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face of non-stationarity: an application to Indian Ocean
yellowfin tuna**

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Catch level projections and management benchmarks in the face of non-stationarity: An application to Indian Ocean yellowfin tuna

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Introduction

- Catch projections are one of the basis of the management advice for fisheries.
- When making projections, assumptions about future recruitment need to be made.
- Recruitment is one of the most uncertain processes.
- The no-stationarity of recruitment and overall productivity of fish stocks can significantly affect science based recommendations for management and produce large differences on the recommended catch levels to achieve management objectives.
- Configuration of projections not homogeneous across tuna RMFOs.
- Indian Ocean yellowfin is a relevant case study due to economic importance.

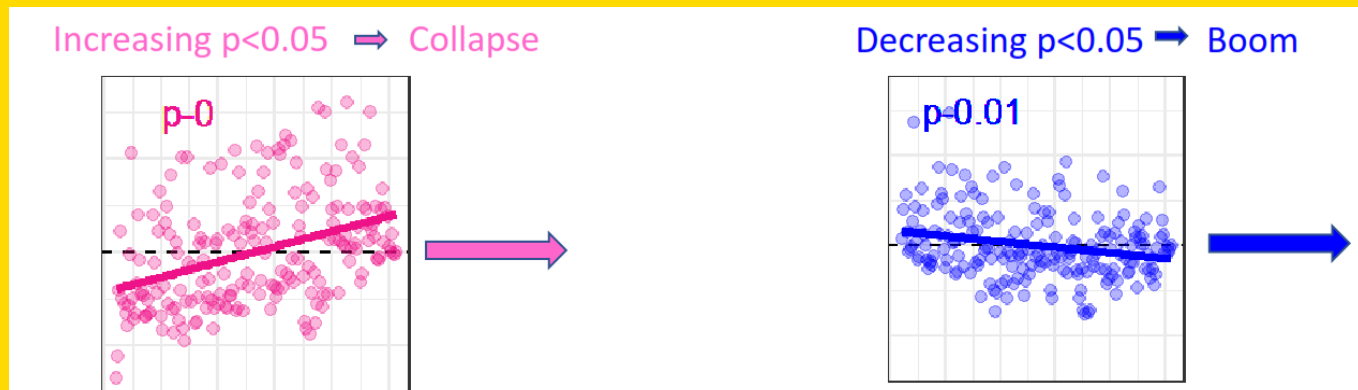
Introduction

- Assessments of tropical tunas (including IO yellowfin) contain trends in recruitment deviates.
- Trends associated with large/low values of estimated productivity.
- When recruitment deviates increase, these can compensate biomass in periods of large catch.
- When this happens, process error is not random (~variability) but part of response to fishing.
- In IOTC assessments, the SS3 model estimates benchmark quantities (B_0 , B_{msy} and F_{msy} etc) based on average recruitment (SR), estimation period.



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- Management implications. Differences between recent and future recruitment (productivity)



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- Management implications. Differences between recent and future recruitment (productivity)
- **Trends in rec devs are probably a cause of model misspecification but they can also indicate changing conditions (productivity etc) linked (or not) to climate change. These need to be addressed to develop robust management advice.**

Objectives

- To analyse the impact of assumptions about future recruitment on projections and management advice.
- Propose a methodology that preserves the link between spawners and recruits but accounts for recent trends in recruitment (model misspecification and/or changes in productivity).
- Apply and discuss the application of this methodology for Indian Ocean yellowfin and compare with other approaches.
- Outline the need to update management benchmarks to make them compatible with assumptions on future recruitment.

Methodology

- Files of the 2021 and 2024 stock assessments (SS3) for Indian Ocean yellowfin.
- Comparison between SS3-options for future recruitment configuration:

1. Recruitment based on equilibrium S-R conditions ($R \sim SSB$)	ICCAT/IOTC
2. Constant recruitment based on recent estimates ($R = R_{\text{recent}}$) (10 and 20 years)	WCPFC/IATTC
3. Recruitment based on S-R adjusted with recent rec devs ($R \sim SSB \times \text{recent rec devs}$) (10 and 20 years)	IOTC YFT (2024)

