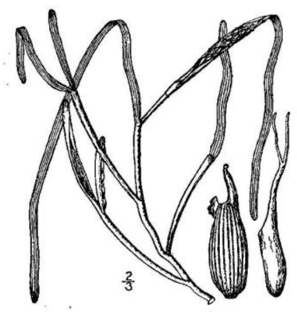
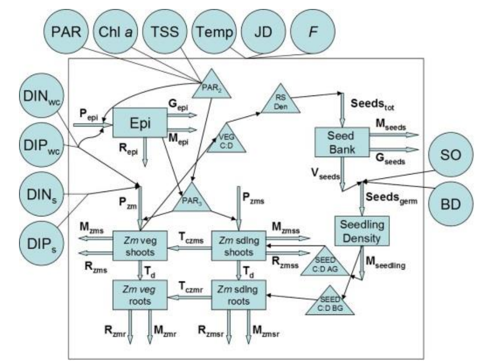
Modelling *Zostera marina* restoration potential in Barnegat Bay New Jersey





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Zostera marina (eelgrass)

- Dominant seagrass species in temperate Northern Hemisphere
- Strap-like leaves with well developed rhizomes
- Flowering form → highly branched
  - Flowers May/June
- Found on both coasts of US
- Dies back during warm summer months
  - Grows best in cooler spring and fall

Zostera is continuing to decline…

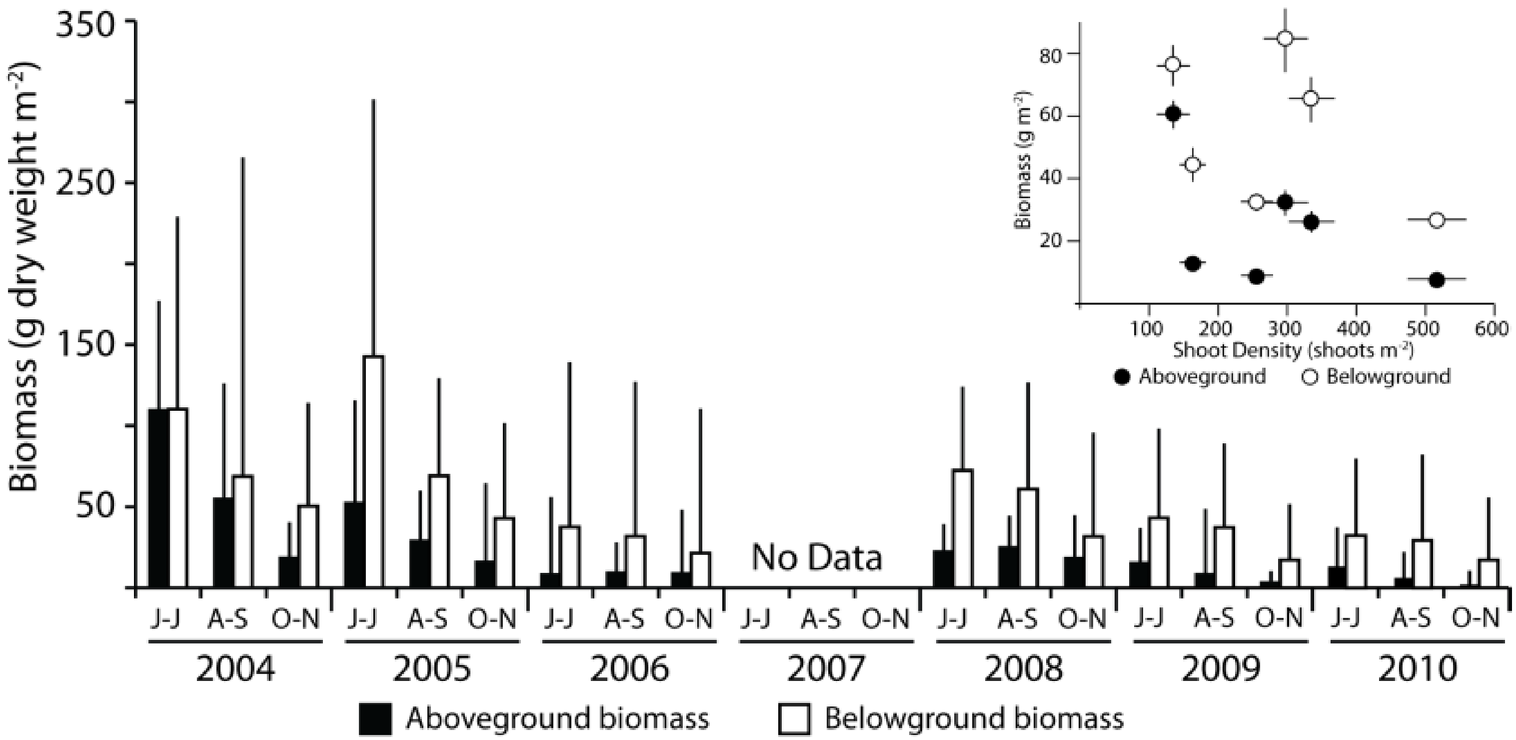


Figure 1. Above and belowground *Z. marina* biomass in BB-LEH from 2004 to 2010. Modified from Kennish et al. Revised.

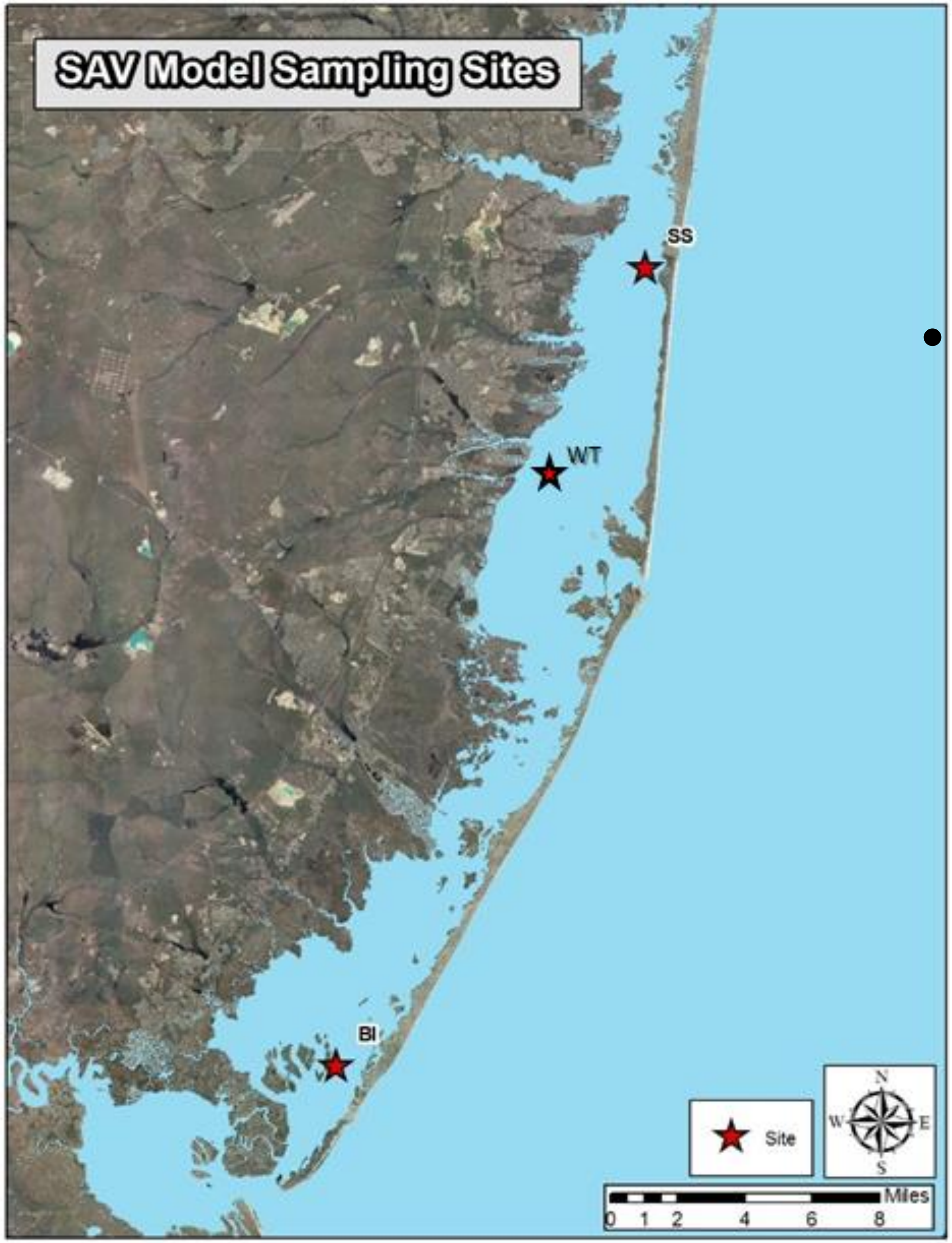
Figure by B. Fertig)

Goals and Objectives

- The goal of this study was to refine and apply the model developed by Jarvis et al. (2014) to quantify SAV resiliency to perturbations through modelling loss and recovery processes within established SAV beds in BB-LEH.

