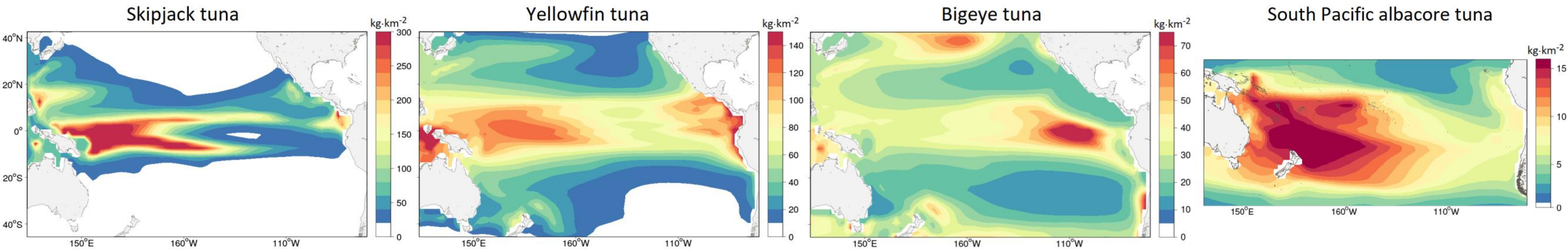
CLIMATE AWARENESS WORKSHOP
WELLINGTON, 19-22 FEBRUARY 2024

Pacific Community
Communauté du Pacifique

Inna Senina, **Pacific Community**

SPATIAL ECOSYSTEM AND POPULATION DYNAMICS MODEL



and modelling of tuna population dynamics

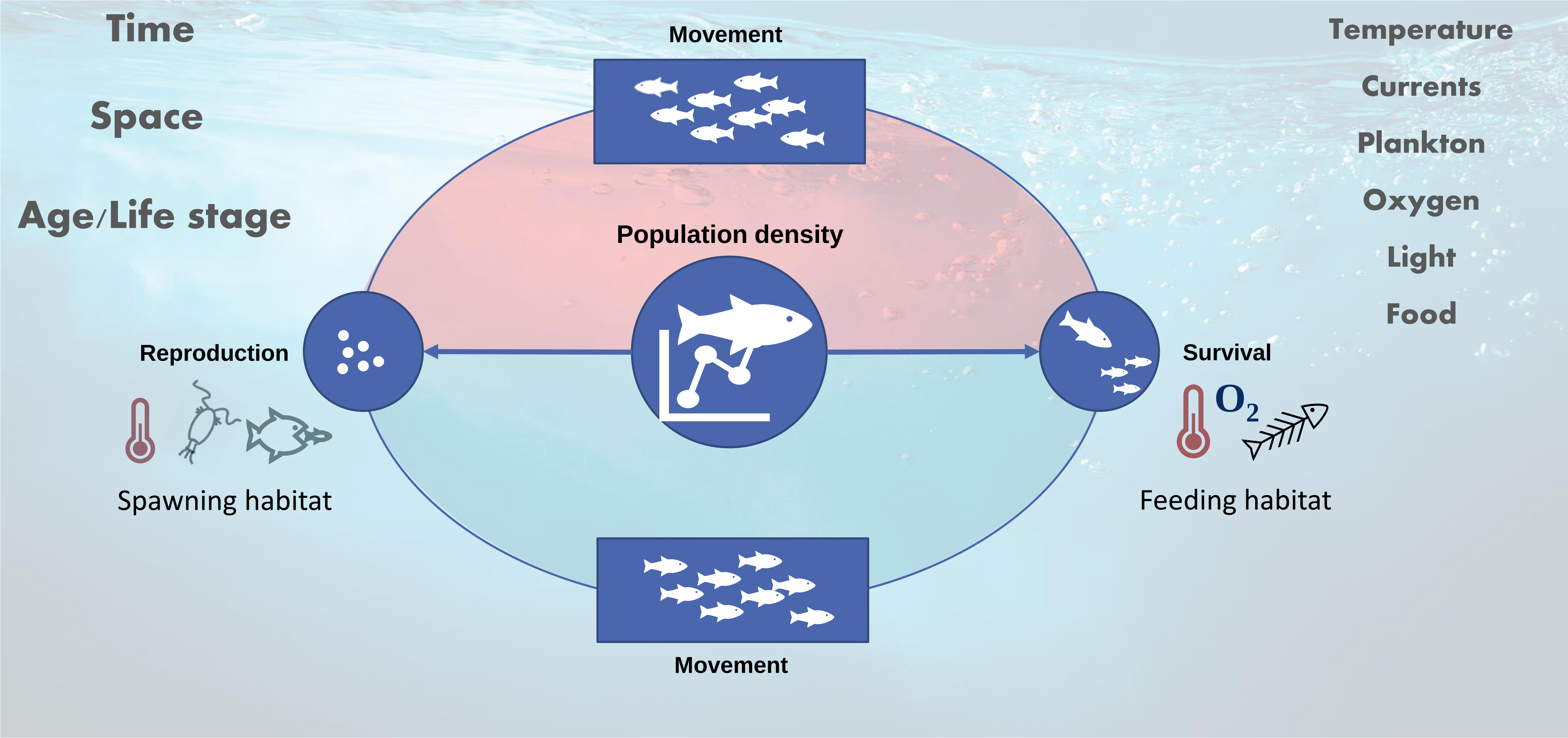
OUTLINE

1. **The Model**
   - How we model tuna habitats, biomass distributions and abundance.
   - Existing uncertainties in modelling of tuna population dynamics.
2. **Learning from Data**
   - How the model estimates tuna habitats, biomass distributions and abundance.
   - Differences among the four target tuna species.
   - Uncertainties in quantitative modelling.
3. **Tuna & Climate Projections**
   - Projected biomass redistributions under climate change and related implications for the Pacific Island Countries and Territories

PART 1. THE MODEL

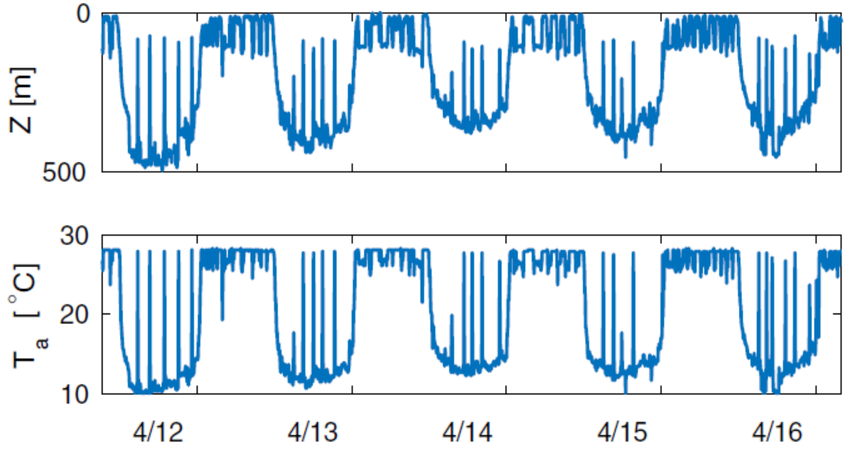
- Simplifying the reality: view of the ecosystem and tuna environment, tuna life cycle, behaviours and population dynamics;
- Modelling habitats and tuna movements;
- Existing uncertainties.

