM cell adjacent to wetlands
C = concentration
f(DO) = limiting factor = DO/(Kh+DO)
f(T) = temperature effect
WOC = wetland oxygen consumption
Aw = area of wetland adjacent to WQM cell

At present, WOC = 0.5 g DO/sq m/d at 20C. WOC doubles for a 10C temperature increase. Kh = 1.0 g DO/m3.

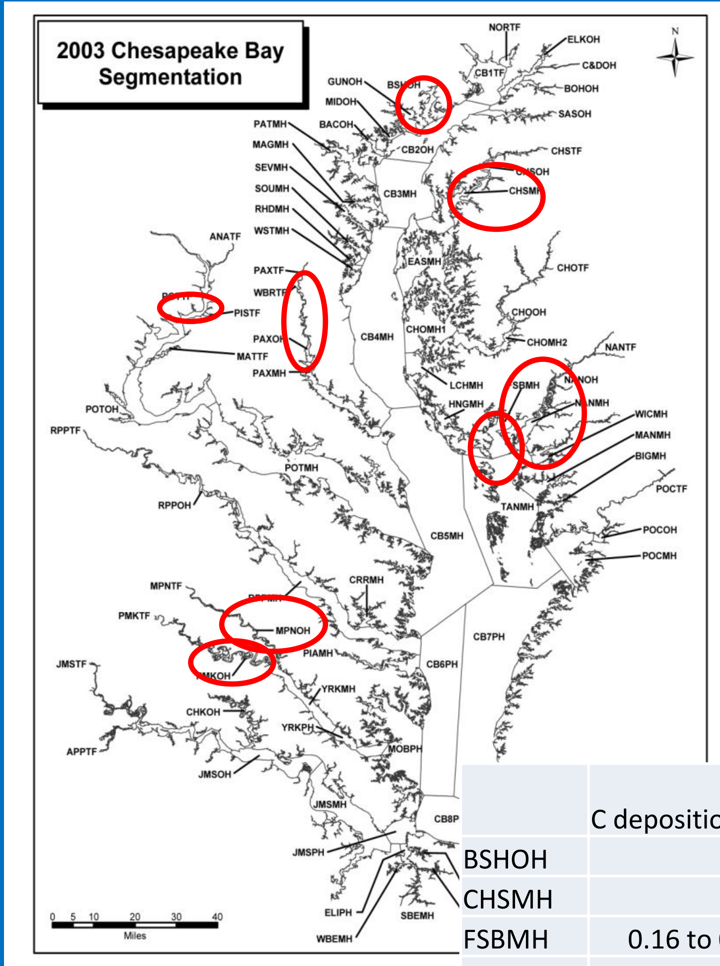
Previous calibration had WOC = 1 g DO/sq m/d and no limiting factor. Wetland areas from TMDL model.

Denitrification

$$V \cdot \frac{dC}{dt} = Transport\ + Kinetics\ - MTC \cdot f(T) \cdot C \cdot Aw$$

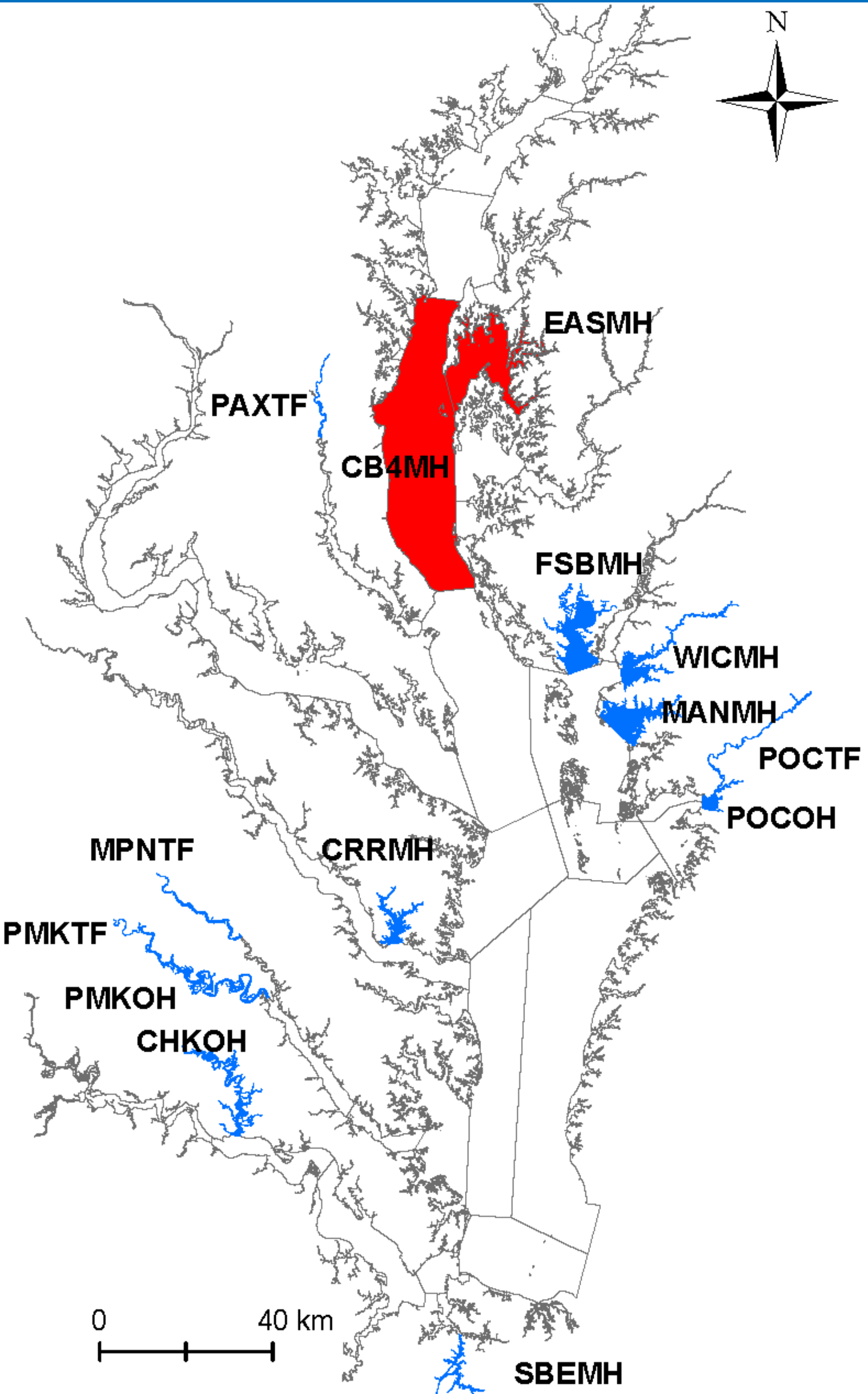
V = volume of WQM cell adjacent to wetlands
C = nitrate concentration
MTC = mass-transfer coefficient
f(T) = temperature effect
Aw = area of wetland adjacent to WQM cell

At present, the mass-transfer coefficient is 0.05 m/d.
Denitrification doubles for a 10C temperature increase.



Hot Spots for Calibration

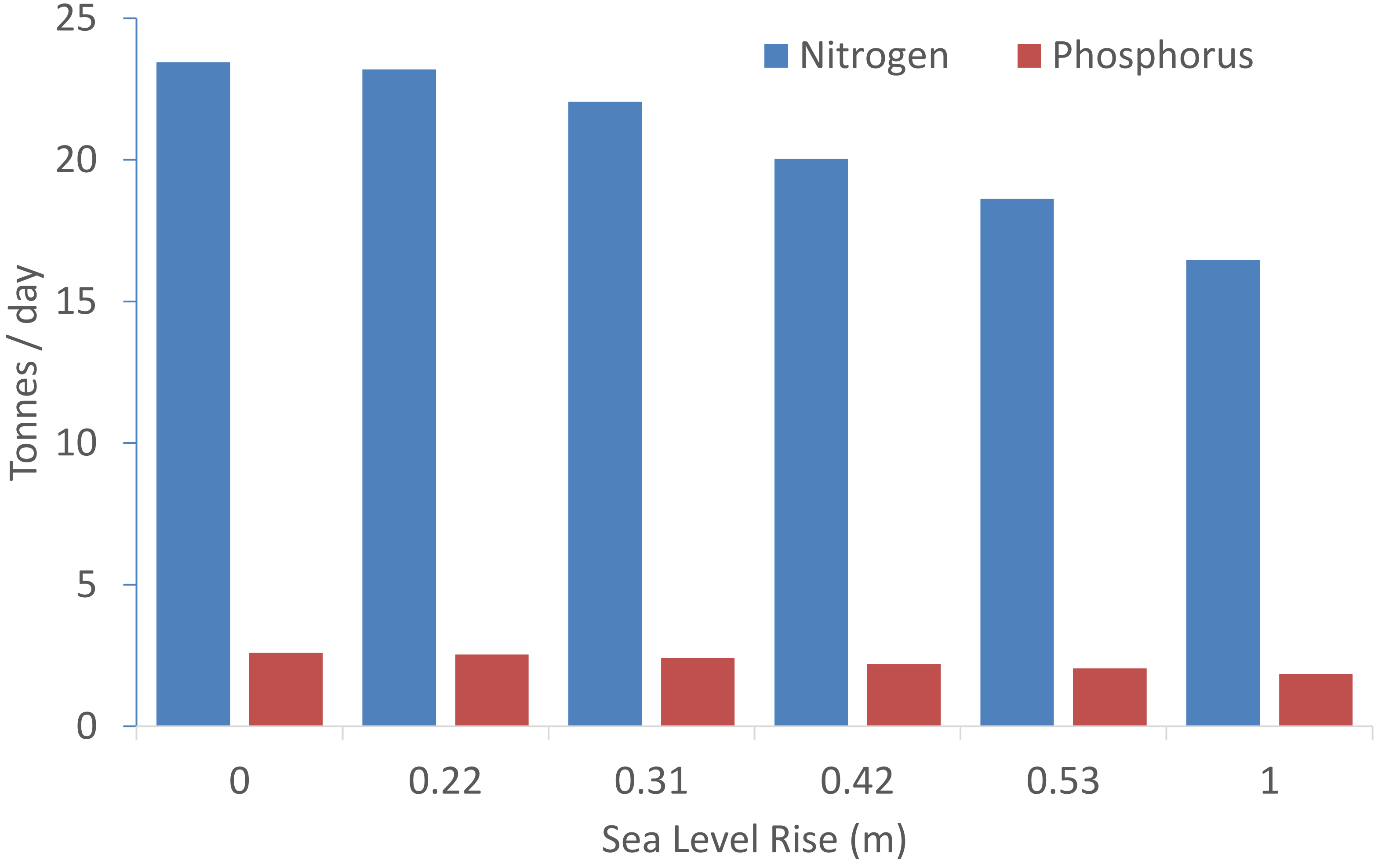
	C deposition	N deposition	P deposition	denitrification	solids deposition	respiration
BSHOH		0.008 to 0.032	0.001 to 0.006			
CHSMH		0.02 to 0.064	0.01 to 0.019		3.6	
FSBMH	0.16 to 0.33				0.3	
MPNOH	0.24 to 2.77	0.019 to 0.238	0.004 to 0.085		1.43 to 42.0	
MPNTF						
NANMH	0.033 to 0.126				1.61 to 8.12	
NANOH	0.033 to 0.126				1.61 to 8.12	
PAXOH		0.008	0.002		5.75	
PAXTF		0.033 to 0.064	0.01	0.108 to 0.197	5.75	
PMKOH	0.61	0.05		0.04		1.12 to 2.77
POTTF	1.44			0.043 to 0.06	5.88	
WICMH	0.033 to 0.126	0.037	2.74x10^-5 to 0.004		1.61 to 8.12	
CHOMH		0.053 to 0.074	4.9x10^-4 to 0.005			
WQGIT			0.0016	0.026		



