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Analysis of recruitment deviates of tropical tuna stock assessments

Options for a new diagnostic for ensembles of models

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WPTT(DataPrepartory)-

IOTC-2022-WPTT24(DP)-19

Context in stock assessments (tropical tunas)

- Stocks productivity (life-history) determines response to fishing.
 - Data (C, CPUE, SFD...) vs underlying productivity.
 - Intrinsic factors (life history traits) vs extrinsic factors (fishing).
 - Productivity: Growth (fixed), M (fixed), steepness (fixed), RO (free).
- Trends in abundance determined by productivity and recruitment deviates allow improving fits to variability of data).

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Context in stock assessments (tropical tunas)

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 - Productivity: Growth (fixed), M (fixed), steepness (fixed), RO (free).
- Trends in abundance determined by productivity and recruitment deviates allow improving fits to variability of data).
- Ideal rec devs (process error) have no trends and maintain properties through time.
- Tropical tuna SA using ensembles of models (combinations of assumptions, often biological).
- Diagnostics routinely incorporated in SA development (retro, hindcast, ... time consuming)
- Diagnostics often developed for base case only.

Objectives

- Explore trends in recruitment deviates and illustrate their links to hypotheses on productivity.
- Elucidate role of rec devs (variability or response to high catch).
- Develop a quick diagnostic to provide statistical support to hypotheses and assumptions in ensembles of models used to provide management advice.



Material and methods

- SS3 and Multifan-CL output from SA of tropical tunas (ICCAT, IOTC, IATTC and WCPFC).
 - Extract recruitment deviates and verify no-trend for each model of ensembles.
 - > No_trend test from funtimes (Lyubichcich et al., 2022), Student's test, p-value (no linear trend).
- Experiments on IO yellowfin stock assessment (Fu et al., 2021).
 - Ensemble of Steepness (h, 3), Growth (G, 2), Mortality (M, 2), Piracy (q, 2), Spatial (Io, Sp, 2), Tag (lambda, 2).
 - Run models without rec devs (Deactivate option in control files) and compare output (MSY, R0 and B/BMSY).
 - Produce bias in growth and mortality and carry out SA from simulated data (Dunn et al., 2020).
 - Compare p-value of no_trend test with other diagnostics (Carvalho et al., 2021).
 - ASPM, Mohn's rho, MASE and others.



(1) Catch history

- Tropical tuna fisheries developed with LL (~60s) and with PS (~80s).
- Peaks reached (1990-2010, second half).
- Some nearby historical maxima.





Indian Ocean yellowfin tuna

(2) Rec devs vs time

- Black (no trend, p >0.1)
- Blue (decreasing, p <0.1)
- Purple (increasing, p <0.1)

