

Long-term yield of cod in the Barents Sea – a joint Russian-Norwegian ecosystem approach

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Improving management of fisheries by

- Including species interactions and environmental impacts into fish stock assessments
- Evaluating harvesting control rules, also on a multispecies basis
- Mike Sinclair:
 - 1: Effects on ecosystem
 - 2: Effects from ecosystem
 - 3: Manipulation
- This project: 2 (adjust expectations)
- It's about knowledge production and integrating knowledge



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Image © 2006 NASA

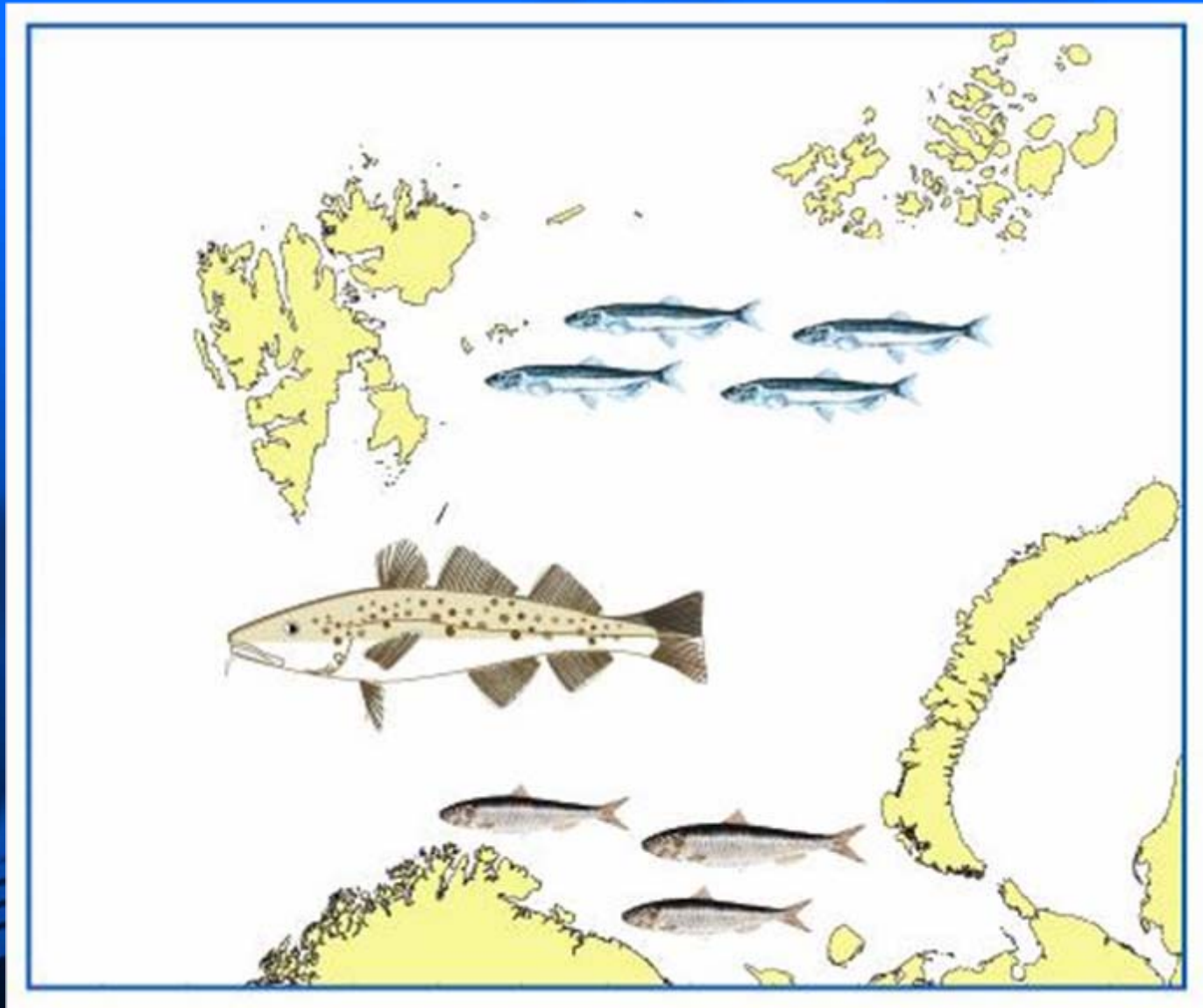
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Pointer 74°42'20.60" N 37°49'05.21" E

