Developing the Climate Test: Climate Robustness as an Attribute of Management Procedures

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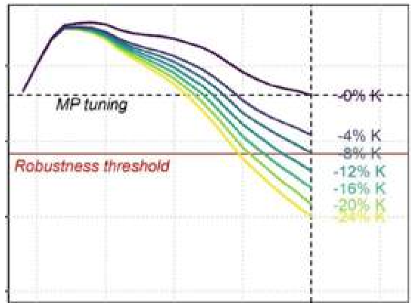

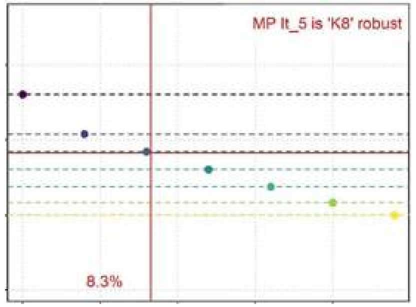

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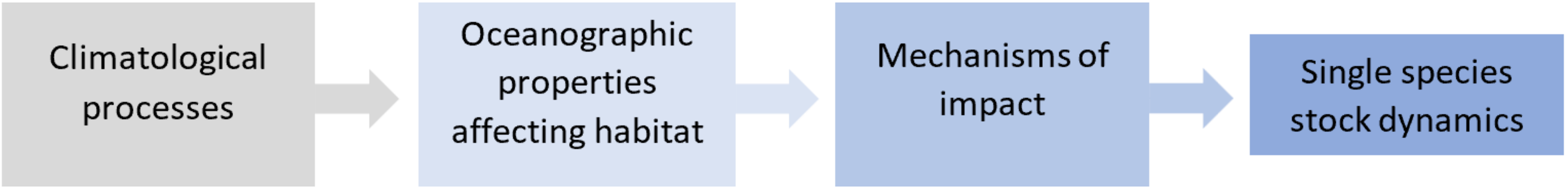
Contents

1. The Problem

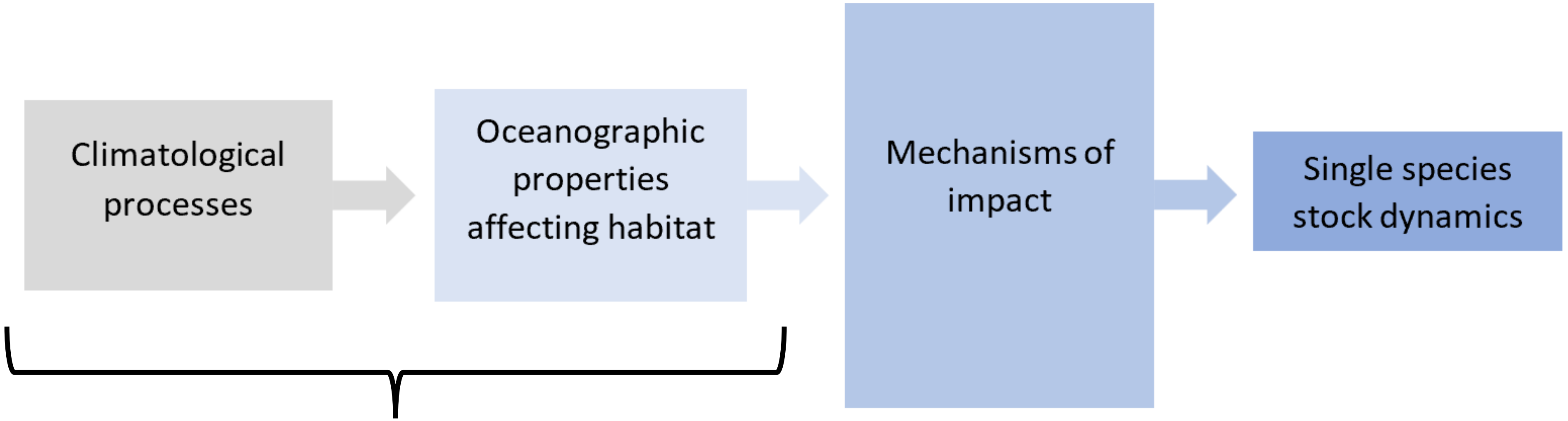
- Marine communities are expected to experience increased impacts from factors relating to climate change.
- There is a need for fishery management practices that are robust to changing environmental conditions, population and fishery dynamics.
- Forecasting of quantitative impacts is highly uncertain 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. Simplification