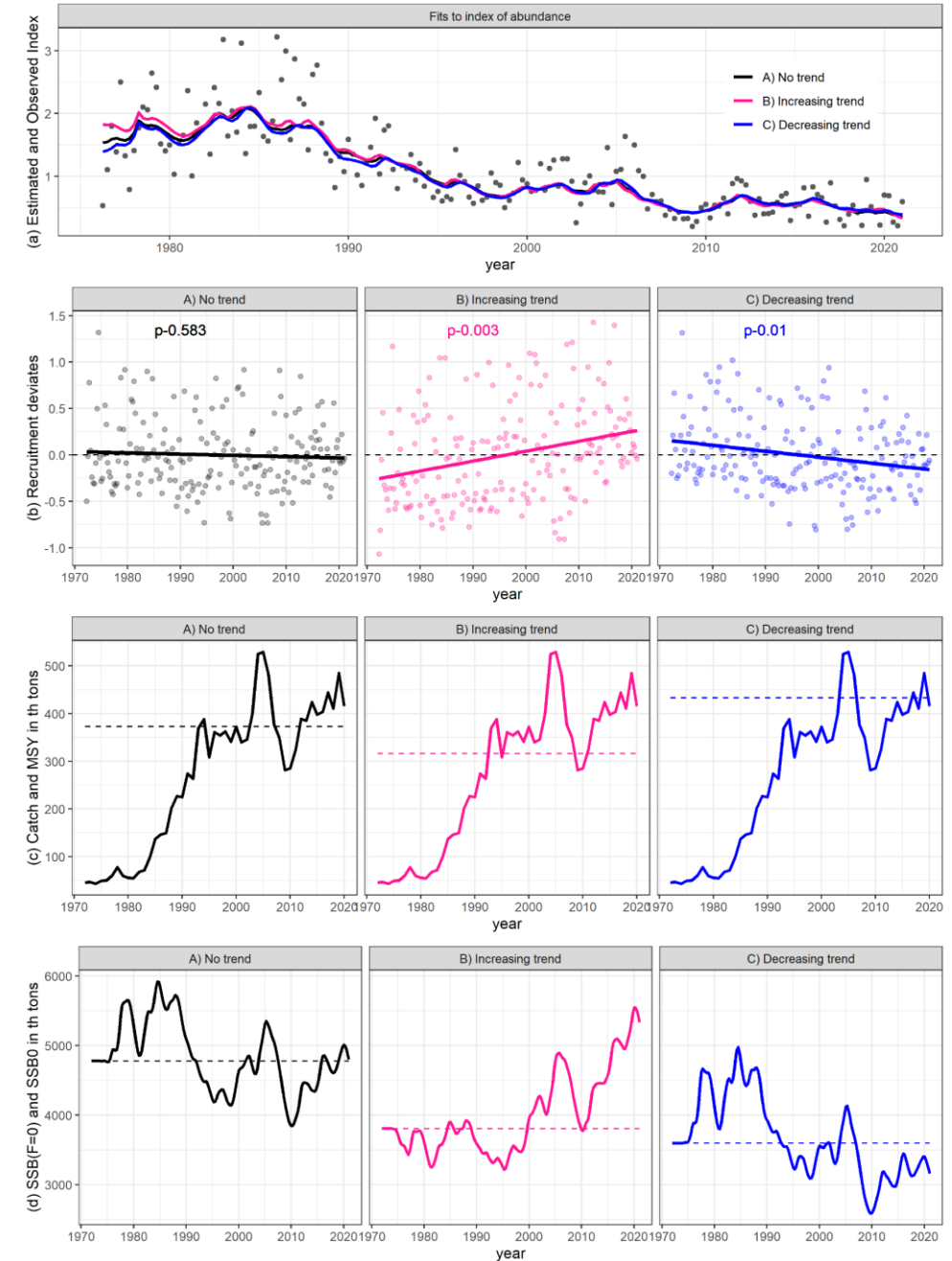
Results (conceptual implications)

	Assumption	Implications of potential trends in recruitment for management advice
Option 1: S-R equilibrium	Recruitment is consistent with the SR relationship throughout the estimation period. Recruitment deviates would help achieve a better fit to observations and they would be randomly distributed throughout the estimation period.	<u>Differences</u> in recruitment in the terminal year of the assessment and forecast. <u>Change</u> in the dynamics of the stock or environment. The status estimated for the terminal year is <u>significantly different</u> to the level in the forecast period. For example, a catch level estimated to be sustainable in the estimation period may be unsustainable in the projection period. <u>Reference Points</u>: Productivity (MSY) and BF=0 differ between estimation and forecast.
Option 2: Constant Rec with recent	Continuity between the estimation and the forecast phases. Future recruitment disconnected from SSB. Consistent with the assumption that very little is known about recruitment, Steepness (~ 1).	<u>Current and future conditions are comparable</u> and thus, the estimated R. <u>Stock will never collapse</u> as the input of new recruits will be independent of spawners. <u>Reference Points</u> (B_{MSY}, MSY, $SSB_{F=0}$) need to be updated with future recruitment. A high recruitment assumption would make a higher B_{MSY} also harder to achieve in equilibrium.
Option 3: SR scaled with recent re devs	Continuity between the estimation and the forecast phases. For models with increasing rec dev trends, the recent devs are added to the SR relationship and the level of catch in the terminal years of the estimation period is sustained by the same level of recruitment. For models with decreasing trends in recruitment deviates, slows the stock recovery predicted with the SR relationship. No impact for models without trends.	<u>Current and future conditions are comparable</u> and thus, the estimated R. <u>Stock continues decline</u> if catch is not reduced. <u>Reference points</u> (B_{MSY}, MSY, $SSB_{F=0}$) should be updated using the scaled SR relationship in the forecast period. A high recruitment assumption would make a higher B_{MSY} also harder to achieve in equilibrium.

