Celtic Sea Sprat

Sustainable exploitation avoiding ecosystem impacts, i.e. stress testing ICES PA MSY advice

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Presentation Outline

1. Motivation
2. Management Strategy Evaluation
   - Management Objectives
   - Robustness
3. Ecosystem and Environmental Effects
4. Management Procedures
   - Management Procedure
   - Empirical Indices
5. Results

Case Study

Celtic Sea Sprat

- Sprat is a valuable commercial species, a major predator on zooplankton, an abundant prey for piscivorous fish and a competitor for herring.
- The sustainable exploitation of sprat is necessary to ensure the health of the Celtic Sea ecosystem and the wider fisheries sector in Ireland.
- Advice is currently based on landings, as there is insufficient information to estimate stock status, trends, or target and limit reference points
- To develop robust advice, that meets management objectives despite uncertainty, we conduct Management Strategy Evaluation using a single species Operating Model conditioned on life-history theory.
- We also demonstrate how ecosystem understanding can be incorporated within the ICES precautionary and maximum sustainable yield frameworks.

Recommendations: WKSPRAT 2018

Evaluate

- **Escapement Strategies** based on an absolute index of abundance
- Impact of **Ecosystem Drivers** on
  - Natural Mortality
  - Weight-at-age
  - Recruitment success

Management Strategy Evaluation

Six Steps

- Identification of **Management Objectives**
- Selection of **Hypotheses** about resource dynamics
- Condition an **Operating Model**, based on data and knowledge;
- Identify candidate **Management Strategies**, i.e. Management Procedures
- Run the Management Procedures as a **Feedback Controller** to simulate the long-term impact of management; in order to
- Identify the strategy that best achieves the **Management Objectives**

Management Strategy Evaluation

Objectives Mapped to

- **Performance Metrics** i.e.
  - **Safety:** $B : B_{lim}$
  - **State:** $F : F_{MSY}$ & $B : B_{BSY}$
  - **Yield:** MSY
  - **Stability:** Inter-annual variation in catch
  - **Ecosystem:** $B_{Escapement}$

Operating Model

Hypotheses chosen to represent **Uncertainty**, and **Concerns** of stakeholders

Scenarios

- **Base Case:** not necessarily the most plausible in this example intended as a strawman that can be used to identify main sources of uncertainty.
- **Robustness Set:** capture the main uncertainties
- **Sensitivity Test:** to identify potential and existing data sets that can improve advice

Operating Model

Conditioning

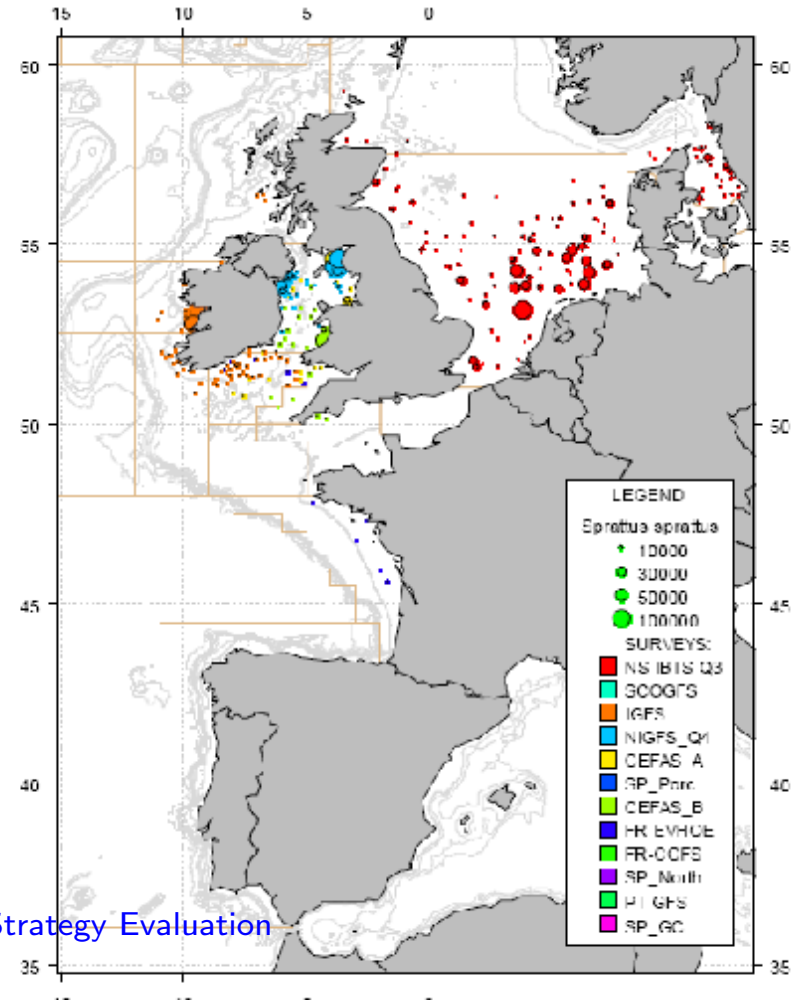
- **Seasonal:** allows for in year growth, mortality, ...
- **Life Histories:** to explore ecological hypotheses and to evaluate benefits of getting stock specific data
- **Natural Mortality:**
  - **M1** Background mortality, e.g. related to climate
  - **M2** Predation mortality
- **Sub-stocks:** Next step

