

Carrying capacity and sustainability of bivalve culture: models come of age

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Growth of cultured bivalves is limited by suspended food sources

Food is renewed by exchange and primary production

Mussel feeding is well known

These processes can be simulated in a model

The big picture:

What kinds of science input can aid in coastal zone management?

How can science be translated to management advice/policy via decision support systems or tools?

How can coastal residents participate in these decisions?

Sustainability

Ecosystem state or function is not pushed beyond its natural limits

Question: HOW MUCH IS TOO MUCH?

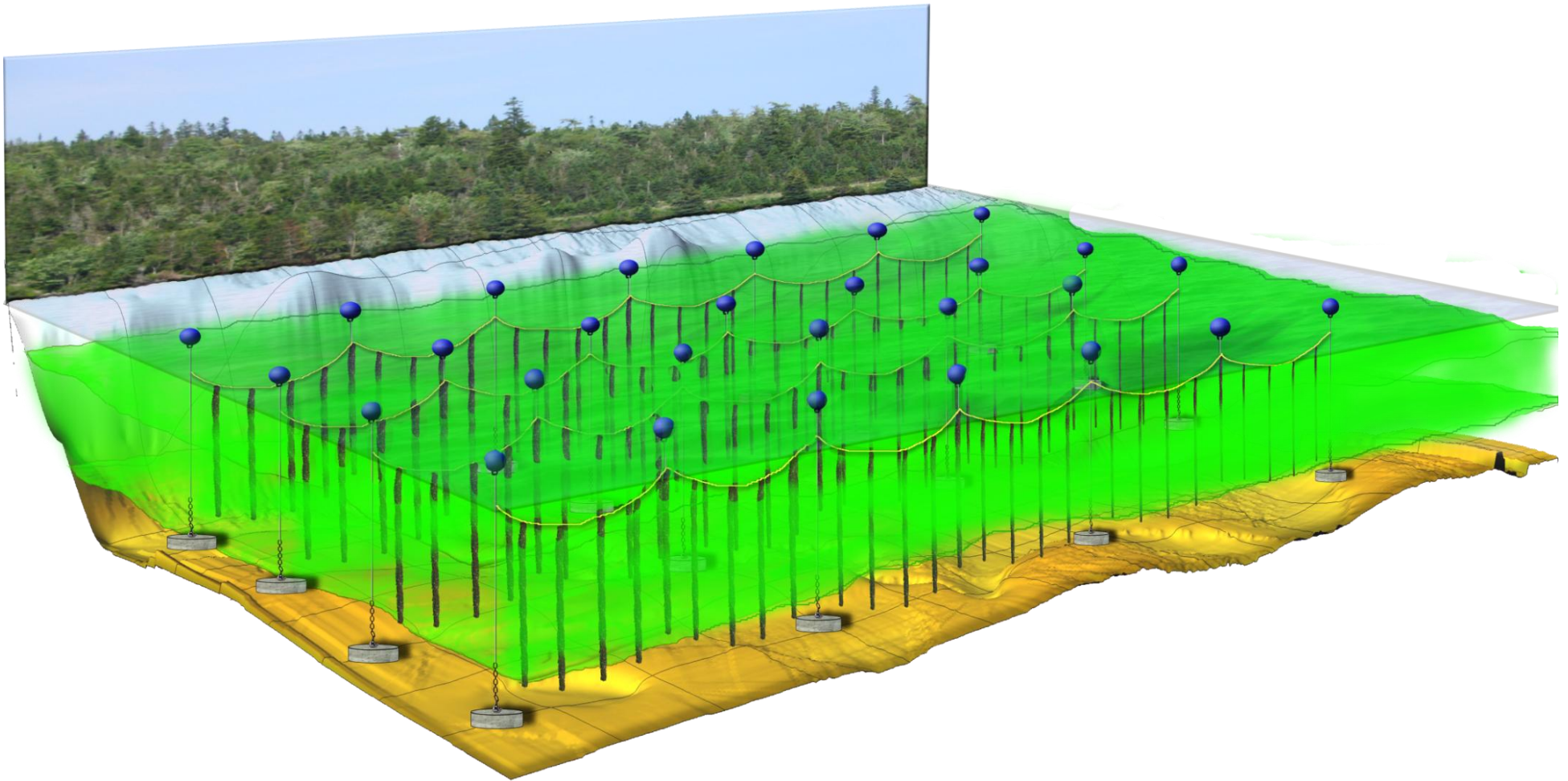
"Carrying capacity"

If stocking density is too high:

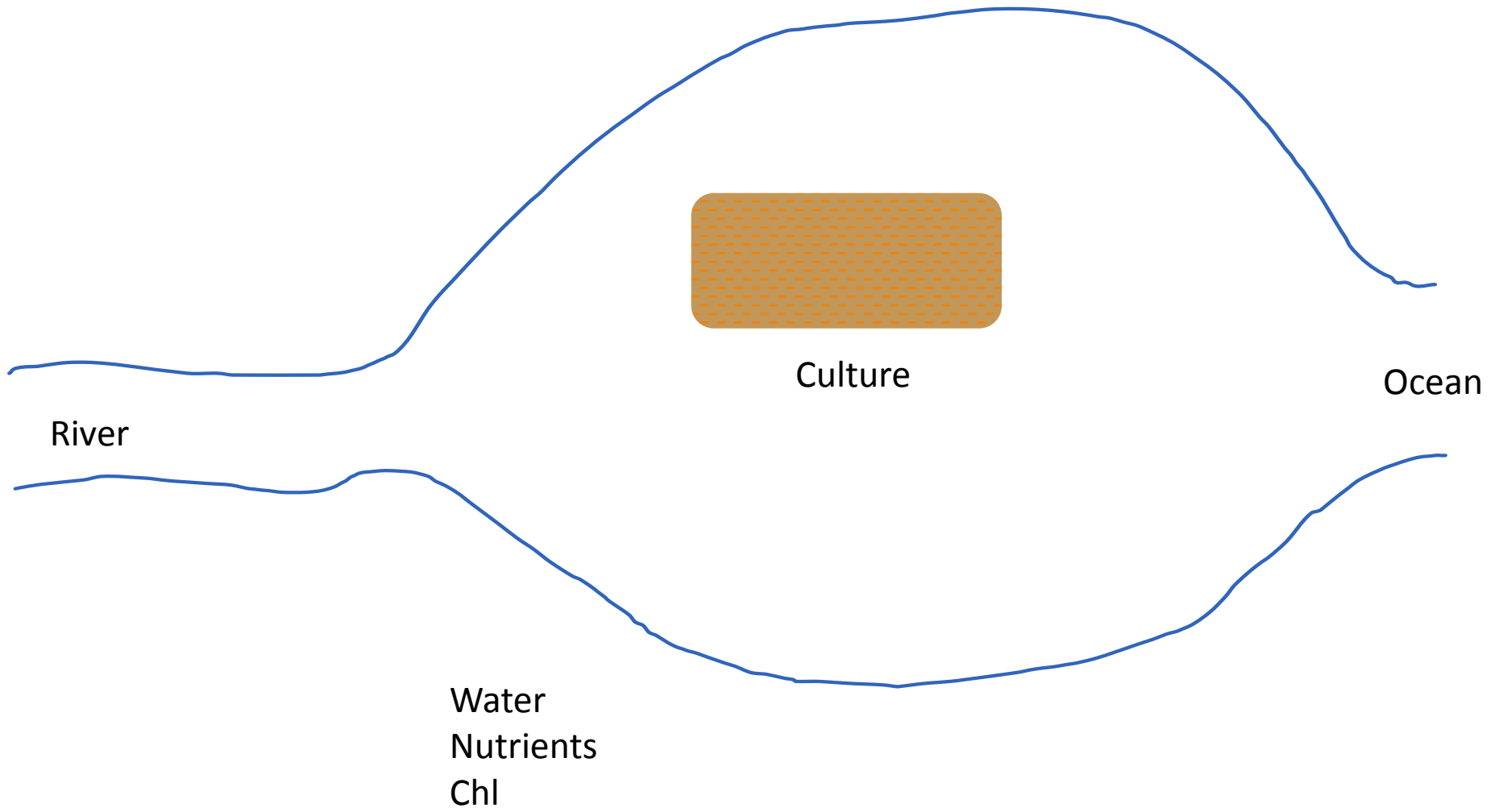
- Food - Too many mussels, not enough food, reduced growth
- Economic - Small mussel size, value of crop is reduced
- Environmental - Changes in ecosystem and/or water/mud quality