Results

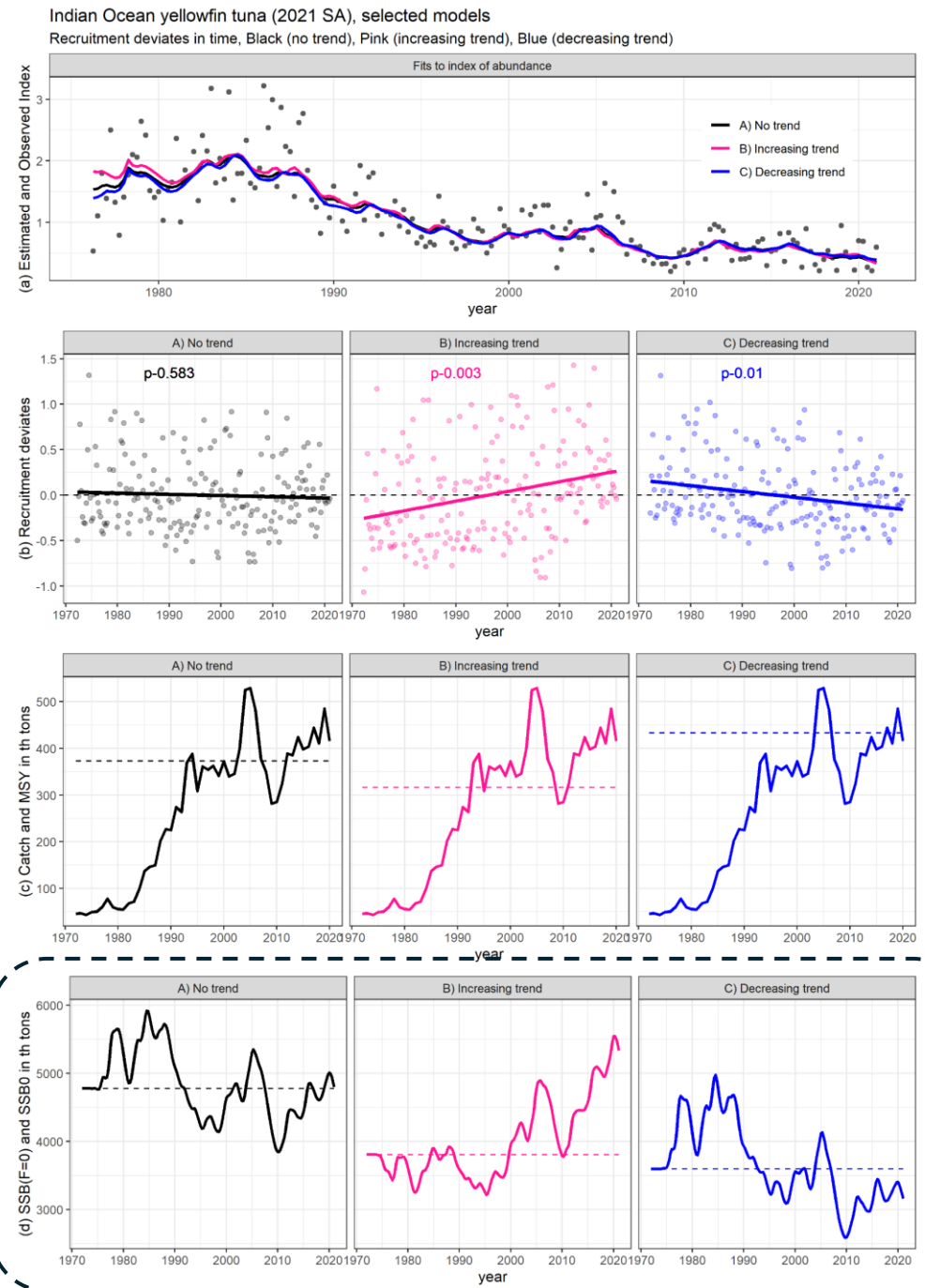
- 3 models with distinct trends in rec devs in 2021.
 - Similar fits to CPUE
- A. Current catch compatible with productivity when no trends in rec devs.
- B. Current catch sustained by rec devs when increasing trends estimated and $MSY \ll \text{Catch}$.
- C. The model needs to reduce MSY to fit declining CPUE.

Indian Ocean yellowfin tuna (2021 SA), selected models
Recruitment deviates in time, Black (no trend), Pink (increasing trend), Blue (decreasing trend)



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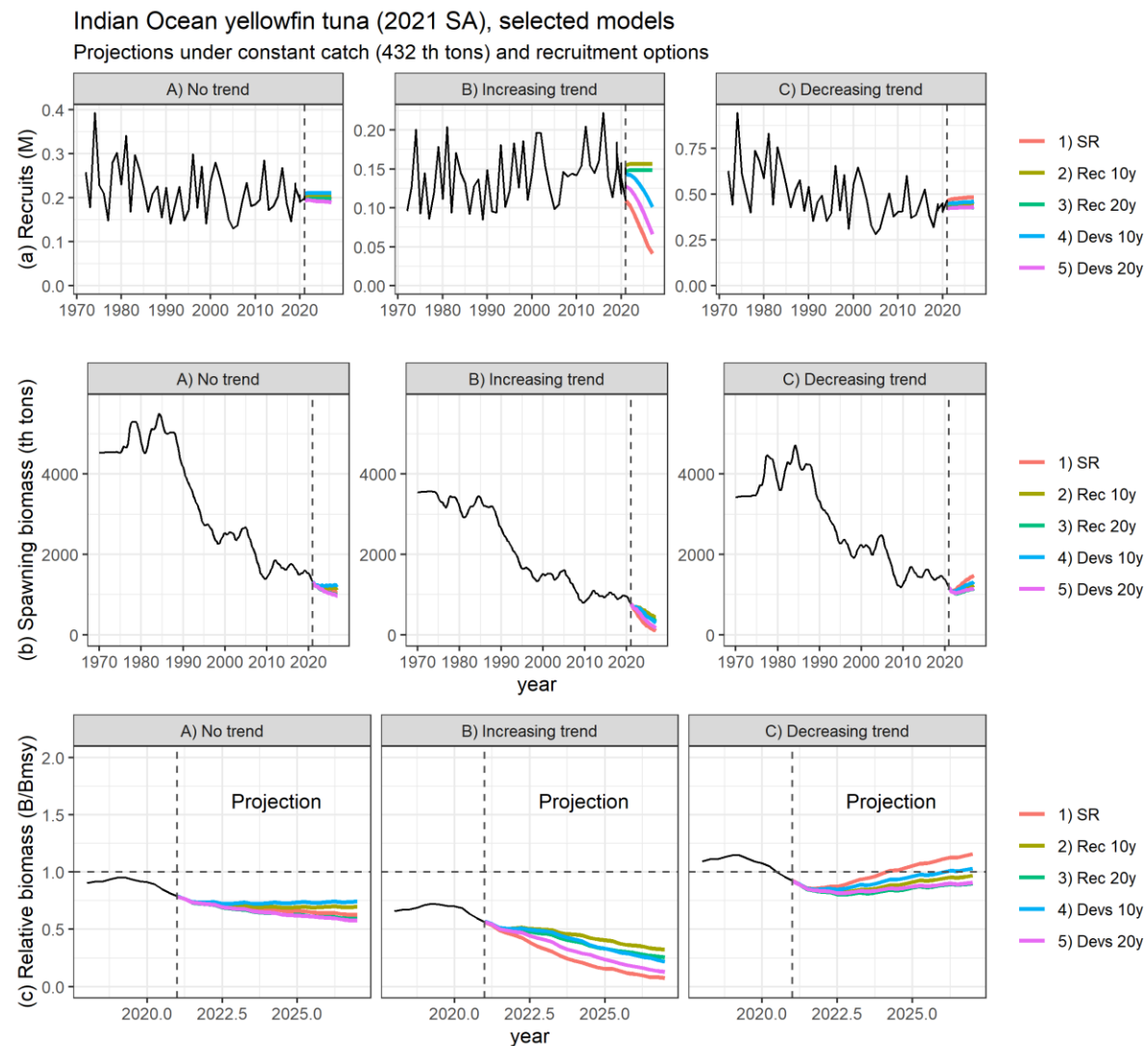
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- C. The model needs to reduce MSY to fit declining CPUE.
- $SSB_{F=0}$ very different to SSB_0 when rec dev trends (B/C).