Gbase Mbase h70	Gbase Mbase h80	Gbase Mbase h90	Gbase Mlow h70	Gbase Mlow h80	Gbase Mlow h90	GDortel Mbase h70	GDortel Mbase h80	GDortel Mbase h90	GDortel Mlow h70	GDortel Mlow h80	GDortel Mlow h90
p-0.16	p-0.044	p-0.014	p-0.643	p-0.936	p-0.59	p-0.321	p-0.941	p-0.577	p-0.003	p-0.005	p-0
And Concert	AN LOUGH	And the second	A CAR CAR		A CONTRACTOR	Annald Contraction		Anne Street		C. C	
p-0.876	p-0.767	p-0.405	p-0.006	p-0.055	p-0.091	p-0.138	p-0.328	p-0.713	p-0.001	p-0.007	p-0.006
	1414 - 5-40 M. 5	1999 - 1999 -	<u> </u>	Martin Contraction		ALMONT CO.	<u> Alfra</u> das	AND STAR			
p-0.608	p-0.319	p-0.228	p-0.236	p-0.24	p-0.296	p-0.059	p-0.124	p-0.174	p-0.001	p-0	p-0.001
And Services	The second	Mary and	ALL PROPERTY	A. S.	A. B. S.	Anthony of the	Stringers .	Service of the servic		Constant of the second se	
p-0.268	p-0.555	p-0.835	p-0.007	p-0.005	p-0.01	p-0.093	p-0.118	p-0.137	p-0	p-0.001	p-0.002
and States		And Constrained				A. S. S. S.			Contraction of the second	A CONTRACTOR	
p-0.085	p-0.031	p-0.012	p-0.756	p-0.851	p-0.679	p-0.947	p-0.801	p-0.52	p-0.011	p-0.023	p-0.043
C. Sector		and the second second	Contraction of the second s					C. C			
p-0.399	p-0.407	p-0.151	p-0.162	p-0.338	p-0.483	p-0.996	p-0.725	p-0.545	p-0.056	p-0.081	p-0.157
p-0.717	p-0.378	p-0.199	p-0.114	p-0.099	p-0.173	p-0.141	p-0.08	p-0.085	p-0.001	p-0.001	p-0
		A Company		A CONTRACTOR OF							
p-0.854	p-0.474	p-0.305	p-0.085	p-0.087	p-0.25	p-0.531	p-0.989	p-0.745	p-0.001	p-0	p-0.001
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p-0.16	p-0.044	p-0.014	p-0.643	p-0.936	p-0.59	p-0.321	p-0.941	p-0.577	p-0.003	p-0.005	p-0
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p-0.268	p-0.555	p-0.835	p-0.007	p-0.005	p-0.01	p-0.093	p-0.118	p-0.137	p-0	p-0.001	p-0.002
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p-0.717	p-0.378	p-0.199	p-0.114	p-0.099	p-0.173	p-0.141	p-0.08	p-0.085	p-0.001	p-0.001	p-0
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p-0.854	p-0.474	p-0.305	p-0.085	p-0.087	p-0.25	p-0.531	p-0.989	p-0.745	p-0.001	p-0	p-0.001
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- Black (no trend, p >0.1)
- Blue (decreasing, p <0.1)
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Evidence of rec dev trends

• Role of rec devs?

Variability vs response to catch

Indian Ocean yellowfin tuna Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)

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p-0.16 p-0.044 -1 p-0.876 p-0.767	p-0.014 p-0.643	p-0.055 p-0.091	p-0.321	p-0.941	p-0.577	p-0.003	p-0.005	p-0
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(3) Rec devs vs MSY

- Black (no trend, p >0.1)
- Blue (decreasing, p < 0.1)
- Purple (increasing, p <0.1)

Evidence of rec dev trends

• Role of rec devs?

Variability vs response to catch

Upper range of MSY Lower range of MSY Middle range of MSY









- Average [1992-2020] = 382 th tons.
- Average [2000-2020] = 401 th tons.
- Sustainable without rec devs?

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- Black (no trend, p >0.1)
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- Purple (increasing, p <0.1)

Evidence of rec dev trends

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Variability vs response to catch

Upper range of MSY Lower range of MSY Middle range of MSY





Black (no trend), Blue (Negative trend), Purple (Positive trend)





(4) Rec devs vs difference with/without devs (MSY)

- Black (no trend, p >0.1)
- Blue (decreasing, p <0.1)
- Purple (increasing, p <0.1)

Evidence of rec dev trends

Role of rec devs?

Variability vs response to catch

Upper range of MSY \longrightarrow MSY_{SA} > MSY_{RecDev0} Lower range of MSY \longrightarrow MSY_{SA} < MSY_{RecDev0} Middle range of MSY \longrightarrow MSY_{SA} ~ MSY_{RecDev0}





Fixed M, G, h -> increase R0 if it needs to fit data with underlying productivity (RecDev0). With rec devs these can be used to respond to high catch instead of underlying productivity (SA).

