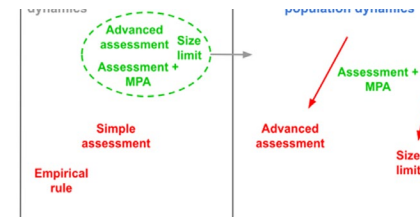
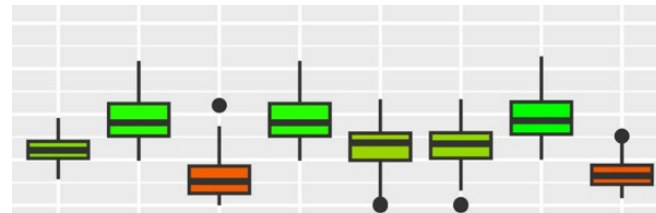
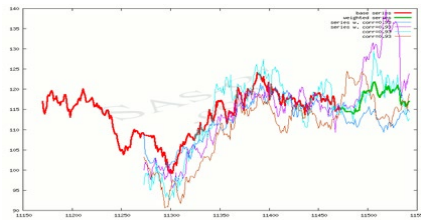


The Role of Management Strategy Evaluation (MSE) in Turning Climate Science into Climate-Informed Management Advice

Tom Carruthers



8th April 2026

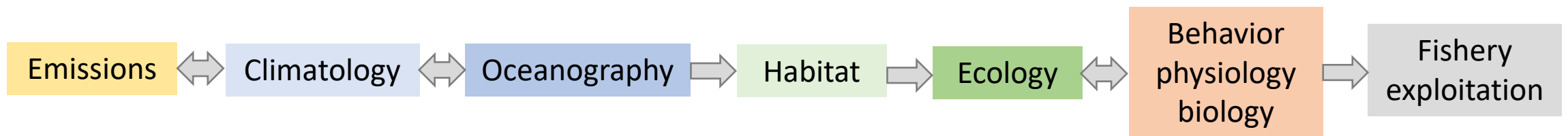
IATTC 2nd Climate Change Workshop

Contents

1. Problem Statement
2. What is MSE and Why is it Relevant?
3. Robustness Testing vs Forecasting
4. The Robustness Set
5. Approaches for Including Climate Scenarios
6. Examples
7. Role of Indicators
8. Discussion & Conclusions