Results

- 3 models with distinct trends in rec devs in 2021.
- Forecast of constant catch under rec options.

- If no trends, very little impact.
- Increasing trends, stock collapse at catch levels that were estimated sustainable with SR.
- Decreasing trends, stock recovers fast with SR.

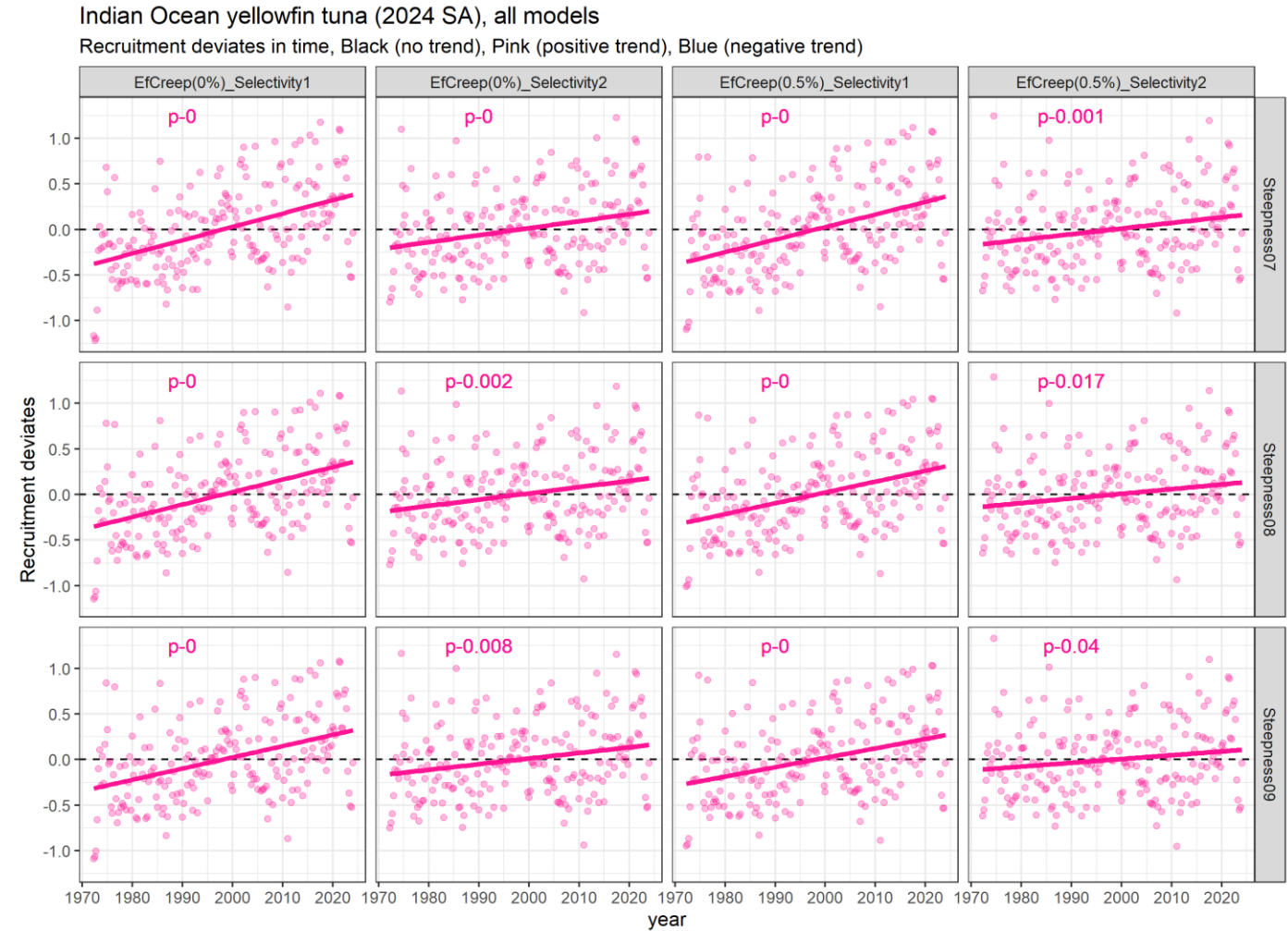