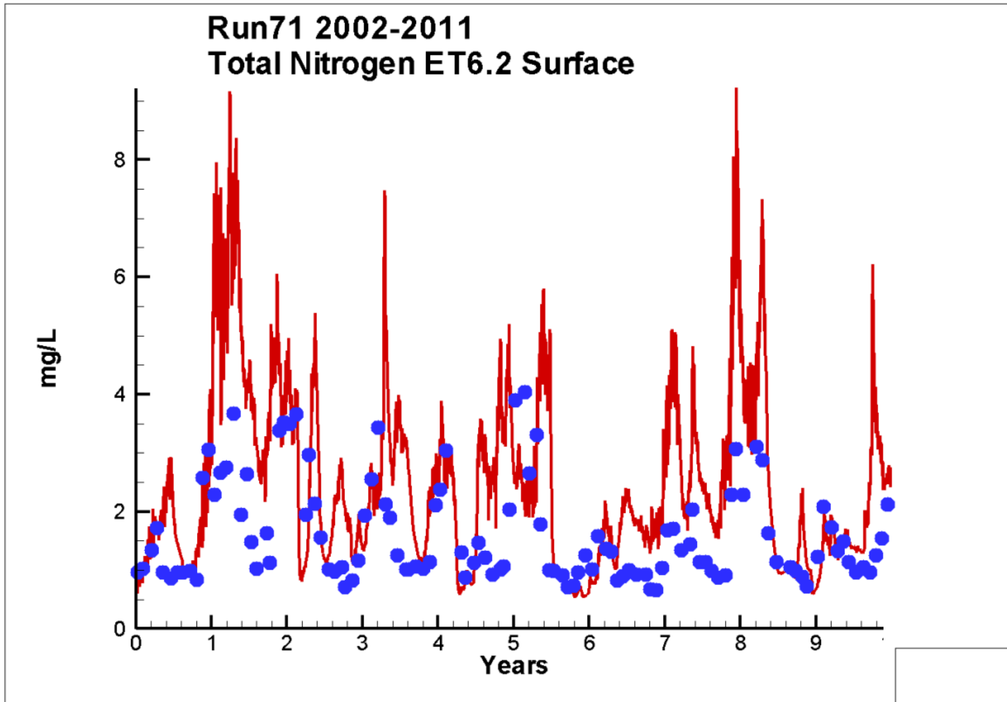
CBPS which show an increase in DO criteria exceedances caused by rise in sea level. Segments highlighted in red show increased exceedances in Deep Water and Deep Channel regions. Segments highlighted in blue show increased exceedances in Open Water regions.

