Linking NPZD Models to ECOPATH/ECOSIM

Dr. Ali Ertürk
Istanbul Technical University

Numerical Solution of Transport-Reaction Equation

Numerical Solutions

- The model domain is discretized into finite number of homogenous regions (spatial discretization).
- Time is discretized into finite number of intervals (temporal discretization).
- Application of mass balance for each homogenous region during each time interval converts the transport equation into a finite number of algebraic equations.

Temporal Discretization

- Explicit methods

  The solution for the **future** time interval is obtained by using the values from the **current** time interval.

- Implicit methods

  The solution for the **future** time interval is obtained by using the values from the **future** time interval.

- Semi implicit methods

  The solution for the **future** time interval is obtained by using the values from the **current and the future** time interval.

Temporal Discretization

$$\frac{d}{dt}C = -k \cdot C$$ → **First order decay equation**

Explicit Solution

$$\frac{C_{t+\Delta t} - C_t}{\Delta t} = -k \cdot C_t$$

$$C_{t+\Delta t} - C_t = -k \cdot C_t \cdot \Delta t$$

$$C_{t+\Delta t} = C_t - \left(k \cdot C_t \cdot \Delta t\right)$$

Temporal Discretization

$$\frac{d}{dt}C = -k \cdot C \longrightarrow$$

First order decay equation

Implicit Solution

$$\frac{C_{t+\Delta t} - C_t}{\Delta t} = -k \cdot C_{t+\Delta t}$$

$$C_{t+\Delta t} - C_t = -k \cdot C_{t+\Delta t} \cdot \Delta t$$

$$C_{t+\Delta t} + k \cdot C_{t+\Delta t} \cdot \Delta t = C_t$$

$$C_{t+\Delta t} \cdot (1 + k \cdot \Delta t) = C_t$$

$$C_{t+\Delta t} = \frac{C_t}{1 + k \cdot \Delta t}$$

Temporal Discretization

$$\frac{d}{dt}C = -k \cdot C$$ → **First order decay equation**

Semi-Implicit Solution

$$\frac{C_{t+\Delta t} - C_t}{\Delta t} = -k \cdot \left(\frac{C_{t+\Delta t} + C_t}{2} \right)$$

$$C_{t+\Delta t} - C_t = -k \cdot \left(\frac{C_{t+\Delta t} + C_t}{2} \right) \cdot \Delta t$$

$$C_{t+\Delta t} = C_t - k \cdot \frac{C_{t+\Delta t}}{2} \cdot \Delta t - k \cdot \frac{C_t}{2} \cdot \Delta t$$

$$C_{t+\Delta t} + k \cdot \frac{C_{t+\Delta t}}{2} \cdot \Delta t = C_t - k \cdot \frac{C_t}{2} \cdot \Delta t$$

$$C_{t+\Delta t} \cdot \left(1 + \frac{k \cdot \Delta t}{2} \right) = C_t \cdot \left(1 - \frac{k \cdot \Delta t}{2} \right)$$

$$C_{t+\Delta t} = C_t \cdot \frac{1 - \frac{k \cdot \Delta t}{2}}{1 + \frac{k \cdot \Delta t}{2}}$$

Explicit solution-One box model

$$V \cdot \frac{d}{dt} C = Q \cdot C^0 - Q \cdot C - k \cdot V \cdot C$$

$$\frac{d}{dt} C = \boxed{\frac{Q}{V} \cdot \left(C^0 - C\right) - k \cdot C}$$

Explicit solution

$$\frac{C_{t+\Delta t} - C_t}{\Delta t} = \frac{Q}{V} \cdot \left(C^0 - C_t\right) - k \cdot C_t$$

$$C_{t+\Delta t} - C_t = \left(\frac{Q}{V} \cdot \left(C^0 - C_t\right) - k \cdot C_t\right) \cdot \Delta t$$

$$C_{t+\Delta t} = C_t + \boxed{\left(\frac{Q}{V} \cdot \left(C^0 - C_t\right) - k \cdot C_t\right) \cdot \Delta t}$$

Explicit solution-One box model

A closer look

$$\underbrace{C_{t+\Delta t}}_{\text{Value at next time point}} = \underbrace{C_t}_{\text{Value of state variable at present time point}} + \underbrace{\left(\frac{Q}{V}\cdot\left(\overbrace{C^0}^{\text{Boundary concentration}} - C_t\right) - k \cdot C_t\right)}_{\text{Derivative (Right side of mass balance equation)}} \cdot \underbrace{\Delta t}_{\text{Time step}}$$

Boundary concentration

Value at next time point

Value of state variable at present time point

Derivative (Right side of mass balance equation)

Time step

Explicit solution-One box model

A closer look to the derivative

Derivative function of transport

Derivative function of kinetics

$$\frac{Q}{V}\cdot\left(C^{0}-C_{t}\right)-k\cdot C_{t}$$

Kinetic coefficient

Derivative function (Right side of the mass balance equation)

Explicit solution-One box model

Generalization of single box model if more than one state variables present

$$C^{1}_{t+\Delta t} = C^{1}_{t} + \left(f_{Transport}\left(C^{0,1}, C^{1}_{t}\right) + f_{Kinetics}\left(k_1, k_2, \ldots, k_m, C^{1}_{t}, C^{2}_{t}, \ldots, C^{ns}_{t}\right)\right) \cdot \Delta t$$

$$C^{2}_{t+\Delta t} = C^{2}_{t} + \left(f_{Transport}\left(C^{0,2}, C^{2}_{t}\right) + f_{Kinetics}\left(k_1, k_2, \ldots, k_m, C^{1}_{t}, C^{2}_{t}, \ldots, C^{ns}_{t}\right)\right) \cdot \Delta t$$

$$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$$

$$C^{ns}_{t+\Delta t} = C^{ns}_{t} + \left(f_{Transport}\left(C^{0,ns}, C^{ns}_{t}\right) + f_{Kinetics}\left(k_1, k_2, \ldots, k_m, C^{1}_{t}, C^{2}_{t}, \ldots, C^{ns}_{t}\right)\right) \cdot \Delta t$$

Derivative function for transport

Derivative function for kinetics

Value of time step at next time point

Value of state variable at present time point

Derivative (Right side of mass balance equation)

Time step

A closer look to kinetics derivative function

$$\left(\frac{\partial C}{\partial t}\right)_{Kinetics} = f_{Kinetics}\left(\underbrace{k_1, k_2, \ldots, k_m}_{\text{Kinetic coefficients}}, \underbrace{C_t^1, C_t^2, \ldots, C_t^{ns}}_{\text{State variables}}\right)$$

$$\begin{matrix} k_1 \\ k_2 \\ \vdots \\ k_m \end{matrix} = \begin{matrix} f_1\left(T, S, pH, C_t^1, C_t^2, \ldots, C_t^{ns}, \text{other environmental conditions}_1\right) \\ f_2\left(T, S, pH, C_t^1, C_t^2, \ldots, C_t^{ns}, \text{other environmental conditions}_2\right) \\ \vdots \\ f_m\left(T, S, pH, C_t^1, C_t^2, \ldots, C_t^{ns}, \text{other environmental conditions}_m\right) \end{matrix}$$

- Kinetic derivative function couples the state variables to eachother.

A closer look to kinetics derivative function

$$\left(\frac{\partial[NO_3-N]}{\partial t}\right)_{Kinetics} = R_{NITRIFICATION} - R_{DENITRIFICATION} - R_{NO3\_UPTAKE,PHY\_D} - R_{NO3\_UPTAKE,PHY\_C} - R_{NO3\_UPTAKE,PHY\_G}$$

State variable of interest

Kinetic coefficient

Dependence on other state variables

$$R_{NITRIFICATION} = k_{NITR} \cdot [NH_4 - N]$$

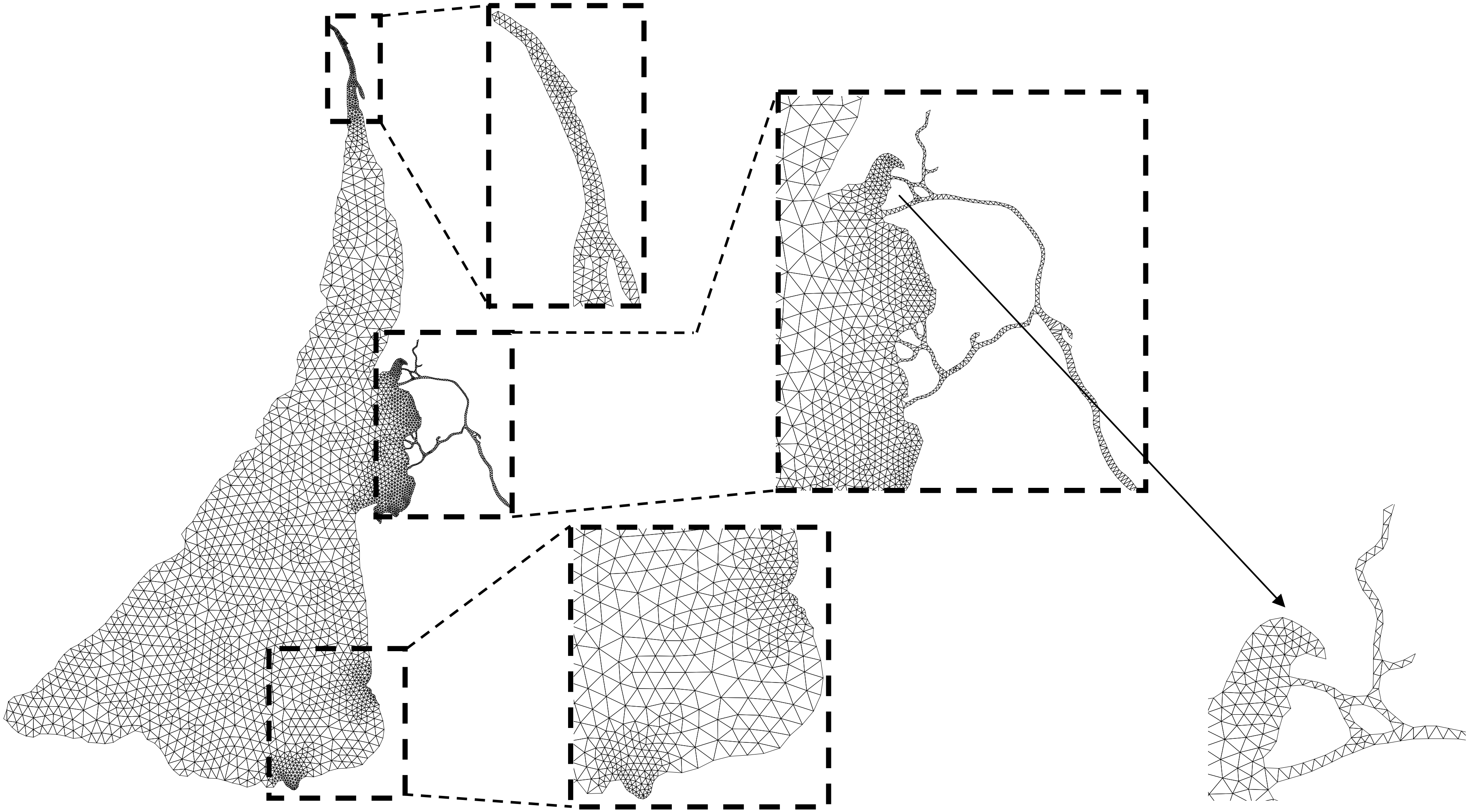
$$k_{NITR} = k_{NITR,20} \cdot \theta_{NITR} \cdot^{T-20} \cdot corr_{NITR,pH} \cdot \left(\frac{[O_2]}{[O_2] + KH_{NITR,O_2}}\right)$$

Kinetic coefficient

- Kinetic derivative function(s) could be complex and non-linear.