Conceptual model of population dynamics



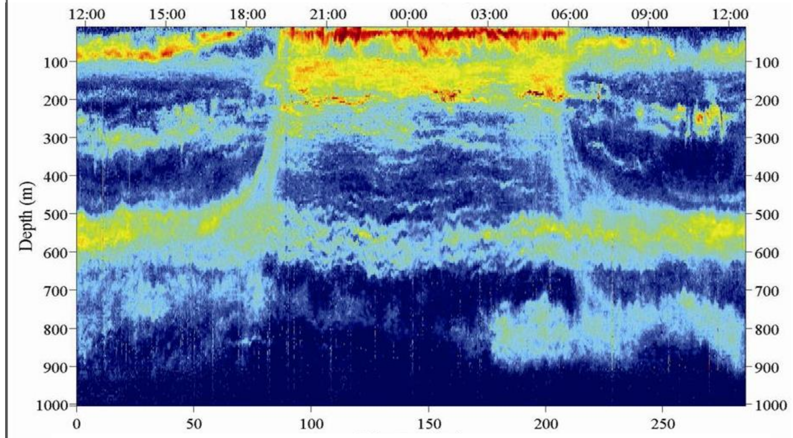
Defining Tuna Environment

Bigeye tuna
(Western Coral Sea, April 2002)



From: Thygesen et al., 2016; Evans et al., 2008

Prey of tuna
(micronekton)

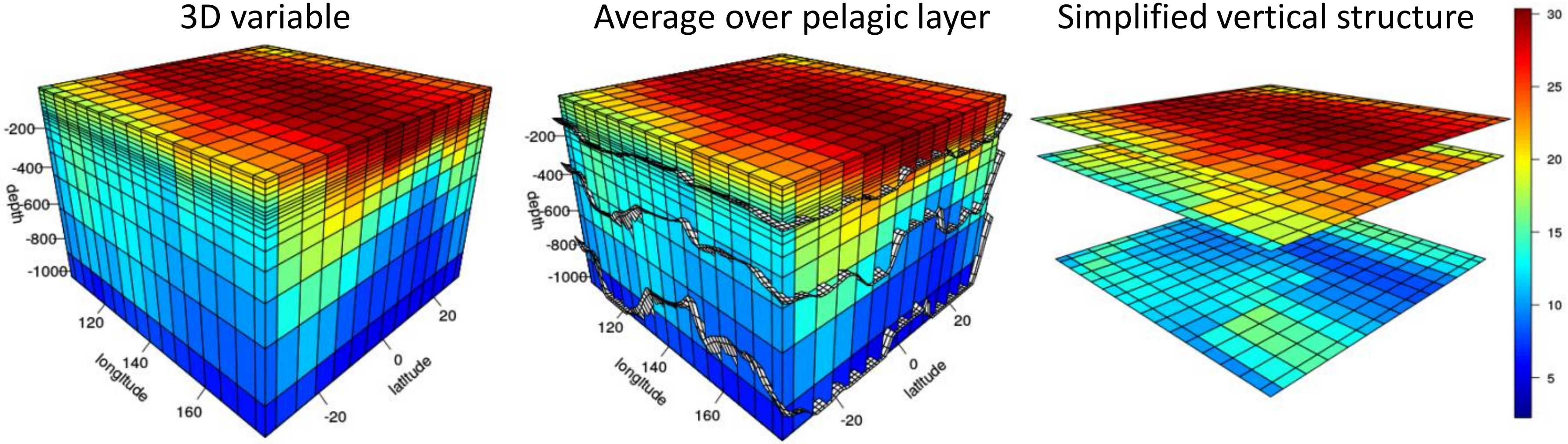


Credit: Réka DOMOKOS (NOAA)

3D variable

Average over pelagic layer

Simplified vertical structure



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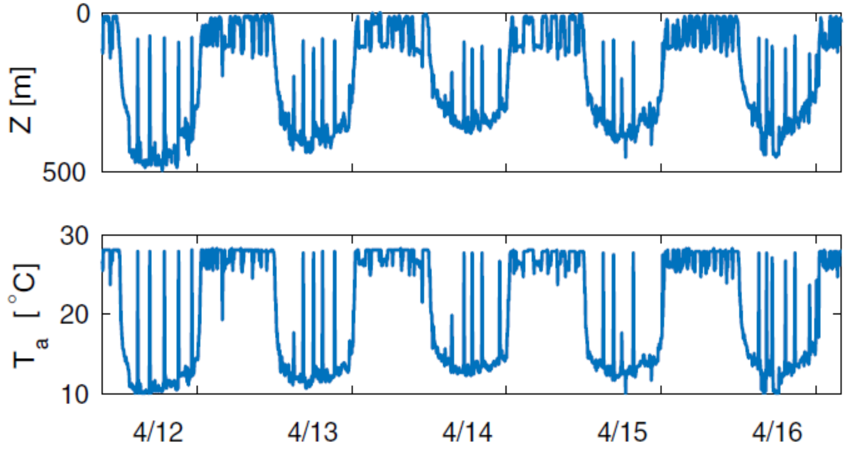

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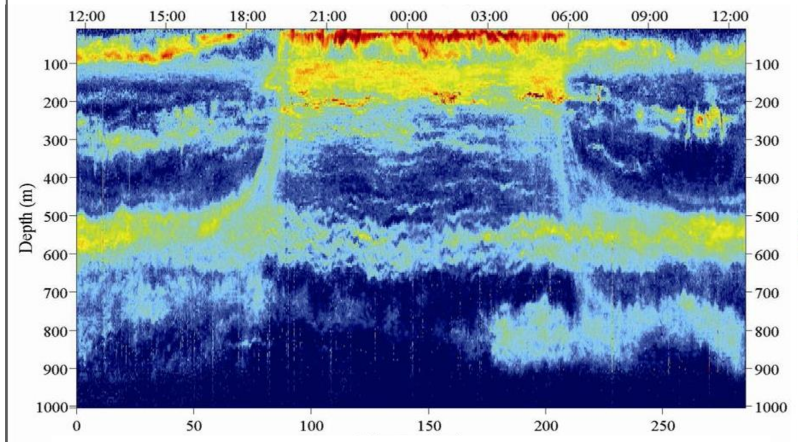
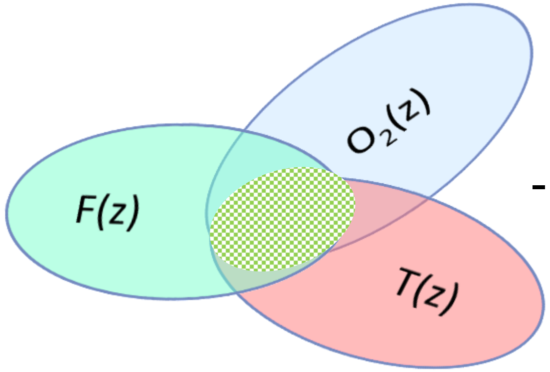


Credit: Réka DOMOKOS (NOAA)