Operating Model

Stock Structure

- **Celtic Sea Sprat**

Stocks and Surveys

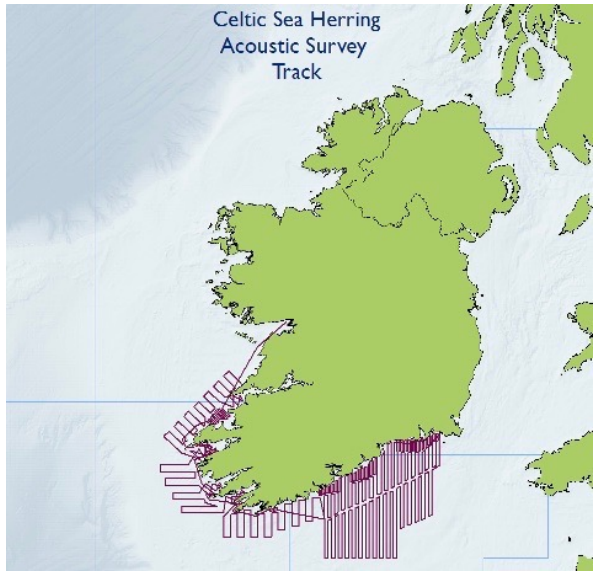


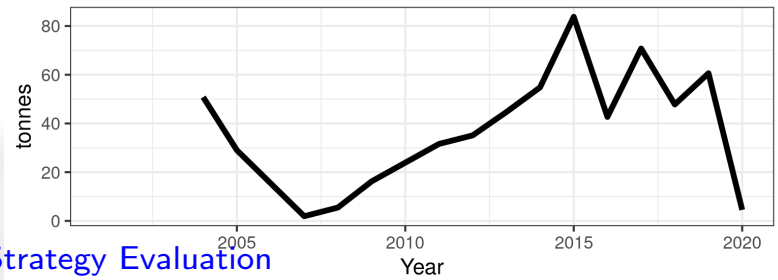
Empirical Control Rule

Observation Error Model

- How does index relate to population biomass.
- **Containment** i.e. process error due to changes in temporal/spatial overlap?

