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Detecting catastrophic transitions – the case of North Atlantic herring

Clupea harengus

Herring ©Scandinavian Fishing Year book

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MARmaED

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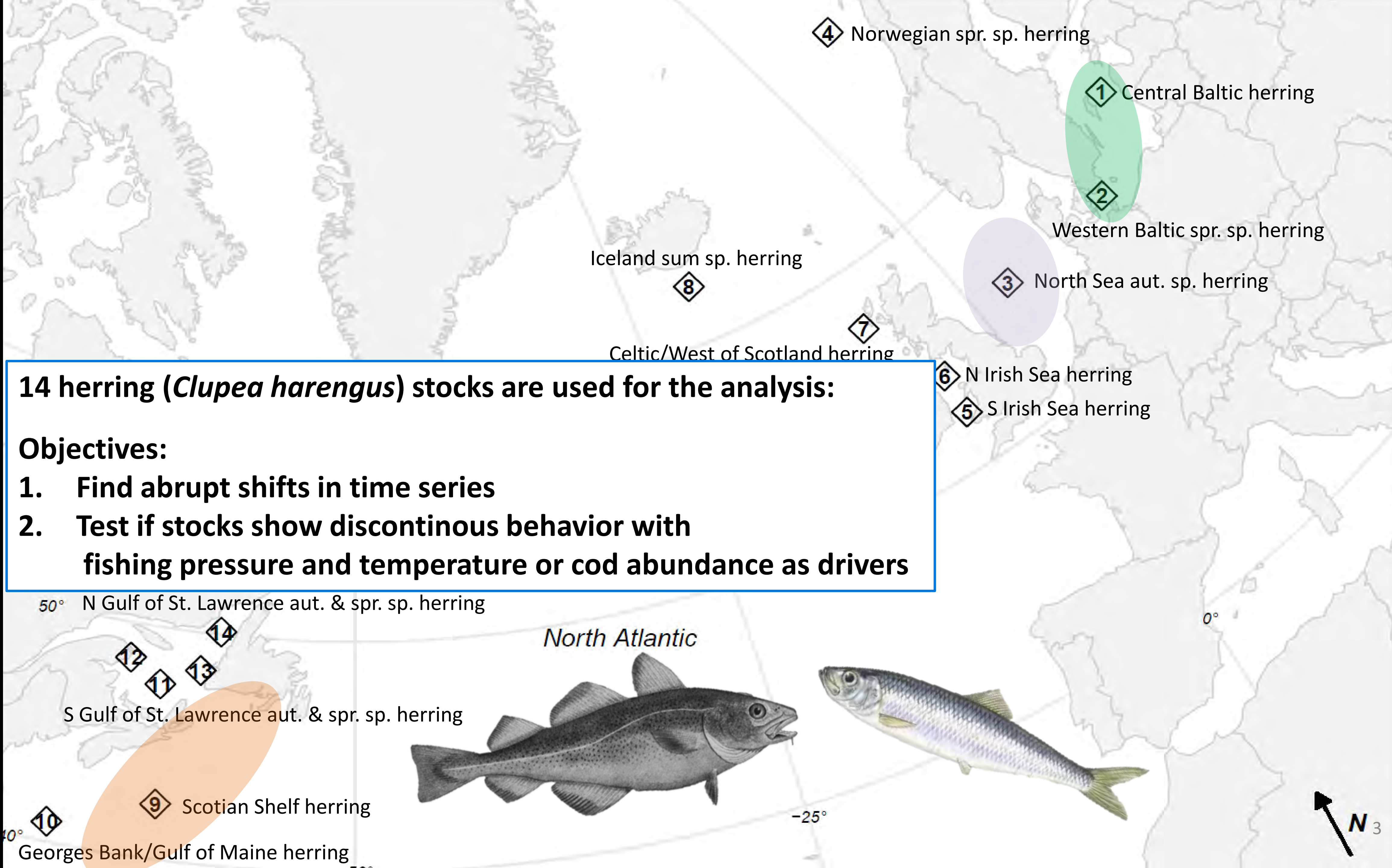
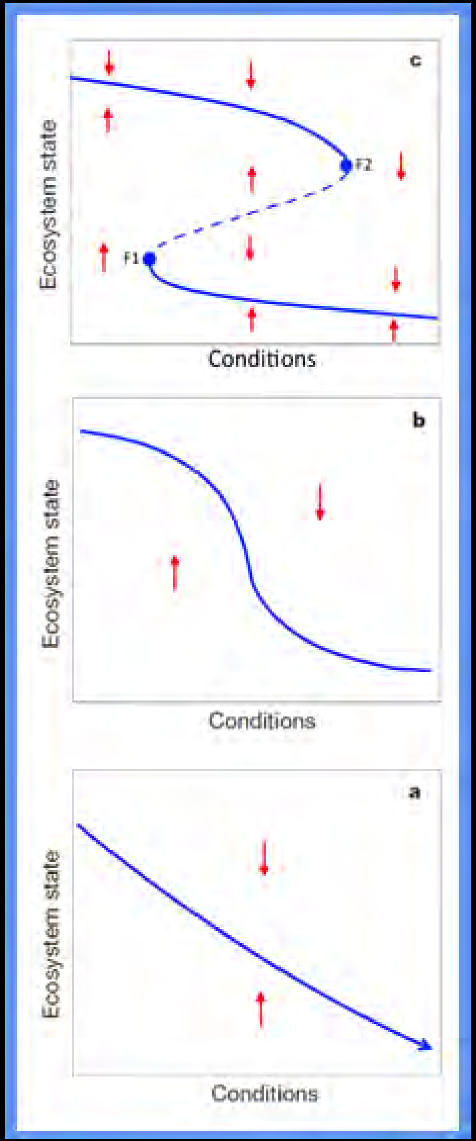
14 herring (*Clupea harengus*) stocks are used for the analysis:

Objectives:

1. **Find abrupt shifts in time series**
2. **Test if stocks show discontinous 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

No

Based on IUCN Red list critieria of endangered species

Mean biomass ≤ 30% of prior biomass or mean biomass ≥ 170% of prior biomass within 10 years

Continuous change

Fluctuations

Yes

No

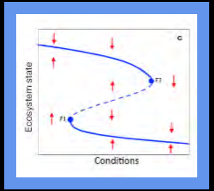
Change in mean or variance: *changepoint* (Killick and Eckley 2014)

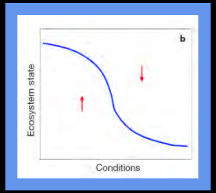
Structural change in linear regression: *strucchange* (Zeileis et al. 2002)

Odds of a change point: Bayesian Analysis of Change Point Problems *bcp* (Erdman and Emerson 2007)

Yes(3/3) (2/3)