- Objectives

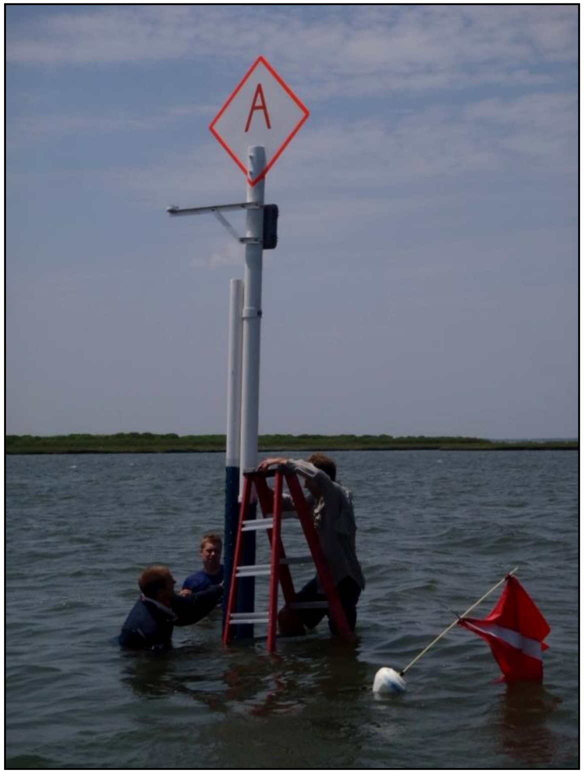
- Refine and calibrate the model developed by Jarvis et al. (2014) to project the response of *Z. marina* beds in BB-LEH to stressful environmental conditions.
- Use the calibrated model to quantify possible effects of reduced nutrient loading rates (i.e. present day, less 10%, less 30%) on seagrass survival of two existing *Z. marina* sites along a nutrient loading gradient in BB-LEH.
- Use the calibrated model to determine suitability of three *Z. marina* sites along a nutrient loading gradient for restoration using the model and NJDEP comprehensive water quality data.

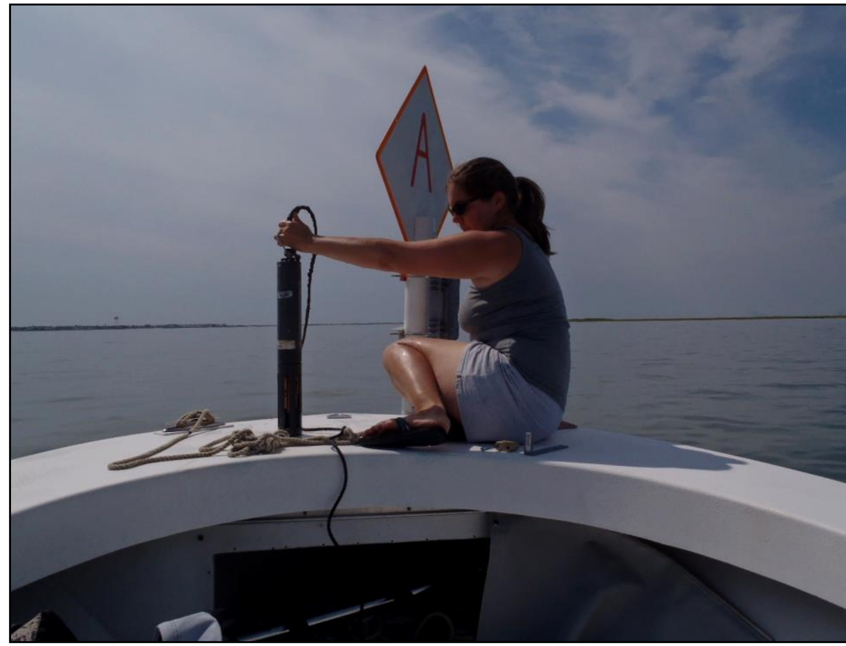


- Map of sampling and modeling sites located in Little Egg Harbor (Barrel Island - BI) and Barnegat Bay (Waretown- WT, Seaside Park - SS).

Data Collection for Model Calibration

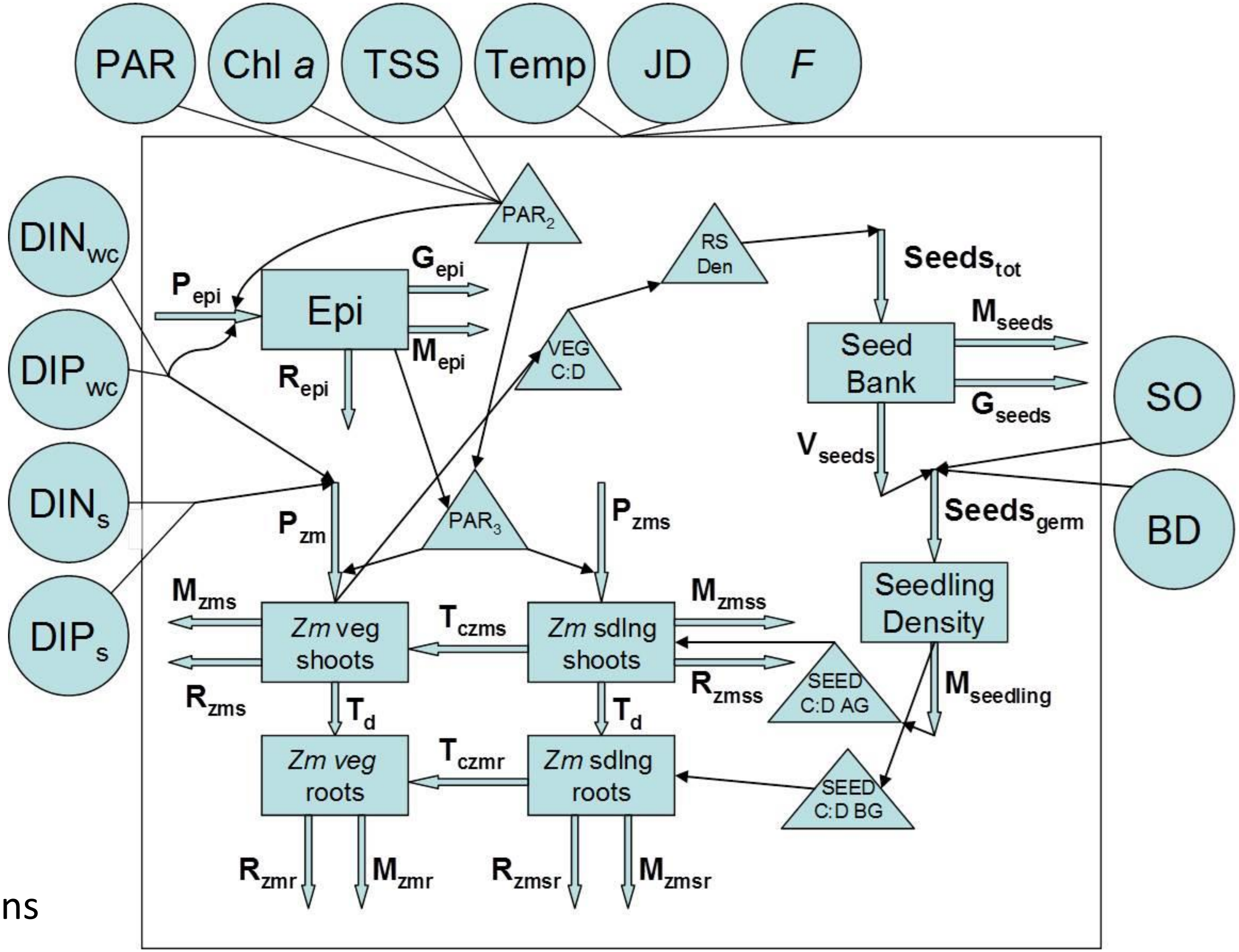
Data Collection for Model Calibration





YSI- continuous -temperature, salinity, Dissolved oxygen, chlorophyll, TSS, pH
LiCor- PAR, Hobo- bottom temperature
Monthly: -water sampling- ammonia, nitrate, orthophosphate, chlorophyll, coring for above and belowground biomass, seed bank and sediment %organics and pore water nutrients (ammonia, nitrate and orthophosphate), plus % cover, epiphyte load, and attached macroalgae