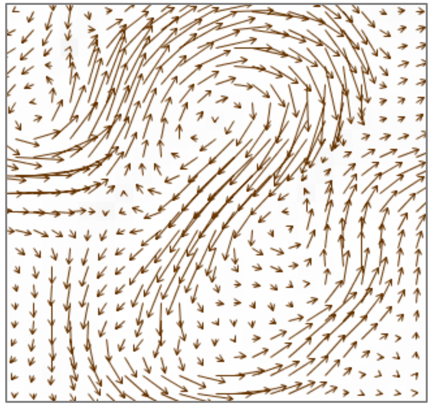


- *Feeding habitat index is* ***accessible micronekton density***

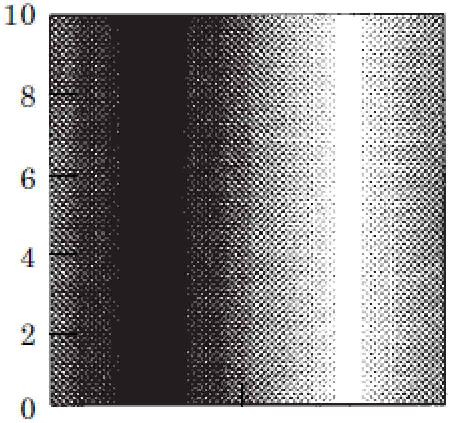
Modelling movement: directional and non-directional

passive	active	
directional		non-directional

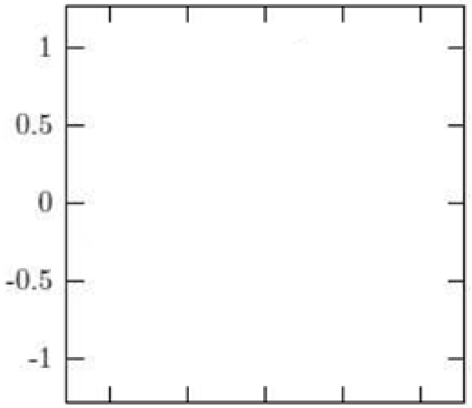
Ocean currents



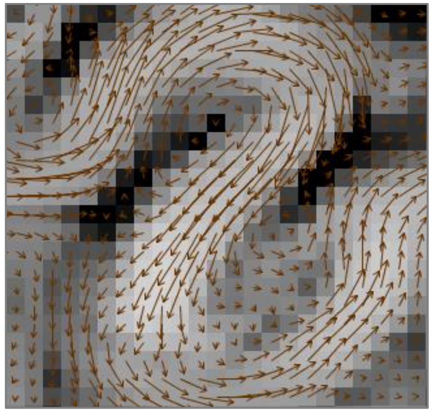
Habitat



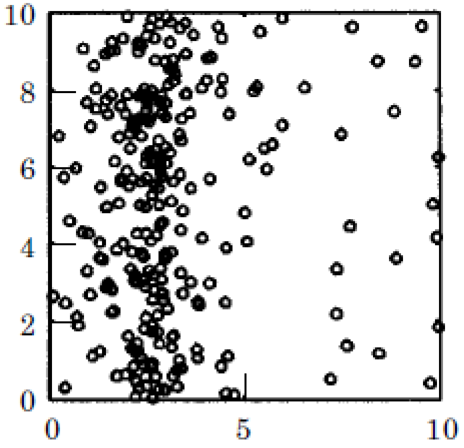
Habitat



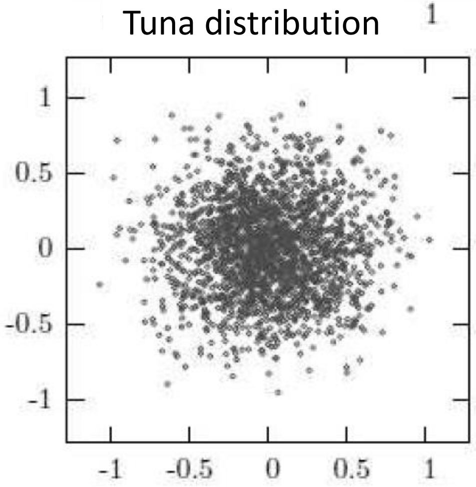
Prey biomass distribution



Tuna distribution



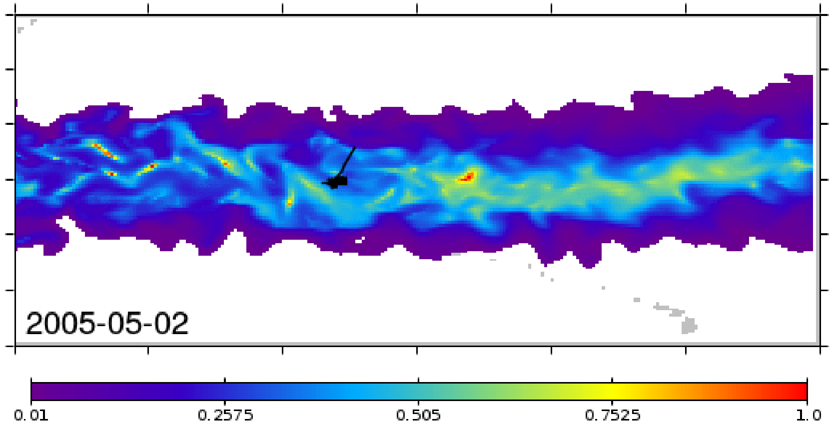
Tuna distribution



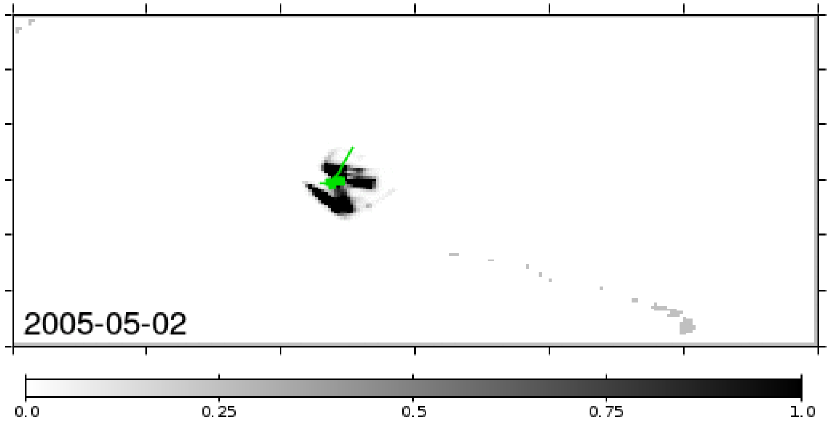
From: Grunbaum, 1999; Flierl et al., 1999; Fougeras et Maury, 2007

Uncertainties associated with the model structure

Feeding habitat



Modelled biomass density



Habitat modeling from Abecassis et al., 2013

Uncertainties

1. **Tuna environment**
    1. **Definition**
    2. **Quantitative power**
2. **Simplifications**
    1. **Dimensions**
    2. **No regional growth differences**
3. **Functional relationships**
4. **Spatio-temporal resolutions**
5. **Numerical method**

PART 2. LEARNING FROM DATA

- Parameter estimation and abundance estimation;
- Differences among the four target tuna species;
- Uncertainties.

