Updated climate change impacts on WCPFC tuna stocks

Fisheries, Aquaculture & Marine Ecosystems Division,
Pacific Community

Pacific Community
Communauté du Pacifique

Acknowledging

NEW ZEALAND FOREIGN AFFAIRS & TRADE Aid Programme	2021-2025	USD3.7 M
FAO, Conservation International, gef	2022-2026	USD0.9M
PEUMP Pacific-European Union Marine Partnership Programme	2018-2024	USD0.8M
Western and Central Pacific Fisheries Commission	2021-2026	USD0.1M
Australian Government Department of Foreign Affairs and Trade	2022-2025	USD1.5M
GREEN CLIMATE FUND	2025-2026	USD0.5M

Outline

- Tools for linking tuna, climate and climate change
  - SEAPODYM
  - Corrected Earth System Models (CMIP6)
  - Global warming levels & IPCC scenario
- Impacts of climate and climate change today
  - Oceanography
  - Skipjack Tuna
- Projected impacts of climate change
- Next steps

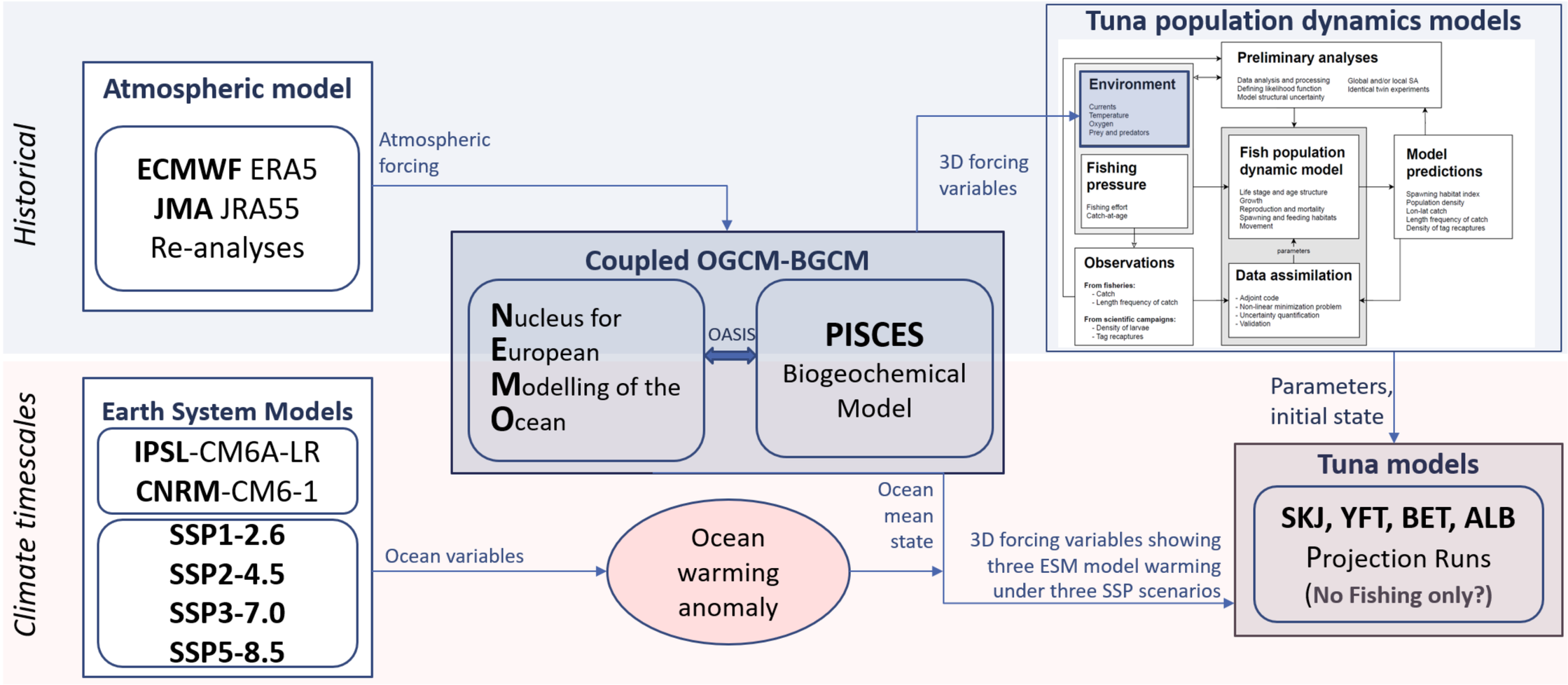
Global warming levels & IPCC scenario

Radiative Forcing (W/m^2)	AR5 Scenario (Baseline)	AR6 Scenario (Current)	GHG Trend	Mean Warming (AR5/CMIP5)	Mean Warming (AR6/CMIP6)
2.6	**RCP 2.6**	**SSP1-2.6***	Peaks ~2020, then declines	**1.0°C**	**1.8°C**
