# Process errors and observation error - can SPiCT be used?
# MSE mini symposium

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# Outline

- What is SPiCT?
- Special features
- Process and observation errors
- Comparison with age-based model (SAM)
- SPM versus age based assessments: Pros and cons

# What is SPiCT?

- A Stochastic surplus Production model in Continuous-Time: SPiCT
- Developed by Martin W. Pedersen and Casper W. Berg.
- Now maintained by Casper Berg, Alexandros Kokkalis, and Tobias Mildenberger.
- Aim: Fast, stable, and accurate model fitting with quantification of uncertainties.
- Relaxing previously used simplifying assumptions: asymmetric production curve, all input data and process equations contain noise.
- Published in *Fish and Fisheries* (2016).
- Extensively tested despite short life-time.
- Reviewed and endorsed by ICES working groups (WKLIFE, WKPROXY, WKMSYCat34) and used for official advice of several stocks.

# Special features

- Separation of process and observation noise.
- Explicit modelling of fishing mortality process allowing for prediction and missing values.
- Observation error on both index and catch.
- Irregular sampling intervals allowed (e.g. mix of yearly and quarterly catches).
- Seasonal dynamics can be accommodated (seasonal fishing pattern and seasonal surplus production).
- Options for time-varying productivity on longer time-scales as well (blocks or gradual change).
- External estimates of observation error can be used to scale uncertainty of data points.
- Both Bayesian and frequentist analyses are possible (priors can be used, but are not required).
- Automatic differentiation (TMB) ensures fast and stable estimation (usually seconds).
- Advanced management functionality including precautionary features that reduce TAC advice as a function of uncertainty in terminal year.