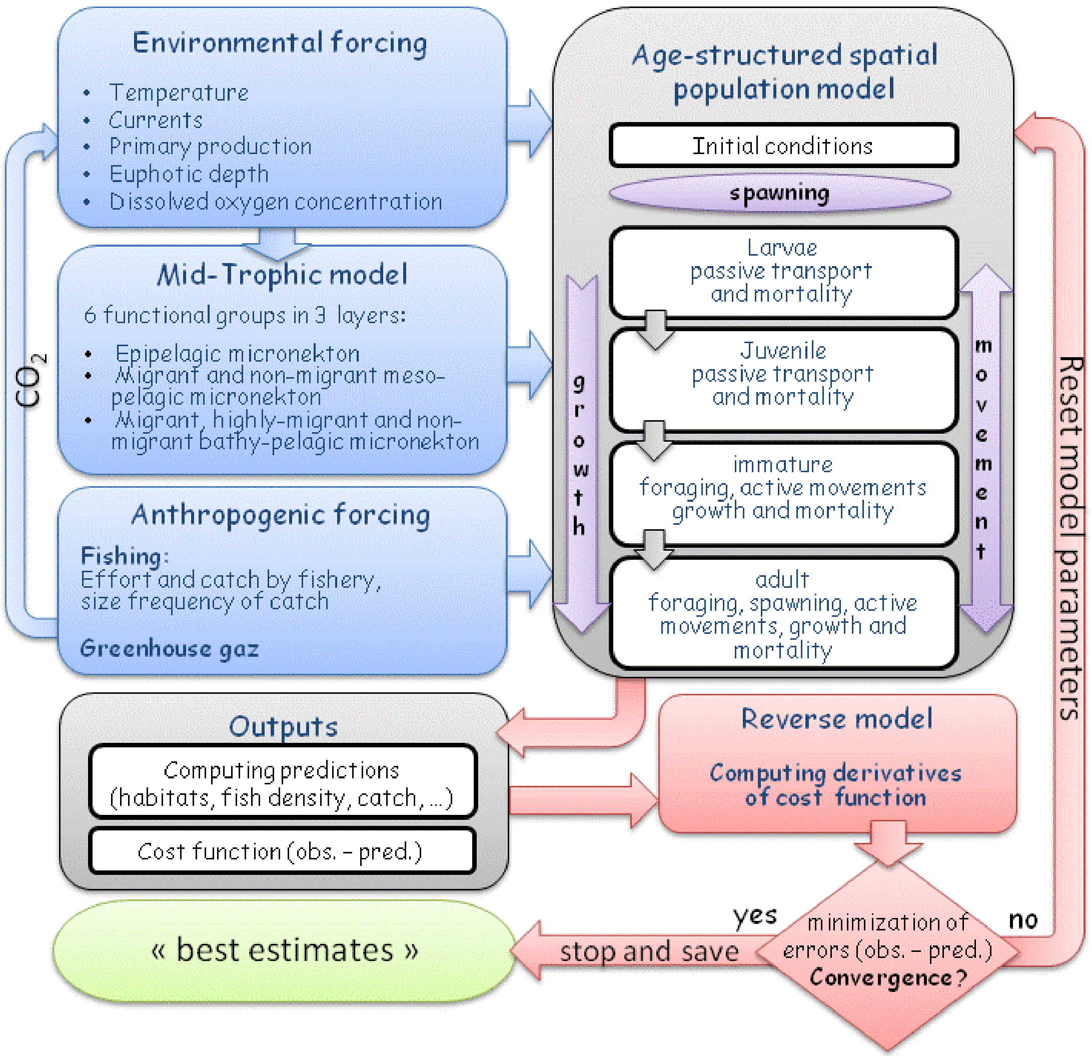
Data inform modelled processes

What we need to estimate:

1. Reproduction rate
2. Mortality rates, including fishing mortality
3. Habitats: spawning (temperature, food, predators) + feeding (preferred temperature, accessibility to prey organisms)
4. Movement rates (excluding transport with ocean currents)
5. Abundance in space (spatial distributions) and time
6. #2-5 along the species life span

Sources of data:

1. Industrial fishing: effort, catch, length-at-catch
2. Scientific campaigns: archival and conventional tagging data; larval survey data



Data inform modelled processes

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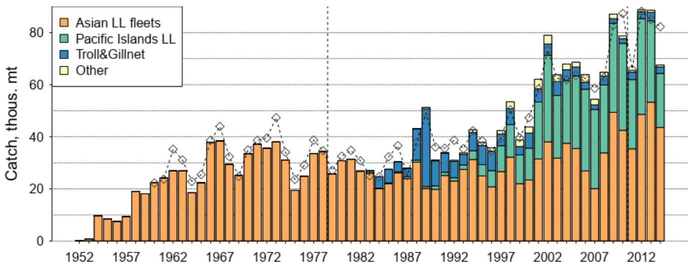
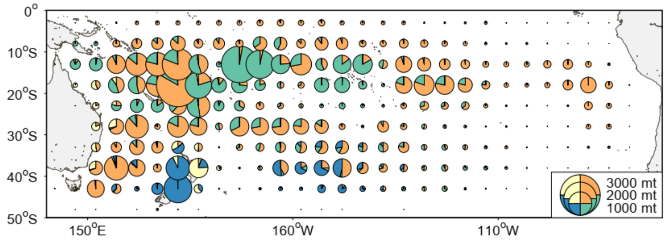
Industrial fishing (example - albacore)

Scientific campaigns (skipjack)

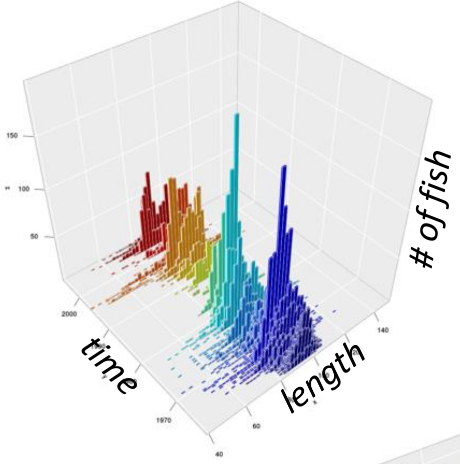
1 - Catch (and effort) data:





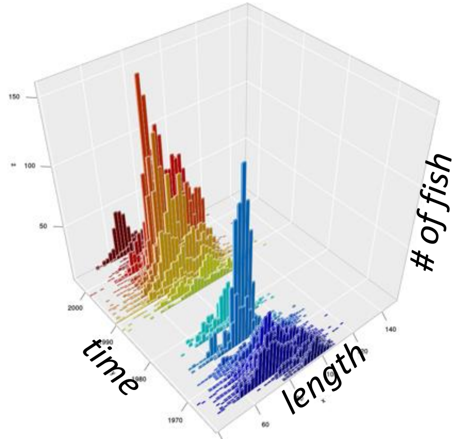
Poor: abundance, natural and fishing mortality
Bad: spatial distributions, habitats and movements, spawning sites

2 - Length data:



