Calculation of Oyster Benefits with a Bioenergetics Model of the Virginia Oyster

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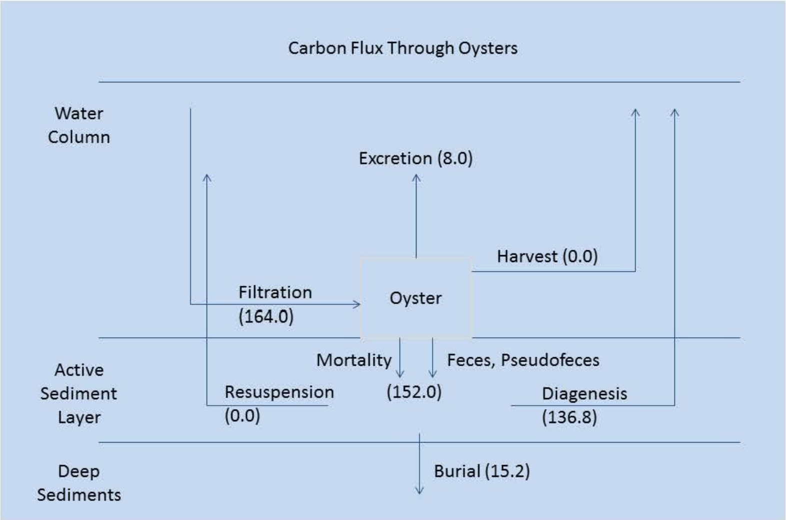
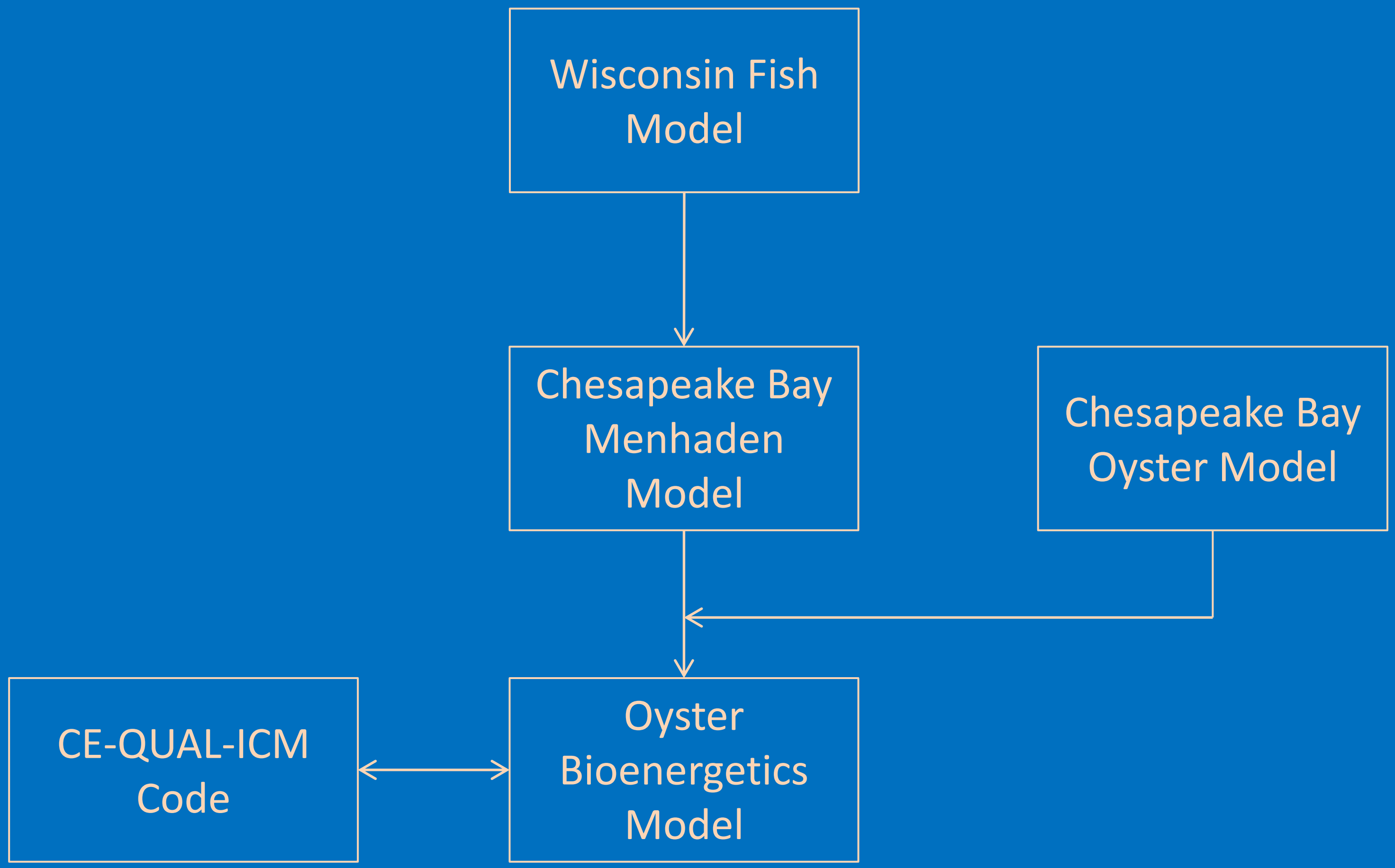


The Heritage



Distinctions

- Individual population model.
- Accounts for size and age of schools or cohorts.
- Energy-based. Model currency is in joules.
- Three energy stores in oysters: soft tissue, shell, reproduction.