Acoustic Survey



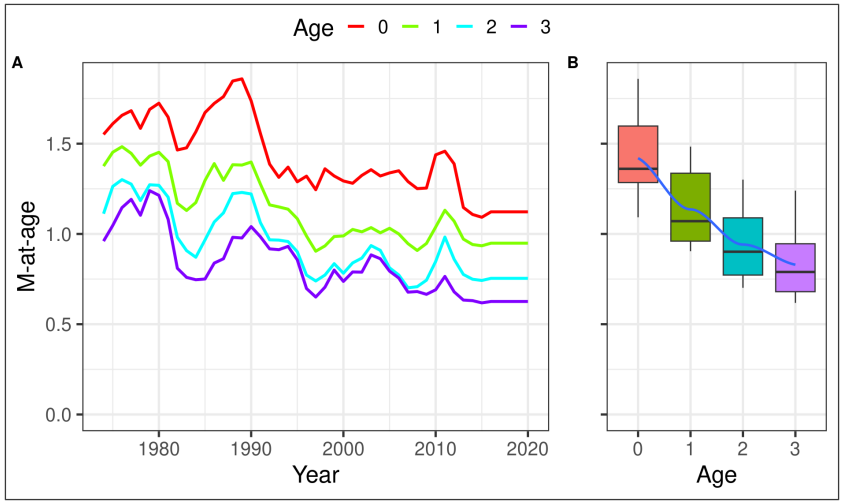


Conditioning

M-at-age

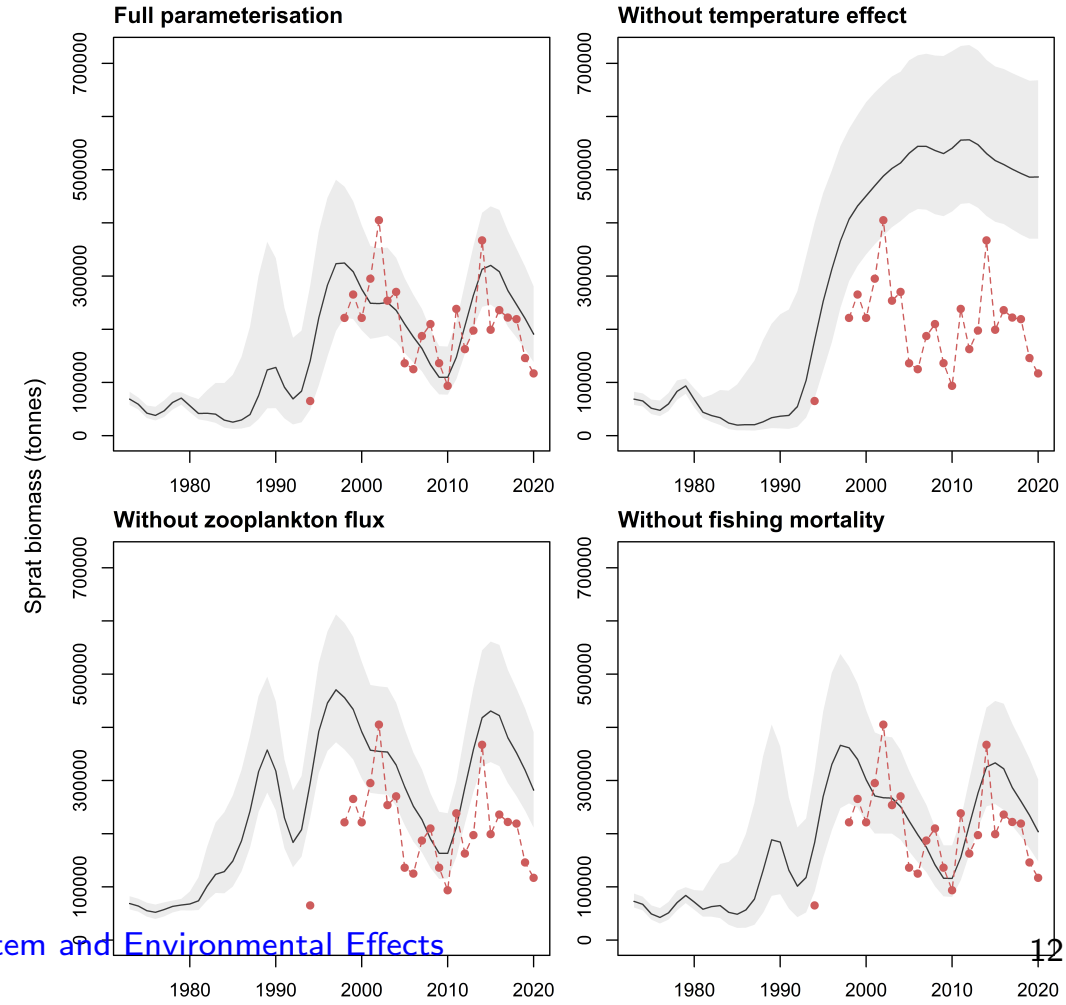
- **North Sea**

Year, age and year-class effects



Ecosystem and Environmental effect

- **Irish Sea** sprat shows an inverse relationship to sea surface temperature.
- Simulation suggest this has been the primary driver of biomass variation in recent years.

