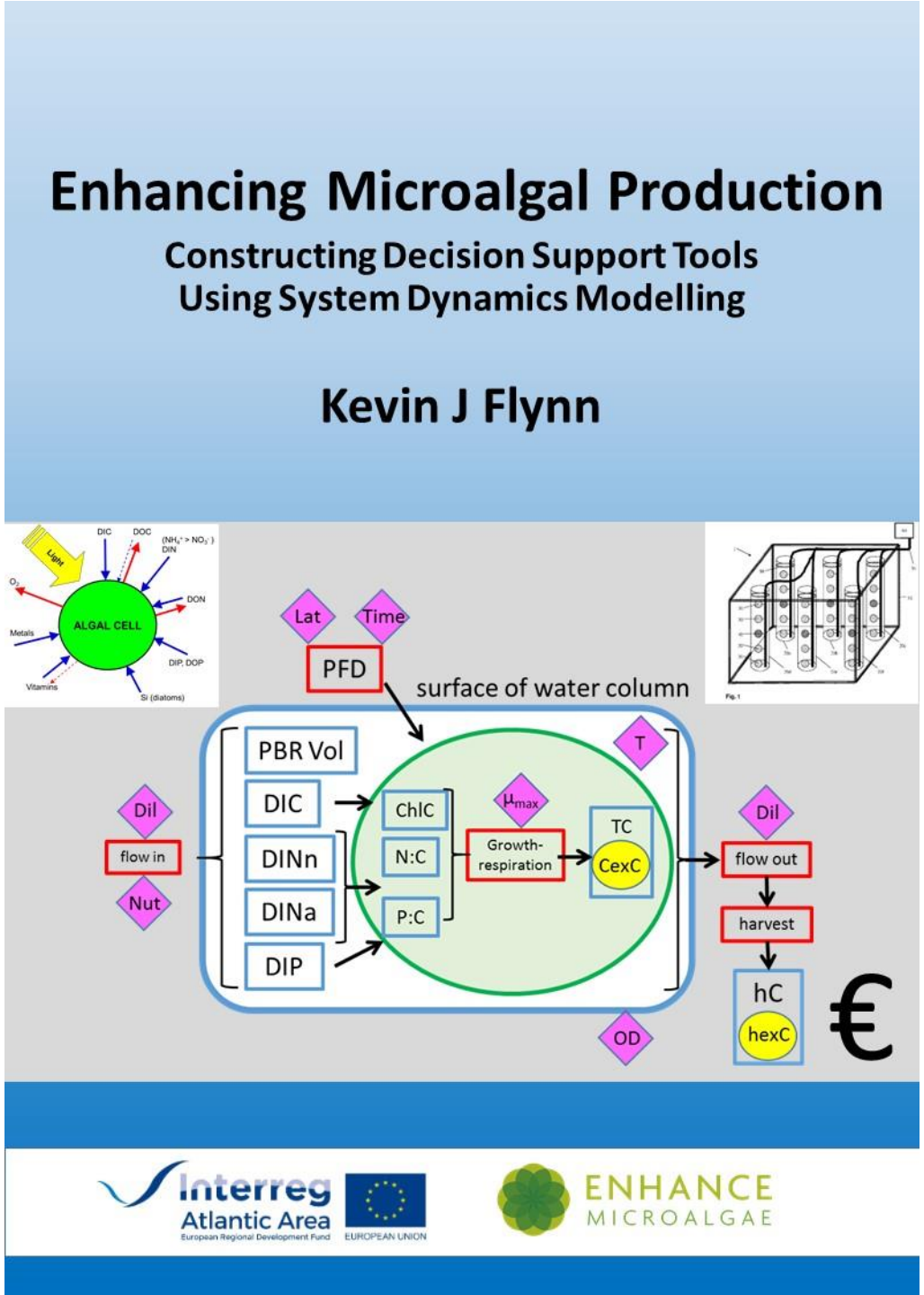
The EMA Decision Support Tool



What and Why ?!

- A computer based simulation description to experiment with!
- Real algal growth is slow and expensive to study
- Mistakes are costly
- Simulations are cheap (free) and fast
- Identify bad options quickly
- Concentrate effort on better options
- Select best options for exploration with a real system

“Models vs Simulations”

- Model = simplification of reality
- May just be a statistical fit
- Steady-state models do not involve “time”
- Simulations are dynamic .. output changes with time
- If you kick it, it kicks back !
- Microalgal systems are very complex, full of feedback processes
- Results can be counter intuitive

Disclaimer

- The contents of this work, and the allied simulation models, are directed towards the commercial production of microalgae. While the contents are offered free and in all good faith, neither the author nor the *EnhanceMicroAlgae* project accept any liability whatsoever for any commercial (or other) judgements made by any persons in consequence of the information contained herein or based upon the output of the models.
- It is the responsibility of the end user to ensure that the models are run under conditions most closely aligned with their interests.
- The simulation models for the DST were developed using Powersim software (www.Powersim.com) Studio 10; they are presented for use under the Powersim Cockpit. The author, nor the EnhanceMicroAlgae project, nor the project funders, endorse Powersim products in any way.

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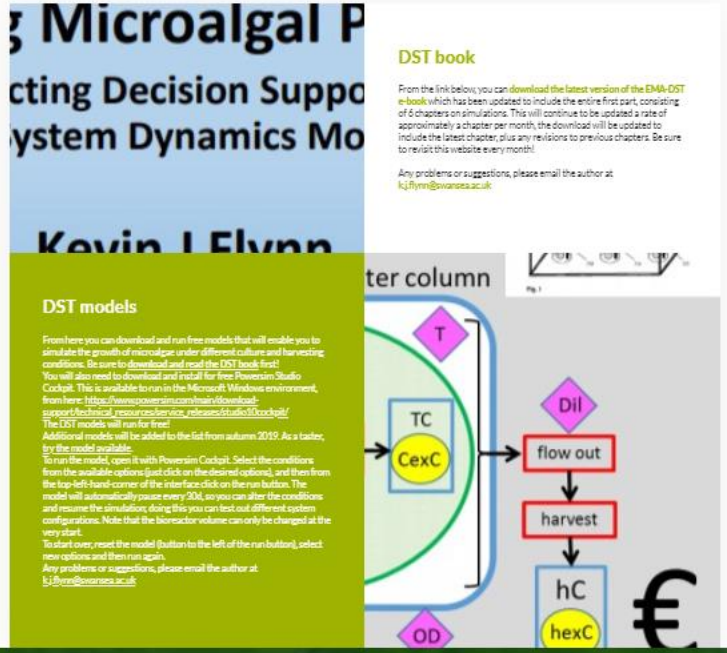
Decision Support Tool

Welcome to the EnhanceMicroAlgae Decision Support Tool (EMA-DST)

The EMA-DST provides you with a better understanding of factors affecting the commercial growth of microalgae, to better enable you to make the correct business decisions. The information we provide includes both a text book and a series of simulation models.
The e-book will be released at a rate of approximately a chapter per month. The download is free, and you only need a pdf reader. Each month we will add the next chapter to the download. Go to the DST book section for further information!
The DST models provide you with the means to explore microalgal growth using a simulation platform. The models will be free to run, though you will need to download (for free) a piece of software to operate the simulations. Initially we provide just a simple example; from autumn 2019 more complex simulators will be made available. Go to the DST models section for further information!



