Modelling Carrying Capacity

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"Just wait 'til I get you home, my pretty."
Carrying capacity

“The amount of external influences that an ecosystem can support without significant negative impacts to its natural state”.

“Just wait 'til I get you home, my pretty.”
External influences

- Algae
- Shellfish
- Birds
- Humans
External influences

Fisheries → Birds → Shellfish → Algae
External influences

- Fisheries
- Aquaculture
- Shellfish
- Birds
- Algae
- Humans
External influences

Fisheries

Aquaculture

Mussel Seed Capture Devices (MZI's)

Algae

Shellfish

Birds
External influences

- Fisheries
- Aquaculture
- Mussel Seed Capture Devices (MZI's)
- Algae
- Birds
- Shellfish
- Invasive species
How to assess Carrying Capacity?

Biomass

- birds
- shellfish
- algae
How to assess Carrying Capacity?

Biomass

- birds
- shellfish
- algae

Generation time

- 2 years (730 days)
- 1 year (365 days)
- 2 days
How to assess Carrying Capacity?

Biomass

- birds
- shellfish
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Generation time

- 2 years (730 days)
- 1 year (365 days)
- 2 days

Production

- birds
- shellfish
- algae
Primary production

Drivers:

- Nutrients (input, residence time)
- Light (turbulence, depth)
PP in shallow coastal estuaries

Western Wadden Sea (Riegman)

Oosterschelde (Malkin & Kromkamp)
In shallow estuarine systems: large bottom-to-water ratio
--> relatively large role for bottom grazers
Secondary production

Drivers:

- Food (food concentration, quality, current velocity, …)
- Mortality / Predation
Drivers:

- Food (food concentration, quality, current velocity, …)
- Mortality / Predation

feedbacks!
Feedbacks of grazers on primary production

Light
(turbidity)
Feedbacks of grazers on primary production

- Nutrient recycling
- Respiration
- Defaecation
- Light (turbidity)
- Nutrient storage
Feedbacks of grazers on primary production

Nutrient recycling

Light (turbidity)

Grazing
Overgrazing

- Filtration rate of a mussel bed: ± 6 m³ hr⁻¹ per m²
- Average depth Oosterschelde: 9m
Overgrazing

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→ Water column can be filtered in 1.5 hr
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→ The whole Oosterschelde-system is filtered in 4-5 days!
Overgrazing

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If Grazing > Primary Production → Overgrazing
Selective grazing

Shellfish

Algae
Selective grazing

Larger algae are eaten
→ smaller algae remain in the system
Generic Ecosystem Model (Delft3D-GEM)

**Nutrients**
- N
  - NH₄-N
  - NO₃-N
- P
  - PO₄-P
  - AIP
  - Si

**Algae**
- C
- N
- P
- Si
- photosynthesis
- respiration
- nitrification
- mineralisation
- consumption
- mortality
- settling

**Detritus**
- C
- N
- P
- Si
- metabolism
- grazing
- settling
- oxygen consumption

**Detritus in Sediment**
- C
- N
- P
- Si
- mineralisation
- mortality

**AIP in sediment**
- C
- N
- P
- Si
- settling

**Microphytobenthos**
- C
- N
- P
- Si
- photosynthesis
- settling

**Extinction**
- PAR
- reaeration

**Grazers**
- consumption
- grazing
- oxygen consumption

**Grazers**
- consumption
- grazing

**DO**
- production
- consumption
- reaeration

**N₂ denitrification**
- mineralisation & nitrification

**Nutrient cycling**
- AIP
  - adsorption

**Microbial processes**
- autolysis
- nitrate reduction
- mineralisation & nitrification
- biodeposition
- biodeposition
- settling
Grazer module

Dynamic Energy Budget (DEB) model for shellfish
Oosterschelde spatial model
Primary production is mainly determined by depth.
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Primary production is mainly determined by depth

- Nutrient limited
- Light limited
Grazing

Chlorophyll concentration

- without grazers
- with grazers
Grazing

Chlorophyll concentration

Primary production

- Without grazers
- With grazers

measured
- modelled without grazers
- modelled with grazers
Grazing:

- negative effect on algal concentration
Grazing:
- negative effect on algal concentration
- positive effect on primary production
Grazing:
- negative effect on algal concentration
- positive effect on primary production
- improved agreement with measurements
Effects SMC-mussels on primary production

- No grazers
- Existing grazer biomass

Graph showing:
- Primary production (gC/m²/yr) on the y-axis
- Percentage of actual grazer biomass (%) on the x-axis

Legend:
- O - existing grazer biomass
- O - no grazers
Effects SMC-mussels on primary production

The graph shows the relationship between primary production (gC/m²/yr) and the percentage of actual grazer biomass (%). The graph has two key points:

1. **No grazers**: This point represents the condition where no mussels are present, showing a baseline primary production.
2. **Existing grazer biomass**: This point indicates the primary production when mussels are present, showing a positive effect on primary production.

The graph also indicates the negative impact of overgrazing, where the primary production decreases significantly as the percentage of actual grazer biomass increases beyond a certain threshold.
The effect of adding grazers (e.g. SMCs or aquaculture) depends on the actual situation of the system.
Effects SMC-mussels on secondary production

Secondary production (gWW/yr)

Yield MZI mussels (gWW)

- oesters
- kolkels
- mosselen
- MZI-mosselen
Effects SMC-mussels on secondary production

The effect of adding grazers (e.g. SMCs or aquaculture) is different per species.
Parameter values from measurements and experiments

- ensis
- mussels
- cockles
- oysters
Other developments

- Asses the 2-way interaction between current velocity-shellfish filtration
Other developments

- Asses the 2-way interaction between current velocity-shellfish filtration

- Asses the effect of the spatial distribution of the MSC on the carrying capacity
Conclusions

- Feedback processes of shellfish on primary production can be significant (+ and -)
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- Impact of external influences on carrying capacity depends on actual situation!
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- Impact may differ per species
Conclusions

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- Impact may differ per species

- Best approach for ecosystem based studies: coupled modelling, field observations and experimental process studies