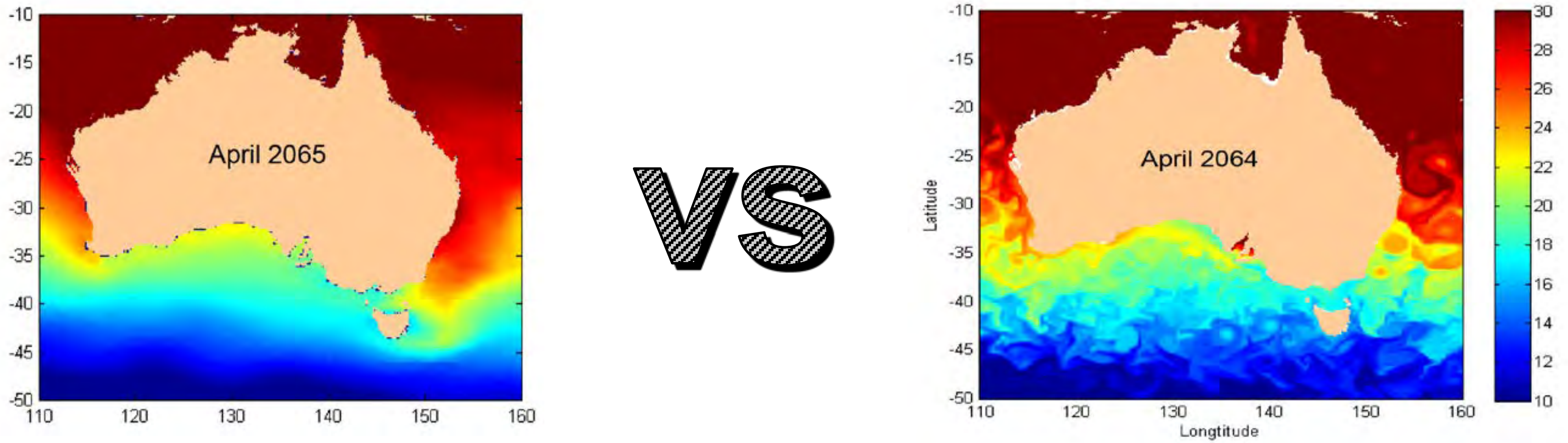


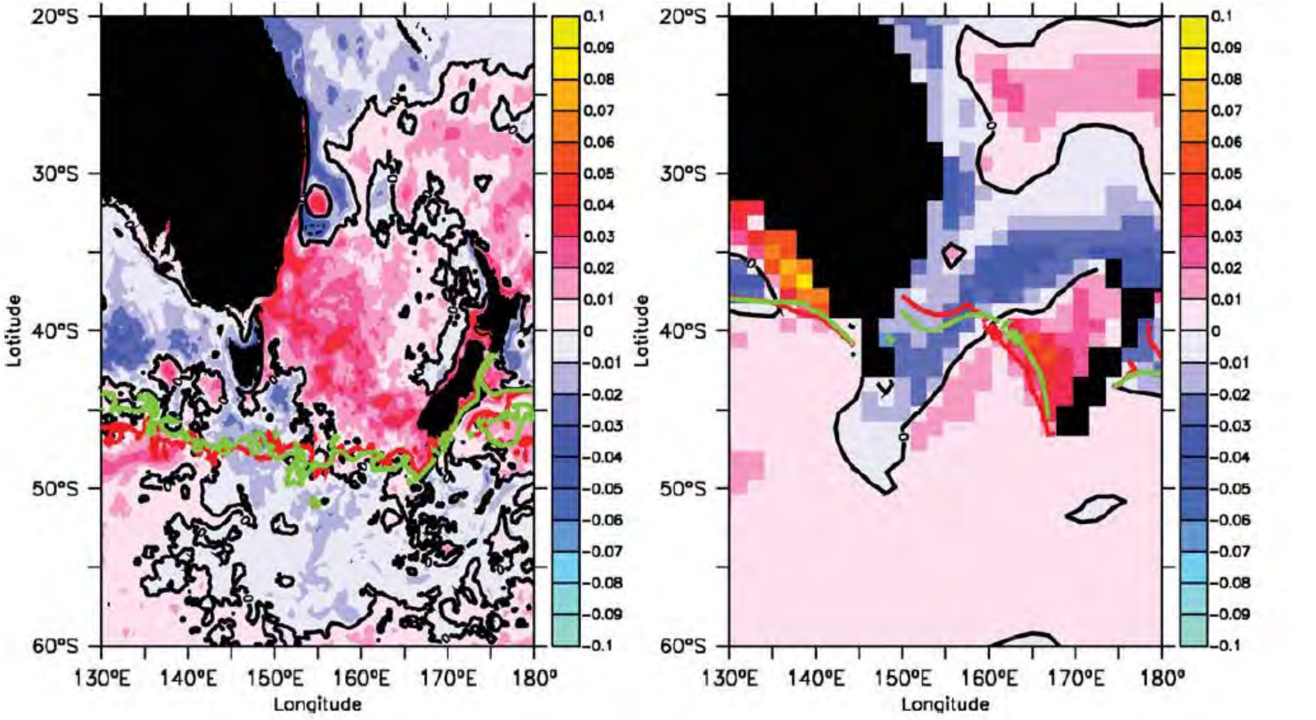
Comparing ecosystem projections under forcing from global & local climate models

Beth Fulton | On behalf of Cathy Bulman & the CSIRO-IMAS forecasting team

2018

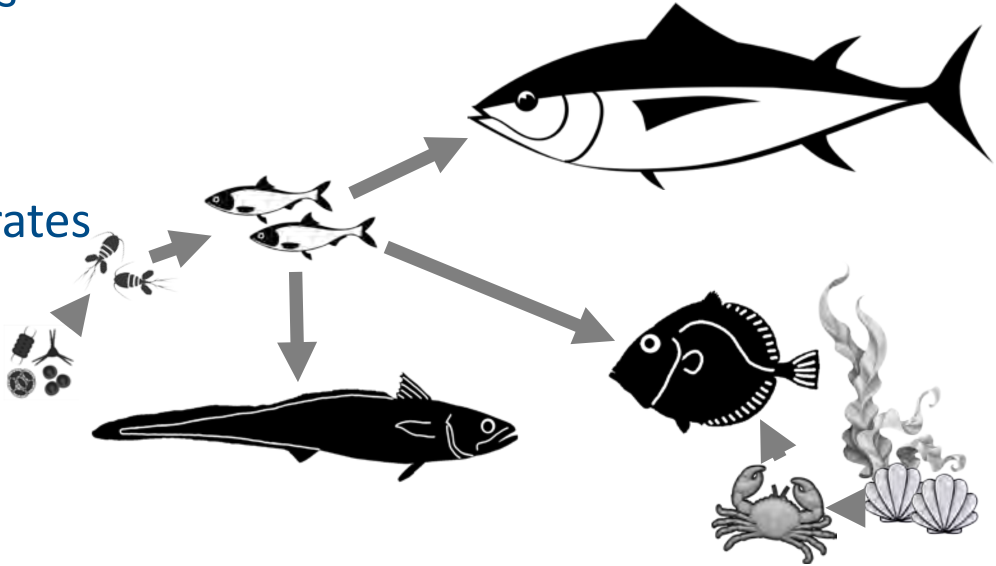
Implications of increased resolution

- Different ocean features, different fisheries implications



Ecopath with Ecosim – Eastern Bass Strait

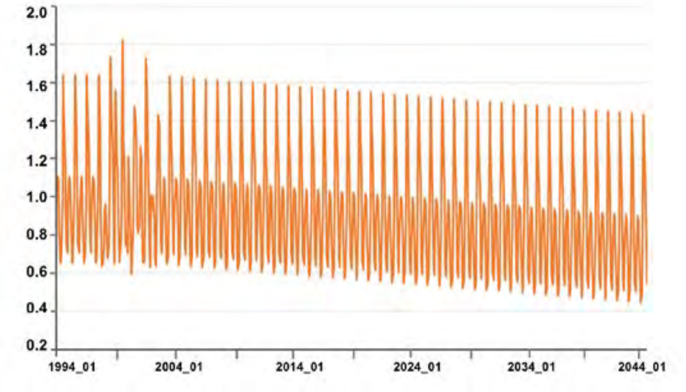
- Trophic model
- No age structure
- 56 groups
  - 3 marine mammals
  - 2 seabirds
  - 3 chondrichthyans
  - 38 teleosts
  - 3 pelagic invertebrates
  - 3 benthos
  - 3 zooplankton
  - Phytoplankton
  - Detritus
- 11 fisheries
- 4 drivers

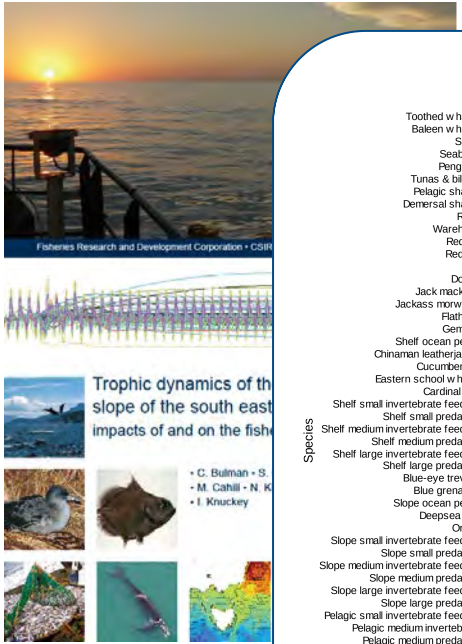


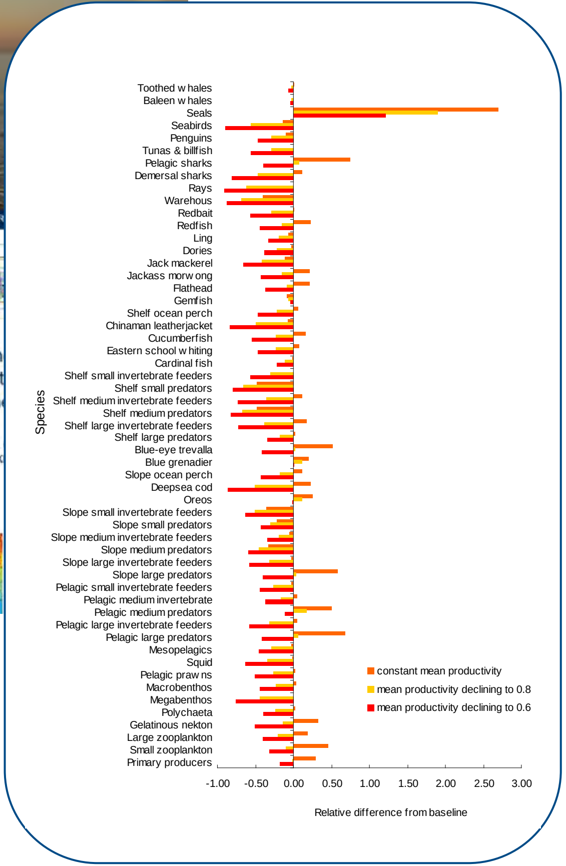
Bulman et al. 2006

In the beginning

- East Bass Strait model developed in 2006
- Derived productivity anomaly time series (using Hoyo estimates from satellite ocean colour)
- Expert based forcing: mean primary productivity **decline** to 80% or 60% over 50 years