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What does the DST comprise?

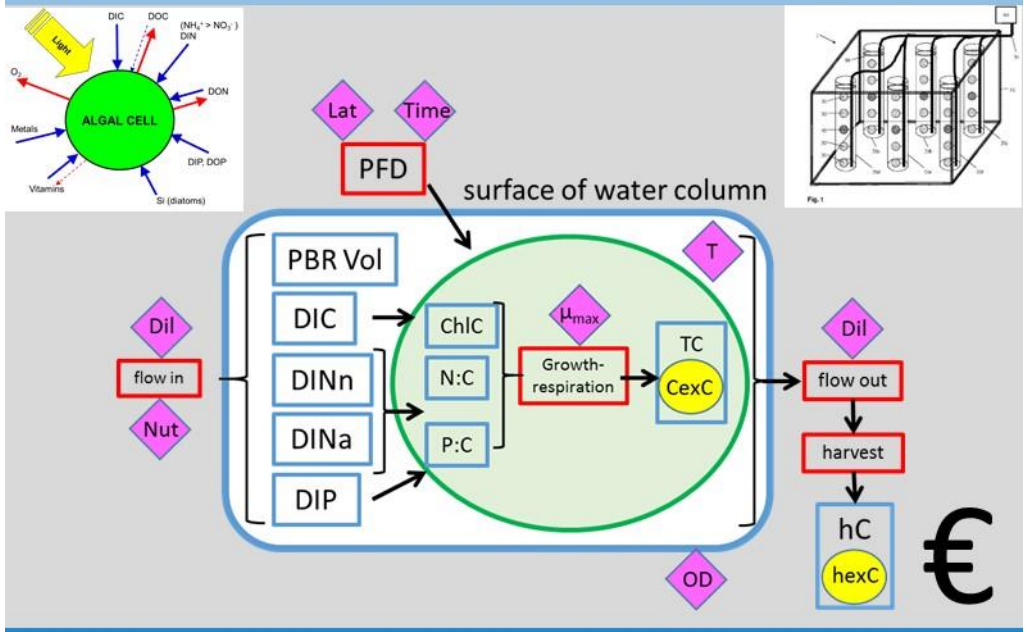
- A free e-book on aspects of algal physiology and culturing, with an introduction to the DST
- An introduction (for those who wish it!) on simulation modelling
- Free simulation models for the end-user to use to aid commercial-facing decisions in the growth of microalgae

If any errors or problems are encountered, please contact the author at kjfplankton@gmail.com

Enhancing Microalgal Production

Constructing Decision Support Tools Using System Dynamics Modelling

Kevin J Flynn



This is a work-in-progress ….

- Development of the book ….

… and of models

… will continue until the end of the project

- The book will carry an ISBN and both it and the models will remain available and operational for at least 3yrs from the end of the EMA project

Book contents

Glossary

Items in italics are described elsewhere in this glossary

α^{C}: the rate of photosynthesis per unit of C-biomass per photon. α^{C} characterises the initial slope of a C-specific *PE curve* (e.g., gC gC^{-1} d^{-1} vs *PFD*).

α^{Chl}: the rate of photosynthesis per unit of chlorophyll per photon. α^{Chl} characterises the initial slope of a Chl-specific *PE curve* (e.g., gC $gChl^{-1}$ d^{-1} vs *PFD*).

Acclimation: changes in organism physiology in response to environmental factors. Often confused with *adaptation*, acclimation is an intra-generational response.

Adaptation: changes in organisms physiology that have come about through natural selection. Adaptation is an inter-generational response to changes in environmental factors. Cf. *acclimation*.

…… etc etc

Part I Core Information

1. General Introduction
2. Microalgae – a (very) brief introduction
3. Microalgal Physiology
4. Culture Systems
5. The Basic of Simulation
6. Decisions Support Tool Use

Part II Simulators

7. Introduction to Using the Models

8. A Simple Model of Microalgal Growth in a PBR

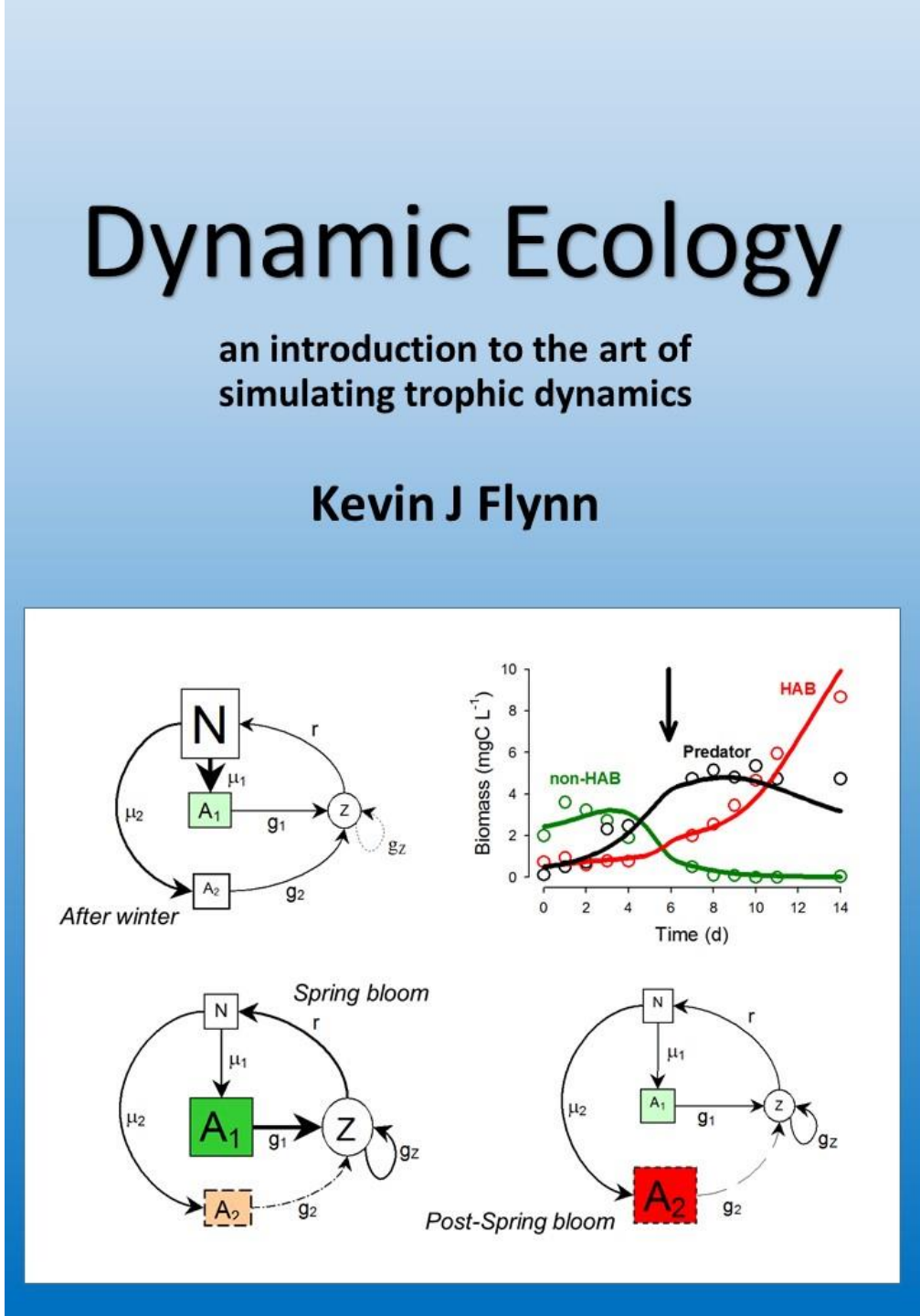
9. An Arrayed Simple Model

- {further chapters on models and their deployment for DST usage}
- Additions will be made ever ca. 2 months until Sept 2020

