2025 Stock Assessment of Striped Marlin in the Southwest Pacific Ocean

Part II: Data-moderate Bayesian Surplus Production Model Approach

N. Ducharme-Barth, C. Castillo-Jordán, F. Carvalho, and P. Hamer

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Openscience

All data inputs, model code, key model outputs, figures, report and presentation files are publicly available on GitHub:

https://n-ducharmebarth-noaa.github.io/2025-swpo-mls-bspm/

Assessment context

- Strategic shift from integrated age-structured model to a Bayesian data-moderate approach
- Previous challenges with:
  - Data conflicts and poor fits to size composition
  - Challenges estimating population scale
- Bayesian Surplus Production Model (BSPM) offers simplified yet robust alternative when data limitations exist
- Complements integrated assessment (Part I) for holistic stock status view

Why BSPM?

Advantages:

- Focuses on estimating **productivity** and **scale** given catch and index data
- Efficient exploration of parameter space
- Explicitly incorporates biological uncertainty through priors
- Proven robust and effective for pelagic fish assessments

Trade-offs:

- Simplifies complex age-structured dynamics
- Assumes single well-mixed population
- Knife-edged selectivity assumption

Model framework

Fletcher-Schaefer production model

Population dynamics:

$$N_t = (N_{t-1} + \text{Production}_{t-1}) \times \text{Process error}_t \times \text{Fishing survival}_{t-1}$$

Fishing impact linked to effort:

$$\text{Fishing survival}_t \text{ inversely proportional to Fishing mortality}_t$$

$$\text{Fishing mortality}_t = \text{Catchability}_t \times \text{Fishing effort}_t$$

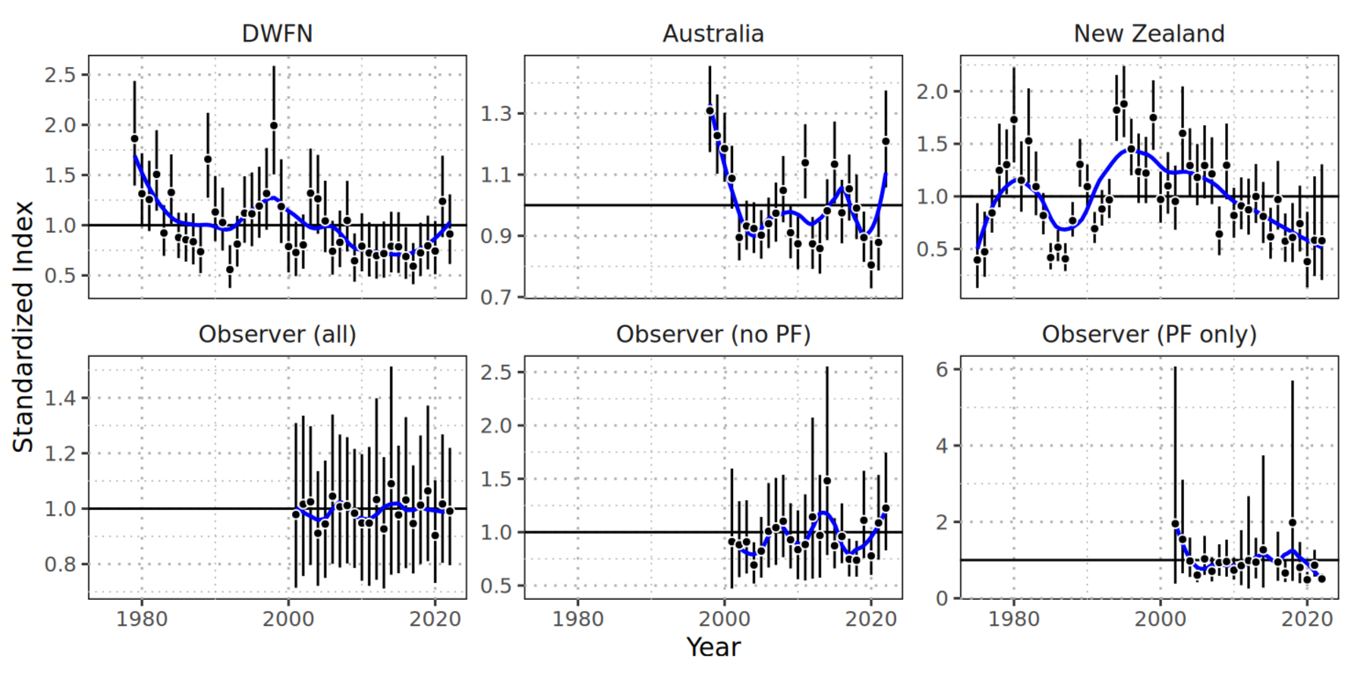
Key features:

- True population (numbers) is treated as an unobserved random variable
- Model only fits to observations of relative abundance and catch
- Catchability is allowed to vary temporally so fishing mortality can match catch
- Biology captured in `Production` as max rate of population growth R_{Max}

Input data

Standardized CPUE indices:

- DWFN longline index (1979-2022) & New Zealand recreational sportfish indices (1975-2022)
- Several observer-based indices explored as sensitivities



> *i* Note
>
> Blue line is a moving average and not a model fit!

Model development approach

1. Develop priors:

- Use biological simulation framework to develop initial prior for R_{Max} and production function shape parameter n
- Develop priors for population scale and catchability based on maximum observed catch and early period CPUE

2. Prior pushforward:

- Pass random parameter combinations through the population dynamics model
- Filter parameter combinations for biological and fishery realism
- Develop a multivariate prior based on emergent parameter correlations

3. Fit models to data □

- Evaluate model performance (fits & diagnostics)
- Draw inference from posterior updates
- Consider sensitivities to data inputs

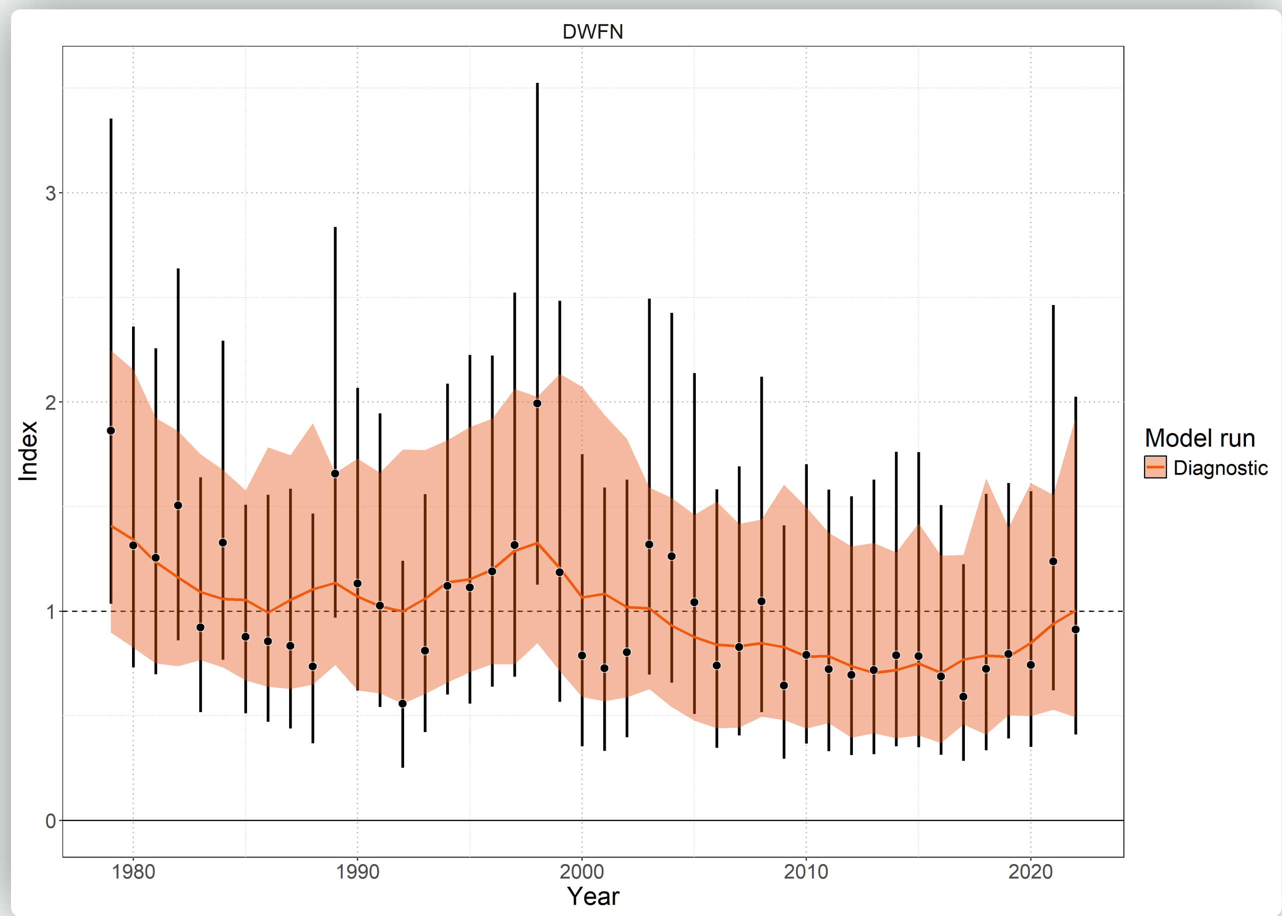
Diagnostic model

- Fits to the DWFN index
- Uses a robust likelihood for fitting to catch data
- Estimates scale, R_{Max}, production shape, annual catchability deviates, process error, and index observation error
- Posterior distributions of estimated quantities were derived from sample chains starting from 5 different starting points
- Standard Bayesian diagnostics indicated that all sample chains satisfactorily converged to a stable distribution without issue

Diagnostic	Value	Criteria	Status
Max $\hat{R}$	1.008	< 1.01	✓
Min ESS	788.000	> 500	✓
Divergent	0.000	= 0	✓
Tree Depth	0.000	= 0	✓

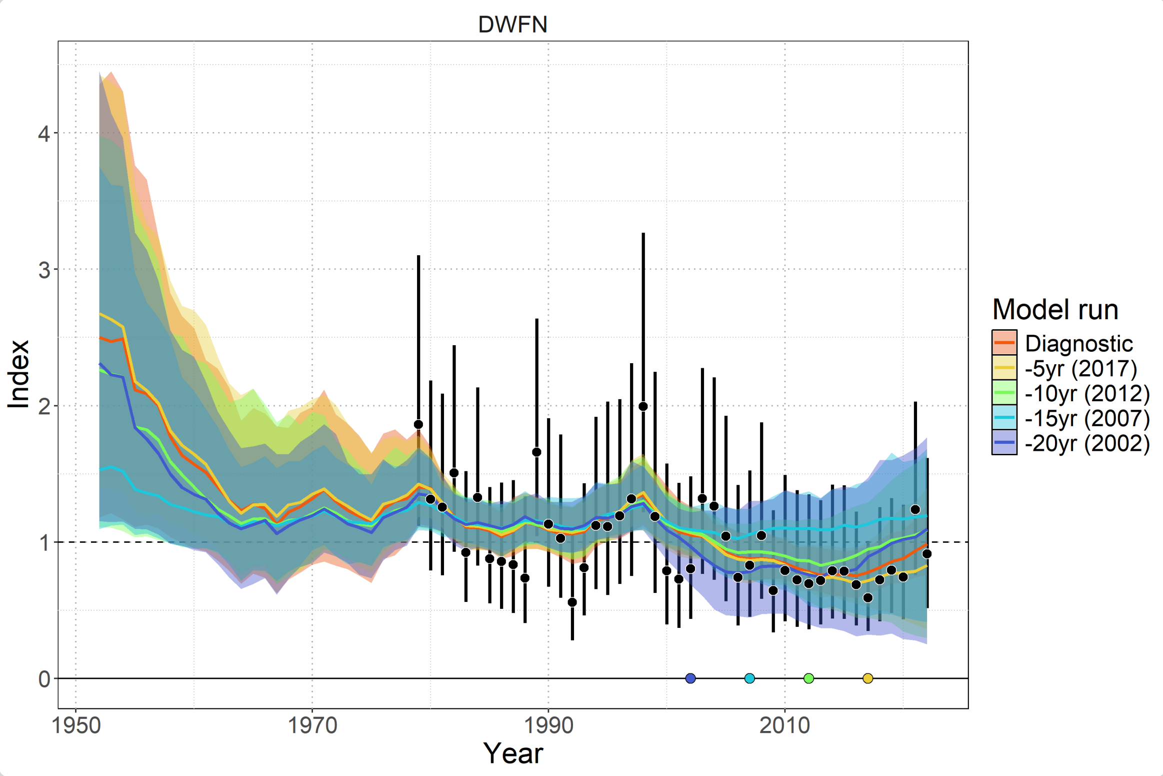
The diagnostic case model is model `0100`.

