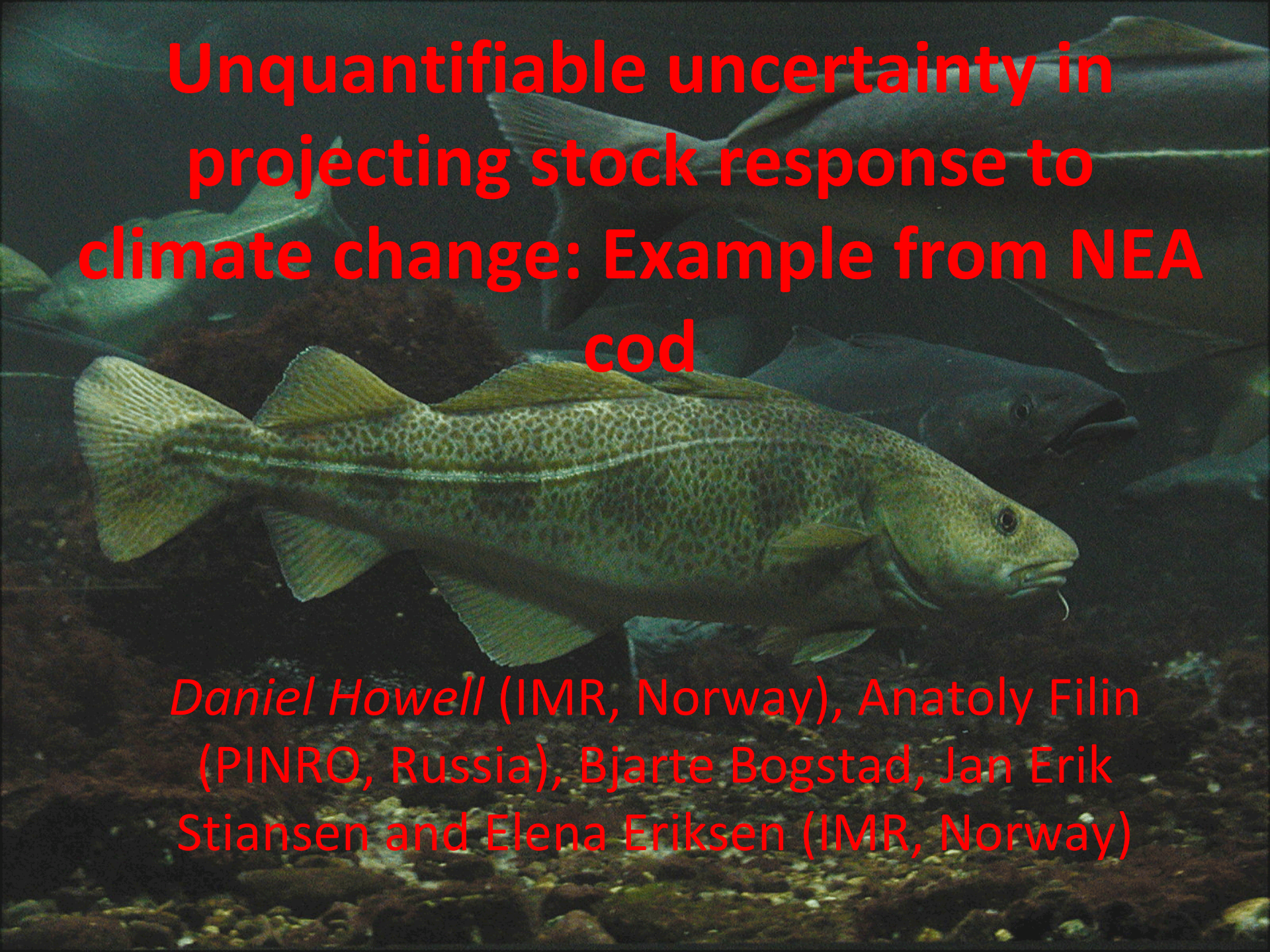
Unquantifiable uncertainty in projecting stock response to climate change: Example from NEA cod



Daniel Howell (IMR, Norway), Anatoly Filin (PINRO, Russia), Bjarte Bogstad, Jan Erik Stiansen and Elena Eriksen (IMR, Norway)