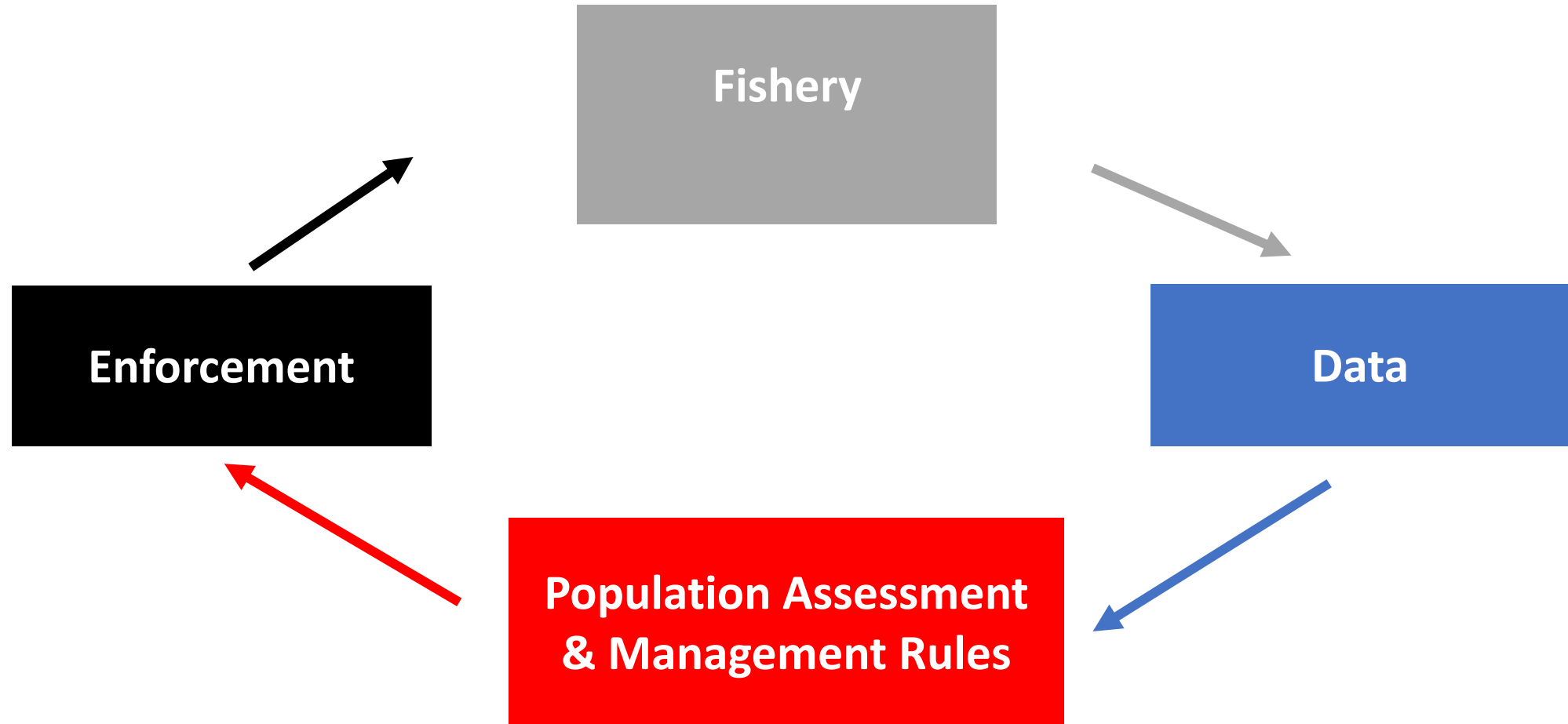
1. Problem Statement

- Marine communities are expected to experience increased impacts relating to climate change.
- There is a need for fishery management practices that are robust to changing environmental conditions, population and fishery dynamics.
- Quantitative forecasting of impacts is highly uncertain and the relative