Criteria Exceedance = Diminished DO

Wetland Nutrient Removal as a Function of Sea-Level Rise

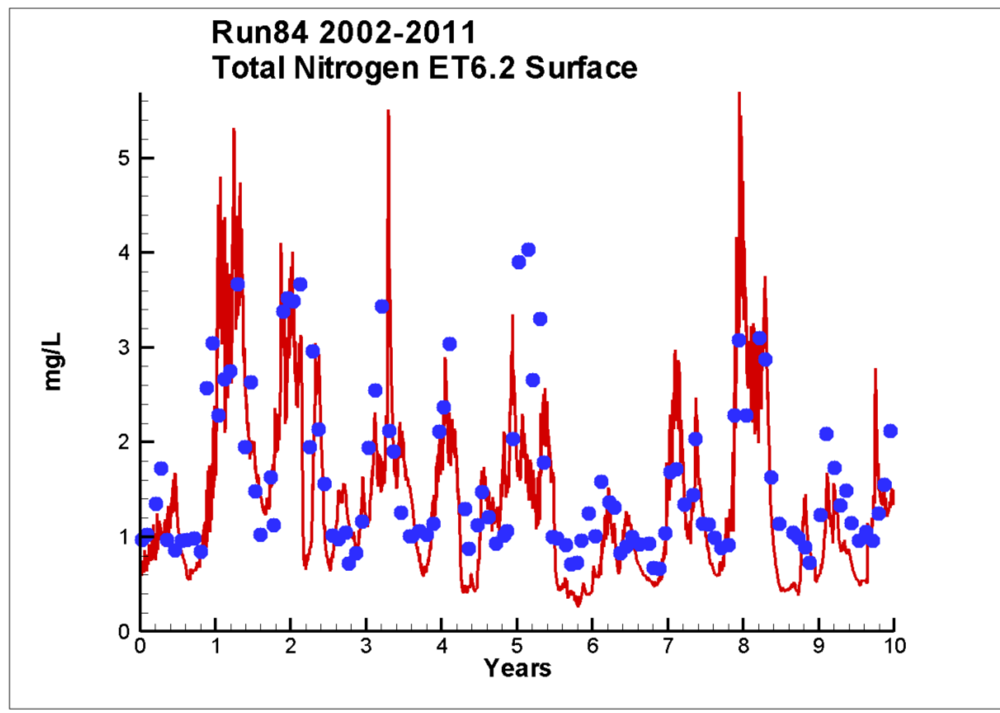


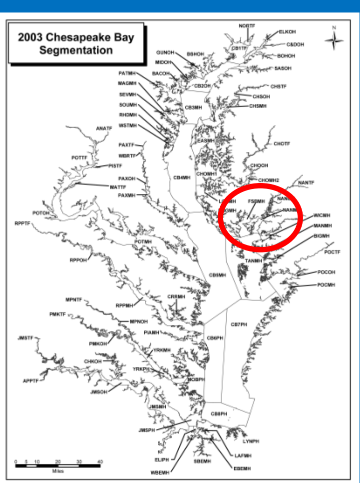
Total Nitrogen in Nanticoke River



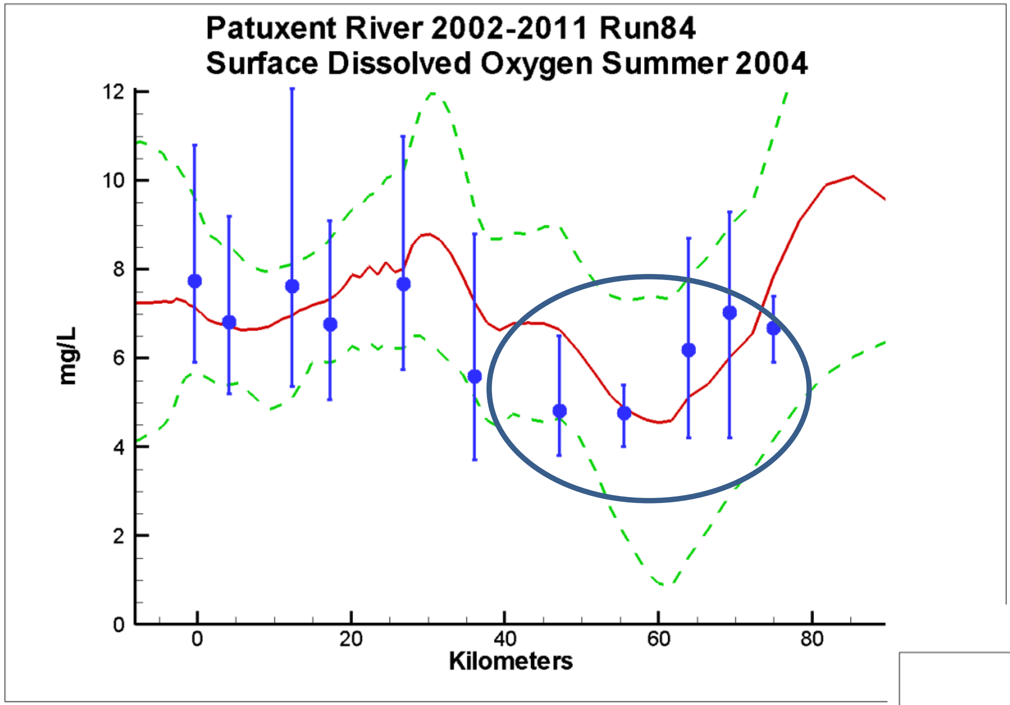
No Wetlands

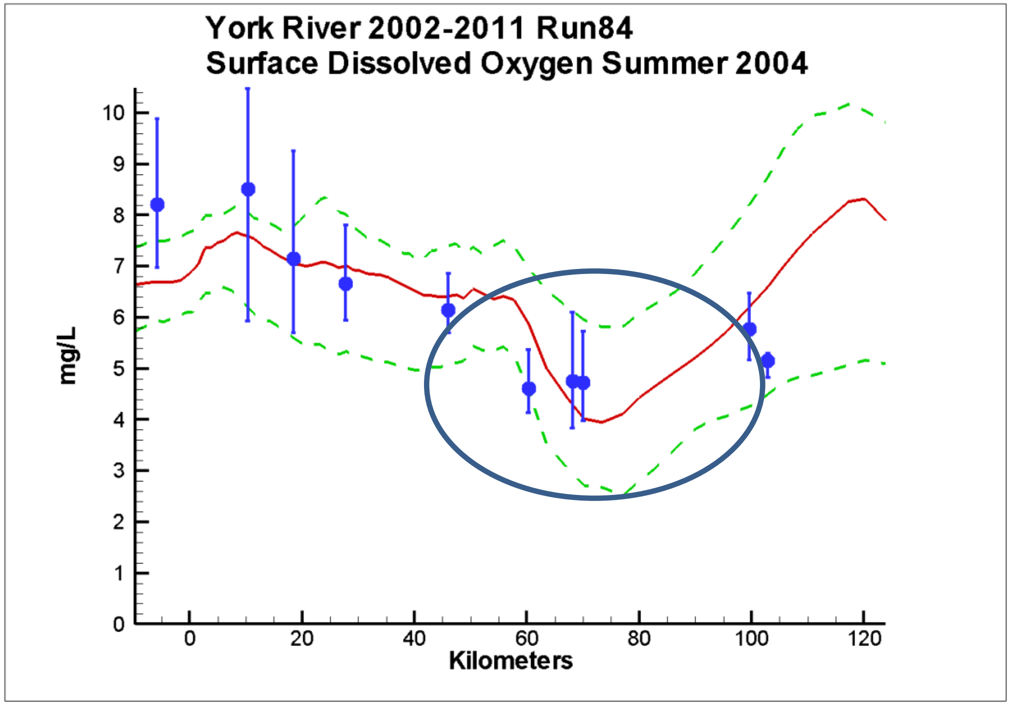
With Wetlands

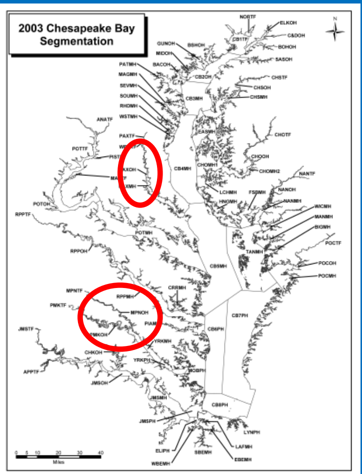




Wetlands DO Effects







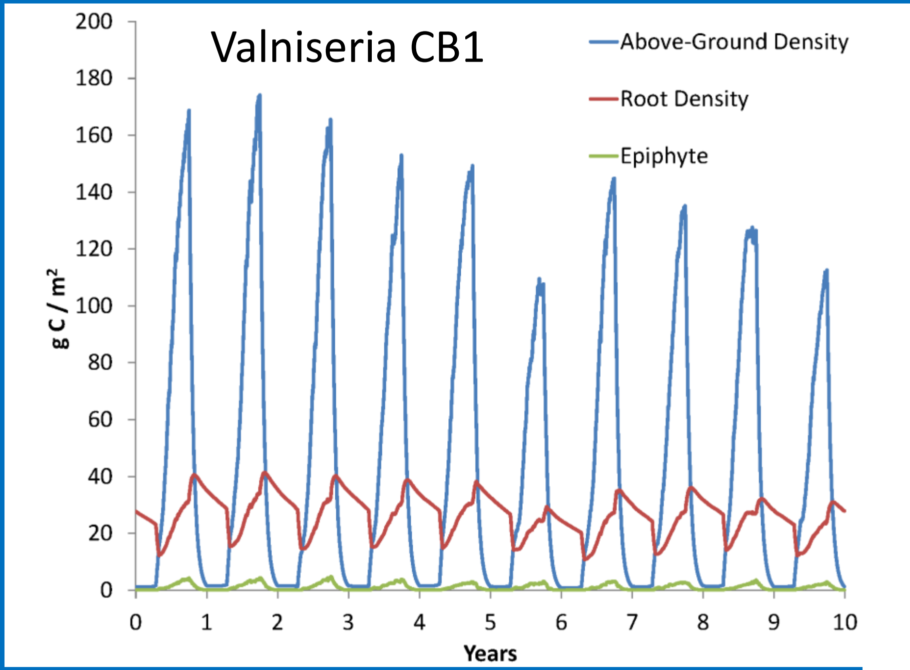
Take-Home Messages

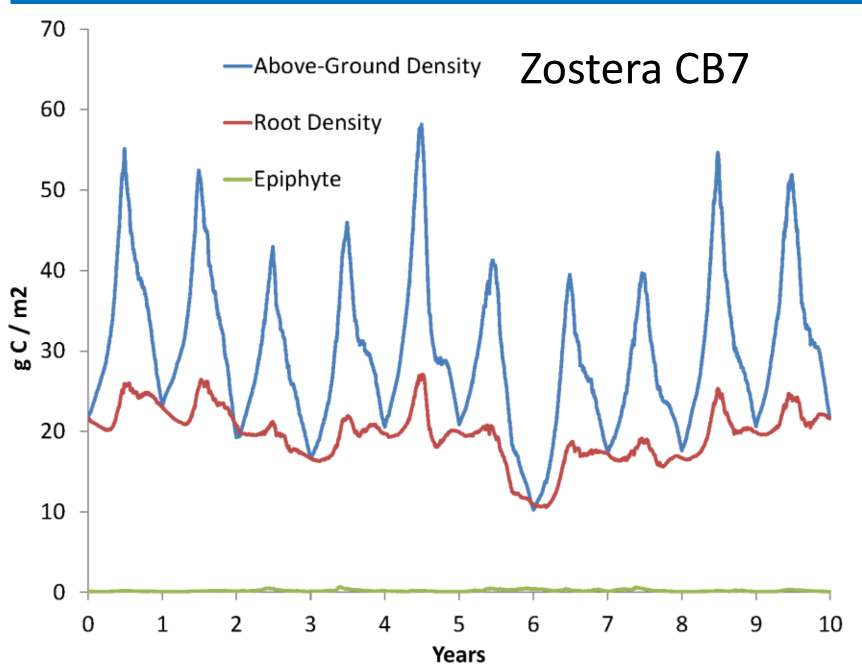
- Total wetlands area is roughly constant up to 30cm rise in sea level. Beyond 30cm, total area decreases.
- Wetlands loss is largely due to erosion in mesohaline regions of the bay. There is a relatively small increase in tidal freshwater wetlands due to migration.
- Wetlands loss and migration pose two challenges to Chesapeake Bay DO standards:
  - Wetlands loss reduces net nutrient uptake by wetlands. Equivalent to an increase in nutrient loading. Results in diminished DO in deep channel waters.
  - Wetlands increase in tidal freshwater and oligohaline regions results in diminished DO in surface waters of shallow embayments and river reaches due to respiration.

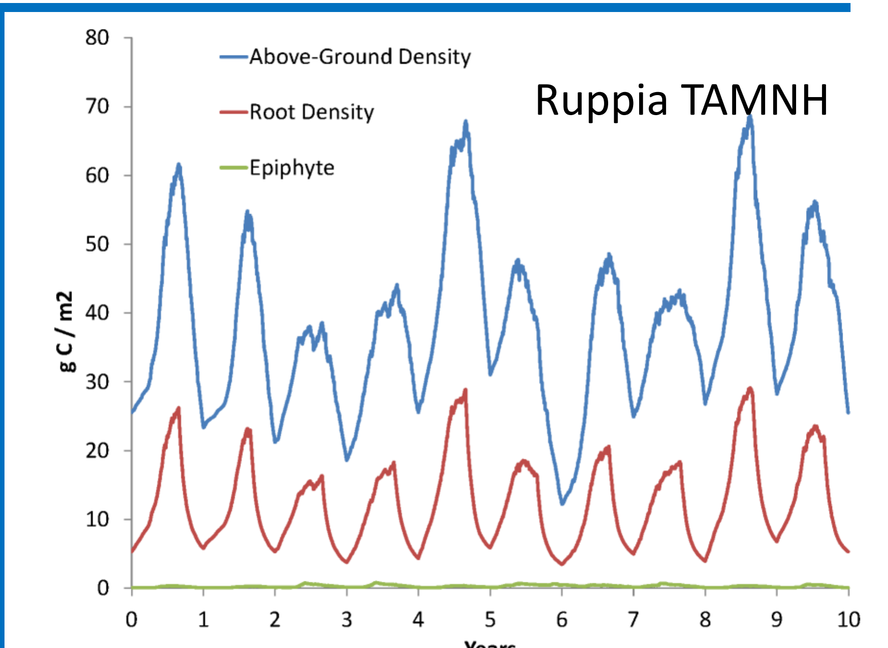
Influence of Submerged Aquatic Vegetation on Sediment-Water Nutrient Fluxes

SAV restoration is a cornerstone of Chesapeake Bay management efforts.

Water temperature increase due to climate change threatens one major SAV community .