- A previous paper (SCRS/2024/104) reviewed the climate – ocean science / fisheries literature and summarized the pathways to impacts on individual stocks starting with climatological processes.



Climatological process	Oceanographic properties affecting habitat
Thermal regime	Currents / mixing / stratification (Cai et al. 2005, Wu et al. 2012, Li et al. 2015) Dissolved oxygen concentration (Stendardo and Gruber 2012) Macronutrients (Dickson et al. 1996) Water temperature (Sarmiento et al. 2004, Brickman et al. 2018, Loder and Wang 2015) pH (Feely et al. 2009)
Atmospheric CO_2	Dissolved oxygen concentration pH (Ganachaud et al. 2011, Caldeira & Wickett 2003)
Atmospheric circulation / aeolian inputs	Micronutrients Currents / mixing / stratification (Sydeman et al. 2014)

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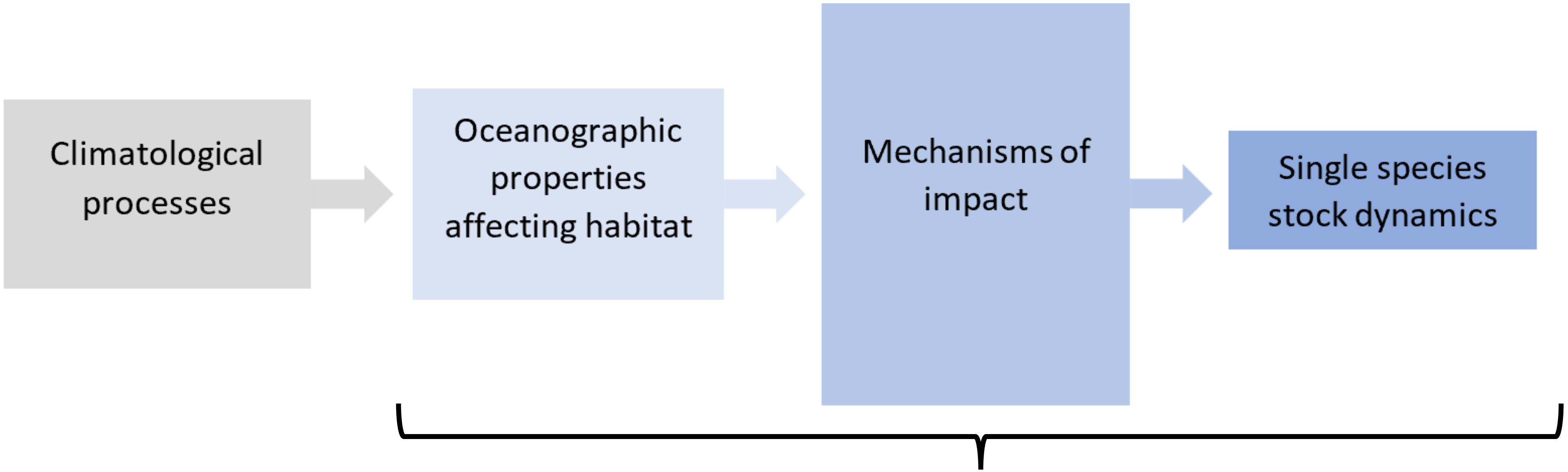

Oceanographic properties affecting habitat	Mechanism	Relevant operating model dynamics
Currents / mixing / stratification	Larval dispersal	Recruitment strength
	Prey availability (Beaugrand and Kirby 2010)	Somatic growth (Perry et al. 2005)
	Vulnerability to fishing gear	Catchability
Water temperature	Physiological stress - thermotaxis	Spatial distribution & phenology (Edwards and Richardson 2004, Perry et al. 2005, Nye et al. 2009, Last et al. 2011, Bell et al. 2011, Erauskin-Extramiana et al. 2019,2020, Tanaka et