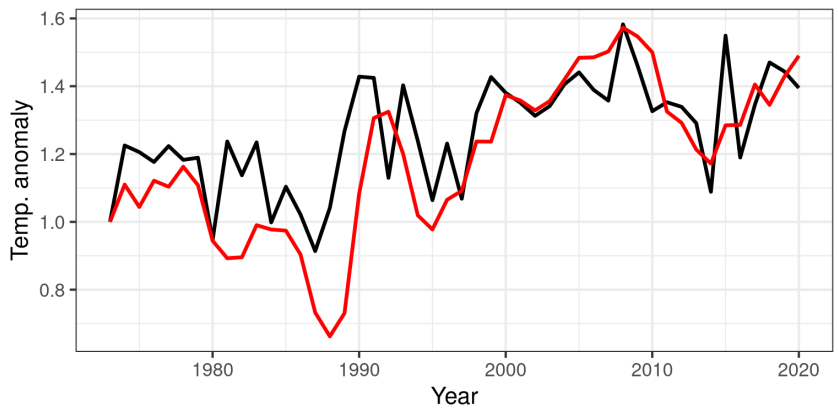


Ecosystem and environmental effect

M1

- Temperature shows a negative correlation with biomass.
  - Spring (May-June) temperature with a one-year lag
  - Three-year moving average

Background Mortality

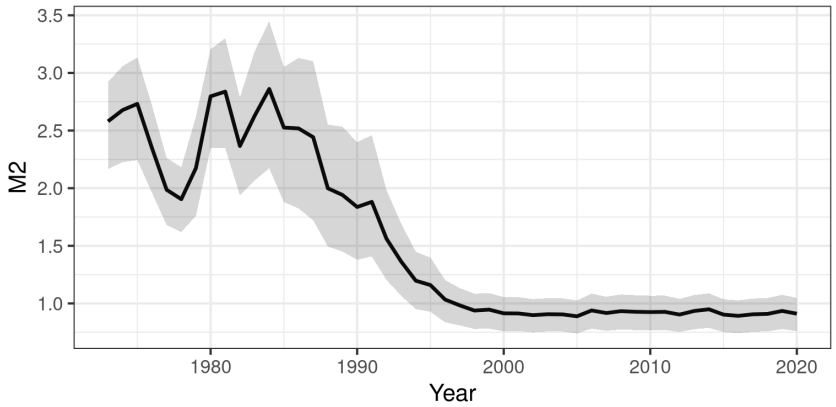


Ecosystem and environmental effect

M2

- Time series is for the entire population and isn't broken down into age groups.
- How to link M2 to predator biomass and needs?

Predation Mortality



Management Procedure

Status Quo

- Survey in October
- HAWG meets in following March
- Advice agreed in July
- Fishing in 4^{th} & 1^{st} Q, a year after survey

In season?

- Survey then fish

Harvest Control Rules

RFB Rule (Fischer *et al.*, 2021)

Sets catch advice (A_y) based on previous catch (C_{y-1}) multiplied by three components

