COMMENT

Reply to 'In defence of the Cell Quota model of micro-algal growth' by M. R. Droop

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Droop's defence of the Cell Quota model shows that it is statistically superior to the 'Chemical Reaction' (CR) model for modelling of the internal nutrient content of cells at a range of dilution rates in a chemostat. As Droop concludes, saturating functions like a rectangular hyperbola appear to be a more appropriate choice of function for algal growth/nutrient content than power law curves. Droop finishes with an interesting speculation as to the reason why algal growth and surface absorption chemistry might share common functional forms.

Droop (Droop, 2002) points out that equation (3) of Baird *et al.* (Baird *et al.*, 2001) contains the maximum growth rate, μ^{max}, where the Cell Quota model is properly defined with the growth rate at infinite internal nutrient content, μ'. The parameter most often used to describe cell division rates is μ^{max}. The literature contains many estimates of μ^{max}, as well as generalized trends of μ^{max} with cell volume (Tang, 1995). In contrast, μ'_m is determined from chemostat cultures, and is not as commonly reported. It is, therefore, not surprising to see that Sharples and Tett (Sharples and Tett, 1994), when applying the Cell Quota concept in a pelagic ecosystem model, substituted, as I have, μ^{max} for μ'_m. Figure 1 in Baird *et al.* (Baird *et al.*, 2001) is perhaps the most likely method of implementing the Cell Quota concept in a pelagic ecosystem model. By substituting μ^{max} for μ'_m, however, figure 1 in Baird *et al.* (Baird *et al.*, 2001) is no longer Droop's original Cell Quota model, and should not have been referred to as such.

The purpose of the Cell Quota model is to predict cellular nitrogen content at a range of dilution rates, for which it is very successful. The primary application of the Chemical Reaction (CR) model is to predict the algal growth rate based on nutrient uptake and light absorption rates in ecosystem-scale models. The CR model treats the algal cells as a 'black box'. It uses the supply rates of nutrients and light, and the maximum rate at which a cell can divide. The CR model uses a power law relationship to relate algal growth rate with internal nutrient content. Power laws are often used to empirically model reactions where a mechanistic understanding of a chemical process is not sufficient to derive a set of equations (Atkins, 1994). By using a power law relationship, the CR model is attempting to make a minimum of assumptions about the internal workings of the cell. Mechanistic formulations of chemical reactions can be determined statistically from power law exponents (Brauner and Shacham, 1996), which may be the basis for an interesting study.

The CR model approach of considering maximum supply rates of light and nutrients has also been applied to benthic plants (Baird, 2002). Whether this is successful is much harder to gauge than for algal cells, since benthic plant growth rates cannot be easily manipulated by varying dilution rates. Nonetheless, it does allow the growth of benthic plants to be a function of the interacting supply rates and maximum growth rate—a useful feature for an ecosystem scale model.

Pelagic ecosystem models are becoming more spatially resolved, with the capacity to calculate the advection and diffusion of biological tracers. The advective and diffusive

terms for total algal nutrient require spatially resolved estimates of algal nutrient content. It will be worth investigating the advective and diffusive terms of algal nutrient content in pelagic ecosystem models with the Cell Quota concept [such as (Sharples and Tett, 1994)] and then with the CR model.

In summary, the CR model was developed with a different application in mind than the Cell Quota model, and performs worse when the two schemes are used to model internal nutrient content of algal cultures in a diluting medium. However, it is more simply applied to modelling a range of aquatic autotrophs in ecosystem scale models—the original application for which it was developed.

REFERENCES

Atkins, P. W. (1994) *Physical Chemistry*, 5th edn. Oxford University Press.

Baird, M. E., Emsley, S. M. and McGlade, J. M. (2001) Modelling the interacting effects of nutrient uptake, light capture and temperature on phytoplankton growth. *J. Plankton Res.*, **23**, 829–840.

Baird, M. E., Walker, S. J., Wallace, B. B., Webster, I. T. and Parslow, J. S. (2002) The use of mechanistic descriptions of algal growth and zooplankton grazing in an estuarine eutrophication model. *Estuarine Coastal Shelf Sci.*, in press.

Brauner, N. and Shacham, M. (1996) Using power-law rate expression parameters for discriminating among mechanistic models in rate data regression. *Chem. Eng. Commun.*, **155**, 1–18.

Droop, M. R. (2002) In defence of the Cell Quota model of micro-algal growth. *J. Plankton Res.*, **25**, 103–107.

Sharples, J. and Tett, P. (1994) Modelling the effect of physical variability on the midwater chlorophyll maximum. *J. Mar. Res.*, **52**, 219–238.

Tang, E. P. Y. (1995) The allometry of algal growth rates. *J. Plankton Res.*, **17**, 1325–1335.