OR

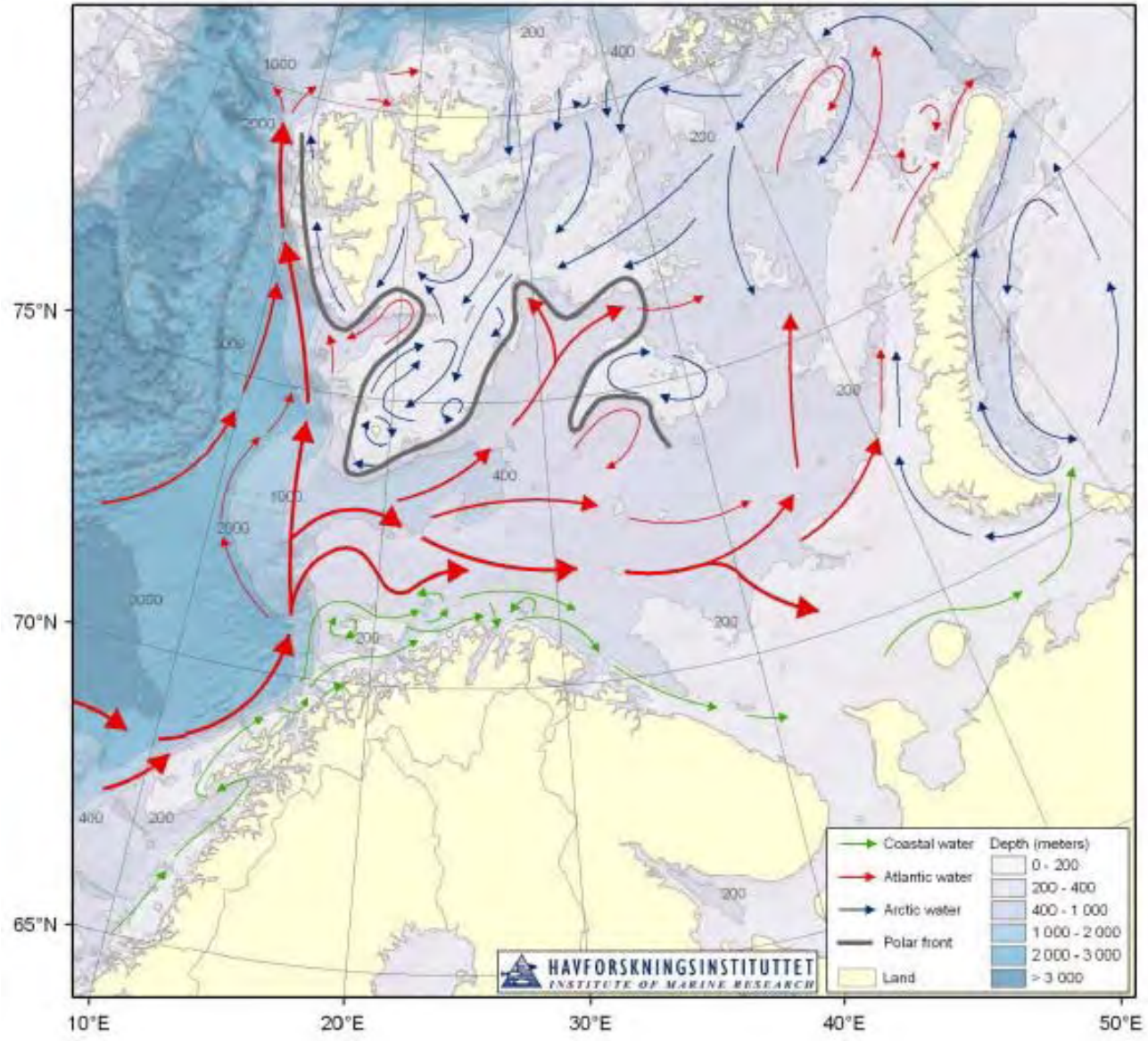
“No, we can’t”

Daniel Howell (IMR, Norway), Anatoly Filin (PINRO, Russia), Bjarte Bogstad, Jan Erik Stiansen and Elena Eriksen (IMR, Norway)

Aim

- Funding agencies in Europe are increasingly asking for uncertainty estimates for multispecies/ecosystem projections
- There are many (many, many) sources of uncertainty in modelling ecosystem responses
- Focus on just one single source
  - Real world example, with good historical data
- Questions are:
  - Does this one source matter?
  - Can we (ever) quantify the uncertainty?