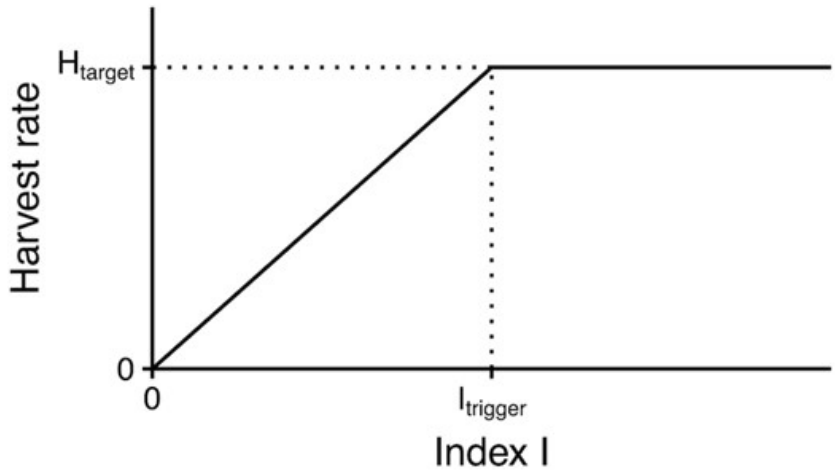
- **r:** an index of biomass
- **f:** a F proxy comparing the recent mean length to a length-based proxy for F_{MSY}
- **b:** reduces the catch when the biomass index falls below a threshold.

Harvest Control Rules

Constant Harvest Rate

- Relative harvest rate (H), defined as the ratio of the catch (C) to a stock size indicator (I), i.e. $H_y = C_y / I_y$
- Advised catch $A_y = \frac{I_y}{H_{\text{target}}}$.

HCR



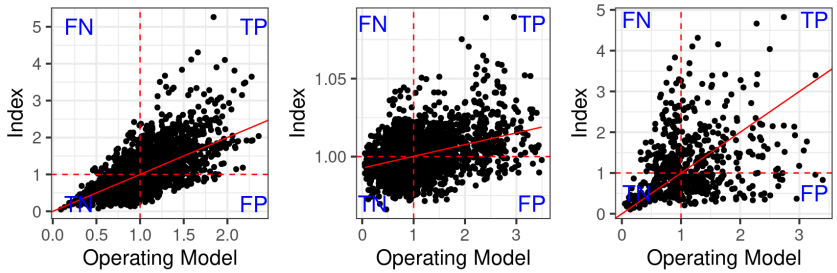
- $I_{trigger} \neq B_{escapement}$

Receiver Operator Characteristics

Prediction Skill

- **Prediction Skill:** Can we detect state?
  - Index
  - Length as a proxy for F
  - Harvest Rate I/C

True Skill Score

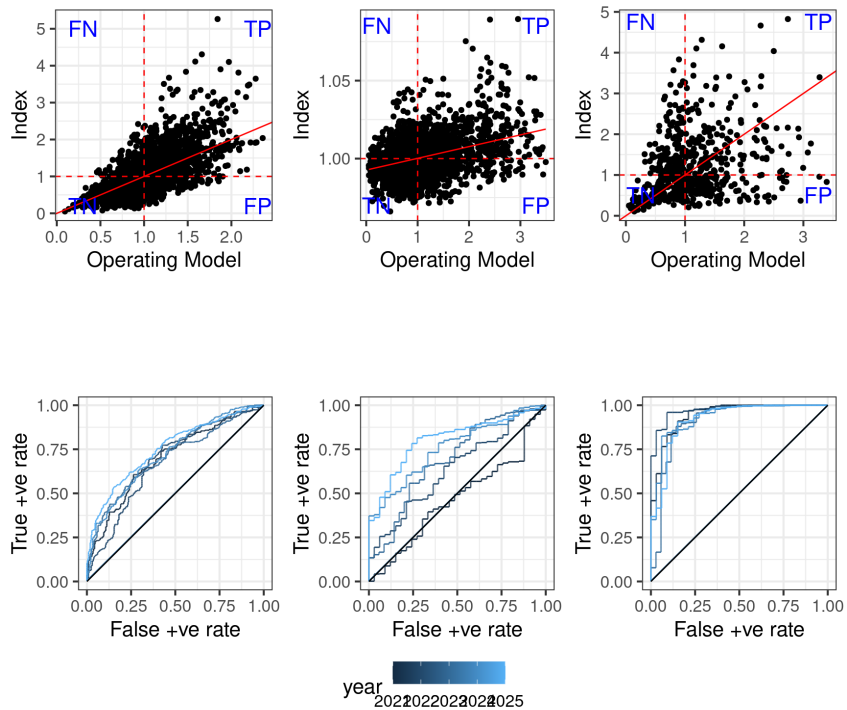


Receiver Operator Characteristics

Prediction Skill

- **Prediction Skill:** Can we detect state?
  - Index
  - Length as a proxy for F
  - Harvest Rate I/C
- **ROC:** (Kell *et al.*, 2022)