Bulman et al. 2006

First climate modelling

- Climate modelling workshop
  - 12 EwE models
  - CSIRO Mark 3.5 forcing (coupled atmosphere-ocean GCM) = primary productivity trend 2000-2050
- East coast – **increases** up to 60% but southeast lower

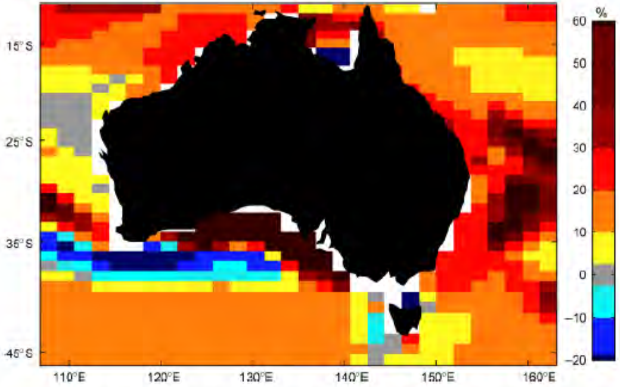


Fig. 2 Predicted relative percent change in phytoplankton production rate from the 2000–2004 mean to 2050 for the Australasian region. The CSIRO Mk 3.5 global climate model (GCM) was used to force a nutrient-phytoplankton-zooplankton submodel under the A2 emission scenario. Phytoplankton production rate is predicted to generally increase around Australia. The pixel size indicates the resolution of the NPZD and land (white spaces) has been overlaid with a high-resolution map.

Global Change Biology

Global Change Biology (2010) **16**, 1194–1212, doi: 10.1111/j.1365-2486.2009.02046.x

Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation

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Abstract

Climate change is altering the rate and distribution of primary production in the world's oceans. Primary production is critical to maintaining biodiversity and supporting fishery catches, but predicting the response of populations to primary production change is complicated by predation and competition interactions. We simulated the effects of change in primary production on diverse marine ecosystems across a wide latitudinal range in Australia using the marine food web model Ecosim. We link models of primary production of lower trophic levels (phytoplankton and benthic producers) under climate change with Ecosim to predict changes in fishery catch, fishery value, biomass of animals of conservation interest, and indicators of community composition. Under a plausible climate change scenario, primary production will increase around Australia and generally this benefits fisheries catch and value and leads to increased biomass of threatened marine animals such as turtles and sharks. However, community composition is not strongly affected. Sensitivity analyses indicate overall positive linear responses of functional groups to primary production change. Responses are robust to the ecosystem type and the complexity of the model used. However, model formulations with more complex predation and competition interactions can reverse the expected responses for some species, resulting in catch declines for some fished species and localized declines of turtle and marine mammal populations under primary productivity increases. We conclude that climate-driven primary production change needs to be considered by marine ecosystem managers and more specifically, that production increases can simultaneously benefit fisheries and conservation. Greater focus on incorporating predation and competition interactions into models will significantly improve the ability to identify species and industries most at risk from climate change.

Keywords: climate change, ecological interactions, fisheries, food web model, marine biodiversity

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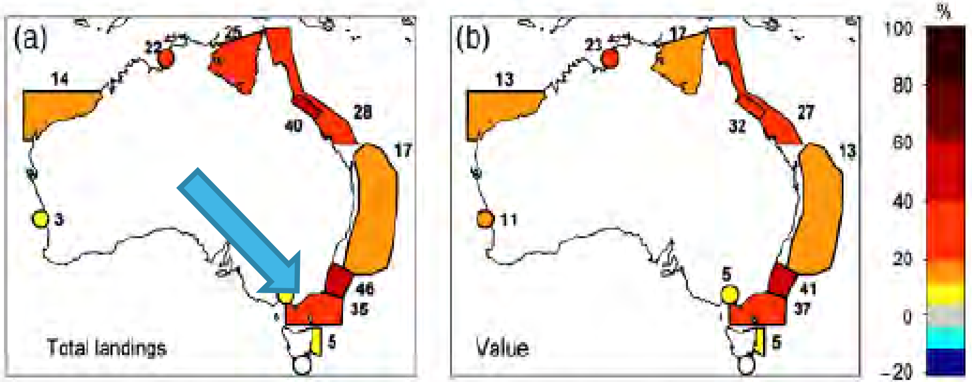
Introduction

Climate change is the most widespread anthropogenic threat that ocean ecosystems face (Halpern *et al.*, 2008). Globally, oceans are warming, becoming more acidic

Brown et al. 2010

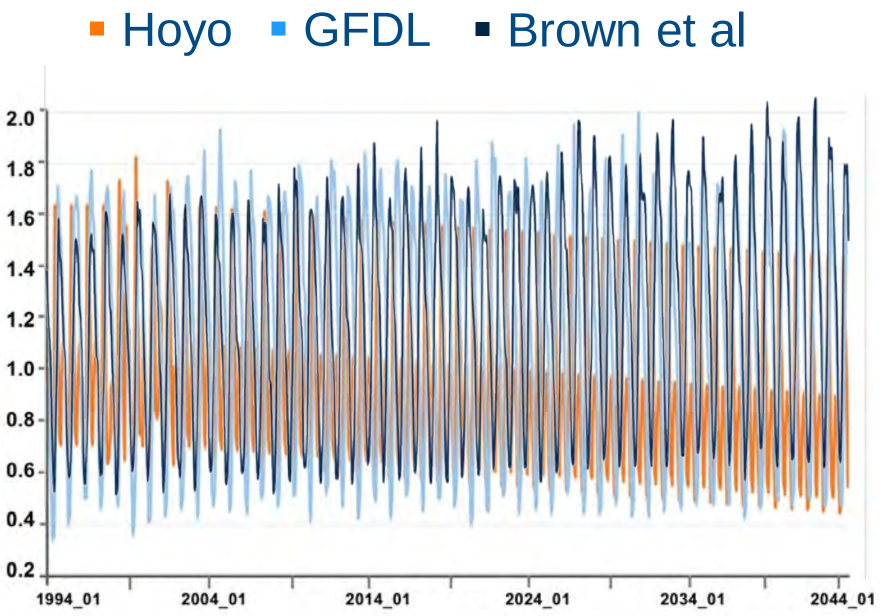
First climate modelling



- Example result: **increased landings** - over 30% in East Bass Strait model (clearly different outcome compared to our earlier assumptions)
- **Conclusion: need to use reliable predictions** from global models and parameterise ecological interactions

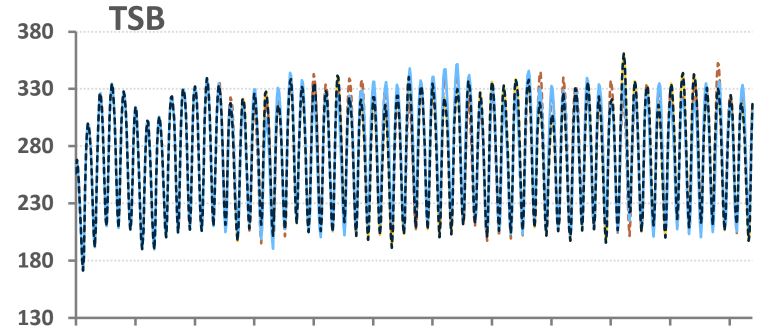
FISH-MIP

- Using global model outputs to force primary productivity:
- GFDL
  - ESM2M reanalysis historical
  - ESM2M GCM4 (Historical, RCPs 2.6, 4.4, 6.0 & 8.5)
- IPSL
  - CM5A GCM2 (Historical, RCPs 2.6, 4.4, 6.0 & 8.5)



- Also clearly different from original assumptions, but not unlike Brown *et al.* results.