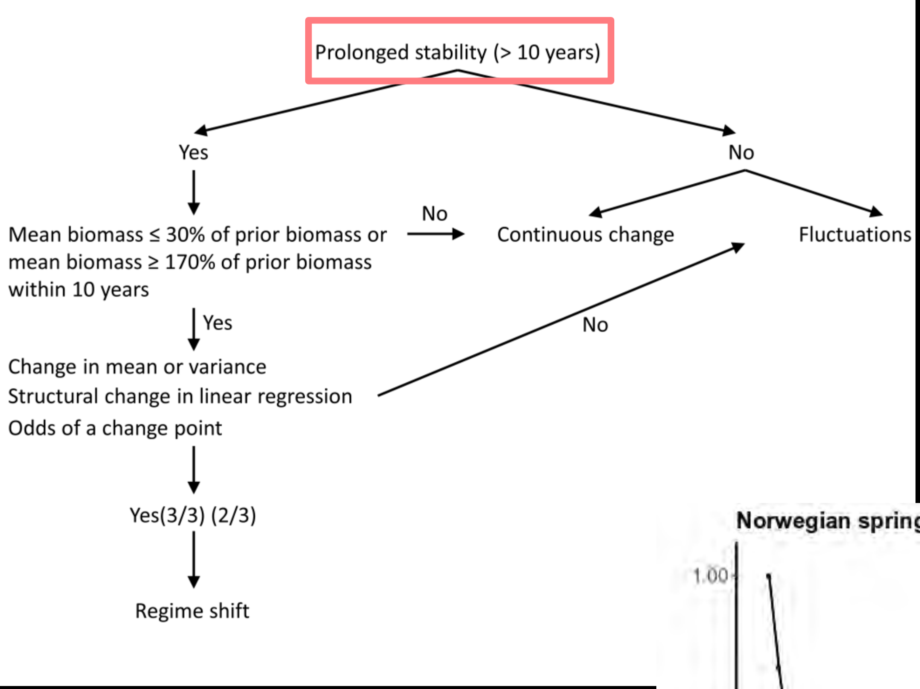
Regime shift

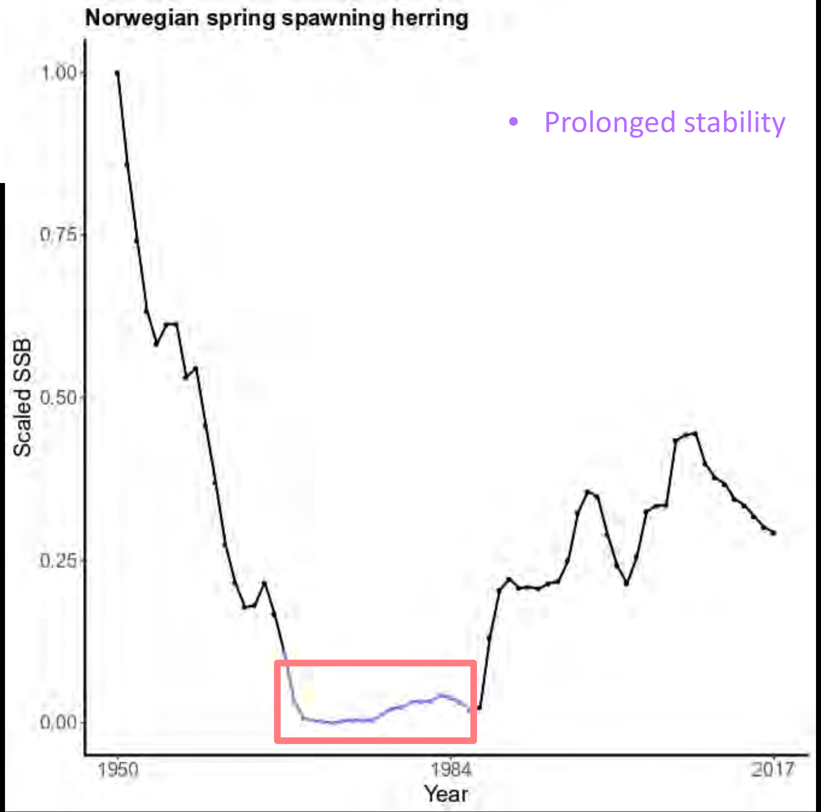


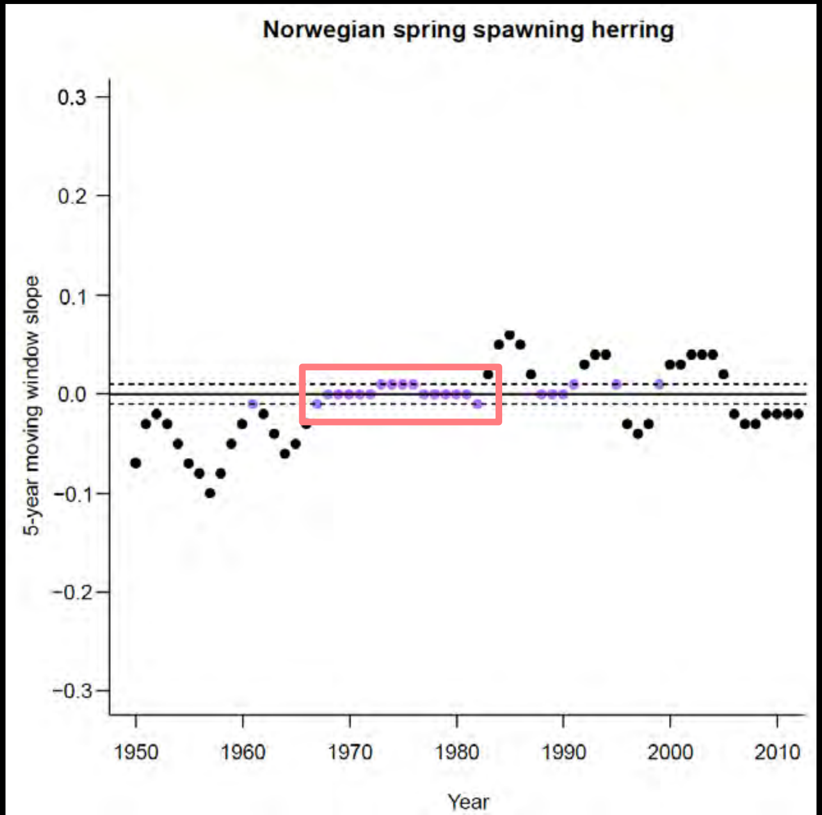


5-year moving window linear regression on median-filtered scaled biomass

$\Rightarrow$Assessing stable slope

