# **Generalized size-based plankton model**

The diversity of unicellular plankton is huge. This confusing diversity makes it difficult to construct a meaningful model of the planktonic ecosystem. The most common approach is the functional group type of models, or “NPZ”-type of models. The simplest of these models represent just two functional types, phytoplankton (P) and zooplankton (Z) (e.g. Evans & Parslow 1985). More advanced version represents additional nutrients (e.g. phosphate and silicate), additional phytoplankton groups (e.g. ciliates, flagellates and diatoms) etc. Examples are the Fasham model (Fasham et al. 1990) or the Ergom model. Variants of these models are currently being used for regional model simulations. They do a good job a representing functional diversity and energy flows. They suffer, however, from having too many parameters. This makes them difficult to setup, but it makes it possible to calibrate them to a specific area, where a given set of parameters represent the dominant species in each functional group. This calibration, however, makes them unsuited to be deployed over large spatial scales (e.g. globally), where there will be a large variation in the dominant species in each groups, and thus in the parameter set used.

One alternative to create a plankton model with a simple set of general parameters is to use a size-based model, e.g (Banas 2011, Ward et al. 2012, Ward & Follows 2016). By throwing away most of the functional types (most cases still maintain the distinction between P and Z), they arrive a parsimonious formulation with a small set of parameters.

The aim of this project is to set up the simplest possible size-based model of uni-cellular plankton driven by light and nutrients. The model will be used to explore how the ratio between primary and secondary production changes with cell size. This question is motivated by a size- and trait-based analysis of the California Current system (see figure). This analysis revealed how oligotrophic open-ocean locations had similar size distribution and ratio between primary and secondary productions despite about a factor 5 difference in biomass. Secondarily the model can be used as a basis for further exploration, e.g., addition of a structured zooplankton model.

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| *Figure. Trait-distribution in the California Current, compared between open-ocean sites (“OO”) and upwelling sites (“UP”). Despite a factor 5 difference in biomass (not shown here), the trait-distribution is remarkably similar. The main differences are in the upper uni-cellular size range (20-above 40) where the upwelling sites have large blooms of diatoms. From unpublished work by Kasia Kenitz.* |

## A minimal size-based model

The model is based upon a general cell with biomass (units of nitrogen per volume):

The cell is considered a generalist which can photosynthesize, take up inorganic nutrients, as well as feed on smaller cells by phagotrophy.

Light

Nutrients

Food

*Uptake of resources*

There are fluxes of nitrogen and carbon into the cell, , , and . Each flux is described by a linear functional response (units of nutrients or carbon per time):

where the subscript “res” represents either light (for carbon), nutrients or food from other organisms. is the resource concentration. is the affinity for uptake, which is a function of the cell size. The relations between affinity and cell size are given by Chakraborty et al. (2017), eqns. 4-6; assume trait values of , and for a start.

The amount of food available, , depends on the biomass of smaller cells (nutrients per volume):

Two versions of the size-preference can be explored. First, a simple version where each size-group represents a trophic level. In that case all elements are zero except the sub diagonal: . The second is to assume that each size group is smaller than a trophic level. The preference for size can then be described by a log-normal size preference function:

where is the preferred predator-prey size ratio and is the width of the size selection (this parameter must be adjusted depending on the width of the size classes: thin classes have and increasing for wider classes. is a rough estimate).

For simplicity, we assume a constant respiratory loss independent of cell size, ; see Chakraborty et al. (2017) for a more complex formulation that also accounts for the respiratory costs of uptake.

*Division rate*

Division rate is limited first by the requirement of a fixed C/N ratio , and second by the synthesis capacity of the cell. The first requirement means that the effective flux of nutrients is (units of nutrients):

where the first term account for the flux of carbon and the second for the flux of nutrient. The limitation of synthesis is described by a functional response to give (units of per time):

where the maximum synthesis rate is considered independent of size

*Mortality*

Mortality emerges from a constant background loss, a predation by higher trophic levels and predation losses:

The losses to higher trophic levels is only non-zero for the largest size groups. It can be used to determine the production to higher trophic levels.

*Nutrient dynamics*

Nutrient dynamics is determined with semi-chemostat dynamics as in (Evans & Parslow 1985):

where is the exchange rate between the euphotic and the aphotic zone, and is the nutrient concentration in the aphotic zone. This formulation embodies two simplifications which may need consideration: 1) there is no remineralization of un-assimilated food or dead cells (); 2) it does not consider that cells may down-regulate their nutrient-uptake or excrete unused inorganic nutrients. Nevertheless, it will do for a start.

*Parameters*

We start by considering a range of sizes from about gC to gC (about three trophic levels; see Andersen et al. (2016) for relevant size ranges and a table for conversions between length and mass).

# Simulations experiments:

1. Fixed environment (N0 and light); open ocean (oligotrophic) environment vs. upwelling (eutrophic) environment:

* What are the size distributions in the two environments?
* How does production vary with cell size?
* What is the flux of energy to higher trophic levels
* What is the flux of losses to the aphotic zone
* What is the efficiency of primary production vs. energy to higher trophic levels? And to fraction lost?

1. Seasonally variable environment; same as above.

# Additions/complications:

1. Add a structured copepod population, characterized by size at maturation. Can it outcompete the unicellular organisms of similar size?
2. Add an explicit representation of traits: phagotrophy, chloroplast, synthesis (similar to what Subhendu does).
3. Implement the model in a water column
4. Add resource recycling with detritus and bacteria
5. Add a diatom functional group, or another trait: investment in defense.
6. …

KHA, March 2017

## References

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