Prediction Skill

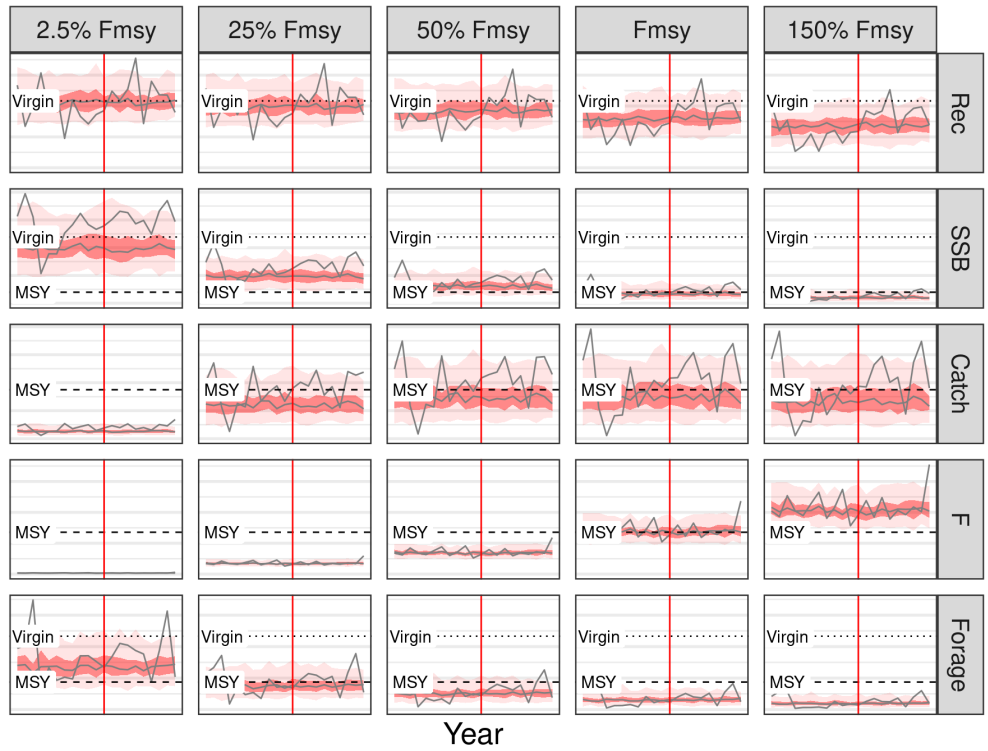


MSE

Summary Stats

- Compare to *MSY* and *Virgin*
  - Recruitment
  - *SSB*
  - *Catch*
  - *F*
  - *Forage*

Simple Projection



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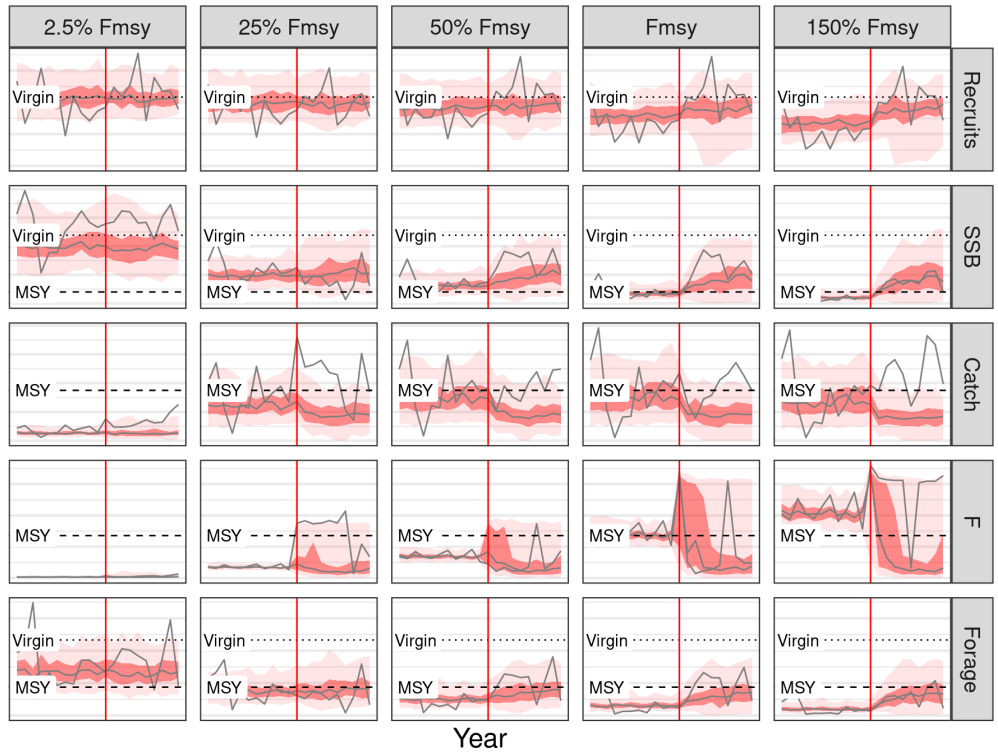
2 over 3 Rule