3. Simplification

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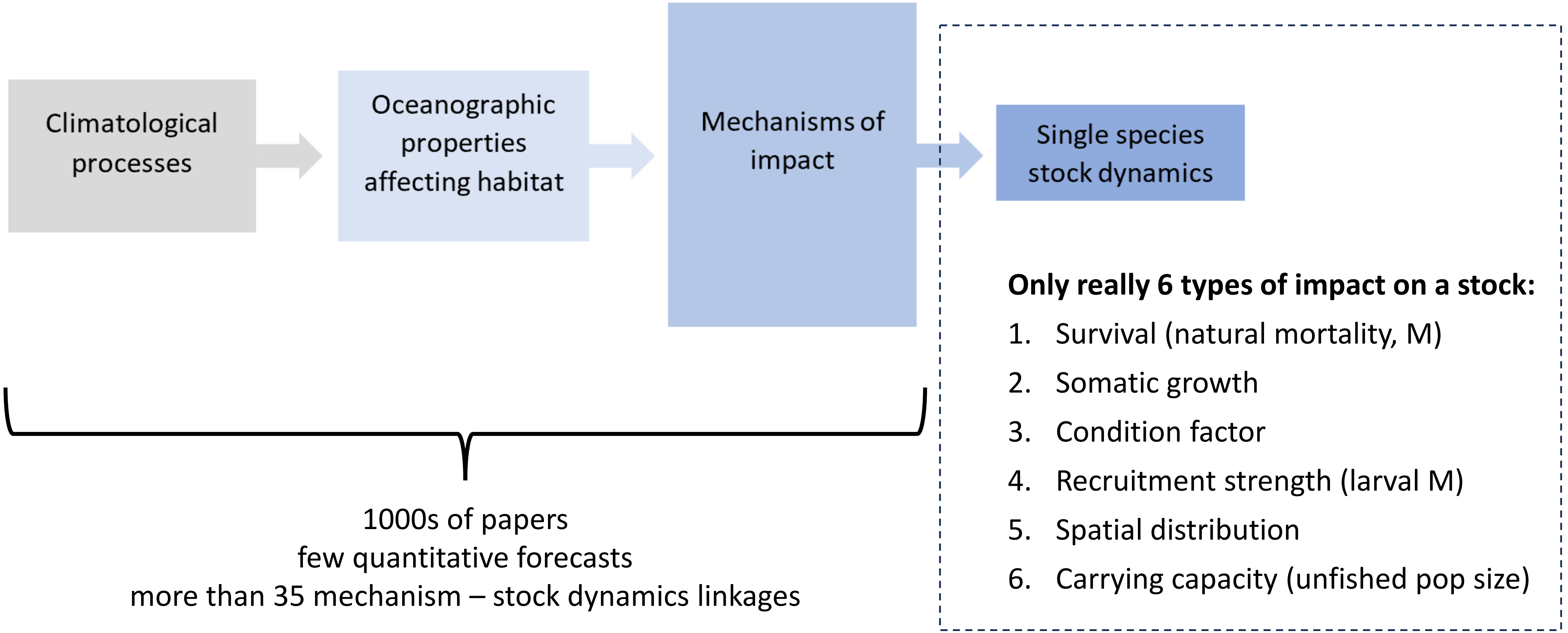


Only really 6 types of impact on a stock:

1. Survival (natural mortality, M)
2. Somatic growth
3. Condition factor
4. Recruitment strength (larval M)
5. Spatial distribution
6. Carrying capacity (unfished pop size)

2. Simplification

Single species stock dynamics

‘Problematic’ direction is also known:

1. Survival (natural mortality, M)	Decreasing	(increasing M)
2. Somatic growth	Decreasing	(e.g., declines in K and Linf)
3. Condition factor	Decreasing	(declines in weight at age)
4. Recruitment strength (larval M)	Decreasing	
5. Spatial distribution	Range contraction, towards fishing	
6. Carrying capacity (unfished pop size)	Decreasing	

3. A solution: Metrics not Operating Models

But we can test performance

Performance rating			
	Cloud: 8	Dusk: 7	Storm: 7
	Cloud: 9	Dusk: 8	Storm: 8
	Cloud: 7	Dusk: 8	Storm: 4

3. A solution: Metrics not Operating Models

Climate Test:	‘M’ Increasing natural mortality rate	‘R’ Decreasing recruitment strength	‘K’ Decreasing somatic growth	‘C’ Decreasing condition factor	‘Q’ Range contraction – increasing catchability	‘S’ Decreasing carrying capacity
Management Procedure 1						
Management Procedure 2						
Management Procedure 3						

4. Methods

Converted the Base 2022 SS3 stock assessment for Atlantic Bigeye Tuna into an OpenMSE operating model.

Created three archetypes of management procedure (following the types adopted / tested for bluefin and swordfish and MSEs elsewhere)

(**It**) Index target (more TAC if *index* above target level, less TAC if *index* below target level)
(**Ir**) Index ratio (TAC = ϑ x *index*)
(**Is**) Index slope (more TAC if index is increasing, less TAC if index is decreasing)

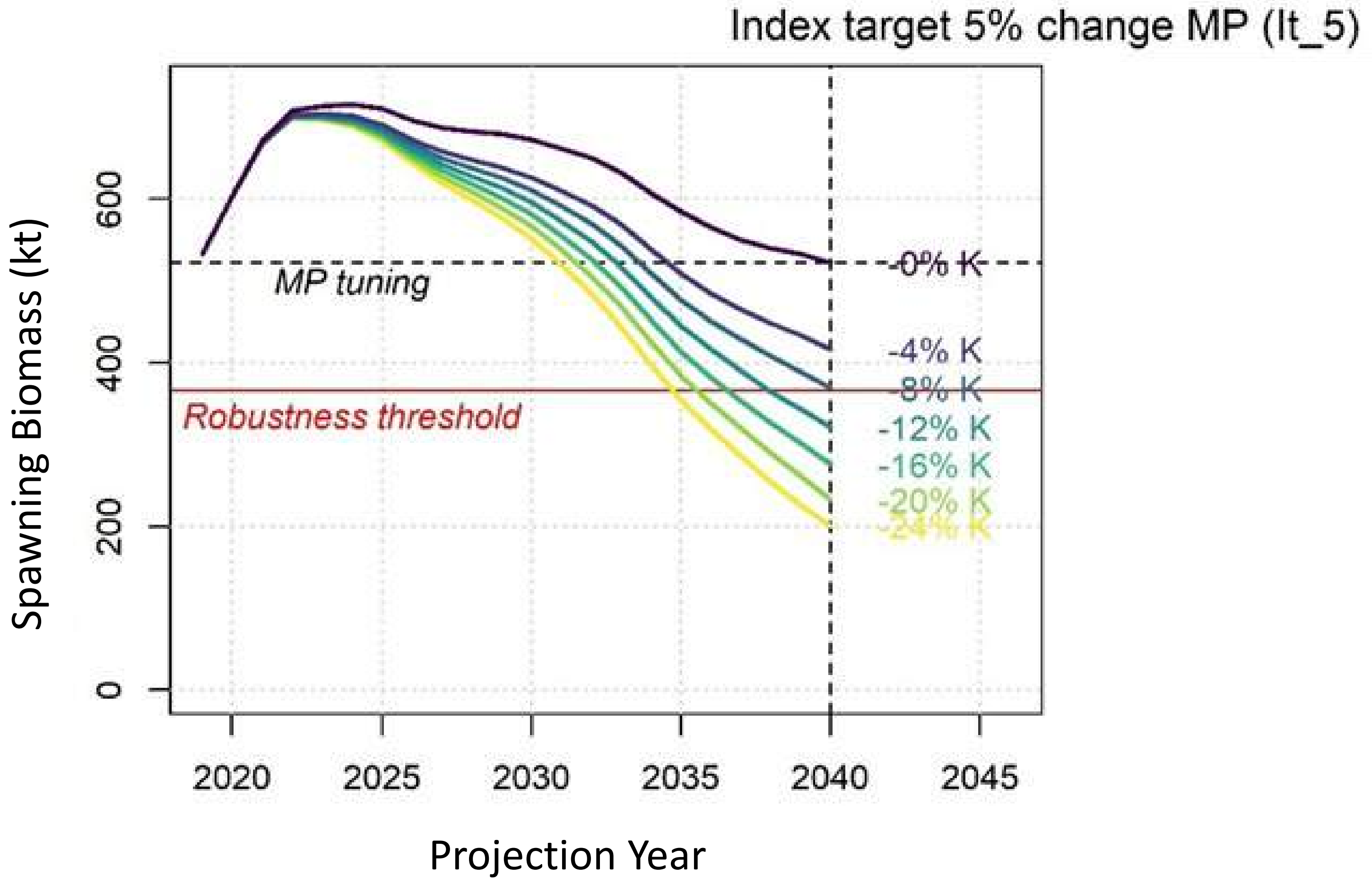
Created two derivatives of each MP archetype:

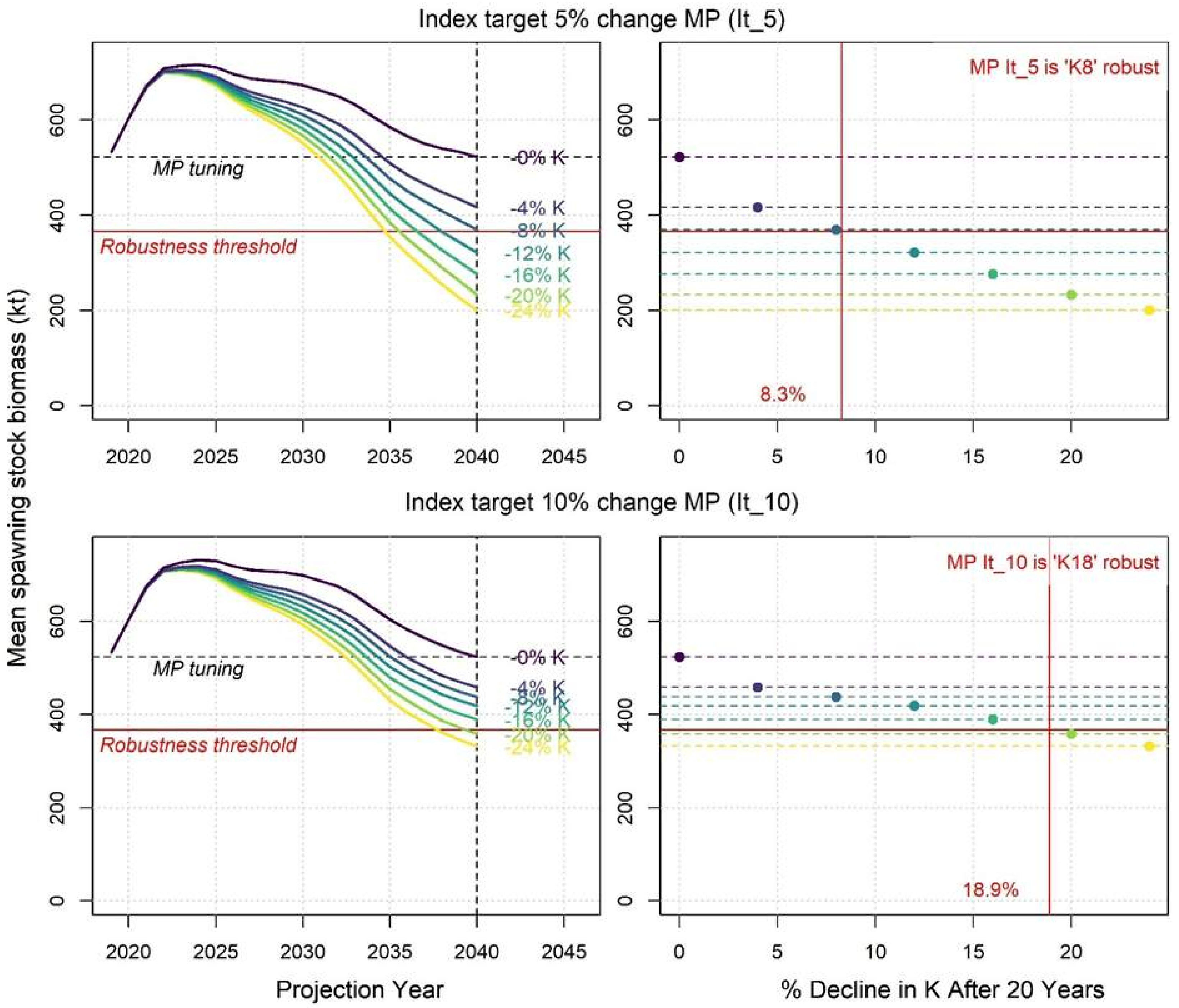
(**_5**) Maximum of 5% changes in TAC among years (It_5, Ir_5, Is_5)
(**_10**) Maximum of 10% changes in TAC among years (It_10, Ir_10, Is_10)