Zostera Conceptual Model



Forcing functions

Table 1. Governing equations for (1) epiphyte biomass ($C_{epi;}$ g C m^{-2}); (2) *Z. marina* vegetative shoot biomass ($C_{zms;}$ g C m^{-2}); (3) *Z. marina* vegetative root/rhizome biomass ($C_{zmr;}$ g C m^{-2}); (4) *Z. marina* seed-bank density (Zm_{seeds}; seeds m^{-2}); and (5) *Z. marina* seedling density (Zm_{sd}; seedlings m^{-2}). Terms include P = production; M = mortality; G = grazing; R = respiration; T_d = translocation down; T_{czmss} = transfer of seedling biomass to vegetative shoot biomass; T_{czmsr} = transfer of seedling root/rhizome biomass to vegetative root/rhizome biomass; $Seeds_{germ}$ = germinated seeds; $Seeds_{prod}$ = total seeds produced; $Seeds_{via}$ = viable seeds; PR_{seeds} = seed predation; Zm_{sd} = germinated seedling density

Differential Equations	
(1)	$C_{epi} = C_{epi}\ (t-dt) + (P_{epi} - M_{epi} - G_{epi} - R_{epi}) * dt$
(2)	$C_{zms} = C_{zms}\ (t - dt) + (P_{zms} + T_{czmss} - M_{zms} - R_{zms} - T_d) * dt$
(3)	$C_{zmr} = C_{zmr}\ (t - dt) + (T_d + T_{czmsr} - M_{zmr} - R_{zmr}) * dt$
(4)	$Zm_{seeds} = Zm_{seeds}\ (t - dt) + (Seeds_{prod} - M_{seeds} - PR_{seeds}) * Seeds_{via} * dt$
(5)	$Zm_{sd} = Zm_{sd}\ (t - dt) + (Seeds_{germ} – M_{zmsd}) * dt$