Streaming ||||| 100%

Eye alt 3667.95 mi

Basic model EcoCod: Background

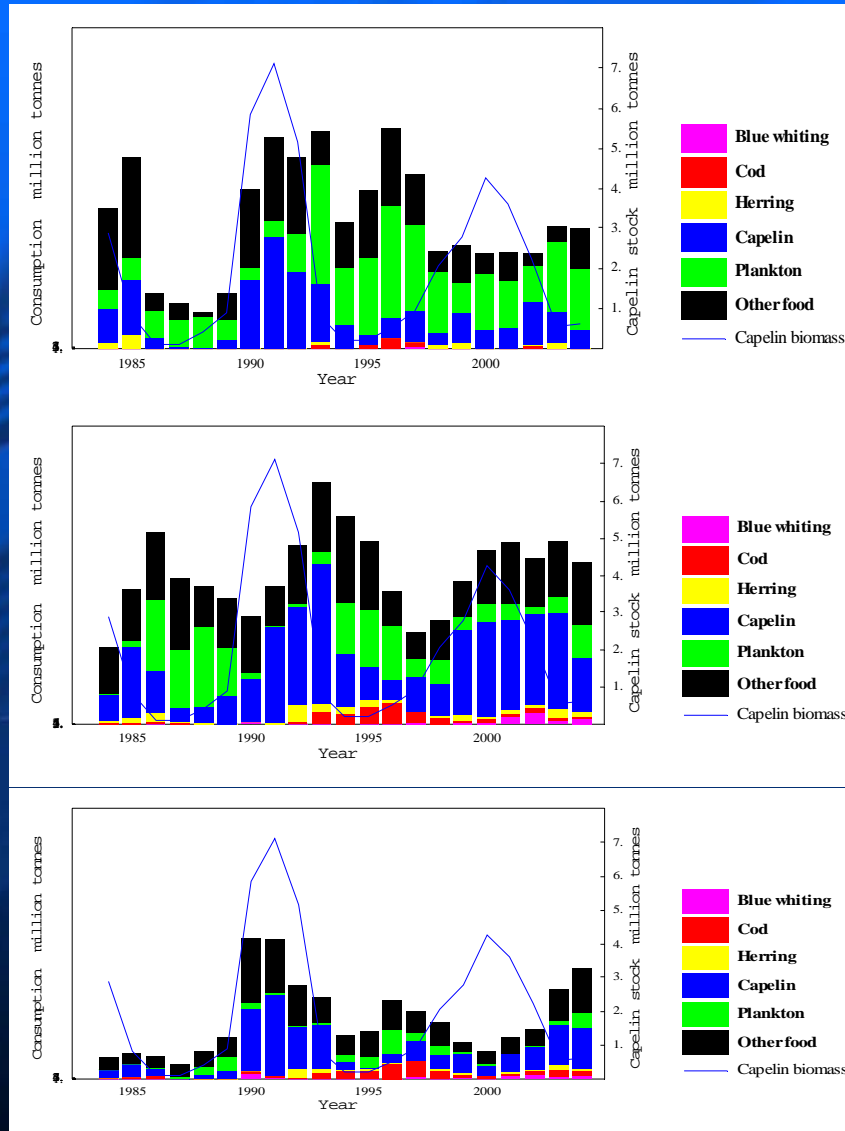


Basic model EcoCod: Background

1-2 years

3-6 years

7 years
and older

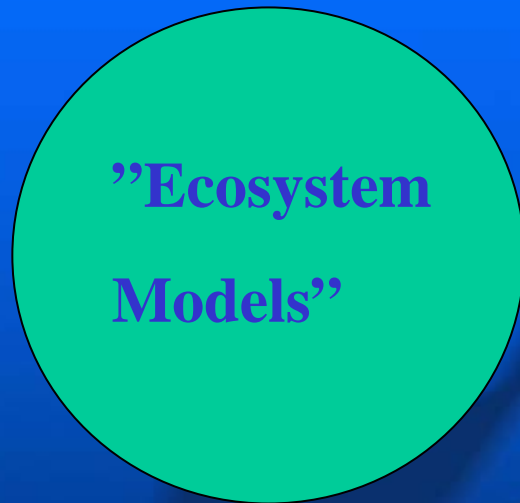




The role of the Russian-Norwegian Fishery Commission

- Negotiating quotas
- Cod:
 - Adopted HCR based on Precautionary Approach considerations
 - Is this good in the long term?
 - **REQUEST:** What are the perspectives for long term yield taking into account species interactions and influence from the environment?
 - Existing science
 - Later to comprise other species (order of priority)
 - Capelin
 - Herring
 - Harp seal
 - Minke whale
 - Shrimp
 - Haddock
 - Etc.

Implementing the Ecosystem Approach: Relating to fish, relating to decision makers