4.5	**RCP 4.5***	**SSP2-4.5***	Plateau ~2050	**1.8°C**	**2.7°C**
6.0	**RCP 6.0**	**(SSP4-6.0)**	Stabilization post-2060	**2.2°C**	**~3.0°C**
7.0	*(None)*	**SSP3-7.0***	High / Continuous growth	*(N/A)*	**3.6°C**
8.5	**RCP 8.5***	**SSP5-8.5***	Very High / Triple by 2100	**3.7°C**	**4.4°C**

*Scenarios used in our modelling ensembles

Sources:
AR5: **IPCC, 2013:** *Climate Change 2013: The Physical Science Basis.* **Table SPM.2**
AR6: **IPCC, 2021:** *Climate Change 2021: The Physical Science Basis.* **Table SPM.1**

SEAPODYM Framework



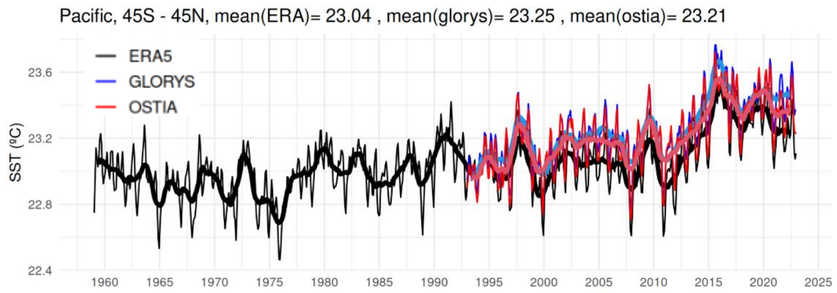
Coupled OGCM-BGCH hindcast

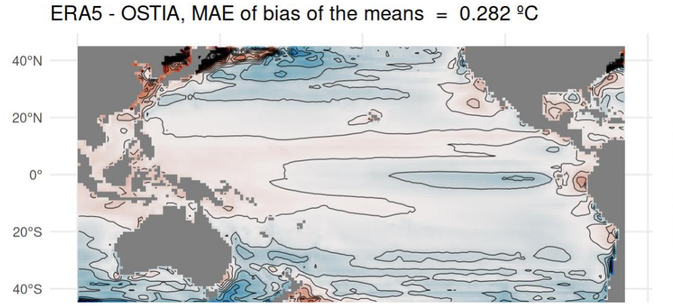
- Both coupled models reconstruct correctly SST in 10S-10N (MAE<0.1C).
- Both models show correct interannual (including ENSO) and decadal variability.
- *Biases*: ERA5 has cold bias in the South Pacific Ocean; both models have positive sub-surface bias in warm-pool and cold bias in the mesopelagic layer (ERA5: persistent -0.6C, -0.5C, JRA55 – local biases, none for 45S-45N average in the epipelagic and mesopelagic layers); models show different spatial patterns of SST and sub-surface temperature biases