Results

(4) Rec devs vs difference with/without devs (R0)

- Black (no trend, p >0.1)
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Evidence of rec dev trends

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Variability vs response to catch

Upper range of MSY \longrightarrow R0_{SA} > R0_{RecDev0} Lower range of MSY \longrightarrow R0_{SA} < R0_{RecDev0} Middle range of MSY \longrightarrow R0_{SA} ~ R0_{RecDev0}







Indian Ocean yellowfin tuna stock assessment vs RecDev0 (B/Bmsy) B/Bmsy for the SA and with RecDev0, Black (no trend), Blue (Negative trend), Purple (Positive trend)

(4) Rec devs vs difference with/without devs (B/B_{msy})

- Black (no trend, p >0.1)
- Blue (decreasing, p <0.1)
- Purple (increasing, p <0.1)

Evidence of rec dev trends

• Role of rec devs?

Variability vs response to catch

Comparable trends

Comparable status terminal year, very different throghout.

Larger B/Bmsy (RecDev0) ty and throughout.







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Evidence of rec dev trends Bias in assumptions?



(5) Rec devs in simulated model (Dunn et al, 2020). Extract data with error from OM using two growth curves (as in OM and Dortel) and a range of biased natural mortality (M050=M50% lower than M100 and M150=50% larger than M100, M100=M from OM).



Evidence of rec dev trends Bias in assumptions?

• Positive and negative trends with extreme bias only (±90%).

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• Black (no trend, p >0.1)

Results

- Blue (decreasing, p <0.1)
- Purple (increasing, p <0.1)

Indian Ocean yellowfin tuna (Simulated)

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)

	M010	M030	M050	M075	M090	M095	M100	M105	M110	M125	M150	M170	M190	
2 -	p-0.014	p-0.506	p-0.787	p-0.438	p-0.129	p-0.227	p-0.282	p-0.171	p-0.277	p-0.15	p-0.197	p-0.126	p-0.039	-
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Evidence of rec dev trends Bias in assumptions?

• Positive and negative trends with extreme bias only (±90%).

Results

• As expected, lower M -> lower MSY -> Increasing trends and likewise higher M.

(5) Rec devs in simulated model (Dunn et al, 2020).

- Black (no trend, p >0.1)
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Results

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(5) Rec devs in simulated model (Dunn et al, 2020).

- Black (no trend, p >0.1)
- Blue (decreasing, p < 0.1)
- Purple (increasing, p < 0.1)

Why only in extreme bias?

- Good consistency between catch, CPUE, Tags and SFD in OM \neq SA.
- IO yft SA disaggregated and trends in regional distribution also identified which suggests additional problems that do not affect the OM.



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Results

(6) Consistency with other diagnostics



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Results

(6) Consistency with other diagnostics

No trend hypothesis and other diagnostics R0 (ASPM-SA) -0.3 -0.3 0.2 0.8 -0.1 -0.6 0.9 MSY (ASPM-SA) 0.8 -0.7 0.9 -0.4 -0.2 0.2 0 0.9 MASE -0.1 -0.1 -0.1 -0.5 0 -0.1 0.4 0 Corr Mohn's rho (F) -0.1 0.2 0.2 0 0.2 0.2 -0.1 0.4 Mohn's rho (B) 0.1 -0.3 -0.4 -0.3 0.4 0.4 -0.2 -0.3 RunsTest 0.2 -0.3 -0.3 -0.3 -0.1 -0.5 -0.4 -0.3 Autocorrelation -0.4 -0.3 -0.4 0.2 -0.1 0.8 0.8 sd (rec-devs) -0.4 -0.3 -0.3 0.2 -0.1 0.9 0.9 p-value NoTrend 0.2 0.1 -0.4 -0.4 -0.1 -0.1 -0.7 -0.6 NST LASINGA ROLASPHERA 2-value No Trend sd theoders) Autocontestion RUNSTEE Notice Hole wom's hole