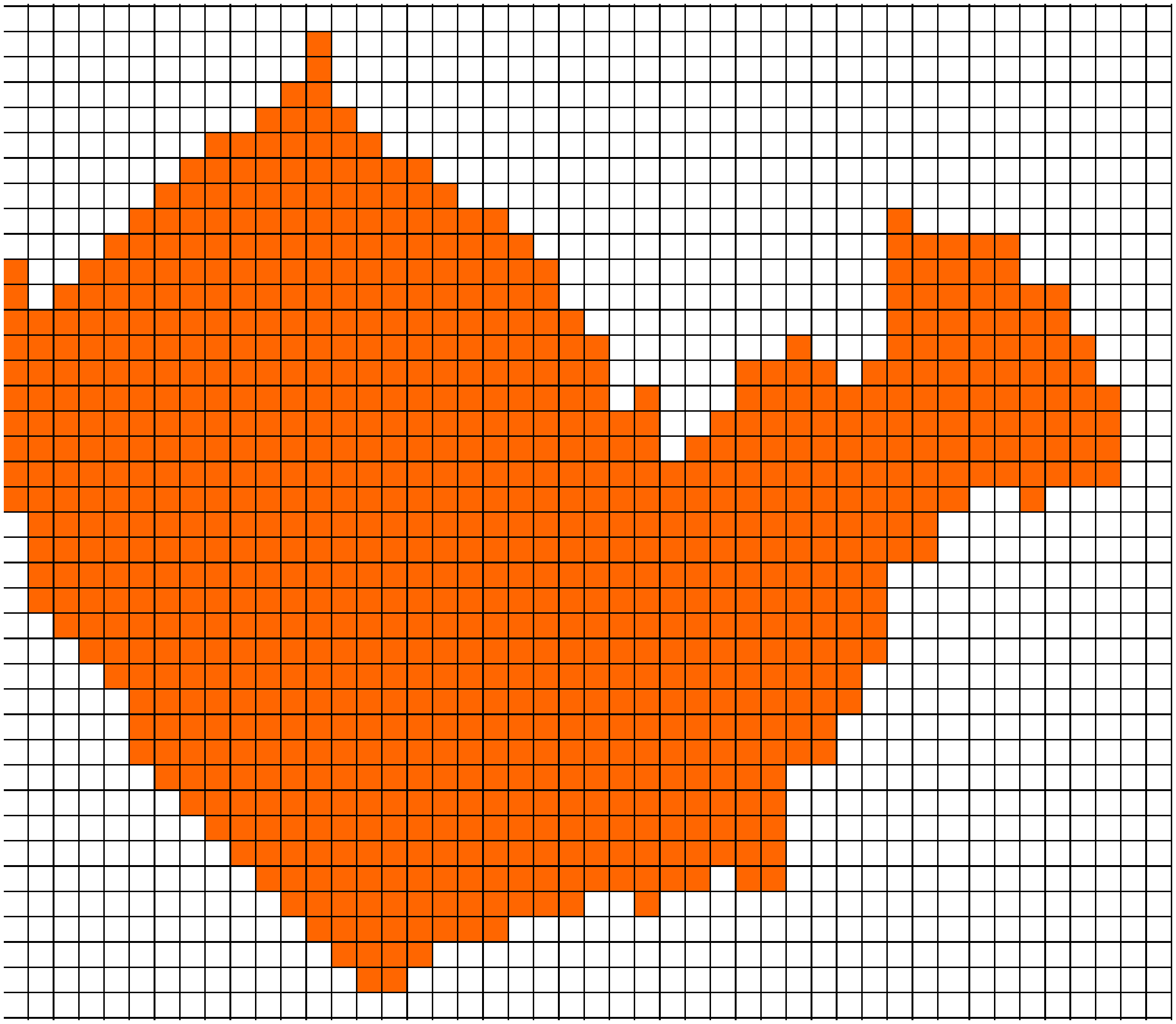
Spatial Discretization

- Finite elements



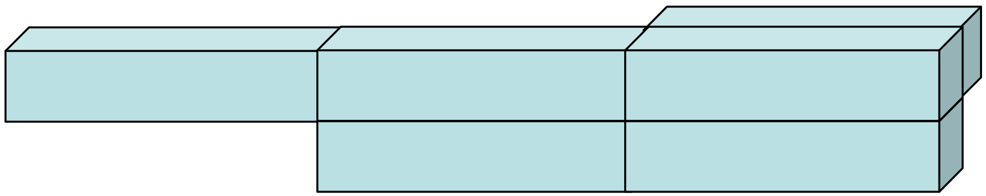
Spatial Discretization

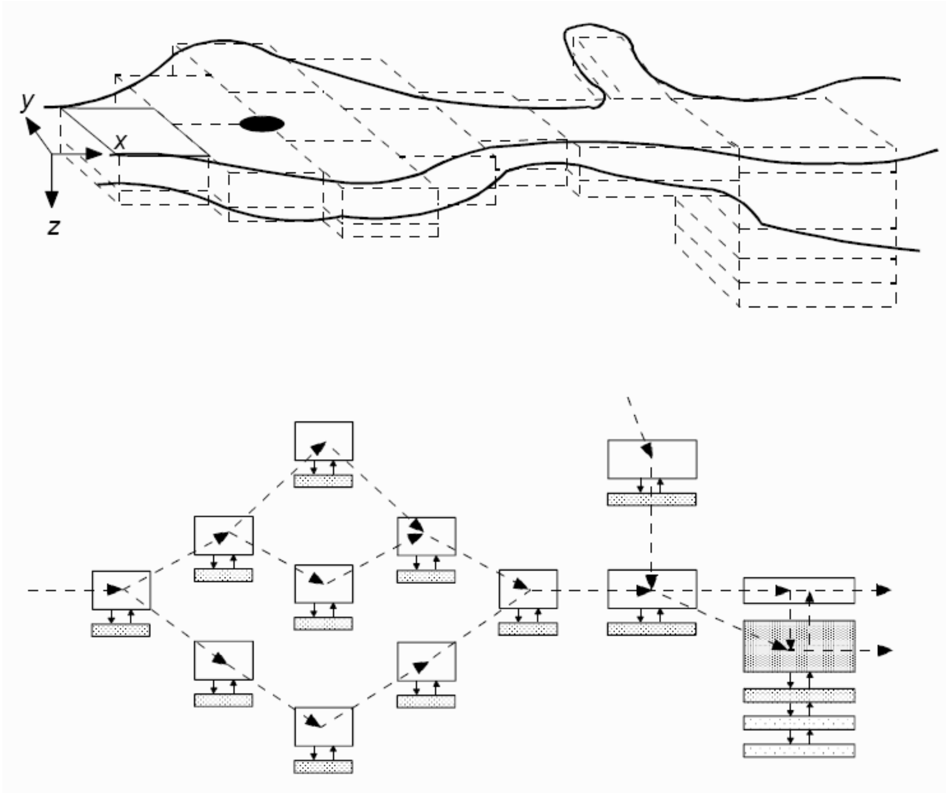
- Finite differences



Spatial Discretization

- Box model (integrated finite differences)





Modelling many boxes with many state variables

$$\frac{d}{dt}C_1^1 = \sum_{j=1}^{n_{1,\text{adv,inflows}}} \frac{Q_{j,1}}{V_1}\cdot C_j^1 - \sum_{j=1}^{n_{1,\text{adv,otflows}}} \frac{Q_{1,j}}{V_1}\cdot C_j^1 + \sum_{j=1}^{n_{1,\text{disp}}} \frac{A_{1,j}\cdot D_{1,j}}{\ell_j \cdot V_1}\cdot\left(C_j^1 - C_1^1\right) + \sum_{m=1}^{n_{1,\text{source and sinks},1}} S_{1,m}^1 + \sum_{k=1}^{n_{1,\text{kinetics}}} R_{1,k}^1$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\frac{d}{dt}C_i^1 = \sum_{j=1}^{n_{i,\text{adv,inflows}}} \frac{Q_{j,i}}{V_i}\cdot C_j^1 - \sum_{j=1}^{n_{i,\text{adv,otflows}}} \frac{Q_{i,j}}{V_i}\cdot C_j^1 + \sum_{j=1}^{n_{i,\text{disp}}} \frac{A_{i,j}\cdot D_{i,j}}{\ell_j \cdot V_i}\cdot\left(C_j^1 - C_i^1\right) + \sum_{m=1}^{n_{i,\text{source and sinks},2}} S_{i,m}^1 + \sum_{k=1}^{n_{i,\text{kinetics}}} R_{i,k}^1$$

$$\frac{d}{dt}C_i^2 = \sum_{j=1}^{n_{i,\text{adv,inflows}}} \frac{Q_{j,i}}{V_i}\cdot C_j^2 - \sum_{j=1}^{n_{i,\text{adv,otflows}}} \frac{Q_{i,j}}{V_i}\cdot C_j^2 + \sum_{j=1}^{n_{i,\text{disp}}} \frac{A_{i,j}\cdot D_{i,j}}{\ell_j \cdot V_i}\cdot\left(C_j^2 - C_i^2\right) + \sum_{m=1}^{n_{i,\text{source and sinks},2}} S_{i,m}^2 + \sum_{k=1}^{n_{i,\text{kinetics}}} R_{i,k}^2$$