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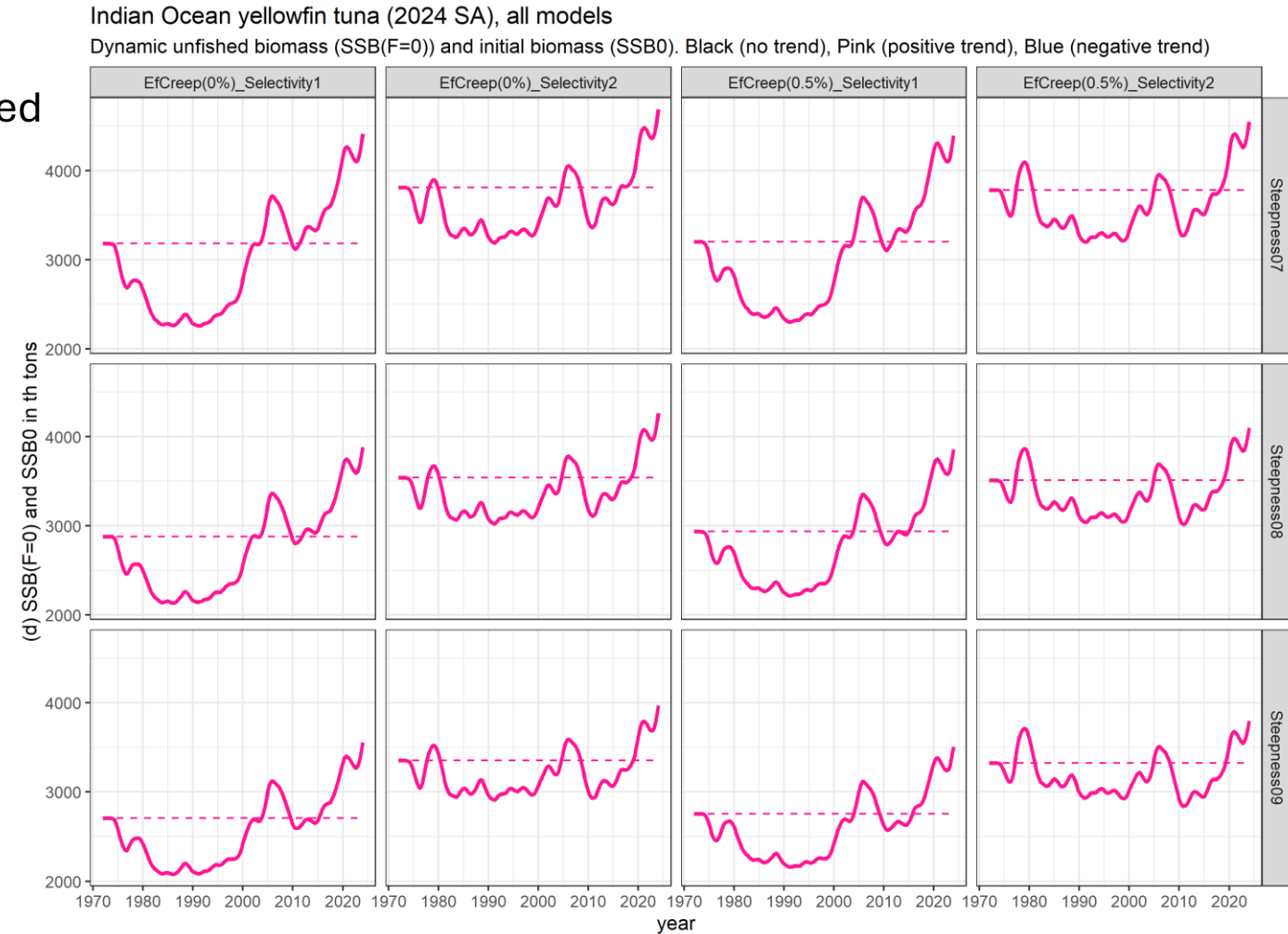
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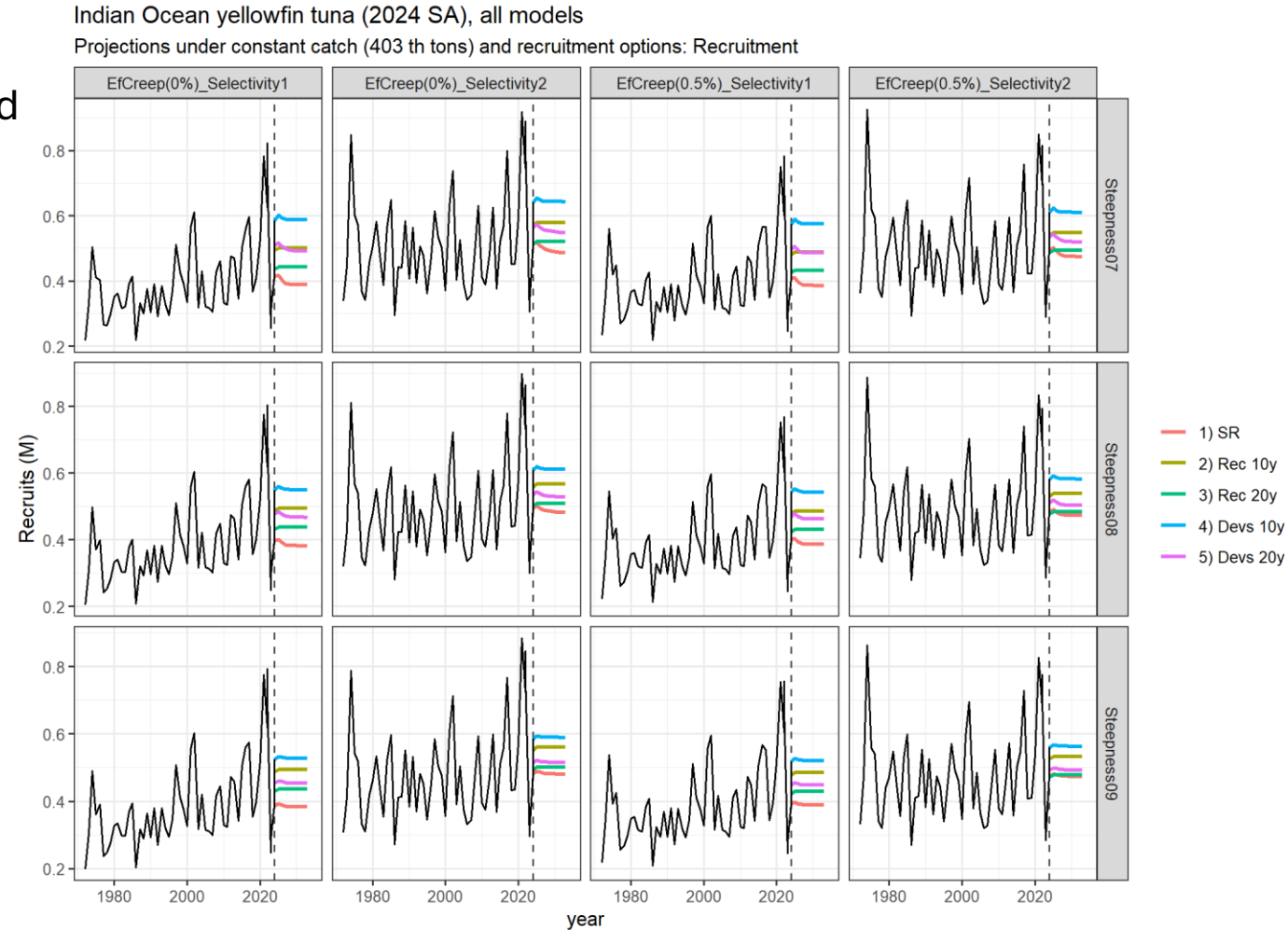
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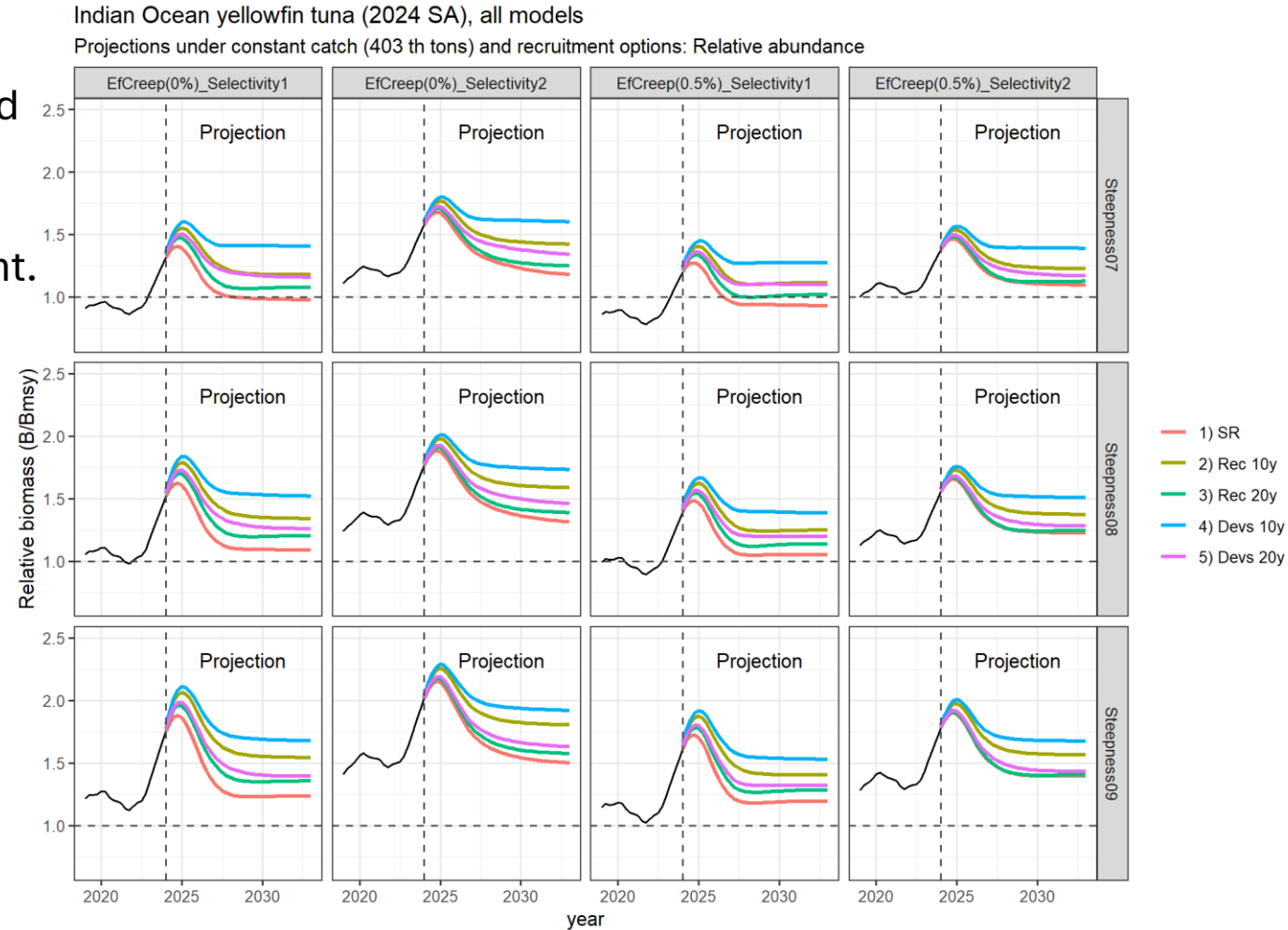
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- Big difference in forecast for rec Options.