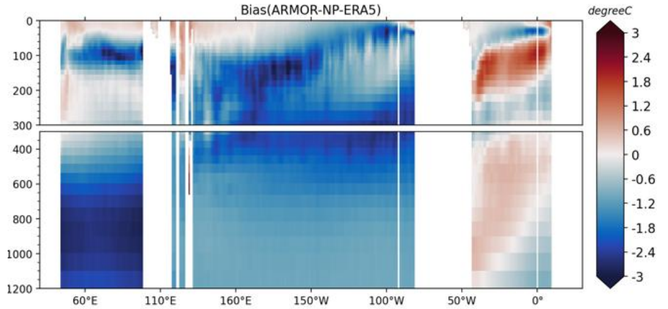
Sea Surface Temperature

Sub-surface temperature

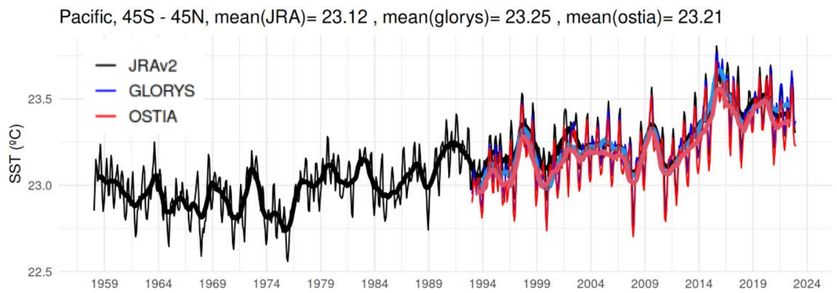
ERA5

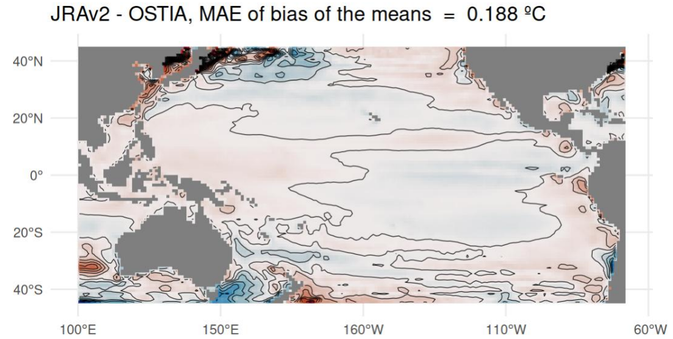


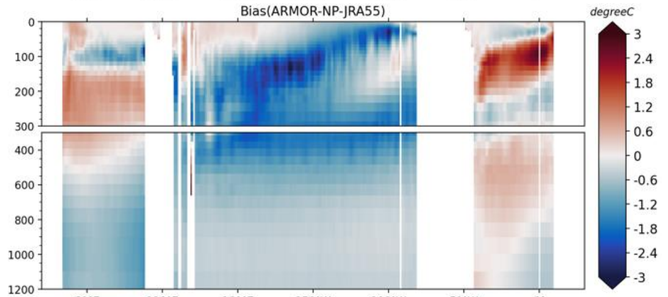




JRA55







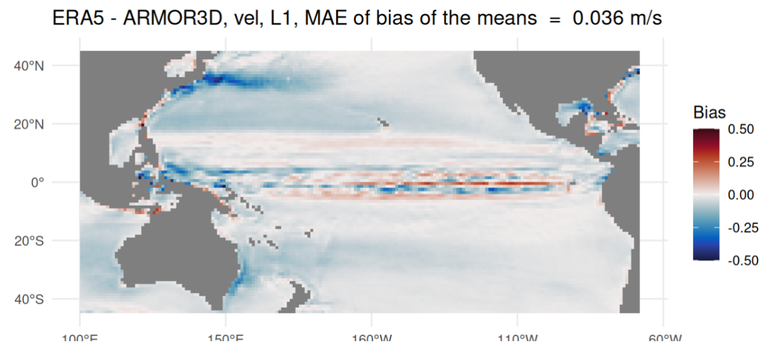
Credits: SST figures by Melanie Abecassis (CI), sub-surface temperature by Karen Guihou (MOi)

Coupled OGCM-BGCH hindcast

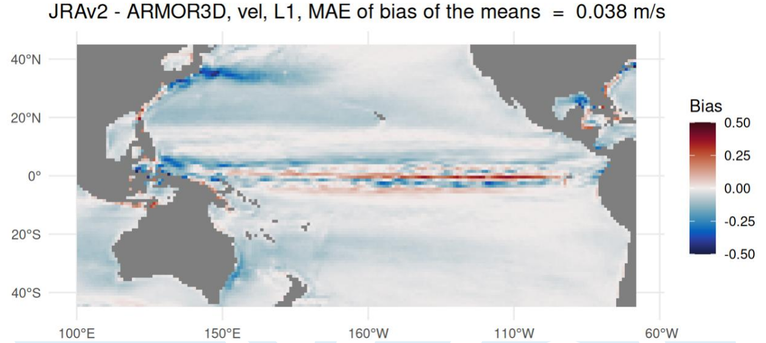
- Both models validated against ARMOR3D overestimate major zonal Equatorial currents and systematically underestimate velocities in highly energetic Kurishio Extension.
- Both simulations overestimate Chl-a and PP in the equatorial EPO as a result of excessive equatorial upwelling due to biases in the equatorial circulation.
- Both models overestimate PP along the equator (5S-5N) but underestimate it in the sub-tropical gyres.