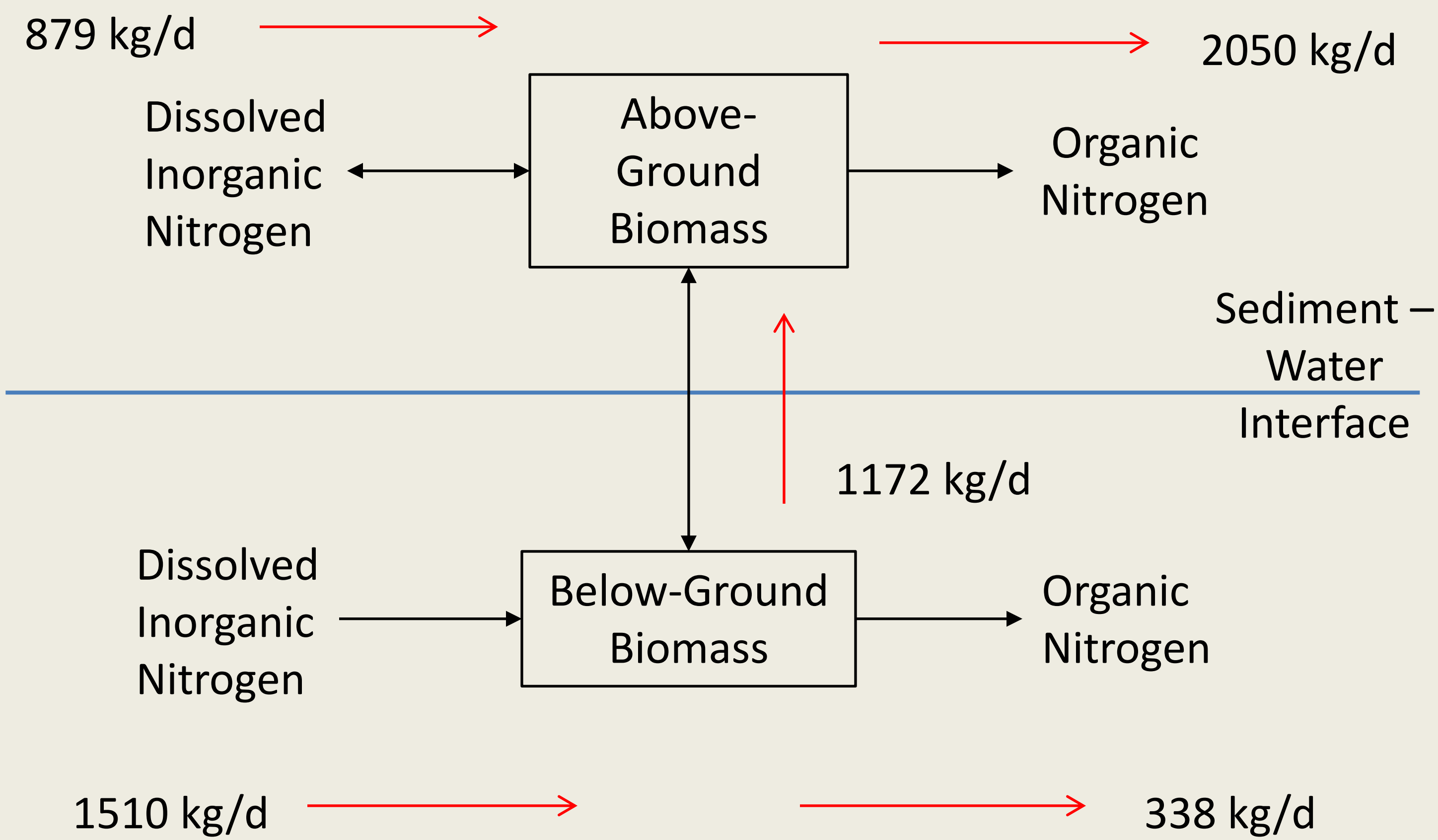




We model three mutually-exclusive SAV communities.

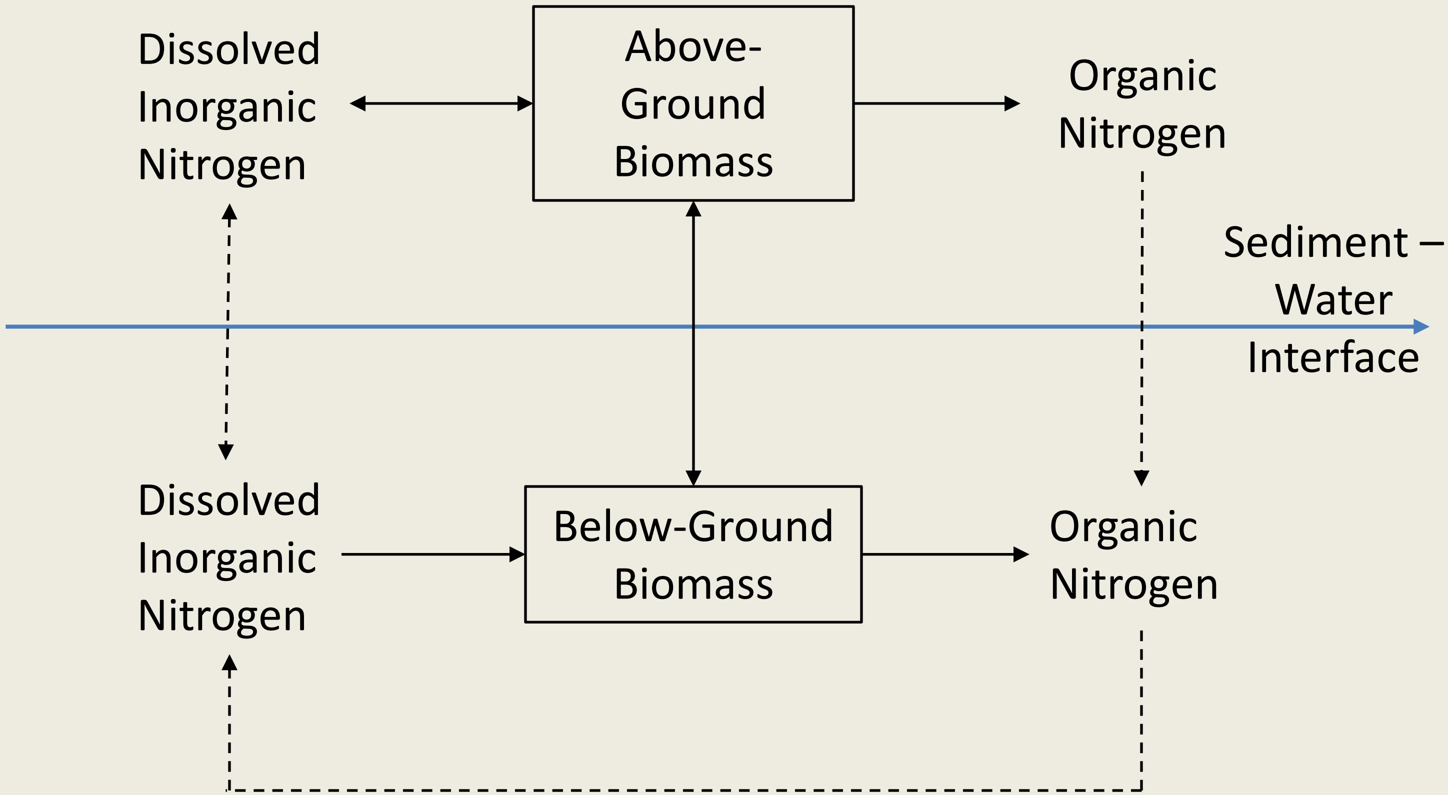
Cerco, C., and Moore, K. (2001) “System-Wide Submerged Vegetation Model for Chesapeake Bay,” Estuaries 24(4) 522-534.

The Nitrogen Cycle

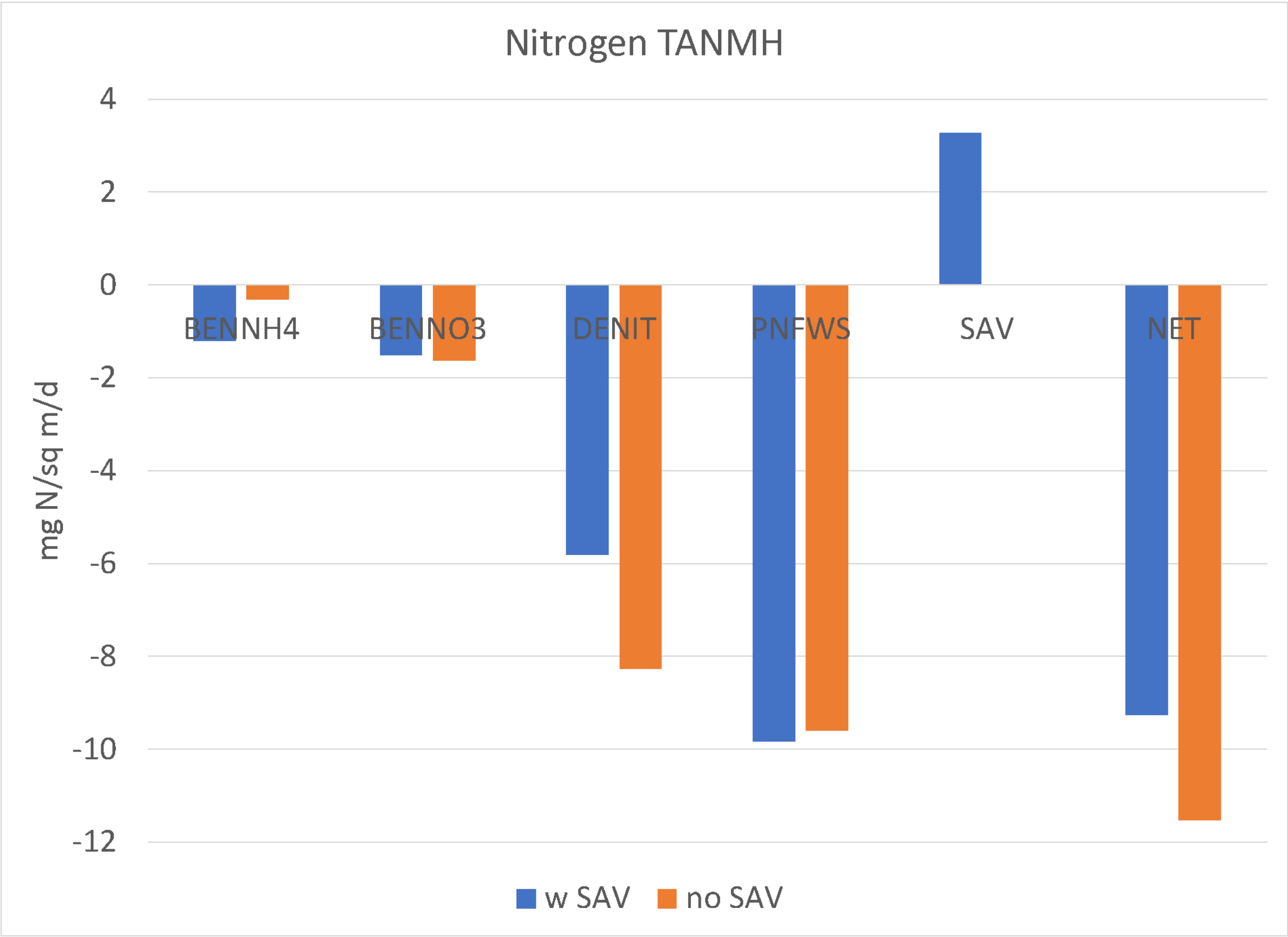


We quantify and can report out the indicated fluxes (CB1TF, vallisneria).