Biologists

Modellers

Assessment

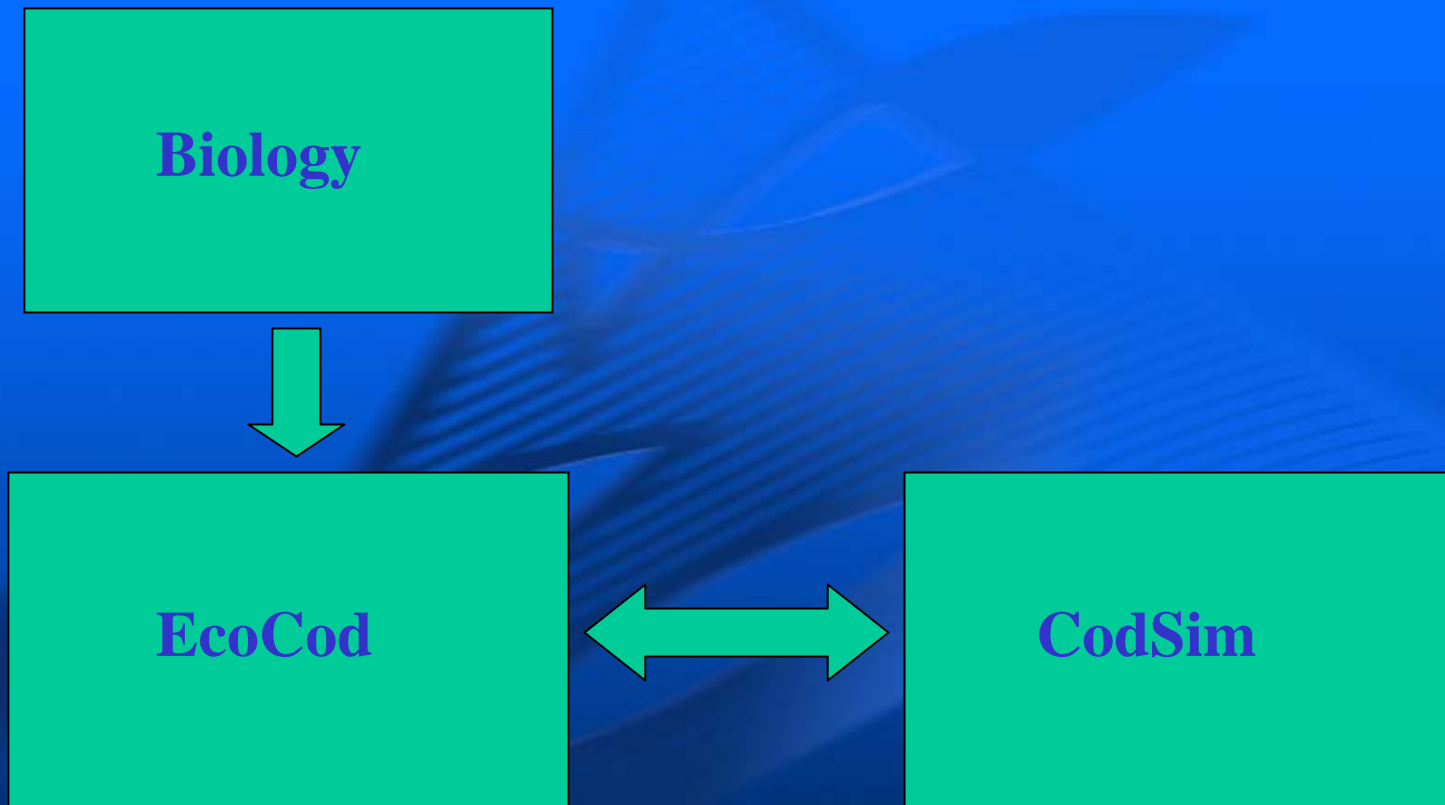
Quota setting

Managers

Starting point

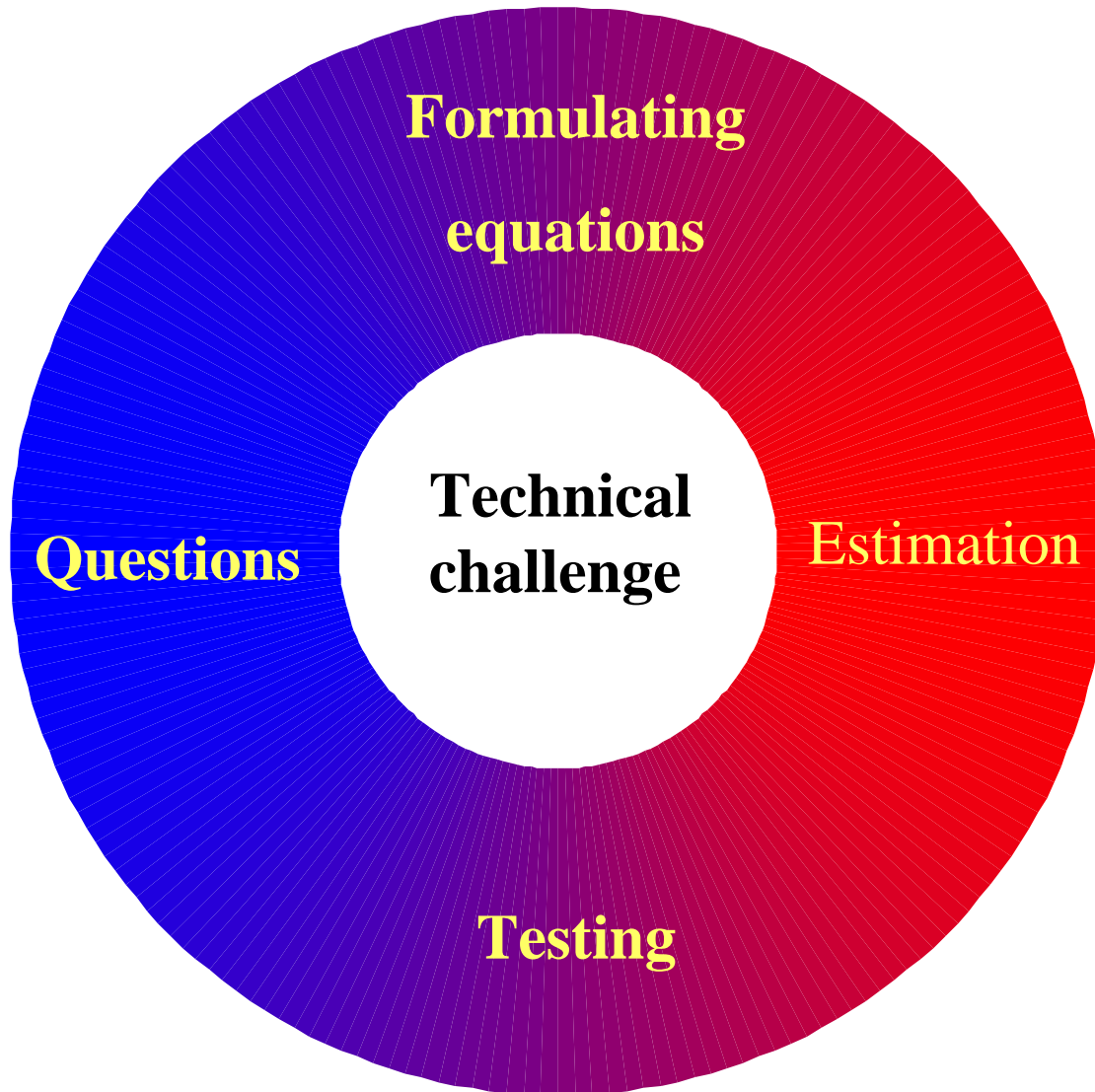
- A HCR for cod has been tested by the model CodSim (in PROST), which is implemented in the line ICES WG -> Commission. The HCR is adopted and now in use
 - $F = 0.40$ (B_{lim} considerations)
 - F decreased when $SSB < B_{pa}$
 - Stability, only 10% change from previous year when $SSB > B_{pa}$
 - Destroyed by illegal fishery
- Technical solution (practical and implementational considerations)
 - PROST is kept as it is
 - Density dependent weight and maturation
 - Cannibalism on age 3 and older
 - Augmented little by little using a separate model EcoCod