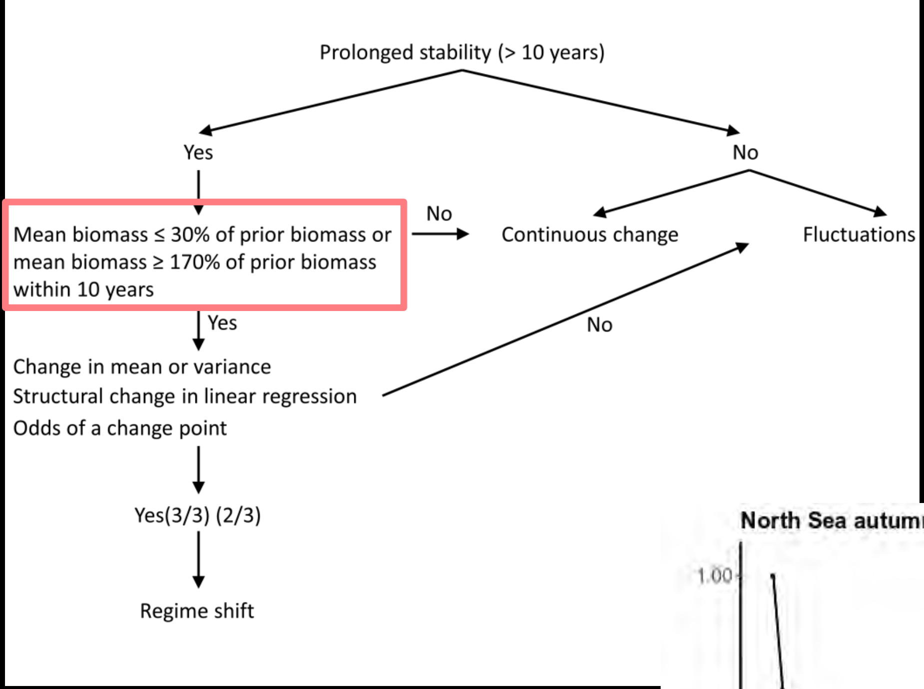


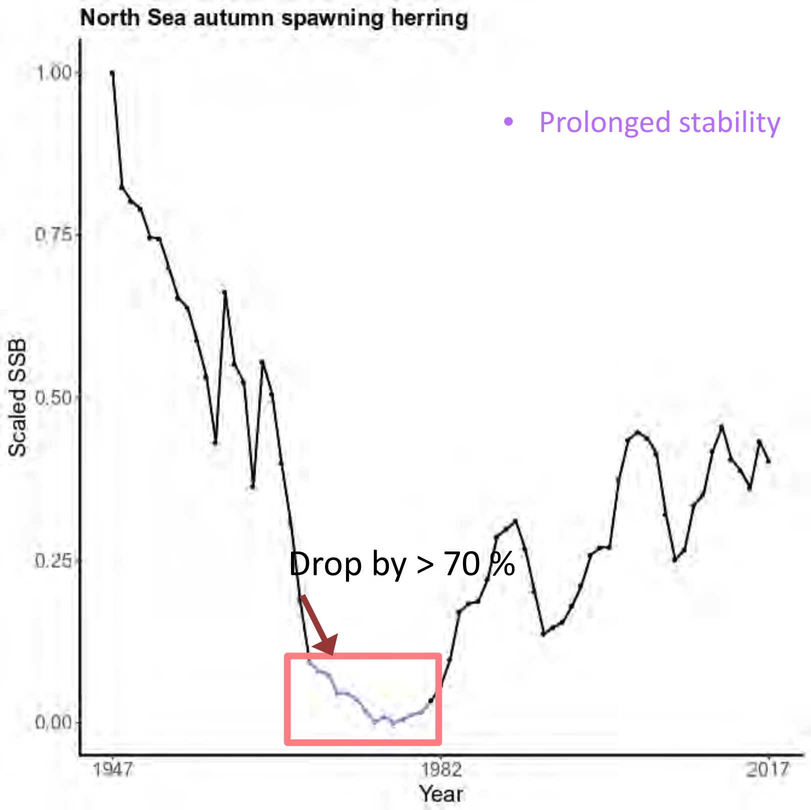


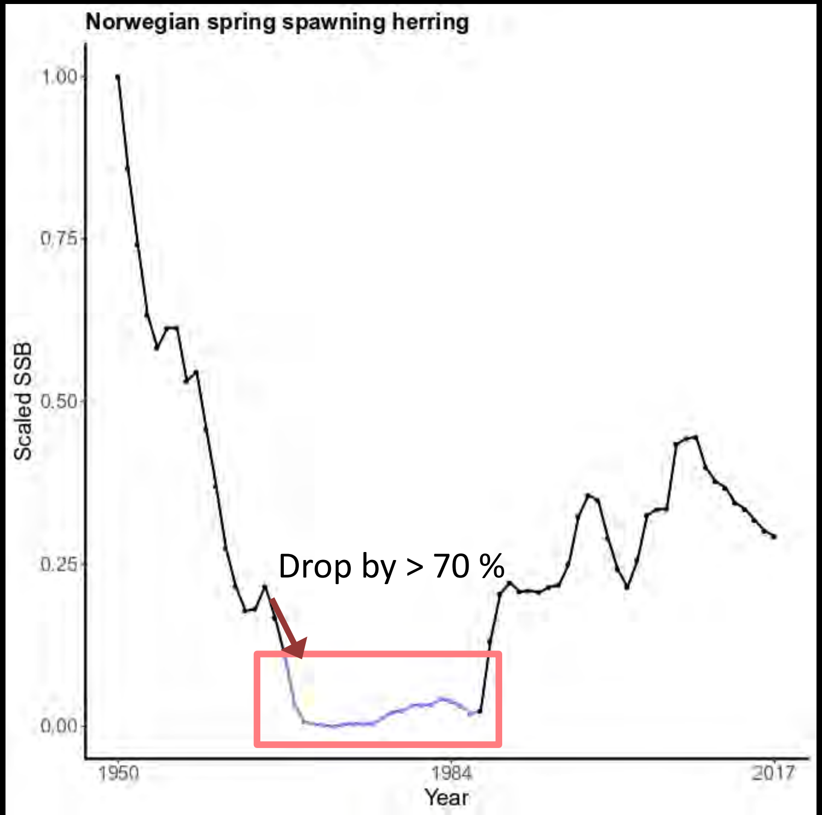


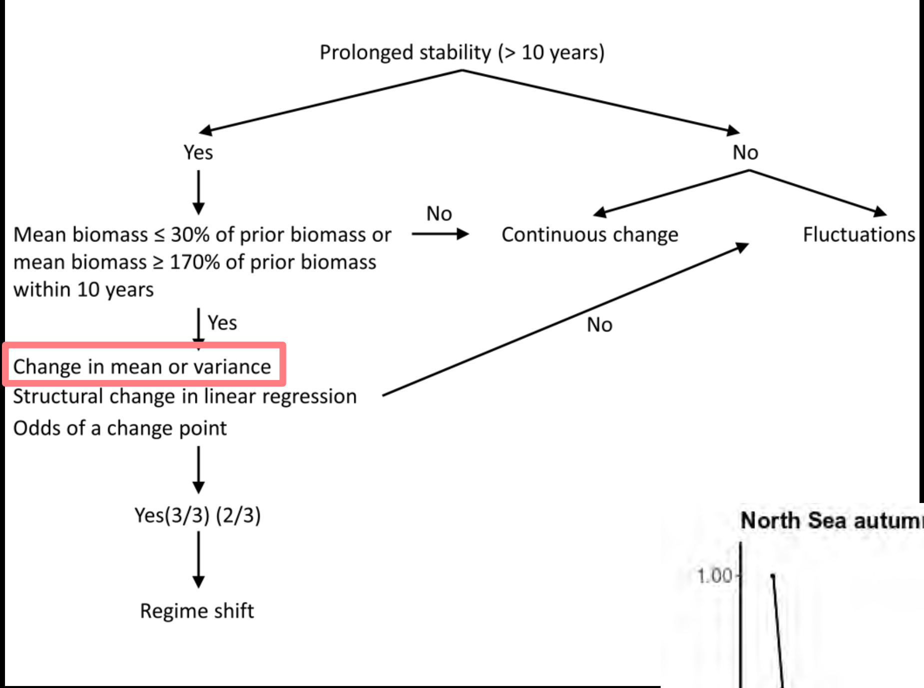
Average of stable years and calculating proportion compared to the previous years