Barents Sea


75°N
70°N
65°N
10°E
20°E
30°E
40°E
50°E
Coastal water
Atlantic water
Arctic water
Polar front
Land
Depth (meters)
0 - 200
200 - 400
400 - 1 000
1 000 - 2 000
2 000 - 3 000
> 3 000
HAVFORSKNINGSINSTITUTTET
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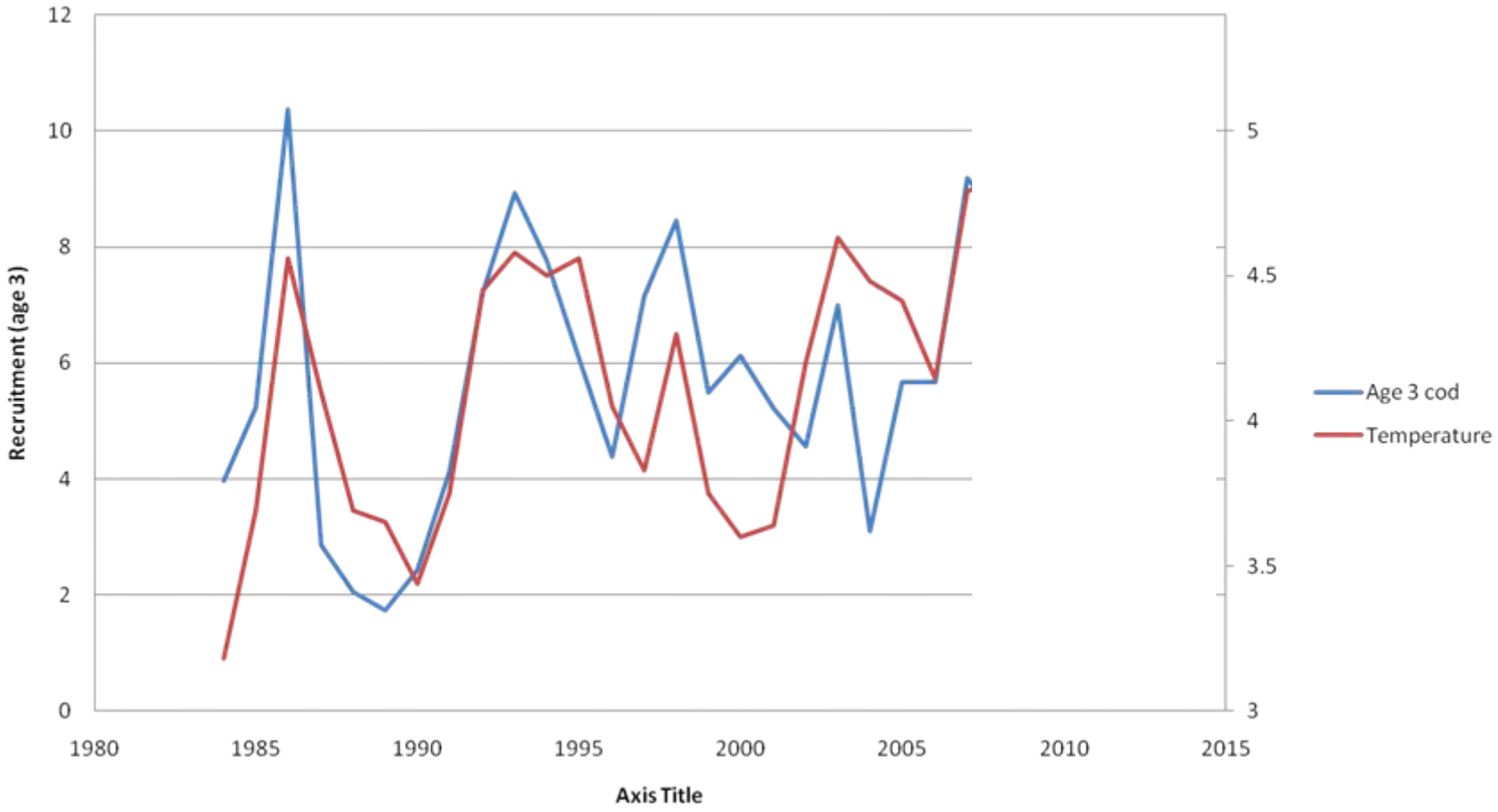
Age 3 cod, Kola Section temperature in year of spawning