Diagnostic model: Fits



The diagnostic case model is model `0100`.

Diagnostic model: Validation

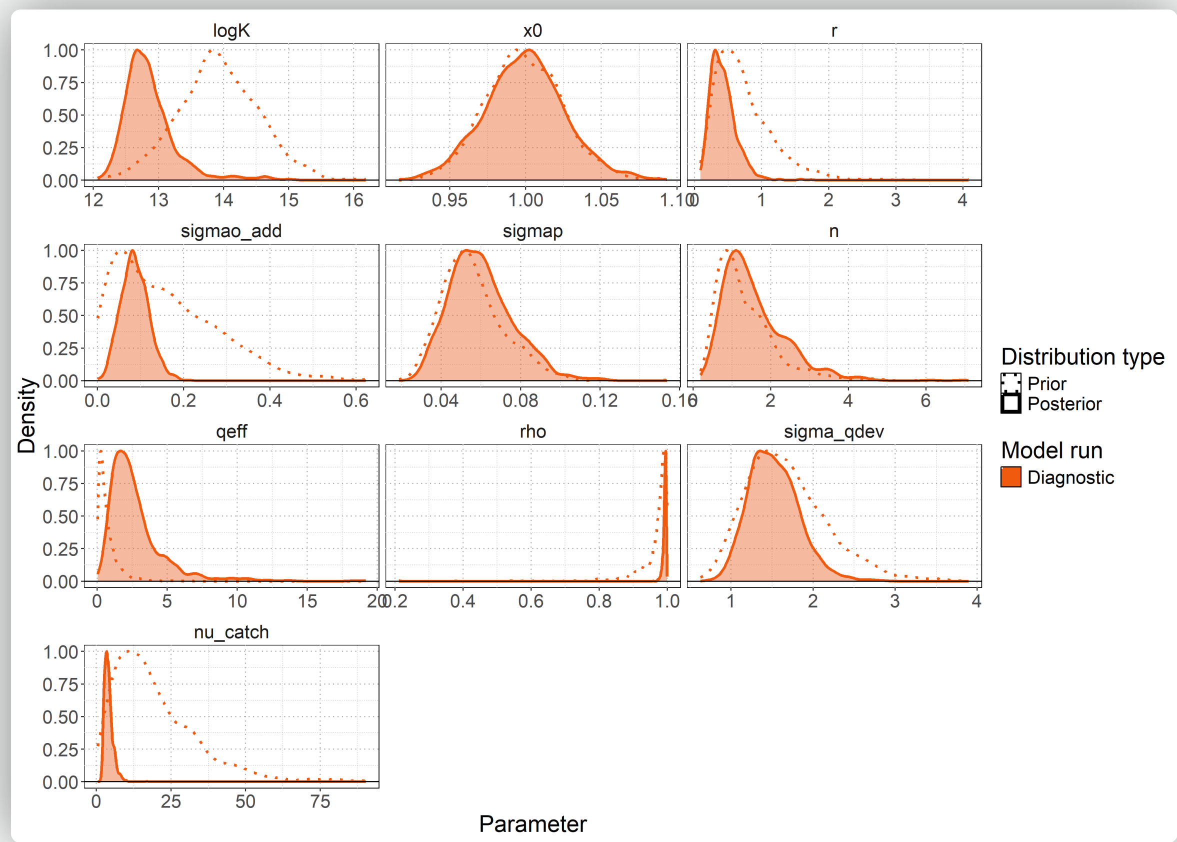


Hindcast

- Model predictions of the index holding out up to 20 years of data
- Good hindcast index fit indicates production and catch drive model estimates

The diagnostic case model is model `0100`.