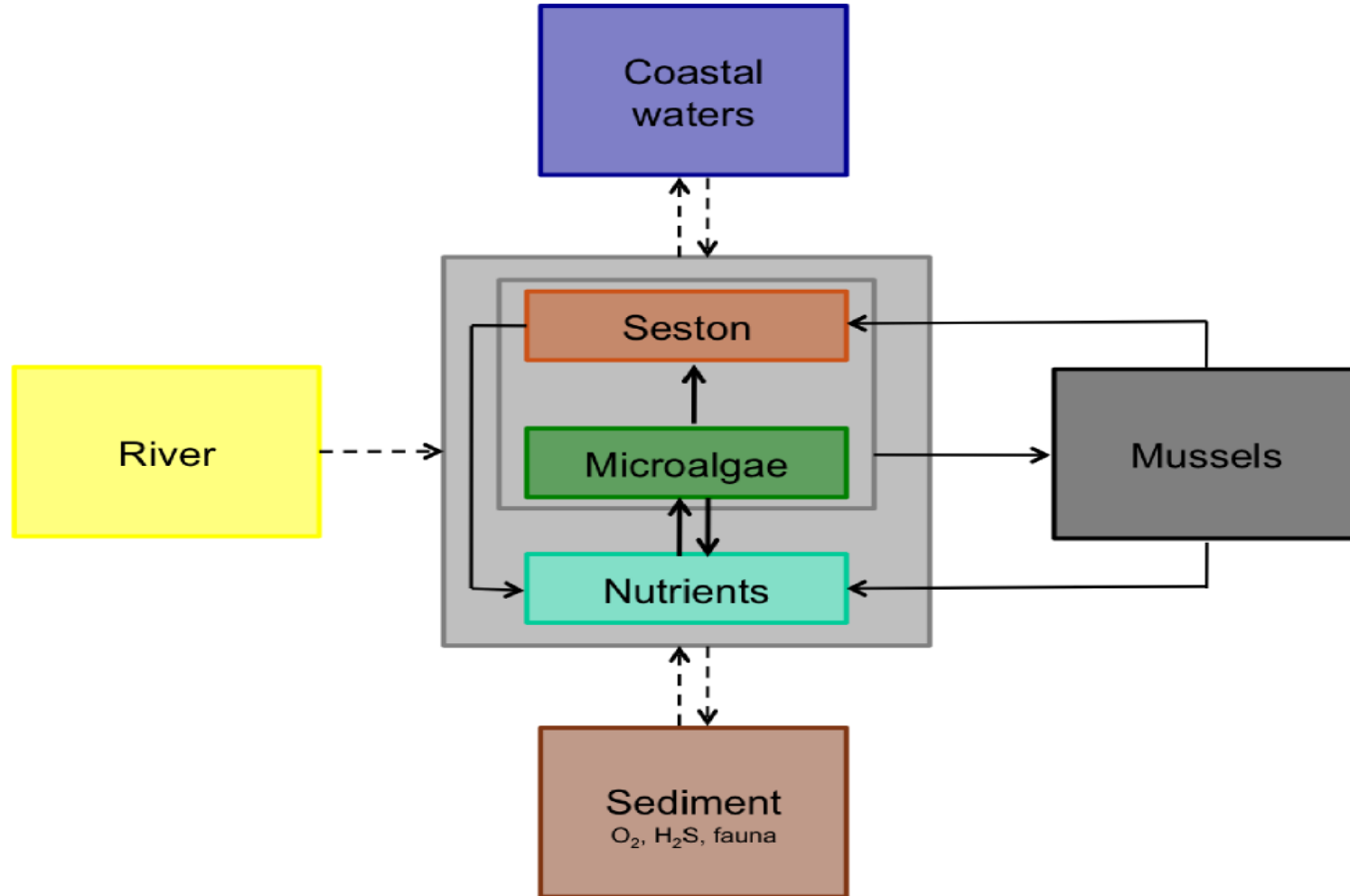
Models require physics and ecology

Seston depletion in suspended mussel culture



Nature simplified





Structure of the ecosystem model used in St. Ann's Bay.

Ecosystem models to predict:

Bivalve growth

Distribution of chlorophyll

Chlorophyll depletion

How can these models be applied to new areas

- in the absence of field data?
- without requiring a multi-year study?

i.e. How can the models be made more operational?

Coupled full spatial model in Simile (simulistics.com)