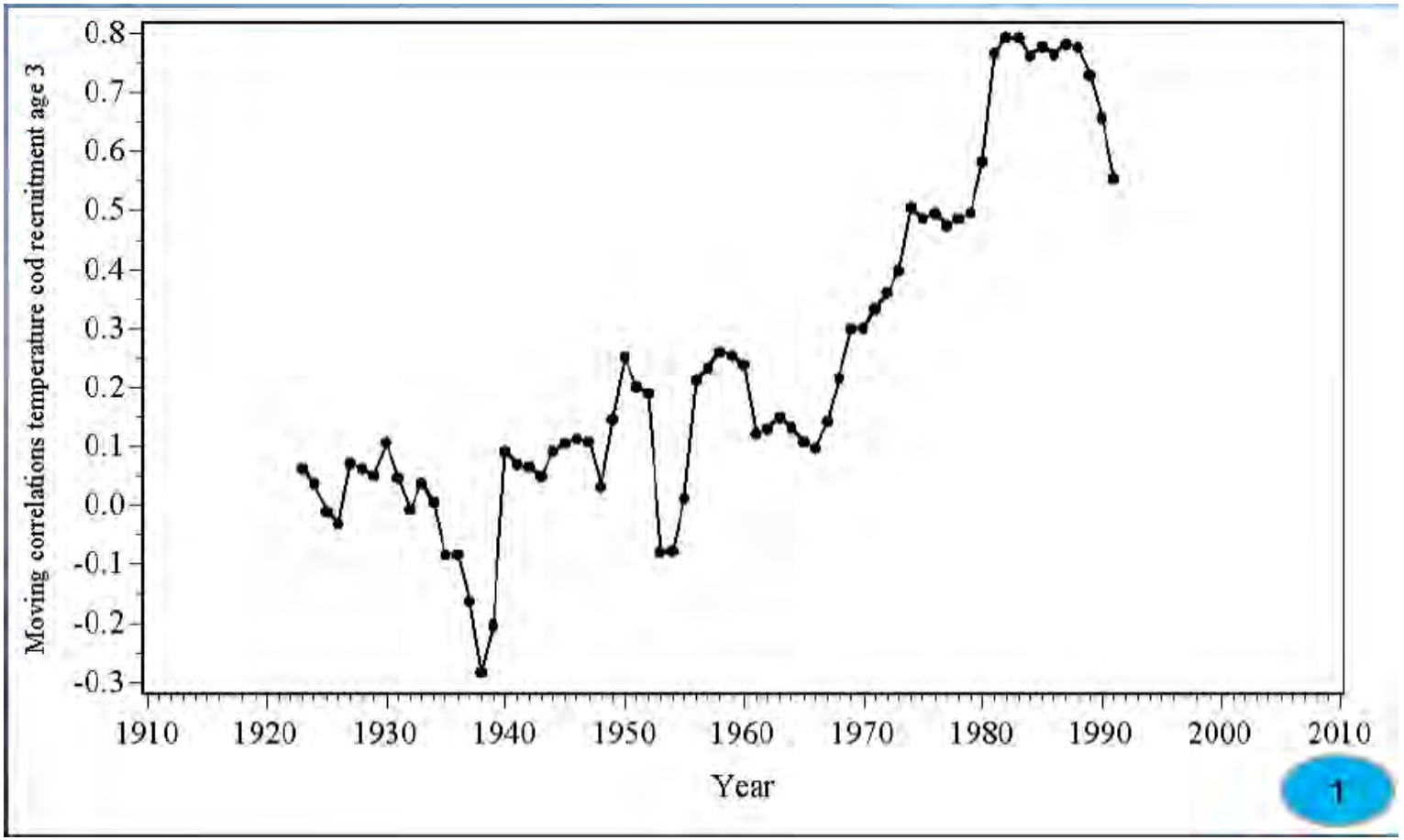


Age 3 cod, Kola Section temperature in year of spawning

Why did this change happen?

- We don’t know
- Maybe thresholds on temperature effects?
- Cod SSB is at record level?
- Cod age structure is becoming more diverse?
- Herring has recovered from their collapse?
- Sea ice changes?
- Or something else?
- Or the wrong question entirely?

Moving correlations between Kola sea-temperature and cod recruitment age 3 (21-year window)



Modelling temperature impact

- Temperature has several effects in our models on the Barents Sea cod:
- Growth
- Consumption
  - Hence cannibalism on young fish
- Recruitment?
  - From adult spawners through to age 1 fish the following year

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Modelling temperature impact

- Temperature has several effects in our models on the Barents Sea cod:
- Growth **<- Process based**
- Consumption **<- Process based**
  - Hence cannibalism on young fish
- Recruitment? **<- NOT process based**
  - From adult spawners through to age 1 fish the following year

Recruitment ”relationships”

- ~~F=MA~~

~~Total Energy – Et:~~ $$\frac{\partial(E_T)}{\partial t}+\frac{\partial(uE_T)}{\partial x}+\frac{\partial(vE_T)}{\partial y}+\frac{\partial(wE_T)}{\partial z}=-\frac{\partial(up)}{\partial x}-\frac{\partial(vp)}{\partial y}-\frac{\partial(wp)}{\partial z}$$
$$+\frac{1}{Re_r}\left[\frac{\partial}{\partial x}(u\tau_{xx}+v\tau_{xy}+w\tau_{xz})+\frac{\partial}{\partial y}(u\tau_{xy}+v\tau_{yy}+w\tau_{yz})+\frac{\partial}{\partial z}(u\tau_{xz}+v\tau_{yz}+w\tau_{zz})\right]$$
$$-\frac{1}{Re_rPr_r}\left[\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}+\frac{\partial q_z}{\partial z}\right]$$

- Recruitment is some function of: SSB, salinity, currents, food, predators, temperature, adult size and condition, spatial overlap, somehow, probably, maybe

Regression relationships

- Just seen from how complex it is to quantify and model even part of this process
- Most models use regression on one (or more) environmental variables to fill the gap
- Fine for describing what has happened
- Problematic for predictions
  - Moving beyond range of observations
- Widely used in ecosystem/multispecies modelling

Projecting regression relationships

- At some point in the changing future any regression relationship is likely to change
  - **Don't** know when
  - **Don't** know how
- Have no data to quantify these uncertainties
  - Can't bootstrap data that doesn't exist
  - Baysean doesn't help without data
  - Ensemble modelling can't help quantify these
- **=> Unquantifiable uncertainty**
- Does it matter to our stock projections?

The small question

- Here is our specific question:
  - Are there significant effects on model projections from the (unquantifiable) uncertainty in the breakdown of the historical temperature recruitment relationship?
- Here this breakdown has happened in the past, so we have data on the change
- Similar breakdowns can be expected in other regression relationships

STOCOBAR model

- Russian developed, Barents Sea model
- Process-based, forward simulation model
- Multi species/extended single species
- Focused on cod
  - With stochastic prey species
  - Incorporating environmental drivers
- Age-structured, single-area and single-fleet model, one-year time step

STOCOBAR

Input data

Report of ICES AFWG 2010

Capelin stock biomass, 1972-2009

Cod stock parameters, 1972-2009

- abundance by age;
- weight- at-age in stock
- length-at-age in stock
- weight-at-age in catch;
- coefficient of fishing mortality;
- maturation ogive.

Data of PINRO

Cod fatness (hepatosomatic index) 1984-2007;
Temperature at the Kola Section, 1951-2009

Joint Russian-Norwegian database

Cod stomach content, 1984-2008

Recruitment

- Estimated Ricker relationships for ”number of age 1 required for the model to fit at age 3+”
- Not: ”actual number of age 1 fish recruited”
- If we had done this a few years ago we might have included temperature as a parameter
- Today probably not