Current velocity in epipelagic layer

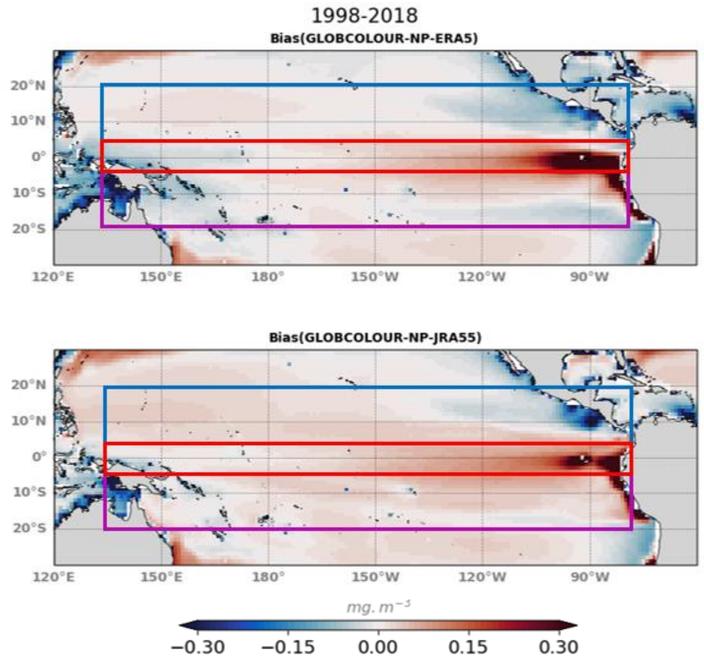
ERA5



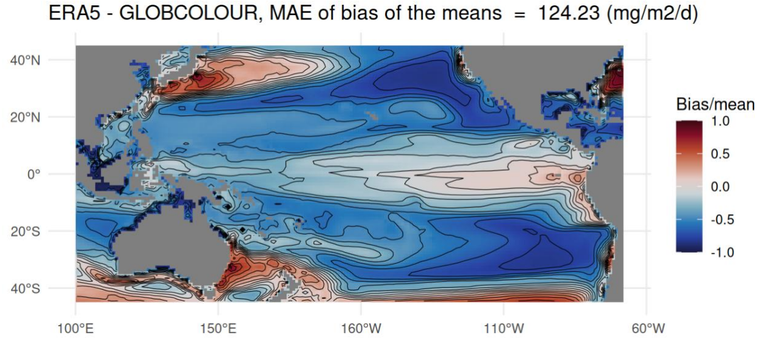
JRA55

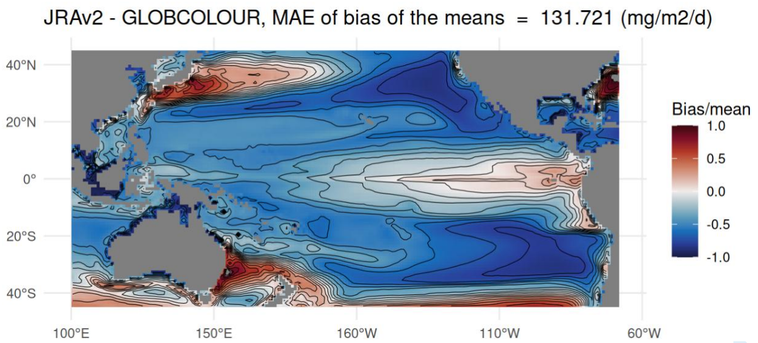


Chlorophyll