Sources of data and parameters

Circulation – physical submodel

Primary production and chlorophyll – remote sensing

Ocean nutrients - historical data, nutrient climatology

River flow – hydrological model

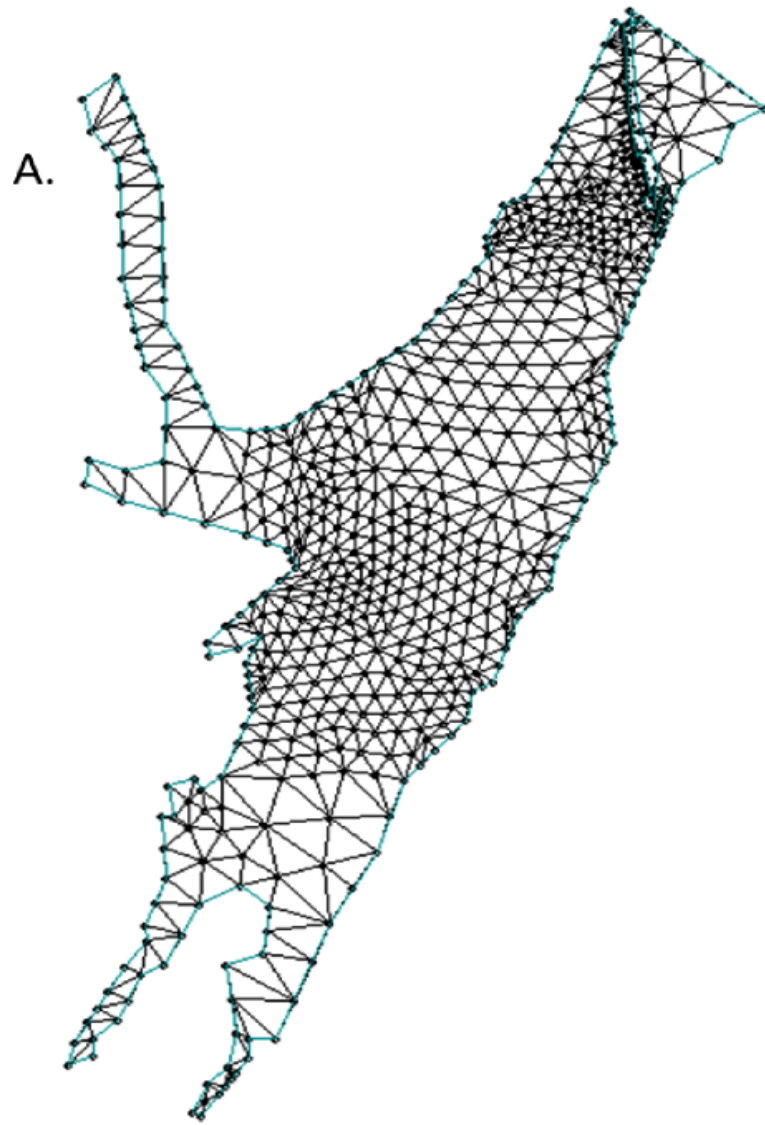
River nutrients – land use patterns

Shellfish – regulators, remote sensing

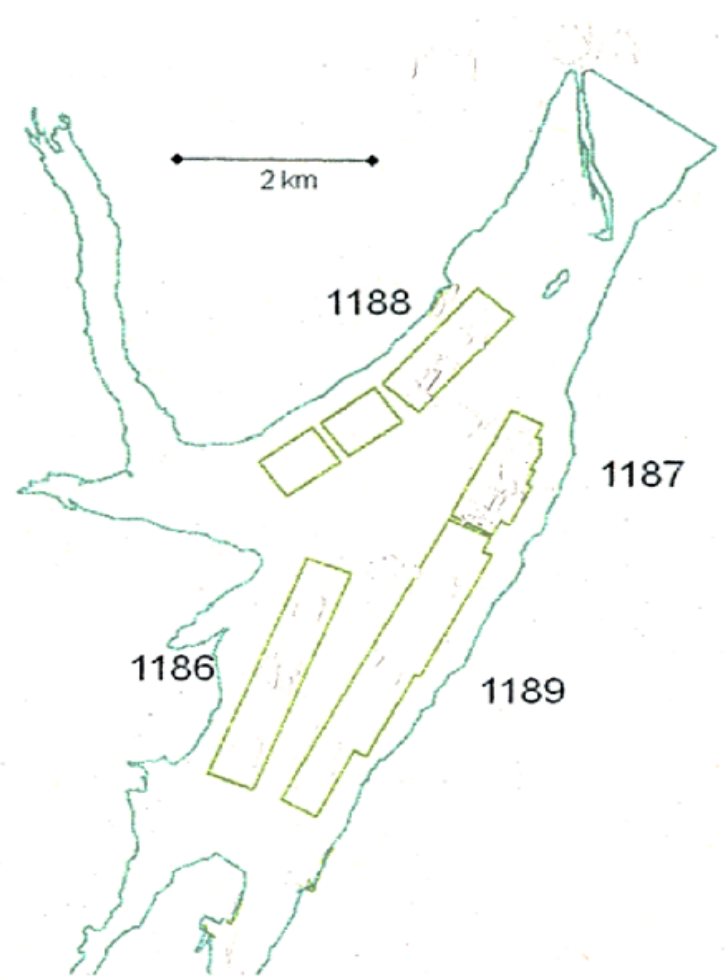
GIS (!)