Population (number of individuals)

$$\Delta N = \Delta Nstv + \Delta Nsuf + \Delta Nprd + \Delta Nfsh \qquad (1)$$

in which:

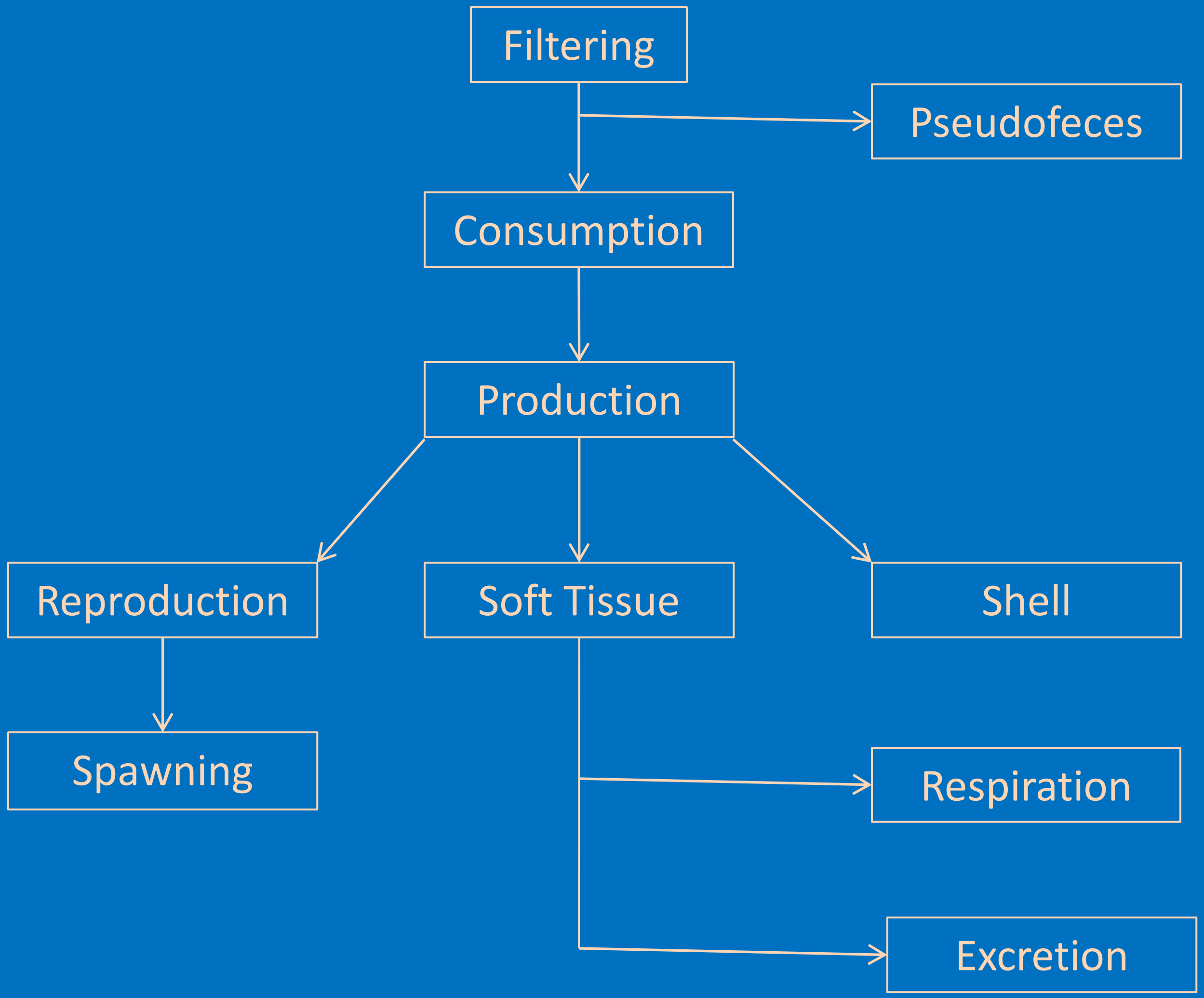
ΔN = number of individuals lost within a model time step
ΔNstv = number of individuals lost to starvation within a model time step
ΔNsuf = number of individuals lost to suffocation within a model time step
ΔNprd = number of individuals lost to predation within a model time step
ΔNfsh = number of individuals lost to fishery within a model time step