Stella Model Equations

```
AG_Biomass(t) = AG_Biomass(t - dt) + (Photo + Seedling_AG_Transfer - Shoots_Resp - AG__trans - Leaf_Mortality) * dt
INIT AG_Biomass = 0
INFLOWS:
  Photo = (AG_Biomass) * PRzs
  Seedling_AG_Transfer = If JD > 182 and AG_Biomass <0.44 then Seed_AG_Biomass ELSE 0
OUTFLOWS:
  Shoots_Resp =
    AG_Biomass*(PRzs*(0.00317*(Water_Temp+0.105)+EXP((0.135*Water_Temp)-10.1)))
  AG__trans = Photo*0.4
  Leaf_Mortality = IF TIME > 275 THEN (IF JD < 166 THEN AG_Biomass*0.002 ELSE
    AG_Biomass*0.0332) ELSE (IF JD < 166 THEN AG_Biomass*0.002 ELSE AG_Biomass*0.0332)
BG__Biomass(t) = BG__Biomass(t - dt) + (AG__trans + Seedling_BG__Transfer - Roots_Resp - Mortality) * d
INIT BG__Biomass = 0

INFLOWS:
  AG__trans = Photo*0.4
  Seedling_BG__Transfer = If JD > 182 and BG__Biomass <0.44 then Seed_BG__Biomass ELSE 0
OUTFLOWS:
  Roots_Resp = BG__Biomass*(Roots__Resp_Rate*1.25^(Water_Temp-22.5))
  Mortality = IF TIME > 275 THEN (IF JD < 152 THEN BG__Biomass*0.0085 ELSE
    BG__Biomass*0.031) ELSE (IF JD < 182 THEN BG__Biomass*0.0085 ELSE BG__Biomass*0.035)

Epi(t) = Epi(t - dt) + (Epi__Photo - Epi_Mortality - Epi_Grazing - Epi_Resp) * dt
INIT Epi = 0
INFLOWS:
  Epi__Photo = (Epi)*PRepi
OUTFLOWS:
  Epi_Mortality = 0.007*(Epi/(AG_Biomass+0.0001))
  Epi_Grazing = (Epi^2)*0.01
  Epi_Resp = Epi*0.05*EXP(0.069*(Water_Temp-24))
Seedling_Density(t) = Seedling_Density(t - dt) + (Germ_Rate - Seedling__Mortality) * dt
INIT Seedling_Density = 0
INFLOWS:
  Germ_Rate = IF Water_Temp < 20 AND JD > 274 AND JD < 364 THEN
    (1/(1+EXP(-(0.1432+(1.1261*Burial__Depth)+(-1.3964*Sed_%_org))))) * Viable__Seed_Output ELSE
    0
OUTFLOWS:
  Seedling__Mortality = IF (AG_Biomass > 2) THEN (Seedling_Density) ELSE (0)
Seed_AG_Biomass(t) = Seed_AG_Biomass(t - dt) + (Seed__Photo + Seedling_AG_B:D -
Seed__Shoots_Resp - Seed_AG__trans - Seed_Leaf_Mortality - Seedling_AG_Transfer) * dt
INIT Seed_AG_Biomass = 0
INFLOWS:
  Seed__Photo = IF AG_Biomass>2 THEN (Seed_AG_Biomass) *Seed_PRzs ELSE 0
  Seedling_AG_B:D = (Seedling_Density-Seedling__Mortality)*0.037395
OUTFLOWS:
  Seed__Shoots_Resp = Seed_AG_Biomass*0.045
  Seed_AG__trans = Seed_AG_Biomass*.1
  Seed_Leaf_Mortality = Seed_AG_Biomass*0.018
  Seedling_AG_Transfer = If JD > 182 and AG_Biomass <0.44 then Seed_AG_Biomass ELSE 0
Seed_BG__Biomass(t) = Seed_BG__Biomass(t - dt) + (Seed_AG__trans + Seedling_BG__B:D -
Seed__Roots_Resp - Seed__Mortality - Seedling_BG__Transfer) * dt
INIT Seed_BG__Biomass = 0
INFLOWS:
  Seed_AG__trans = Seed_AG_Biomass*.1
  Seedling_BG__B:D = (Seedling_Density-Seedling__Mortality)*0.038425
OUTFLOWS:
  Seed__Roots_Resp = Seed_BG__Biomass*(Seeds_Roots__Resp_Rate_2*1.25^(Water_Temp-20))

  Seed__Mortality = IF Seed_BG__Biomass = 0 THEN (0) ELSE (Seed_BG__Biomass *
    (Seed_Leaf_Mortality/Seed_AG_Biomass))
  Seedling_BG__Transfer = If JD > 182 and BG__Biomass <0.44 then Seed_BG__Biomass ELSE 0
Total__Seeds(t) = Total__Seeds(t - dt) + (Seed_Input - Viable__Seed_Output - Seed_Mort) * dt
INIT Total__Seeds = 500
INFLOWS:
  Seed_Input = (Flowering__Density*11.07)
OUTFLOWS:
  Viable__Seed_Output = IF (JD >349 and JD<364) THEN ((Total__Seeds - Predation) * 0.4*0.1) ELSE
    (0)
  Seed_Mort = IF (JD > 364) THEN (Total__Seeds*10) ELSE (0)
Burial__Depth = GRAPH(TIME)
(1.00, 3.00), (2.00, 3.00), (3.00, 3.00), (4.00, 3.00), (5.00, 3.00), (6.00, 3.00), (7.00, 3.00), (8.00, 3.00), (9.00, 3.00), (10.0, 3.00), (11.0, 3.00), (12.0, 3.00), (13.0, 3.00), (14.0, 3.00), (15.0, 3.00), (16.0, 3.00), (17.0, 3.00), (18.0, 3.00), (19.0, 3.00), (20.0, 3.00), (21.0, 3.00), (22.0, 3.00), (23.0, 3.00), (24.0, 3.00), (25.0, 3.00), (26.0, 3.00), (27.0, 3.00), (28.0, 3.00), (29.0, 3.00), (30.0, 3.00), (31.0, 3.00), (32.0, 3.00), (33.0, 3.00), (34.0, 3.00), (35.0, 3.00), (36.0, 3.00), (37.0, 3.00), (38.0, 3.00), (39.0, 3.00), (40.0, 3.00), (41.0, 3.00), (42.0, 3.00), (43.0, 3.00), (44.0, 3.00), (45.0, 3.00), (46.0, 3.00), (47.0, 3.00), (48.0, 3.00), (49.0, 3.00), (50.0, 3.00), (51.0, 3.00), (52.0, 3.00), (53.0, 3.00)...
Chl = GRAPH(TIME)