⇒Measuring drop in biomass

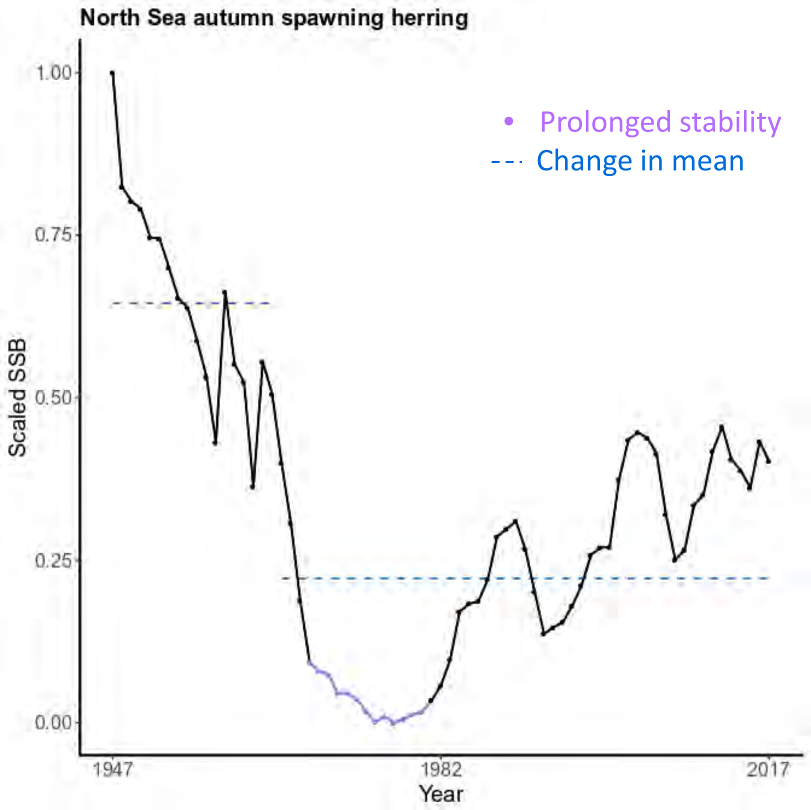


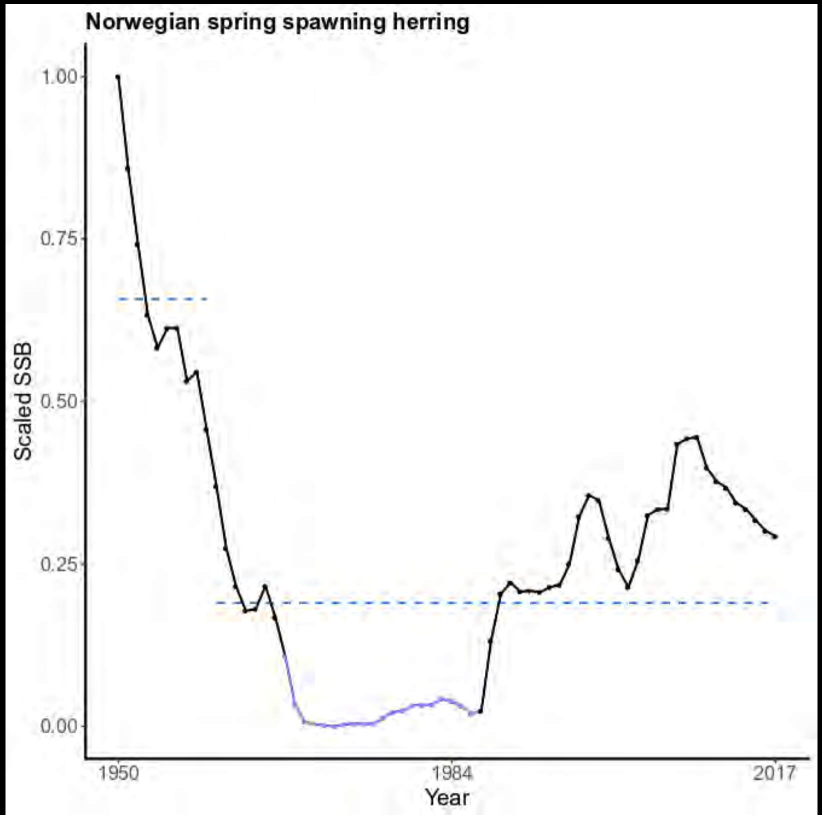




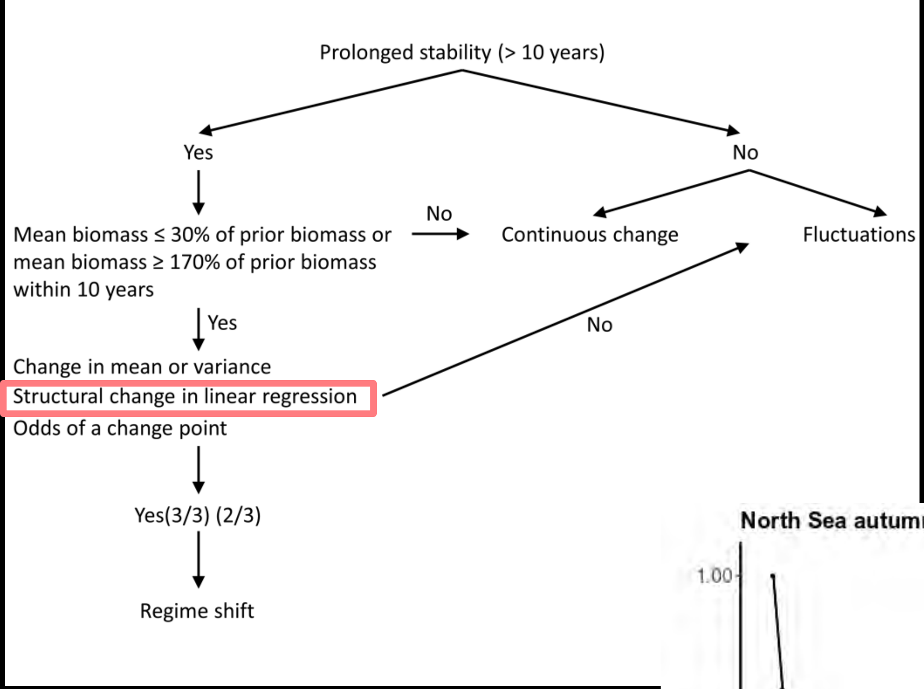


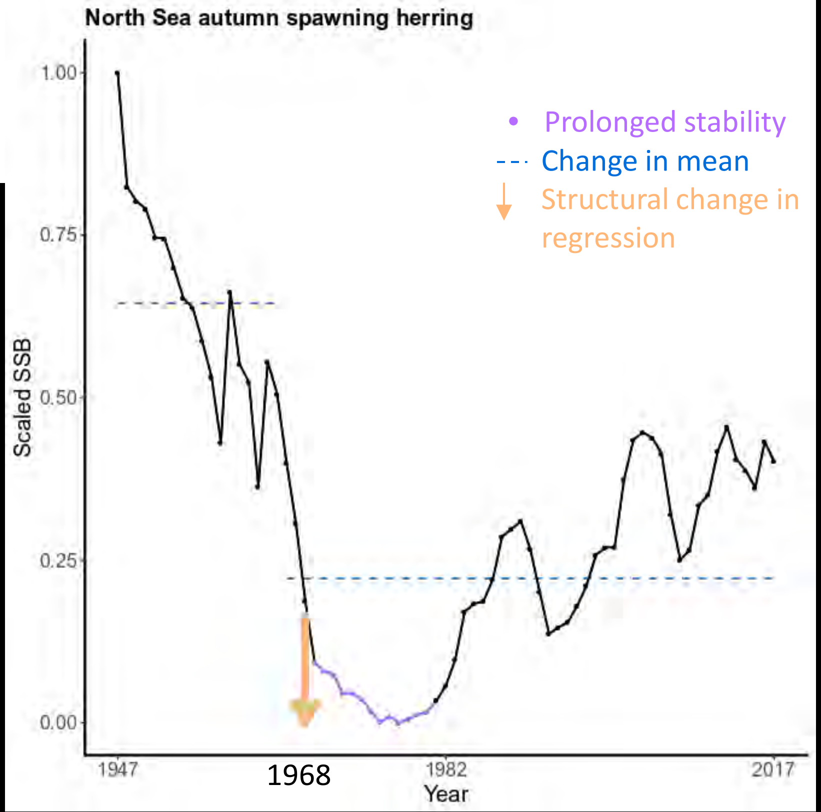
Binary segmentation
⇒Changes in mean of SSB

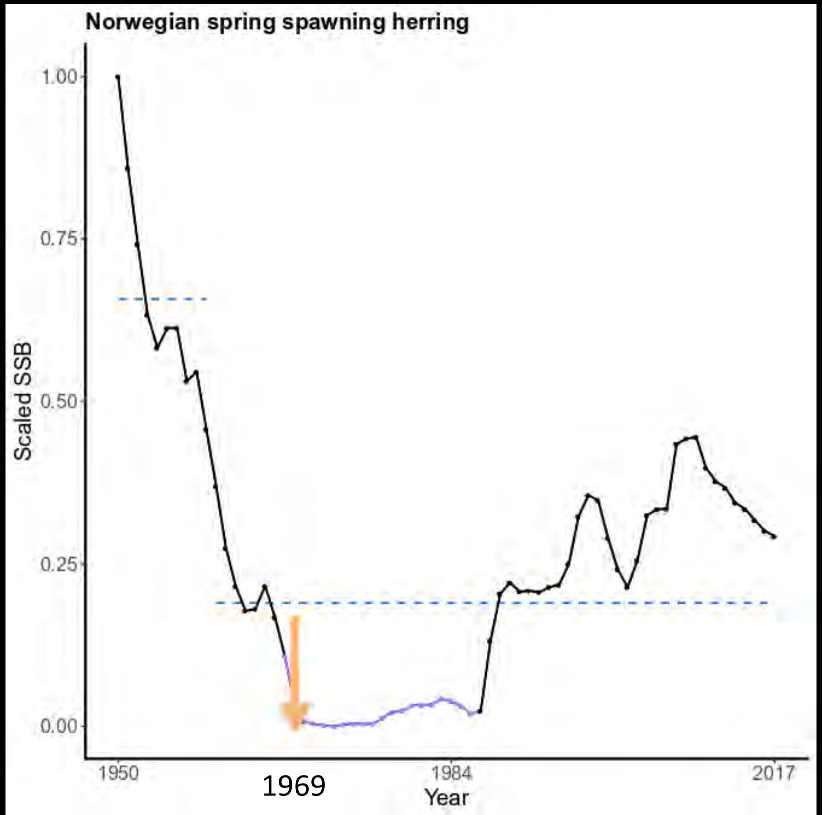




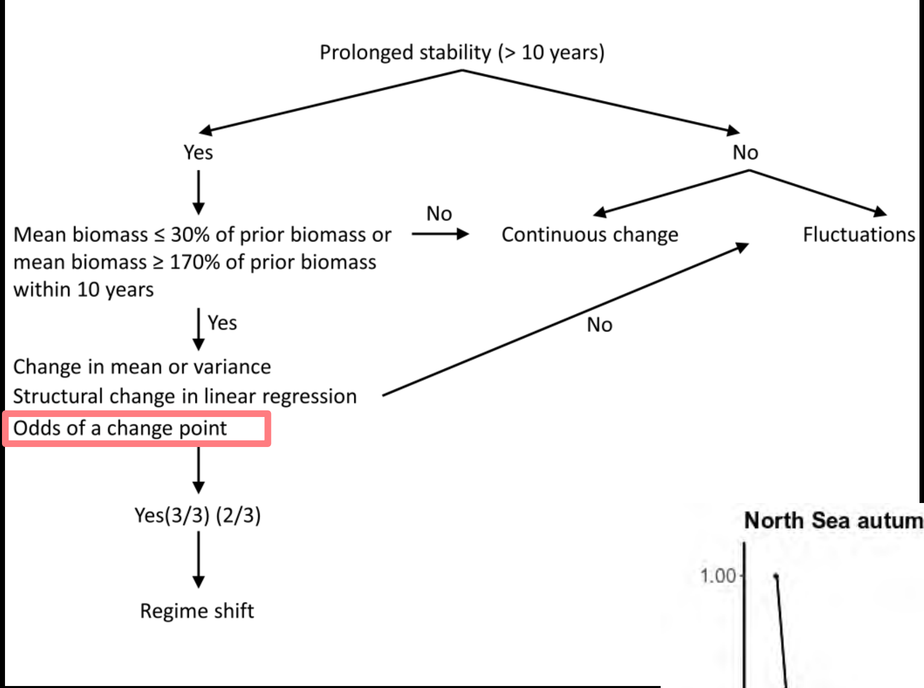
Structural changes in linear regression on differenced time series.