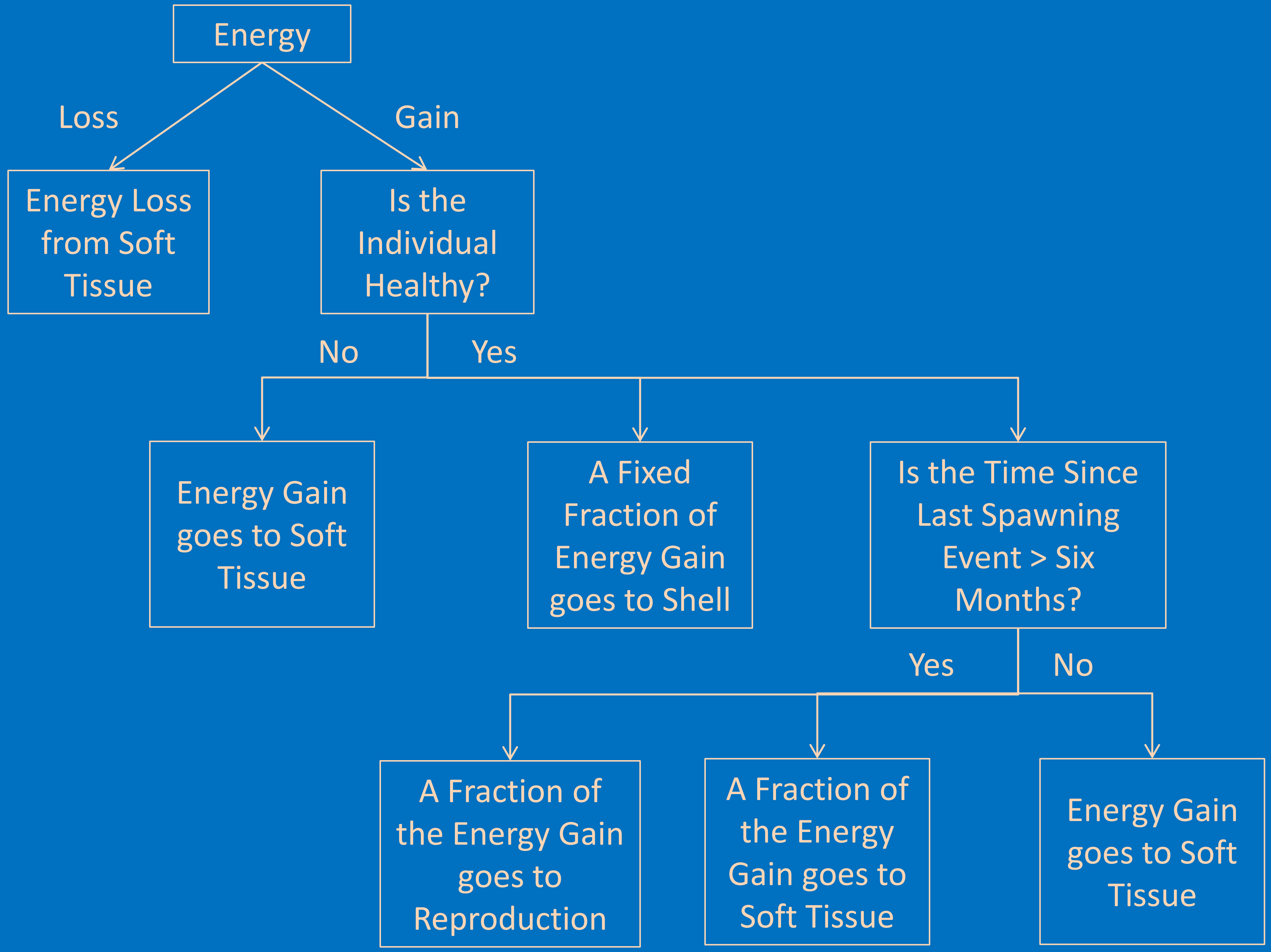
Individual Weight

$$\frac{dW}{dt} = \left\{C - \left[(BM + S) + (F + U)\right]\right\} \frac{1}{EPRD} \qquad (5)$$

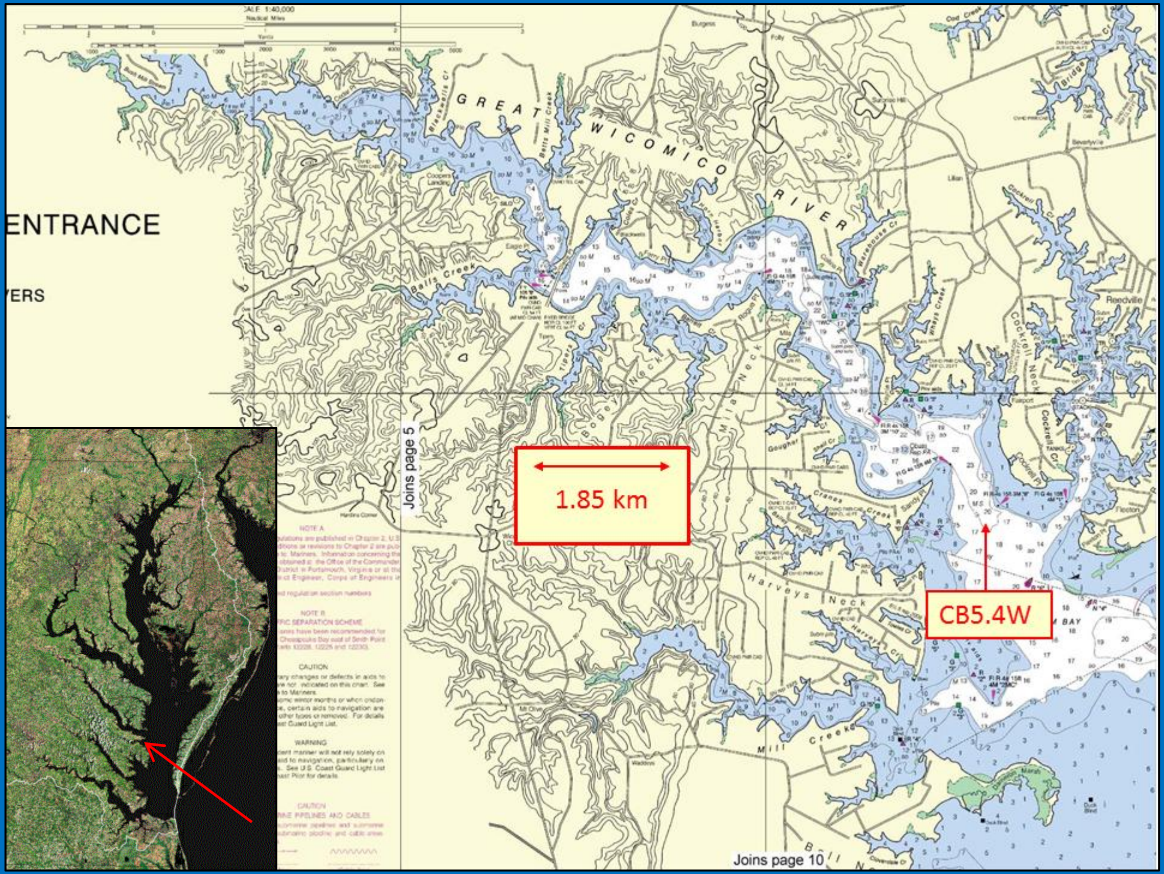
in which:

C = consumption (j s^{-1})
BM = basal metabolism (j s^{-1})
S = specific dynamic action (or active respiration, j s^{-1})
F = feces (j s^{-1})
U = excretion (j s^{-1})
EPRD = fish energy density (j g^{-1} DW)


Filtering
Pseudofeces
Consumption
Production
Reproduction
Soft Tissue
Shell
Spawning
Respiration
Excretion

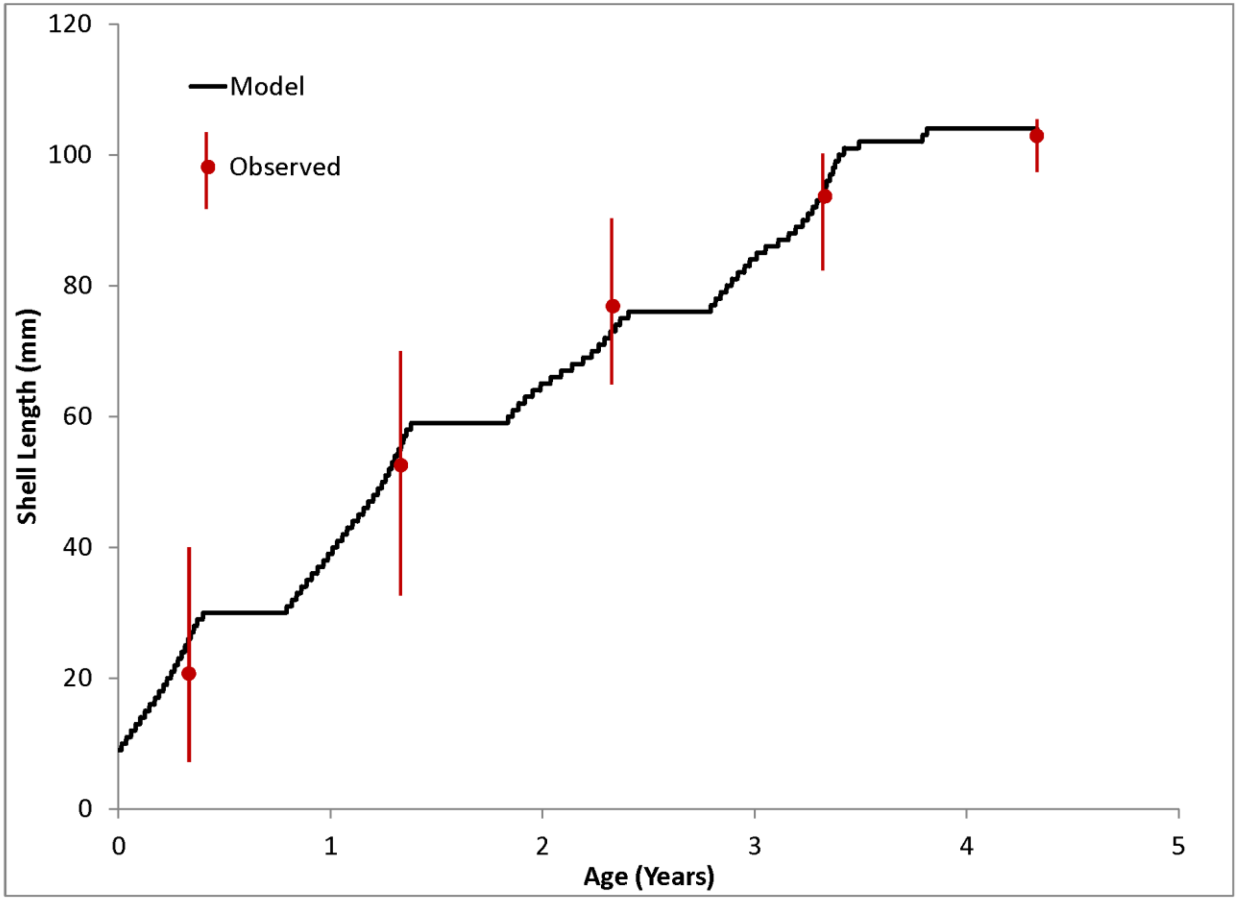

Energy
Loss
Gain
Energy Loss from Soft Tissue
Is the Individual Healthy?
No
Yes
Energy Gain goes to Soft Tissue
A Fixed Fraction of Energy Gain goes to Shell
Is the Time Since Last Spawning Event > Six Months?
Yes
No
A Fraction of the Energy Gain goes to Reproduction
A Fraction of the Energy Gain goes to Soft Tissue
Energy Gain goes to Soft Tissue