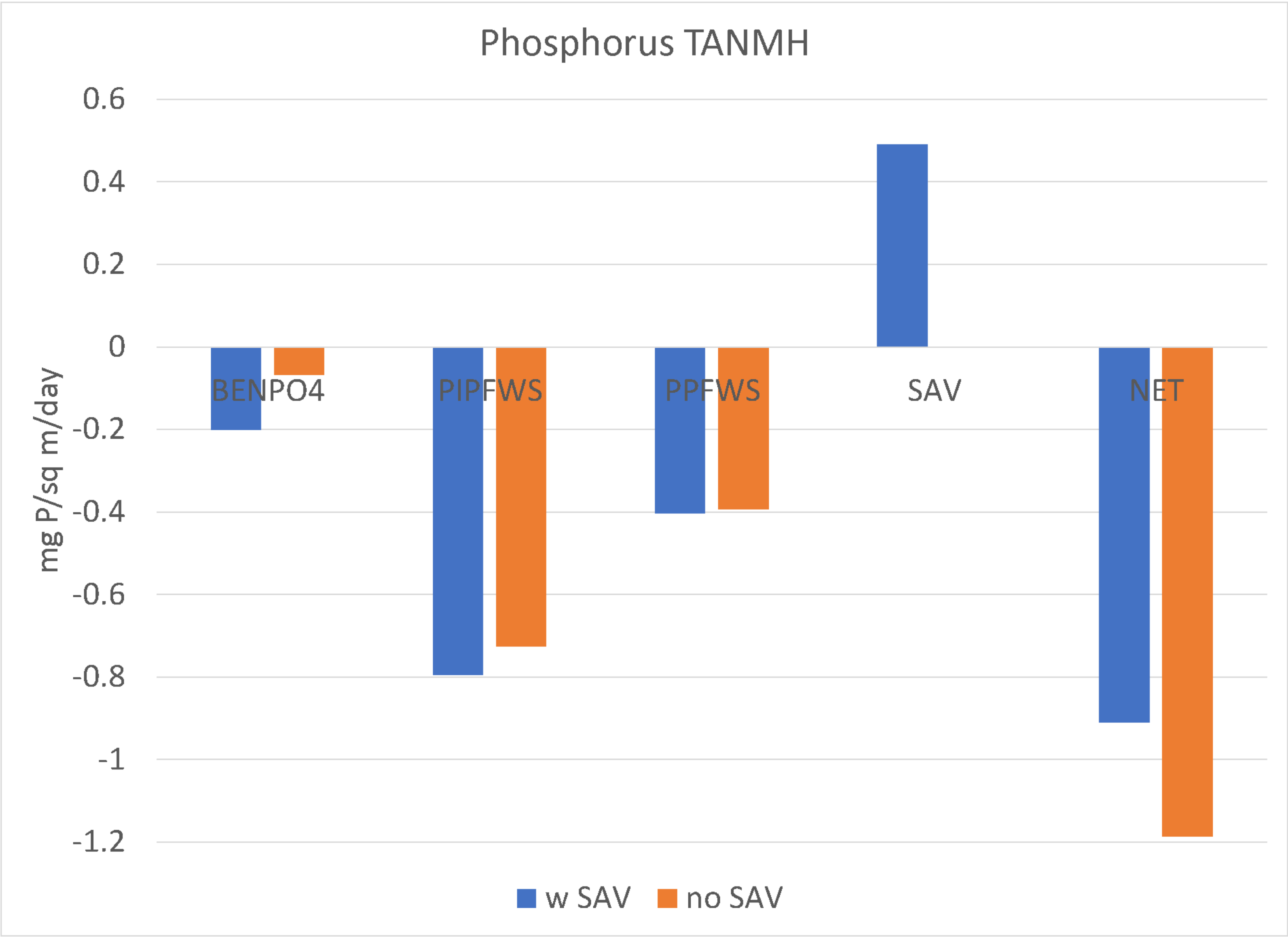
Complications

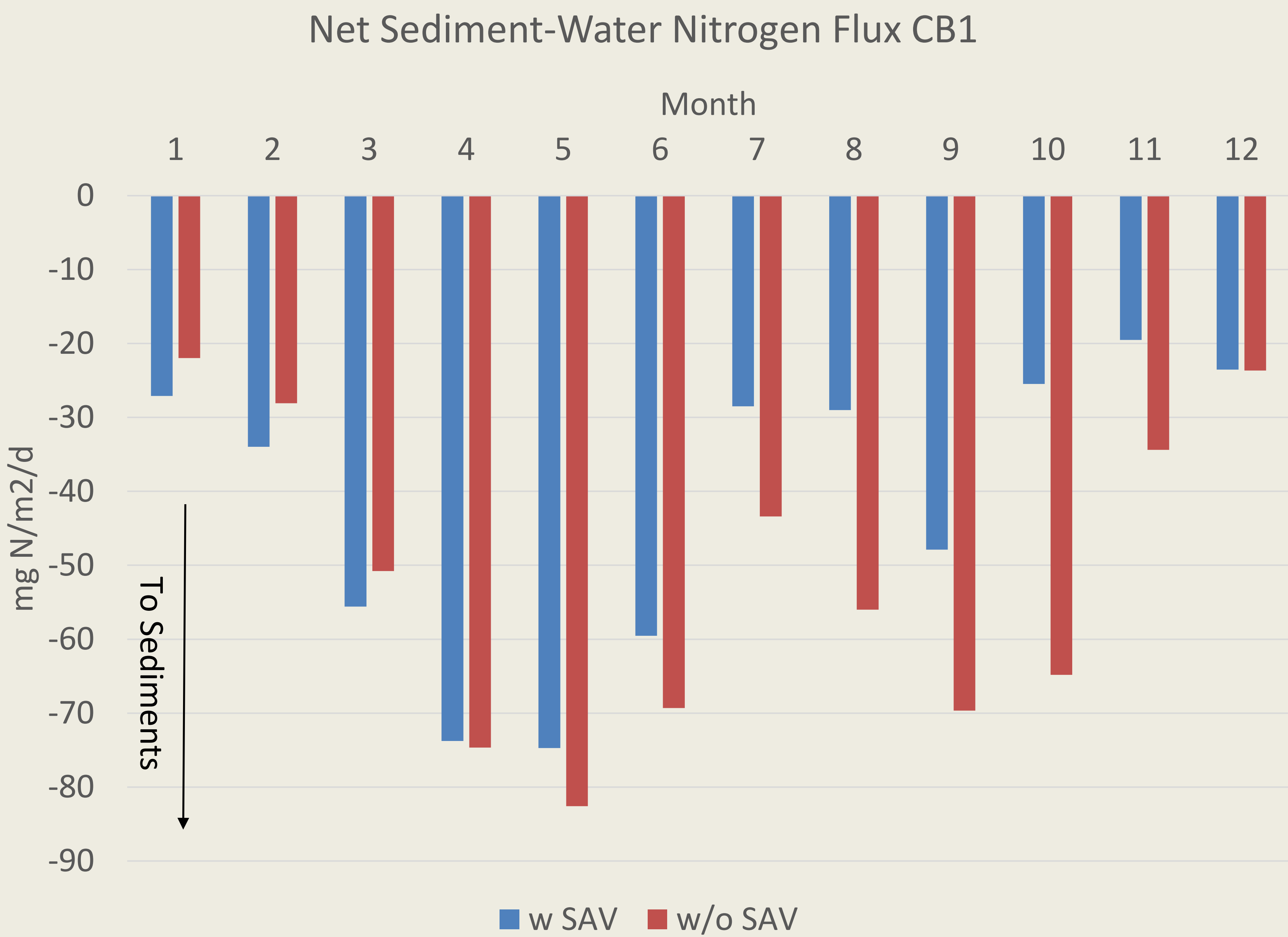


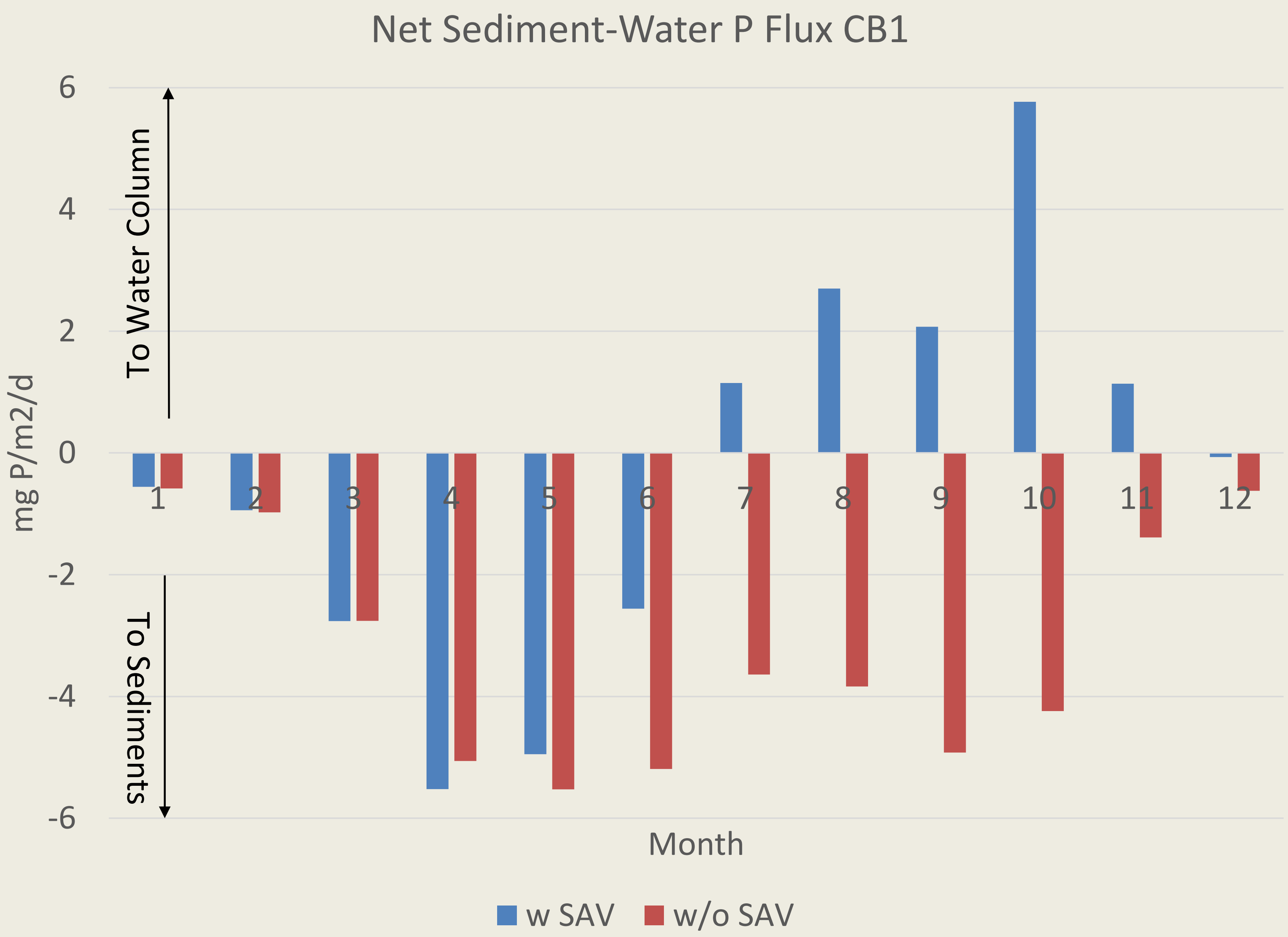
We quantify and can report out the additional fluxes but it is difficult to isolate the influence of SAV.



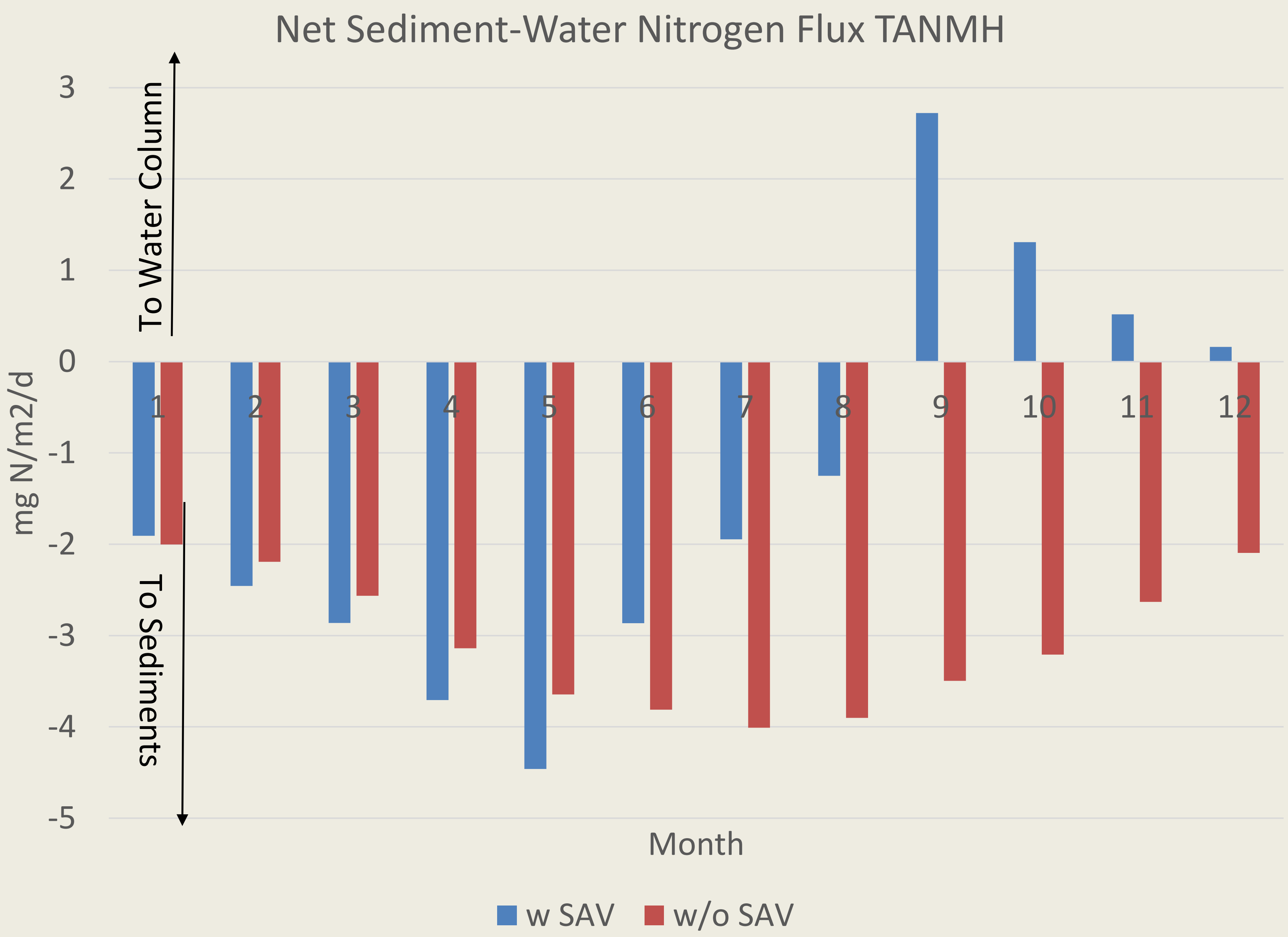
Nitrogen TANMH
4
2
0
-2
-4
-6
-8
-10
-12
mg N/sq m/d
BENNH4
BENNO3
DENIT