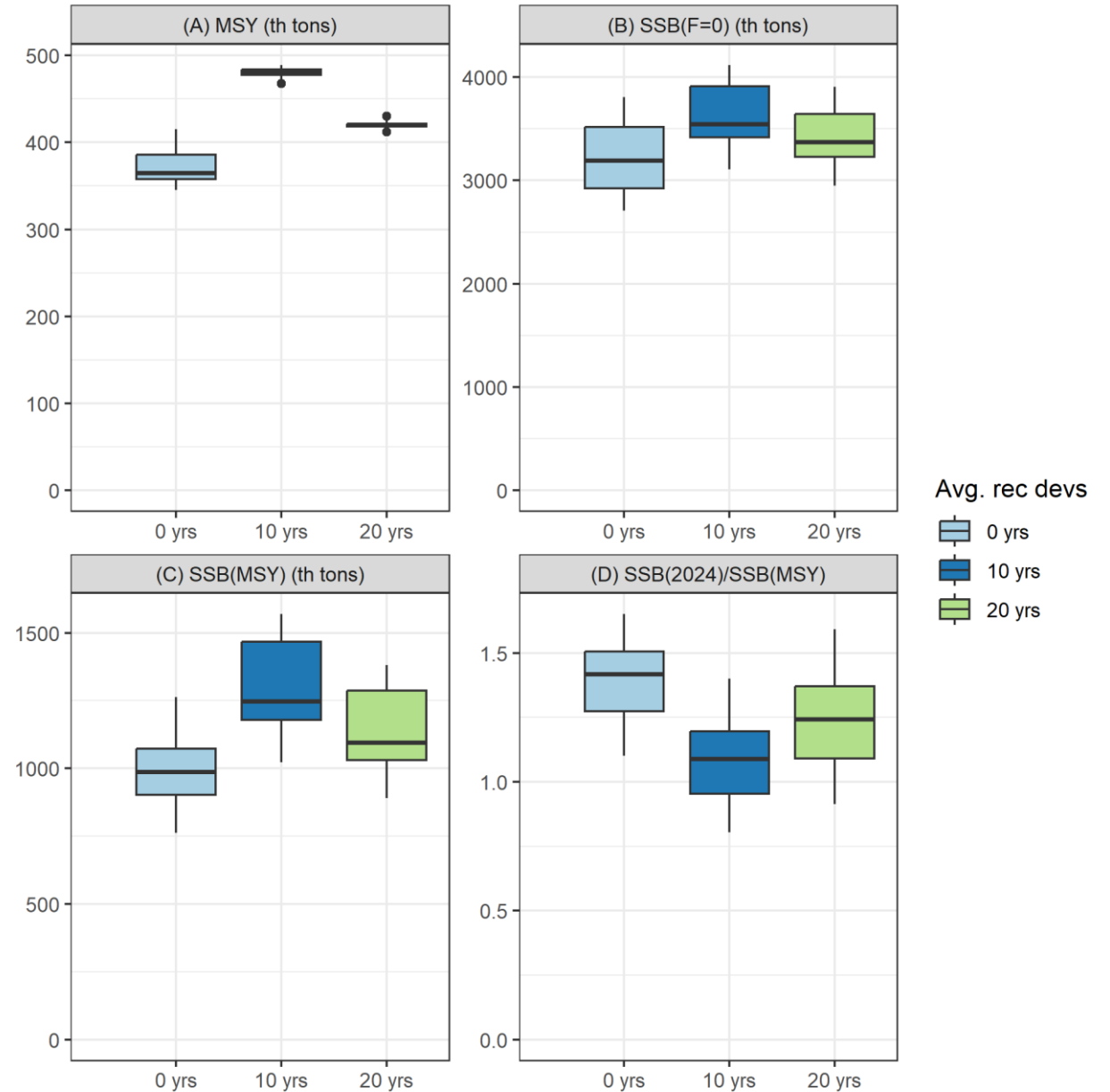
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- Need to harmonize recent and future recruitment.