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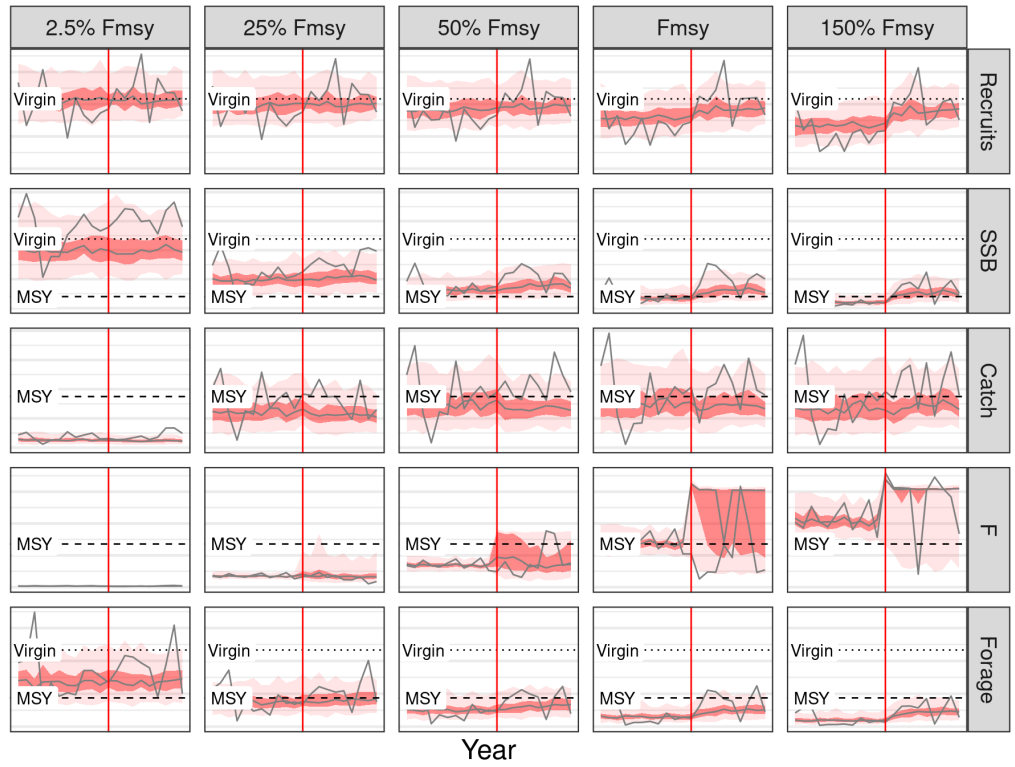
Harvest Rate