References

A free tutorial e-book on simulation modelling, plus models, is also available!

www.mixotroph.org/models



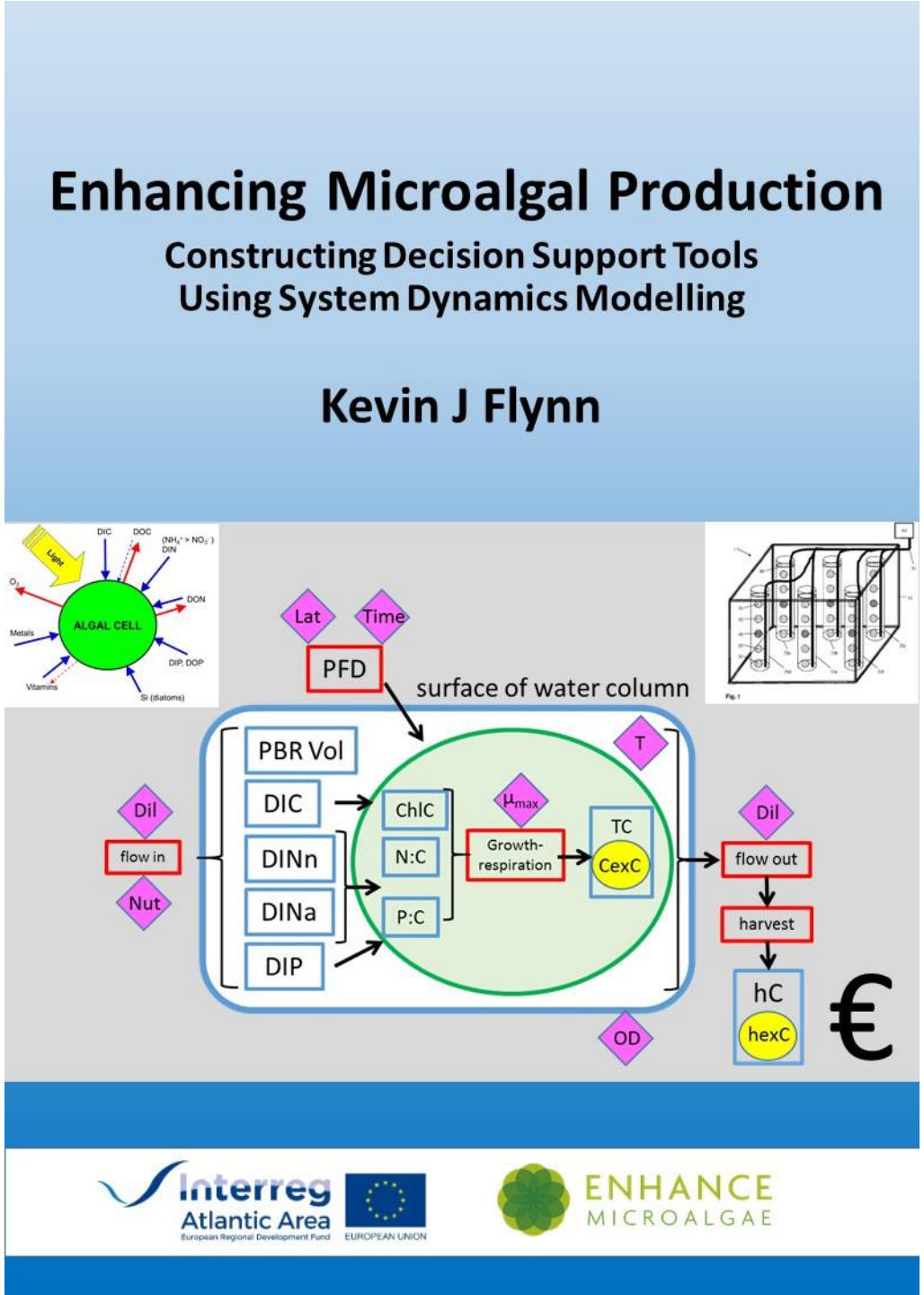
Making and using models

- Simulation models run using special software
- Unless you use R or Python etc., options tend to be expensive
- Very expensive for commercial usage!
- **This DST can be used for free**
- You just need a Windows-based PC or laptop

Break ….

The EMA Decision Support Tool

Continued …..



A word about units used in models

- These are “system dynamics” models
- Units have to make sense
- Nutrient-N is used to make biomass-N
- So both nutrient and biomass must have the same unit (e.g., mgN L^{-1})
- Dry weight, wet weight make no sense in such a model
- A “transform” is required to convert the primary model units into other units
- So, for e.g. dry weight (g) $\approx 3 \times$ gC

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Renewable Energy; Simulation of solar power

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- Includes all features
- Try out tutorials
- Build own models

Valid for 30 days — More >>

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- Connect to Excel data

Not time limited — More >>

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- Distribute custom-made simulators
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Desktop solutions only — More >>