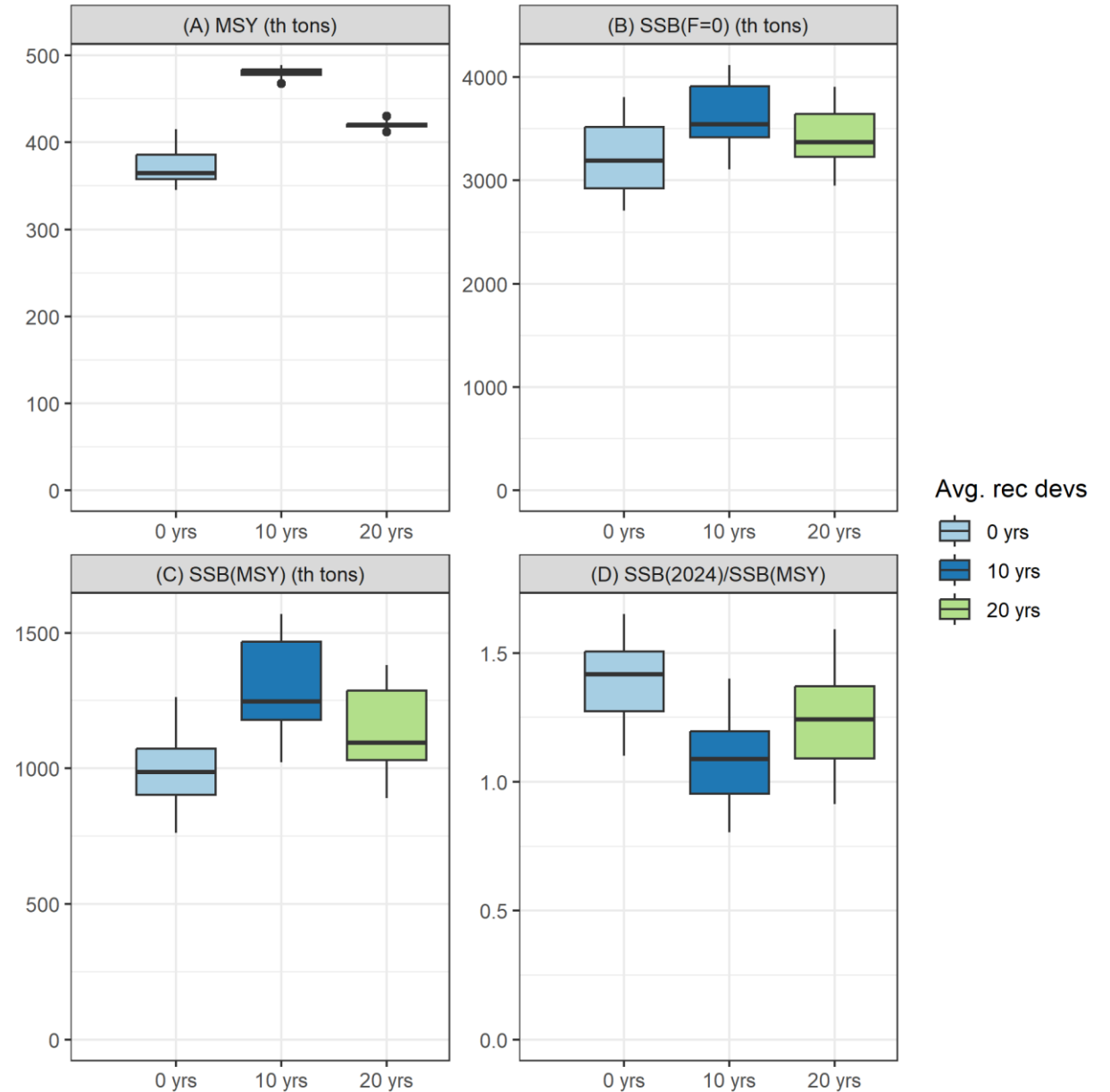
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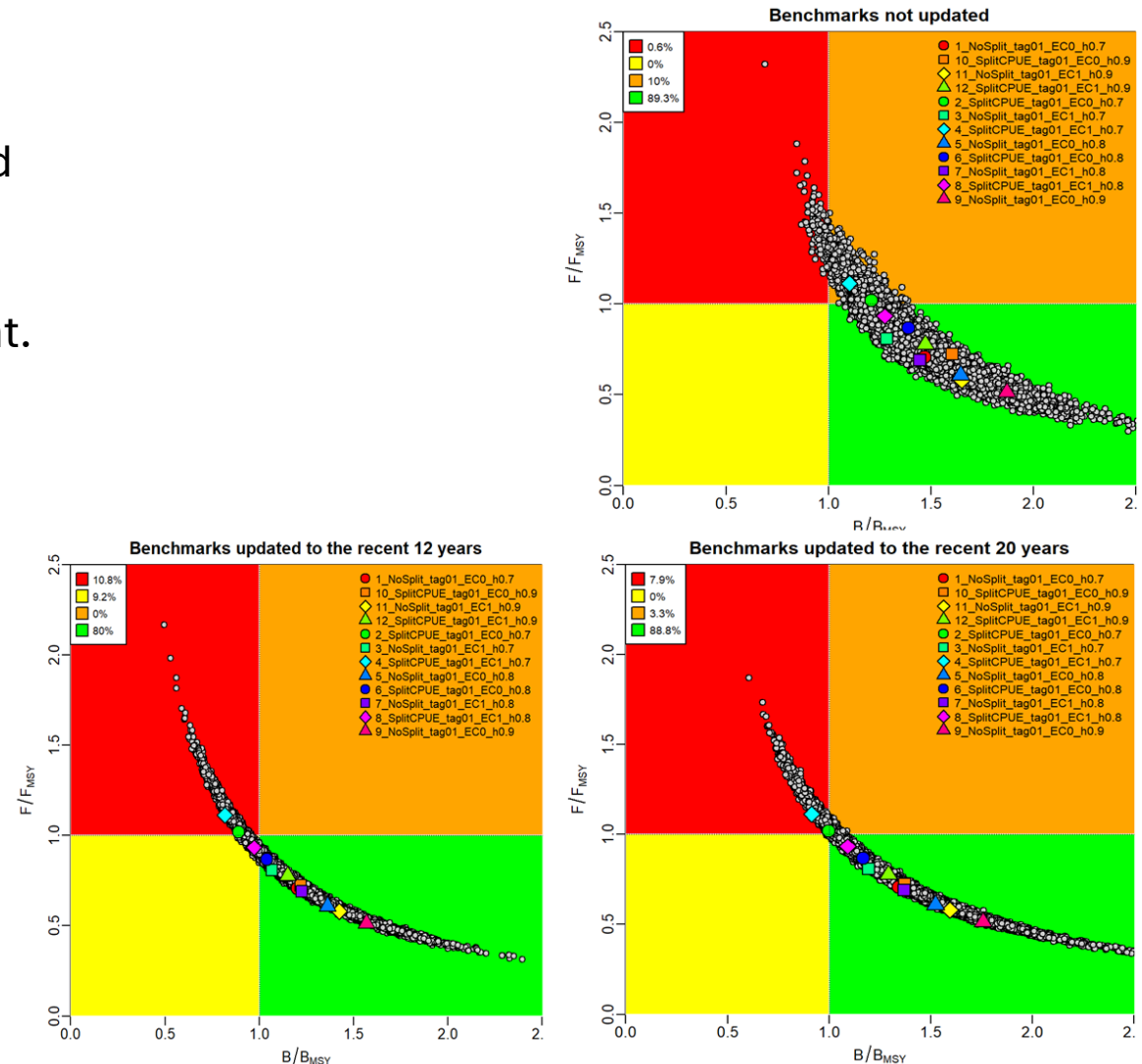
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 - Short: (1,5,10 years)...
 - Medium (10, 20 years)...
 - Longer (equilibrium)...