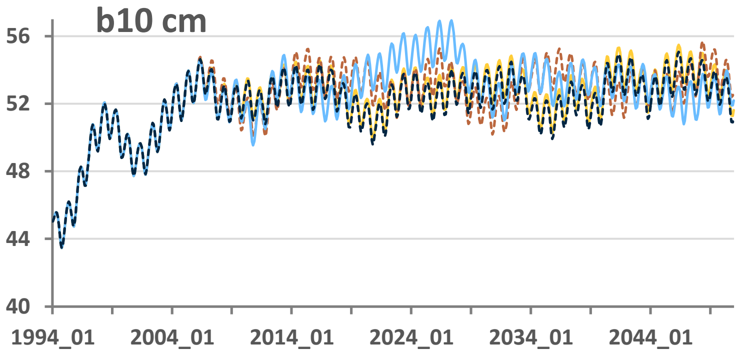
FISHMIP outputs for GFDL RCPs

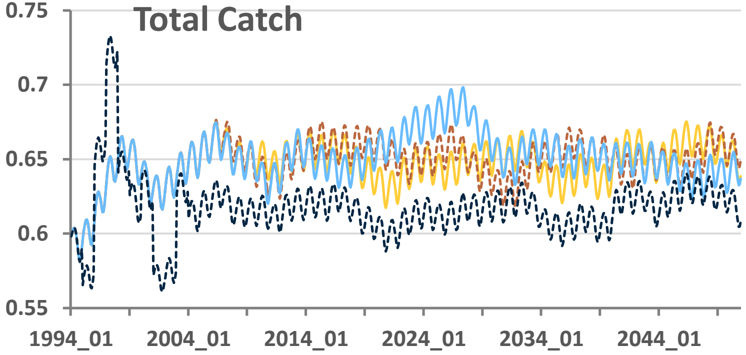


1994-2050 simulations

rcp 2.6
rcp 4.5
rcp 6.0
rcp 8.5

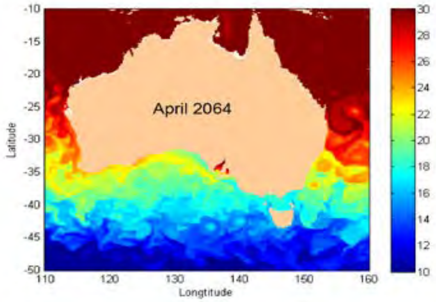
1994_01 2004_01 2014_01 2024_01 2034_01 2044_01





FRDC - Regional hydrodynamic model

- Ensemble investigation of the effect of RCP 8.5 on major Australian fisheries (*Pethybridge/Fulton S12*)
- Forcing: Ocean Forecasting Australia Model (OFAM3) coupled with a BGC = more highly resolved for coastal areas
- BGC-GCM = decline in productivity



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2017GL074176

Key Points:
- The distribution of future sea level rise around Australia results from combination of ocean dynamics, loss of land ice, and GIA
- Dynamic sea level is the leading process to induce regional variations, under moderate and strong emission scenarios
- Downscaling with a 1/10° OGCM produces better dynamic sea level responses from climate models, linked to ocean gyre circulation

Supporting Information:
- Supporting Information S1

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Sea level projections for the Australian region in the 21st century

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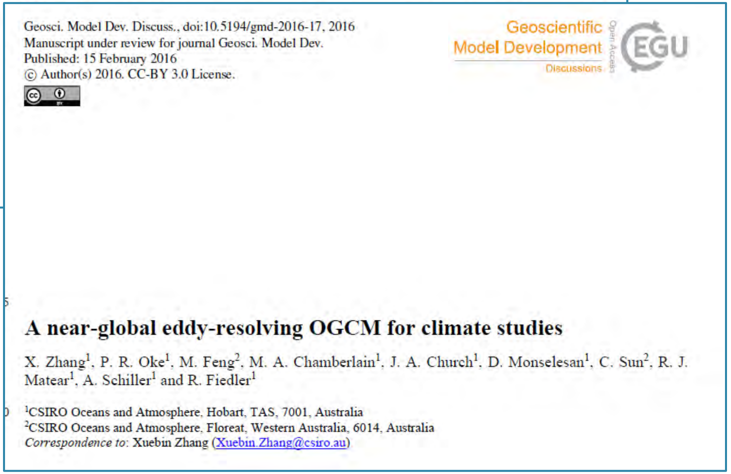
[1]Centre for Southern Hemisphere Oceans Research (CSHOR), CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia, [2]Climate Change Research Centre, University of New South Wales, Sydney, New South Wales, Australia, [3]CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia, [4]CSIRO Oceans and Atmosphere, Aspendale, Victoria, Australia



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Manuscript under review for journal Geosci. Model Dev.
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Geoscientific Model Development Discussions — Open Access — EGU

A near-global eddy-resolving OGCM for climate studies

X. Zhang[1], P. R. Oke[1], M. Feng[2], M. A. Chamberlain[1], J. A. Church[1], D. Monselesan[1], C. Sun[2], R. J. Matear[1], A. Schiller[1] and R. Fiedler[1]

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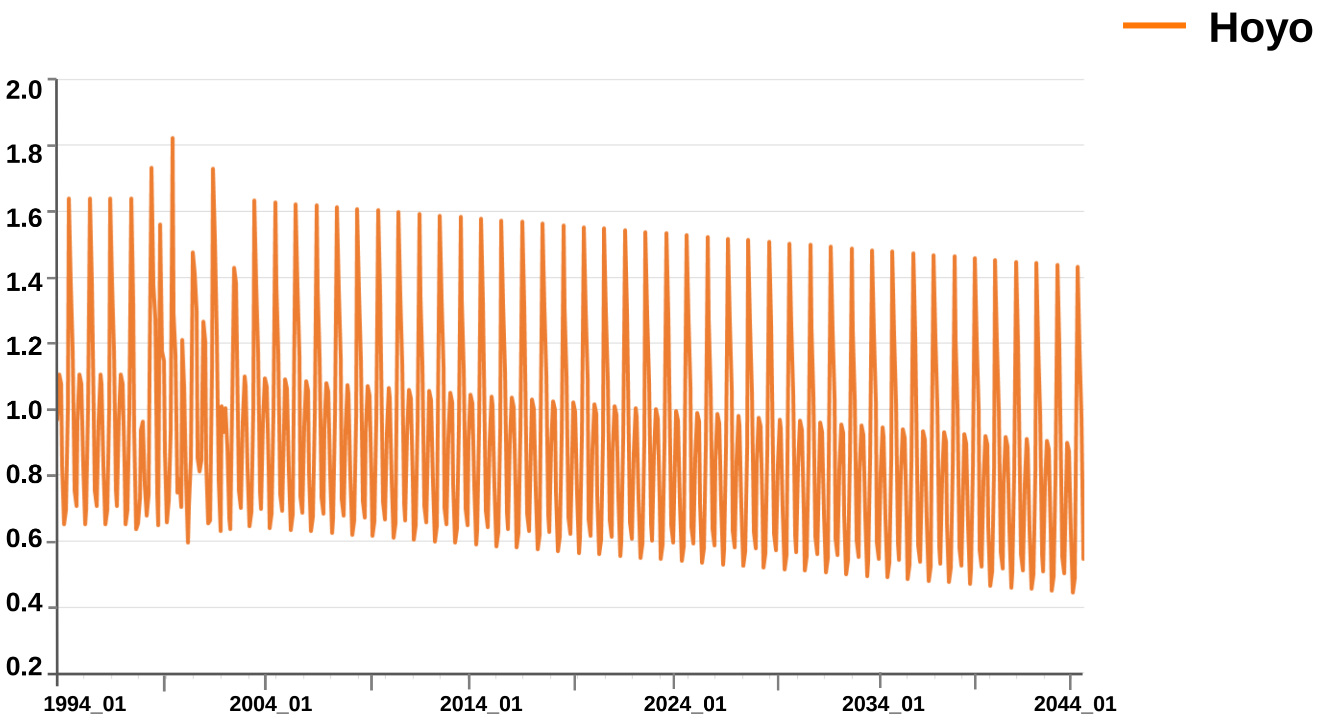
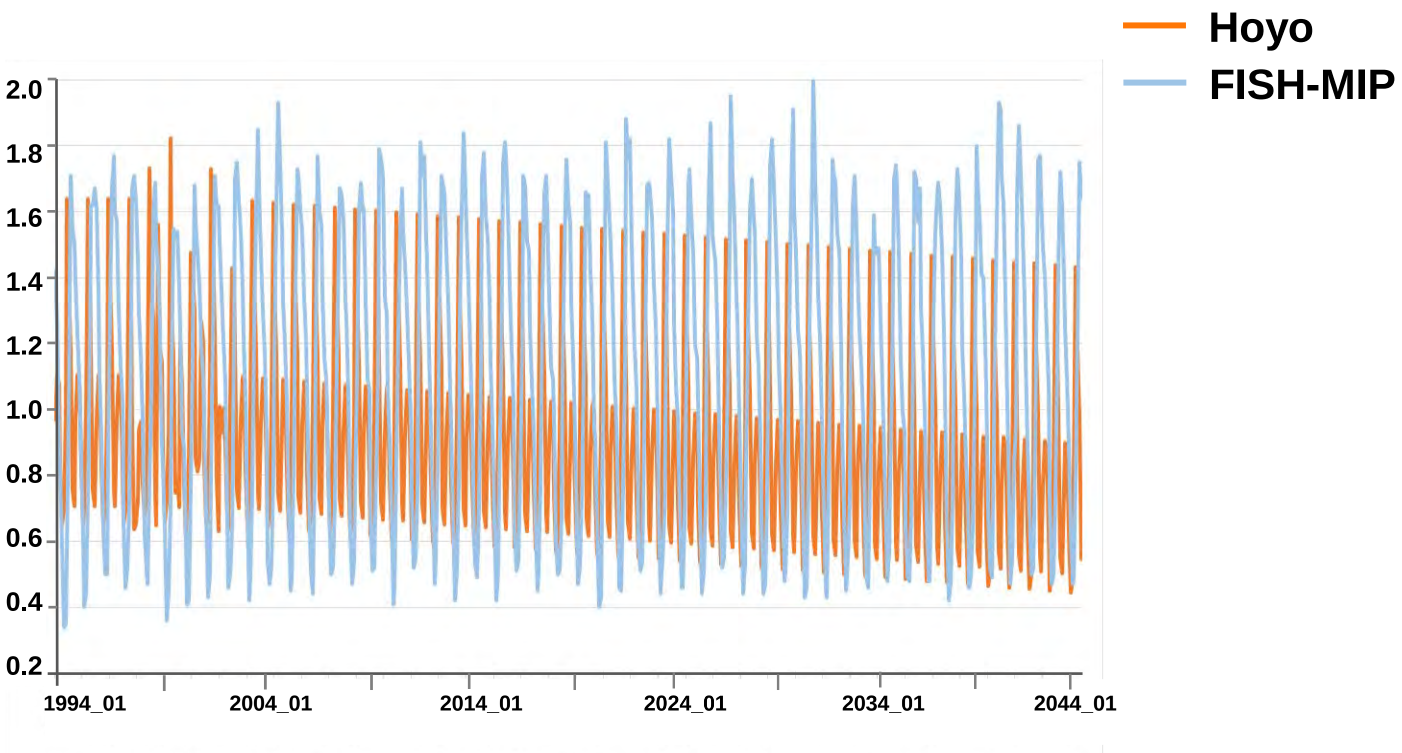
Forcing time series trends