Trend in recruitment deviates (p-value<0.1) Yes No 10.0 7.5 7.5-5.0-5.0 2.5 2.5 0.0 0.0 0.50 0.55 0.40 0.45 0.60 0.2 0.3 0.4 0.5 0.6 sd (rec-devs) Autocorrelation 6 7.5 5 4 5.0 3 2 2.5 Number of models 0.0 1.2 0.1 0.2 1.1 0.0 1.0 MASE Mohn's rho (B) 10.0 7.5-5.0 3 2 2.5 0.0 0.0 0.2 0.3 0.10 0.1 0.00 0.05 0.15 Mohn's rho (F) RunsTest 15 5 10 4 3-2 -5 0 0 10 20 30 10 15 20 0 0 5 R0 (ASPM-SA) (%) MSY (ASPM-SA) (%)

0.3

25

1.0 0.5

0.0

-0.5

-1.0



How to use diagnostics to assign plausibility to models in ensembles (Maunder, 2020).

Some diagnostics are time consuming, the p-value of the no-trend for rec devs is estimated in seconds.

1.0 0.5

0.0

-0.5

-1.0

23

(6) Consistency with other diagnostics

-

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• Plausibility of models when advice developed from ensembles of models (Maunder et al 2020):



- Plausibility of models when advice developed from ensembles of models (Maunder et al 2020):
 - ✓ Statistical support to assumptions (combinations of hypotheses and not individual factors)
 - ✓ Compatibility of assumptions and data.



- Plausibility of models when advice developed from ensembles of models (Maunder et al 2020):
 - ✓ Statistical support to assumptions (combinations of hypotheses and not individual factors)
 - Compatibility of assumptions and data.
- Catch advice -> Projections with rec deviates to reduce uncertainty.

Increasing, p < $0.1 \rightarrow$ Collapse



Decreasing, p <0.1→ Boom











IO Bigeye

Indian Ocean bigeye tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)



iotc ctoi



IO Skipjack

Indian Ocean skipjack tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)



iotc ctoi



AO Bigeye

Atlantic Ocean bigeye tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)









Atlantic Ocean yellowfin tuna

AO Yellowfin

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)











Eastern Pacific bigeye tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)



150000 200000 Estimated MSY (tons)

100000





EPO Yellowfin

East Pacific Ocean yellowfin tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)







WCPO Bigeye

Western Central Pacific Ocean bigeye tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)



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WCPO Yellowfin

Western Central Pacific Ocean yellowfin tuna

Recruitment deviates in time, Black (no trend), Blue (Negative trend), Purple (Positive trend)

CondLen_Size20	CondLen_Size200	CondLen_Size500	CondLen_Size60	Rich_Size20	Rich_Size200	Rich_Size500	Rich_Size60	SizeComp_Size20	SizeComp_Size200	SizeComp_Size500	SizeComp_Size60		
1- p-0.289	p-0.363	p-0.226	p-0.388	p-0.928	p-0.938	p-0.692	p-0.897	p-0.411	p-0.404	p-0.938	p-0.953	v	vestern Centra
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¹ p-0.002	p-0.023	p-0.055	p-0.011	p-0.155	p-0.15	p-0.492	p-0.104	p-0.001	p-0.086	p-0.329	p-0.01		
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Western Central Pacific Ocean yellowfin tuna Black (no trend), Blue (Negative trend), Purple (Positive trend)



time





WCPO Skipjack





Discussion

- Assessments of tropical tunas contain trends in recruitment deviates.
- Trends associated with large/low values of estimated productivity and differences with assumptions run without rec devs.
- 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.
- Trends in process error can also be due to misspecification of parameters and data conflict.
- Projections for K2SM should include recent recruitment deviates (reduce uncertainty).
- If evidence of changes on underlying productivity (e.g. climate change), reference points updated in all models (or as factors) but in a large ensemble context...
- p-value of no-trend useful when using large ensembles of models (ICCAT/IOTC) together with other diags.
- Models with a low p-value for no-trend (threshold 0.1 arbitrary) should be analysed (re-configured) before selection for ensemble to develop management advice.
- For Joint Tuna RFMO, harmonize specifications of rec devs (phases, role, constrains...).

Thanks!

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