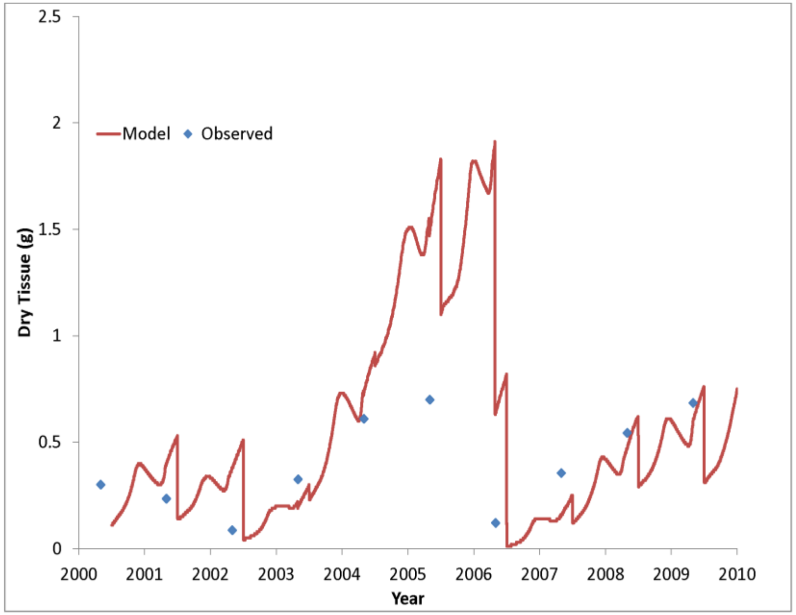
Application to Great Wicomico River



Southworth, M., Harding, J., Wesson, J., and Mann, R. (2010). "Oyster (*Crassostrea virginica*, Gmelin 1791) population dynamics on public reefs in the Great Wicomico River, Virginia, USA," *Journal of Shellfish Research* 29(2), 271-290.

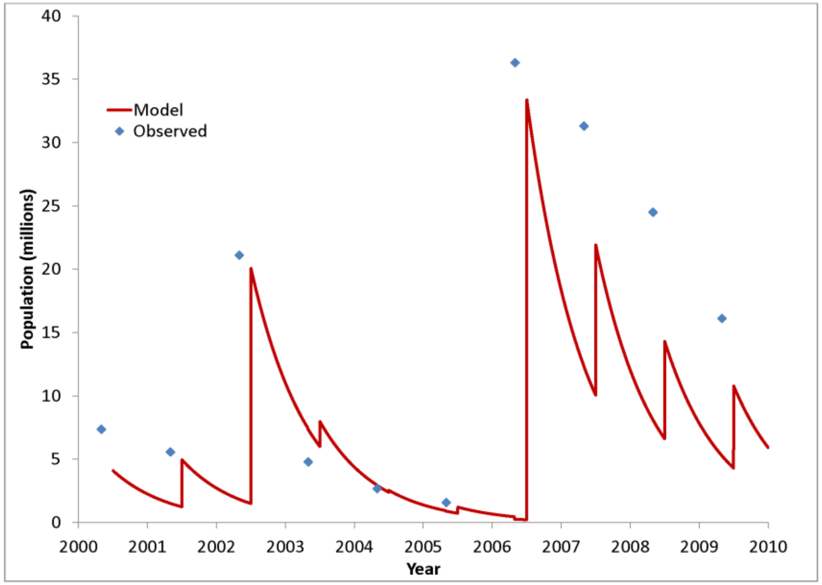
Computed and observed "age at length" relationships

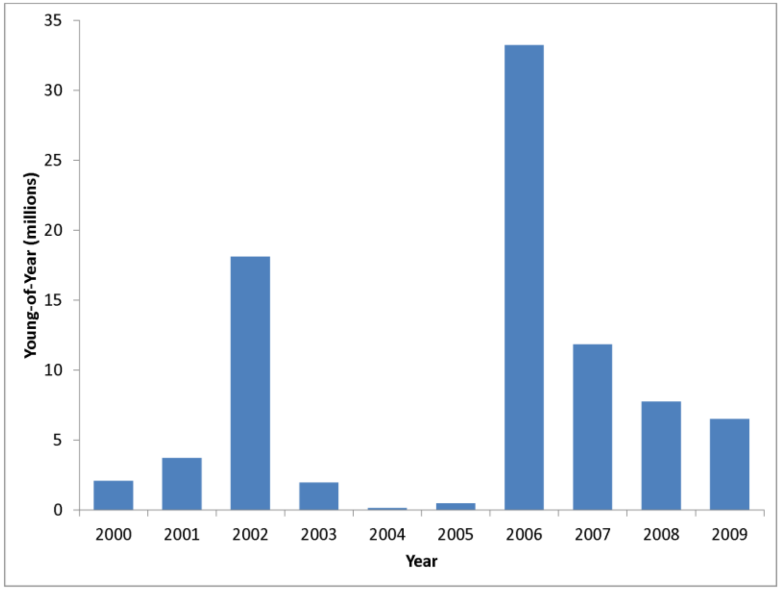




Computed and observed oyster population.