credibility of scenarios is unknown. Forecasts are the product of various theoretical models, for which empirical support varies:



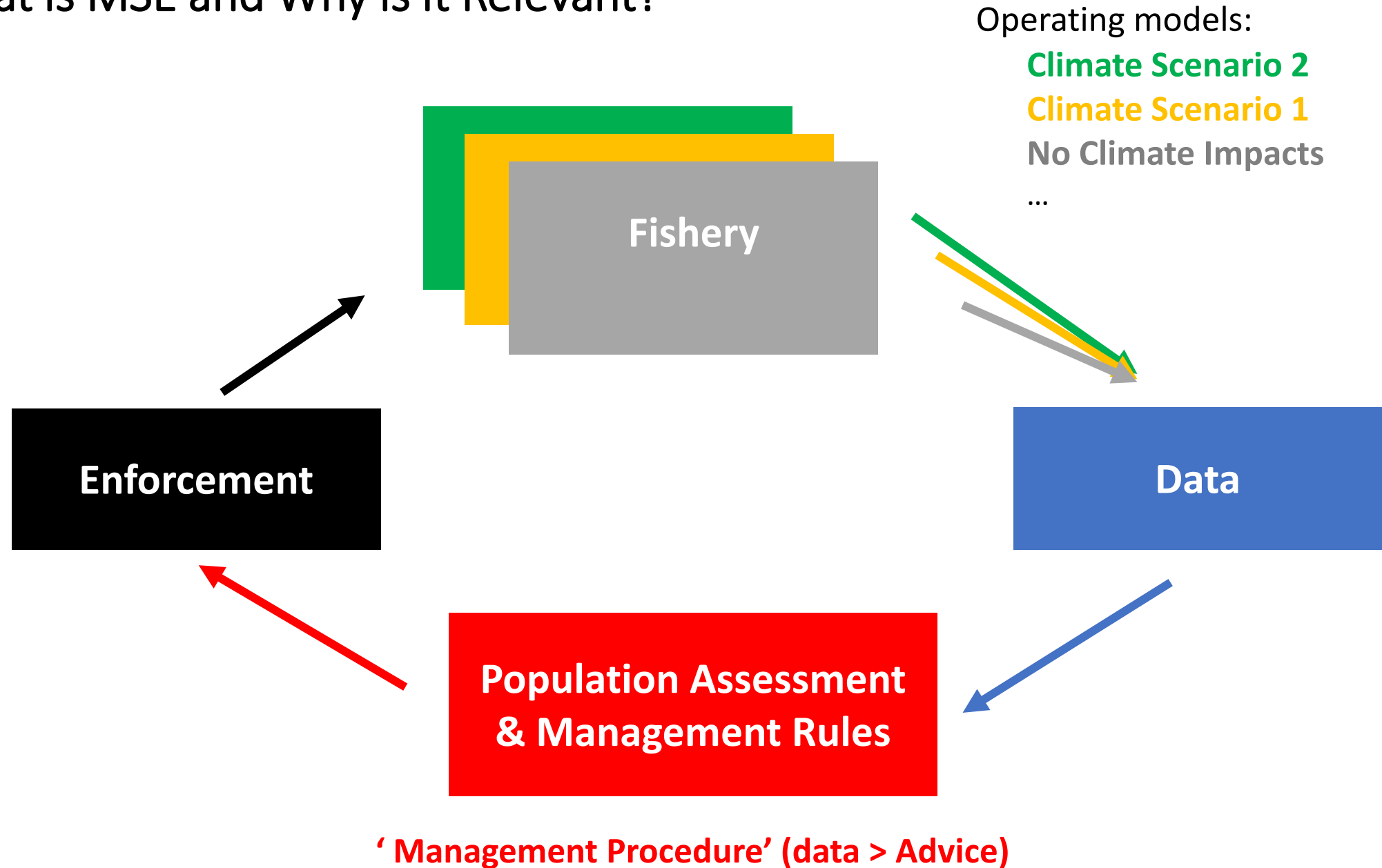
If scientific uncertainty over climate impacts on fish populations is inevitably very high, should this necessarily obstruct progress in establishing robust fishery management practices?