(1.00, 15.9), (2.00, 16.0), (3.00, 16.0), (4.00, 16.0), (5.00, 16.1), (6.00, 16.1), (7.00, 16.1), (8.00, 16.1), (9.00, 16.2), (10.0, 16.2), (11.0, 16.3), (12.0, 16.3), (13.0, 16.3), (14.0, 16.3), (15.0, 16.4), (16.0, 16.4), (17.0, 16.4), (18.0, 16.5), (19.0, 16.5), (20.0, 16.5), (21.0, 16.6), (22.0, 16.6), (23.0, 16.6), (24.0, 16.7), (25.0, 16.7), (26.0, 16.7), (27.0, 16.8), (28.0, 16.8), (29.0, 16.8), (30.0, 16.9), (31.0, 16.9), (32.0, 16.9), (33.0, 16.9), (34.0, 17.0), (35.0, 17.0), (36.0, 17.0), (37.0, 17.1), (38.0, 17.1), (39.0, 17.1), (40.0, 17.2), (41.0, 17.2), (42.0, 17.2), (43.0, 17.3), (44.0, 17.3), (45.0, 17.3), (46.0, 17.4), (47.0, 17.4), (48.0, 17.4), (49.0, 17.5), (50.0, 17.5), (51.0, 17.5), (52.0, 17.6), (53.0, 17.6)...
DIN = GRAPH(TIME)
(1.00, 14.4), (2.00, 14.9), (3.00, 15.4), (4.00, 15.9), (5.00, 16.4), (6.00, 16.9), (7.00, 17.4), (8.00, 17.9), (9.00, 18.4), (10.0, 18.9), (11.0, 19.4), (12.0, 19.9), (13.0, 20.4), (14.0, 20.9), (15.0, 21.4), (16.0, 21.9), (17.0, 22.4), (18.0, 22.9), (19.0, 23.4), (20.0, 23.9), (21.0, 24.4), (22.0, 24.9), (23.0, 25.4), (24.0, 25.9), (25.0, 26.4), (26.0, 26.9), (27.0, 27.4), (28.0, 27.9), (29.0, 28.4), (30.0, 28.9), (31.0, 29.4), (32.0, 29.9), (33.0, 30.4), (34.0, 30.9), (35.0, 31.4), (36.0, 31.9), (37.0, 32.4), (38.0, 32.9), (39.0, 33.4), (40.0, 33.9), (41.0, 34.4), (42.0, 34.9), (43.0, 35.4), (44.0, 35.9), (45.0, 36.4), (46.0, 36.9), (47.0, 37.4), (48.0, 37.9), (49.0, 38.4), (50.0, 38.9), (51.0, 39.4), (52.0, 39.9), (53.0, 40.4)...
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Stella Model Equations (continued)

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DIN__Both = ((DIN+(0.32*Sed_DIN))/(0.13+(DIN+(0.32*Sed_DIN))))
DIP = GRAPH(TIME)
(0.00, 0.37), (1.00, 0.37), (2.00, 0.36), (3.00, 0.36), (4.00, 0.36), (5.01, 0.36), (6.01, 0.35), (7.01, 0.35), (8.01, 0.35), (9.01, 0.34), (10.0, 0.34), (11.0, 0.34), (12.0, 0.33), (13.0, 0.33), (14.0, 0.33), (15.0, 0.32), (16.0, 0.32), (17.0, 0.32), (18.0, 0.31), (19.0, 0.31), (20.0, 0.31), (21.0, 0.3), (22.0, 0.3), (23.0, 0.3), (24.0, 0.29), (25.0, 0.29), (26.0, 0.29), (27.0, 0.28), (28.0, 0.28), (29.0, 0.28), (30.0, 0.27), (31.0, 0.27), (32.0, 0.27), (33.0, 0.26), (34.0, 0.26), (35.0, 0.26), (36.0, 0.25), (37.0, 0.25), (38.0, 0.25), (39.0, 0.24), (40.0, 0.24), (41.0, 0.24), (42.0, 0.23), (43.0, 0.23), (44.0, 0.23), (45.0, 0.22), (46.0, 0.22), (47.0, 0.22), (48.0, 0.21), (49.1, 0.21), (50.1, 0.21), (51.1, 0.21), (52.1, 0.2)...

DIP__Both = (((DIP+(0.2*Sed_DIP))/((0.02+(DIP+(0.2*Sed_DIP))))))
Epi_PAR = (PAR_2/(PAR_2+90))
Epi_Photo_Rate = (0.003*(Water_Temp*(1-((Water_Temp-25)/19))))
Epi__DIN = (DIN/(0.025+DIN))
Epi__DIP = DIP/(0.001+DIP)
Flowering__Density = IF TIME >610 AND (Water_Temp < 21)  AND (JD<182) THEN ((0.01*Veg__D:C)) ELSE
(0)
JD = GRAPH(TIME)
(1.00, 122), (2.00, 123), (3.00, 124), (4.00, 125), (5.00, 126), (6.00, 127), (7.00, 128), (8.00, 129), (9.00, 130), (10.0, 131), (11.0, 132), (12.0, 133), (13.0, 134), (14.0, 135), (15.0, 136), (16.0, 137), (17.0, 138), (18.0, 139), (19.0, 140), (20.0, 141), (21.0, 142), (22.0, 143), (23.0, 144), (24.0, 145), (25.0, 146), (26.0, 147), (27.0, 148), (28.0, 149), (29.0, 150), (30.0, 151), (31.0, 152), (32.0, 153), (33.0, 154), (34.0, 155), (35.0, 156), (36.0, 157), (37.0, 158), (38.0, 159), (39.0, 160), (40.0, 161), (41.0, 162), (42.0, 163), (43.0, 164), (44.0, 165), (45.0, 166), (46.0, 167), (47.0, 168), (48.0, 169), (49.0, 170), (50.0, 171), (51.0, 172), (52.0, 173), (53.0, 174)...

Light_Lim = ( PAR_3/(57.5+PAR_3))
PAR_1 = GRAPH(TIME)
(1.00, 225), (2.00, 96.8), (3.00, 132), (4.00, 334), (5.00, 85.6), (6.00, 257), (7.00, 286), (8.00, 336), (9.00, 72.5), (10.0, 354), (11.0, 423), (12.0, 430), (13.0, 398), (14.0, 241), (15.0, 190), (16.0, 281), (17.0, 415), (18.0, 447), (19.0, 457), (20.0, 302), (21.0, 105), (22.0, 148), (23.0, 341), (24.0, 347), (25.0, 379), (26.0, 370), (27.0, 352), (28.0, 438), (29.0, 446), (30.0, 134), (31.0, 402), (32.0, 274), (33.0, 380), (34.0, 397), (35.0, 252), (36.0, 251), (37.0, 357), (38.0, 351), (39.0, 410), (40.0, 390), (41.0, 439), (42.0, 297), (43.0, 143), (44.0, 158), (45.0, 192), (46.0, 475), (47.0, 475), (48.0, 319), (49.0, 350), (50.0, 272), (51.0, 423), (52.0, 442), (53.0, 250)...

PAR_2 = (PAR_1*(EXP(-(((0.054*(Chl^0.667))+0.0088*Chl)+((0.0396*TSS)+0.39)+0.03)*Z)))
PAR_3 = (PAR_2*(EXP(0.32-(0.42*(2.5*Epi)))))
Photo_Period = (12-(2.5*COS(2*PI*(JD-354)/365)))/24
Predation = 0.33*Total__Seeds
PRepi = Epi_Photo_Rate* MIN(Epi_PAR, MIN(Epi__DIN, Epi__DIP))
PRzs =  MIN(DIN__Both, MIN(DIP__Both, Light_Lim))*Zm_Photo_Rate*Photo_Period