PNFWS
SAV
NET
w SAV
no SAV


Phosphorus TANMH
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
mg P/sq m/day
BENPO4
PIPFWS
PPFWS
SAV
NET
w SAV
no SAV

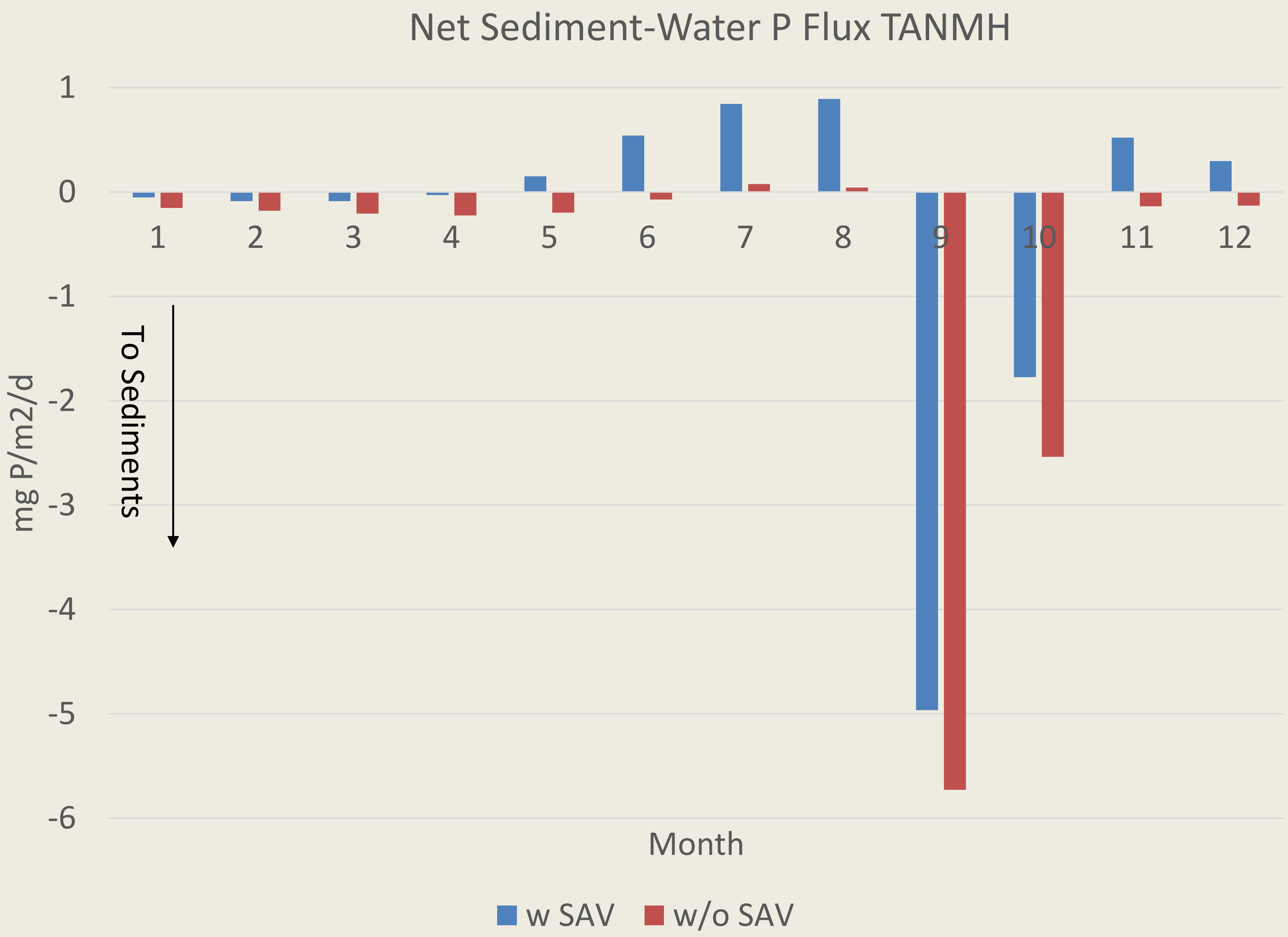

Net Sediment-Water Nitrogen Flux CB1
Month
1
2
3
4
5
6
7
8
9
10
11
12
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
mg N/m2/d
To Sediments
w SAV
w/o SAV