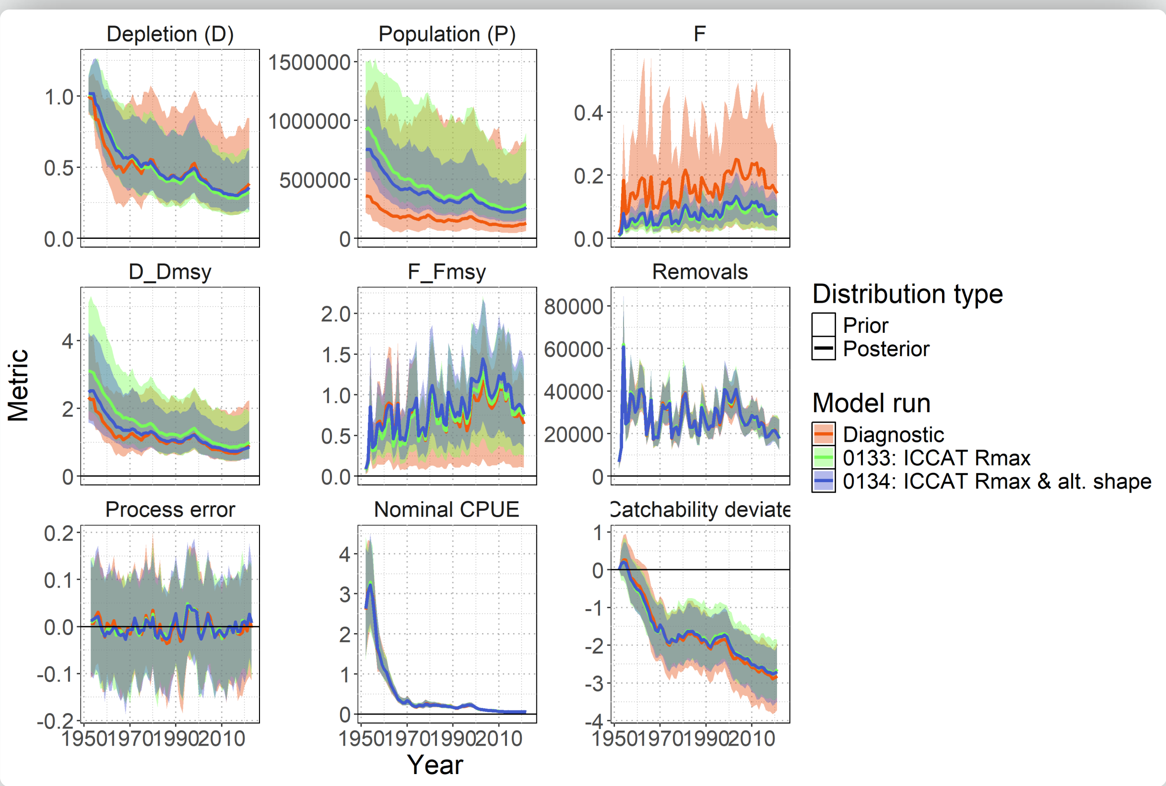
Diagnostic model: Inference



Posterior update

- If posterior (solid line) differs from realized prior (dotted line) distribution, data inform estimates
- Both key population dynamics parameters for scale (*logK*) and R_{Max} (*r*) indicate strong influence of data on estimates