Primary production



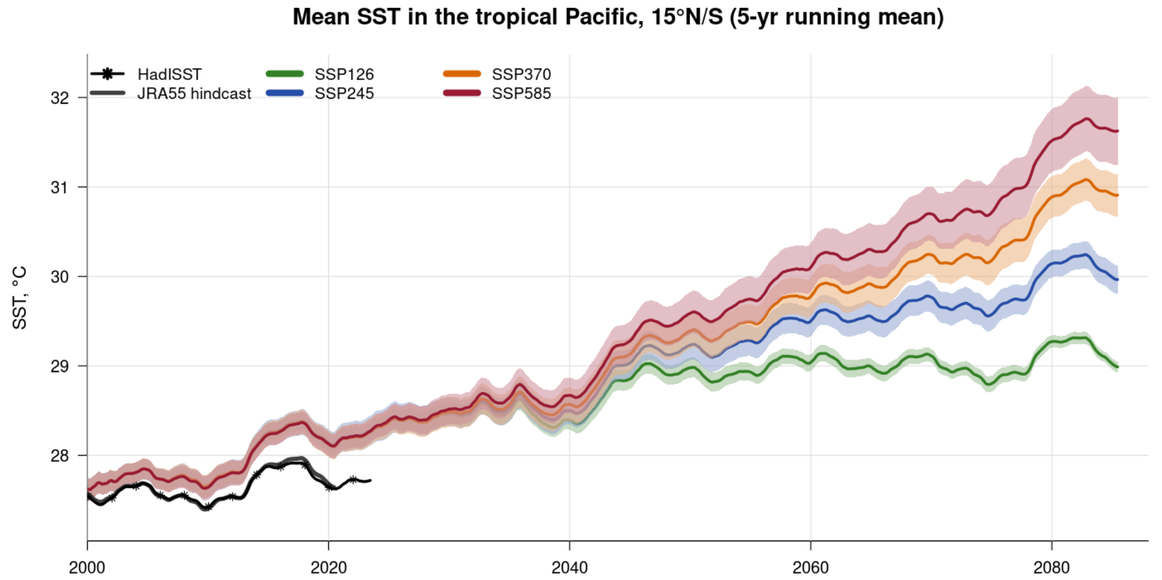


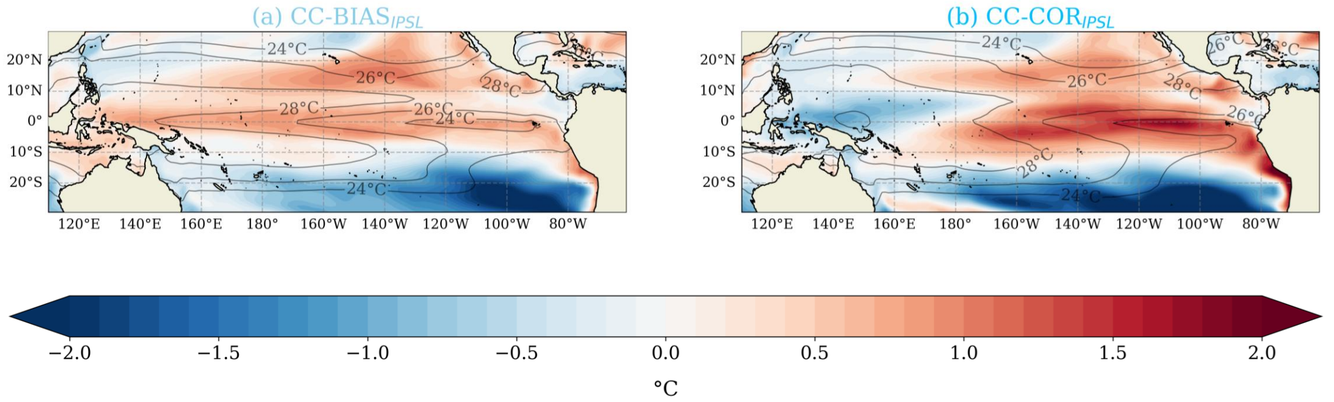
Credits: V and PP figures by Melanie Abecassis (CI), Chl-a by Karen Guihou (MOi)