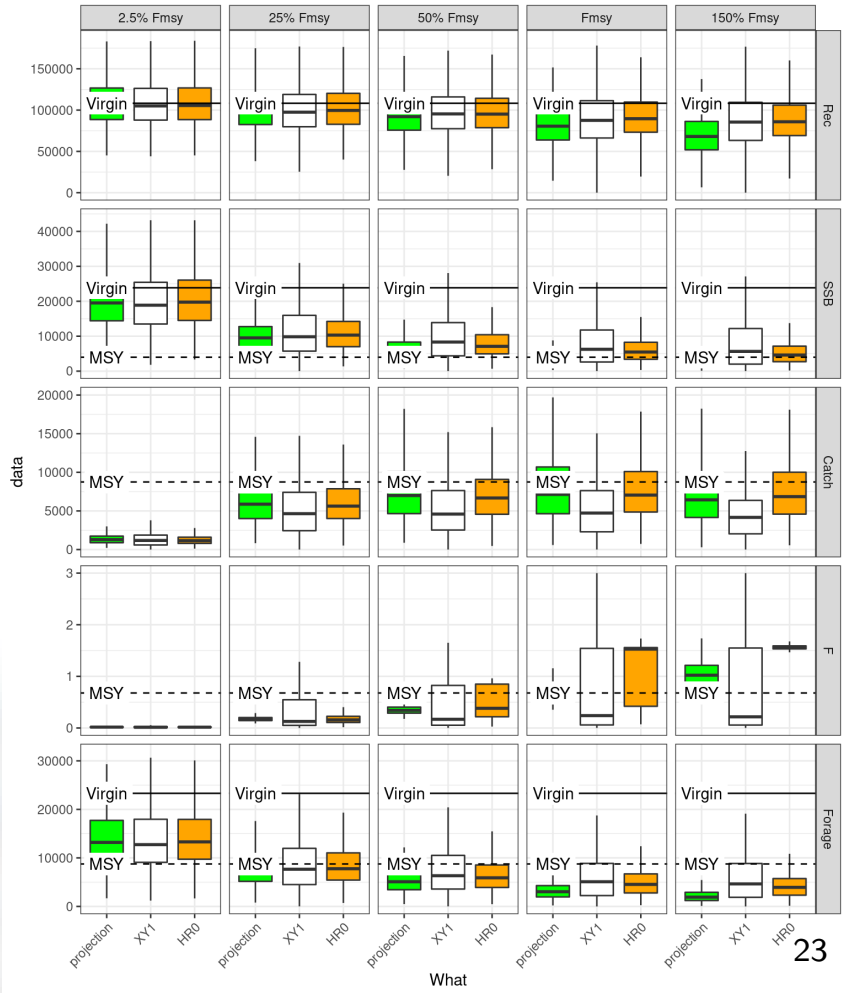


MSE

Summary Stats

- Green is the reference, i.e. the **best** you can do
- White is the **2 over 3** rule
- Orange is the **constant harvest** rate

x



Summary

Current Steps

- Uses **Ecological Theory** rather than stock assessments to condition OMs
- Links **Environmental Drivers** to population processes
- **Screens Indicators** for use in HCR before running MSE
- **Stress Tests** ICES PA and MSY Approach

Next Steps

- Agree Objectives,
- Agree how to include ecosystem effects, e.g. F_{ECO} to scale fishing mortality down when the ecosystem conditions for the stock are poor and up when conditions are good (Bentley *et al.*, 2021).
- Stock structure
- Risk equivalence

References

Bentley, Jacob W, Lundy, Mathieu G, Howell, Daniel, Beggs, Steven E, Bundy, Alida, De Castro, Francisco, Fox, Clive J, Heymans, Johanna J, Lynam, Christopher P, Pedreschi, Debbi, *et al.* 2021. Refining fisheries advice with stock-specific ecosystem information. *Frontiers in Marine Science*, **8**, 602072.

Fischer, Simon H, De Oliveira, José AA, Mumford, John D, & Kell, Laurence T. 2021. Using a genetic algorithm to optimize a data-limited catch rule. *ICES Journal of Marine Science*, **78**(4), 1311–1323.

Kell, Laurence T, Minto, Cóilín, & Gerritsen, Hans D. 2022. Evaluation of the skill of length-based indicators to identify stock status and trends. *ICES Journal of Marine Science*, **79**(4), 1202–1216.