Upper St. Ann's Bay



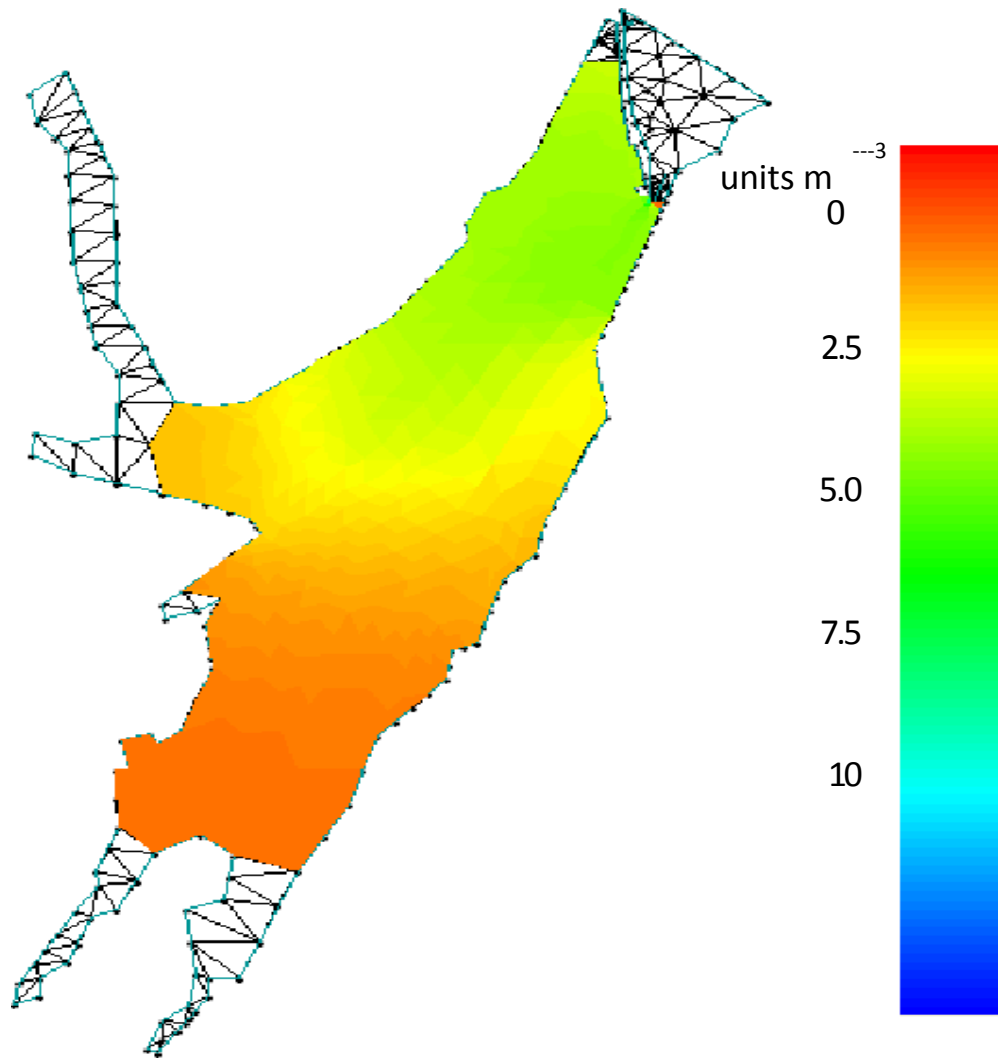


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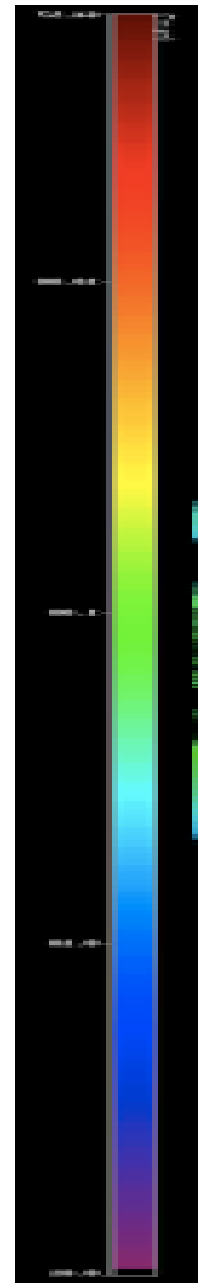
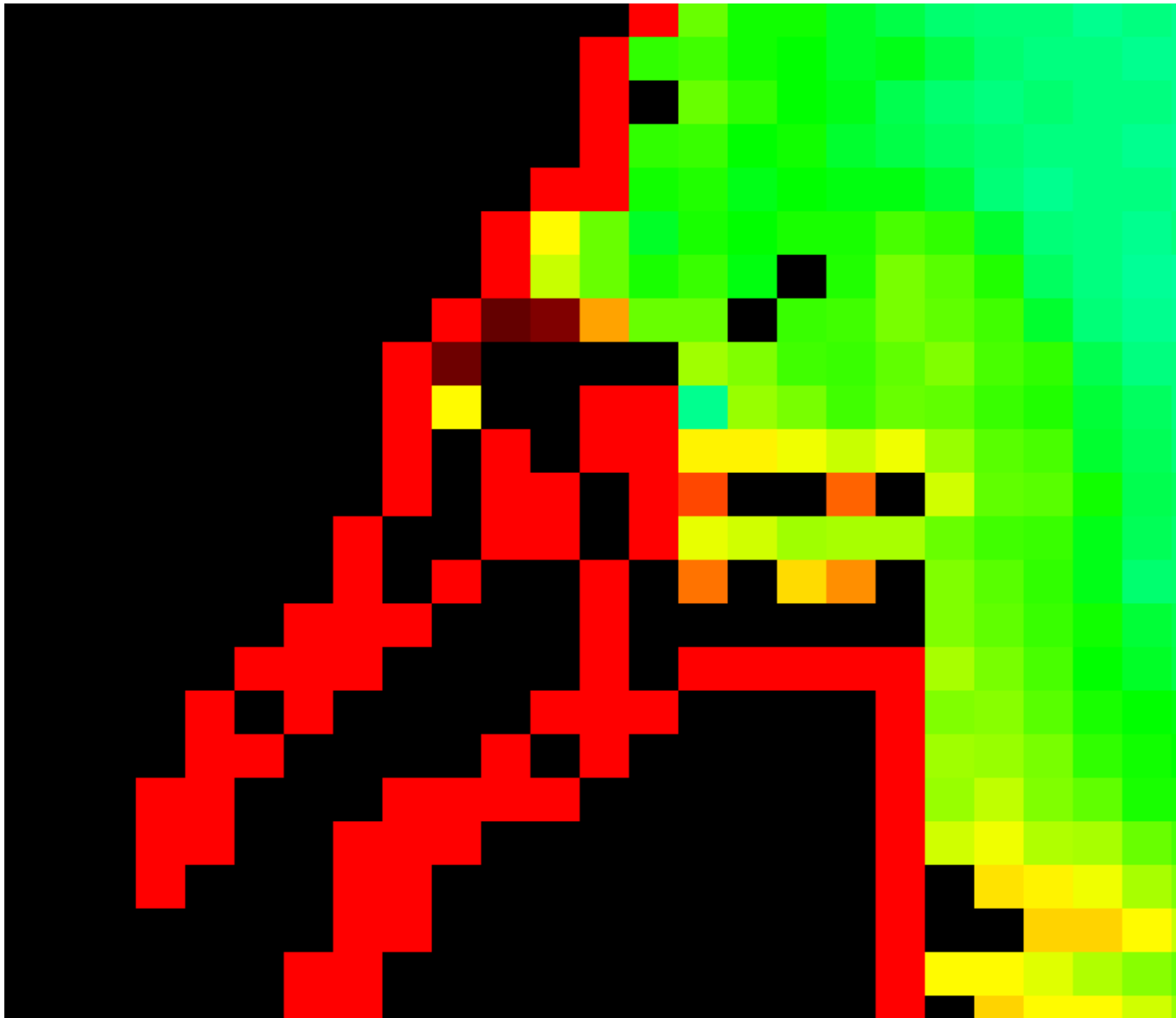
The model grid used within the bay for physical and biological exchange. B. The location of mussel leases in the bay.