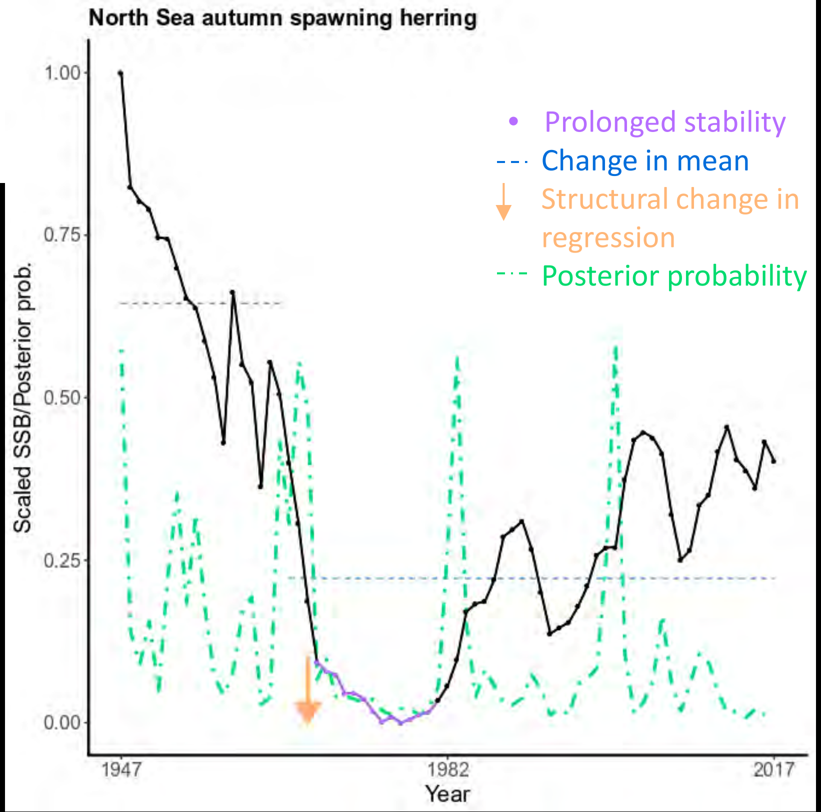


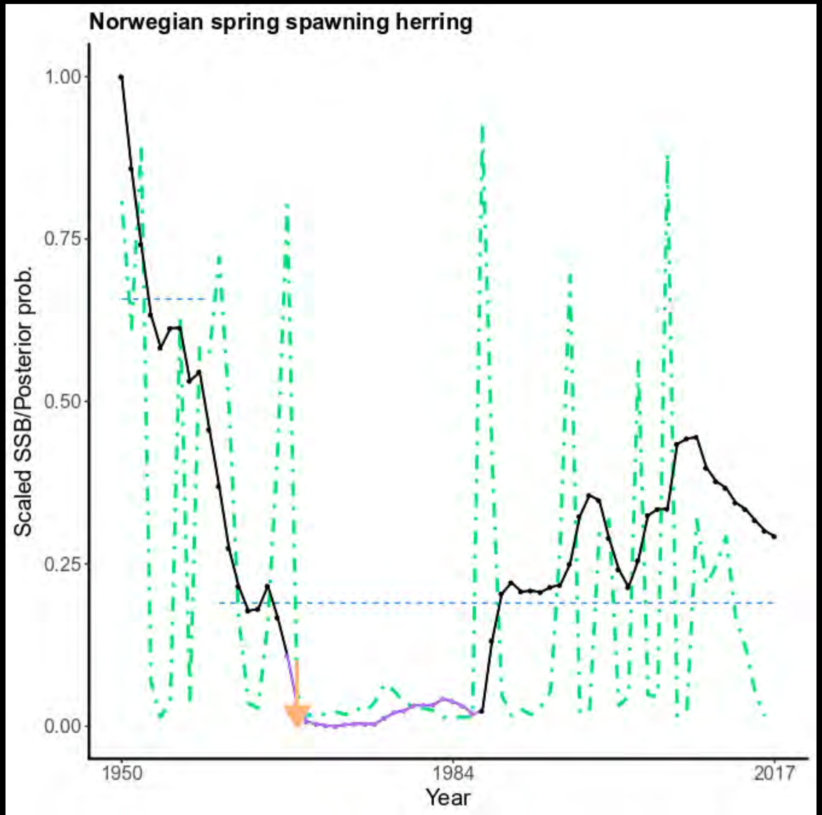




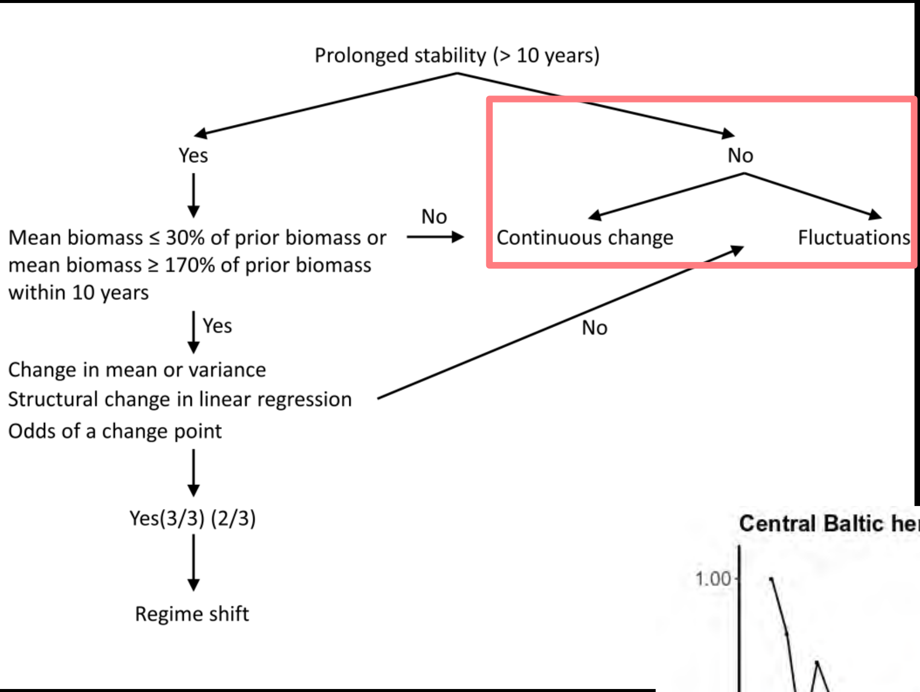
Bayesian posterior probability distribution of a change point.