ESM Ensemble and Bias Correction

- Two CMIP6 models and four SSPs for projection
- Bias correction
  - Mean state of hindcast simulation
  - Retention of seasonal & decadal variability
  - Smooth transition at the projection origin
  - Preserving the ESM warming trend

$$Q_i(t) = Qe(t) - Te(t) + Tc_i(t) + C$$

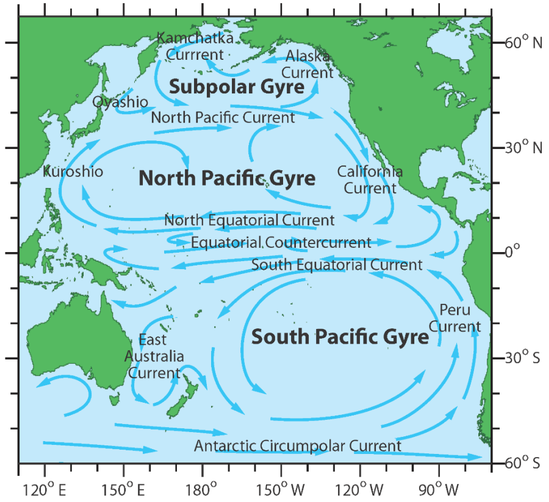


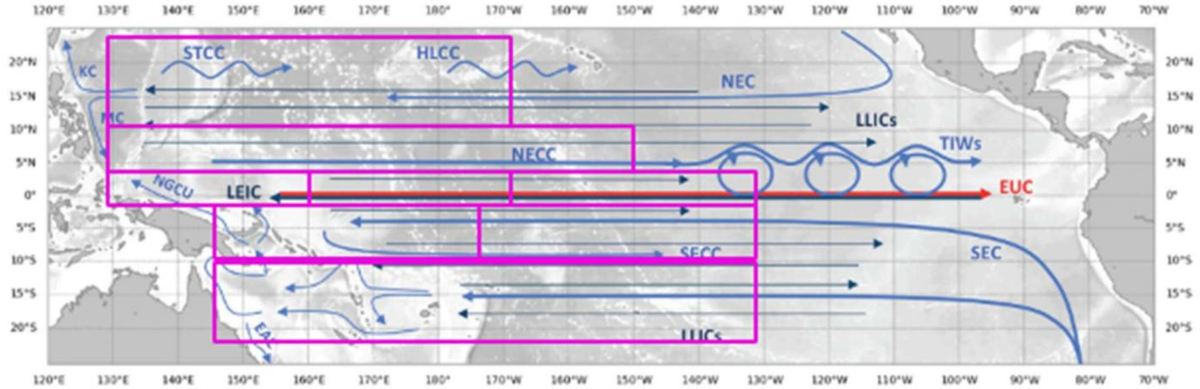


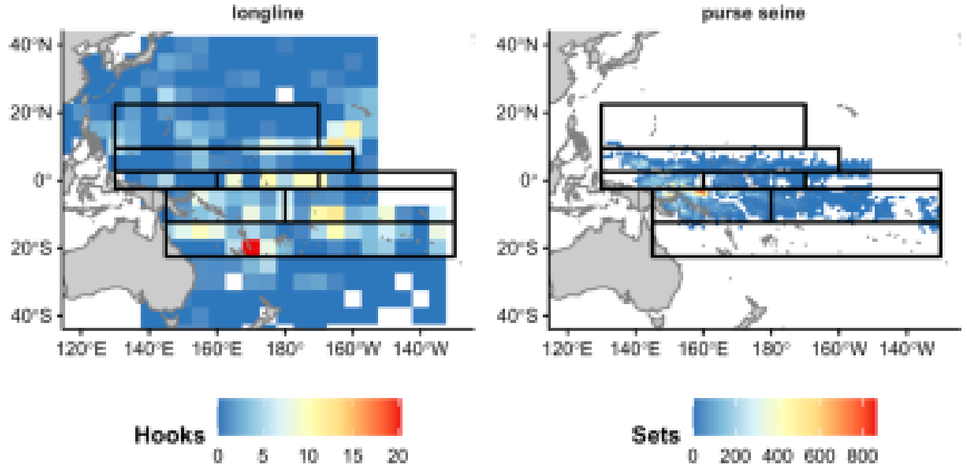
Impacts of Climate and Climate Change: *Ocean Climate Reporting*