$$\vdots \qquad \vdots \qquad \vdots$$

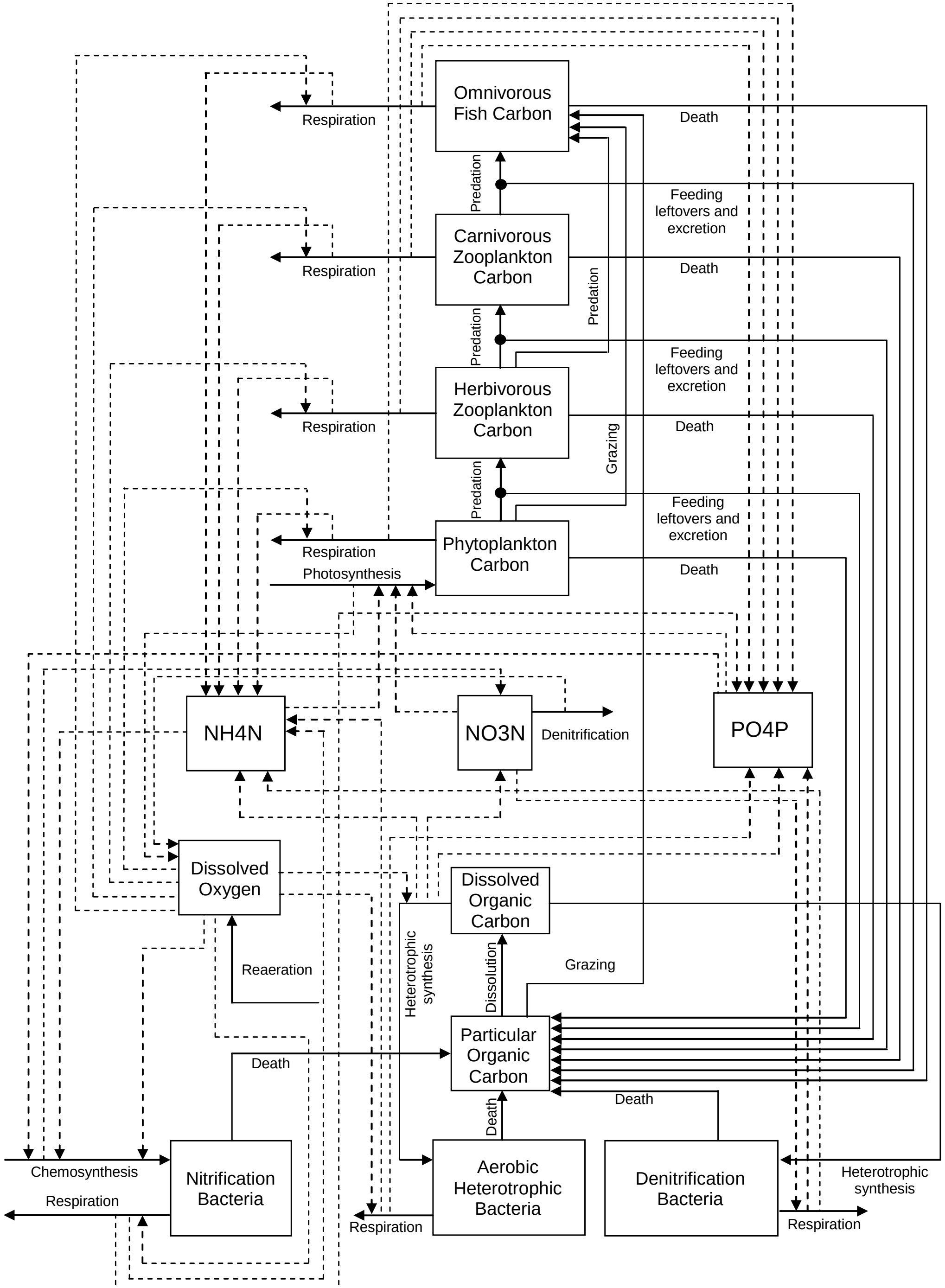
$$\frac{d}{dt}C_i^{ns} = \sum_{j=1}^{n_{i,\text{adv,inflows}}} \frac{Q_{j,i}}{V_i}\cdot C_j^{ns} - \sum_{j=1}^{n_{i,\text{adv,otflows}}} \frac{Q_{i,j}}{V_i}\cdot C_j^{ns} + \sum_{j=1}^{n_{i,\text{disp}}} \frac{A_{i,j}\cdot D_{i,j}}{\ell_j \cdot V_i}\cdot\left(C_j^{ns} - C_i^{ns}\right) + \sum_{m=1}^{n_{i,\text{source and sinks},ns}} S_{i,m}^{ns} + \sum_{k=1}^{n_{i,\text{kinetics}}} R_{i,k}^{ns}$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\frac{d}{dt}C_{nb}^{ns} = \underbrace{\sum_{j=1}^{n_{nb,\text{adv,inflows}}} \frac{Q_{nb,i}}{V_{nb}}\cdot C_j^{ns} - \sum_{j=1}^{n_{nb,\text{adv,otflows}}} \frac{Q_{nb,j}}{V_{nb}}\cdot C_j^{ns} + \sum_{j=1}^{n_{nb,\text{disp}}} \frac{A_{nb,j}\cdot D_{nb,j}}{\ell_j \cdot V_{nb}}\cdot\left(C_j^{ns} - C_{nb}^{ns}\right) + \sum_{m=1}^{n_{nb,\text{source and sinks},ns}} S_{nb,m}^{ns}}_{\text{Derivative function for transport}} + \underbrace{\sum_{k=1}^{n_{nb,\text{kinetics}}} R_{nb,k}^{ns}}_{\text{Derivative function for kinetics}}$$

Derivative function for transport

Derivative function for kinetics



An Ecological Model

Examples of Biogeochemical Cycle Models

- **N models:** Simulate nutrients only with very simplified consideration of primary production (such as Vollenwieder model)
- **N,P models:** Simulate nutrients and phytoplankton only, along with dissolved oxygen and simplified effect of organic carbon (such as QUAL2E).
- **N,P,D models:** Simulate nutrients, phytoplankton and detritus (such as WASP/EUTRO).
- **N,P,Z,D models:** Simulate nutrients, phytoplankton, detritus and zooplankton.

ECOPATH as an ECOLOGICAL MODEL FOR THE HIGHER LEVELS OF FOODWEB

Master Equation of ECOPATH

- Production equation
- Energy equation

Production Equation

- In words

$$\text{Production} = \text{catches} + \text{mortality by predation} + \text{biomass accumulation} + \text{net migration} + \text{other mortality}$$

- In mathematical terms

$$P_i = Y_i + B_i M2_i + E_i + BA_i + P_i(1 - EE_i)$$

i	: index for the relevant group
P_i	: total production rate of group i
Y_i	: total fishery catch rate of group i
$M2_i$	: total predation rate for group i
B_i	: biomass of the group i
E_i	: net migration rate (emigration – immigration)
BA_i	: biomass accumulation rate for group I
EE_i	: Ecotrophic efficiency of group i

Production Equation

- Rearranged

$$B_i \left(\frac{P}{B}\right)_i EE_i - \left(\sum_{j=1}^{n} \left(B_j \left(\frac{Q}{B}\right)_j \right) DC_{j,i} \right) - Y_i - E_i - BA_i = 0$$

P/B_i	: Production/biomass ratio
Q/B_i	: Consumption/biomass ratio
$DC_{j,i}$	: Fraction of prey j in the average diet of predator i (diet composition).
Y_i	: Total fishery catch rate of group i
E_i	: Net migration rate (emigration – immigration)
BA_i	: Biomass accumulation rate for group i
EE_i	: Ecotrophic efficiency of group i

Production Equation for many Ecological Compartments

- Linear system of Equations

$$B_1\left(\frac{P}{B}\right)_1 EE_1 - B_1\left(\frac{Q}{B}\right)_1 DC_{1,1} - B_2\left(\frac{Q}{B}\right)_2 DC_{2,1} - \cdots - B_n\left(\frac{Q}{B}\right)_n DC_{n,1} - Y_1 - E_1 - BA_1 = 0$$

$$B_2\left(\frac{P}{B}\right)_2 EE_2 - B_1\left(\frac{Q}{B}\right)_1 DC_{1,2} - B_2\left(\frac{Q}{B}\right)_2 DC_{2,2} - \cdots - B_n\left(\frac{Q}{B}\right)_n DC_{n,2} - Y_2 - E_2 - BA_2 = 0$$

$$\vdots$$

$$B_n\left(\frac{P}{B}\right)_n EE_n - B_1\left(\frac{Q}{B}\right)_1 DC_{1,n} - B_2\left(\frac{Q}{B}\right)_2 DC_{2,n} - \cdots - B_n\left(\frac{Q}{B}\right)_n DC_{n,n} - Y_n - E_n - BA_n = 0$$

- The consumption Equation

$$\text{Consumption} = \text{production} + \text{respiration} + \text{unassimilated food}$$

Basic Ecopath Input

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption	Unassimil. / consumption	Detritus import (g/m²/year)
1	Greens	1,000	0,770	57,680					
2	Diatoms	1,000	0,890	53,150					
3	Cyanobacteria	1,000	1,550	134,120					
4	Bacteria	1,000	0,110	189,000	247,620			0,200	
5	Grazing zooplankton	1,000	0,300	49,980	237,600			0,200	
6	Carnivorous zooplankt	1,000	0,0800	37,800	237,600			0,200	
7	Planktivorous fish	1,000	0,0140	0,700	10,130			0,200	
8	Deposit feeders gastro	1,000	0,153	8,640	40,500			0,323	
9	Chironomids	1,000	0,224	10,800	59,400			0,200	
10	Oligochets	1,000	0,396	5,110	10,400			0,200	
11	Demersal fish	1,000	1,777	0,700	3,000			0,200	
12	Grey heron	1,000	0,000858	0,300	30,940			0,200	
13	Seagull	1,000	0,0159	0,300	12,380			0,200	
14	Goosander	1,000	0,00181	0,300	45,351			0,200	
15	Great Crested Grebe	1,000	0,00115	0,300	56,876			0,200	
16	Cormorants	1,000	0,0137	0,300	15,840			0,200	
17	Predatory fish	1,000	0,419	0,760	2,710			0,200	
18	Filtrators bivalves	0,240	10,440	0,270	10,000			0,400	
19	Meiobenthos	1,000		18,900	44,420	0,950		0,200	
20	Mysids	1,000	0,0226	8,000	14,500			0,200	
21	POC	1,000	3,690						20,080
22	DOC	1,000	6,940						33,620
23	Detritus	1,000	35,200						0,000