Tracer Concentration after 26 days

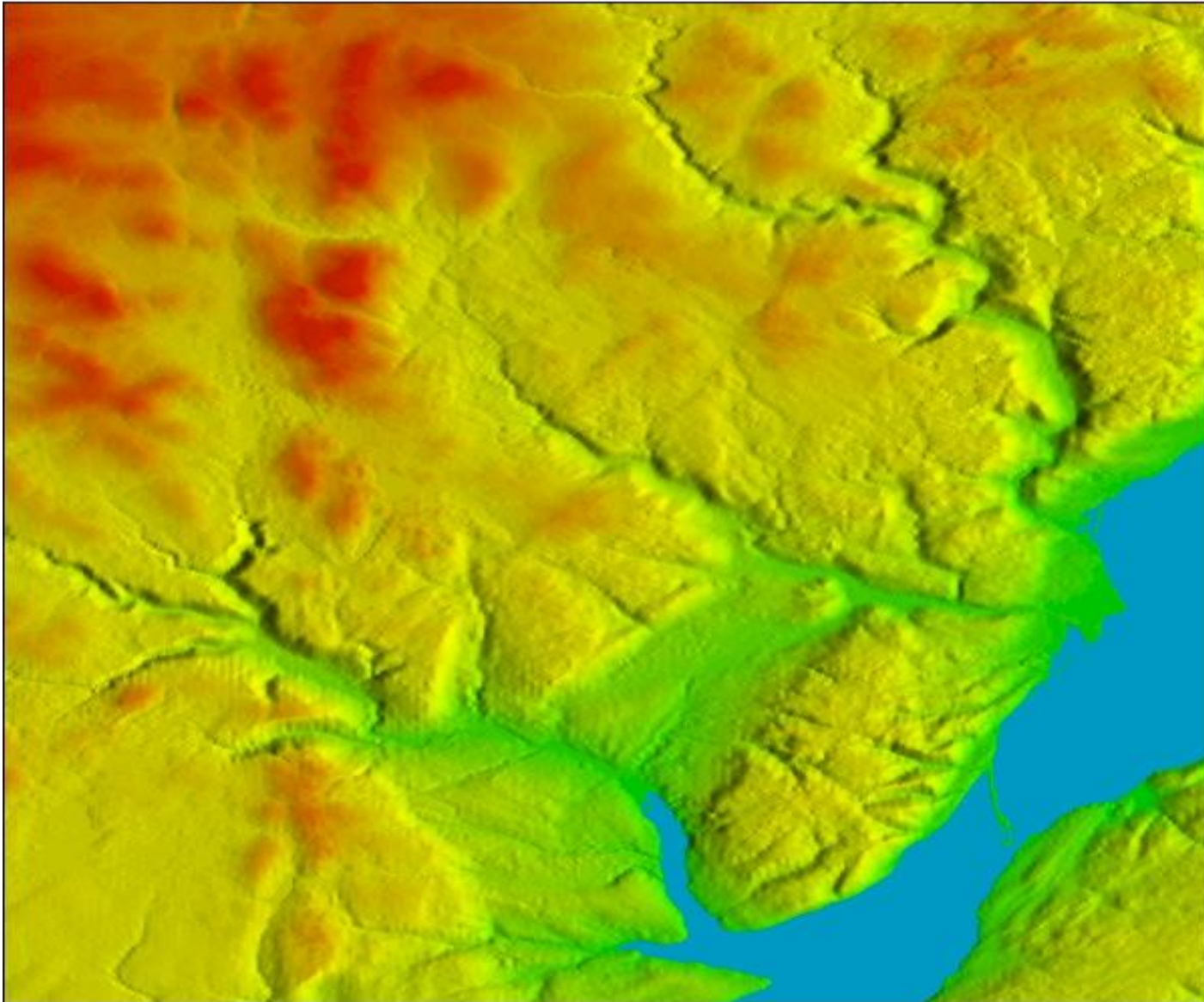


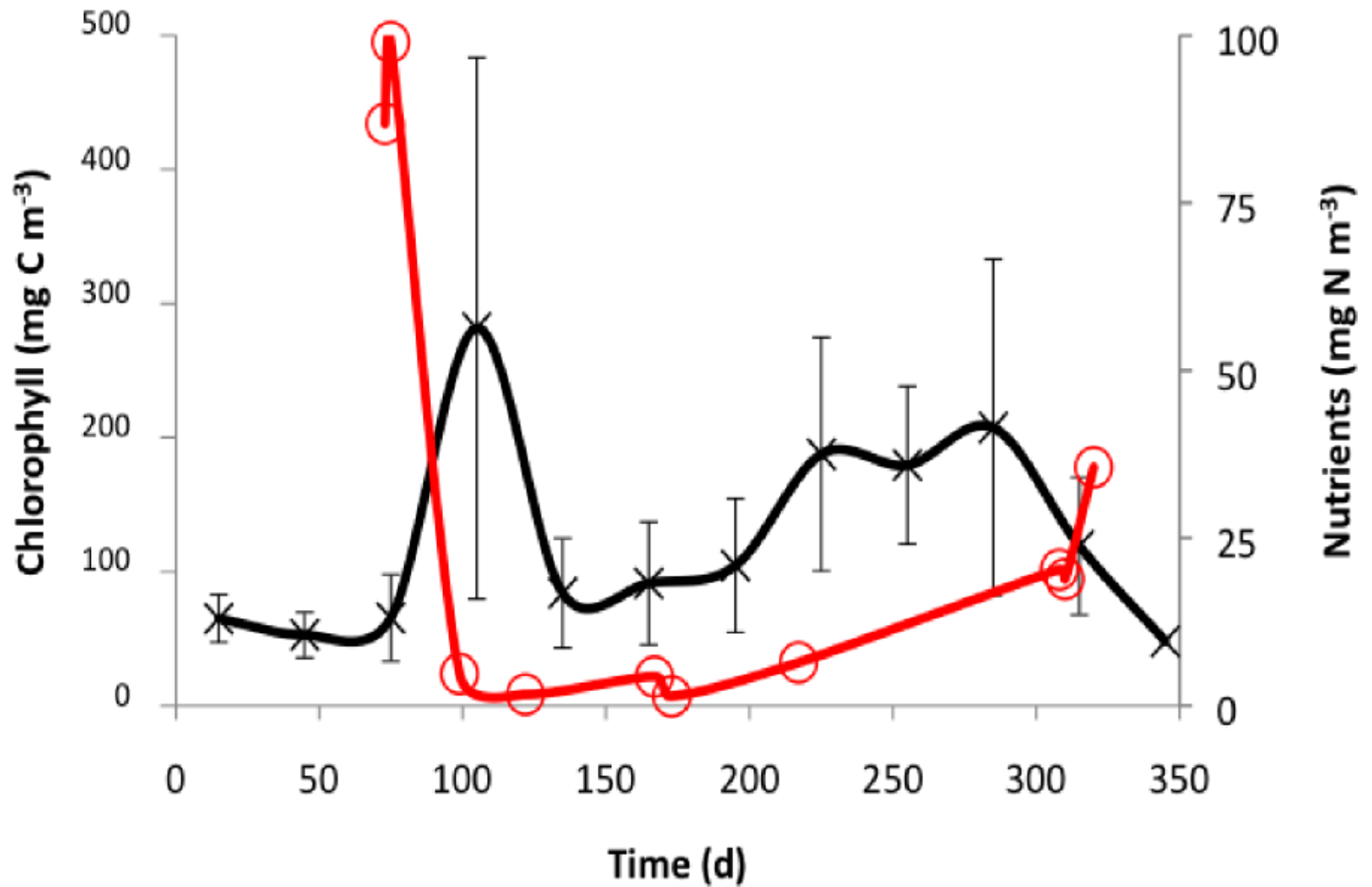
Tracer conditions indicating relative exchange rates in St. Ann's Bay.