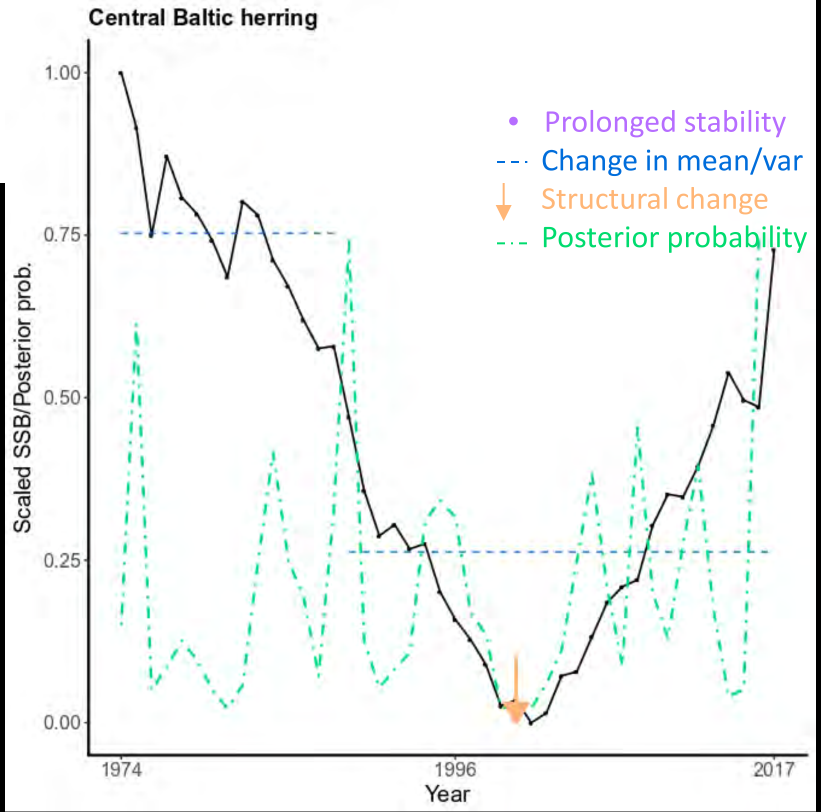


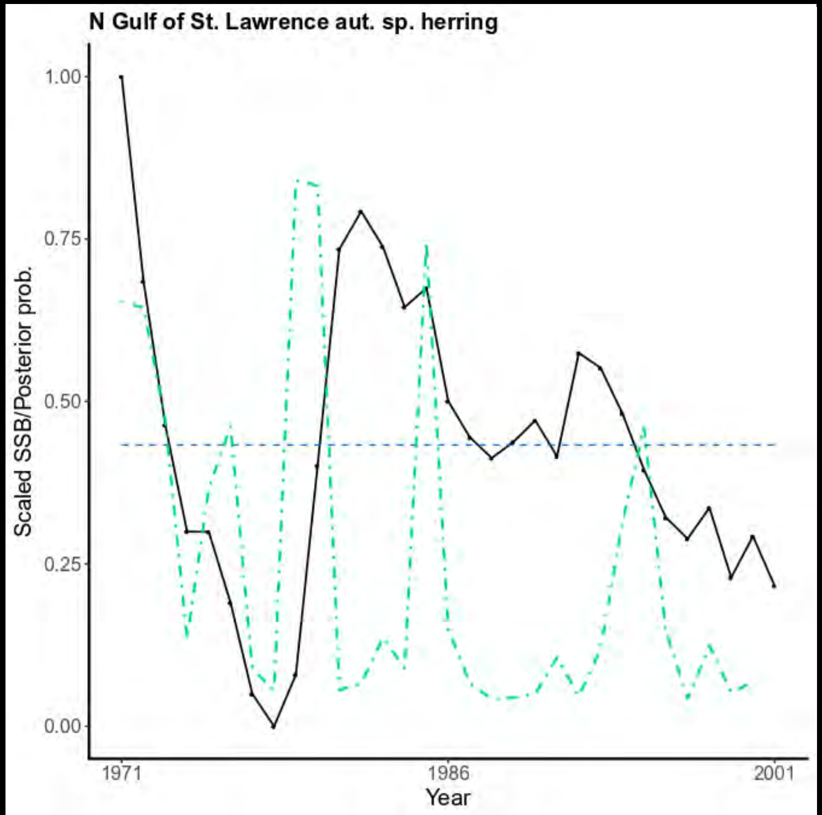




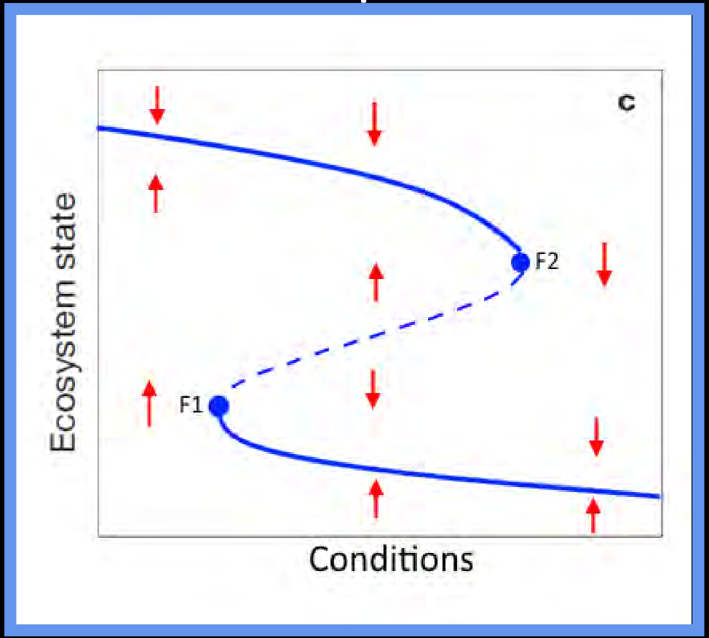
No prolonged stability and abrupt jump in the time series.