Diet Composition

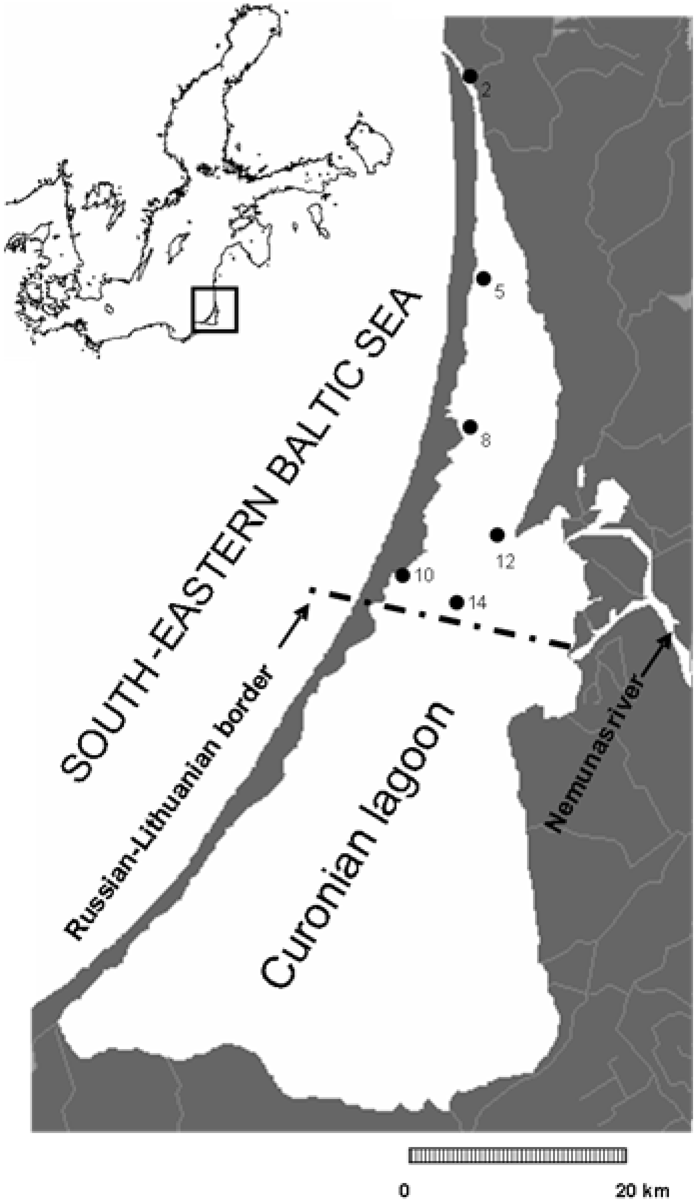
	Prey \ predator	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Greens		0,390	0,100												0,100		0,0500
2	Diatoms		0,0800	0,100		0,100	0,300	0,150								0,110	0,100	0,0550
3	Cyanobacteria															0,190		0,0950
4	Bacteria			0,100												0,150	0,100	0,100
5	Grazing zooplankton			0,600	0,800				0,0140									0,200
6	Carnivorous zooplankton			0,100	0,200				0,00600									
7	Planktivorous fish									0,00500	0,00500	0,00500	0,00500	0,00500				
8	Deposit feeders gastropods								0,150									
9	Chironomids								0,350						0,0136			
10	Oligochets						0,100		0,100									
11	Demersal fish									0,655	0,655	0,655	0,655	0,655	0,500			
12	Grey heron																	
13	Seagull																	
14	Goosander																	
15	Great Crested Grebe																	
16	Cormorants																	
17	Predatory fish									0,140	0,140	0,140	0,140	0,140	0,125			
18	Filtrators bivalves								0,0300									
19	Meiobenthos						0,100	0,200									0,200	0,100
20	Mysids								0,00500						0,0550			
21	POC		0,530													0,450		
22	DOC	1,000																
23	Detritus					0,900	0,500	0,650									0,600	0,400
24	Import	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,345	0,200	0,200	0,200	0,200	0,200	0,306	0,000	0,000	0,000
25	Sum	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Linking a NPZD model with a Trpohic Network Model

- NPZD Models are good for modelling the nutrient cycles, but may get to complicated if the higher trophic levels of the foodweb is considered
- NPZD models are designed for faster components of the aquatic ecosystems.
- Trophic network models such as Ecopath are better suited for simulating the higher trophic levels of foodweb.
- However, they are usually not very well suited for simulating the biogeochemical cycles or details of primary production.

Data Sources

- Lithuanian Marine Research Centre
- Lithuanian Meteorology Centre
- Institute of Botany, Vilnius
- Coastal Research and Planning Institute



Models Used

- **The NPZD Model (ESTAS-ALUKAS)**

  Box modelling tool and model for the lower trophic levels of the Curonian Lagoon.

- **Ecopath (Christensen et al., 2007)**

  Used as a modelling environment for the upper Curonian Lagoon trophic network model (Razinkovas and Zemlys, 2000) that was updated in this study.

Advanced NPZD Model - Transport

$$\frac{\partial C}{\partial t} = -u\frac{\partial C}{\partial x} + D_x\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial y} + D_y\frac{\partial^2 C}{\partial y^2} - w\frac{\partial C}{\partial z} + D_z\frac{\partial^2 C}{\partial z^2}$$

$$+ f_{settling}\left(\upsilon_{settling}, C\right) + f_{sediment}\left(D_{water-sediment}, C, C_{sediment}\right)$$

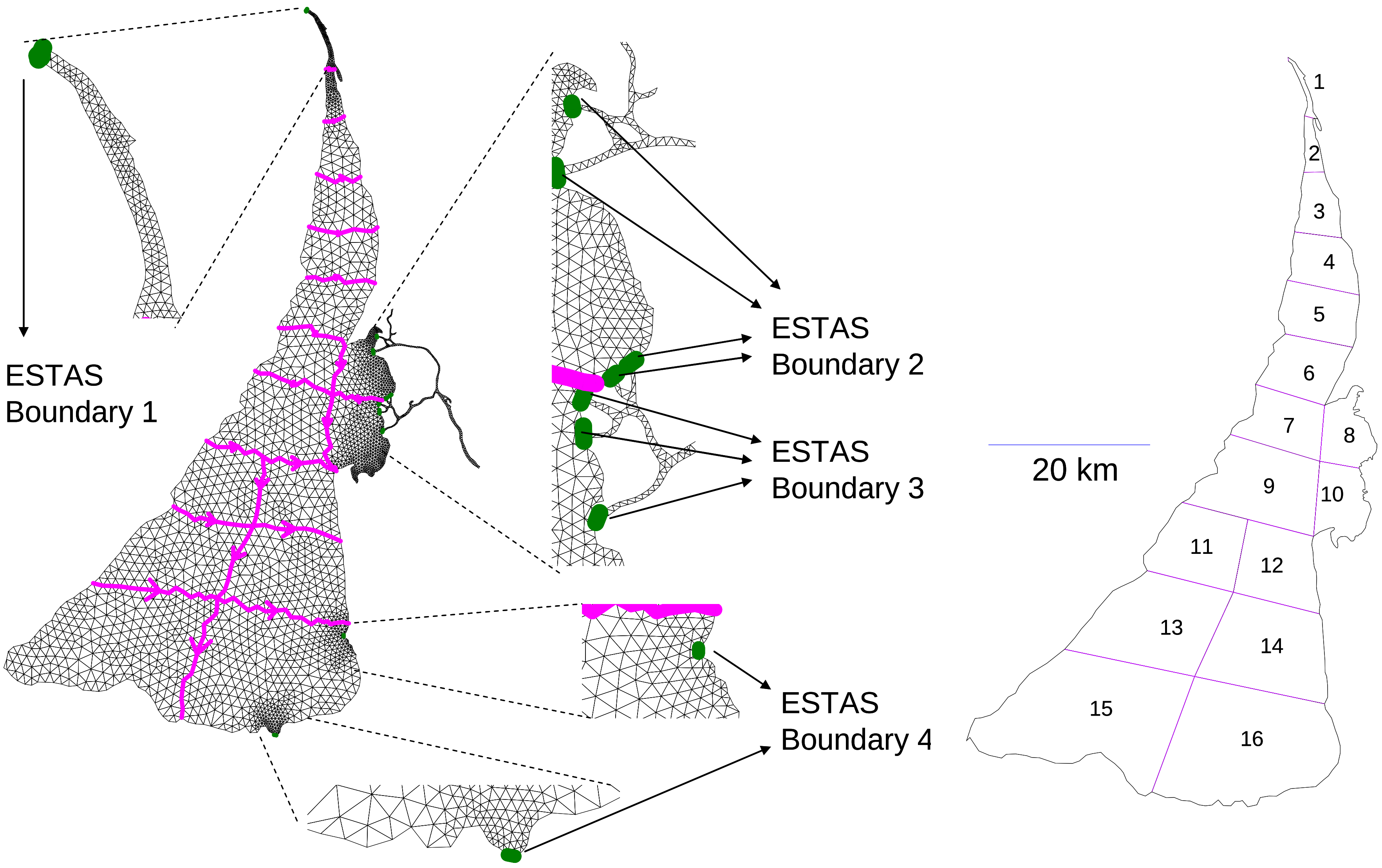
$$+ f_{external}\left(Q_{external}, C_{external}, M_{external}\right) + f_{kinetics}\left(k_1, \ldots, k_n, C\right)$$