Forcing time series trends



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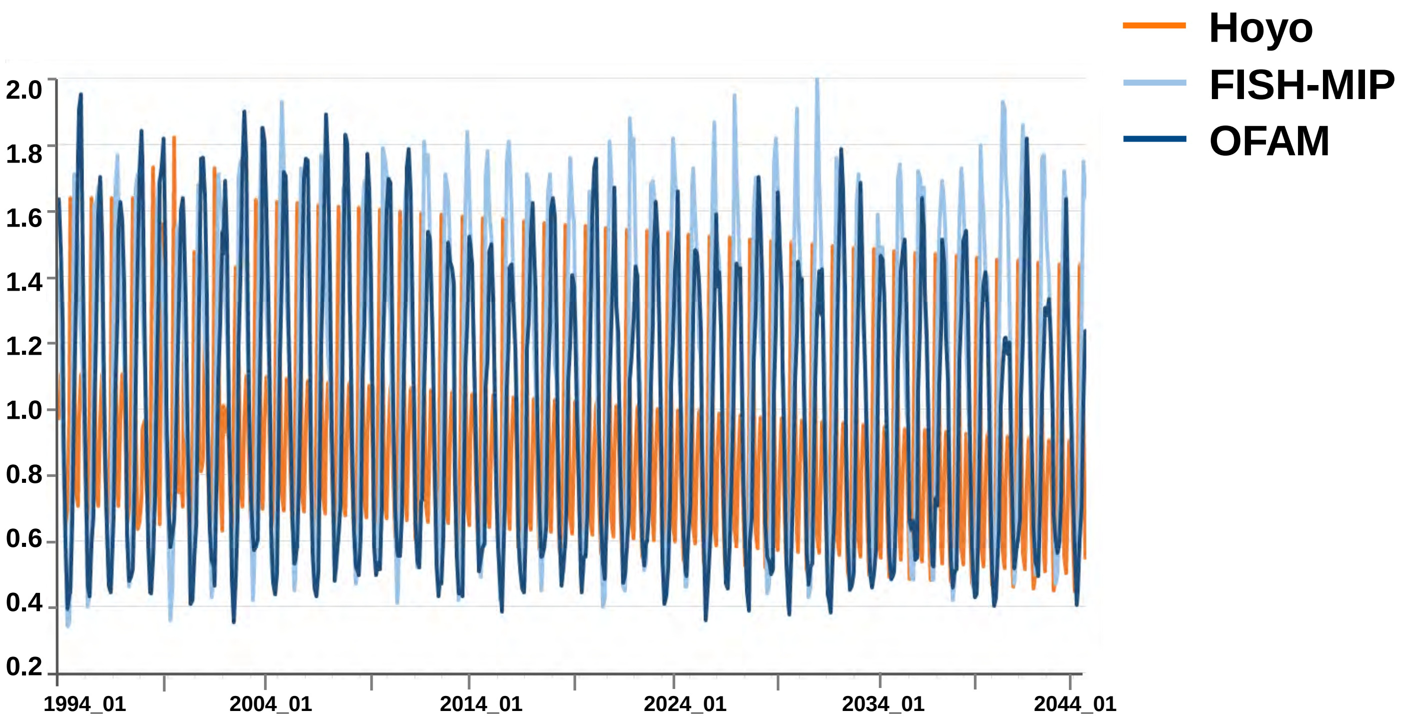

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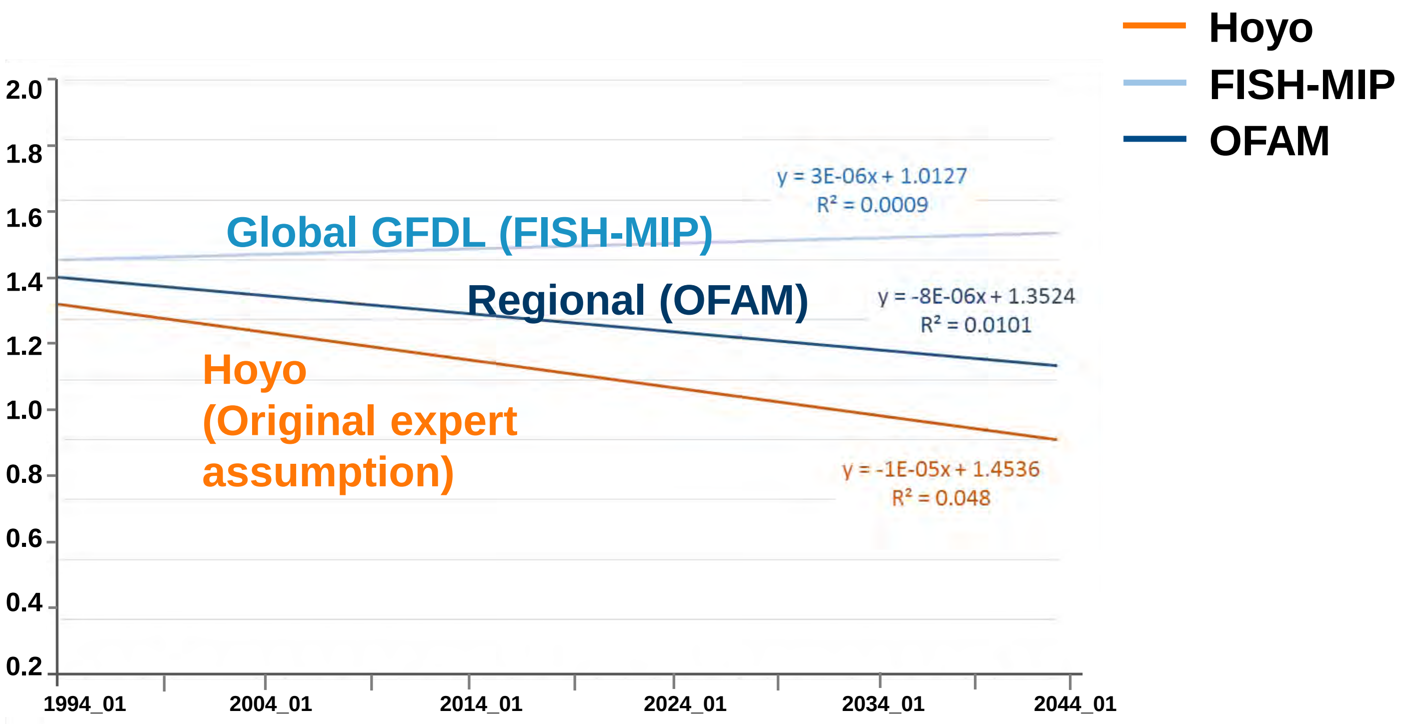
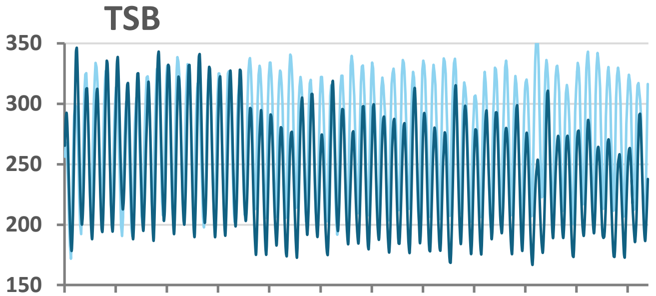
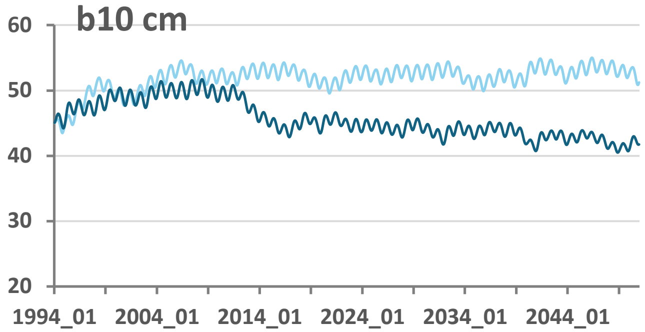