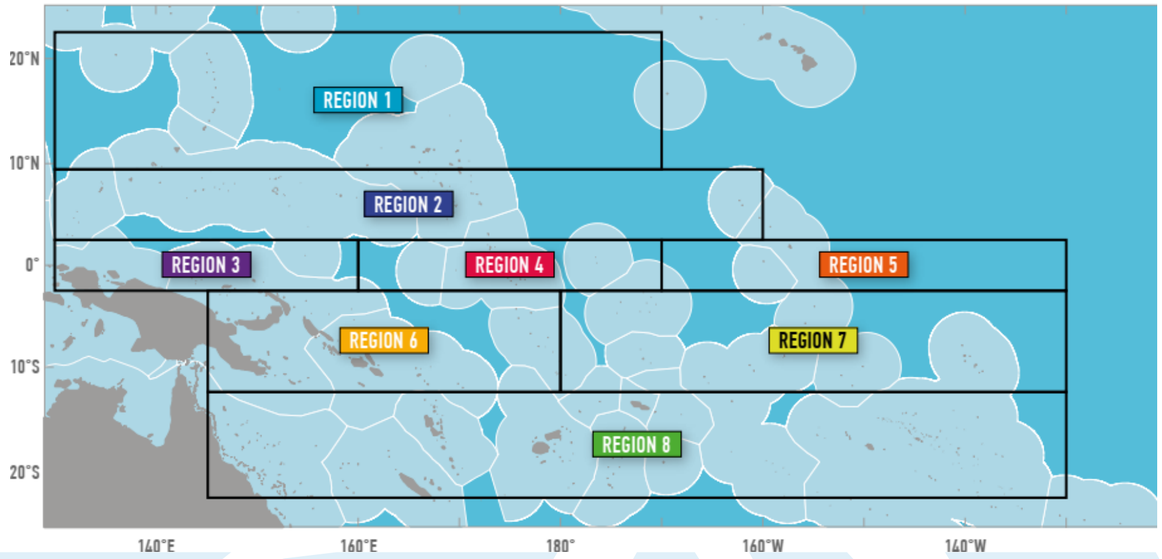
- Indicators of ocean state provide managers and industry with context for observed changes in fishery performance and ecosystem conditions.
    - Provide a mechanism to monitor and quantify environmental variability and change more explicitly and consistently.
- Regional delineation that capture oceanographic and climate processes
    - Considering the WCPO as a single homogeneous region masks inter-annual variability and climate change signals.
    - For example, off-equatorial regions exhibit warming in SST and increased OHC, whereas equatorial regions are dominated by ENSO-driven interannual variability.
- Integrates observed data rather than model inferred output
    - Reanalysis products