Key sensitivities

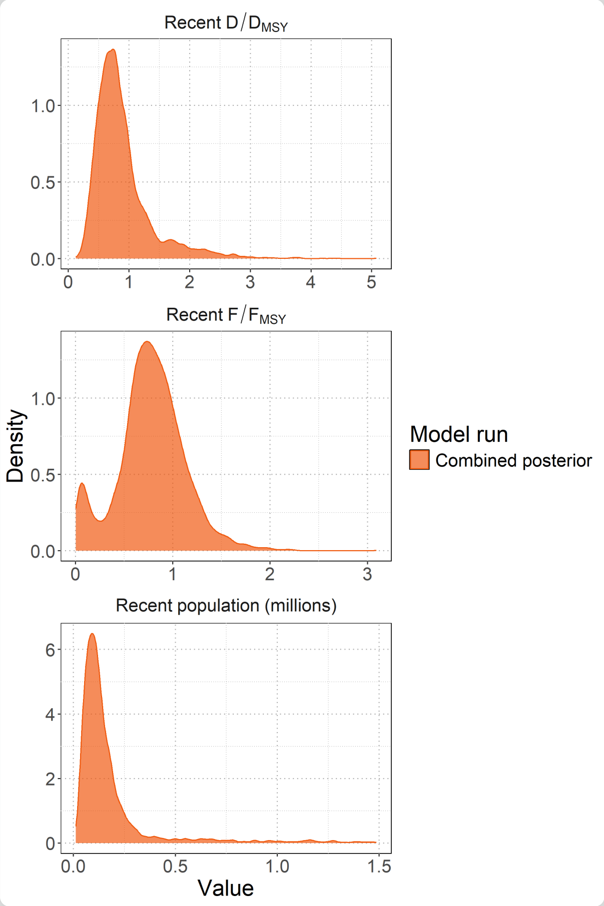


Alternative R_{Max} prior

- Lower productivity assumption based on Atlantic white marlin
- Results in larger population scale but similar relative stock status metrics
- Choice of shape *n* prior impacts scale estimate and *MSY* based reference points

Key sensitivities: indices (`0071-0075` & `0129-0132`), early data (`0079-0083`), catch reporting (`0115-0117`), and R_{Max} prior (`0133-0134`).

Model ensemble



ⓘ Marginal posterior distributions

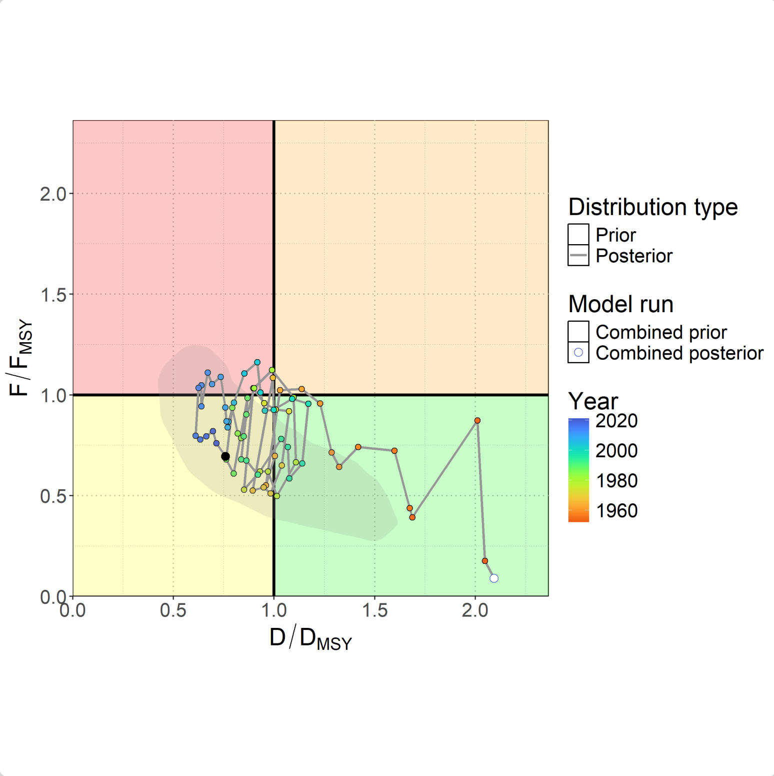
- D/D_{MSY}: Majority of distribution (74%) below D/D_{MSY}
- F/F_{MSY}: Minority of distribution (23%) above F/F_{MSY}
- Population scale: Data supports a small recent population with large, asymmetric uncertainty to the high side

D_{recent} refers to the average over 2019-2022

F_{recent} refers to the average over 2018-2021

Ensemble models: `0100`, `0102`, `0105`, `0107`.