Roots__Resp_Rate = 0.00005
Sed_%_org = GRAPH(TIME)
(1.00, 1.12), (2.00, 1.11), (3.00, 1.10), (4.00, 1.09), (5.00, 1.08), (6.00, 1.07), (7.00, 1.05), (8.00, 1.04), (9.00, 1.03), (10.0, 1.02), (11.0, 1.01), (12.0, 1.00), (13.0, 0.99), (14.0, 0.98), (15.0, 0.96), (16.0, 0.95), (17.0, 0.94), (18.0, 0.93), (19.0, 0.94), (20.0, 0.95), (21.0, 0.95), (22.0, 0.96), (23.0, 0.97), (24.0, 0.97), (25.0, 0.98), (26.0, 0.99), (27.0, 0.99), (28.0, 1.00), (29.0, 1.01), (30.0, 1.01), (31.0, 1.02), (32.0, 1.03), (33.0, 1.05), (34.0, 1.07), (35.0, 1.09), (36.0, 1.11), (37.0, 1.13), (38.0, 1.15), (39.0, 1.18), (40.0, 1.20), (41.0, 1.22), (42.0, 1.24), (43.0, 1.22), (44.0, 1.21), (45.0, 1.19), (46.0, 1.17), (47.0, 1.16), (48.0, 1.14), (49.0, 1.12), (50.0, 1.11), (51.0, 1.09), (52.0, 1.08), (53.0, 1.06)...

Sed_DIN = GRAPH(TIME)
(0.00, 28.6), (1.00, 28.5), (2.00, 28.3), (3.00, 28.1), (4.00, 27.9), (5.01, 27.7), (6.01, 27.5), (7.01, 27.4), (8.01, 27.2), (9.01, 27.0), (10.0, 26.8), (11.0, 26.6), (12.0, 26.4), (13.0, 26.3), (14.0, 26.1), (15.0, 25.9), (16.0, 25.7), (17.0, 25.5), (18.0, 25.3), (19.0, 25.2), (20.0, 25.0), (21.0, 24.8), (22.0, 24.6), (23.0, 24.4), (24.0, 24.2), (25.0, 24.1), (26.0, 23.9), (27.0, 23.7), (28.0, 23.5), (29.0, 23.3), (30.0, 23.1), (31.0, 22.9), (32.0, 22.8), (33.0, 22.6), (34.0, 22.4), (35.0, 22.2), (36.0, 22.0), (37.0, 21.9), (38.0, 21.7), (39.0, 21.5), (40.0, 21.3), (41.0, 21.1), (42.0, 20.9), (43.0, 20.8), (44.0, 20.6), (45.0, 20.4), (46.0, 20.2), (47.0, 20.0), (48.0, 19.8), (49.1, 19.6), (50.1, 19.5), (51.1, 19.3), (52.1, 19.1)...

Sed_DIP = GRAPH(TIME)
(0.00, 11.7), (1.00, 11.7), (2.00, 11.7), (3.00, 11.7), (4.00, 11.7), (5.01, 11.7), (6.01, 11.7), (7.01, 11.7), (8.01, 11.7), (9.01, 11.7), (10.0, 11.7), (11.0, 11.7), (12.0, 11.7), (13.0, 11.7), (14.0, 11.8), (15.0, 11.8), (16.0, 11.8), (17.0, 11.8), (18.0, 11.8), (19.0, 11.8), (20.0, 11.8), (21.0, 11.8), (22.0, 11.8), (23.0, 11.8), (24.0, 11.8), (25.0, 11.8), (26.0, 11.8), (27.0, 11.8), (28.0, 11.9), (29.0, 11.9), (30.0, 11.9), (31.0, 11.9), (32.0, 11.9), (33.0, 11.9), (34.0, 11.9), (35.0, 11.9), (36.0, 11.9), (37.0, 11.9), (38.0, 11.9), (39.0, 11.9), (40.0, 11.9), (41.0, 11.9), (42.0, 11.9), (43.0, 12.0), (44.0, 12.0), (45.0, 12.0), (46.0, 12.0), (47.0, 12.0), (48.0, 12.0), (49.1, 12.0), (50.1, 12.0), (51.1, 12.0), (52.1, 12.0)...

Seeds_Roots__Resp_Rate_2 = 0.0005
Seed_Photo__Rate = (0.095 + (0.0309*EXP(-0.5*(((Water_Temp-22.5)/3.2)^2))))
Seed_PRzs =  MIN(DIN__Both, MIN(DIP__Both, Light_Lim))*Seed_Photo__Rate*Photo_Period
TSS = GRAPH(TIME)
(1.00, 3.35), (2.00, 2.07), (3.00, 1.65), (4.00, 2.00), (5.00, 1.97), (6.00, 2.00), (7.00, 1.80), (8.00, 8.62), (9.00, 4.74), (10.0, 2.80), (11.0, 3.23), (12.0, 4.16), (13.0, 6.25), (14.0, 4.84), (15.0, 3.52), (16.0, 3.42), (17.0, 3.20), (18.0, 3.24), (19.0, 3.66), (20.0, 4.87), (21.0, 2.70), (22.0, 2.60), (23.0, 2.97), (24.0, 3.12), (25.0, 3.98), (26.0, 7.76), (27.0, 11.2), (28.0, 14.3), (29.0, 11.1), (30.0, 7.64), (31.0, 6.60), (32.0, 7.41), (33.0, 8.30), (34.0, 9.34), (35.0, 7.22), (36.0, 4.55), (37.0, 4.70), (38.0, 6.10), (39.0, 5.93), (40.0, 6.05), (41.0, 7.74), (42.0, 7.30), (43.0, 7.18), (44.0, 6.62), (45.0, 4.79), (46.0, 6.00), (47.0, 9.16), (48.0, 9.11), (49.0, 7.17), (50.0, 7.04), (51.0, 8.61), (52.0, 9.33), (53.0, 10.5)...

Veg__D:C = (AG_Biomass/0.016781021)
Water_Temp = GRAPH(Time)
(1.00, 14.6), (2.00, 14.3), (3.00, 14.0), (4.00, 15.1), (5.00, 15.5), (6.00, 15.2), (7.00, 16.0), (8.00, 16.6), (9.00, 17.2), (10.0, 17.1), (11.0, 16.9), (12.0, 17.6), (13.0, 18.9), (14.0, 19.6), (15.0, 19.3), (16.0, 19.8), (17.0, 20.1), (18.0, 19.7), (19.0, 19.2), (20.0, 19.1), (21.0, 17.9), (22.0, 18.1), (23.0, 20.0), (24.0, 21.2), (25.0, 21.6), (26.0, 23.1), (27.0, 24.0), (28.0, 24.8), (29.0, 25.9), (30.0, 25.4), (31.0, 24.4), (32.0, 23.2), (33.0, 22.7), (34.0, 22.0), (35.0, 20.5), (36.0, 18.5), (37.0, 19.5), (38.0, 20.3), (39.0, 21.1), (40.0, 21.9), (41.0, 22.7), (42.0, 23.2), (43.0, 22.7), (44.0, 21.7), (45.0, 20.9), (46.0, 21.4), (47.0, 22.1), (48.0, 22.2), (49.0, 22.2), (50.0, 22.5), (51.0, 24.1), (52.0, 26.2), (53.0, 26.5)...

Z = 0.5
Zm_Photo_Rate = ( 0.0948+(0.0309*EXP(-0.5*(((Water_Temp-22.5)/3.2964)^2))))
```
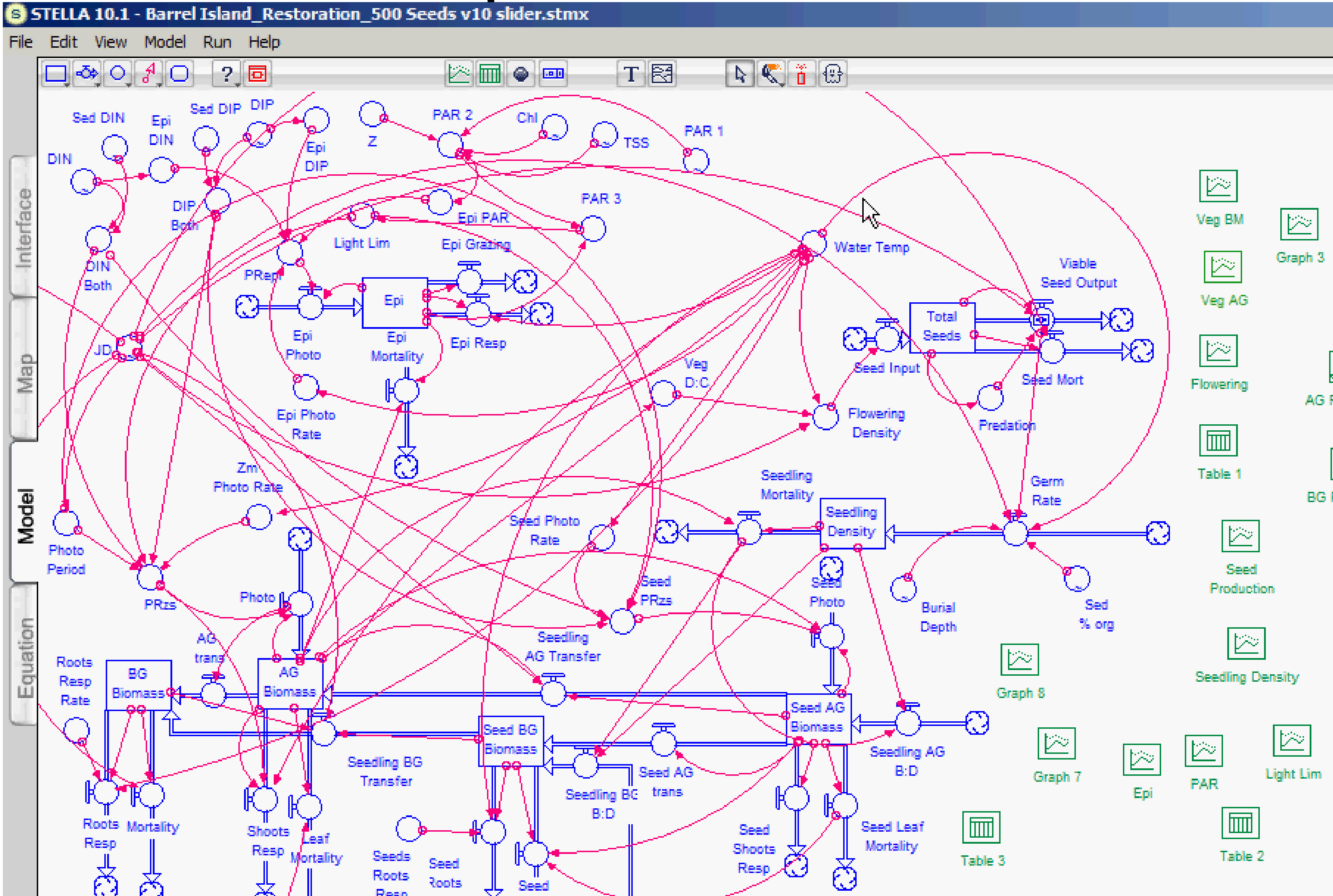
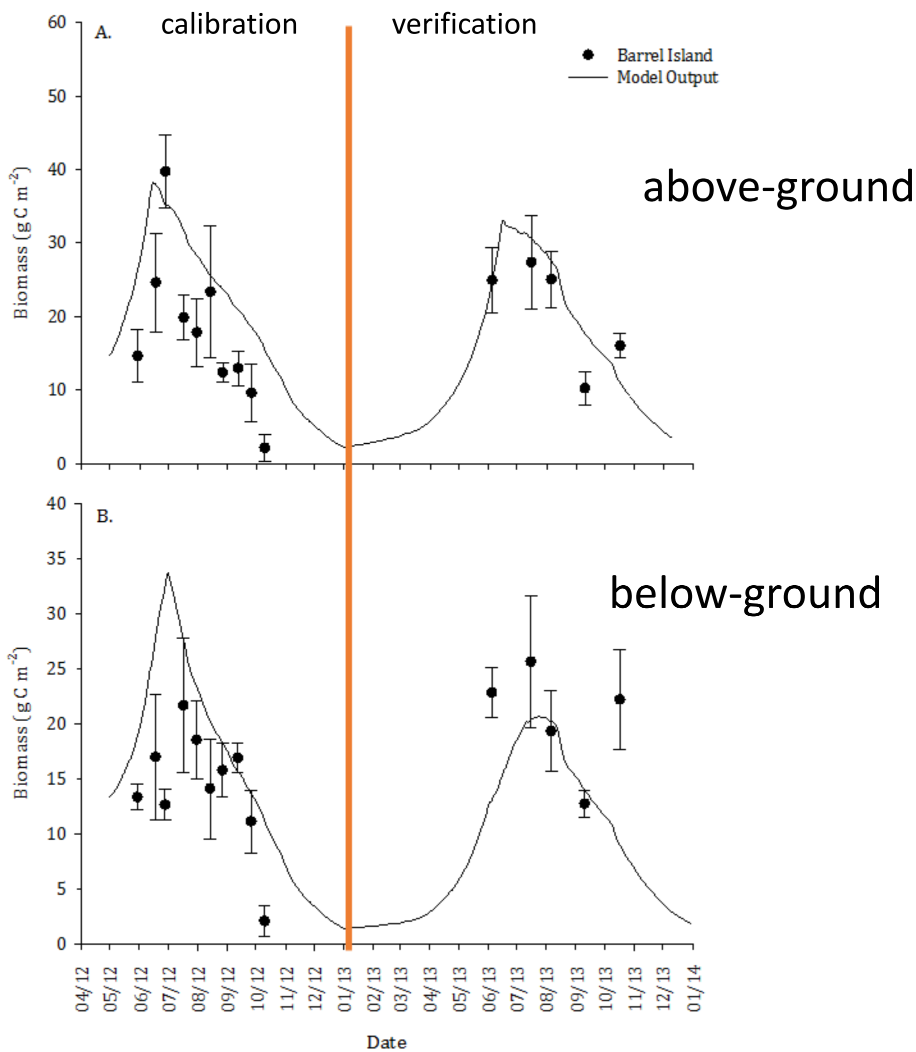