Modelling

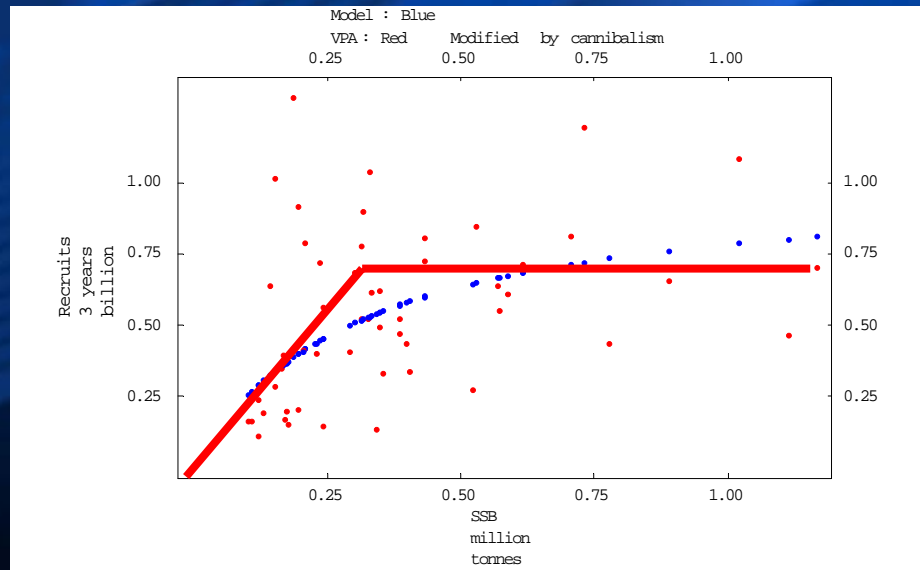
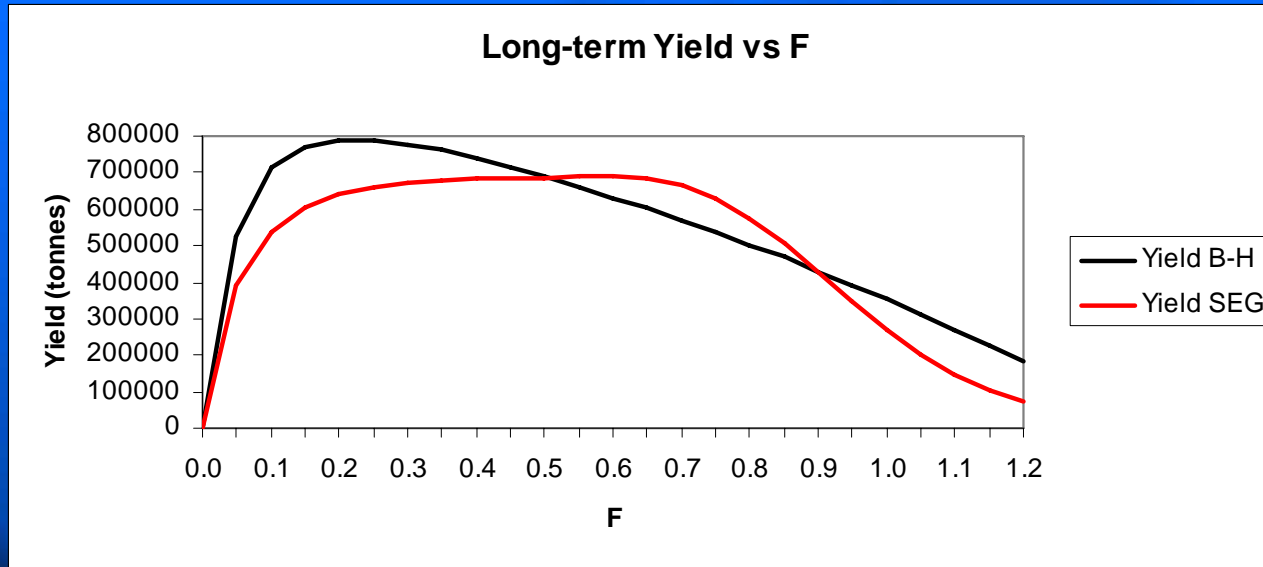