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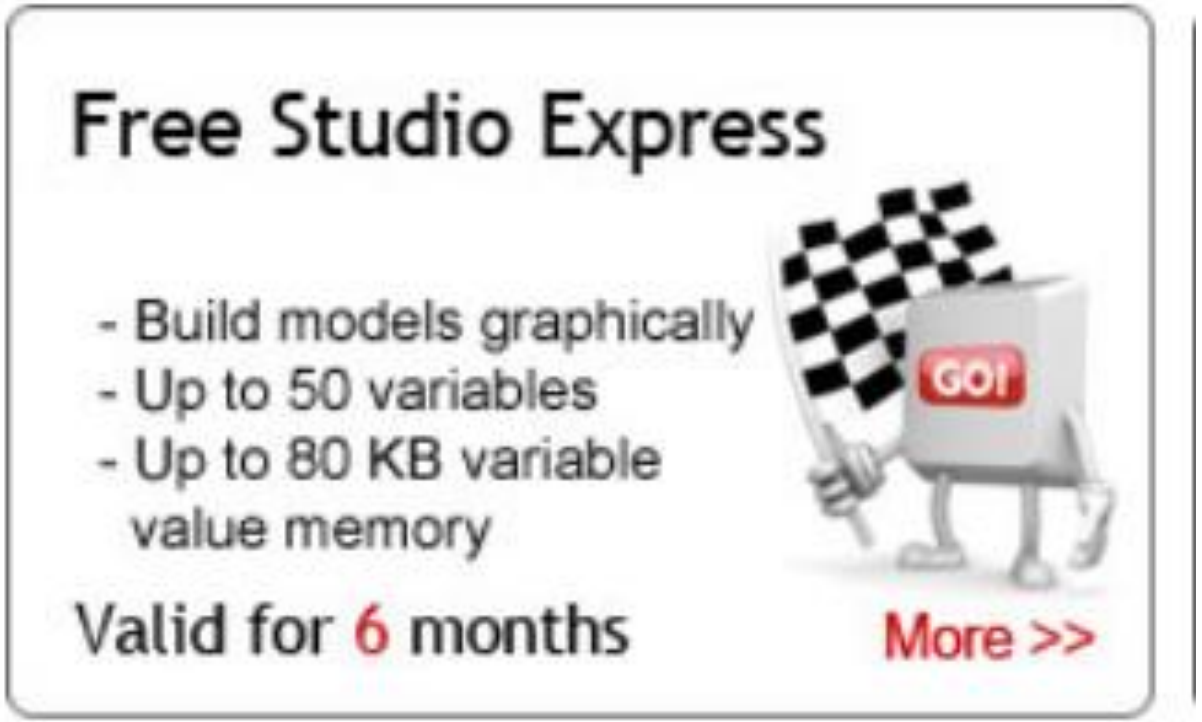
If you download Studio Express

… you can play around with simple models and get an idea as to how system dynamics models work

Start with a very simple model

- Free software
- But limited in scope
- Valid for 6mo, but you can just reload it



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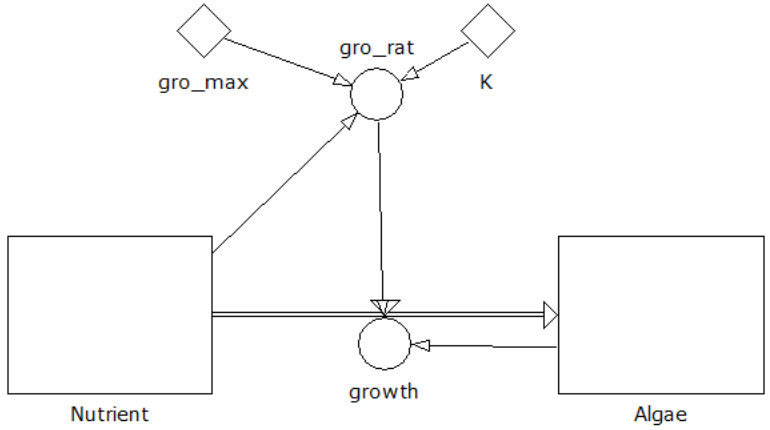
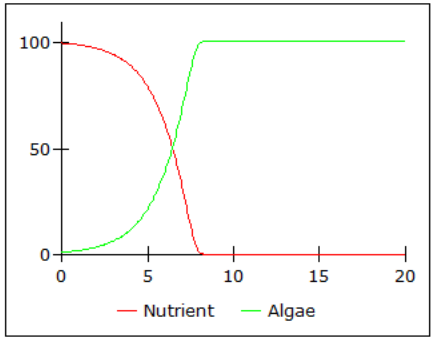
Chapter 7





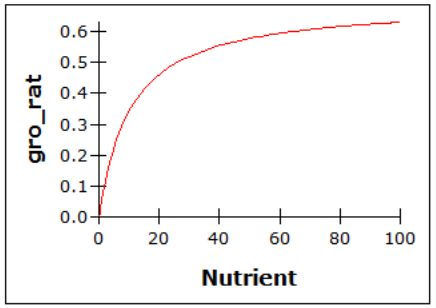


Diagram 1 Diagram 2 Diagram 3

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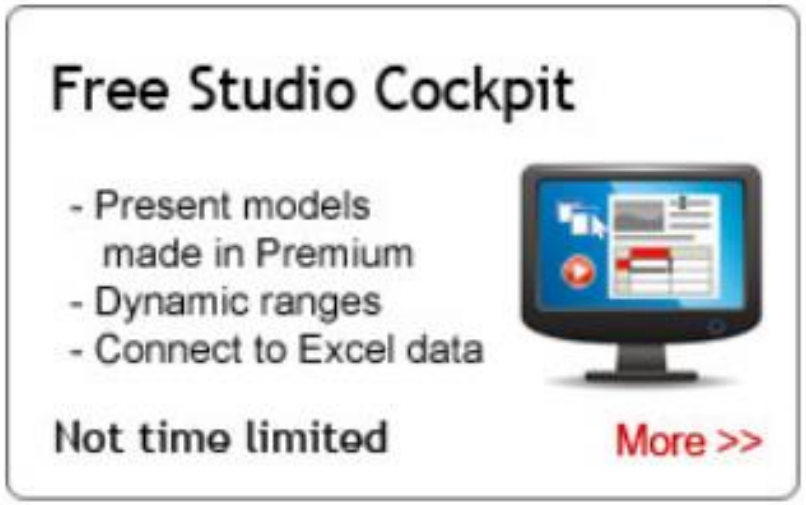
Just to show you how easy this can be ..

{demonstration}

And then a more complex light-N limited description

- To make big models you need the full software
- For academic use, this is cheap
- For commercial use, it is not cheap!
- **But you can use pre-built DST models for free !**