2. What is MSE and Why is it Relevant?

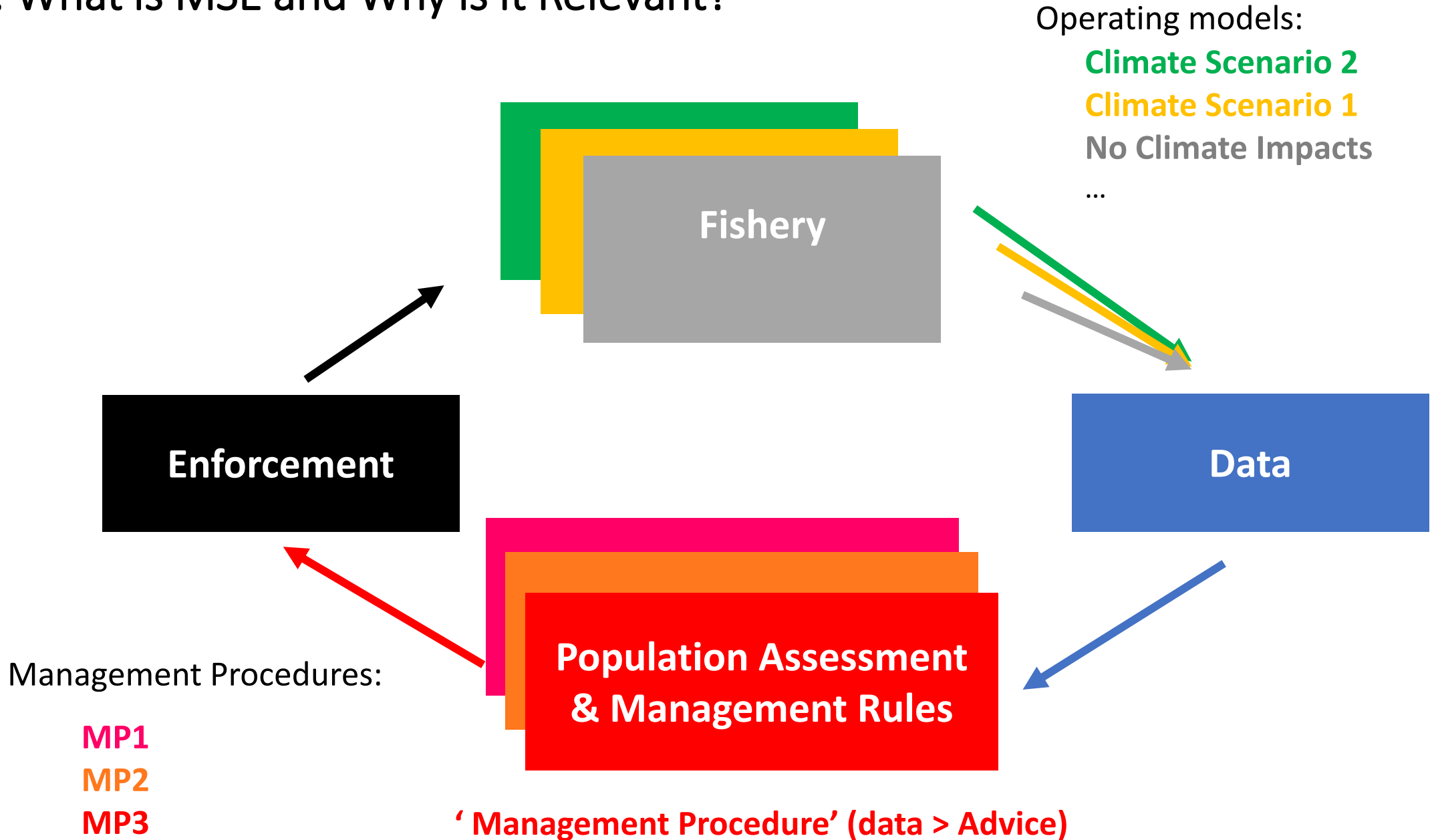


'Management Procedure' (data > Advice)

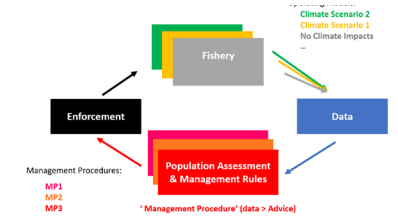
2. What is MSE and Why is it Relevant?



2. What is MSE and Why is it Relevant?



2. What is MSE and Why is it Relevant?



- A **Management Procedure (MP)** is any reproducible method for calculating management advice from data (e.g., a stock assessment + harvest control rule, simple catch/index ratio) and can include simple regulations such as size limits or spatio-temporal closures.
- MSE is a simulation testing framework for MPs. It is analogous to testing pilots (MPs) in flight simulators.
- The focus of MSE is robustness of MPs to uncertainties in system dynamics.
- Stock assessment is simply part of a possible MP and its focus is generally on scientific veracity (MSE and stock assessment are not comparable).
- MSE aims for management certainty in the face of scientific uncertainty.