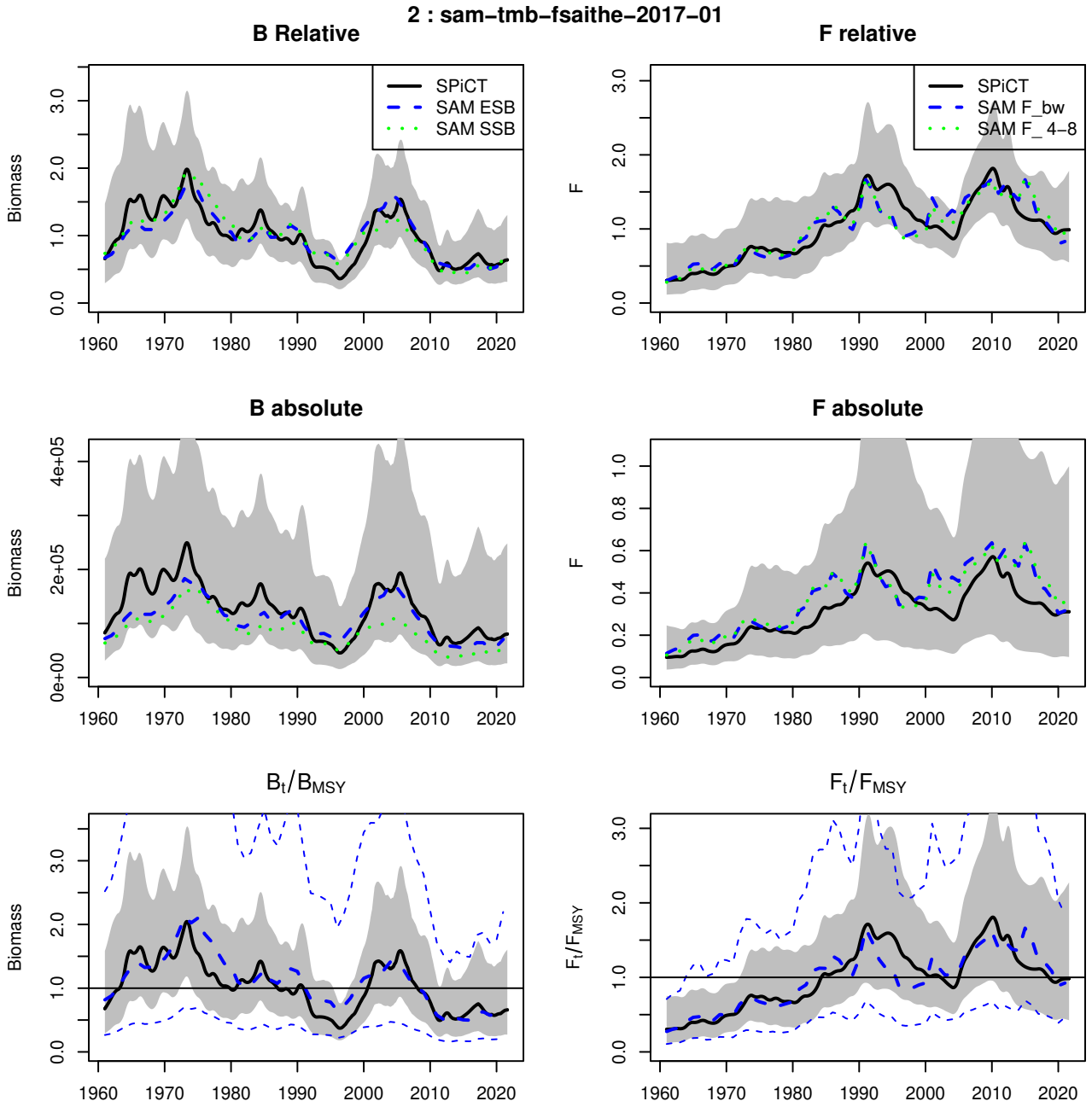
# Process and observation errors

- Biomass process equation defines probability distribution of $B_{t+\Delta t}$ given current state $(B_t, F_t)$.
- No process error implies we can predict next state perfectly given we know current state perfectly as well.
- Infinite process error implies model cannot predict anything.
- Process error includes random changes in recruitment, growth, natural mortality, selectivity.
- Observation error can be reduced by improving sampling scheme while process error cannot be reduced (unless model is changed).
- Correct data weighting (e.g. multiple CPUE indices) requires correct quantification of observation error.
- Process error and observation error on CPUE indices usually substantial - neither can be ignored.