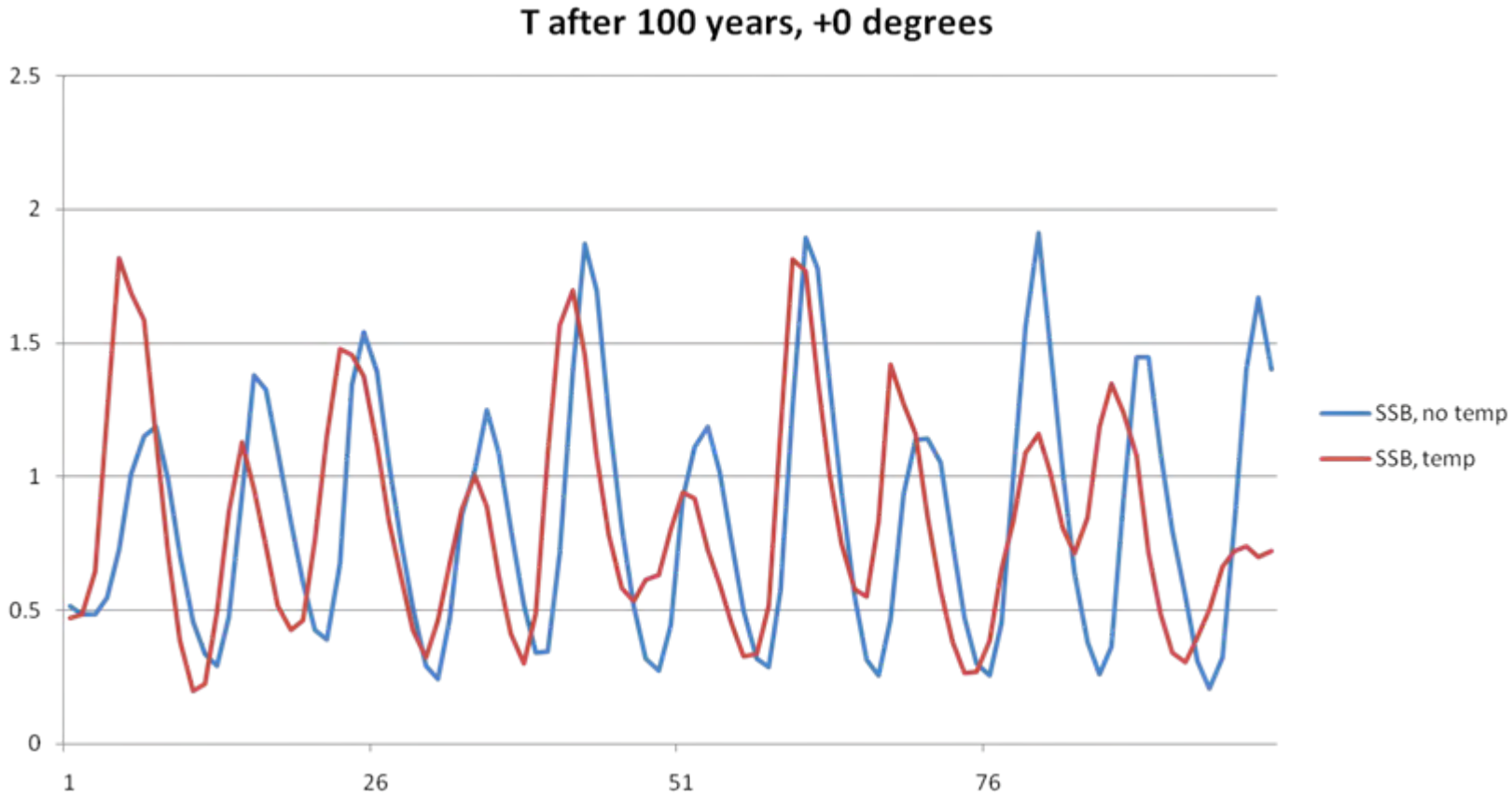
- **How much difference does this make?**

Forward simulations

- Stochastic temperature based on historical data
- Add a warming trend of +0, +1, +2, +4 degrees after 100 years
- **Two alternatives: With and without temperature in recruitment**
  - Still in growth and consumption for both cases
- Approximation to current management rules
- Assume high carrying capacity
- Just showing SSB here for the sake of time