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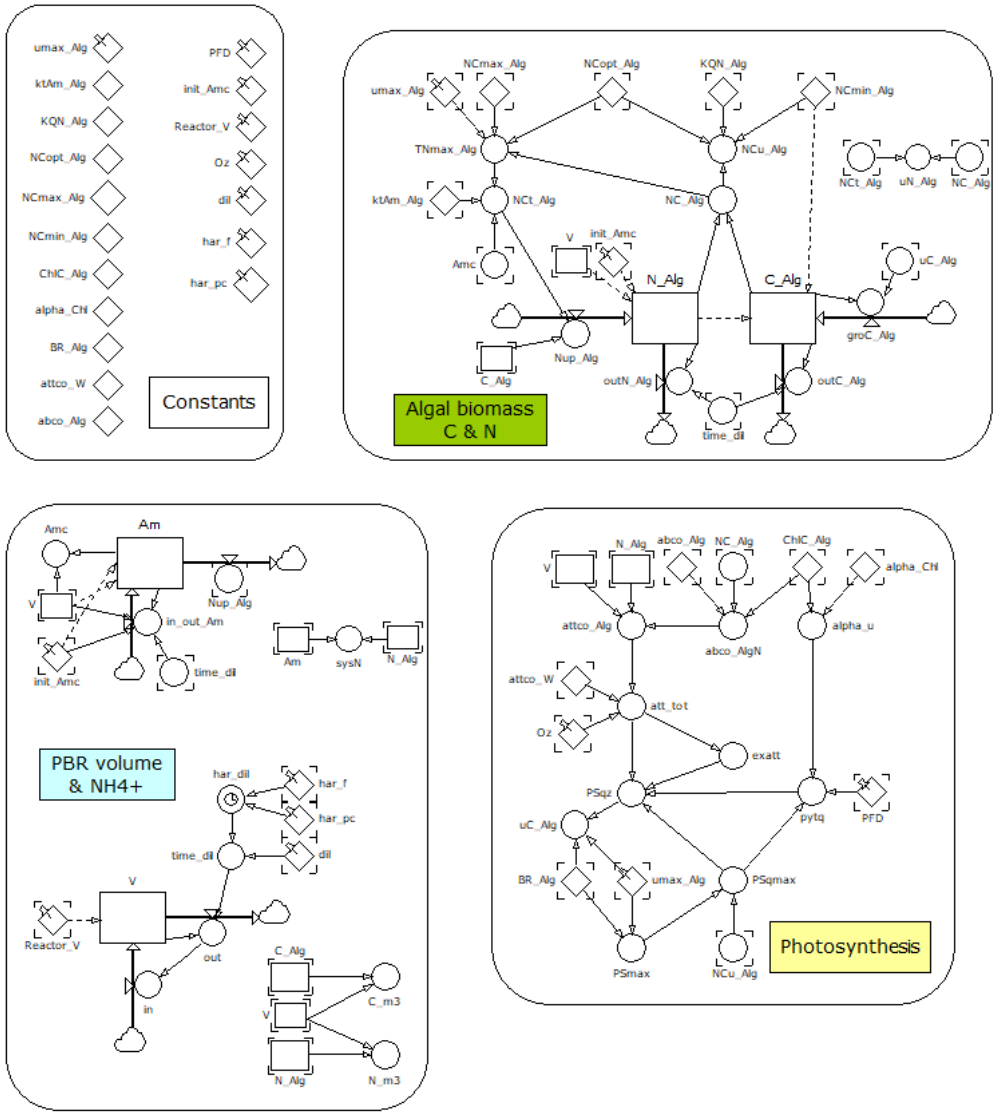

Name
- har_f
- har_pc
- in
- in_out_Am
- init_Amc
- KQN_Alg
- ktAm_Alg
- N_Alg
  - Nup_Alg.in
  - outN_Alg.o
- N_m3
- NC_Alg
- NCmax_Alg
- NCmin_Alg
- NCopt_Alg
- NCt_Alg
- NCu_Alg
- Nup_Alg
- out
- outC_Alg
- outN_Alg
- Oz
- PFD
- PSmax
- PSqmax
- PSqz
- pytq
- Reactor_V
- sysN
- time_dil
- TNmax_Alg
- uC_Alg
- umax_Alg
- uN_Alg
- V
  - in.in
  - out.out

Diagram 1 / plots

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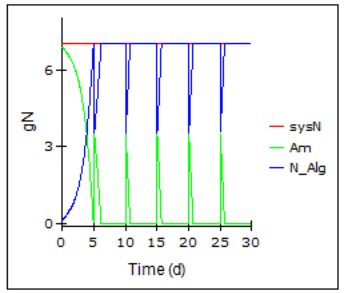
This is controlled via push-buttons

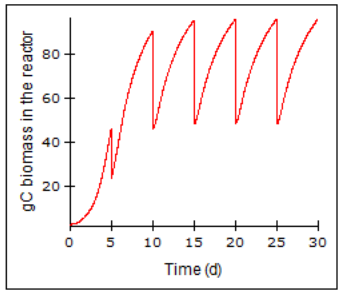
You can change …

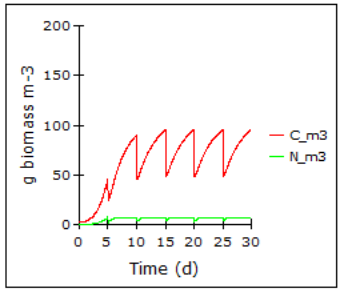
- Reactor volume
- Optical depth
- Light
- Nutrients
- Maximum growth rate
- Harvesting frequency and proportion

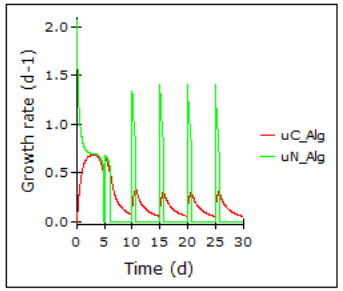
Powersim Simulation Presentation

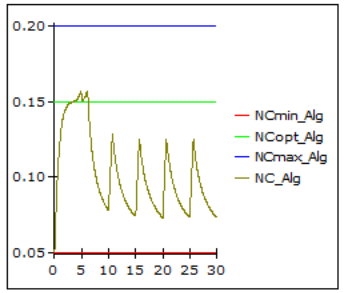
75%

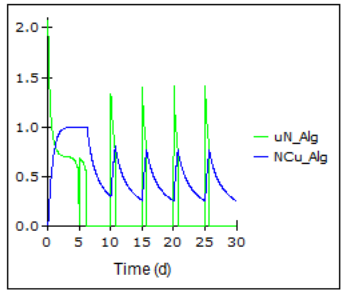












A low NC_Alg indicates N-limitation and a high lipid/carbohydrate content.
A high NC_Alg indicates a high protein content

Reactor volume (m3)

- 0.50
- 1.00
- 10.00

Background dilution (d-1)

- 0.00
- 0.05
- 0.10

Maximum growth rate (d-1)

- 0.35
- 0.69
- 1.39

Optical depth

- Small Bore
- 10cm Bore
- Pond

Harvest frequency (d)

- 2.00
- 5.00
- 10.00

Light (PFD; umol m-2 s-1)