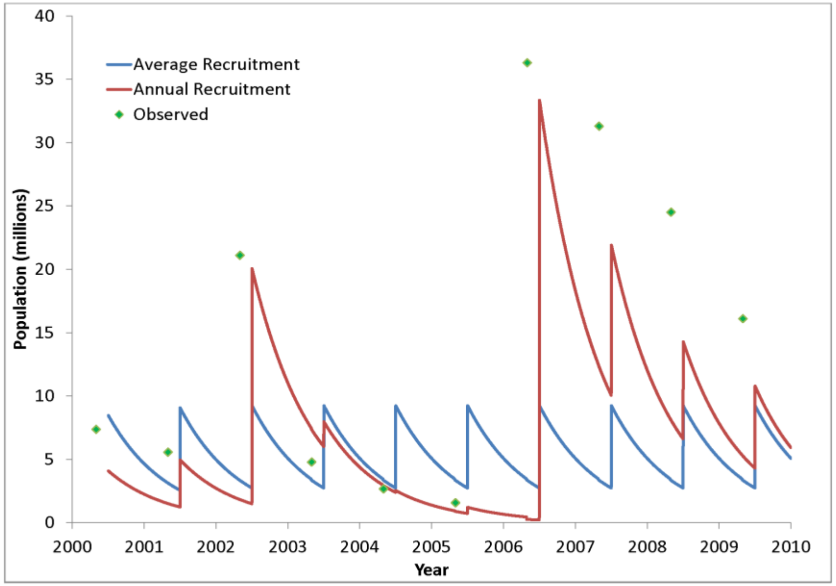
Computed and observed population-average individual dry tissue weight.

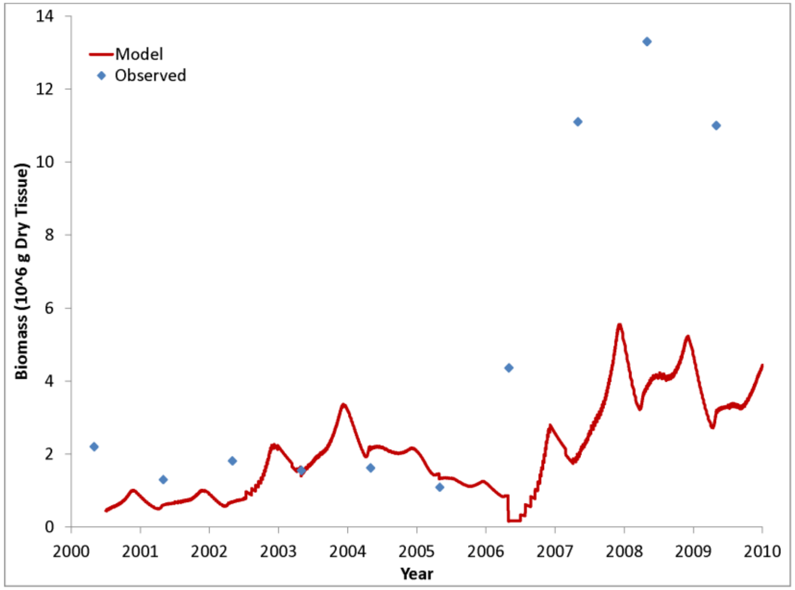




Observed “young-of-year.”

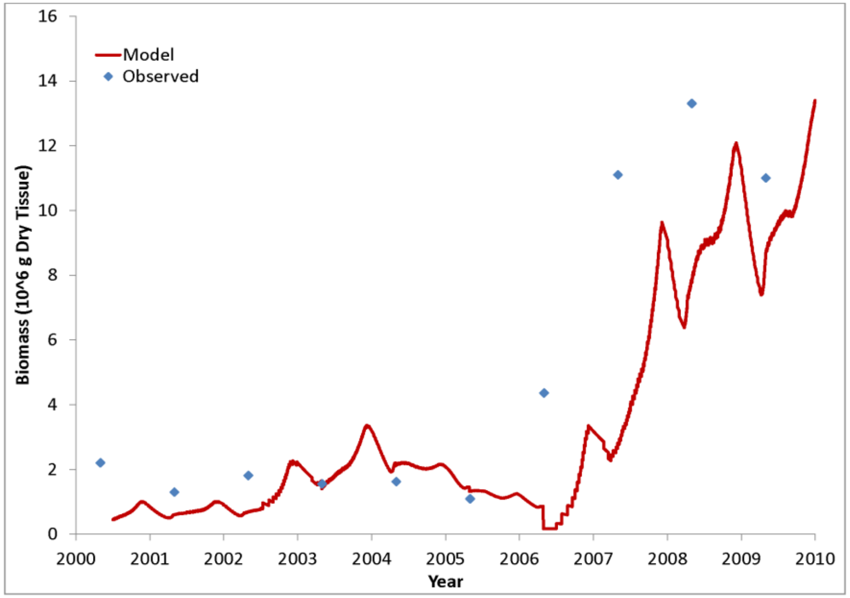
Sensitivity of computed population to recruitment rate. Two computations are shown, one based on observed recruitment in individual years, the other based on recruitment rate averaged over all years.





Total biomass computed on the basis of two mortality rates, 1.2 yr^{-1} for 2000 – 2005 and 0.77 yr^{-1} for 2006 – 2010.

Computed and observed total biomass of oyster dry tissue.