$$C \rightarrow \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix}$$

Key variables representing the lower trophic level of the lagoon

Key processes representing the lower trophic level of the lagoon

ESTAS linkage with SHYFEM



ALUKAS
State Variables Summary

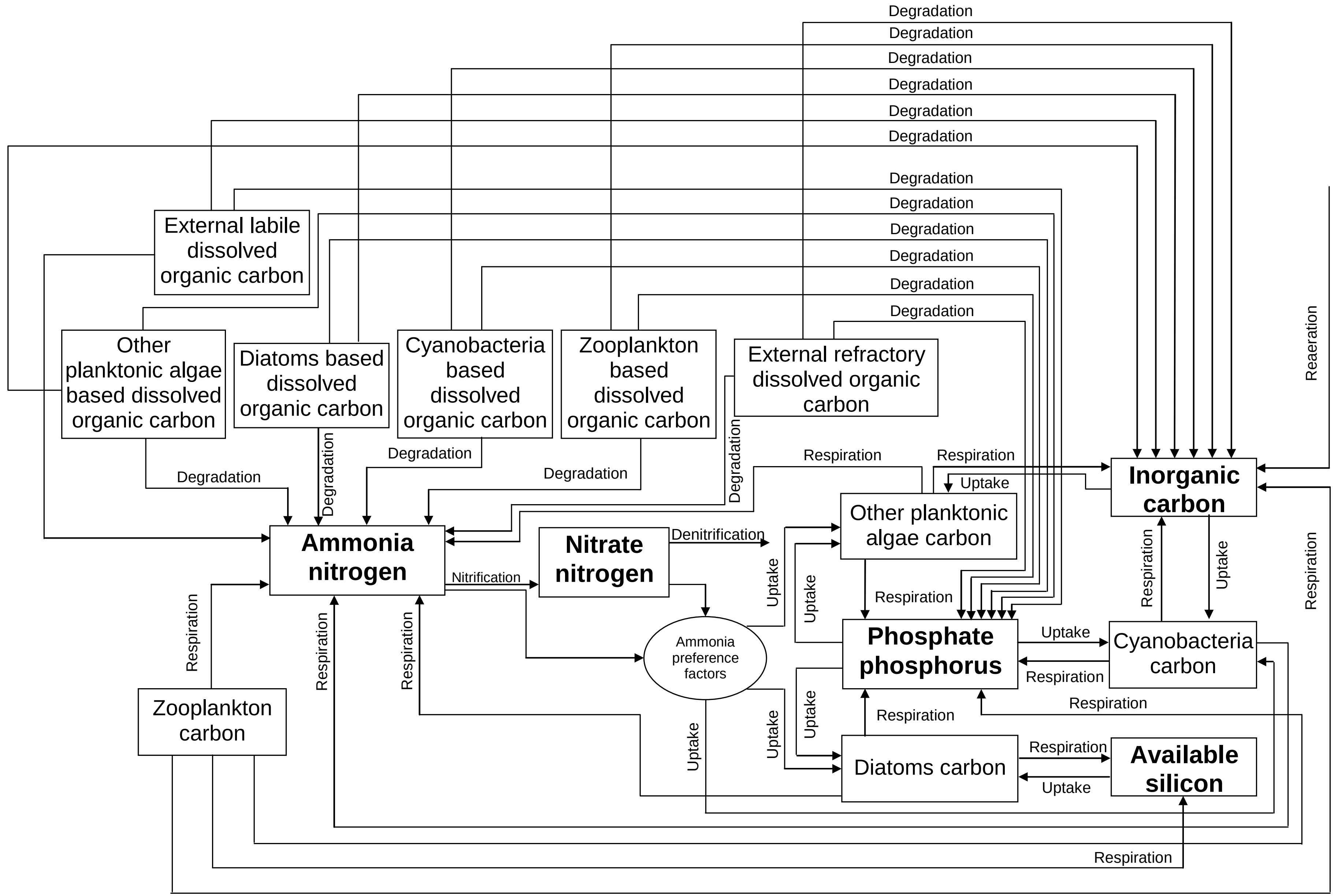
- **Nutrients (N, P, Si)**
- **Dissolved oxygen**
- **Three groups of phytoplankton, Diatoms, Cyanobacteria and Other Planktonic Algae**
- **One group of herbivorous and detrivourus zooplankton**
- **Detailed carbon/detritus cycle**

ALUKAS
State Variables

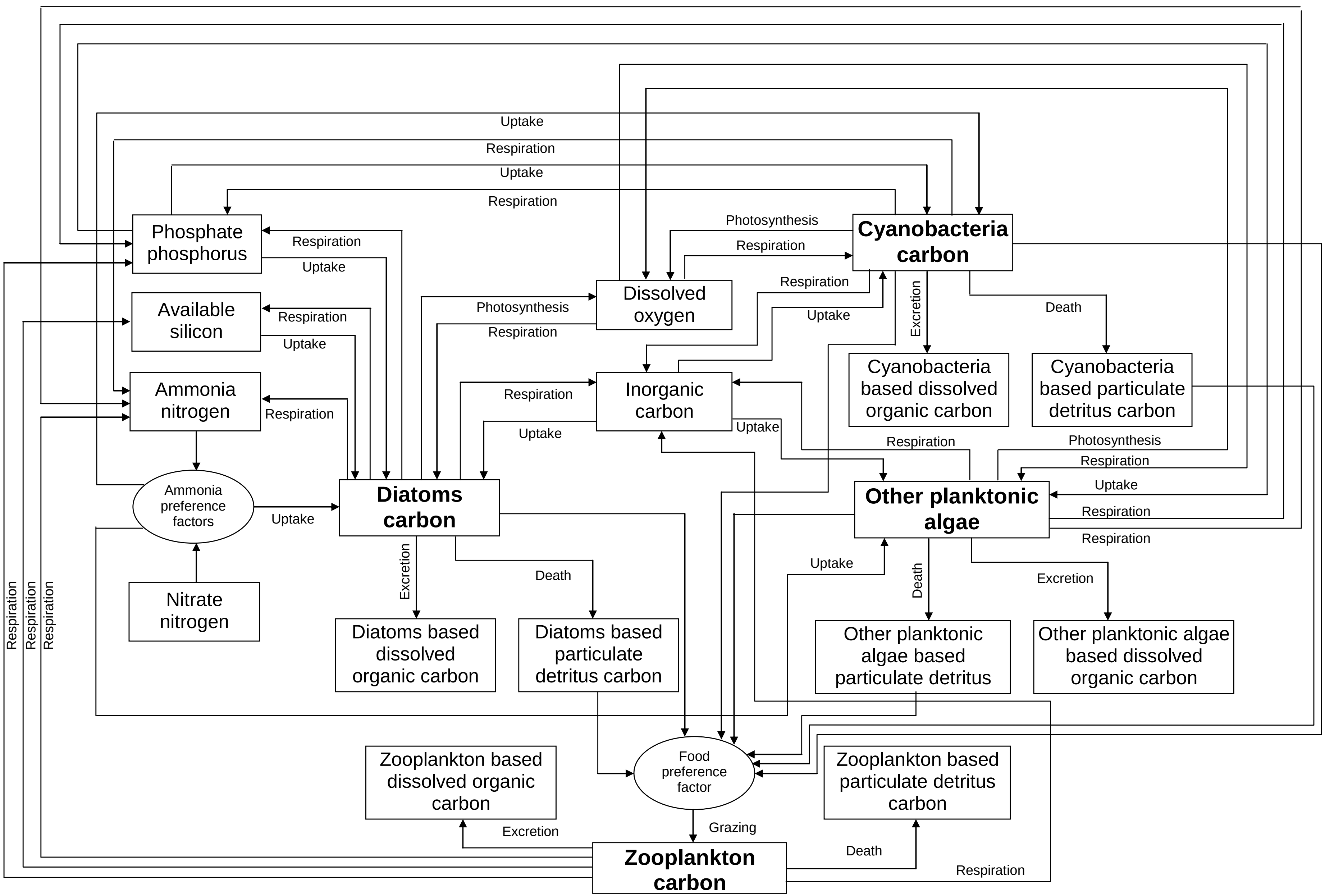
- **NH4-N**
- **NO3-N**
- **PO4-P**
- **Available Si**
- **Inorganic C**
- **Dissolved Oxygen**
- **Greens-C**
- **Diatoms-C**
- **Cyanobacteria-C**
- **Zooplankton-C**

- **External Labile Diss. Org.C**
- **External Labile Par. Det. C**
- **External Refractory Diss. Org. C**
- **External Refractory Par. Det. C**
- **Other planktonic algae based Diss. Org. C**
- **Other planktonic algae based Part. Det. C**
- **Diatoms based Diss. Org. C**
- **Diatoms based Part. Det. C**
- **Cyanobacteria based Diss. Org. C**
- **Cyanobacteria based Part. Det. C**
- **Zooplankton based Diss. Org. C**
- **Zooplankton based Part. Det. C**