Tested these 6 MPs for future scenarios for increasing natural mortality rate (M), decreasing recruitment strength (R), decreasing somatic growth (K) and decreasing condition factor (C)

4. Methods

- Defined a **threshold for 'robust'** as a decline in biomass of more than 30% after 20 projected years
- Tuned a range of empirical MPs to zero trend (flat) over 30 projected years
- Imposed increasing levels of each climate test and recorded the level where the MP passed the threshold:





The Index target MP is substantially more robust to climate scenarios when it allows for TAC changes of 10%

5. Results

- Index target MP allowing up to a 10% TAC change was consistently more 'climate robust' than the other MPs
- Smaller % changes in M were required to breach the threshold (MPs were most sensitivity to M, then K, then recruitment, then condition factor)
- The highest variability in climate resilience occurred with respect to condition factor

Tabulated numbers are the percentage change in each impact before the robustness threshold is reached. Higher percentages that are shaded green represent higher robustness. Shading is scaled per climate test (by column) according to the maximum robustness (highest %)

M = increasing natural mortality rate

R = decreasing recruitment strength

K = decreasing somatic growth

C = decreasing condition factor (weight at age)

Management Procedure	Climate Test			
	M	R	K	C
Index target 5% change	7	19	9	26
Index target 10% change	9	24	18	56
Index ratio 5% change	8	20	9	26
Index ratio 10% change	8	22	13	42
Index slope 5% change	7	18	6	20
Index slope 10% change	7	19	7	23

5. Results

Western Atlantic Skipjack Tuna MSE

Management Procedure	Climate Test			
	K	C	M	R
SPAH_CT	20	21	4	10
SP_CT	22	26	4	12
IR_CT	53		7	18

Adopted MP was most robust >

North Atlantic Swordfish MSE

Management Procedure	Climate Test			
	K	C	M	R
CE_b_CT	13	40	11	18
MCC11_b_CT	18	61	11	23

Adopted MP was most robust >

5. Discussion and Conclusions

- Should we wait for scientifically defensible forecasts for individual taxon and location before developing climate-robust management advice?
- There are relatively few types of single-species impacts arising from 1000’s of papers on possible pathways for climate impacts.
- The ‘problematic direction’ of impacts are known.
- Quantifying climate robustness as an attribute of a management procedure, alleviates the need for a defensible scientific forecast of impacts.
- In this demonstration, one management procedure was consistently more robust than the others across multiple climate tests.
- Phrasing climate robustness as an attribute of a management procedure provides a language (e.g. ‘M6 robust’) for accounting for climate resilience in tactical advice.

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