The crux: Spawning stock – recruitment relationship

The modelling cycle



Starting point: Recruitment relation matters



Organisation of project

- Jointness in all parts, essential for successful implementation
- First stage: 2005-2007 – Cod i focus
- Second stage: 2008 – 2014 – Multispecies modelling
 - STOCOBAR
 - Bifrost
 - SystMod
 - Further elaboration of EcoCod

How does a changing environment change cod population dynamics?

- Environment: Temperature and capelin
- Growth
 - Increases with temperature
 - Increases with food abundance
- Fecundity
 - Increases with food abundance
- Malformation of eggs
 - Decreases with age (Env. Effect not linked to model temperature yet)
- Mortality
 - Decreases with food abundance (Cannibalism)
 - Increases with marine mammals
- Recruitment
 - Increases with temperature
 - Increases with food abundance (SSB)
 - Decreases with food abundance (Cannibalism)

Non-modellable entities: Scenarios

- Temperature
- Marine mammals
 - Problematic: Harp seals
 - Technical problem: Marine mammals influence M on cod in the assessment (age 3 and older)

Regressions

- Growth of cod
 - Capelin has an effect of cod younger than 7 years
 - Temperature has an effect on cod younger than 8 years
 - Cod has an effect for all age groups, most pronounced for the oldest
- Fecundity
 - Dependent on length and condition
- Malformation of eggs
 - Dependent on age (environmental effect?)
- Skipped spawning
 - Fish with condition less than 0.7 skips second-time spawning
 - Distribution (normal) of condition from August surveys
 - Mean condition from model
- Pre-recruit cannibalism
 - Dependent on capelin

The cod-capelin-plankton-herring model



The cod-capelin-plankton-herring model

(estimated parameters in red)

- Biomass age-structured capelin model
- Capelin recruits as 2 years
- Mature capelin: > 14 cm in autumn
- Capelin model:

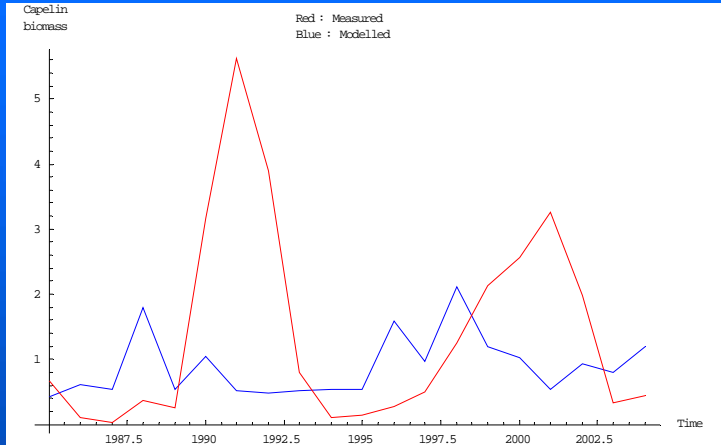
$$\text{capelinRecruits} = \text{capRecMax} \tilde{a} \text{capRecHerr} \text{youngHerring} \frac{\text{capelinMatureBiomass}}{\text{capRecHalf} + \text{capelinMatureBiomass}}$$

$$\text{capelinBiomass} = \text{capelinBiomass} + \tilde{a} \text{capelinMortality} + \text{weightCapelinPlankton} (\text{planktonBiomass} - \text{weightCapelinPlanktonSetpoint}) - \text{capelinCod} \text{TotalCodBiomass}$$