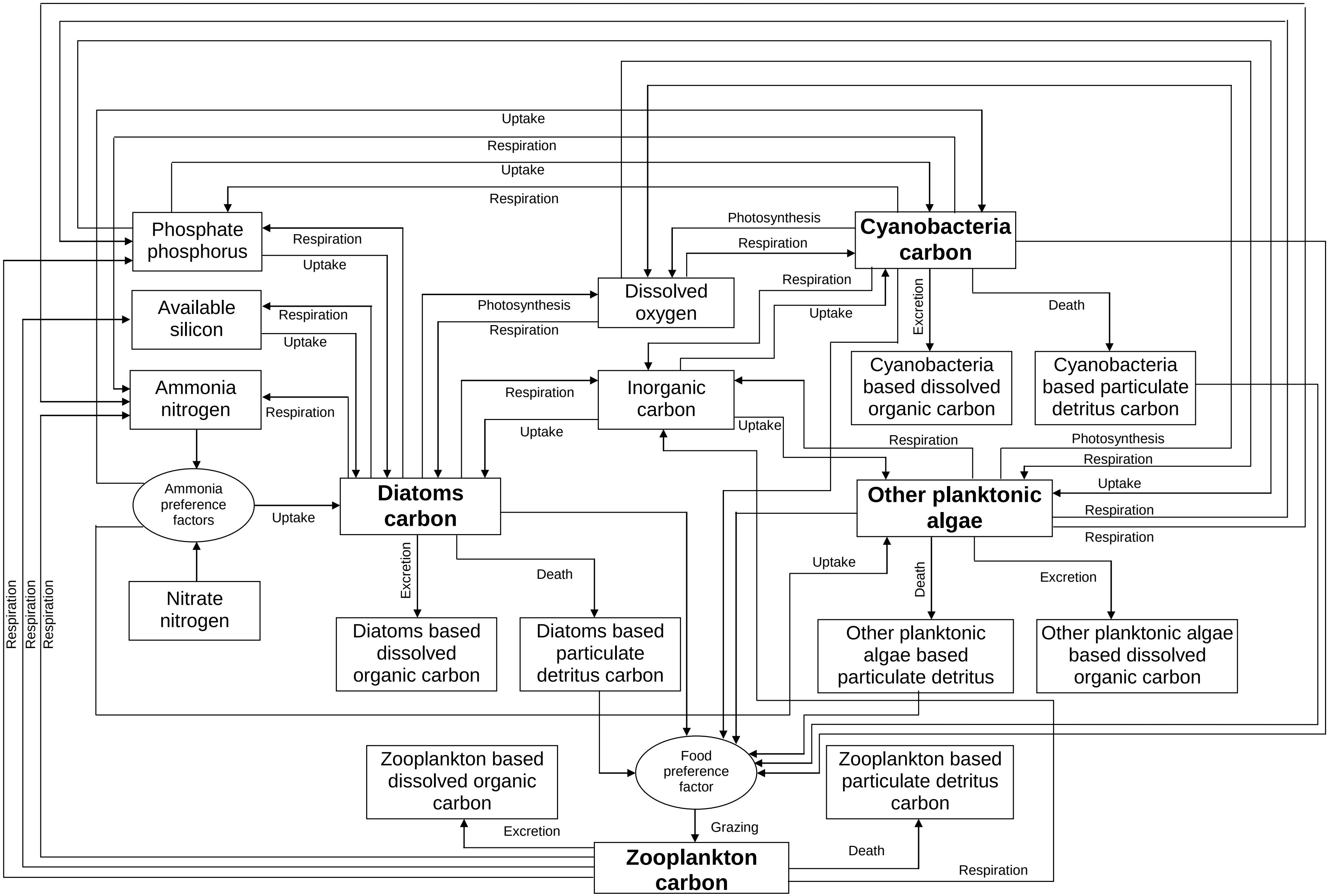
ALUKAS-Nutrient Cycle



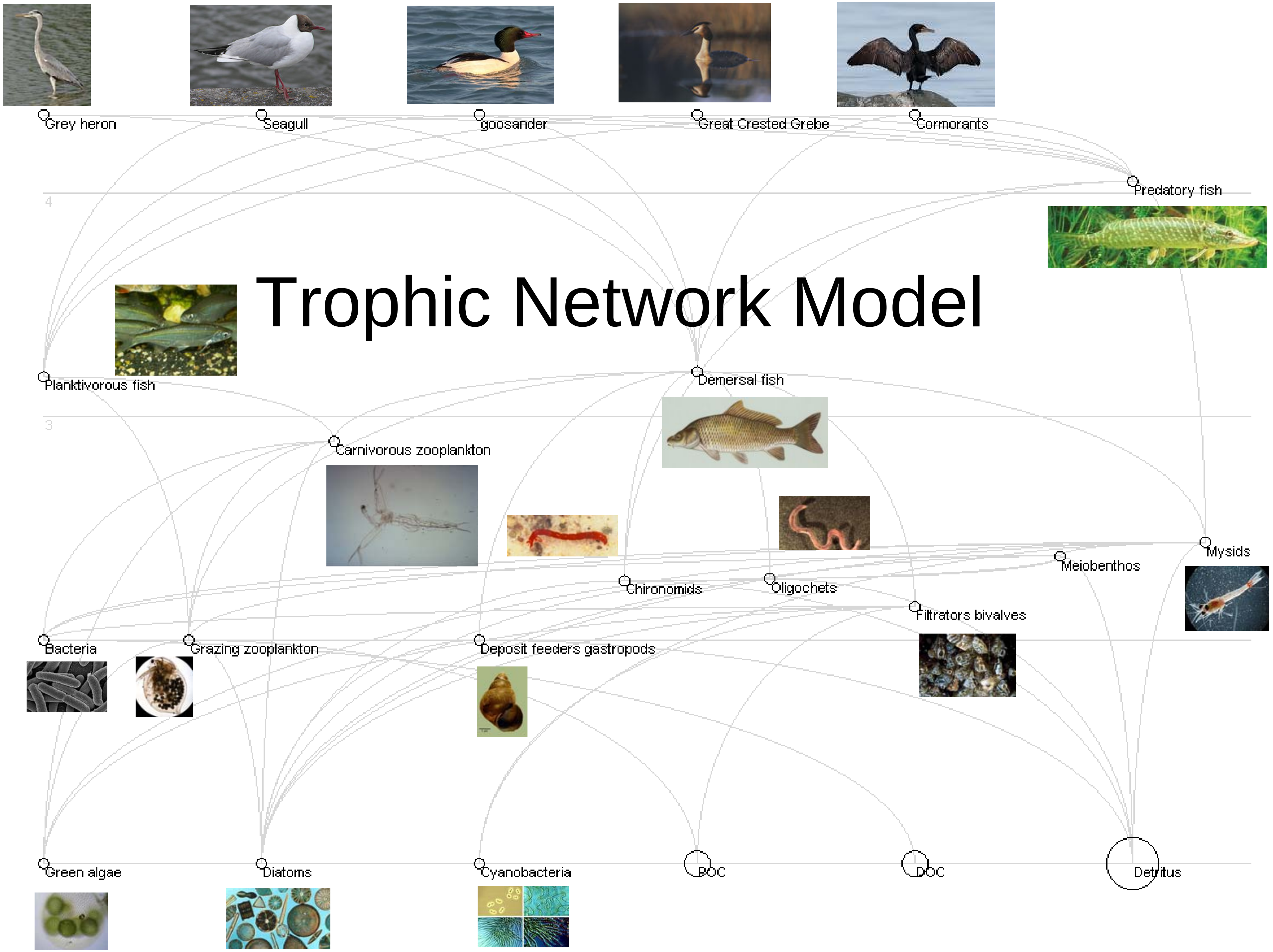
ALUKAS-Plankton Interactions



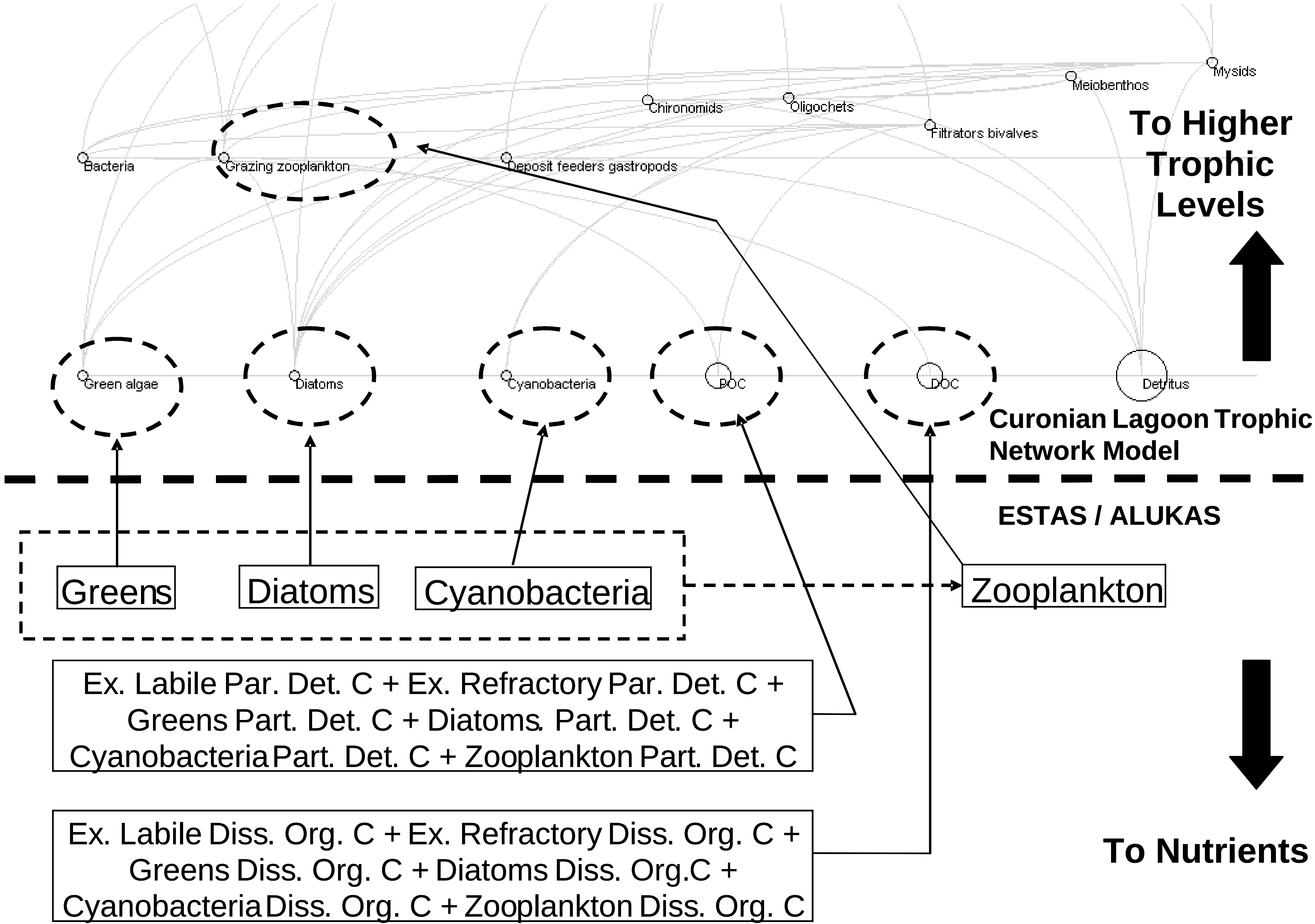
ALUKAS-Detritus Cycle



Trophic Network Model



Linkage of ALUKAS with Trophic Network Model – State Variable Level



Link of ALUKAS with Trophic Network Model – Process Level

What to do with

- Production over biomass?
- Diet Composition?

Production over Biomass

Who does it in NPZD model?

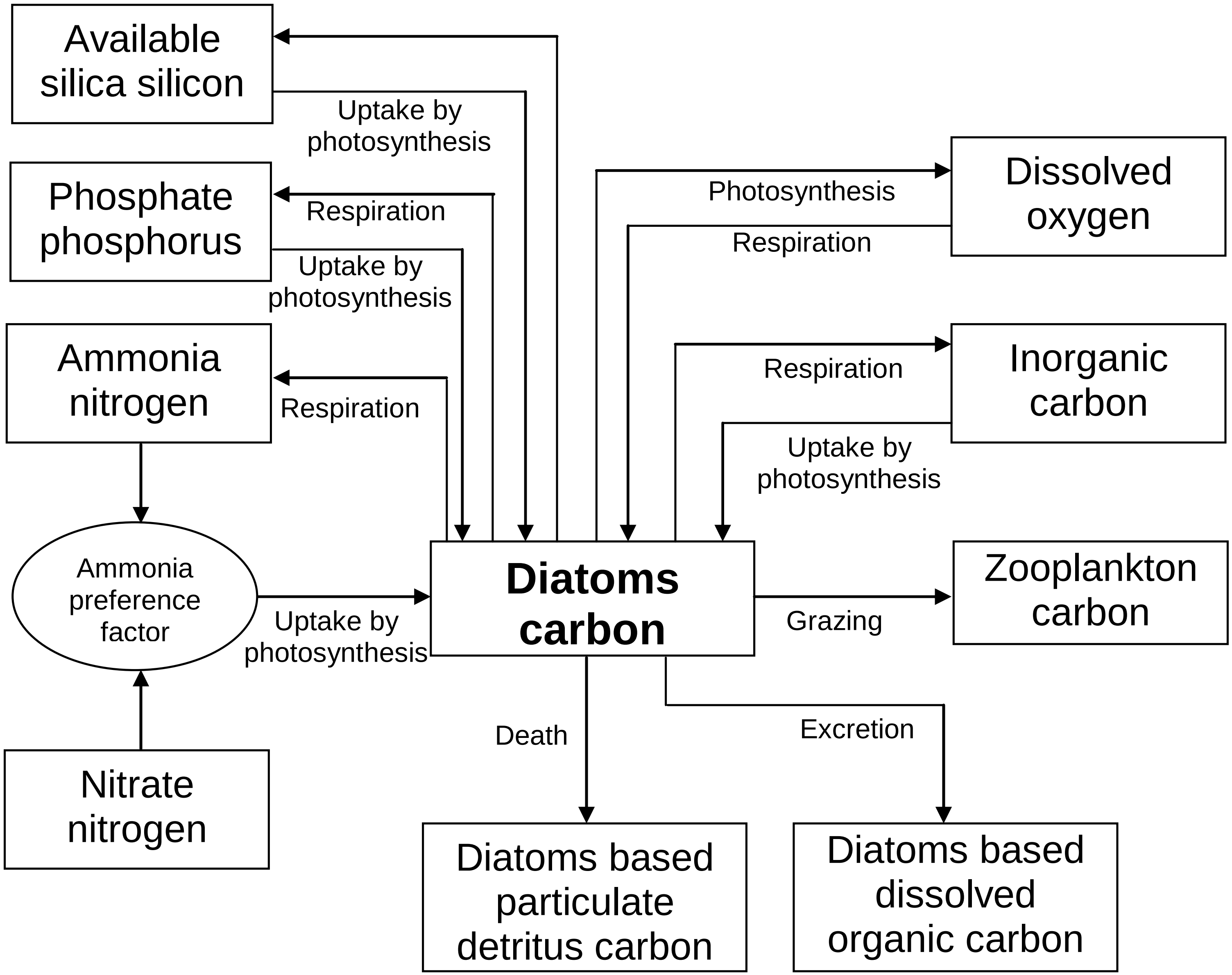
- Phytoplankton (Diatoms, Cyanobacteria, Other planktonic algae)
- Zooplankton

Who does it in Curonian Lagoon Trophic Network model?