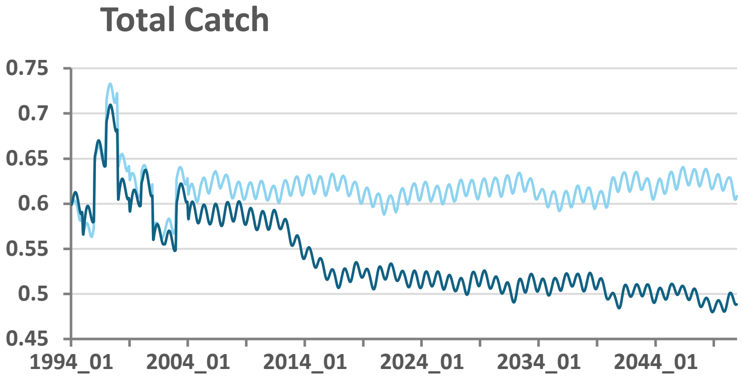
Regional v global

1994-2050 simulations

GFDL 8.5 OFAM3 8.5





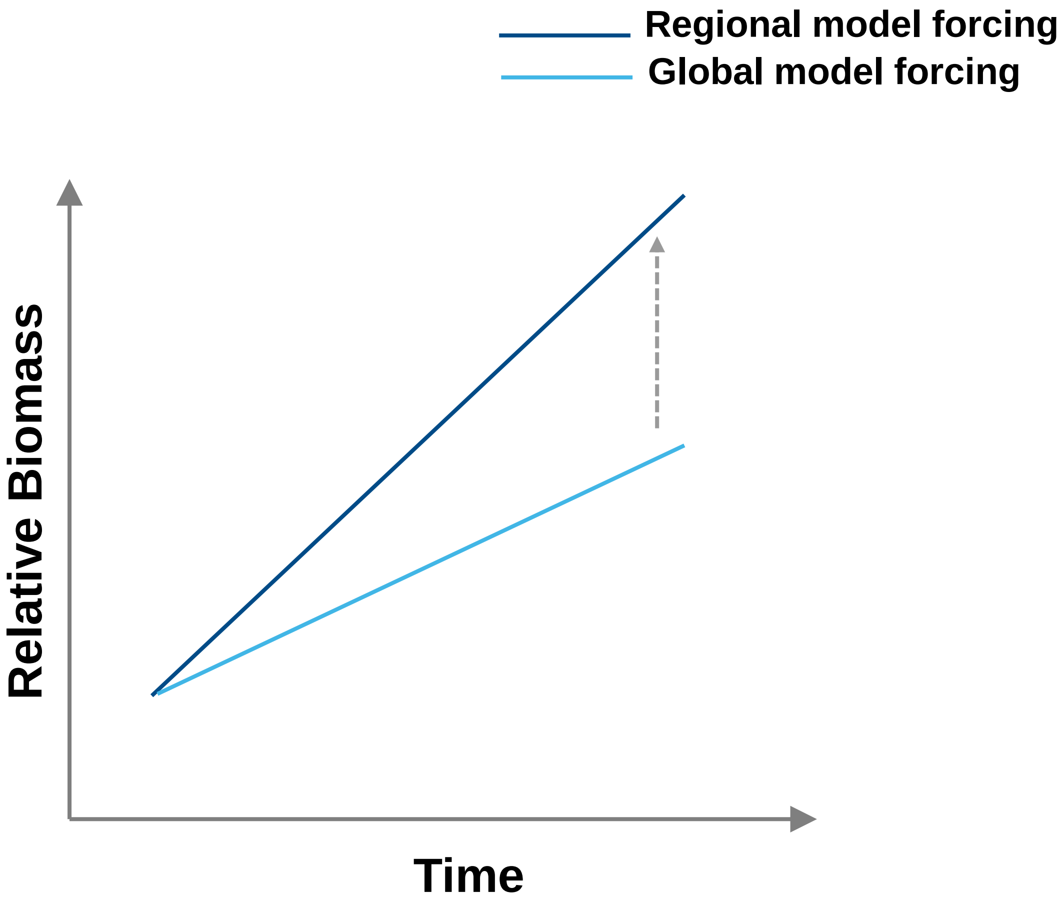


CSIRO

Regional v global

- 5 classes of response

1) **Greater increase**
2) Lesser decline
3) Lesser increase
4) Negative reversal
5) Greater (worse) decline



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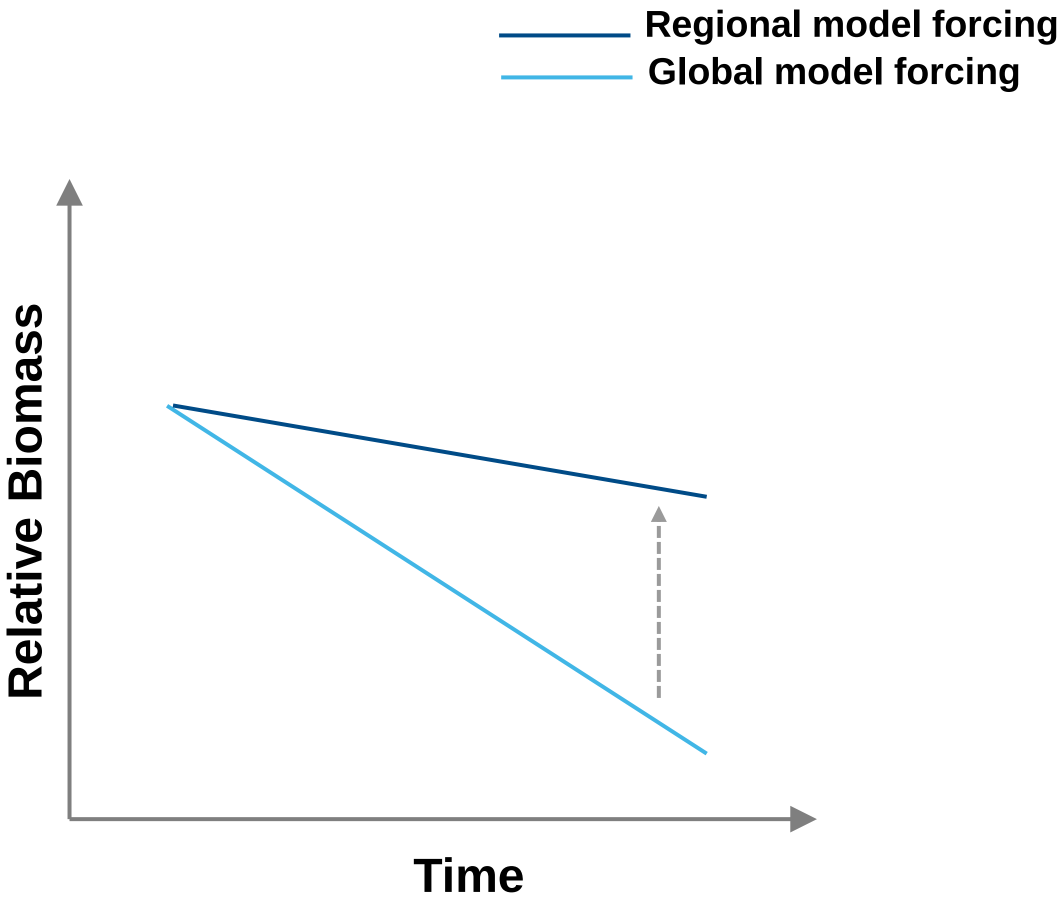

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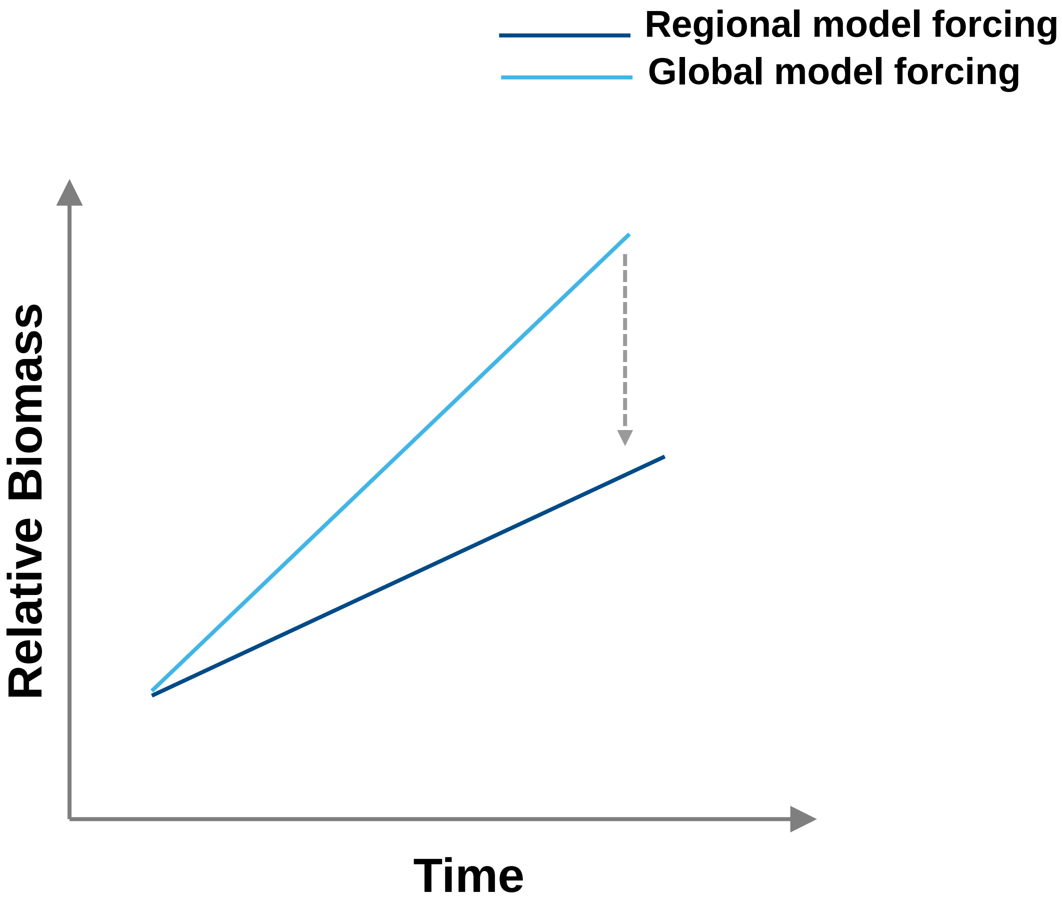

