Detecting catastrophic transitions –
the case of North Atlantic herring

Leonie Färber
l.a.farber@ibv.uio.no
@leonie_farber

Camilla Sguotti, Joël M. Durant, Øystein Langangen, Saskia Otto, Christian Möllmann

This project has received funding from the European Union’s Horizon 2020 and Innovation programme under the Marie Skłodowska-Curie grant agreement no. 675997. The content of this presentation reflects only the author’s view and the Commission is not responsible for any use that may be made of the information it contains.
14 herring (*Clupea harengus*) stocks are used for the analysis:

Objectives:
1. Find abrupt shifts in time series
2. Test if stocks show discontinuous behavior with fishing pressure and temperature or cod abundance as drivers
The ecosystem can display different behaviors to changing conditions.

- Catastrophic transition, critical transition, regime shift, discontinuity, collapse, abrupt change, prolonged stable states, hysteresis

- Continuous, abrupt change, regime shift, reversible

- Continuous, linear change, reversible

Modified from Scheffer et al. 2001
“Decision tree” for an abrupt change in the time series of the SSB of herring.

- Prolonged stability (> 10 years)
  - Yes
    - Based on IUCN Red list criteria of endangered species
      - Mean biomass ≤ 30% of prior biomass or mean biomass ≥ 170% of prior biomass within 10 years
        - Yes
          - Change in mean or variance: changepoint (Killick and Eckley 2014)
          - Structural change in linear regression: strucchange (Zeileis et al. 2002)
          - Odds of a change point: Bayesian Analysis of Change Point Problems bcp (Erdman and Emerson 2007)
        - No
          - Regime shift
  - No
    - Continuous change
    - Fluctuations

- No
Prolonged stability (> 10 years)

- Mean biomass ≤ 30% of prior biomass or mean biomass ≥ 170% of prior biomass within 10 years
- Change in mean or variance
  - Structural change in linear regression
  - Odds of a change point

Yes(3/3) (2/3)

- Regime shift

5-year moving window linear regression on median-filtered scaled biomass
⇒ Assessing stable slope
Average of stable years and calculating proportion compared to the previous years ⇒ Measuring drop in biomass
Prolonged stability ($> 10$ years)

- Yes
  - Mean biomass $\leq 30\%$ of prior biomass
  - Mean biomass $\geq 170\%$ of prior biomass within $10$ years

- No
  - Continuous change
  - Fluctuations

Change in mean or variance

Structural change in linear regression
Odds of a change point

- Yes
  - $3/3$ ($2/3$
  - Regime shift

$\Rightarrow$ Changes in mean of SSB
Structural changes in linear regression on differenced time series.

- Prolonged stability
- Change in mean
- Structural change in regression
Bayesian posterior probability distribution of a change point.
No prolonged stability and abrupt jump in the time series.
Fold catastrophe

Scheffer et al. 2001

Cusp catastrophe

Modified from Grasman et al. 2009

Modified from Petraitis & Dudgeon 2016
Fishing and temperature as drivers.
Fishing and abundance of cod as drivers.
Conclusion

• Most herring stocks show no prolonged stability, thus no regime shift with changing conditions

• Most stocks are not moving over the cusp area and show a smooth transition, thus continuous behavior.

• Temperature and abundance of cod are not important variables influencing herring SSB

• Mostly driven by fishing
  ⇒ sustainable fishing to prevent undesirable state
  ⇒ cusp might indicate reference points for management

l.a.farber@ibv.uio.no  @leonie_farber  www.marmaed.eu