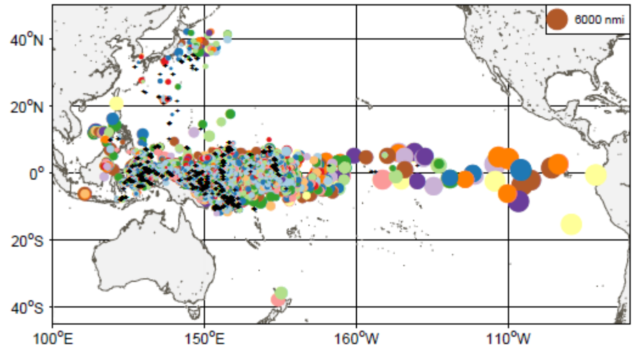
LL north of 25S

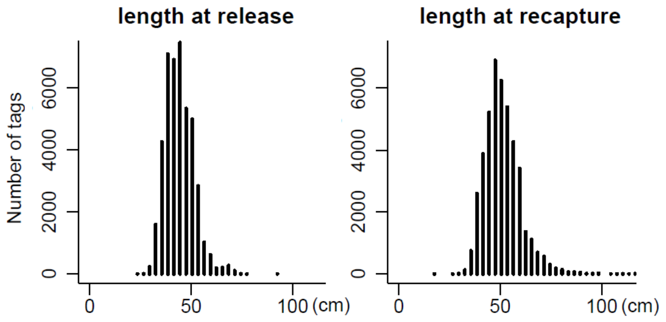
LL south of 25S



Catch + Length
Good: reproduction and mortality rates, spatial extent
Poor: spatial distributions and movements

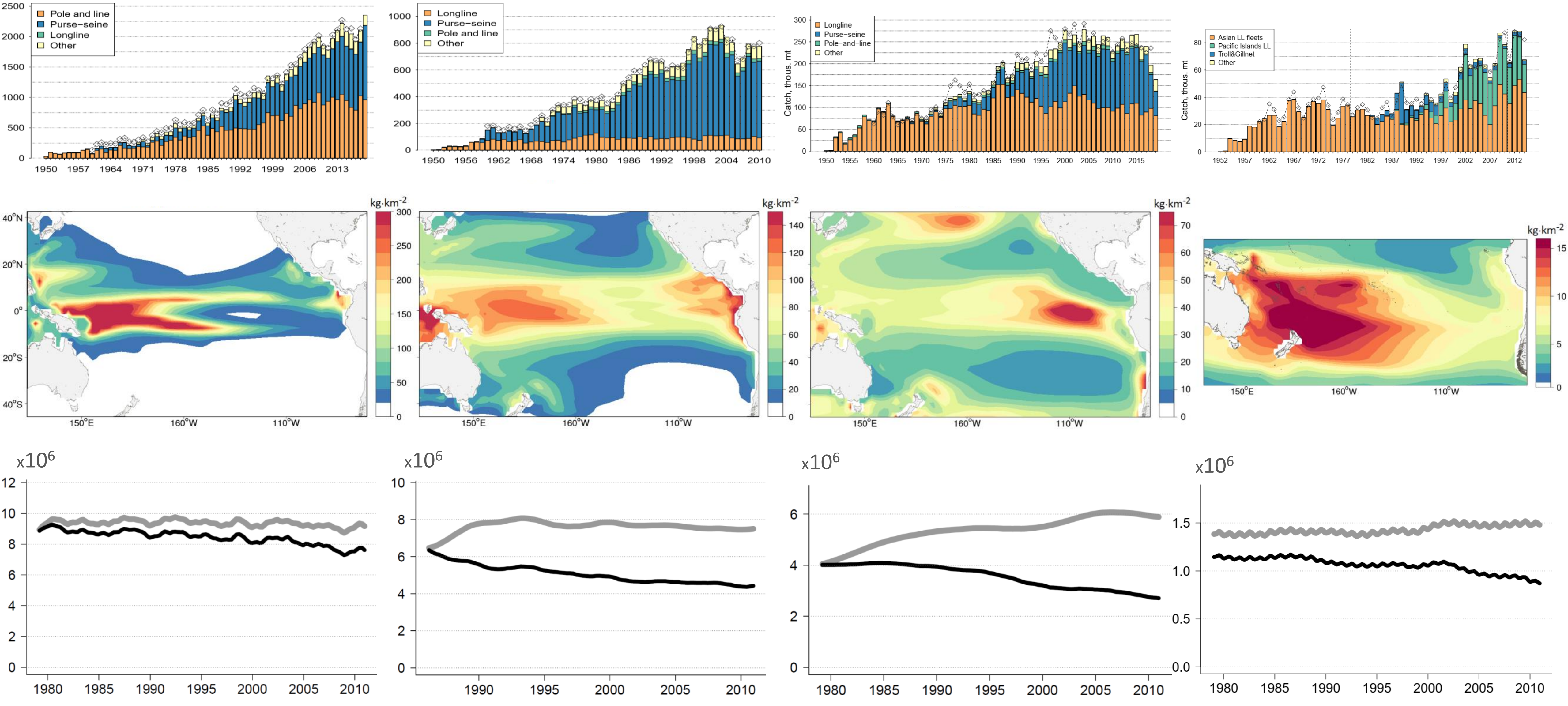
3 – Conventional tagging data:



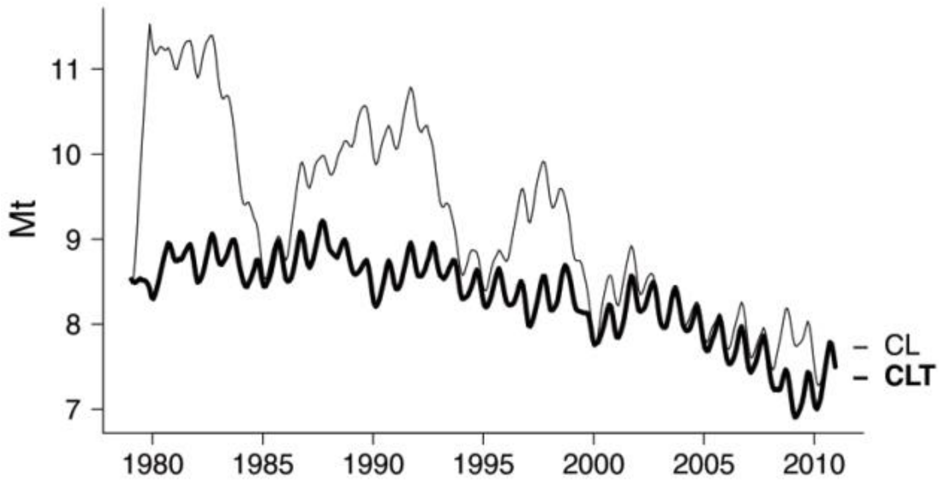


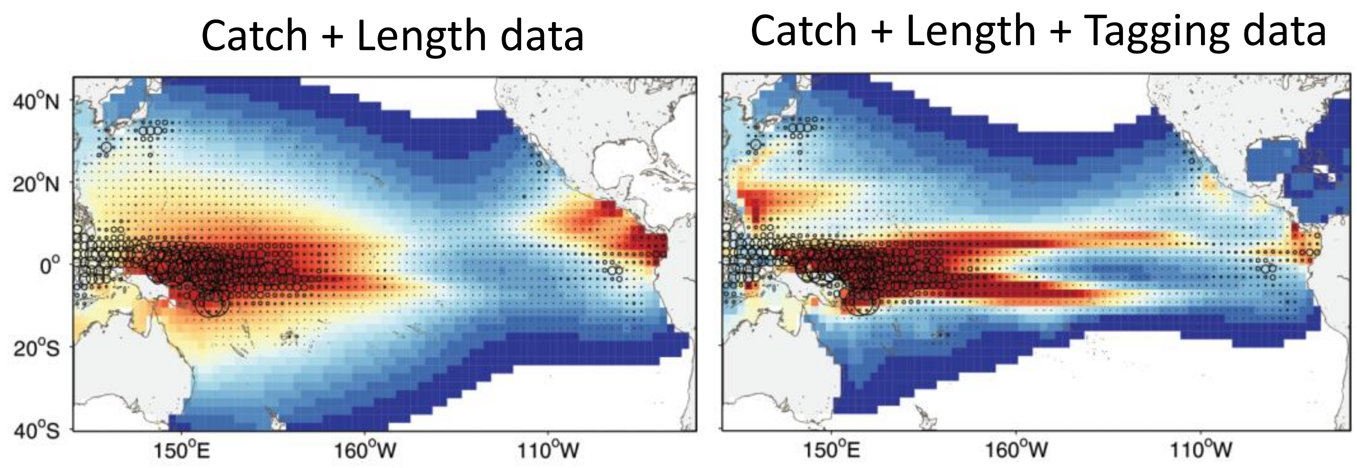
Good: habitats, movement rates, spatial distribution