3. Robustness Testing vs Forecasting

The Pilot – Flight Simulator Analogy

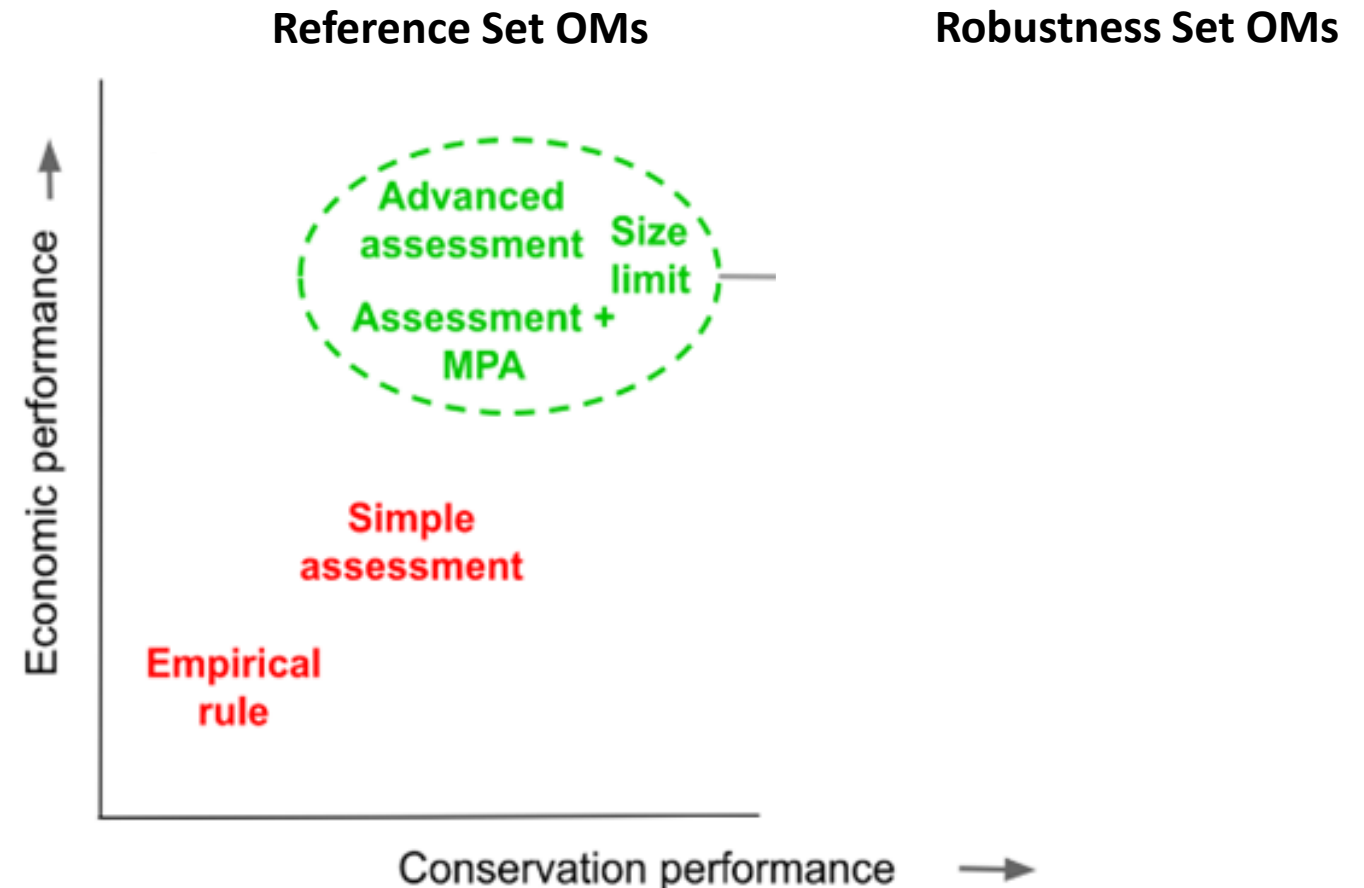
- Do we need a weather forecast for the next five years to hire a pilot?
- No, because we have simulation tested their performance across a wide range of weather conditions and have confidence in their abilities.
- Do those simulation tests have to exactly match the conditions they will experience?
- No, because (A) they are tested under relatively extreme scenarios and (B) flying ability is often shared among tests, e.g., a pilot that flies well in extreme crosswinds is likely to also fly well in turbulent air and perhaps difficult conditions in general.

Back to MSE and Climate Impacts...

- Forecasted impacts of climate on fishery dynamics are highly uncertain.
- This is a problem for assessments that require defensible forecasts, but less so for MSE that focuses on the properties of MPs, their responsiveness and robustness.
- Even imperfect characterisation of possible climate scenarios is likely to inform the selection of MPs that are broadly robustness to changing conditions (e.g., those that don't rely on assumptions of stationary stock productivity) .

4. The Reference and Robustness Set of Operating Models

- The Reference Set of OMs is the primary basis for MP selection and usually span uncertainties for which there is some empirical evidence. The Robustness Set of OMs are used as a basis for further discrimination among MPs that perform similarly for the Reference set.
- Consider **! AN EXAMPLE !** where three management procedures perform similarly under the reference set of operating models.
- Why not choose an MP that is also robust to potential, hypothetical climate impacts if it performs comparably under the reference set of operating models?
- Does it matter if the robustness tests are not well supported empirically? E.g., an uncertain forecast of climate impacts?



