Management implications of trends in recruitment deviates of Indian Ocean yellowfin

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Summary

The stock assessments of tropical tunas contain scenarios with significant trends in process error that have been overlooked. However, the implications of these trends remain unquantified. In this document we address the trends in recruitment deviates of the 2021 stock assessment of Indian Ocean yellowfin. We use recent average recruitment and deviates' estimates in forward projections and discard models with significant trends in recruitment deviates to evaluate their management implications. With these, we provide a range of catch levels that would allow recovering the stock towards management targets and compare it with the management advice developed during the 2021 stock assessment.

Introduction

As in 2015, 2016 and 2018, the 2021 assessment of Indian Ocean yellowfin tuna (Fu et al., 2021) determined that this stock is overfished and subject to overfishing. The model developed in 2021 was projected forward to develop the Kobe II Strategy Matrix (Urtizberea et al., 2021), which was used to develop management advice in terms of the catch reduction necessary to recover the stock towards reaching or avoiding reference points in different timeframes (3 and 10 years) and their associated probabilities.

However, the model developed in 2021 contains trends in recruitment deviates that were not sufficiently explored. In 2022, it has been demonstrated that the ensemble of 96 models used contained 28 models (29%) with significant trends in process error (Merino et al., 2022). These scenarios are linked to extreme productivity scenarios. 25 were identified as scenarios where recruitment deviates compensate the loss of biomass in periods of high catch beyond the surplus production. In these cases, variation in recruitment is not a random process but rather takes the function of a compensatory and systematic driver of productivity in scenarios with unrealistically low estimates of productivity. The forward projections developed from these models were carried out omitting these trends which resulted in the underestimation of the productivity of the stock in 25 of the 96 models. In 3 models that were identified with decreasing trends, the productivity was overestimated in the deterministic projections.

The management implications of these trends have not been sufficiently explored. In this work, we apply alternative methods to address the observed trends in process error, which include (i) discarding models with trends in process error, (ii) using recent estimated recruitment for the projections and (iii) including the estimated recent average recruitment deviates in the projections. We explore the probabilities of reaching the target reference point (B_{MSY} and F_{MSY}) in different timeframes and discuss differences with the K2SM developed in 2021.

Material and methods

The files of the 2021 assessment of Indian Ocean yellowfin were used for this study. From these, we have explored alternative ways to address the trends in recruitment deviates:

1) *Discard models with trends:* The simplest option to address problems with individual scenarios when using model ensembles is to discard models that do not pass a statistical test or achieve a threshold value in diagnostics. We explore this option by re-calculating the K2SM of 2021 without the models identified with trends in recruitment deviates.
2) *Run projections using recent recruitment deviates:* The models of the 2021 were projected forward without accounting for recruitment variability. Therefore, models with increasing trends were projected with lesser recruits than the estimated recent recruitment. Models with decreasing trends in recruitment deviates were projected with more recruits than the estimated recent recruitment. We re-run the forward projections using a correction factor to the estimated stock recruitment relationship based on the recruitment deviates of the last 10 years of the estimation period. We applied in two ways: First, only to the models identified with recruitment deviation trends and second, to all models of the ensemble.
3) *Run projections using recent recruitment:* The ensemble of models was projected forward using the estimated recruitments of the last 10 years of the estimation period. We also applied this to the models identified with trends and to all models of the ensemble.

Results

The probabilities associated with the stock being above the target reference points for this stock (B_{MSY} and F_{MSY}) are shown in Tables 1 and 2. The K2SM developed in 2021 indicates that the catch reduction required to achieve the management target of the stock remaining at or above B_{MSY} and the fishing mortality at or below F_{MSY} by 2030 would need to be between 20% and 30%. When addressing the trends in recruitment deviates with the different approaches investigated in this study, the estimated catch reduction to achieve the same target in 2030 would range between (10% and 15%).

Aproach	tac	2021	2022	**2023**	2024	2025	2026	2027	2028	2029	**2030**
2021 K2SM	60%	83	62	**48**	38	31	25	20	18	16	**14**
	70%	84	70	**59**	53	48	45	42	37	34	**32**
	80%	86	75	**69**	66	61	62	62	60	59	**59**
	85%	87	77	**73**	68	69	70	70	70	70	**71**
	90%	87	79	**77**	75	75	78	80	86	88	**90**
	100%	88	78	**78**	80	87	91	94	96	97	**98**
	110%	88	81	**84**	89	97	99	100	100	100	**100**
	120%	90	91	**91**	98	100	100	100	100	100	**100**
Discard models with trends in rec devs	60%	79	56	**34**	20	10	6	4	2	1	**1**
	70%	81	63	**50**	37	28	23	20	19	18	**15**
	80%	82	71	**64**	56	55	53	52	49	47	**46**
	85%	83	73	**70**	66	65	64	63	62	62	**60**
	90%	83	78	**73**	69	70	70	73	74	75	**76**
	100%	84	81	**80**	79	78	81	85	88	91	**95**
	110%	86	85	**85**	86	91	96	98	99	100	**100**
	120%	88	76	**87**	95	98	99	100	100	100	**100**
Low p only, Recent recruitment	60%	82	60	**30**	15	5	2	1	0	0	**0**
	70%	83	67	**48**	32	21	14	9	5	4	**3**
	80%	85	73	**65**	56	48	41	36	32	32	**31**
	85%	85	75	**71**	64	62	57	52	51	50	**49**
	90%	86	79	**75**	69	68	65	63	62	61	**62**
	100%	86	82	**82**	83	83	83	83	85	87	**88**
	110%	88	86	**87**	89	91	96	97	99	99	**100**
	120%	84	86	**90**	93	96	99	100	100	100	**100**
All models, recent recruitment	60%	78	54	**28**	13	5	2	1	0	0	**0**
	70%	80	63	**44**	27	19	13	7	6	4	**2**
	80%	82	71	**61**	51	43	37	33	31	28	**25**
	85%	82	74	**70**	64	57	52	49	47	45	**45**
	90%	83	79	**75**	69	65	62	60	58	57	**57**
	100%	83	68	**71**	73	75	77	79	83	85	**88**
	110%	85	87	**87**	84	88	95	97	99	99	**100**
	120%	69	76	**84**	94	97	99	100	100	100	**100**
Low p only, Recent rec devs	60%	81	56	**33**	16	4	1	0	0	0	**0**
	70%	83	65	**45**	33	21	11	5	2	1	**0**
	80%	83	71	**60**	51	42	35	31	28	24	**22**
	85%	85	76	**65**	58	53	49	48	45	41	**40**
	90%	86	77	**70**	66	63	59	57	54	53	**51**
	100%	87	79	**77**	75	73	79	79	79	81	**77**
	110%	87	83	**87**	86	85	90	92	97	97	**99**
	120%	88	84	**86**	91	97	99	99	100	100	**100**