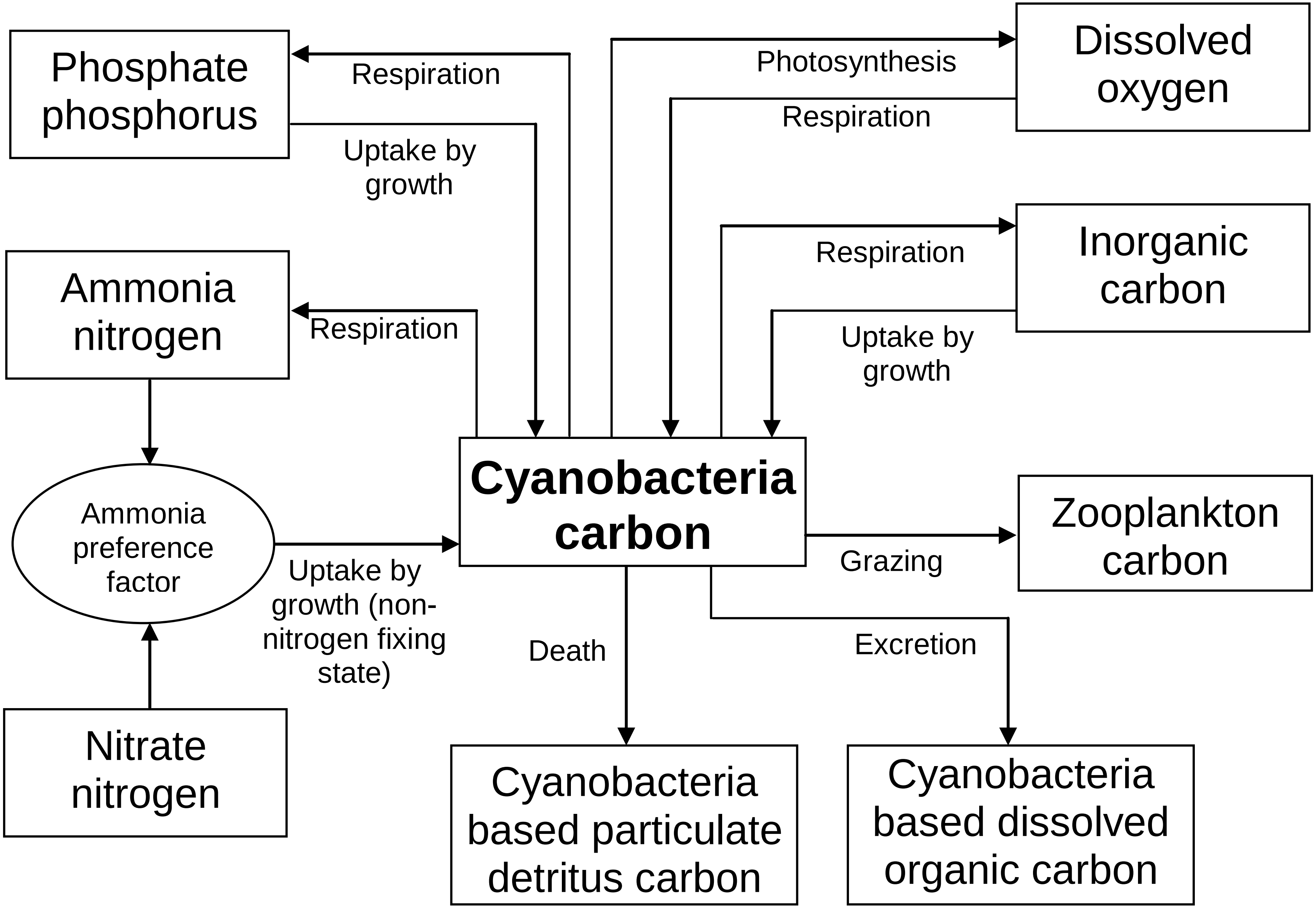
- Phytoplankton (Diatoms, Cyanobacteria, Other planktonic algae) - Get from NPZD model
- Grazing Zooplankton (Get from NPZD model)
- Higher Trophic Levels

(Unfortunately NPZD model will not help)