- 200.00
- 500.00
- 2,000.00

Harvest proportion

- 25%
- 50%
- 95%

Ammonium concentration

- 100uM N
- 500uM N
- 1000uM N

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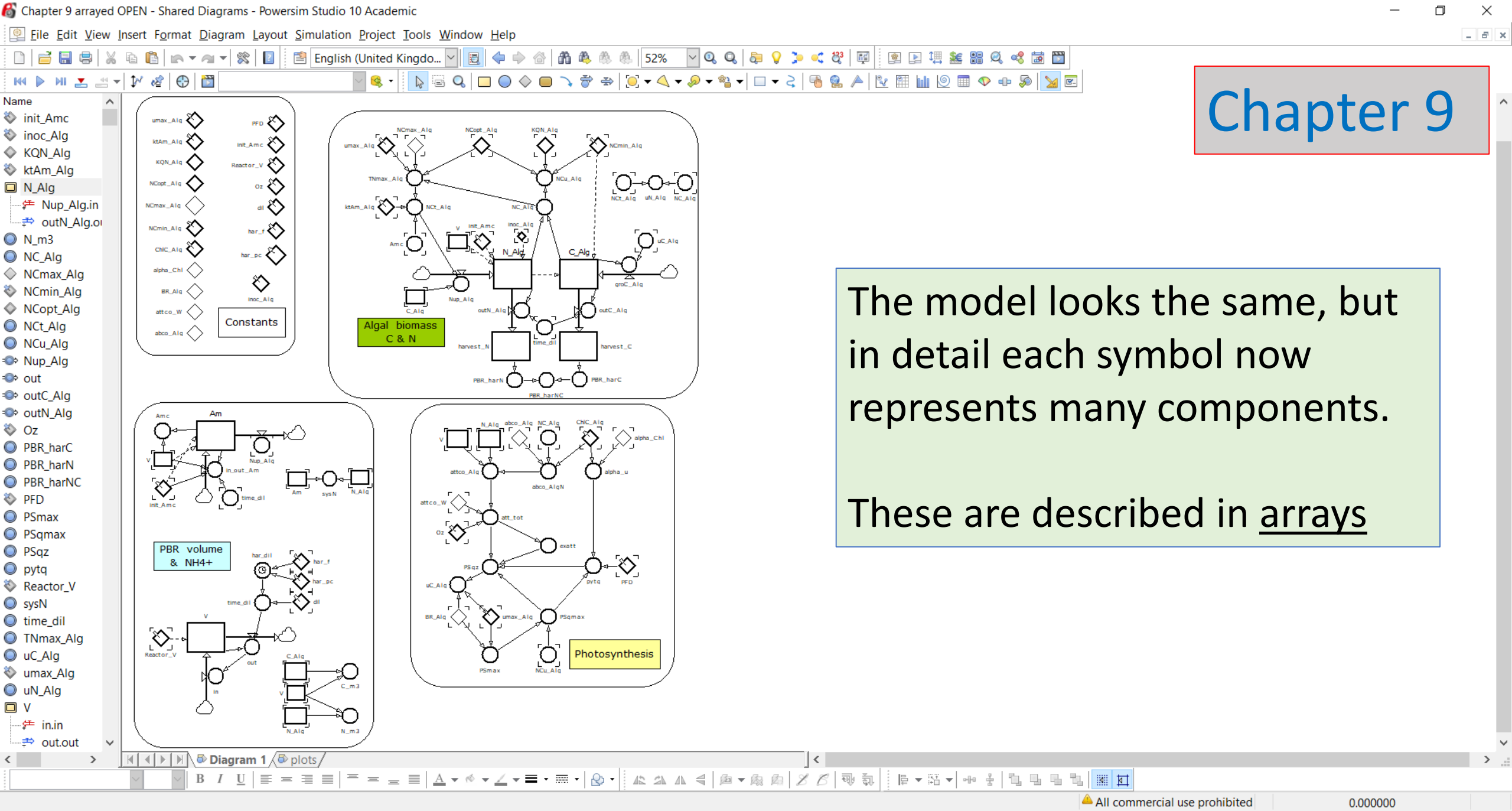
Lets try that …

An arrayed model

- Many species options
- Many PBR configuration options
- Many PBR operational options
- Use the model to explore different configurations for optimising commercial production

Chapter 9



The model looks the same, but in detail each symbol now represents many components.

These are described in <u>arrays</u>

Powersim Simulation Presentation

60%

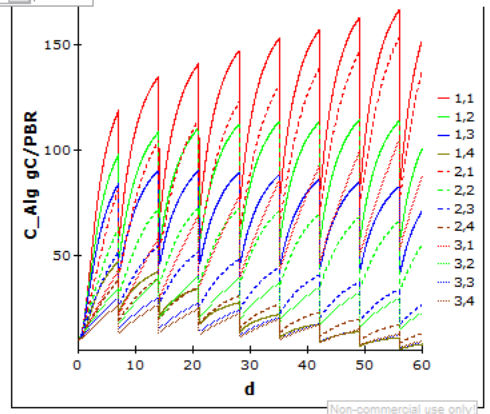
Sp config	umax_Alg	ktAm_Alg	NCmin_Alg	ChlC_Alg
unit	d-1	gN m-3	gN (gC)-1	gChl (gC)-1
sp#1	1.20	0.01	0.05	0.06
sp#2	1.20	0.01	0.05	0.04
sp#3	1.20	0.01	0.05	0.03
sp#4	0.69	0.01	0.05	0.06

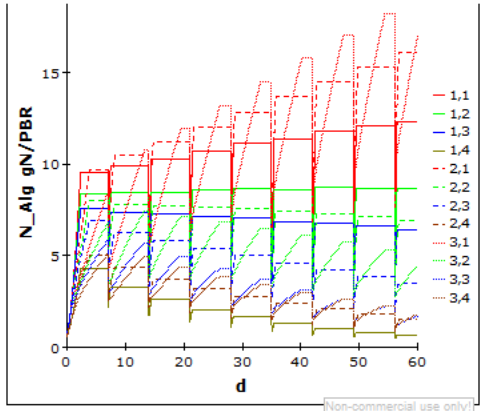
PBR config	unit	PBR#1	PBR#2	PBR#3
Oz	m	0.05	0.10	0.20
Reactor_V	m3	1.00	1.00	1.00
PFD	mol m-2 s-1	500.00	500.00	500.00
dil	d-1	0.00	0.00	0.00
har_f	d	7.00	7.00	7.00
har_pc	fraction	0.50	0.50	0.50
init_Amc	gN m-3	28.00	28.00	28.00

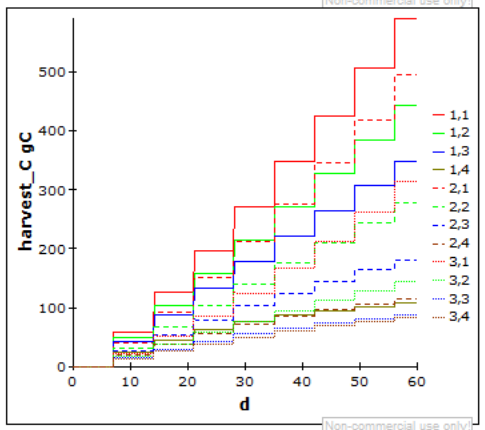
Enter "0" not to inolculate with this species, or "1" to inoculate.

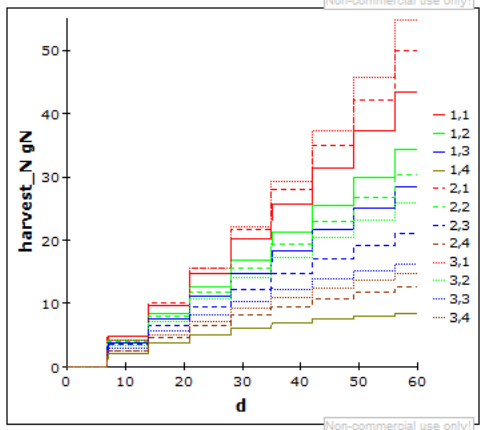
Do NOT enter numbers other than "0" or "1"!

inoculate			
0 or 1	PBR#1	PBR#2	PBR#3
sp#1	1.00	1.00	1.00
sp#2	1.00	1.00	1.00
sp#3	1.00	1.00	1.00
sp#4	1.00	1.00	1.00