Table. 1. Probability of SSB falling below SSB_{MSY} in different timeframes for different catch levels (%relative to catch in 2020).

Aproach	tac	2021	2022	**2023**	2024	2025	2026	2027	2028	2029	**2030**
2021 K2SM	60%	27	20	**16**	13	12	10	9	9	9	**9**
	70%	43	36	**33**	30	32	33	33	32	32	**31**
	80%	56	54	**54**	53	52	53	53	52	52	**51**
	85%	64	60	**62**	58	59	60	61	62	61	**60**
	90%	70	67	**65**	63	64	66	68	72	73	**74**
	100%	78	74	**74**	75	75	77	80	84	86	**90**
	110%	83	82	**83**	84	87	92	95	98	99	**99**
	120%	90	91	**92**	96	97	98	99	99	100	**100**
Discard models with trends in rec devs	60%	13	9	**6**	5	3	3	2	1	1	**1**
	70%	27	23	**22**	19	18	15	13	13	12	**10**
	80%	43	41	**45**	46	46	44	46	44	41	**41**
	85%	52	50	**56**	55	54	55	54	52	51	**51**
	90%	58	62	**61**	62	62	62	61	61	62	**63**
	100%	70	72	**73**	73	71	67	68	72	75	**86**
	110%	81	82	**82**	82	82	88	91	94	95	**97**
	120%	88	85	**88**	90	91	93	95	98	100	**100**
Low p only, Recent recruitment	60%	23	13	**7**	4	2	1	1	1	0	**0**
	70%	40	31	**25**	19	15	13	10	8	7	**6**
	80%	57	53	**49**	47	46	44	42	41	40	**39**
	85%	64	62	**60**	58	57	57	55	54	54	**53**
	90%	71	70	**67**	64	64	64	64	64	64	**63**
	100%	77	79	**81**	81	82	79	77	78	79	**83**
	110%	88	89	**88**	88	87	89	90	93	94	**95**
	120%	90	92	**93**	92	93	94	95	97	98	**99**
All models, recent recruitment	60%	11	7	**3**	2	1	0	0	0	0	**0**
	70%	26	19	**15**	12	9	7	5	4	4	**3**
	80%	44	40	**37**	34	32	31	28	28	28	**26**
	85%	51	50	**55**	52	51	48	47	46	44	**45**
	90%	58	62	**60**	59	58	56	56	55	56	**56**
	100%	69	65	**66**	67	67	66	69	69	72	**73**
	110%	82	83	**83**	78	78	85	86	92	94	**95**
	120%	78	81	**84**	87	90	91	94	97	100	**100**
Low p only, Recent rec devs	60%	21	12	**6**	3	1	1	0	0	0	**0**
	70%	37	28	**20**	15	11	8	5	3	3	**1**
	80%	52	46	**41**	38	35	31	29	29	25	**25**
	85%	62	56	**51**	49	48	45	45	43	41	**42**
	90%	67	63	**61**	59	56	55	54	52	52	**51**
	100%	76	74	**73**	73	71	69	69	69	70	**71**
	110%	84	83	**82**	81	80	83	83	88	90	**91**
	120%	87	86	**87**	87	92	93	99	99	99	**100**
All models, recent rec devs	60%	18	7	**3**	1	1	0	0	0	0	**0**
	70%	33	23	**15**	10	7	5	3	3	2	**2**
	80%	51	43	**36**	33	29	26	24	22	20	**18**
	85%	57	53	**49**	46	44	41	40	39	38	**36**
	90%	65	62	**58**	57	55	54	54	53	53	**53**
	100%	73	72	**71**	69	68	70	68	68	66	**66**
	110%	84	83	**82**	84	81	81	86	84	84	**82**
	120%	86	86	**88**	85	86	89	90	89	89	**94**

Table. 2. Probability of F exceeding F_{MSY} in different timeframes for different catch levels (%relative to catch in 2020).

Discussion

This study aims to contribute to the ongoing review of the Indian Ocean yellowfin stock assessment. Looking at trends in recruitment deviates we can identify models that contain unplausible combinations of fixed parameters (Merino et al., 2022). In the case of yellowfin, these models are associated with poorer scores in other diagnostics too (Carvalho et al., 2021;

Merino et al., 2022). These results are consistent with the identification of models of the Indian Ocean yellowfin model ensemble where recruitment deviates were an inherent component of the stock's response to high catch. This enables to maintain the stocks at reasonable biomass levels despite the low productivity estimated for these models (R0 and MSY), (Merino et al., 2022).

References

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