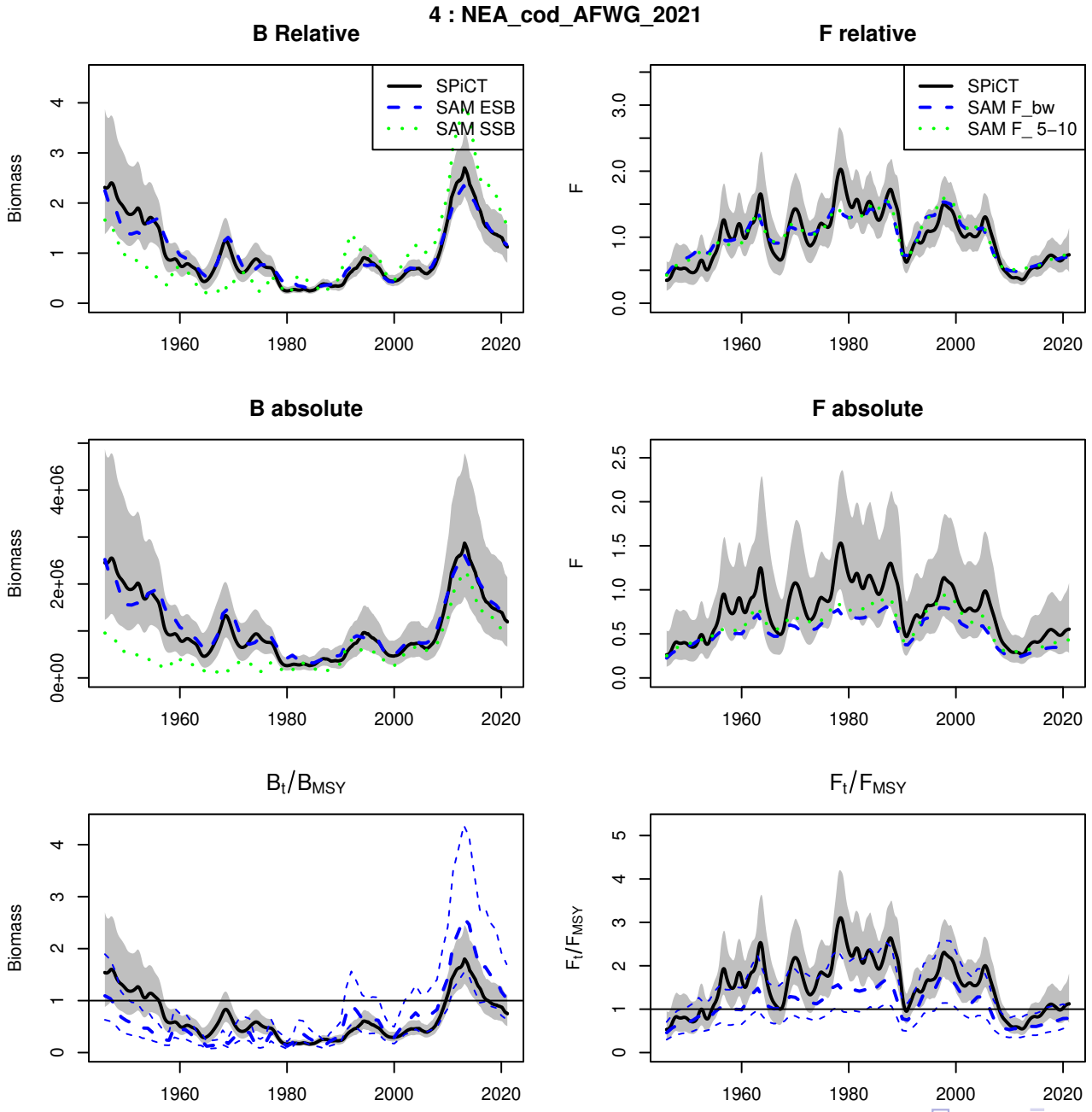
# Process and observation errors - continued

- Accurate estimation of process and observation error requires many data points (often more than we have).
- SPiCT uses vague default priors on ratios of observation to process error to ensure convergence and avoid that neither of them is estimated to zero.
- Alternatively priors can be set directly on observation variance parameters (often a better option).
- External estimates of observation variances for each data point should be standard part of input for all assessment models (on indices, catches).
- Quantification of uncertainty on model input and output is important: More data more quota.