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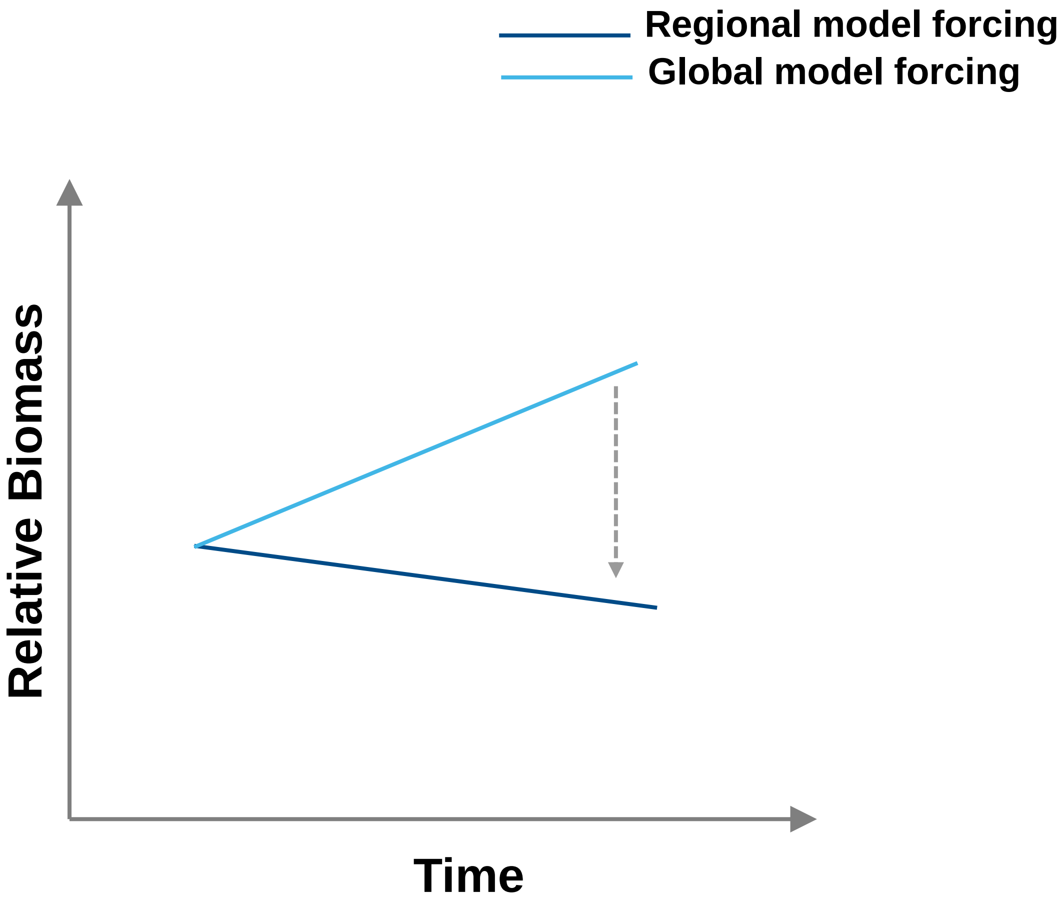

Regional v global

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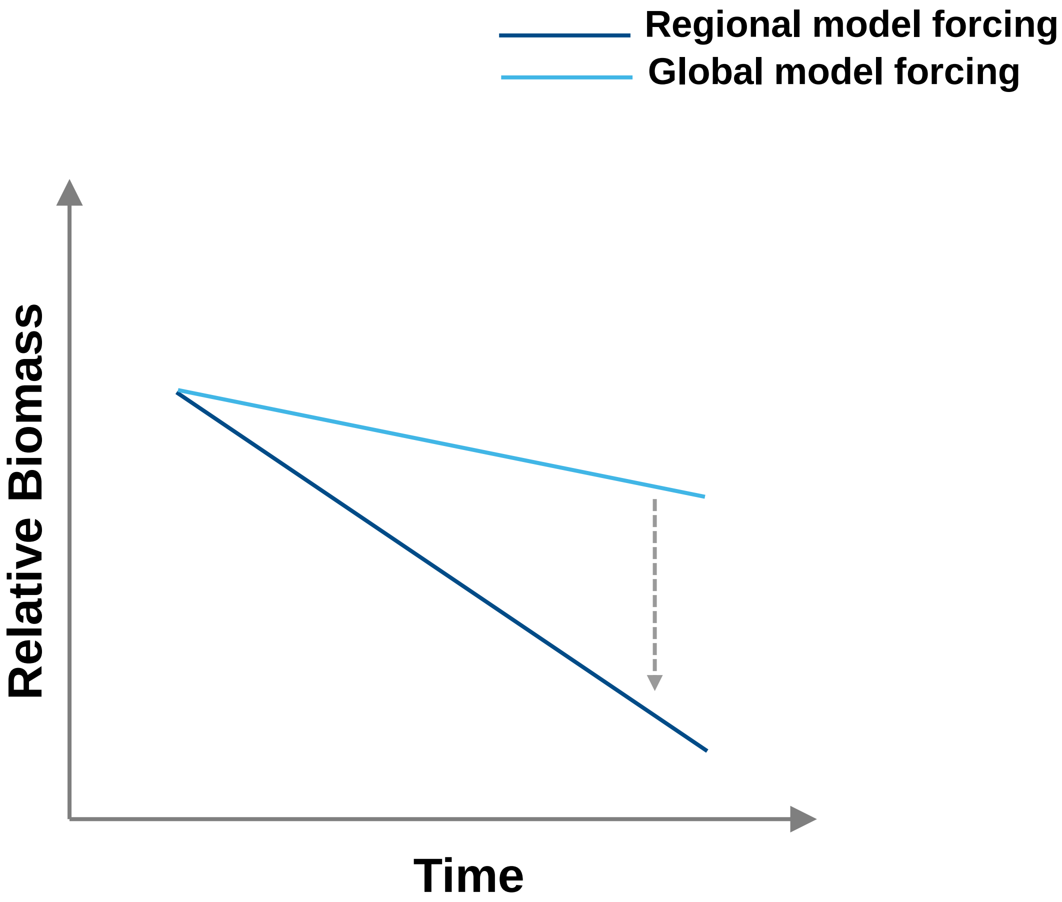
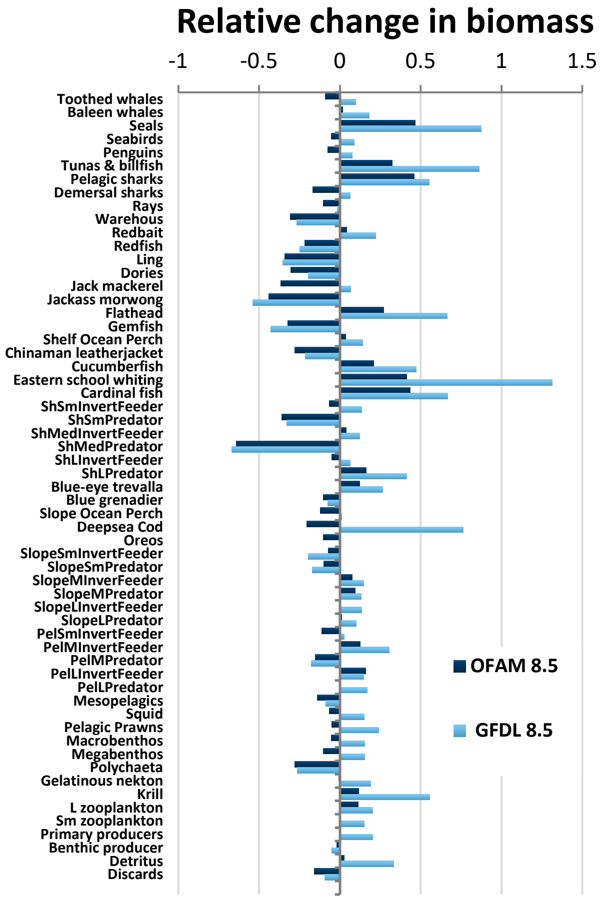


Regional v global

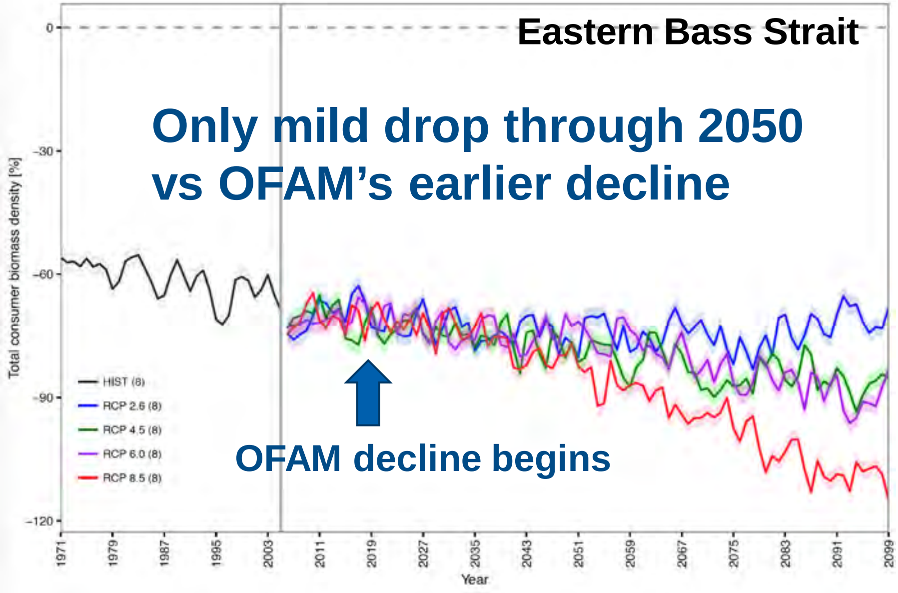
- A lot of differences in overall biomass in fished system - majority less productive (50 of 60 species)

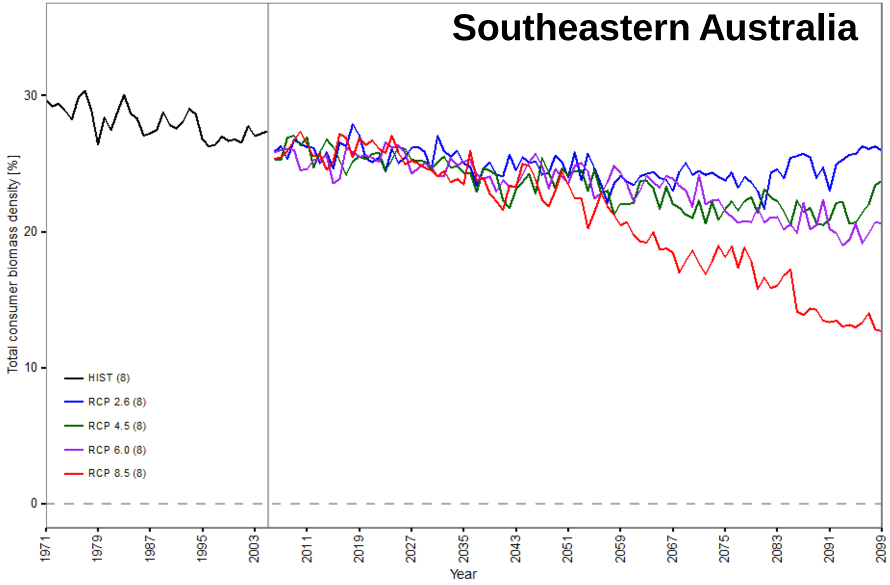
	GREATER INCREASE	LESSER DECLINE	LESSER INCREASE	NEGATIVE REVERSAL	WORSE DECLINE
All groups	1	9	22	19	9