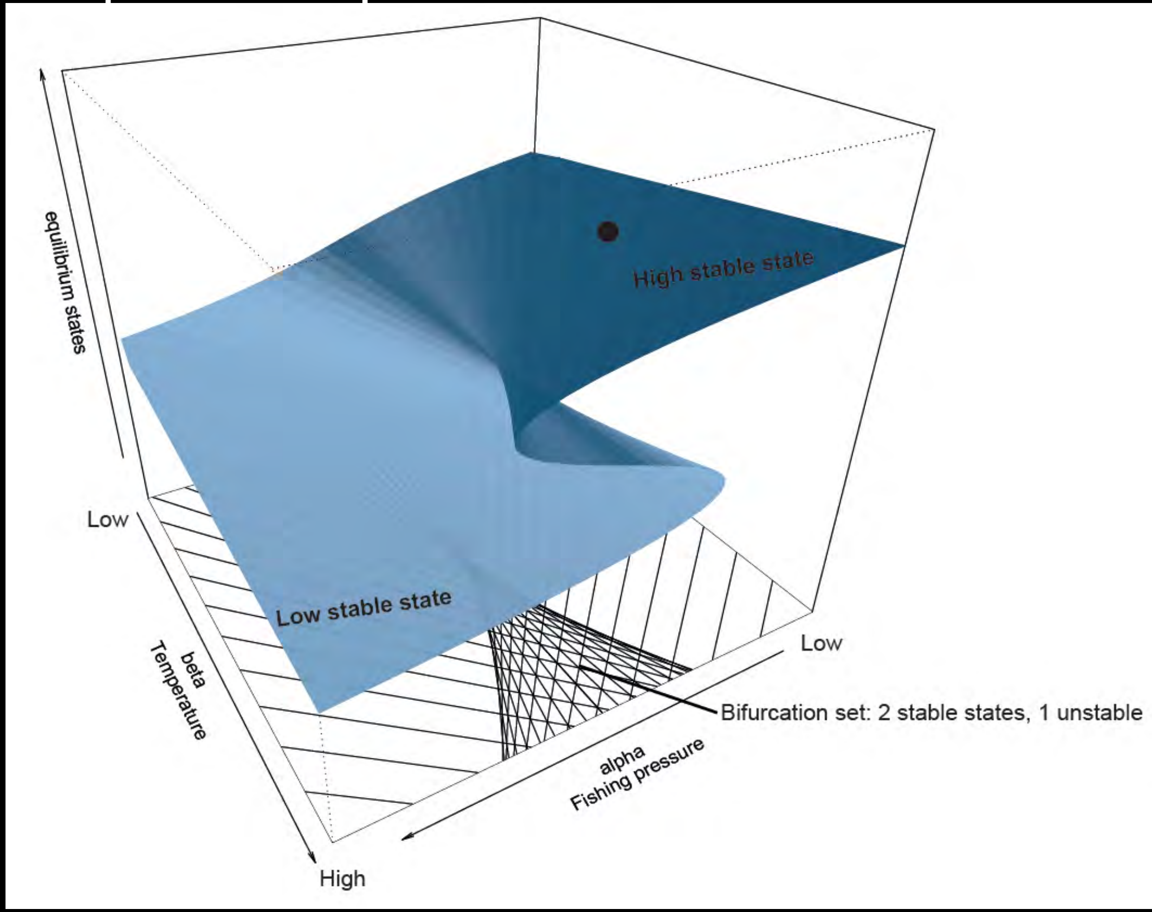


Fold catastrophe

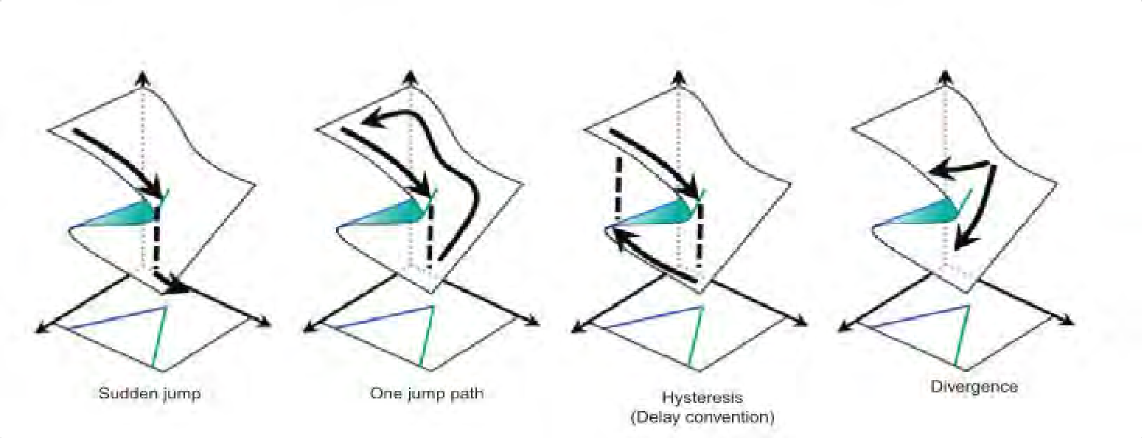


Scheffer et al. 2001

Cusp catastrophe

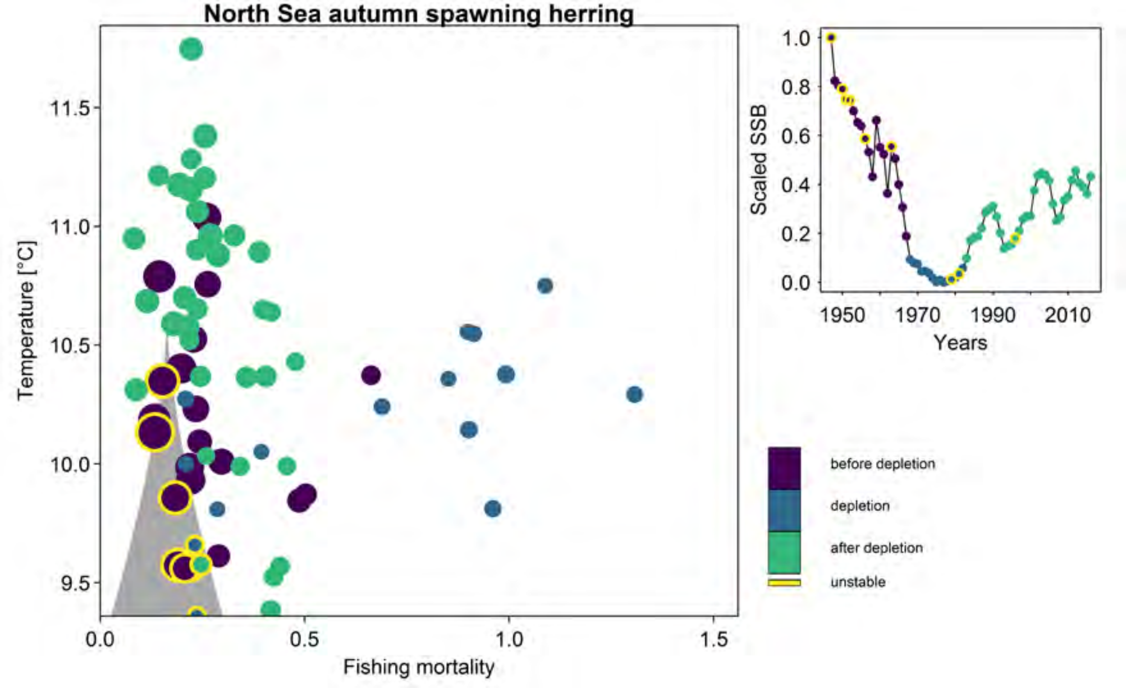


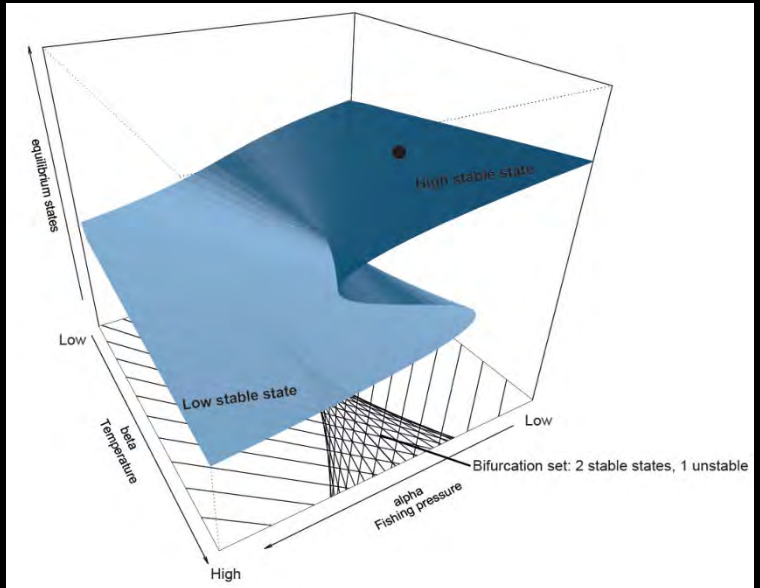
Modified from Grasman et al. 2009

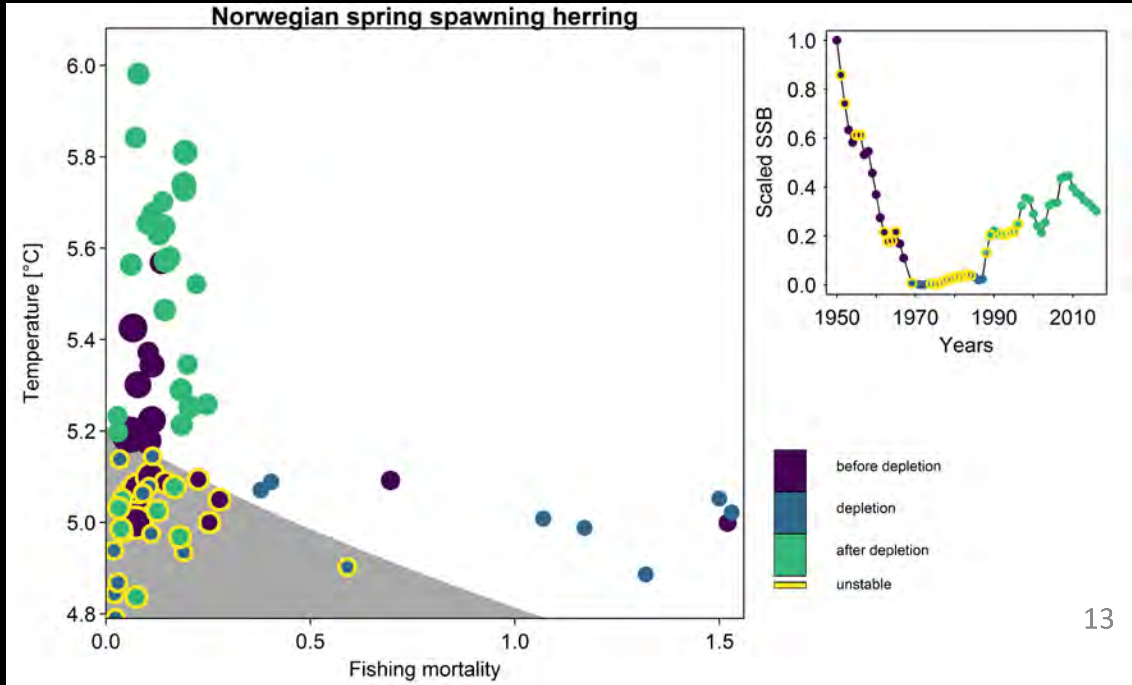


Modified from Petraitis & Dudgeon 2016