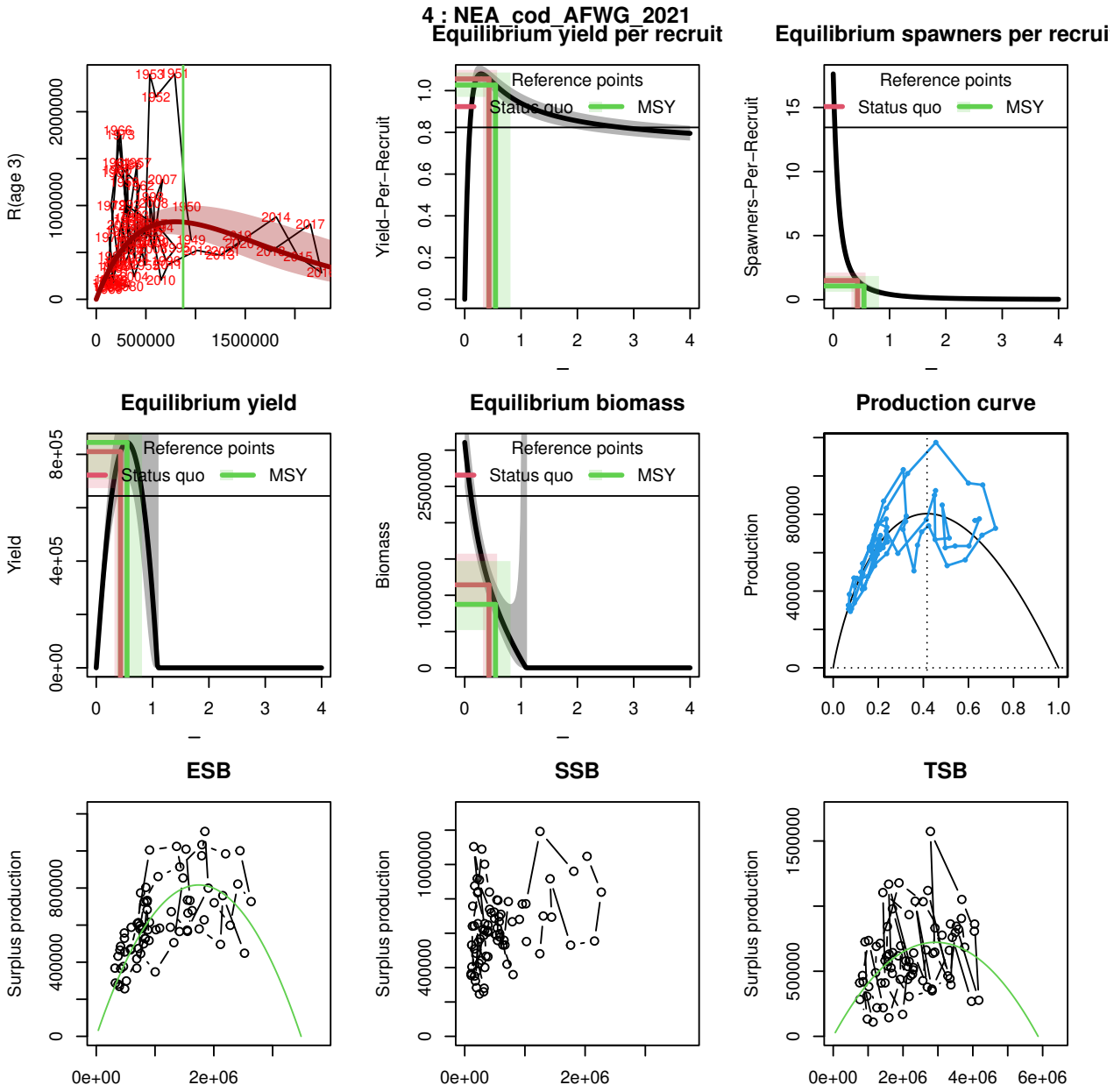
# Comparison with SAM - Faroese Saithe



# Comparison with SAM - NEA cod



# Comparison with SAM - NEA cod 2



# SPM versus age based assessments: Pros and cons

Pro:

- No need for age sampling.
- Estimates of natural mortality, growth and maturity not needed.
- Simpler model means less risk of errors - faster and easier to configure than age based assessments, more runs/scenarios can be tested.

Con:

- Less accurate short term forcast due to lack of unexploited size groups in model.
- Trends in selectivity not accounted for.
- Harder to account for trends in productivity that are NOT due to density dependence (e.g. reduced growth due to climate change).
- Relative cohort strength signal in CPUE indices is often stronger than abundance signal (i.e. more information in age-based data).
- Density dependence in other processes can (somewhat) be accounted for through time-varying values of growth, M, and maturity.
- By explicitly modelling more processes, we can better detect and predict changes in each of these, for example by finding links between recruitment and environmental drivers, or by including density dependence in process models for weight- or mortality-at-age.

# References


- SPiCT homepage: https://github.com/DTUAqua/spict
- *A stochastic surplus production model in continuous time*. MW Pedersen, CW Berg. Fish and Fisheries 18 (2), 226-243
- *Time-variant productivity in biomass dynamic models on seasonal and long-term scales*. TK Mildenberger, CW Berg, MW Pedersen, A Kokkalis, JR Nielsen. ICES Journal of Marine Science 77 (1), 174-187
- *Implementing the precautionary approach into fisheries management: Biomass reference points and uncertainty buffers*. TK Mildenberger et al. Fish and Fisheries 23 (1), 73-92
- *Benchmark Workshop on the development of MSY advice for category 3 stocks using Surplus Production Model in Continuous Time; SPiCT (WKMSYSPiCT)*, ICES 2021.