Evaluation of maximum long-term yield for Northeast Arctic cod

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Aim of study

- To evaluate maximum long-term yield of Northeast Arctic (NEA) cod in a single-species context
- First sub-project in the joint Russian-Norwegian research program: “Optimal long-term harvest in the Barents Sea ecosystem”
Background

- Previous studies of long-term yield of NEA cod have been made using models with very simplistic population biology.
- Time series of weight and maturity at age were revised in 2001, and more biological knowledge should be utilized in such studies.
- J RNC harvest control rule (F=0.40 above $B_{pa}$ max 10% annual change in TAC) found to be precautionary, but important also to search for rules giving maximum long-term yield.
Method

- Stochastic long-term simulations are made using the computer program PROST
- Runs are made for a 100-year period, and the mean yield etc. for the last 80 years of the period is calculated
- Age groups 3-13+ used, as in current assessment
- Assessment error ignored
Population sub-models

- Recruitment
- Growth
- Maturation
- Natural mortality/cannibalism
- Fishing pattern
Stock-recruitment for NEA cod

Segmented regression function fit to data

SSB, thousand tonnes.

Recruitment age 3, million individuals
Population models

- Cyclic term and stochastic term added to segmented regression recruitment function
- Density-dependent weight at age in stock for age 6-9
- Weight at age in catch and maturity a function of weight at age in stock
- Cannibalism on age 3-4 a function of predator (large cod) abundance or of SSB 3 year previously
Harvest control rule/fishing pattern

- Will only show results of fixed F rules
- Fishing pattern as present or shifted one age group up or downwards
Yield – changing selection pattern and density-dependence

![Yield versus F graph](image-url)

- **Yield versus F**

  - **1000 Tonnes**

  - **F5-10**

  - **Standard pattern**
  - **Pattern+1 year**
  - **Pattern-1 year**
  - **Not-dens-dep**
SSB- changing selection pattern and density-dependence

SSB versus F

1000 Tonnes

F5-10

- Standard pattern
- Pattern+1 year
- Pattern-1 year
- Not-dens-dep
Yield for different cannibalism functions

![Graph showing yield for different cannibalism functions with two functions labeled Function 1 and Function 2. The graph plots yield (in 1000 Tonnes) against a parameter F, ranging from 0.00 to 1.20. The curves for Function 1 and Function 2 are distinct, with Function 1 peaking earlier and Function 2 peaking later.]
Conclusions

- Method/framework for studying maximum LTY for NEA cod has been established
- Maximum LTY around 900 000 tonnes for F in range 0.2-0.4
- Including cannibalism *may* change this result
- LTY drops significantly above F=0.7
- Results for F below 0.2 extrapolations (higher stock sizes than historically observed) and thus not reliable
Choice of strategies

- The fishing mortality used in the current management strategy ($F=0.40$) seems to give long-term yield close to maximum.

- Should stick to this strategy for some years, to get observations of how the stock behaves when exploited at $F$ values around 0.40.

- Further work: How to find compromise between precautionary rules, maximum yield and stability?
Further work

- Add more biological knowledge
- Improve time series of data (discards, cannibalism before 1984 etc.)
- Try different functional forms for biological processes
- Include assessment uncertainty
- Extend to multispecies models
- Effect of climate changes
- Genetic effects