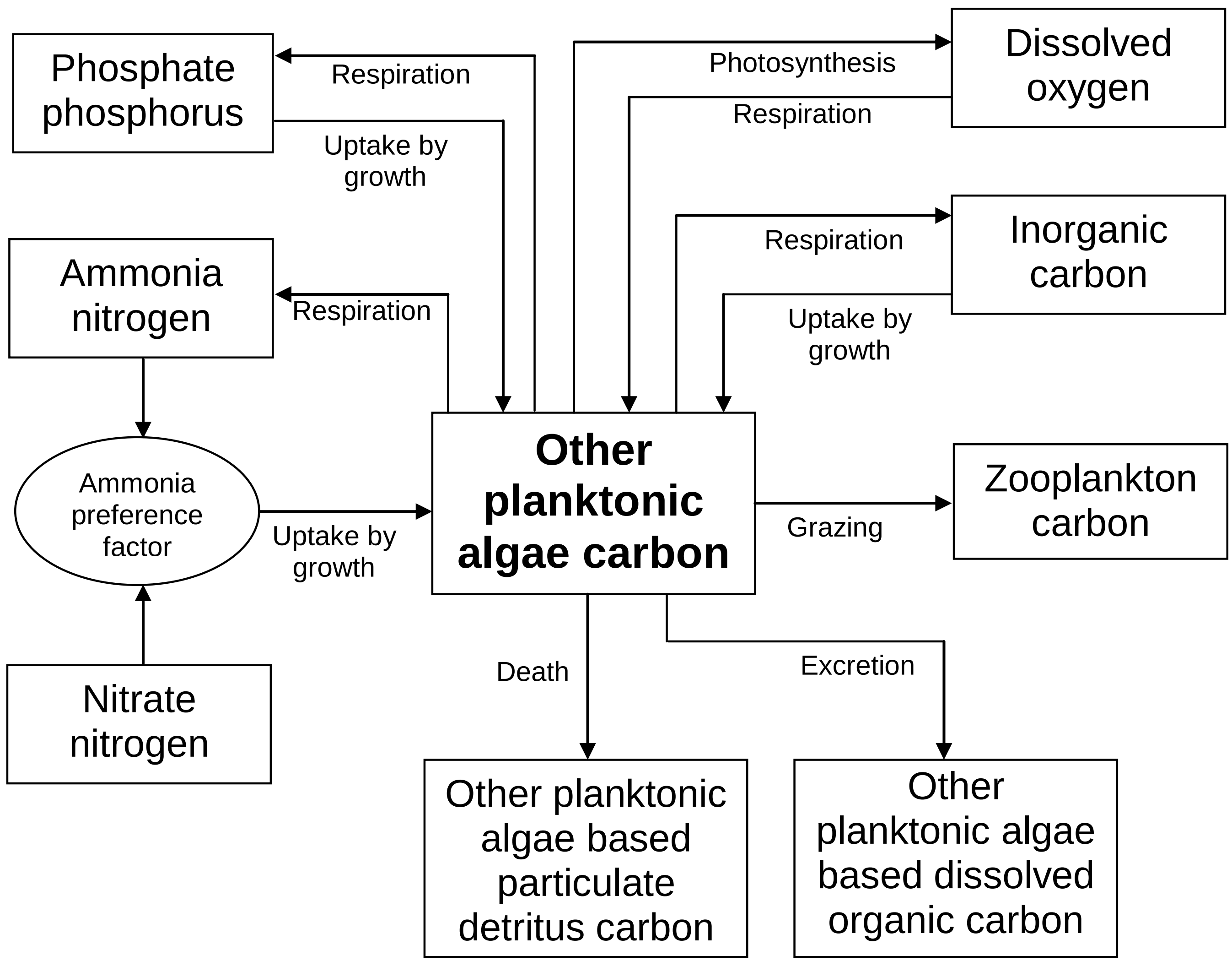
Diatoms in ALUKAS



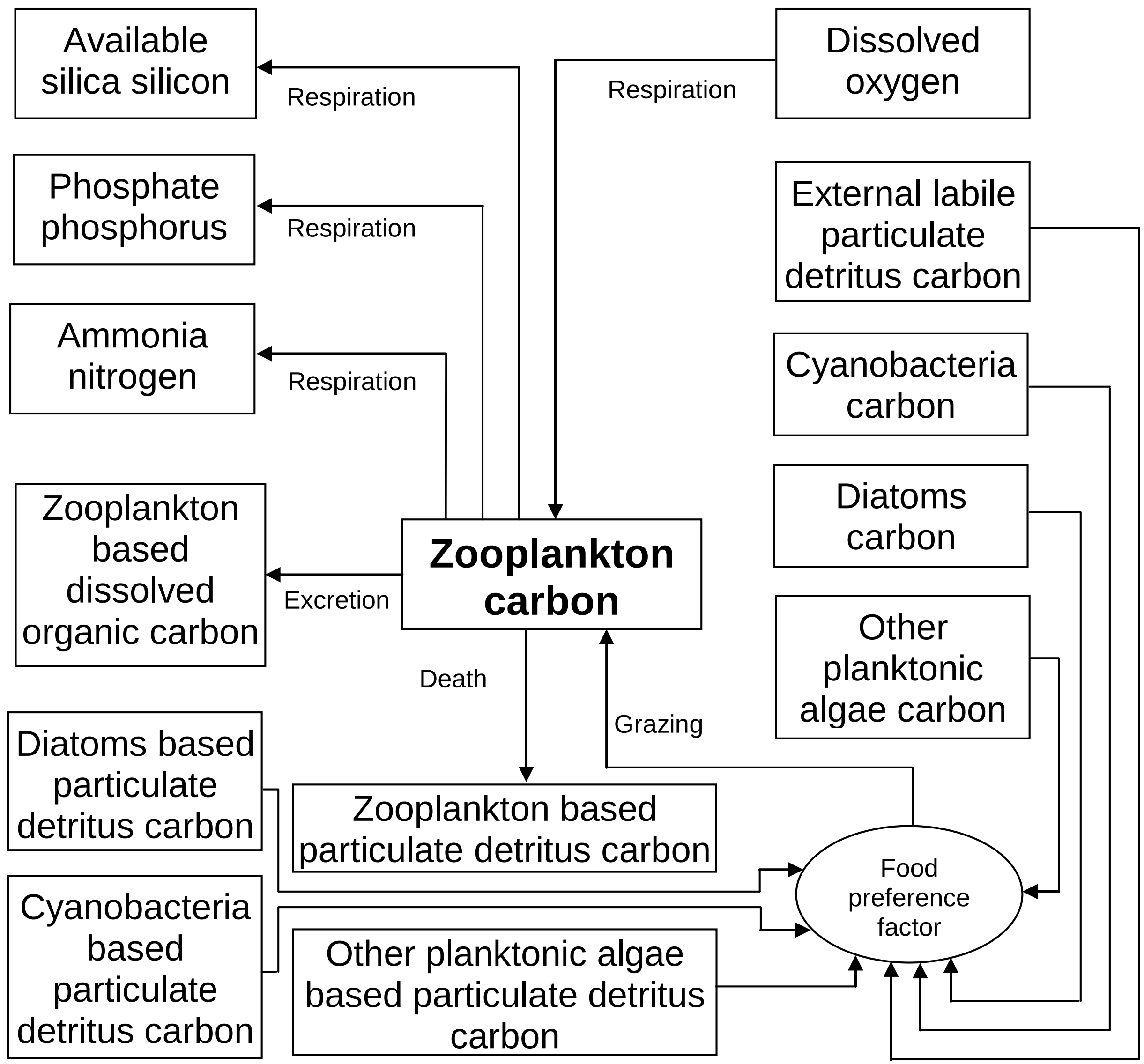
Cyanobacteria in ALUKAS



Other Planktonic Algae in ALUKAS



Zooplankton in ALUKAS



Production over Biomass

$$\frac{\partial[\text{DIA-C}]}{\partial t} = \text{PHYT\_D}_{\text{GPP}} - \text{PHYT\_D}_{\text{RESP}} - \text{PHYT\_D}_{\text{EXCR}} - \text{PHYT\_D}_{\text{DEAD}} - \text{ZOOP}_{\text{GRAZ,PHY\_D}}$$

$$\frac{\partial[\text{CYN-C}]}{\partial t} = \text{PHYT\_C}_{\text{GPP}} - \text{PHYT\_C}_{\text{RESP}} - \text{PHYT\_C}_{\text{EXCR}} - \text{PHYT\_C}_{\text{DEAD}} - \text{ZOOP}_{\text{GRAZ,PHY\_C}}$$

$$\frac{\partial[\text{OPA}-\text{C}]}{\partial t} = \text{PHYT\_G}_{\text{GPP}} - \text{PHYT\_G}_{\text{RESP}} - \text{PHYT\_G}_{\text{EXCR}} - \text{PHYT\_G}_{\text{DEAD}} - \text{ZOOP}_{\text{GRAZ,PHY\_G}}$$

$$\frac{\partial[\text{ZOO-C}]}{\partial t} = \text{eff}_{\text{GRAZ,ZOOP}} \cdot \text{ZOOP}_{\text{GRAZ}} - \text{ZOOP}_{\text{RESP}} - \text{ZOOP}_{\text{EXCR}} - \text{ZOOP}_{\text{DEAD}}$$

Diet Composition

Who does it in NPZD model?

- Zooplankton

Who does it in Curonian Lagoon Trophic Network model?

- Grazing Zooplankton (Get from NPZD model)
- Higher Trophic Levels

(Unfortunately NPZD model will not help)

Diet of Zooplankton

$$ZOOP_{GRAZ} = ZOOP_{GRAZ,OPA} + ZOOP_{GRAZ,DIA} + ZOOP_{GRAZ,CYN} + ZOOP_{GRAZ,EX\_LAB\_DET} + ZOOP_{GRAZ,OPA\_DET} + ZOOP_{GRAZ,DIA\_DET} + ZOOP_{GRAZ,CYN\_DET}$$

$$ZOOP_{GRAZ,PHY\_G} = k_{MAX\_GRAZ,ZOOP} \cdot LIM_{TEMP,ZOOP} \cdot FF_{ZOOP,PHY\_G} \cdot [ZOO\text{-}C]$$

$$FF_{ZOOP,PHY\_G} = \frac{pref_{ZOOP,GRAZ,PHY\_G}\left([OPA\text{-}C] - food_{MIN,ZOOP}\right)}{food_{AVAIL,ZOOP} + K_{H,ZOOP,GRAZ}}$$

ECOPATH INPUTS

SPECIAL ECOPATH OUTPUT FOR CURONIAN LAGOON MODEL

ECOPATH REGION = 1
TIME = 364.9000

BASIC INPUT

Group Name	BIOMASS (g/m^2)	P/B (1/year)	DET. IMP. (g/m^2/year)
Green algea	0.77763	57.68125	*********************
Diatoms	0.89151	53.15159	*********************
Cyanobacteria	1.55569	134.12609	*********************
Grazing zooplankton	0.33191	49.97820	*********************
POC	3.69393	************	20.08187
DOC	6.94585	************	33.62536

DIET COMPOSITION

Prey / predator	5 (Grazing Zooplankton)	18 (Filtrators bivalves)
Green algea	0.39395	0.09646
Diatoms	0.08129	0.11058
Cyanobacteria	0.00000	0.19296
POC	0.52476	************************

OTHER PRODUCTION

Group name	Immigration (g/m^2/year)	Emigration (g/m^2/year)
Green algea	0.30938	2.38178
Diatoms	0.86282	7.98224
Cyanobacteria	0.29384	7.48961
Grazing zooplankton	0.04397	1.28896

Basic Input

	Group name	Habitat area (fraction)	Biomass in habitat area (g/m²)	Production / biomass (/year)	Consumption / biomass (/year)	Ecotrophic efficiency	Production / consumption	Unassimil. / consumption	Detritus import (g/m²/year)
1	Greens	1,000	0,770	57,680					
2	Diatoms	1,000	0,890	53,150					
3	Cyanobacteria	1,000	1,550	134,120					
4	Bacteria	1,000	0,110	189,000	247,620			0,200	
5	Grazing zooplankton	1,000	0,300	49,980	237,600			0,200	
6	Carnivorous zooplankt	1,000	0,0800	37,800	237,600			0,200	
7	Planktivorous fish	1,000	0,0140	0,700	10,130			0,200	
8	Deposit feeders gastro	1,000	0,153	8,640	40,500			0,323	
9	Chironomids	1,000	0,224	10,800	59,400			0,200	
10	Oligochets	1,000	0,396	5,110	10,400			0,200	
11	Demersal fish	1,000	1,777	0,700	3,000			0,200	
12	Grey heron	1,000	0,000858	0,300	30,940			0,200	
13	Seagull	1,000	0,0159	0,300	12,380			0,200	
14	Goosander	1,000	0,00181	0,300	45,351			0,200	
15	Great Crested Grebe	1,000	0,00115	0,300	56,876			0,200	
16	Cormorants	1,000	0,0137	0,300	15,840			0,200	
17	Predatory fish	1,000	0,419	0,760	2,710			0,200	
18	Filtrators bivalves	0,240	10,440	0,270	10,000			0,400	
19	Meiobenthos	1,000		18,900	44,420	0,950		0,200	
20	Mysids	1,000	0,0226	8,000	14,500			0,200	
21	POC	1,000	3,690						20,080
22	DOC	1,000	6,940						33,620
23	Detritus	1,000	35,200						0,000

Diet Composition

	Prey \ predator	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Greens		0,390	0,100												0,100		0,0500
2	Diatoms		0,0800	0,100		0,100	0,300	0,150								0,110	0,100	0,0550
3	Cyanobacteria															0,190		0,0950
4	Bacteria			0,100												0,150	0,100	0,100
5	Grazing zooplankton			0,600	0,800				0,0140									0,200
6	Carnivorous zooplankton			0,100	0,200				0,00600									
7	Planktivorous fish									0,00500	0,00500	0,00500	0,00500	0,00500				
8	Deposit feeders gastropods								0,150									
9	Chironomids								0,350						0,0136			
10	Oligochets						0,100		0,100									
11	Demersal fish									0,655	0,655	0,655	0,655	0,655	0,500			
12	Grey heron																	
13	Seagull																	
14	Goosander																	
15	Great Crested Grebe																	
16	Cormorants																	
17	Predatory fish									0,140	0,140	0,140	0,140	0,140	0,125			
18	Filtrators bivalves								0,0300									
19	Meiobenthos						0,100	0,200									0,200	0,100
20	Mysids								0,00500						0,0550			
21	POC		0,530													0,450		
22	DOC	1,000																
23	Detritus					0,900	0,500	0,650									0,600	0,400
24	Import	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,345	0,200	0,200	0,200	0,200	0,200	0,306	0,000	0,000	0,000
25	Sum	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Ecopath Results

Ecopath group	Trophic Level	Ecotrophic Efficiency		Production / consumption	
		1999	2000	1999	2000
Greens	1.00	0.77	0.78	Not defined	Not defined
Diatoms	1.00	0.50	0.34	Not defined	Not defined
Cyanobacteria	1.00	0.03	0.07	Not defined	Not defined
Bacteria	2.00	0.33	0.33	0.76	0.76
Grazing zooplankton	2.00	0.80	0.46	0.21	0.22
Carnivorous zooplankton	2.89	0.65	0.65	0.16	0.16
Planktivorous fish	3.18	0.30	0.30	0.07	0.07
Deposit feeders gastropods	2.00	0.60	0.60	0.21	0.21
Chironomids	2.27	0.78	0.78	0.18	0.18
Oligochets	2.28	0.92	0.92	0.49	0.49
Demersal fish	3.20	0.98	0.98	0.23	0.23
Grey heron	4.35	0.00	0.00	0.01	0.01
Seagull	4.35	0.00	0.00	0.02	0.02
Goosander	4.35	0.00	0.00	0.01	0.01
Great Crested Grebe	4.35	0.00	0.00	0.01	0.01
Cormorants	4.35	0.00	0.00	0.02	0.02
Predatory fish	4.05	0.80	0.80	0.28	0.28
Filtrators bivalves	2.15	0.24	0.24	0.03	0.03
Meiobenthos	2.38	0.95	0.95	0.43	0.43
Mysids	2.44	0.49	0.49	0.55	0.55
POC	1.00	0.55	0.82	Not defined	Not defined
DOC	1.00	0.11	0.13	Not defined	Not defined
Detritus	1.00	0.50	0.38	Not defined	Not defined