Stella Graphical Model Run



Results

Calibration and verification data of *Zostera marina model*



biomass model (black line)
with observed Barrel Island (BI) data (circles)

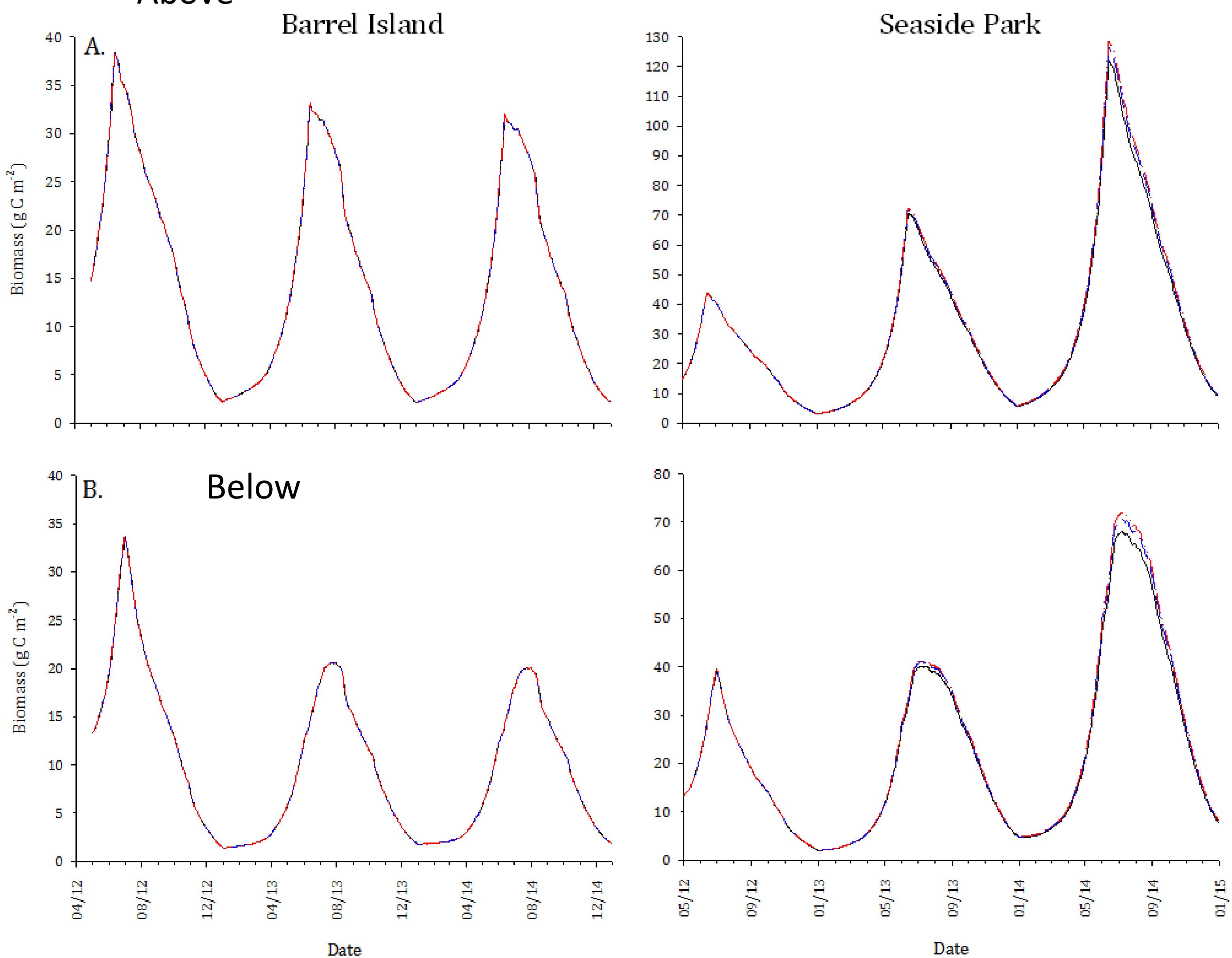
- Observed data are given in monthly means ± SE.
- The orange line denotes separation between calibration and verification datasets.
- The model captured the overall seasonal trends in above ground biomass
- Under typical conditions it produced repeatable annual biomass cycles
- Calibration run tended to over-predict above-ground and to a lesser extent below-ground biomass
- Verification (BI 2013) good predictor May-Sept- tend to over-predict October.

Model Scenario Results

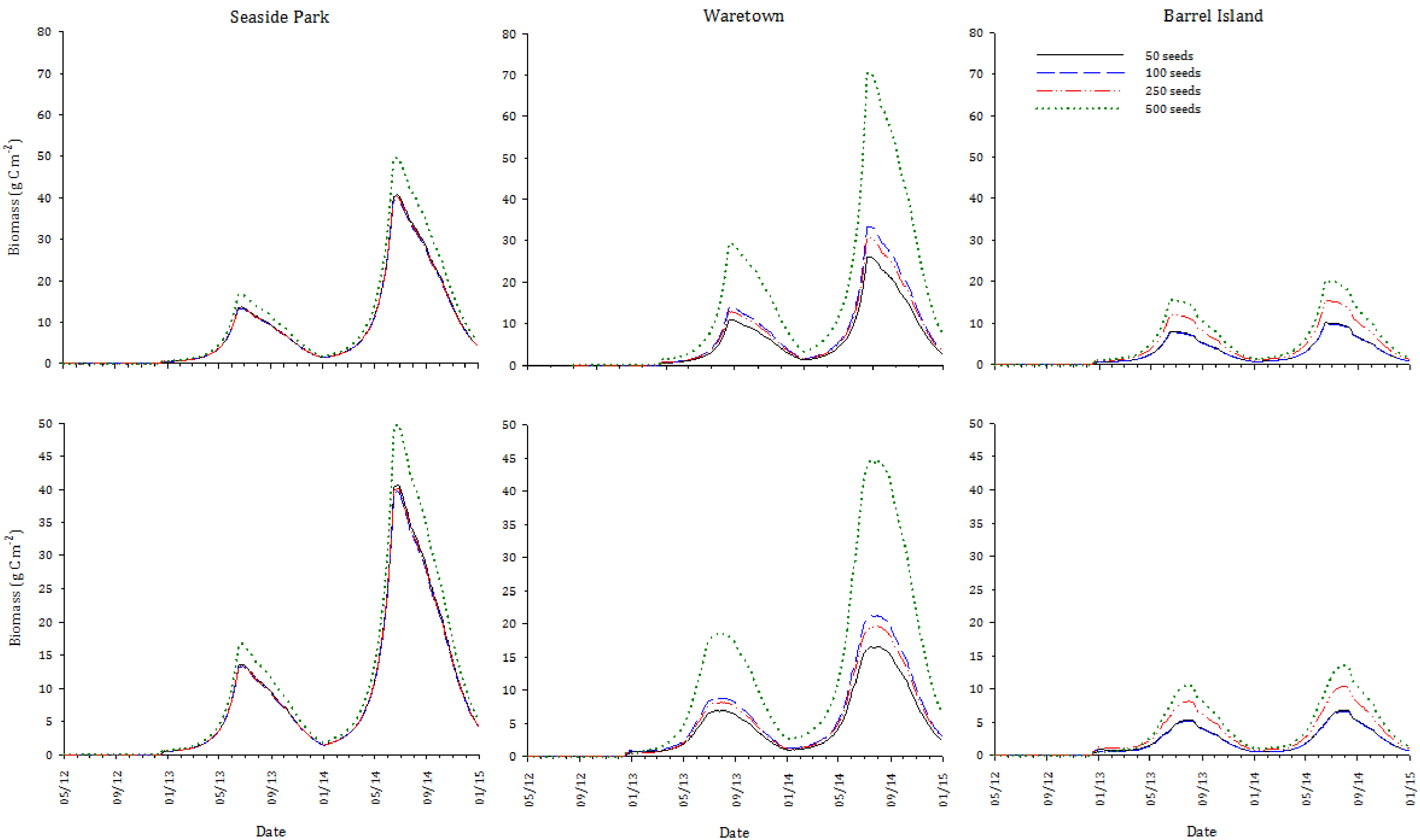
- I. Nutrient reduction- 10%, 30% at Seaside (SS)/Northern Barnegat bay and Barrel Island (BI)
- II. Restoration Potential with seeds on a north south, high to lower nutrient gradient. Seaside (SS)/Northern Barnegat bay, Waretown (WT) and Barrel Island (BI).

Nutrient reductions (ambient, 10%, 30%)

Above



Restoration Potential for 3 Sites in BB/LEH



Discussion

- The model presented here reproduced the general observed trends in above and below ground *Zostera marina* biomass in Barnegat Bay – Little Egg Harbor in 2012 – 2013. Given adequate water quality (total suspended solids, chlorophyll *a*, total available light), sediment (% organic content), and nutrient data (water column and sediment DIN, DIP) the model calibrated here was shown to accurately project both the magnitude and seasonality of *Z. marina* above and below ground biomass growth in this system

Discussion Management Scenarios- Nutrient reduction

- Reductions of water column and sediment nutrient concentrations up to 30 % below ambient conditions unexpectedly did not result in increased *Z. marina* above or below ground biomass in any model scenarios
- Eutrophic conditions are associated with SAV loss in BB-LEH. However loss is not observed through direct negative effects of excess nutrient concentrations, but rather through indirect negative effects due to greater benthic macro-algal or phytoplankton biomass which limits the amount of available light for SAV growth and survival or through the production of metabolic by-products like anoxia and sulphides.
- The lack of effect in model scenarios presented here were due in part to the lack of large scale macro-algal or phytoplankton blooms in either SS or BI in 2012 – 2013

Discussion Management Scenarios- Seed Restoration

- Successful restoration of *Z. marina* in lagoonal systems like BB-LEH have been documented in areas where a lack of propagule supply was the main limiting factor. However, in areas where additional stressors such as episodic low light and high water temperatures occur, successful large scale restoration of *Z. marina* can be limited by poor site selection.