Differences among the four target tuna species



Uncertainties in quantitative modelling





1-5. **Tuna model structural uncertainties;**

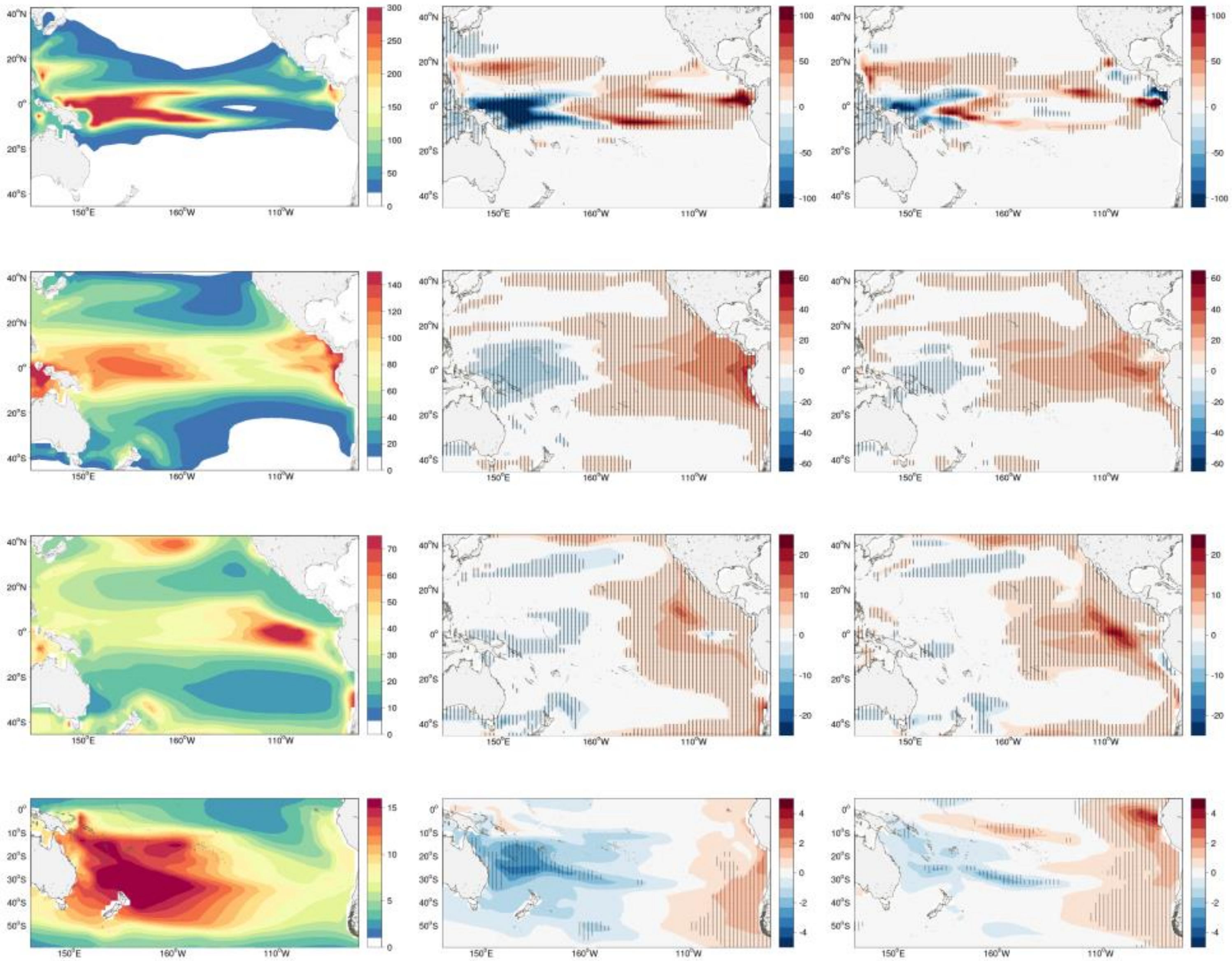
6. **Parameter estimation sensitivity to**
   1. **data (fisheries) structures and errors in the data**
   2. **ocean forcings (*as fixed parameters*) and their biases**
   3. **data coverage / parameter observability from data**
   4. **time window selection**
   5. **model resolution**

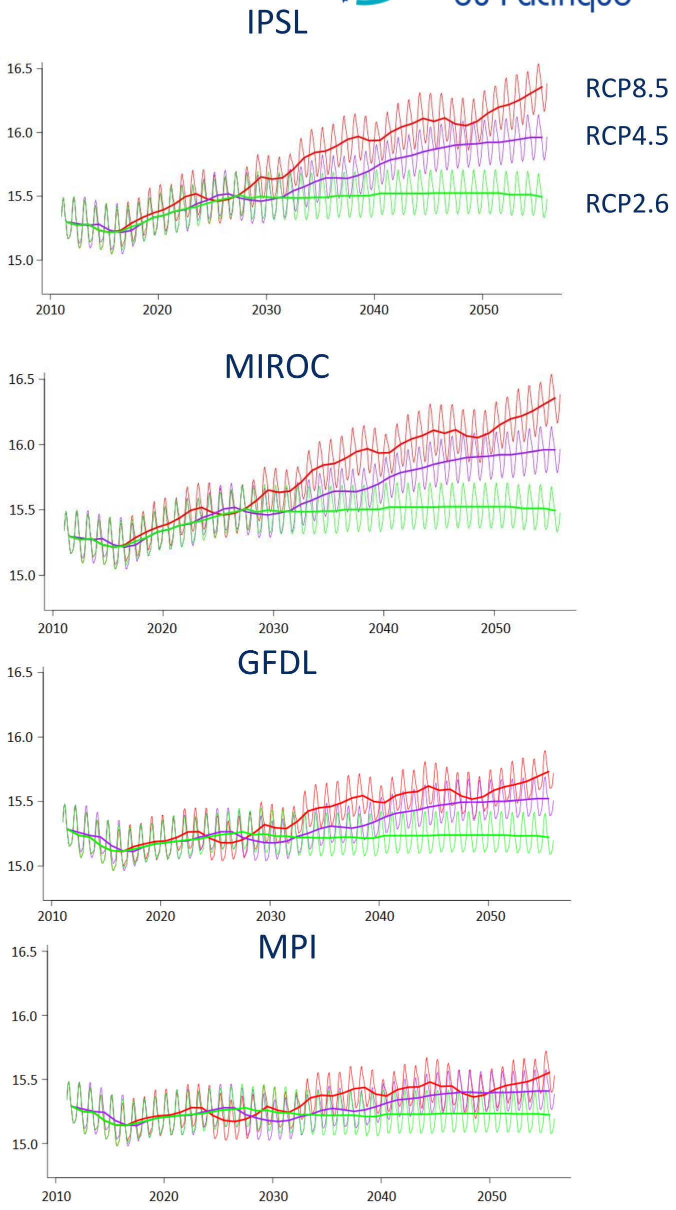
PART 3. **TUNA & CLIMATE PROJECTIONS**

- Projected biomass and spatial redistributions;
- Implications for the Pacific Island Countries and Territories;
- Uncertainties in biomass projections.

