*The following supplement accompanies the article*

# Modeling estuarine response to load reductions in a warmer climate: York River Estuary, Virginia, USA

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**Table S1**. Primary equations from the reduced complexity ecosystem model. See Table S2 for definitions. Full details can be found in Lake & Brush (2015).

| Primary Model Equations |
|---|

Phytoplankton Biomass and Production[1]

$$NPP_d = \left[b_{BZI} + m_{BZI}\left(BZ_pI_0\right)\right] \cdot 10^{-3}$$

$$m_{BZI} = [0.76 \cdot e^{0.051 \cdot T - 15}]$$

$$NPP_d^* = NPP_d \cdot \frac{pNPP_d}{100}$$

Pelagic Respiration[2]

$$R_{WC} = PHY_{10} \cdot R_{WC_0} \cdot e^{R_{WC_k} \cdot T}$$

Carbon Deposition and Sediment Fluxes[2]

$$NPP_{SED}^* = \int NPP_{SED} \cdot NPP_d^*$$

$$R_{SED} = SED_C \cdot R_{SED_0} \cdot e^{(R_{SED_k} \cdot T)}$$

$$\rho N_{den} = N_{den_0} \cdot e^{(0.0693 \cdot T)}$$

$$DENIT_{EFF} = 0.4 + (0.0518 \cdot O_2)$$

$$DIP_{Hypoxic-Flux} = 0.0286 \cdot e^{(-0.6271 \cdot O_2)}$$

Oxygen

$$O_2 = O_{2\,prod} + O_{2\,resp} + O_{2\,exch} + O_{2\,diff}$$

$$O_{2\,prod} = O_{2\,NPP\,PHY} + O_{2\,GPP_{MPB}}$$

$$O_{2\,resp} = O_{2\,R_{WC}} + O_{2\,R_{MPB}} + O_{2\,R_{SED}} + O_{2\,R_{OC}}$$

$$O_{2\,diff} = k_{O_2}\left(O_2^{eq} - O_{2\,avil}\right)$$

$$k_{0_2} = e^{(1.09 + 0.29 \cdot W)} \cdot \left(\frac{24}{100}\right)$$

[1]Production is converted to oxygen using a photosynthetic quotient (PQ) of 1, and N and P demand is computed using molar ratios of 106:16 (C:N) and 106:1 (C:P). Rates are prorated when nutrients are limiting.

[2]Respiratory rate is converted into an oxygen demand using a respiratory quotient (RQ) of 1. N and P are remineralized stoichiometrically using the C:N and C:P ratios listed above. Rates are limited by the available supply of oxygen.

**Table S2**. Parameters, terms, and constants for the equations included in Table S1.

| Parameter | Definition | Unit |
|---|---|---|
| *Phytoplankton Biomass and Production* | | |
| $NPP_d$ | Potential daytime phytoplankton net production | g C m$^{-2}$ d$^{-1}$ |
| $b_{BZI}$ | y-intercept | |
| $m_{BZI}$ | Slope of BZI equation *(modeled as a function of temperature)* | |
| $B$ | Chlorophyll-*a* biomass | mg m$^{-3}$ |
| $Z_p$ | Photic depth | m |
| $I_o$ | Incident irradiance | E m$^{-2}$ d$^{-1}$ |
| $T$ | Temperature | °C |
| $NPP_d^*$ | Realized NPP<br>*(production rate is prorated when nutrients are limiting)* | g C m$^{-2}$ d$^{-1}$ |
| $pNPP_d$ | Depth corrected fraction of $NPP_d$ (based on Brawley et al. 2003) | |
| *Pelagic Respiration* | | |
| $R_{WC}$ | Water column respiration | g C m$^{-2}$ d$^{-1}$ |
| $PHY_{10}$ | 10-day moving average of predicted phytoplankton biomass | g m$^{-2}$ |
| $R_{WC_k}$ | Temperature-respiration exponent reported in Smith & Kemp (1995)<br>*(boxes 1&2 = 0.05, boxes 3-8 = 0.071 and 0.104* for surf and bottom, respectively*)* | $^{o}C^{-1}$ |
| $R_{WC_0}$ | 0°C value *(0.025)* | d$^{-1}$ |
| *Carbon Deposition* | | |
| $NPP^*_{SED}$ | Daily phytoplankton production to the sediments | g C m$^{-2}$ d$^{-1}$ |
| $NPP_d^*$ | Realized NPP | g C m$^{-2}$ d$^{-1}$ |
| $\int NPP_{SED}$ | Fraction of $NPP_d^*$ deposited to and respired in the sediments *(25%)* | |
| $R_{SED}$ | Respiration of the sediment carbon pool | g C m$^{-2}$ d$^{-1}$ |
| $SED_C$ | Sediment carbon pool | g C m$^{-2}$ |
| $R_{SED_0}$ | 0°C value *(boxes 1-3 = 0.05, boxes 4-8 = 0.025)* | d$^{-1}$ |
| $R_{SED_k}$ | Temperature-respiration exponent<br>*(0.08 for all boxes, except bottom layers of boxes 4–8 = 0.06)* | $^{o}C^{-1}$ |
| *Sediment Fluxes* | | |
| $\rho N_{den}$ | Potential loss of nitrogen to denitrification | g N m$^{-2}$ d$^{-1}$ |
| $N_{den_0}$ | 0°C value *(0.01)* | |
| $DENIT_{EFF}$ | Denitrification efficiency | |
| $O_2$ | Dissolved oxygen concentration | mg $O_2$ l$^{-1}$ |
| $DIP_{HYPOXIC-FLUX}$ | Increase in sediment DIP fluxes over baseline normoxic rates | g P m$^{-2}$ |

| Parameter | Definition | Unit |
|---|---|---|
| *Oxygen* | | |
| $O_2$ | Dissolved oxygen concentration | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2\,prod}$ | Photosynthetic production of oxygen | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2NPP_{PHY}}$ | Phytoplankton production of oxygen *(PQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2\,exch}$ | Exchange of oxygen between spatial elements | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2\,diff}$ | Rate of oxygen diffusion | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2GPP_{MPB}}$ | Microphytobenthic production of oxygen *(PQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2\,resp}$ | Total respiratory consumption of oxygen | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2R_{WC}}$ | Water column consumption of oxygen *(RQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2R_{MPB}}$ | Microphytobenthos consumption of oxygen *(RQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2R_{SED}}$ | Sediment consumption of oxygen *(RQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $O_{2R_{OC}}$ | POC and DOC respiratory consumption of oxygen *(RQ = 1)* | g $O_2$ $m^{-2}$ $d^{-1}$ |
| $k_{O_2}$ | Piston velocity exchange coefficient | m $d^{-1}$ |
| $O_2^{eq}$ | Concentration at saturation *(function of temperature, salinity, and density from Pilson (1998)* | g $O_2$ $m^{-3}$ |
| $O_{2\,avil}$ | Modeled available dissolved oxygen concentration | g $O_2$ $m^{-3}$ |
| $W$ | Average daily wind speed | m $s^{-1}$ |

## LITERATURE CITED


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