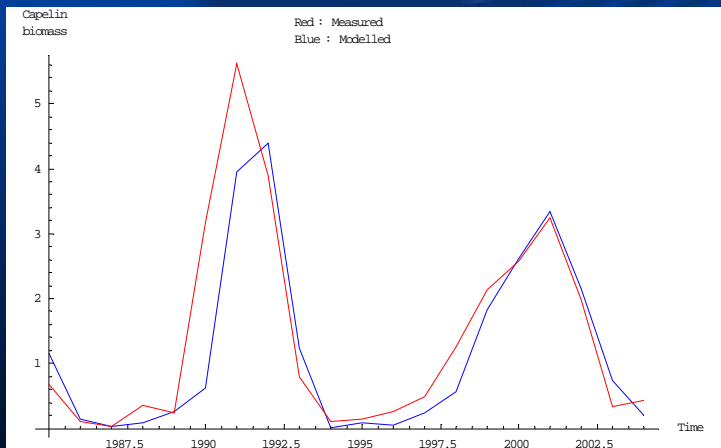
- Plankton model:

$$\text{planktonBiomass} = \text{planktonBiomass} + \text{planktonCapelin} (\text{planktonCapelinSetpoint} - \text{capelinBiomass}) + \text{inflow}$$

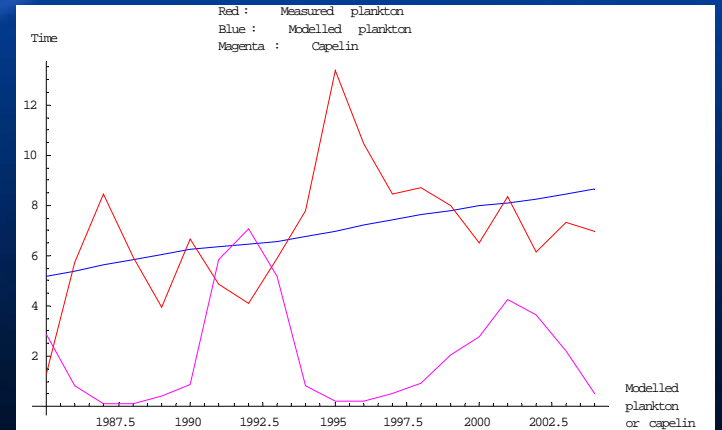
The cod-capelin-plankton-herring model



No update capelin
– good fit to plankton



Update capelin –
good fit to capelin



Simulations

- Constant cod length distribution
- Constant capelin maturation ogive
- Constant temperature
- Constant herring abundance
- Temperature affects (as yet) only growth of cod younger than 7 year (not recruitment)
- Uncertainty: Only estimation uncertainty in cod recruitment
- 150 years, 10 replicates

Modification of MSY

F

Range:

0.06

20%

F_M

B

S

G^C

A

MSY: Range 1 million tonnes

Large variation in MSY, small variation in F_{MSY}

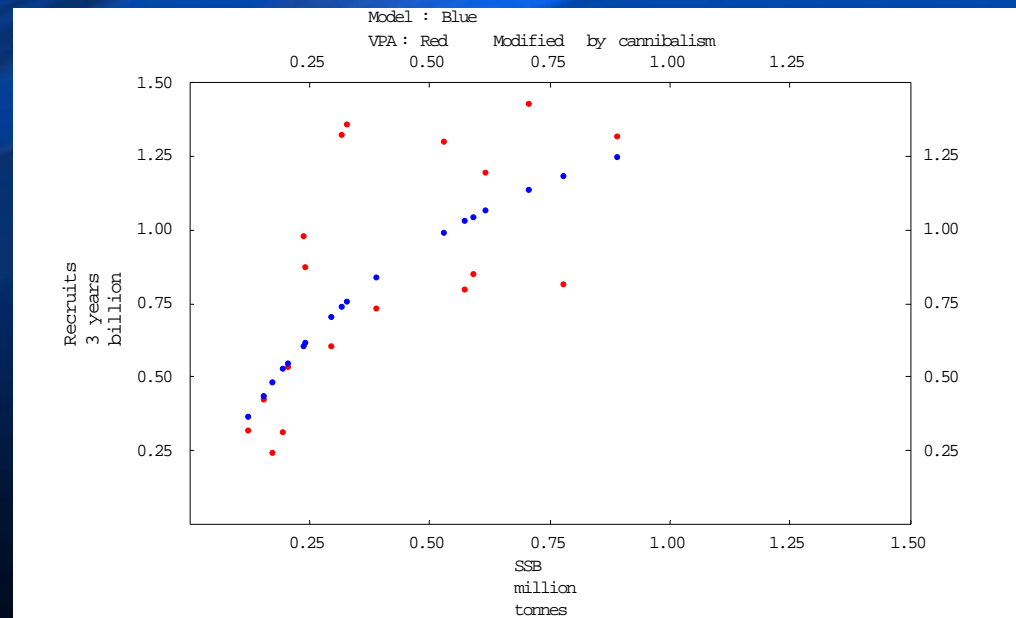
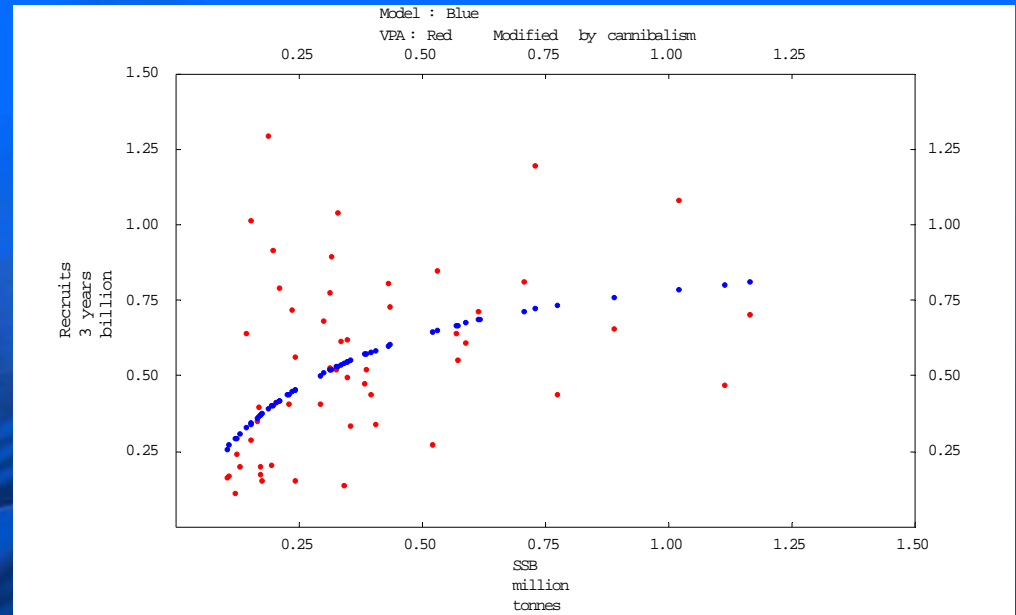
Must explore the spawning stock – recruitment relation

It's all in the recruitment relation

PROST model

Including
ecosystem effects

(only recent
points)



Next steps

- Stochastic herring scenarios from herring assessment model
- Improvement of recruitment relation
 - Temperature
 - Model uncertainty
- Plankton as food for cod
- Marine mammals
- Uncertainty
 - Here: Only estimation uncertainty in recruitment model
 - Uncertainty in other sources
 - Model uncertainty
 - Recruitment
 - Beverton-Holt
 - Segmented regression
 - Other
- Implementation
 - IMR/PINRO
 - Commission (“Basic Document”)
 - ICES (Arctic Fisheries WG)
 - Stakeholders?