Tuna projections under global warming with RCP8.5 and RCP4.5

2011-2020 | RCP 8.5 2050 | RCP 4.5 2050





Predicted impacts on biomass and PS catches

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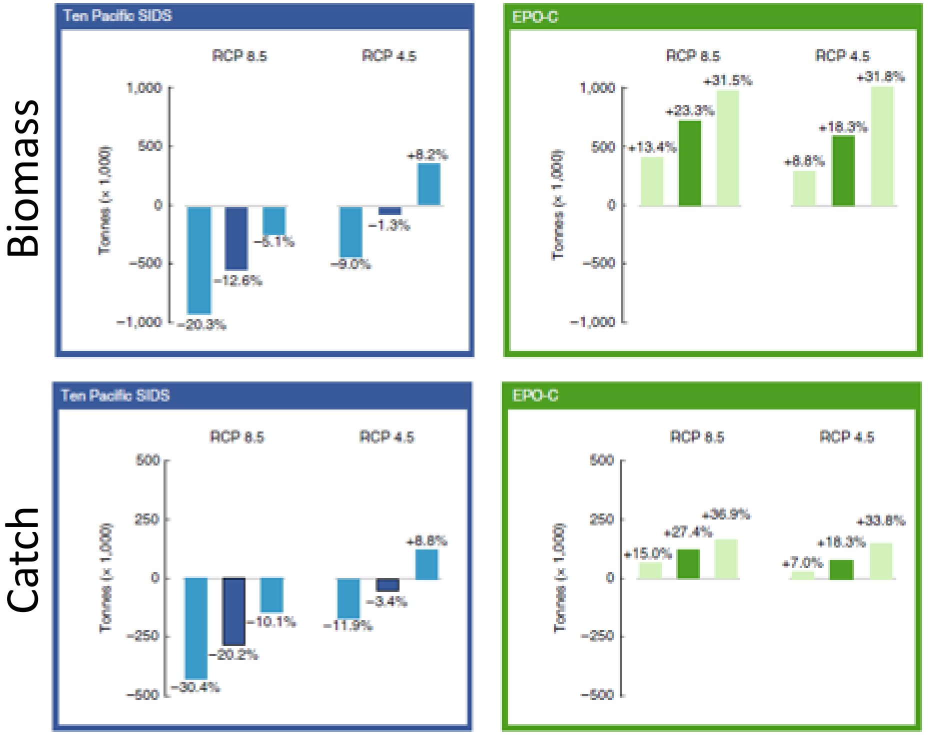
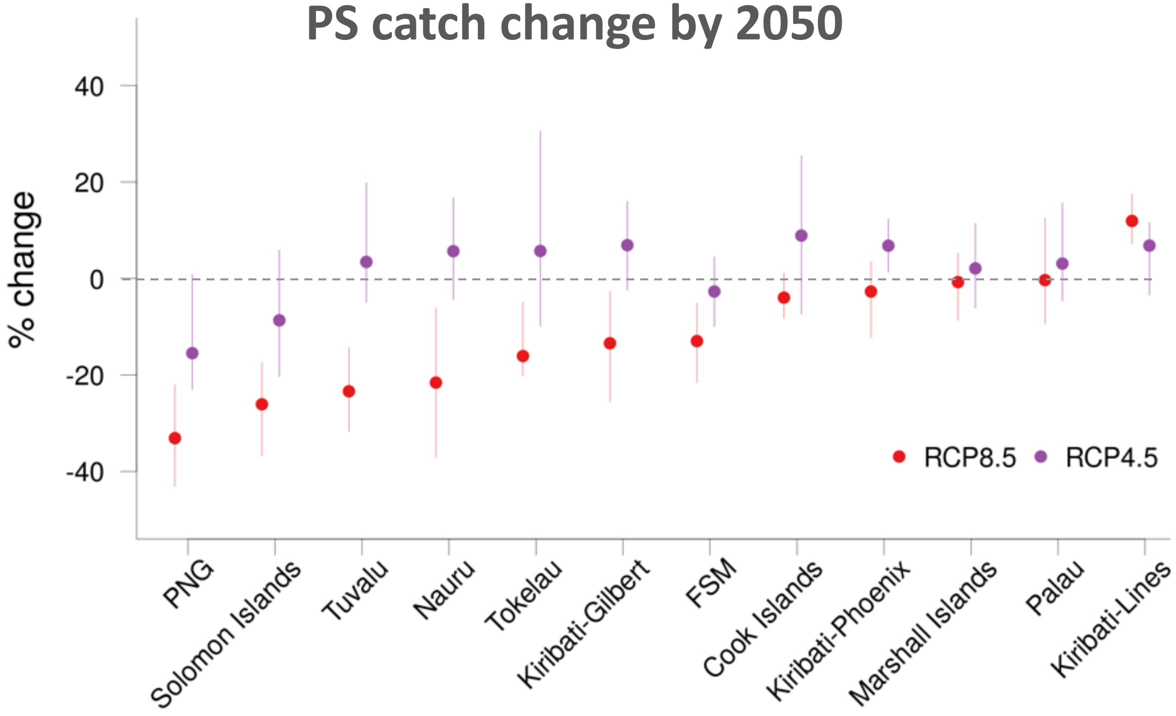