1 km chlorophyll pixels, MODIS Aqua

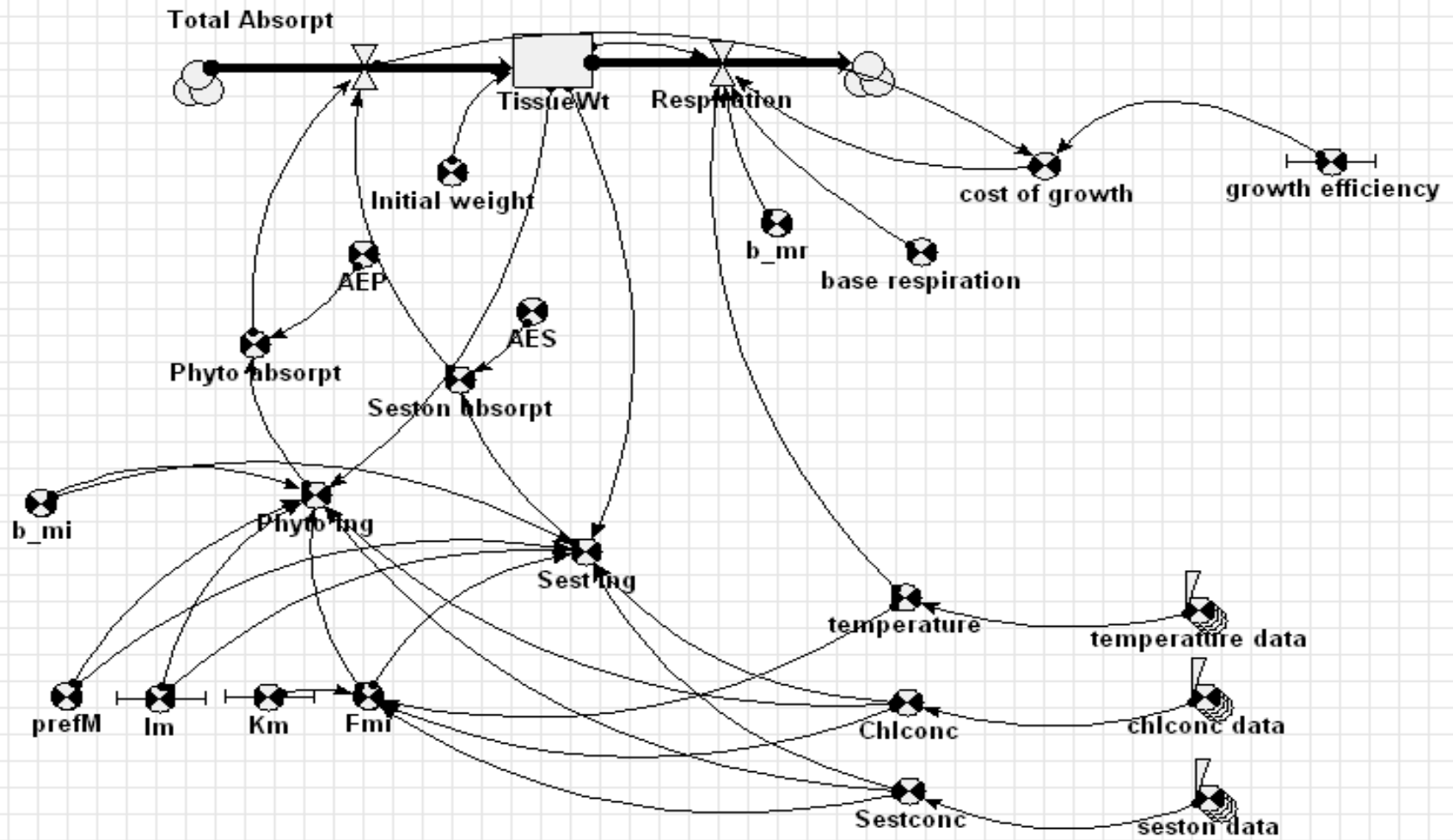


Digital elevation model

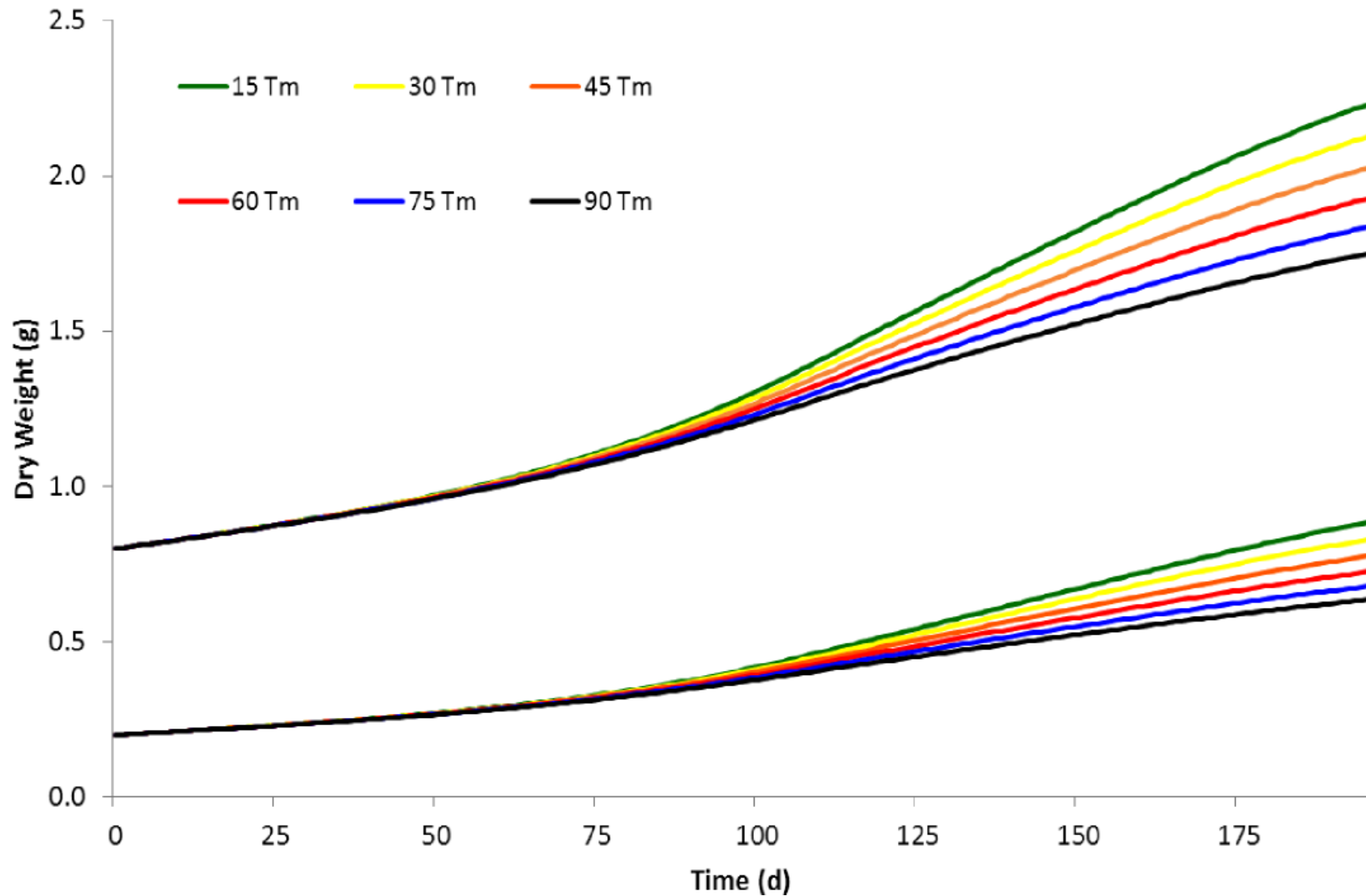




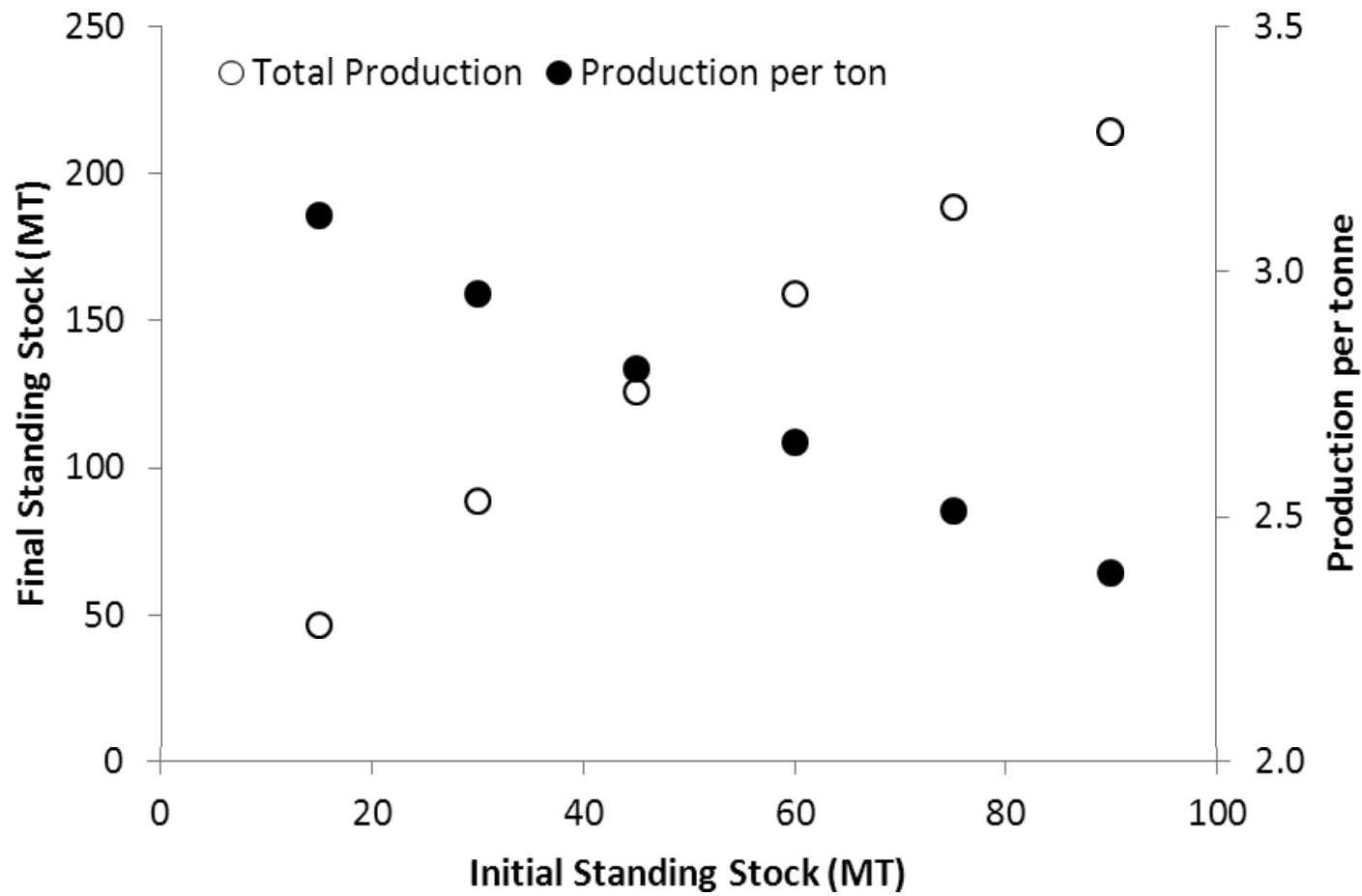
The chlorophyll and nitrogen nutrients time series used to force the model at the ocean boundary.