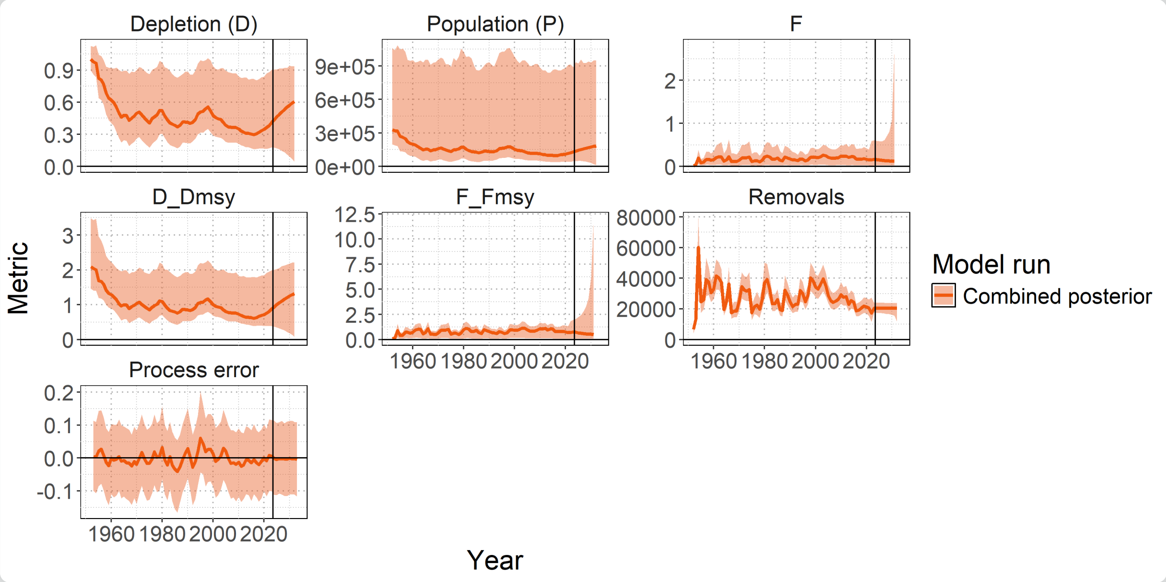
Stock status



Metric	Median [95% CI]	Probability
Recent Status		
D_{recent}/D_{MSY}	0.77 [0.33–2.3]	74% below D_{MSY}
F_{recent}/F_{MSY}	0.77 [0.05–1.51]	22.9% above F_{MSY}
Latest Status		
D_{latest}/D_{MSY}	0.81 [0.32–2.36]	70% below D_{MSY}
F_{latest}/F_{MSY}	0.69 [0.05–1.51]	18.4% above F_{MSY}

Conclusion: Stock is overfished but not undergoing overfishing. Only 22.9% joint probability of being simultaneously overfished and undergoing overfishing.

Projections



Projection assumptions

- Recent average catch (2018-2022)
- Stationary productivity & environment
- Process error resampled from model period

Future overfished probabilities:

- 2027: 40.9%
- 2032: 26%

Conclusion: Continued recovery expected under recent catch levels with decreasing risk of overfishing.

Limitations

Data representativeness:

- CPUE indices may not represent true stock trends
- Potential under-reporting of catches for bycatch stock
- Stock structure uncertainty (genetic evidence of SWPO fish in North Pacific catches)

Model simplifications:

- Single well-mixed population assumption
- Knife-edged selectivity
- No age structured dynamics
- Stationary productivity and carrying capacity over 70 years

Parameter uncertainty:

- Substantial uncertainty in absolute population scale
- Shape parameter n not estimable from data
- High uncertainty in key biological processes translates to uncertainty in R_{Max}

Environmental factors:

- Future variability in environmental and oceanographic conditions are not explicitly modeled
- Process error spikes suggests unmodeled dynamics

Recommendations

Stock structure research:

- Develop conceptual model for SWPO striped marlin
- Collaborate with ISC Billfish Working Group

Data and biological research:

- Reduce uncertainty in key biological processes where possible
- Investigate representativeness of abundance indices
- Address stock connectivity questions with genetic research

Future modeling approach:

- Progressive development within Bayesian framework
- Move toward Bayesian fully integrated age-structured models similar to WCPO oceanic whitetip shark

Conclusions

- In the end, the BSPM shows similar results to the SS3 model
- Existing data do not support a large population, but a small highly productive stock
- Maximum catches are $\sim \mathbf{70k}$ but average between $\mathbf{20k} - \mathbf{30k}$
- Since indices show declines given those catches, the population must be small
- However, as seen in the sensitivities, different productivity assumptions, larger catches or a flatter CPUE index would all support a larger population
- Relative to the SS3 model, the BSPM identifies a production function giving greater confidence in model estimates, and more appropriately integrates over possible uncertainty in population scale and productivity

Acknowledgements

Collaborative Assessment Process

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