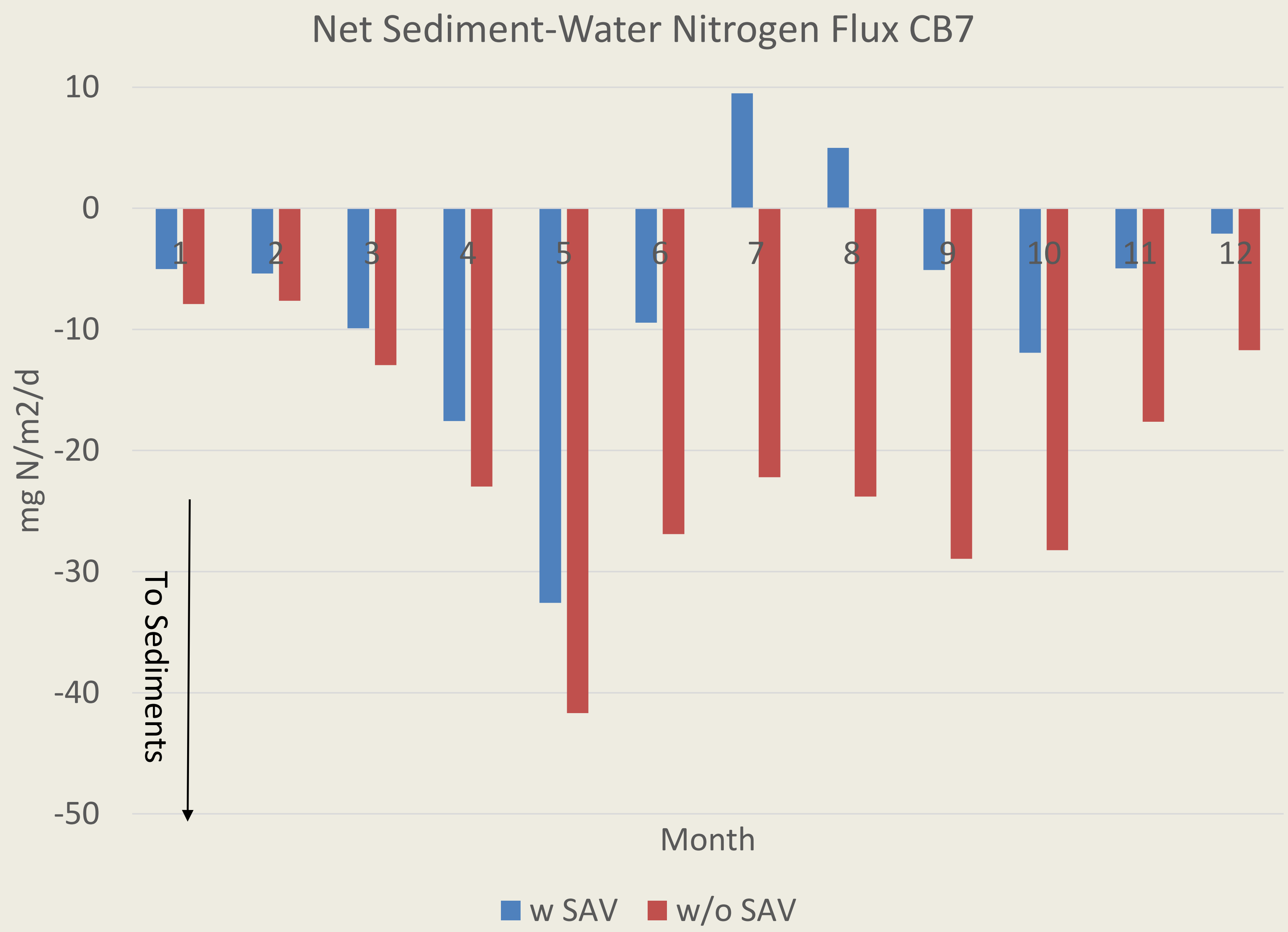
Net Sediment-Water P Flux CB1
6
4
2
0
-2
-4
-6
mg P/m2/d
To Water Column
To Sediments
1
2
3
4
5
6
7
8
9
10
11
12
Month
w SAV
w/o SAV



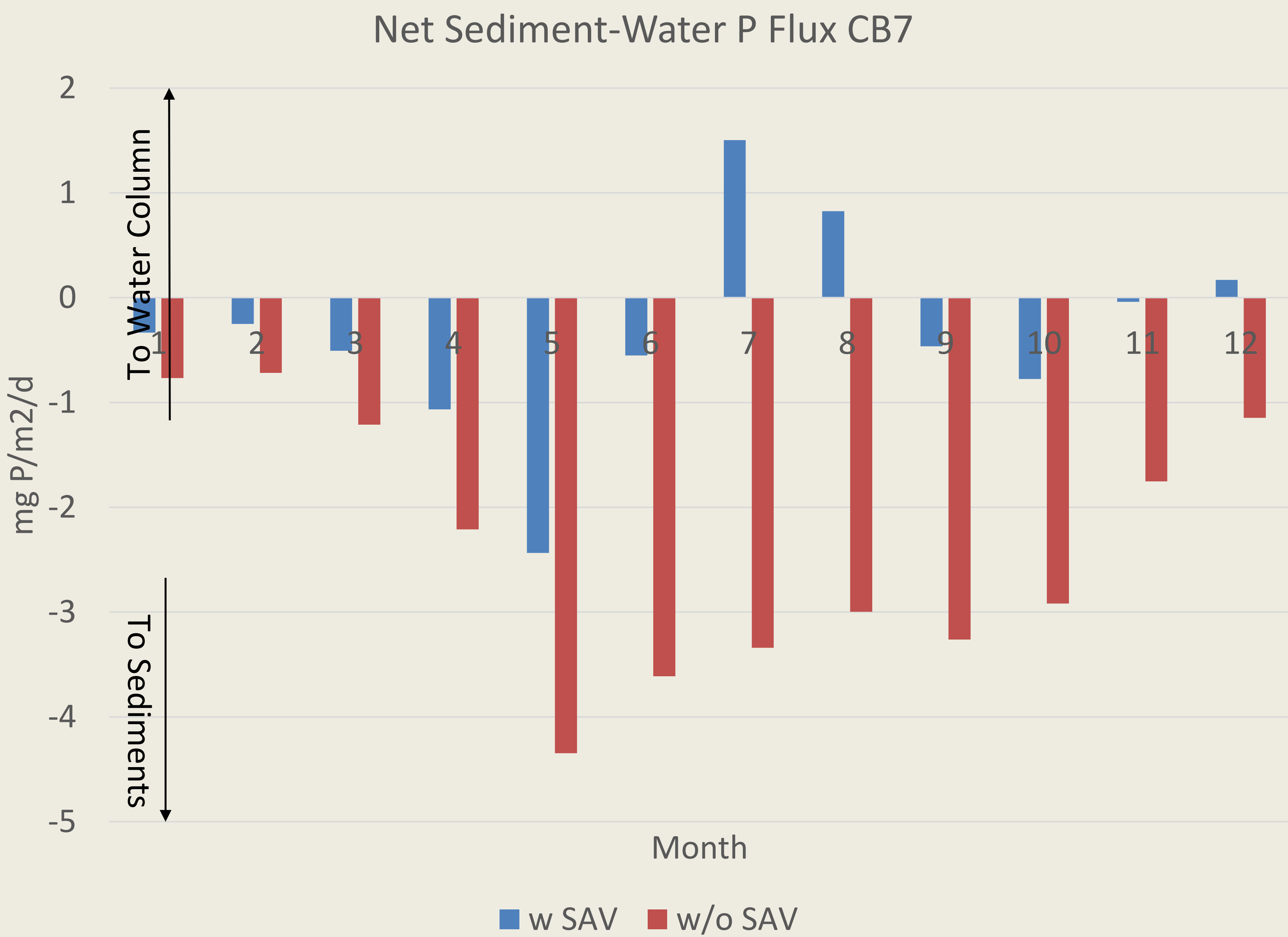
Net Sediment-Water Nitrogen Flux TANMH
3
2
1
0
-1
-2
-3
-4
-5
mg N/m2/d
To Water Column
To Sediments
1
2
3
4
5
6
7
8
9
10
11
12
Month
w SAV
w/o SAV



Net Sediment-Water P Flux TANMH
1
0
-1
-2
-3
-4
-5
-6
1
2
3
4
5
6
7
8
9
10
11
12
mg P/m2/d
To Sediments
Month
w SAV
w/o SAV