Describes 4 species in 3 reactors .. in any combination

The array syntax is {PBR, species}

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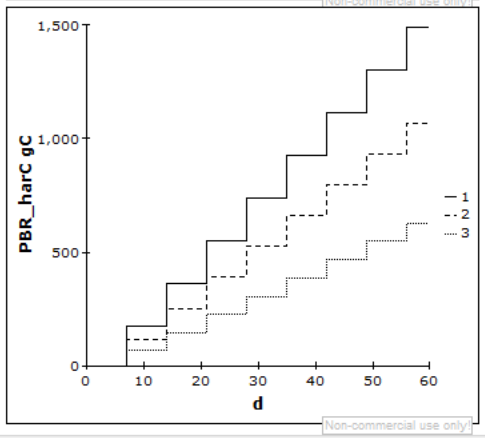
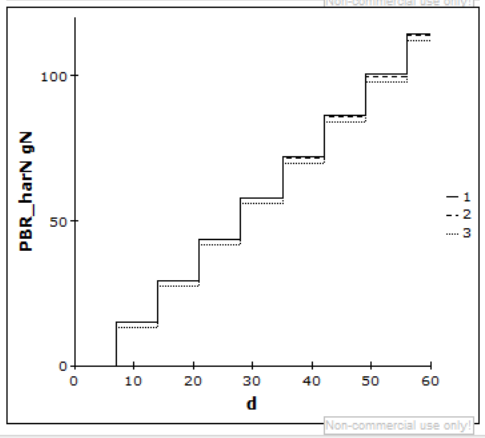
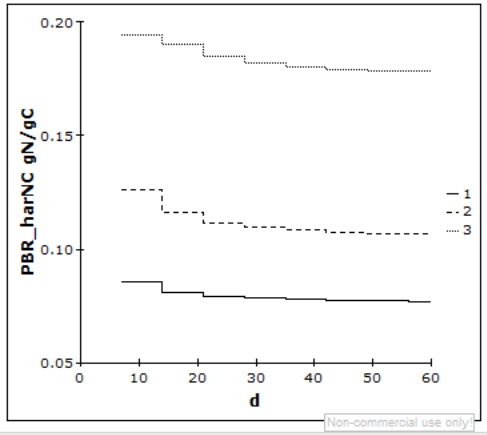
A high NC_Alg indicates a high protein content







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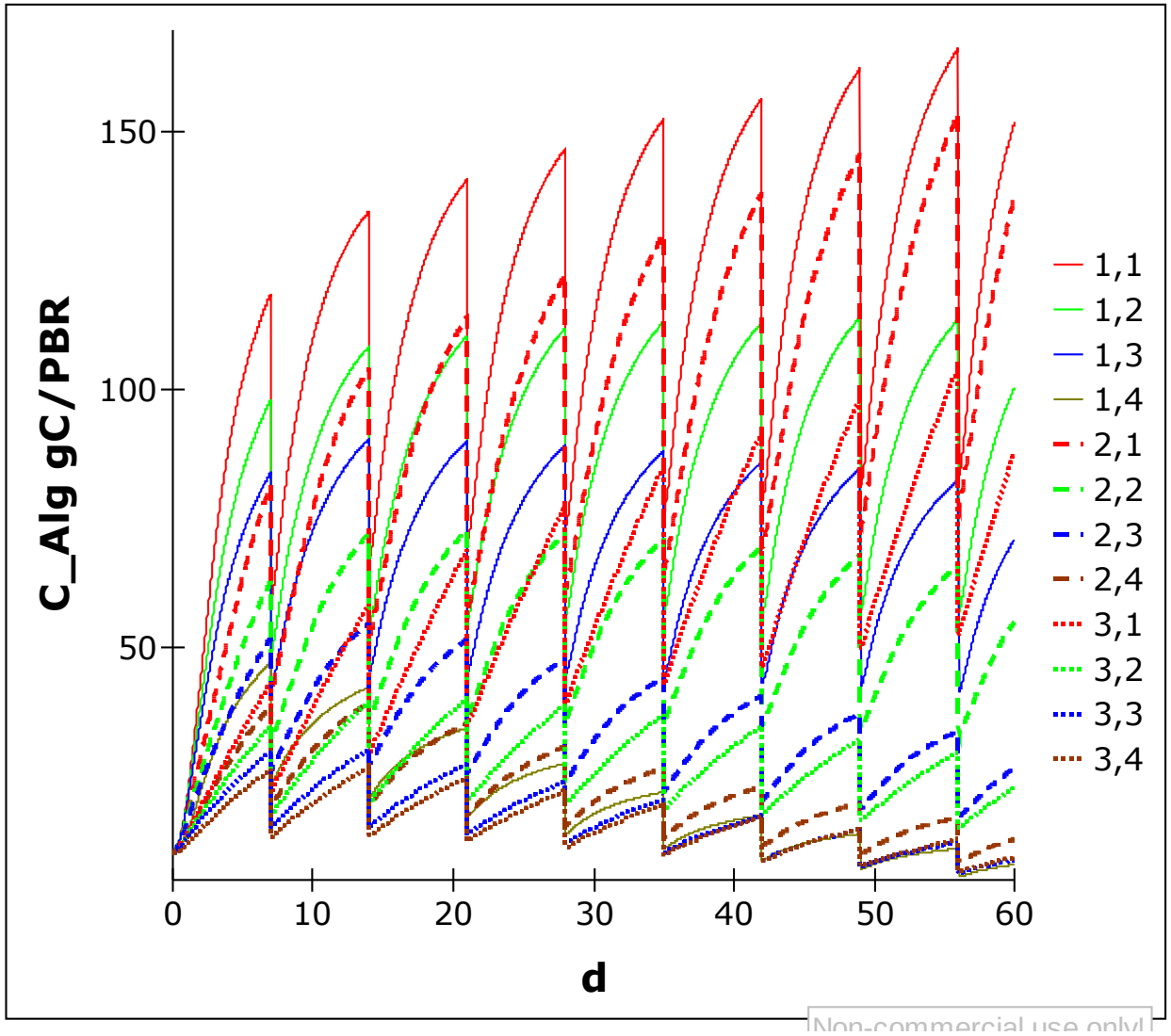
Controlling the model

- Specify the physiology of the microalgae
- Specify the PBR design
- .. and decide how you will operate the PBR
- Decide which species of microalgae to inoculate into each PBR