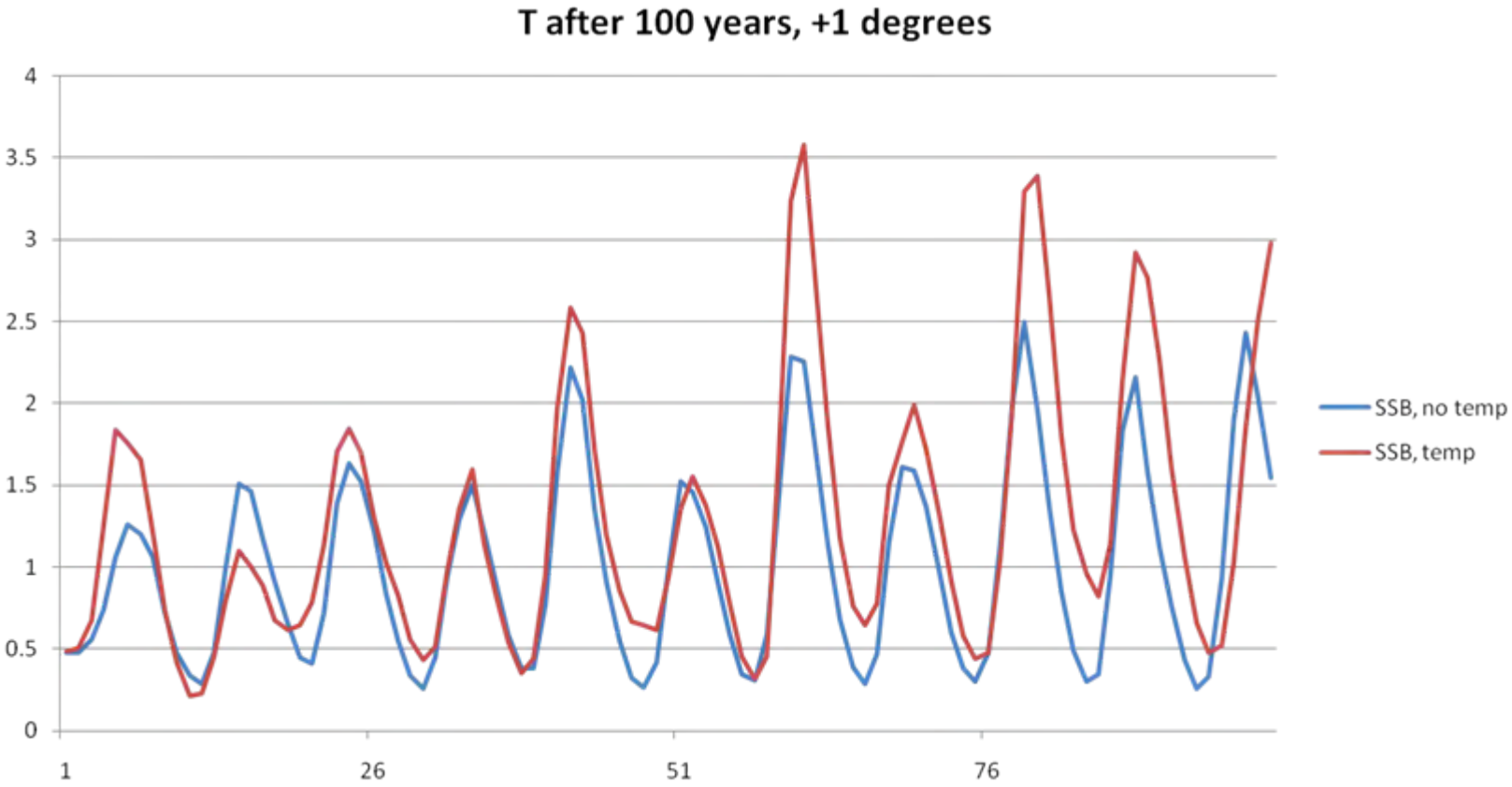
SSB RESULTS: +0 degrees

- Average biomass: 0.83 / 0.84 million tonnes



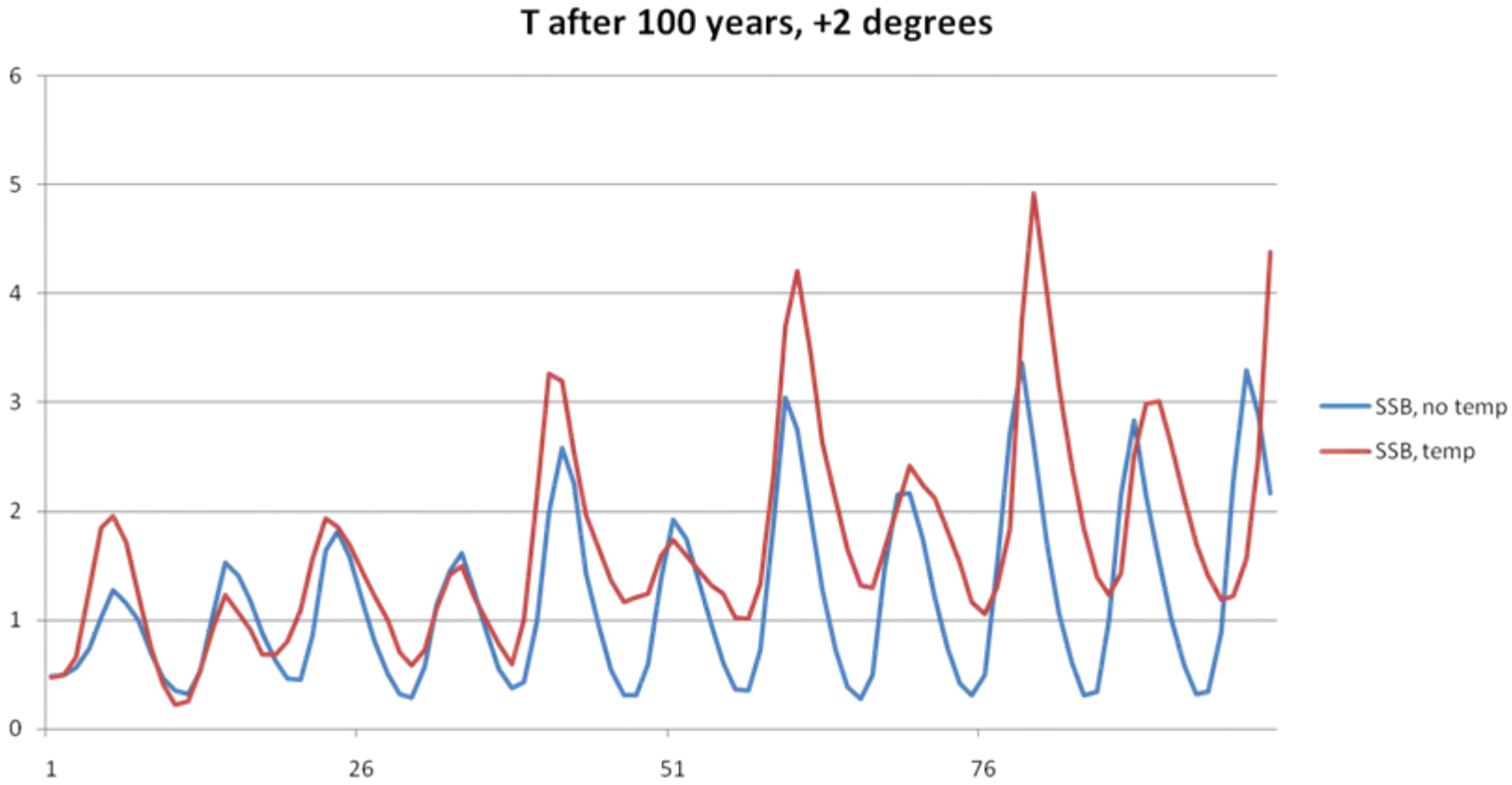
SSB RESULTS: +1 degree

- Average biomass: 1.28 / 1.01 million tonnes



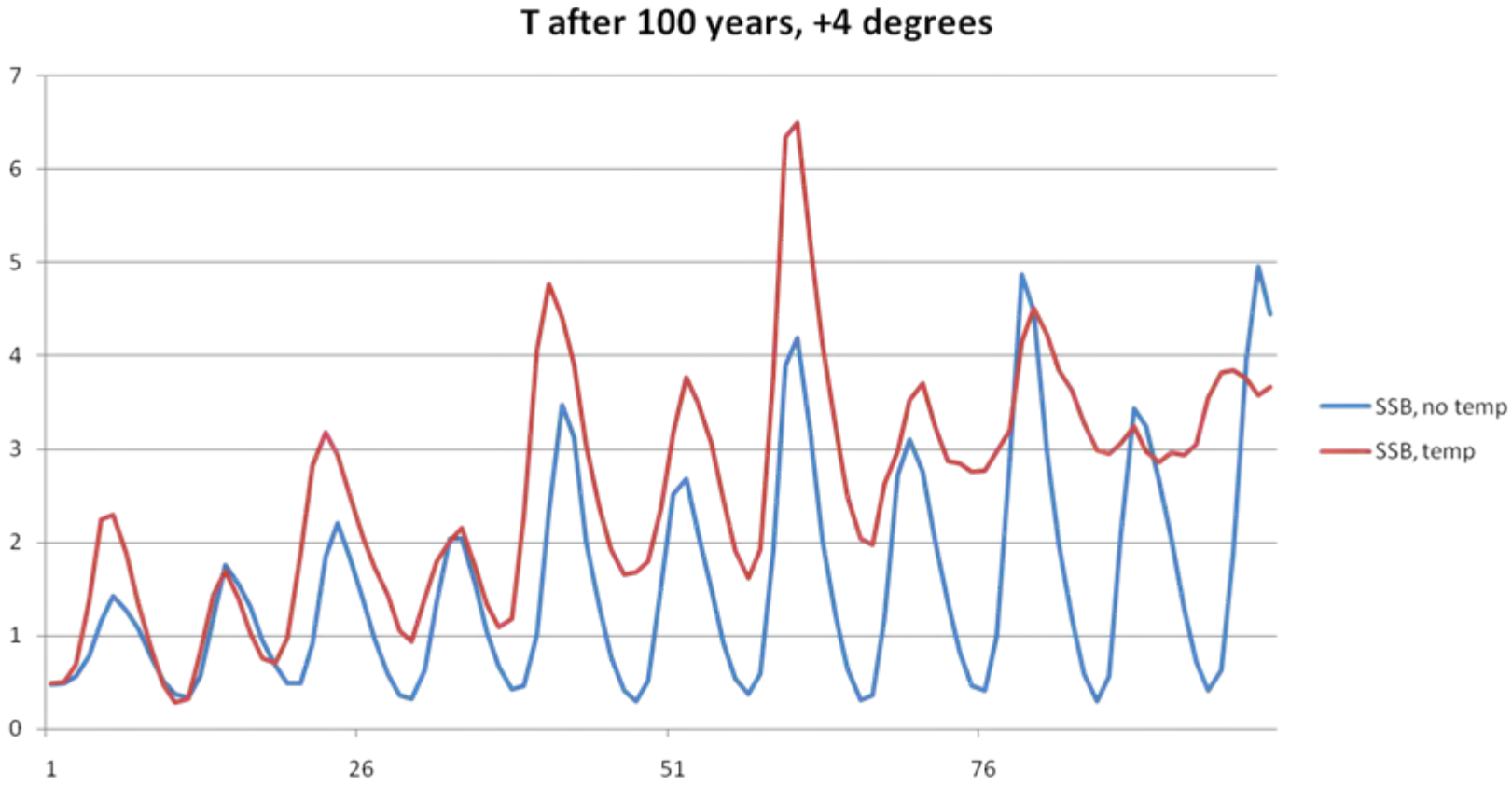
SSB RESULTS: +2 degrees

- Average biomass: 1.68 / 1.18 million tonnes



SSB RESULTS: +4 degrees

- Average biomass:2.55/ 1.54 million tonnes



Results

- The **unquantifiable uncertainty** from using regression as a basis for the temperature part of the recruitment relationship for the Barents Sea cod produces major changes in predicting:
  - Overall stock levels
  - Stock dynamics
  - Minimum biomass
  - Optimum management
    - MSY, Precautionary

Answers to our small question

Are there significant effects on model projections from the (unquantifiable) uncertainty in the breakdown of the historical temperature recruitment relationship?