- While all sites selected as potential restoration sites for *Z. marina* in BB-LEH supported the establishment and growth of SAV populations, modelled *Z. marina* above and below ground biomass was greater at WT compared to both SS and BI sites regardless of the number of seeds used to initiate recovery. The greater light availability due to lower turbidity and chlorophyll *a* concentrations indicate that restoration site selection which focuses on those sites where light availability is greatest may result in short term restoration success.

Model Limitations

- One of the greatest percent errors in base model calibration occurred due to a significant overestimate of fall *Z. marina* production which may be attributed to the use of constant rates for translocation of carbon from *Z. marina* above ground to below ground biomass. Defining the seasonality of the relationships between temperature and the rate and direction of carbon translocation in *Z. marina* plants is necessary to increase the accuracy of the model.

- There were several limitations on the accuracy of sexual reproductive output in the model resulting in overestimation of total and viable seed bank densities. The areas that are primarily lacking in the BB-LEH application of the model include the lack of change in mortality, grazing and viability rates over time

Model Limitations (continued)

- In order to more accurately predict the response of SAV populations to potential management scenarios the indirect effects of benthic and epiphytic macroalgae need to be quantified. The relationships between environmental drivers and changes in macroalgal biomass over time within BB-LEH need to be defined before they can be incorporated into the model.
- As *Z. marina* populations continue to decline and populations of other SAV species, including *Ruppia maritima*, increase the model should be expanded to incorporate inter-species interactions. Both the inclusion of indirect effects and the incorporation of multiple SAV species would likely increase the overall accuracy and applicability of the model.

Online Model Interface

Zostera (Eelgrass) Restoration Simulation

Southern Barnegat Bay/Little Egg Harbor

This simulation allows you to vary the number of seeds used to begin a seagrass restoration project and to follow the growth of the bed over the first 2 years in a given part of the bay with similar conditions.

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More information

An eelgrass (Zostera marina) meadow

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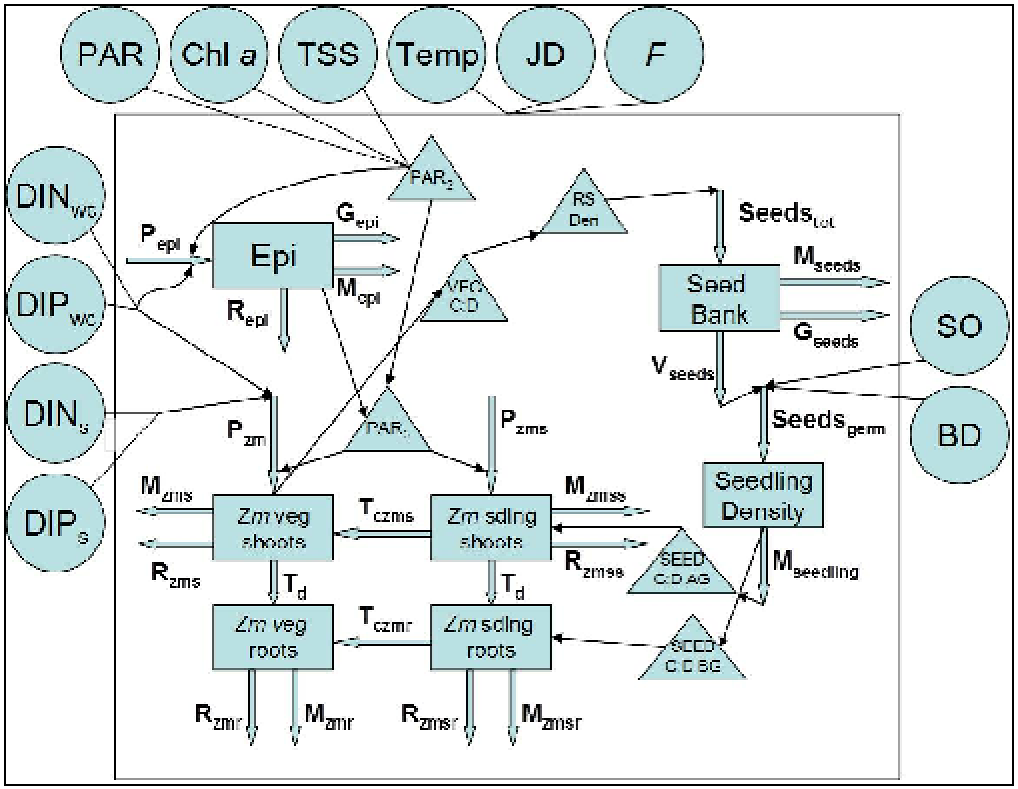
Online Model Information page

The Zostera marina production model

Model Information



Governing equations for (1) epiphyte biomass (Cepi; g C m-2); (2) Z. marina vegetative shoot biomass (Czms; g C m-2); (3) Z. marina vegetative root/rhizome biomass (Czmr; g C m-2); (4) Z. marina seed-bank density (Zmseeds; seeds m-2); and (5) Z. marina seedling density (Zmsd; seedlings m-2). Terms include P = production; M = mortality; G = grazing; R = respiration; Td = translocation down; Tczmss = transfer of seedling biomass to vegetative shoot biomass; Tczmsr = transfer of seedling root/rhizome biomass to vegetative root/rhizome biomass; Seedsgerm = germinated seeds; Seeds prod = total seeds produced; Seedsvia = viable seeds; PRseeds = seed predation; Zmsd = germinated seedling density

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Online Model Run Page

Viable Seed Output

0.0 1.0

1.0

Zostera Restoration Scenario

Vary viable seeds broadcast/m2

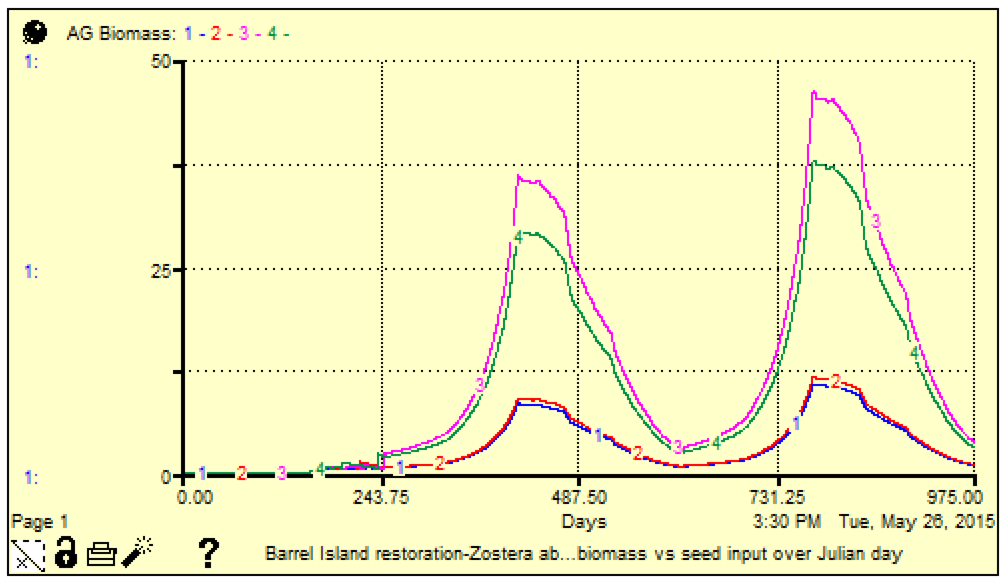
Graph 1

Use the slider to vary the seed input into the restoration project.

1.0 is 500 seeds/m2
0.5 is 250 seeds/m2
0.2 is 100 seeds/m2
01. is 50 seeds/m2
0 is 0 seeds/m2

You can run at various seed densites and compare on the graph.

Use reset to clear all runs and start again.



Run

Reset

Home

Hit the print icon to print the

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Online Model –Acknowledgements page/download information

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You may download the Stella 10 (tm ISEE corp) Model programming for this and other Zostera models from the project Forio.com simulate site. Site specific forcing functions can be added to the model layer using data collected by the NJ DEP or other sources to investigate site specific simulations within the Barnegat Bay region. Contact the authors at "peter.straub@stockton.edu" for more information

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