Regional v global

- Production forcing related response (as beyond EwE)
  e.g. total consumer biomass (FISH-MIP global mult-model mean)

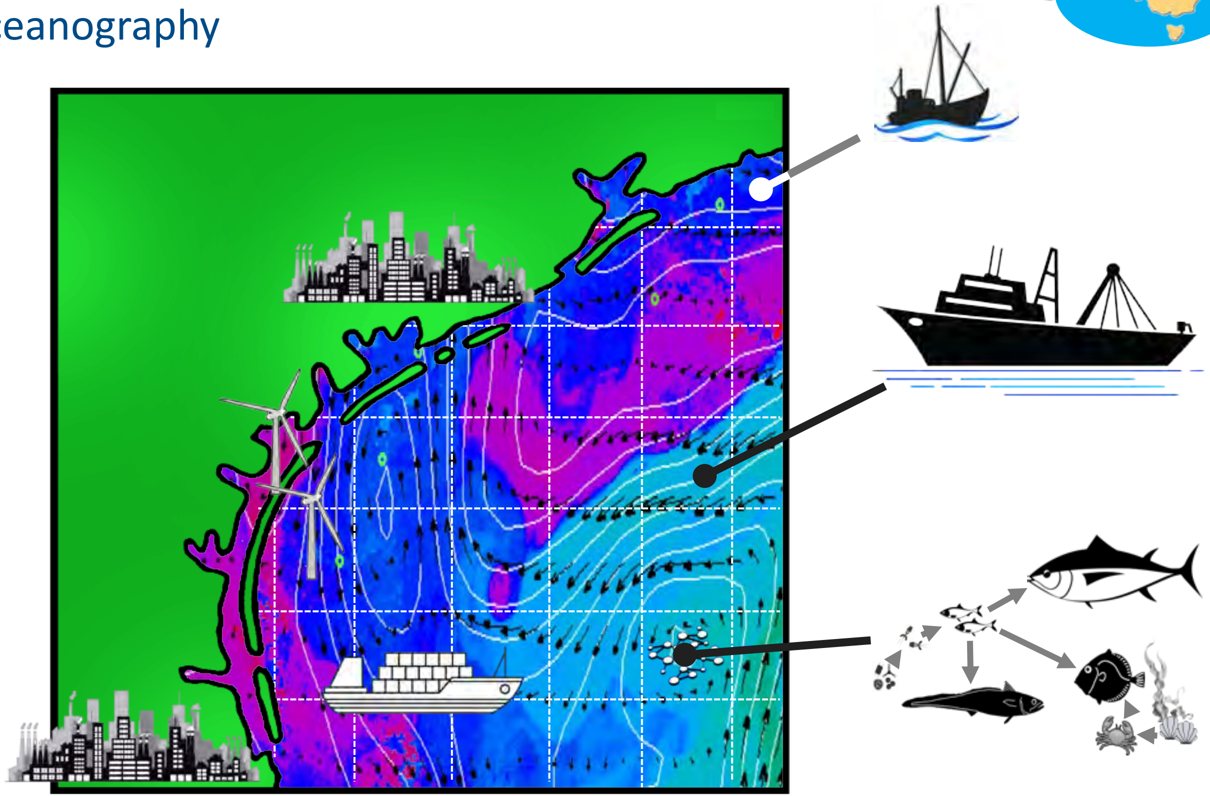




- Biogeochemical model effect, what about ecosystem model effect?

Alternative Model to Consider: Alantis

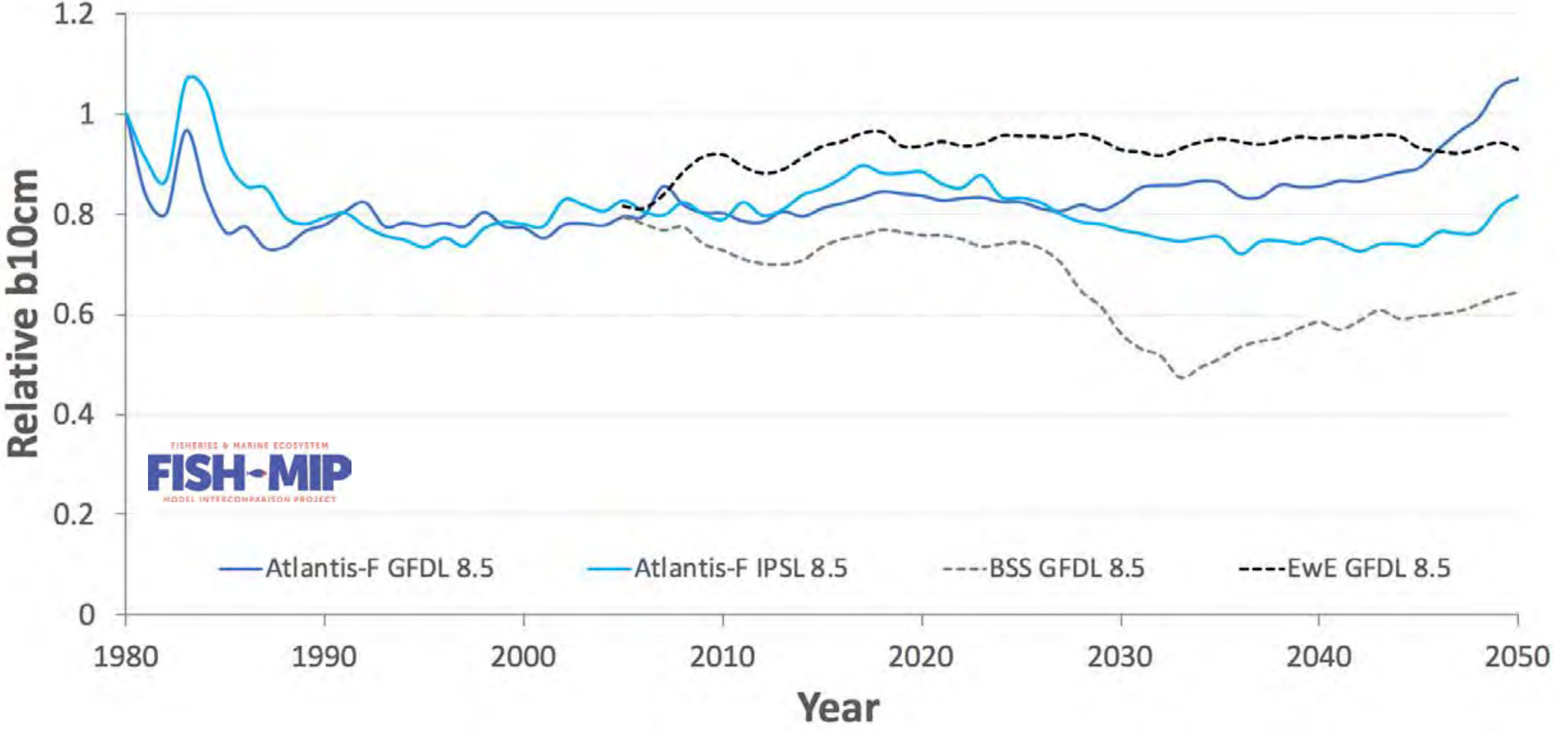
- Biogeochemical with explicit oceanography
- Biomass pools & age structure
- 64 groups
  - 5 marine mammals
  - 2 seabirds
  - 7 chondrichthyans
  - 23 teleosts
  - 10 benthos
  - 2 pelagic invertebrates
  - 4 zooplankton
  - 6 primary producers
  - 2 bacteria
  - 3 detritus
- 32 fisheries + other users



Fulton and Gorton 2014

Results

- Differences due to model type forcing (and mode type) & human dynamics



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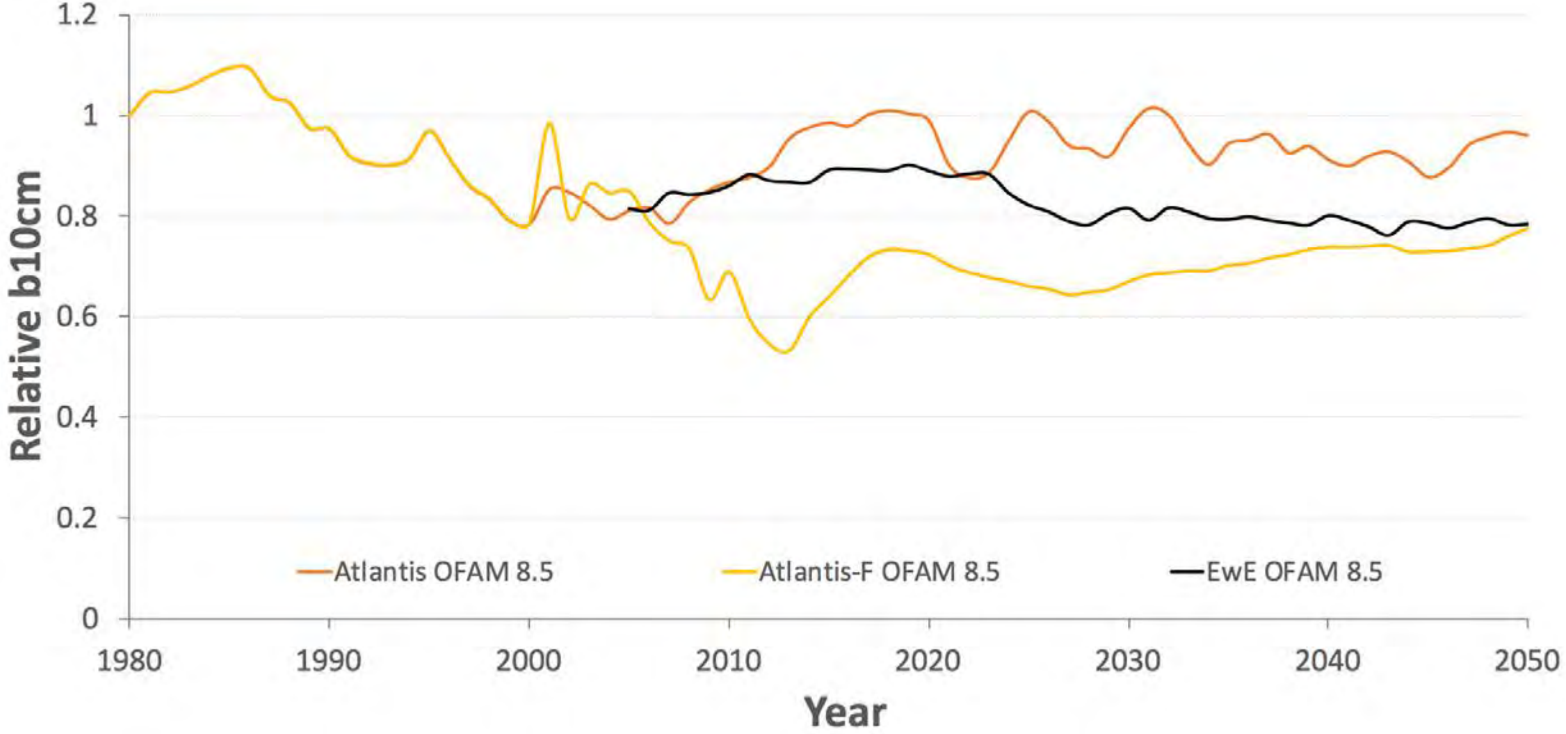