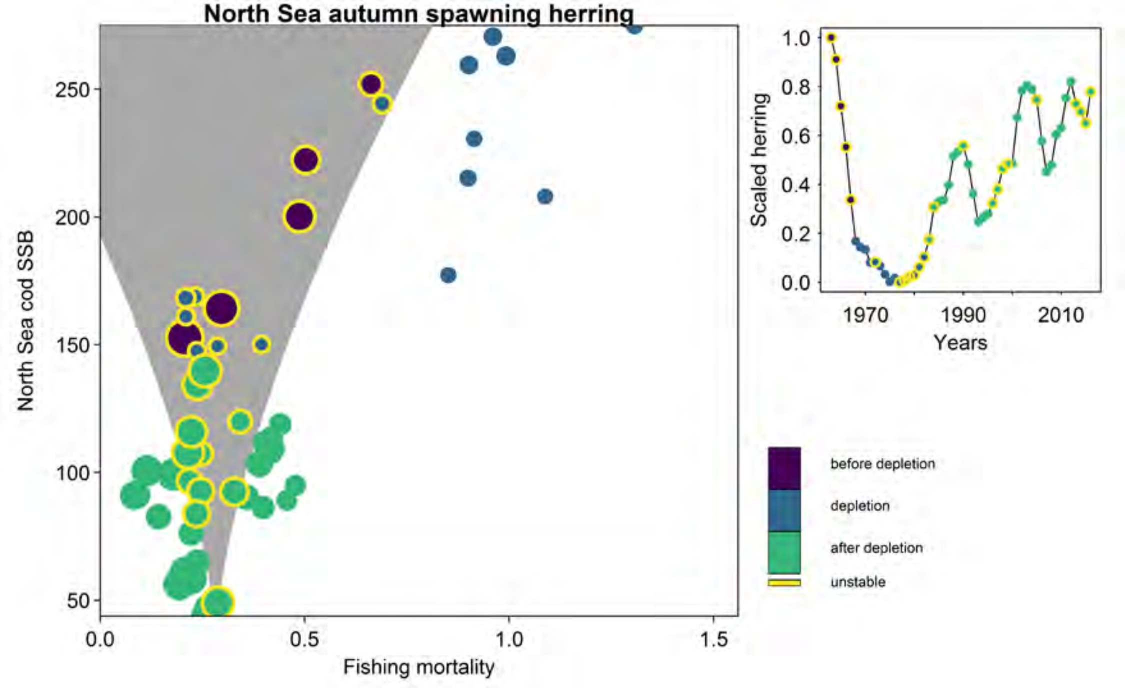
Fishing and temperature as drivers.

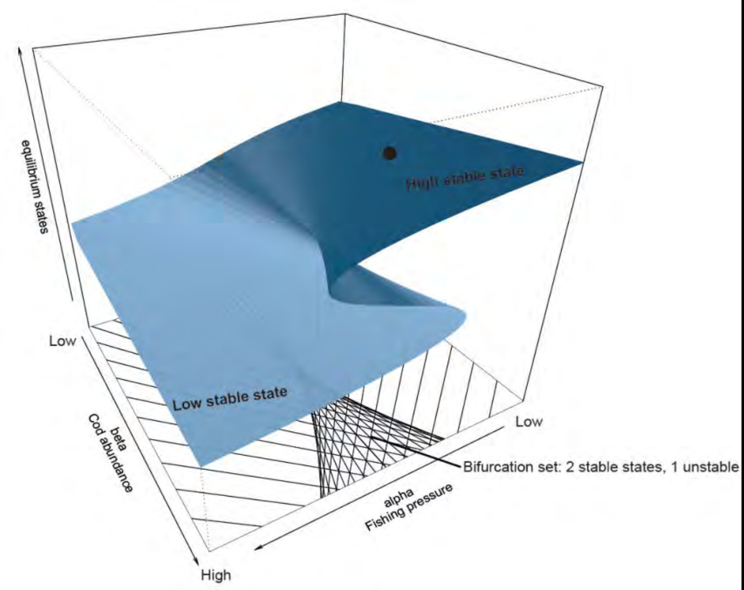


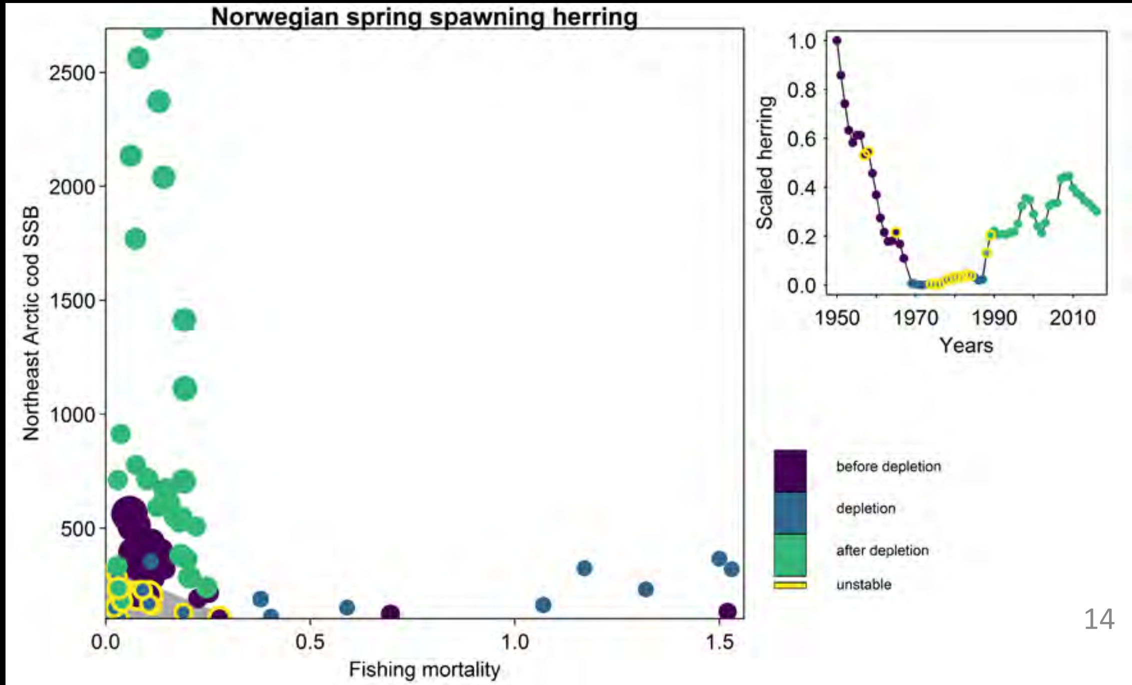




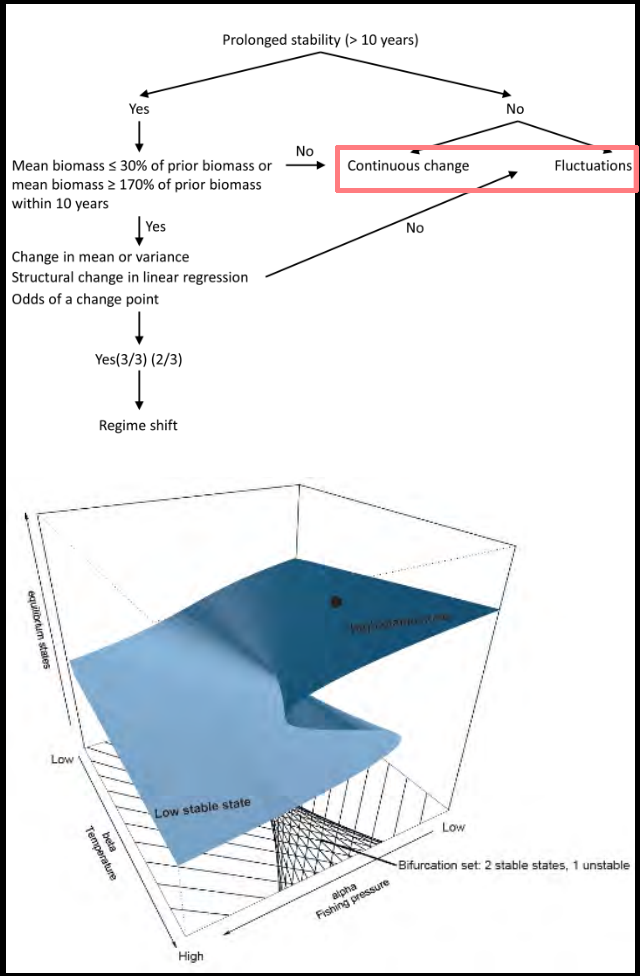
Fishing and abundance of cod as drivers.







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