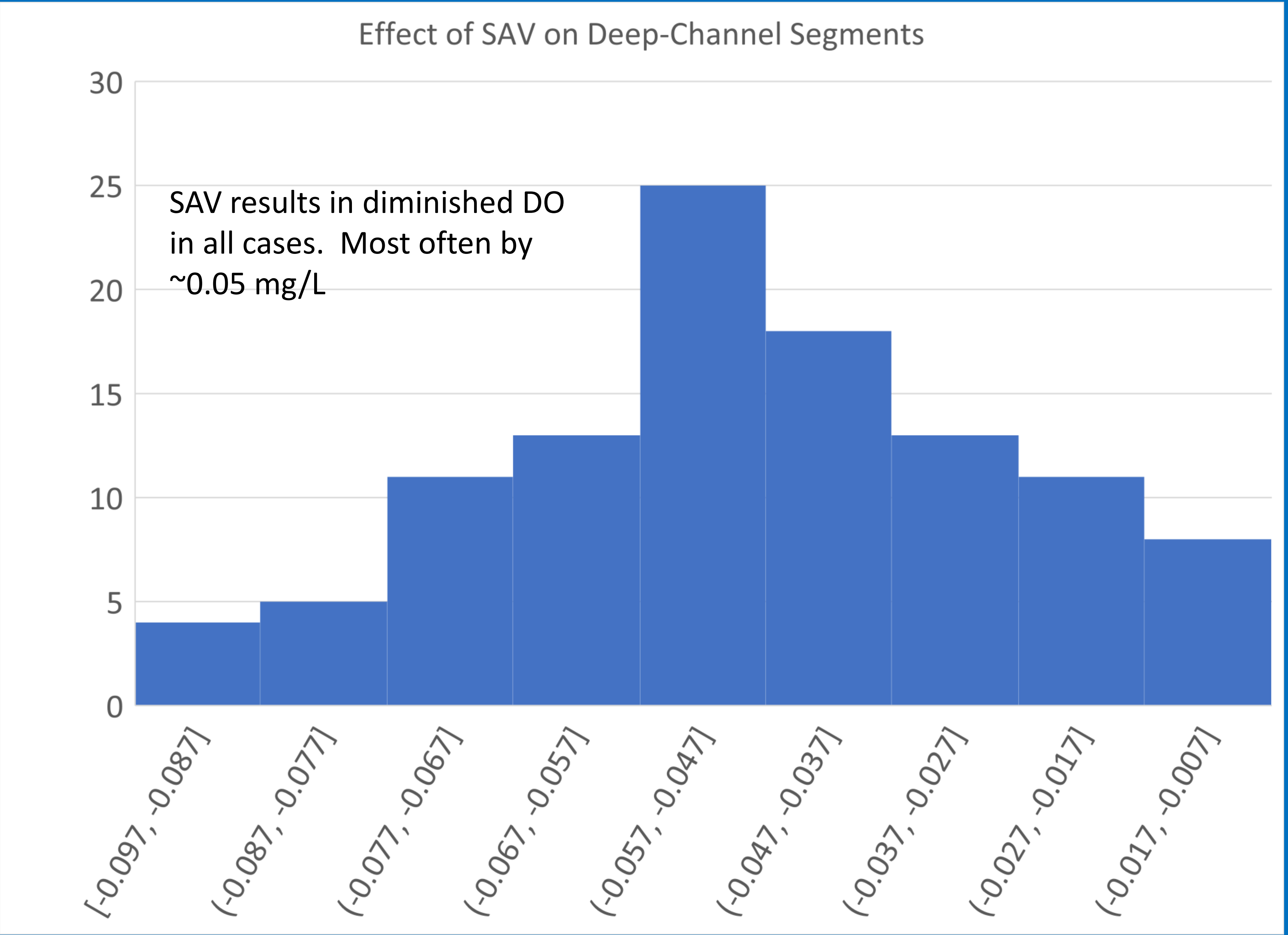
Net Sediment-Water Nitrogen Flux CB7
10
0
-10
-20
-30
-40
-50
mg N/m2/d
To Sediments
1
2
3
4
5
6
7
8
9
10
11
12
Month
w SAV
w/o SAV

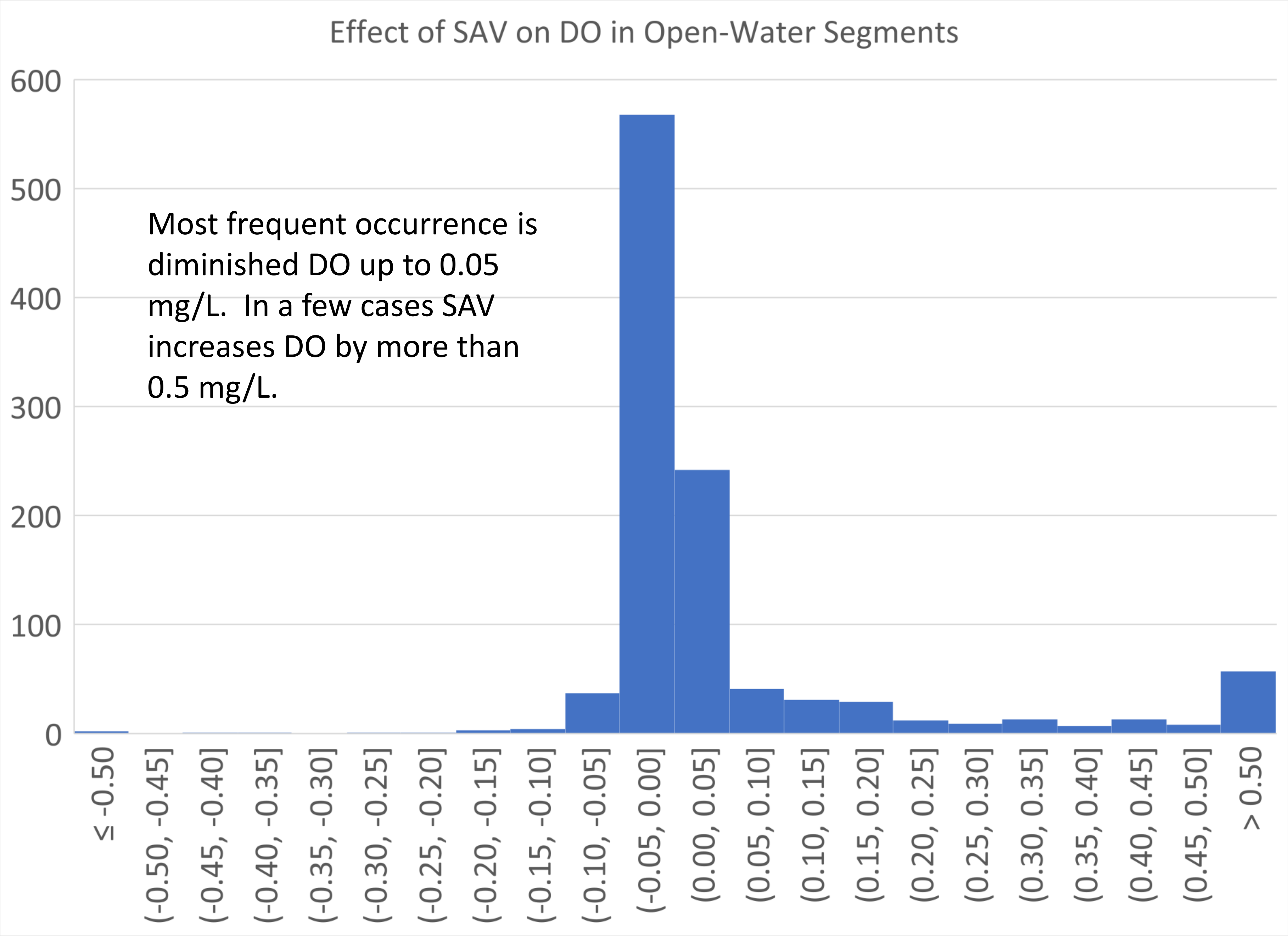


Net Sediment-Water P Flux CB7
2
1
0
-1
-2
-3
-4
-5
mg P/m2/d
To Water Column
To Sediments
1
2
3
4
5
6
7
8
9
10
11
12
Month
w SAV
w/o SAV

Conclusions/Next Steps

- SAV diminishes net sediment nutrient retention. In some instances, SAV reverses net sediment retention to net sediment release.
- Impact on water quality isn’t revealed by examination of fluxes alone.
- Our next step is to examine key water quality parameters (e.g. DO, chlorophyll) with and without SAV.


Effect of SAV on Deep-Channel Segments
SAV results in diminished DO in all cases. Most often by ~0.05 mg/L
30
25
20
15
10
5
0
[-0.097, -0.087]
(-0.087, -0.077]
(-0.077, -0.067]
(-0.067, -0.057]
(-0.057, -0.047]
(-0.047, -0.037]
(-0.037, -0.027]
(-0.027, -0.017]
(-0.017, -0.007]


Effect of SAV on DO in Open-Water Segments
600
500
400
300
200
100
0
Most frequent occurrence is diminished DO up to 0.05 mg/L. In a few cases SAV increases DO by more than 0.5 mg/L.
≤ -0.50
(-0.50, -0.45]
(-0.45, -0.40]
(-0.40, -0.35]
(-0.35, -0.30]
(-0.30, -0.25]
(-0.25, -0.20]
(-0.20, -0.15]
(-0.15, -0.10]
(-0.10, -0.05]
(-0.05, 0.00]
(0.00, 0.05]
(0.05, 0.10]
(0.10, 0.15]
(0.15, 0.20]
(0.20, 0.25]
(0.25, 0.30]
(0.30, 0.35]
(0.35, 0.40]
(0.40, 0.45]
(0.45, 0.50]
> 0.50

Plans for Future Model Development

The original management model of the Bay was oriented towards management of deep-channel hypoxia.

A curvilinear non-orthogonal computational grid, which emphasized channel resolution was employed.

We can see that increasedattention is now being devoted to shallow, near-shore regions.

A grid more suited to these regions is required