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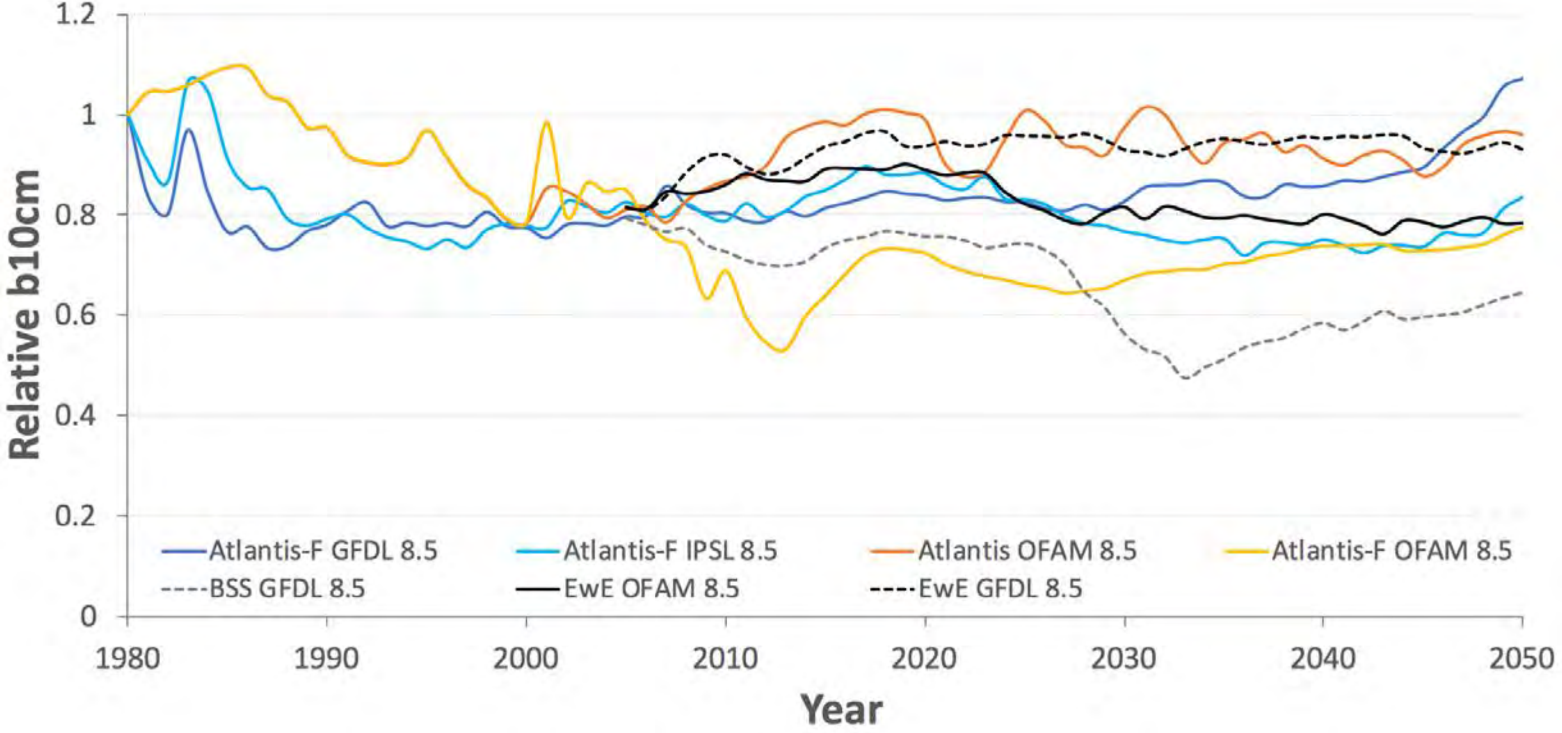
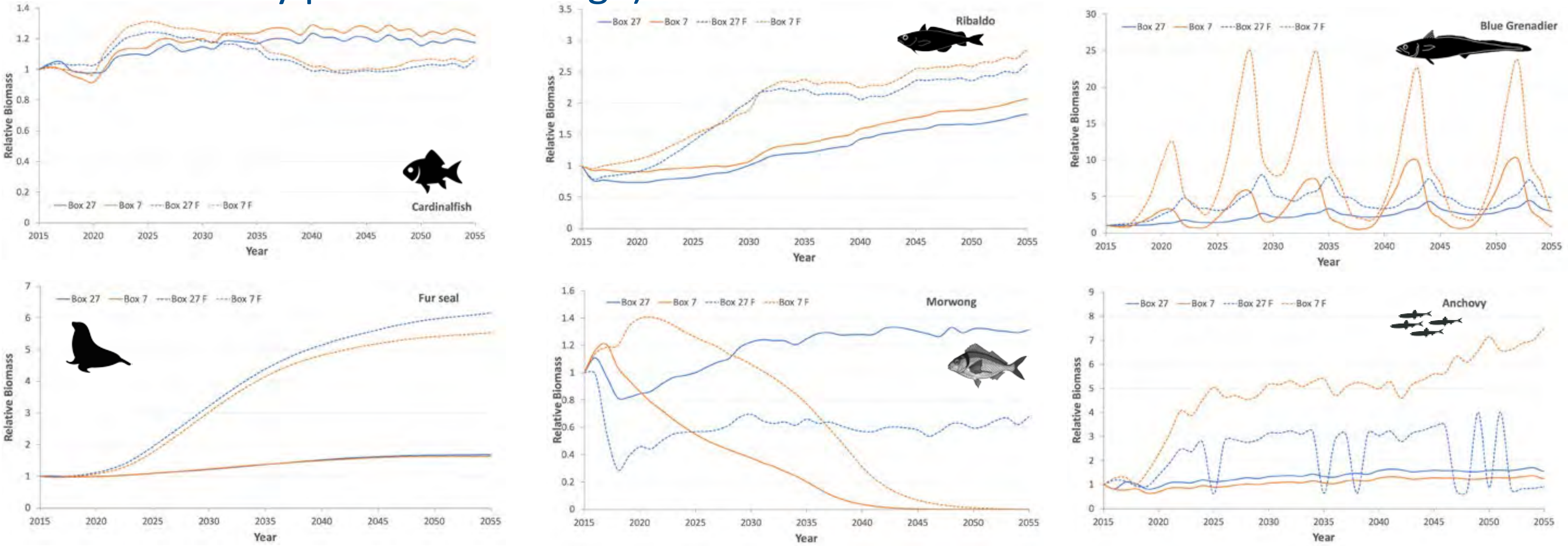


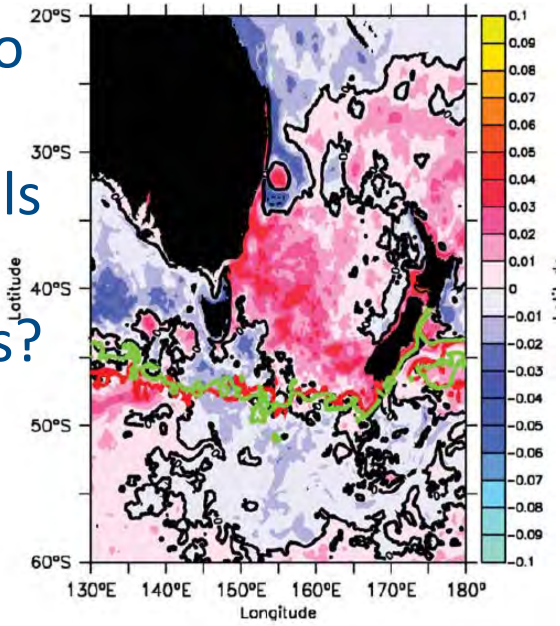
Alantis spatial results

- Differential outcomes across species & stocks (i.e. across space)
- Dependent on human behaviour & decisions (typically exaggerate change, can modify pattern of change)



Conclusions

- Regional climate models give different results to global models
- Care required if using forcing from global models for regional studies (biased productivity)
- Future finely resolved OGCM will overcome this?
- Still need to consider process & structural uncertainty in ecosystem models
- Spatial models also → different results as span several productivity coastal patterns (e.g. east coast Australia vs Great Australian Bight)



CSIRO

Thanks

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