Oyster Benefits

Quantifiable carbon benefits include:

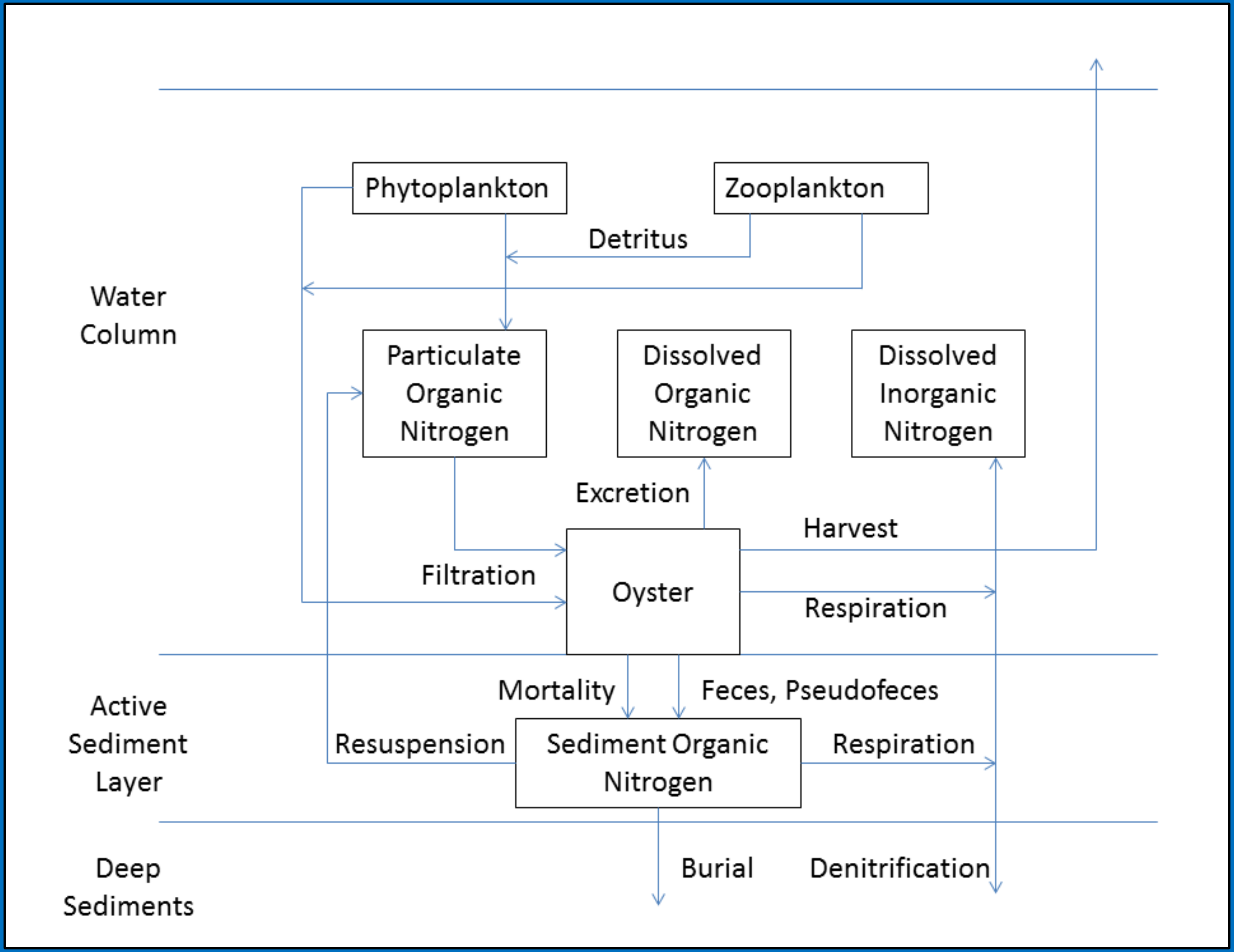
- Carbon filtered from the water column
- Enhanced carbon burial to deep inactive sediments
- Carbon removed through oyster harvesting
- Carbon sequestered in *oyster biomass*

Quantifiable nitrogen benefits include:

- Nitrogen filtered from the water column
- Enhanced nitrogen burial to deep inactive sediments
- Enhanced denitrification in active bottom sediments
- Nitrogen removed through oyster harvesting
- Nitrogen sequestered in oyster biomass

Quantifiable shell benefits include:

- Accumulation in-situ
- Carbon sequestration associated with in-situ accumulation
- Collection as a by-product of oyster harvesting
- Carbon sequestration in harvested oyster shell



The model nitrogen cycle including oysters. The quantifiable benefits include nitrogen removal via fisheries harvest, nitrogen removal through burial to deep, inactive sediments, and nitrogen removal via denitrification.

A Departure from the Bay program

Adopt a “model of moderate complexity:

- Calculate some parameters.
- Estimate other parameters.

Denitrification is considered by first computing the rate of nitrogen incorporation into active bottom sediments (that is, the fraction not resuspended):

$$rateNDeposited = \left[rateNRecycle + rateNNatMort + rateNSpawn\right] \cdot \left[FLPON + FRPON\right] \cdot \left(1 - resusp\right) \quad (5)$$

in which:

rateNDeposited = rate of organic nitrogen deposition to active surficial sediments (kg d^{-1})
rateNRecycle = rate at which oysters recycle organic nitrogen through the processes of respiration, feces, and pseudofeces (kg d^{-1})
rateNNatMort = rate at which oysters recycle organic nitrogen through natural mortality (kg d^{-1})
rateNSpawn = rate at which organic nitrogen is recycled through spawning (kg d^{-1})
FLPOCN = fraction of recycled organic nitrogen that is labile particulate organic nitrogen ($0 \leq FLPON \leq 1$)
FRPON = fraction of recycled organic nitrogen that is labile particulate organic nitrogen ($0 \leq FRPON \leq 1$)

Estimate resuspension rate, 0.0 to 10%.