From: Bell et al., 2021

Biomass change by 2050

	RCP 8.5	RCP 4.5
10 SIDS	-13%	-1%
EPO	+23%	+18%

PS catch change by 2050



Tuna projections under global warming with RCP8.5 and RCP4.5

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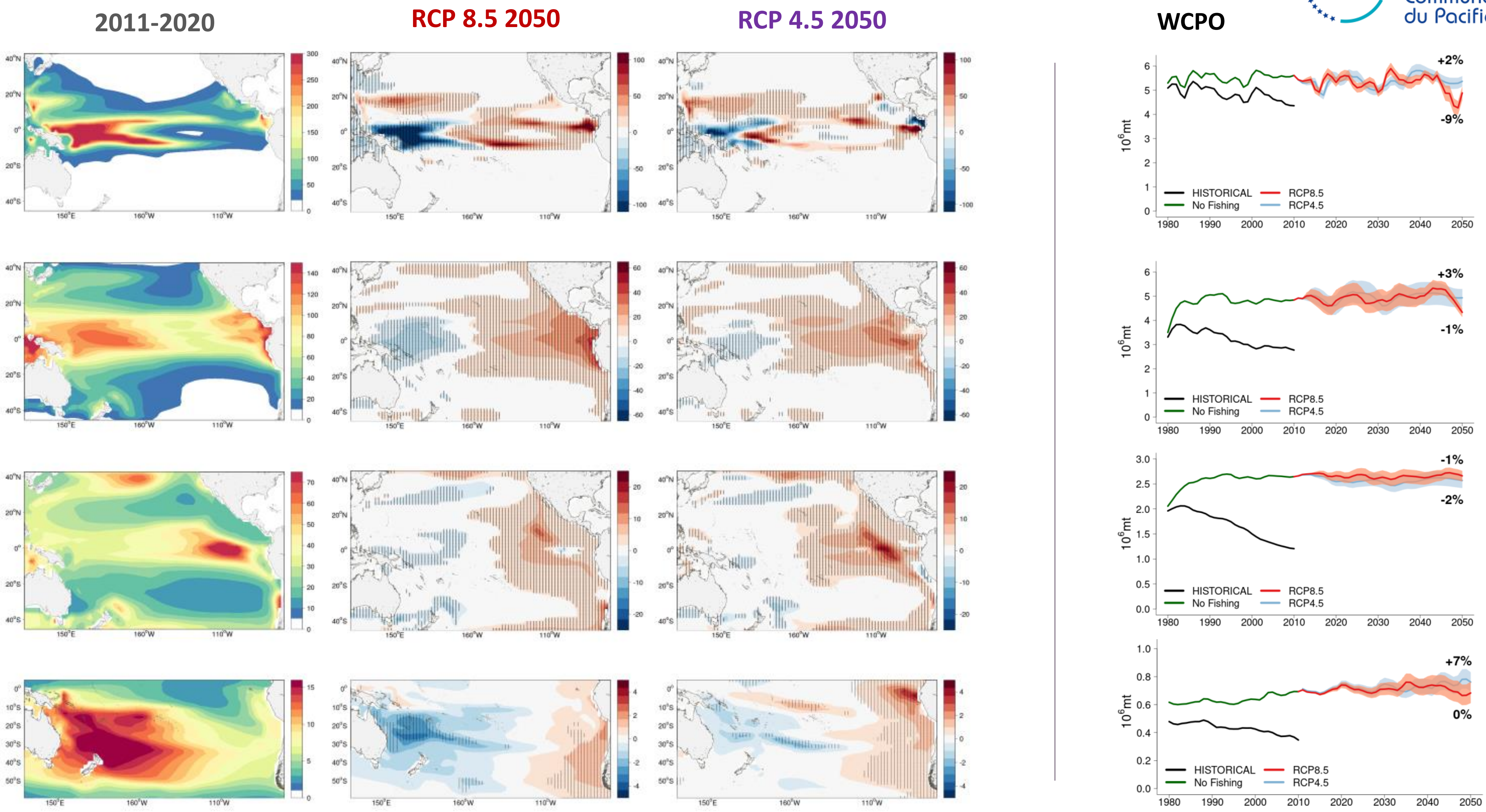
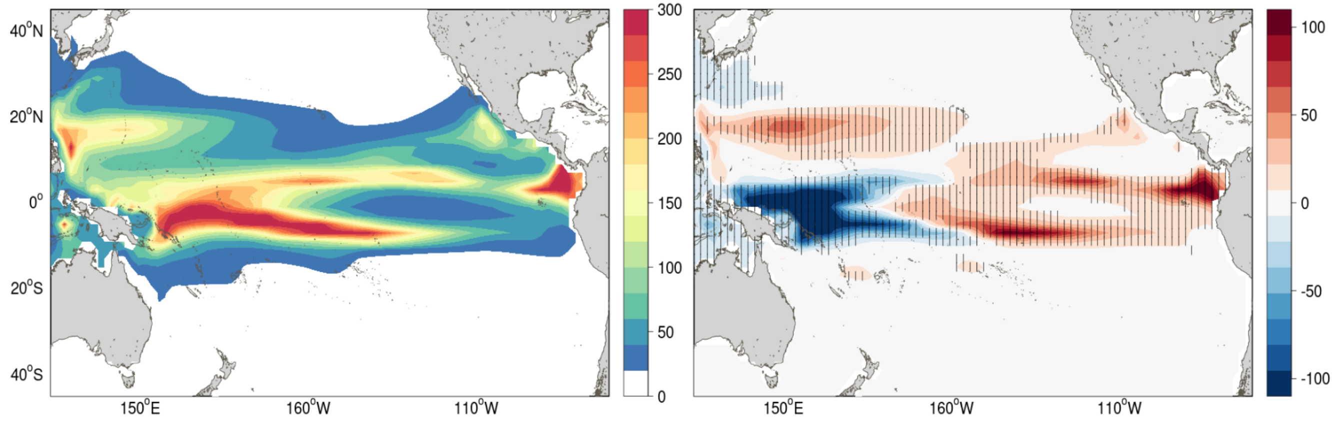
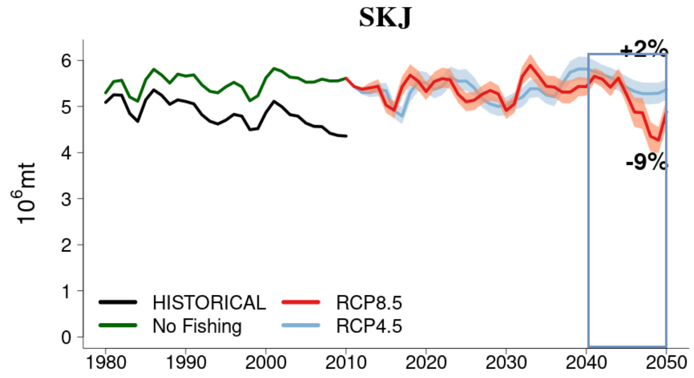
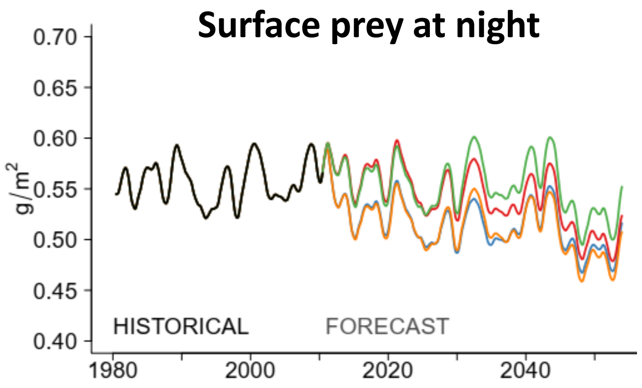


Results and uncertainties in climate projections

2050







1-6. **Tuna model biases**

7. **RCP/SSP scenarios**

8. **Earth System Model biases**

9. **Modelling design (warming, bias correction etc.)**

Conclusions

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- Despite of model uncertainties, agreement between different models on distributional shifts suggests that it’s not a question of ‘IF’ the tuna biomass will shift due to climate change from the Pacific SIDS EEZs, but ‘WHEN’ and ‘TO WHAT EXTENT’.

- Moderate redistributions of tuna under a lower-emissions scenario indicates that reductions in greenhouse gas emissions, in line with the Paris Agreement, would provide a pathway to sustainability for tuna-dependent Pacific Island economies.

- Quantitative (Predictive) modeling of fish populations dynamics requires data to observe all modelled dynamic processes and realistic description of tuna environment on historical, decadal and climate timescales.

- Ongoing and future work is dedicated to reducing uncertainties linked to the model structure and parameter estimation, and to providing better quantification of uncertainties related to climate modelling.