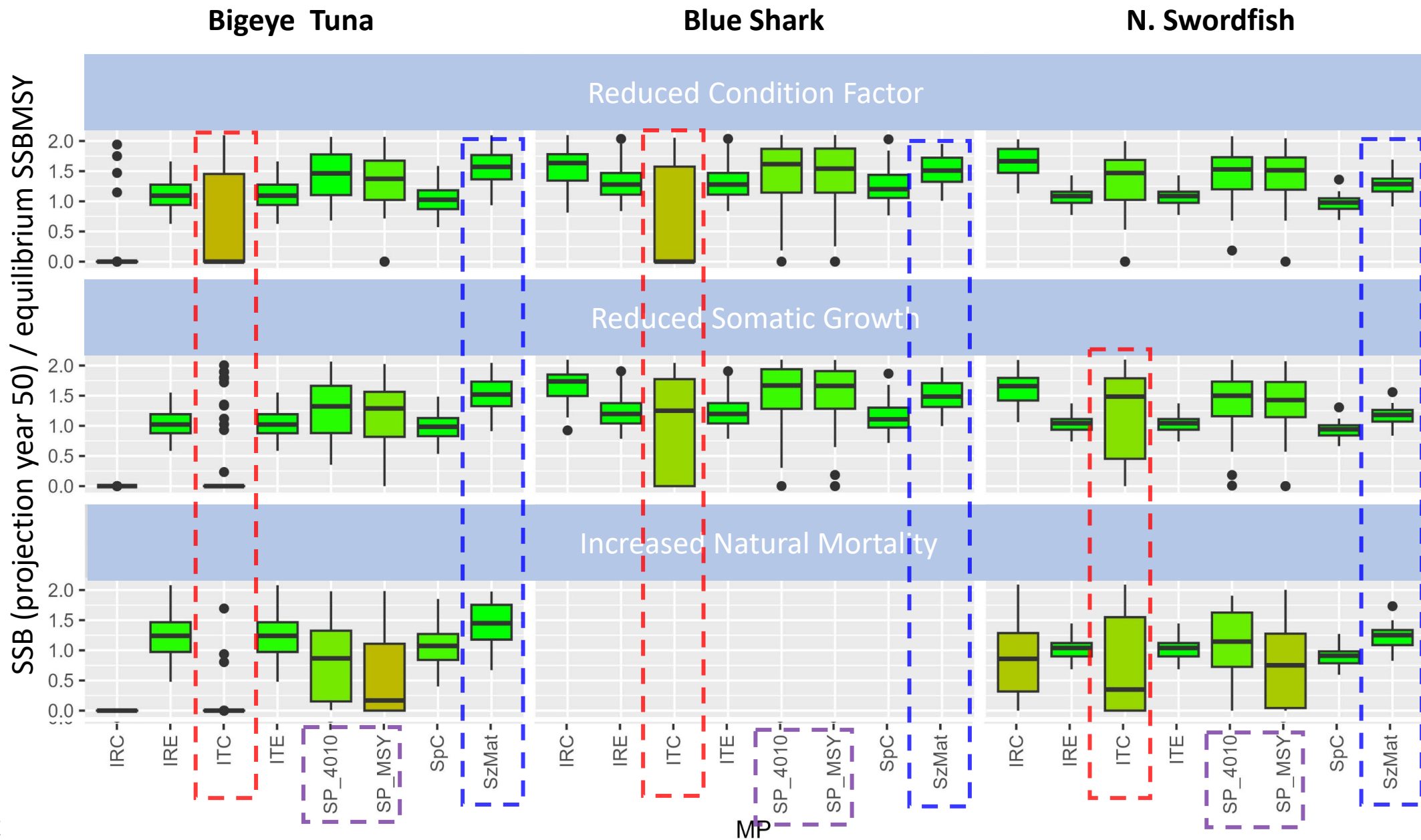
4. Robustness Testing Seven MPs for Three Stocks and Three Potential Climate Impacts

Index Target
Catch control
(ITC) among the
least robust.

Regulations such
as a minimum
size limit at size
at 75% spawning
fraction very
robust (SzMat)

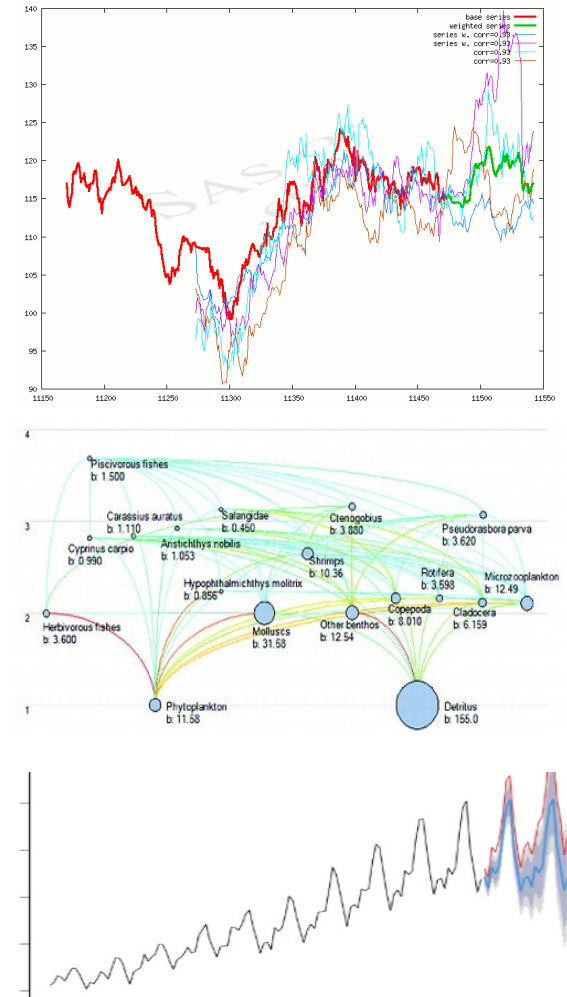
Harvest control
rules
implemented
with
assessments
were more
robust (SP_4010
vs SP_MSY)

