Modeling secondary production in the Norwegian Sea with a fully coupled model system

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• Background and motivation
• Coupled model system
  • Model upset and parameterizations
  • Trophic coupling and impacts of various drivers
• Summary and future plans –towards NORWECOM.E2E
Need: an integrated system of models that describe the ecosystem function with focus on processes of importance to harvestable stocks
Coupled model system

- OCEAN MODEL
  - NORWECOM

- PHYTOPLANKTON MODEL
  - IBM

- 3D field of current, temperature, turbulence

- Predator field

- Phytoplankton distribution

- C. FINMARCHICUS
Prognostic variables: Primary production (diatoms, flagellates), nutrients (inorganic nitrogen, phosphorus, silicate), oxygen, detritus, biogenic silicia, light in water column, suspended matter.
Forcing by: light, temperature, nutrients (river+atmosphere), algae death

Processes included: respiration, regeneration of nutrients, self shading, turbidity, sedimentation, resuspension, denitrification, detritus (N and P) and diatom skeletals (Si), oxygen.

Individual-based model (IBM) Calanus-model

From http://pulse.unh.edu/

Feeding: functional response, type 2 (Campbell 2001)

Growth: bioenergetics (Carlotti & Wolf 1998)

Reproduction: mature adults above weight and fat thresholds, in mixed layer

Vertical movement: dvm, annual cycle

Horizontal movement: by currents

Huse et al (in prep)
Calanus mortality

1. Geographical limitations (Nordic Seas)
2. Stage specific weight limitations (i.e. starvation)
3. Age and spawning stress limitations (< 400 days and <800 eggs)
4. Invertebrate predation parameterized (not year specific)
   1. day/night dependent
   2. geographically uniform & exponentially decaying in upper 1000m
5. Predation from pelagic fish parameterized (not year specific)
   1. preysize and daylight dependent
   2. geographically uniform & restricted to upper 600m
Physical forcing for year 1997

NORWECOM initialization
- Typical winter values of Atlantic water for nutrients (12.0, 5.5 and 0.8 uM inorganic nitrogen, silicate and phosphoros)
- Small amounts of algae (0.10 mgNm$^{-3}$)
- 200 mgN/m$^2$/year added from the atmosphere

CALANUS initialization
- 50,000 super individuals with influence ratio of 4 gridcells
- "Standard" initial $C. Finmarchicus$ distribution
- $\sim 10^{11}$ C5 individuals distributed on 50,000 super individuals
- Structural weight 80µg, fat level 40µg; total mass: 17 mill tonn C
- Overwintering depth 300-1100m
- Diapause termination: Feb 10 – April 9
Model performance

Initial no of calanus (overwintering C5) 100*fold increased, slightly elevated at end of simulation

Biomass ~stable

No of super-individuals elevated; increased computer time 😞
Calanus Finmarchicus copepodite abundance
Initial: \(0-100,000\) ind/m\(^2\)

Apr-July: peak values of \(400,000\) ind \(m^{-2}\), \(40,000\) ind \(m^{-2}\) C6

Overwintering population: \(0-100,000\) ind \(m^{-2}\), in Atlantic Water zone
Geographical distribution of a) annual production and b) mean of daily top to bottom biomass. Unit is $\text{gC/m}^2$. Below panels the same quantities integrated within the Norwegian Sea.

**Biomass:**

~$10 \text{ gC m}^{-2}$
Norw Sea: 8 mill tonnes C

**Production:**

~$60 \text{ gCm}^{-2}$
Norw Sea: 34 mill tonnes C

**PB ratio:**

Annual production/mean summer biomass = 6.3
Trophic coupling through Calanus mortality

Geographical limitations
Starvation
Age and spawning stress
Invertebrate predation
Diapause termination

WUD early:
• production weakly increased in Atlantic Water zone/coastal waters; otherwise reduced.
• Biomass increase in Atlantic Water zone, reduced elsewhere.

WUD late:
• production decreased in coastal waters, increased elsewhere.
• Biomass reduced in coastal/Atlantic Water zone, increased elsewhere.

WUD light dependent:
• production pattern as for WUD early.
• Biomass weakly increased in northern coastal/Atlantic Water zone, decreased elsewhere.
Summary

- Coupled model system for the Norwegian Sea implemented and running
- ~50,000 calanus super-individuals sufficient
- Stable biomass development; multi-year simulations possible
- Two way coupling between different trophic levels
  - Stock collapse due to food limitations within one year possible
  - Diapause termination changes production more & different than biomass
- Towards end-to-end modelling:
  NORWECOM.E2E is a suitable model tool to study ecosystem dynamics
- Flexible module system allows easy inclusion of new species
NORWECOM.E2E
future plans

OCEAN MODEL
ROMS

PHYTOPLANKTON
MODEL
NORWECOM

C. Finmarchicus
C. Glacialis
C. Hypoboreus
C. Helgolandicus
Krill

Phytoplankton
distribution

Predator field

Herring, blue whiting,
mackerel
Mesopelagic fish and
Gonatus
Marine mammals
Fish larvea.......

Zooplankton
distribution

Phytoplankton
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Predator field

3D field of current, temperature, turbulence
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