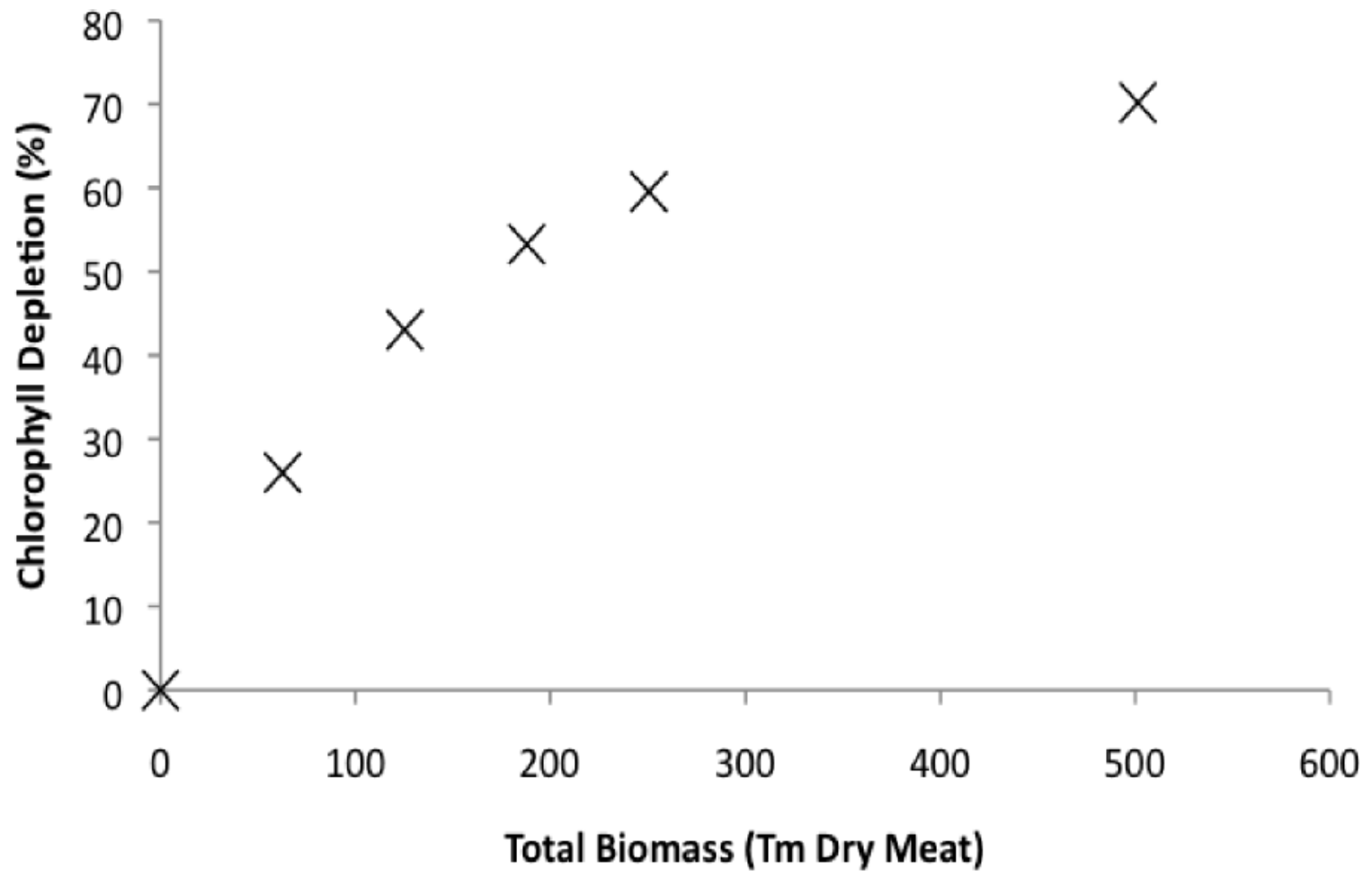
Submodel: mussel bioenergetics



Growth of individual mussels through time, Year 1 (lower lines) and 2 cohorts, as a function of stocking density



Relationship between stocking and yield, as well as normalized production on the right hand axis.