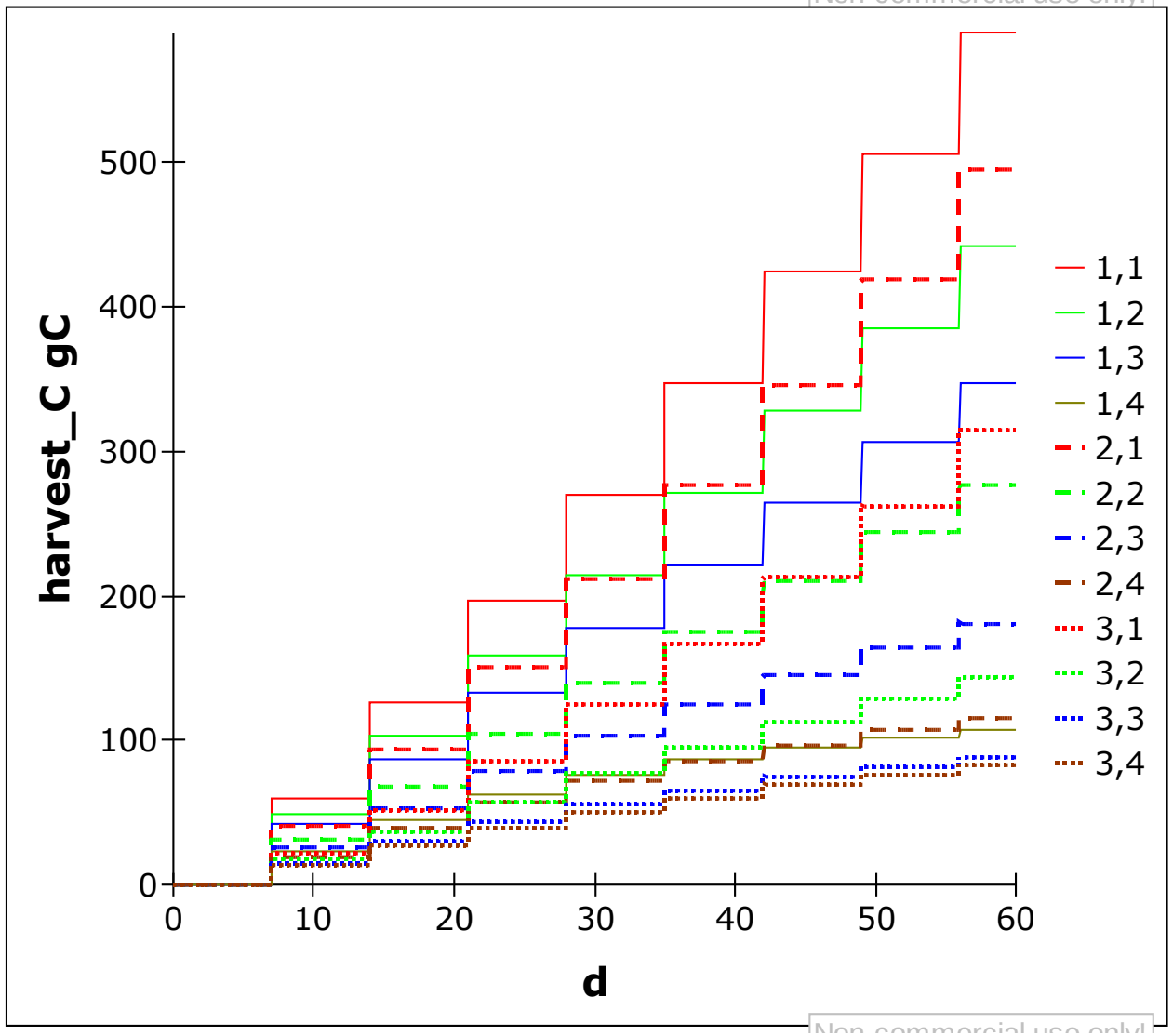
Biomass of each species in each PBR

{PBR, species}

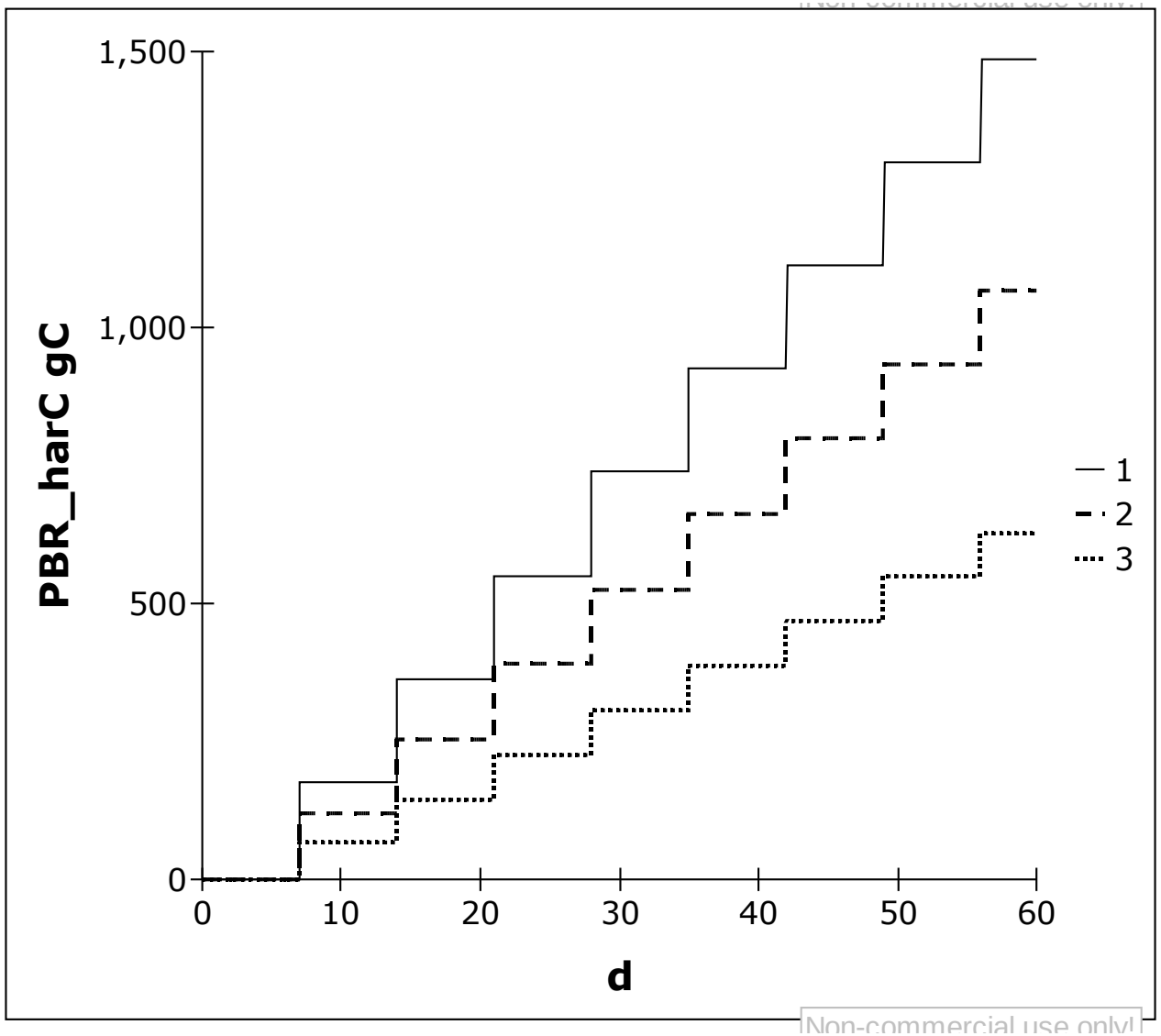


Harvest of each species in each PBR

{PBR, species}



Harvest biomass in each PBR



Lets try that …

This may look complex but actually this is a simple model …

- The physiology is only C,N
- No P
- No Si for diatoms
- No DOC for heterotrophy
- No Chl for photoacclimation

Future book chapters and models

- Multi-nutrient (N, P, Si)
- Variable light (L/D cycle)
- Heterotrophy (addition of sugar, amino acids)
- Direct coupling to aquaculture (bivalve, shrimp)
- Others?

Any questions?

- During the project k.j.flynn@swansea.ac.uk
- After the project kjfplankton@gmail.com