The nitrogen deposited can undergo two fates: diagenesis (respr) or burial (1-respr). A fraction of the portion that undergoes diagenesis can undergo further denitrification (denitr). The total removal rate becomes:

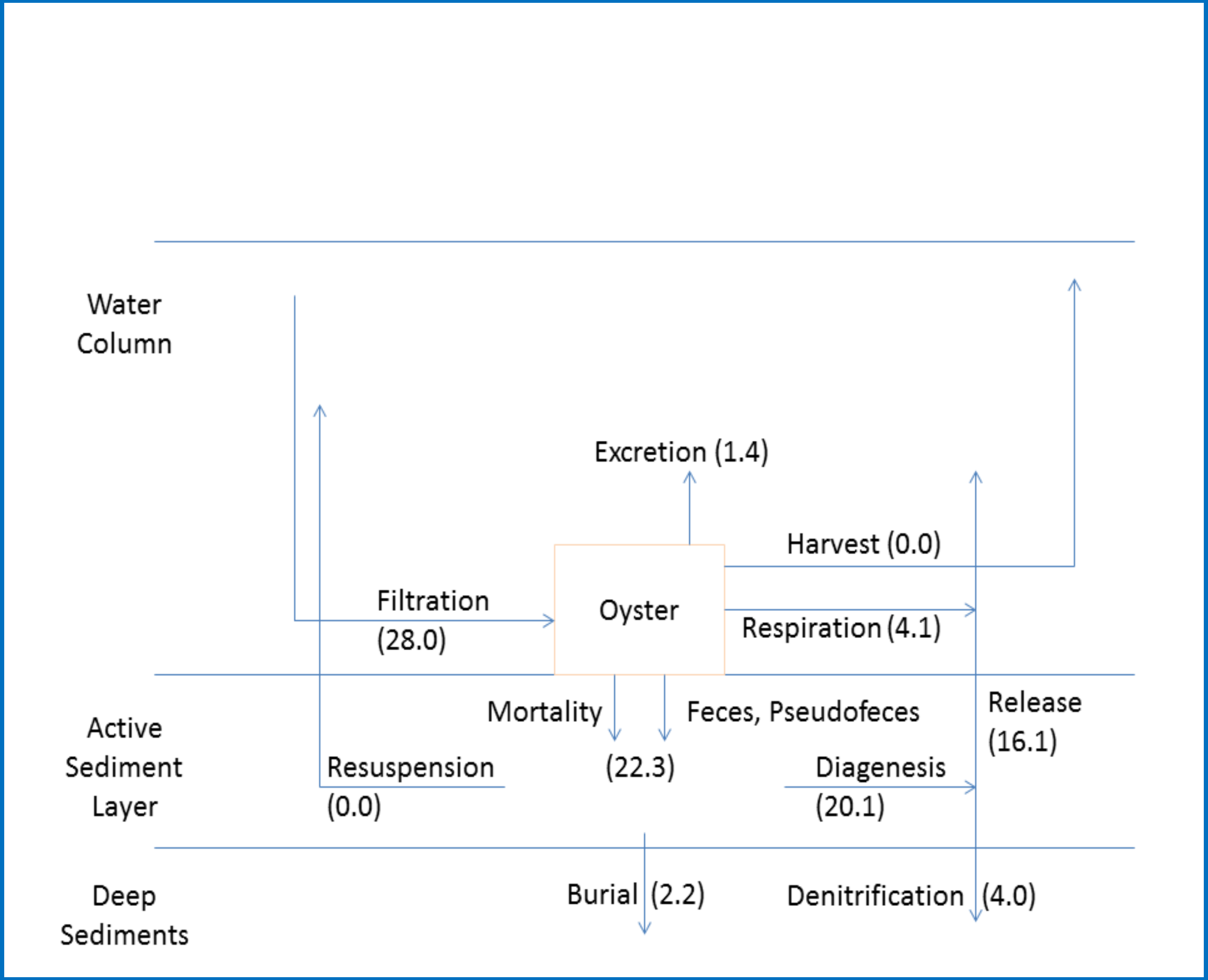
$$rateNRemoved = rateNDeposited \cdot (1 - respr) + rateNDeposited \cdot respr \cdot denitr \qquad (6)$$

in which:

rateNRemoved = rate of organic nitrogen removal in sediments due to burial and denitrification (kg d^{-1})
denitr = fraction of nitrogen diagenesis that undergoes denitrification ($0 \leq denitr \leq 1$)

Estimate:

- respr (the fraction available for diagenesis) = 0.9
- Denitr (the fraction denitrified) = 0.2



Computed nitrogen fluxes and benefits in the Great Wicomico. All values are annual averages in metric tons.

The Bioenergetics Approach

- Advantages:
  - Representation of three energy pools (soft tissue, shell, reproduction).
  - Population dynamics.
- Disadvantages:
  - Highly parameterized.
  - Requires population-specific info (mortality, recruitment).
  - The conversion between energy and mass is clumsy (and unnecessary).

The Next Steps

- Oysters were “downplayed” in the development of the 2010 TMDL.
- We know we want to investigate oyster refuges and aquaculture operations in the 2017 reassessment.
- So……
  - Is this approach desirable for the 2017 reassessment?

The Next Steps

- Explore application to Chesapeake Bay.
- Compare with previous model.
- Improve parameterization. Apply to additional data sets, locations.
- Couple to ICM diagenesis model and resuspension algorithms.
- Investigate potential for use in aquaculture applications.