- Did the uncertainty matter: YES
- Could we quantify it: NO

Step Back

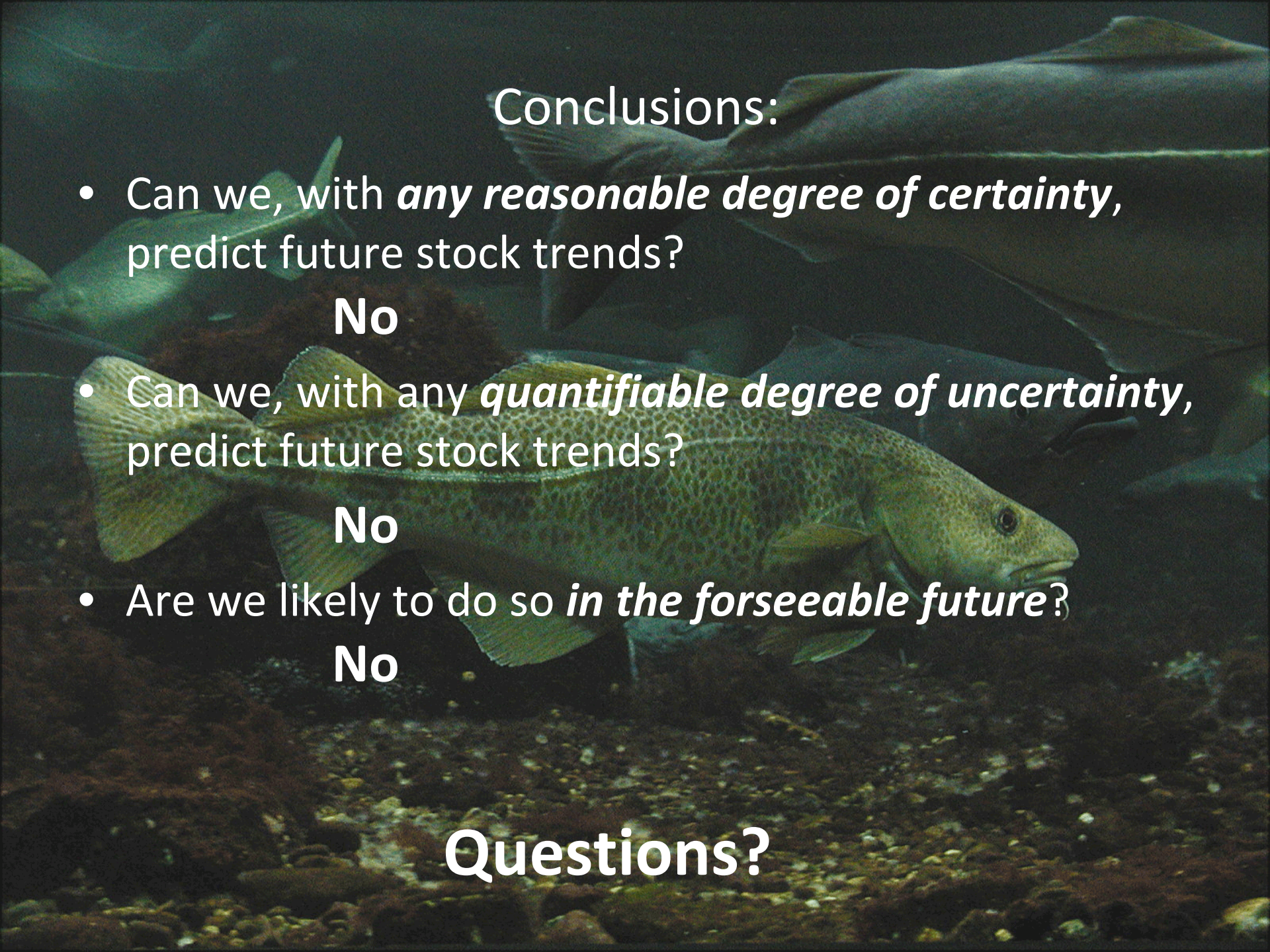
- These are results for NEA cod
- Specific to our ecosystem
- Specific to the particular model we used

- But:

- Similar effects from changes in regression relationships are likely in any ecosystem and any ecosystem model

What we can do

- Quantify some sources of uncertainty
  - But not all
- Produce ”plausible” scenarios (ensemble)
- Run Managent Strategy Evaluations for these scenarios
  - Identify where management rules are robust
  - Identify indicators that we may be moving to conditions were the management rule may fail
- **But** in terms of quantifying overall uncertainty:



Conclusions:

- Can we, with ***any reasonable degree of certainty***, predict future stock trends?

  No

- Can we, with any ***quantifiable degree of uncertainty***, predict future stock trends?

  No

- Are we likely to do so ***in the forseeable future***?

  No

Questions?

- 1. Regression relationships tend to break down when projected beyond data
- 2. By definition there is no data to quantify the probability or nature of this change in advance
- 3. These changes can have a large impact on model projections
- 4. Most (all?) ecosystem models rely on regression relationships.
- Therefore: none of these models can quantify the overall uncertainty in their projections, unless the remove the reliance on regression relationships