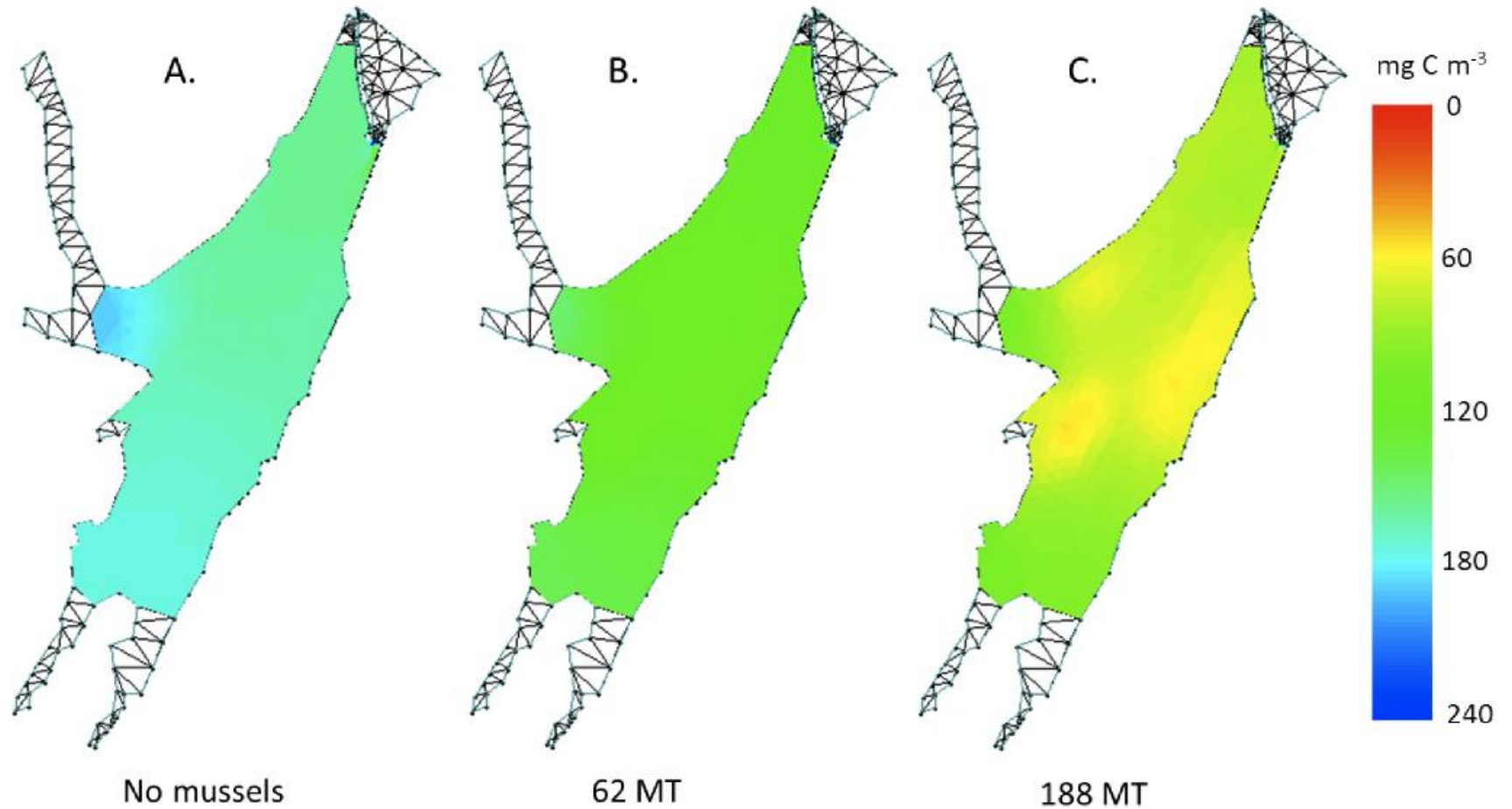


The relationship between stocked biomass and chlorophyll depletion.

Sustainability criteria:

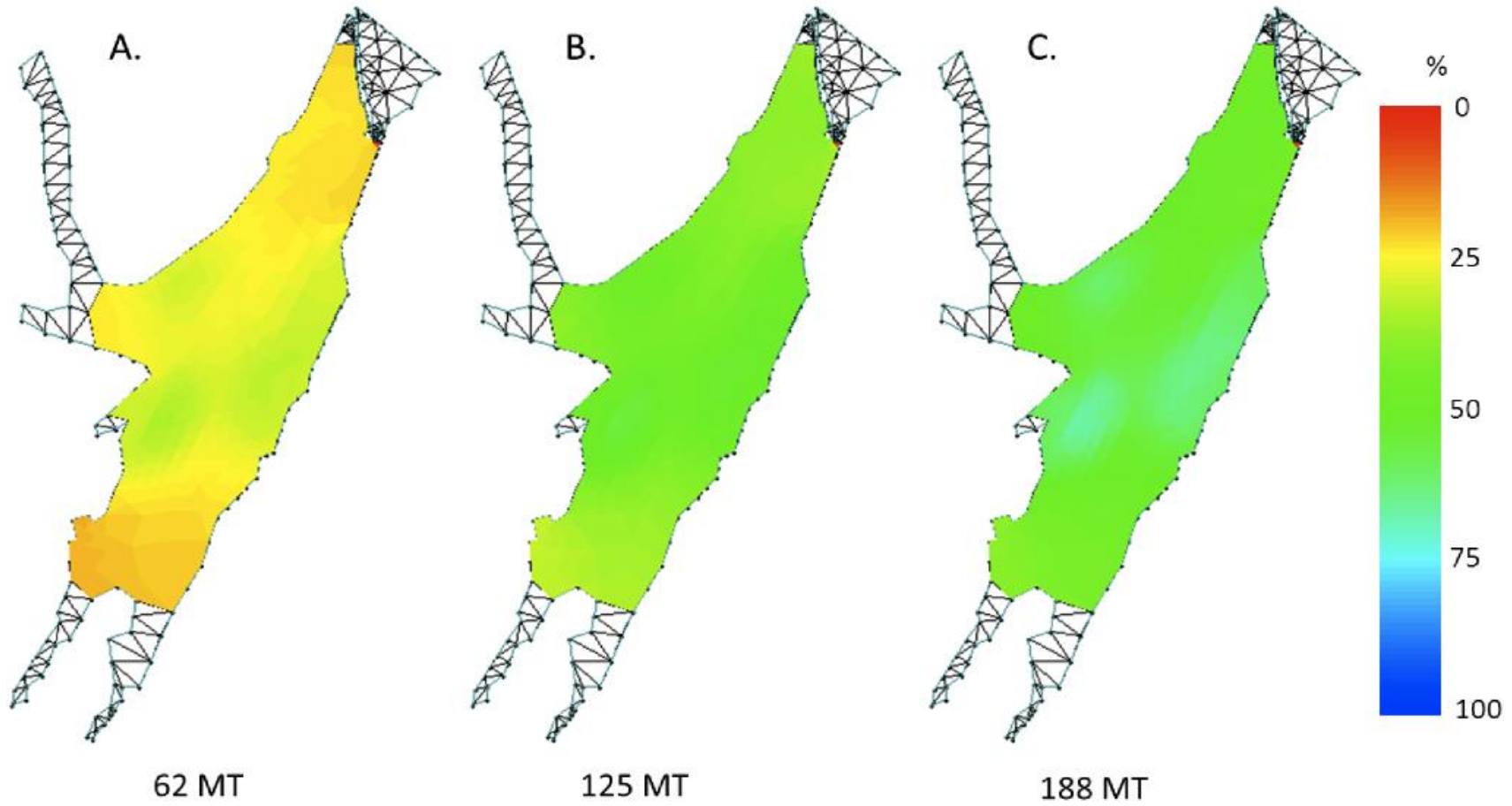
- Maintain ecosystem structure (focus on chlorophyll as the base of the food chain)
- Maintain ecosystem function
- Optimize growth rate according to harvest size or time
- Satisfy regulators, certification, etc.

Average Chlorophyll Content



Annual average of chlorophyll in St. Ann's Bay from model output, as a function of stocking density

Average Chlorophyll Depletion



Chlorophyll depletion relative to no mussels as a function of stocking density in St. Ann's Bay

Conclusions

Consequences of overstocking include a mussel growth penalty as well as an 'ecosystem penalty'

Culture may expand beyond carrying capacity during the growth cycle

Criteria for sustainability are not absolute.

Standards important to farmers and regulators will hopefully converge

Model is only useful as an adaptive tool in consultation. It is not delivered as an absolute.

Model is applicable to all bivalves, including oysters and has been used worldwide

Model can be used for benthic impacts of shellfish and finfish.