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 - Medium (10, 20 years)...
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- Discussed in 2024...



Discussion

- The stock status, benchmarks and projections need to reflect recent trends and current conditions.
- WPCFC and IATTC (2024), resample recent recruitment in projections (by pass SR relationship) and to estimate benchmarks... recruits would be constant even at heavily depleted stocks.
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RECOMMENDATION:

- Use of scalar (Option 1) in the forecast file, using the scalar estimated from recent rec devs.

0	Forecast recruitment: 0 = spawner recruit curve; 1 = value*(spawner recruit curve); 2 = value*(virgin recruitment); and 3 = recent mean from year range above.	Option 0, ignore input and do forecast recruitment as before SS v.3.30.10, if 1, then use next value as a multiplier applied after env/block/regime is applied, if 2, then use value as multiplier times adjusted virgin recruitment (after time-varying adjustments to R0), and if 3, then use value as the number of years from end of main recruitment deviations to average (mean is the recruitments, not the deviations). Need to set phase to -1 in control to get constant recruitment in MCMC.
1	Scalar or number of years of recent main recruitments to average.	This input depends upon option selected directly above. If option 1 or 2 selected this value should be a scalar value to be applied to recruitment. If option 3 is selected above this should be input as the number of years to average recruitment.

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RECOMMENDATION:

- Use of scalar (Option 1) in the forecast file, using the scalar estimated from recent rec devs.
- But management benchmarks (B_{MSY} , MSY , $SSB_{F=0}$ etc) needed to be updated for recent conditions as well, using the scalar estimated for recent recruitment. Recent ~ arbitrary timeframe (ad-hoc).

Thanks!