Carruthers 2024



5. Approaches for including climate impacts in MSE

- Descriptive ‘model free’ approaches that identify correlations among observed variables, hypothesize a functional relationship (E.g., somatic growth as a function of sea surface temperature) and then project the dependant variable based on a forecast of the independent variable.
- Model-based approaches that establish theoretical models of system dynamics which are fitted to data to ensure empirical plausibility (sometimes called ‘mechanistic’ but are still strictly speaking descriptive and hypothetical).
- Retrospective: (A) replay a recent historical period with observed changes believed to be climate-driven and compare performance of MPs or (B) reuse historical dynamics in projections.
- Expert judgement: essentially ‘made up’ as a basis for stress testing and further discrimination among MPs.



6. Examples

- Atlantic Bluefin Tuna (ICCAT 2022):
 - increasing catchability - range contraction [made-up]
 - Persistent changes in stock distribution [historical replay]
 - Large recruitment shifts flipping back to past historical levels [hist. replay]
- North Atlantic Swordfish (ICCAT 2023)
 - Increasing catchability - range contraction [made-up]
 - Cyclical recruitment pattern [descriptive / made-up]
 - Lower recruitment in projections [made-up]
- Atlantic Dolphinfish (mahi mahi) (NOAA 2026)
 - Decreasing growth, condition factor, nat. survival [descriptive / made-up]
 - Increasing catchability - range contraction [made-up]
 - Consistent northwards distribution shift [hist. replay / made-up]
- ClimateTest (Carruthers 2026) [model-based 'mechanistic']



7. Role of Indicators

Three outcomes of MP robustness testing:

When testing an MP for climate robustness, three discrete outcomes can be envisaged that depend on the frequency with which the MP fails to meet management objectives given the climate test robustness scenarios ('failure rate'):

- | | |
|----------------------|---|
| (robust) | Failure rate of the MP is acceptably low; |
| (conditional) | Failure rate of the MP is higher than acceptable but conditions where the MP fails are detectable given available data; |
| (not robust) | Failure rate of the MP is higher than acceptable and conditions where the MP fails are not detectable given available data. |

A lack of robustness may be acceptable with indicators of problematic simulation conditions (exceptional circumstances)

8. Conclusion & Discussion

- Should we wait for scientifically defensible forecasts of climate impacts before developing climate-robust management advice for exploited fish stocks?
- MSE provides an established framework for including hypothetical scenarios in tactical advice.
- A great deal of flexibility in how climate research could enter the MSE process. For example:
 - Qualitative hypotheses and quantitative models in the construction of operating models;
 - Use of indicators of problematic climate impacts; and
 - the design of climate-robust MPs.
- Could be argued that via MSE, climate-tested management procedures are already in place that provide tactical advice.

Acknowledgements

This research was funded by



Thanks to

Rebecca Scott

Adrian Hordyk

Quang Huynh

Shana Miller

and

Grantly Galland

References

Carruthers, T. R. 2024. Developing the Climate Test: Robustness Trials for Climate-Ready Management Procedures. Col. Vol. Sci. Pap. 81(6): 1—26. Available from: https://www.iccat.int/Documents/CVSP/CV081_2024/n_6/CV08106104.pdf

Carruthers, T.R. 2026. ClimateTest. Rating the Climate Readiness of Fishery Management Options. Available from: <https://climatetest.bluematterscience.com/>

ICCAT. 2022. Management Strategy Evaluation for Atlantic Bluefin Tuna. Available from: <https://iccat.github.io/abft-mse/>

ICCAT. 2023. Management Strategy Evaluation for North Atlantic Swordfish. Available from: <https://iccat.github.io/nswo-mse/>

NOAA. 2026. Management Strategy Evaluation for Atlantic Dolphinfish. Available from: <https://blue-matter.github.io/mahiMSE/>