Ocean Climate Reporting



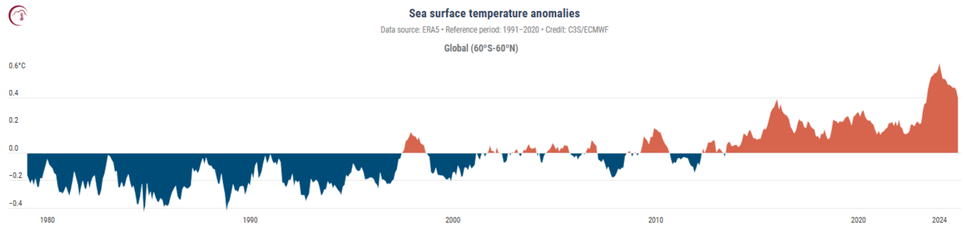


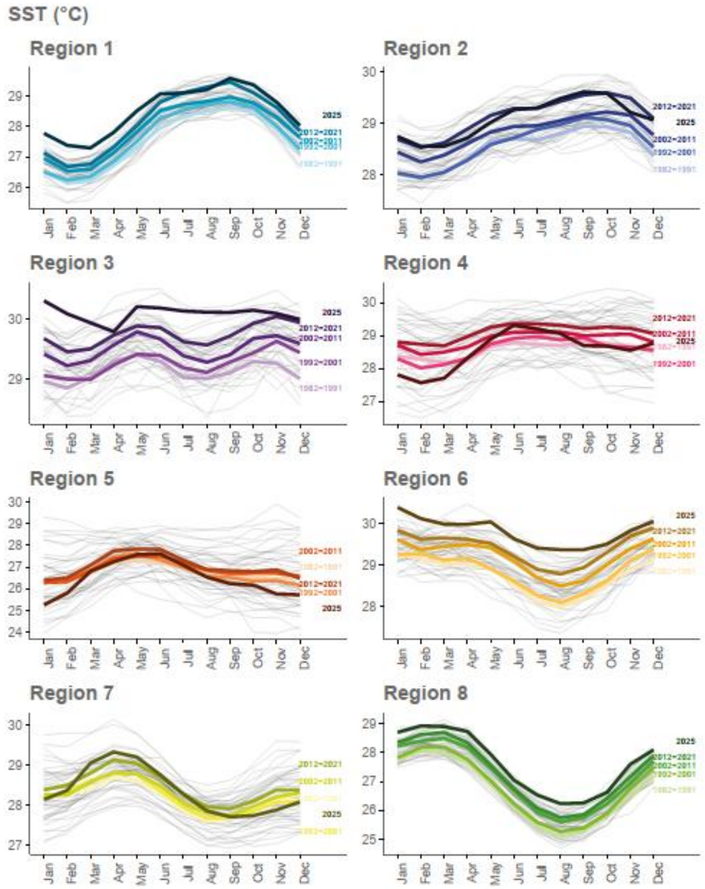


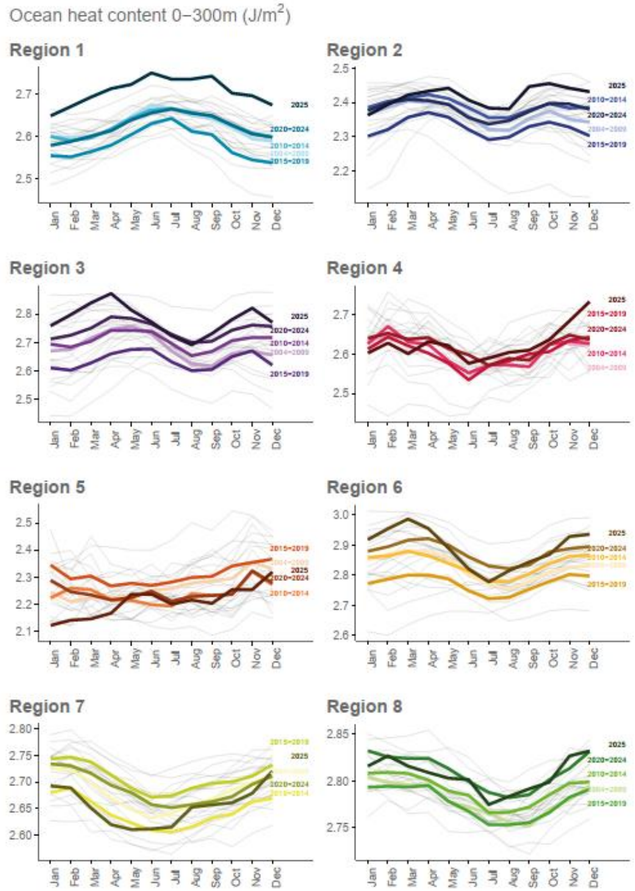


Ocean Temperatures

- Off-equatorial regions exhibit consistent SST warming.
- Increasing OHC patterns in northern Pacific.
- Equatorial regions are dominated by ENSO-driven interannual variability.
- 2025 ranked among the warmest years on record in off-equatorial regions, whereas equatorial regions remained close to their long-term average, consistent with the prevailing neutral ENSO conditions.
- Global SST anomalies exhibit warming for the last decade.

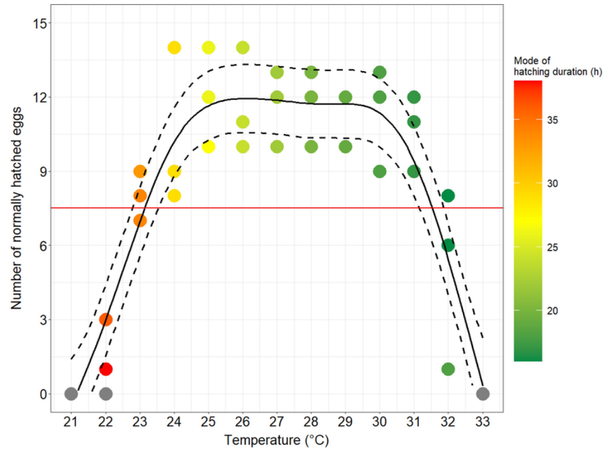




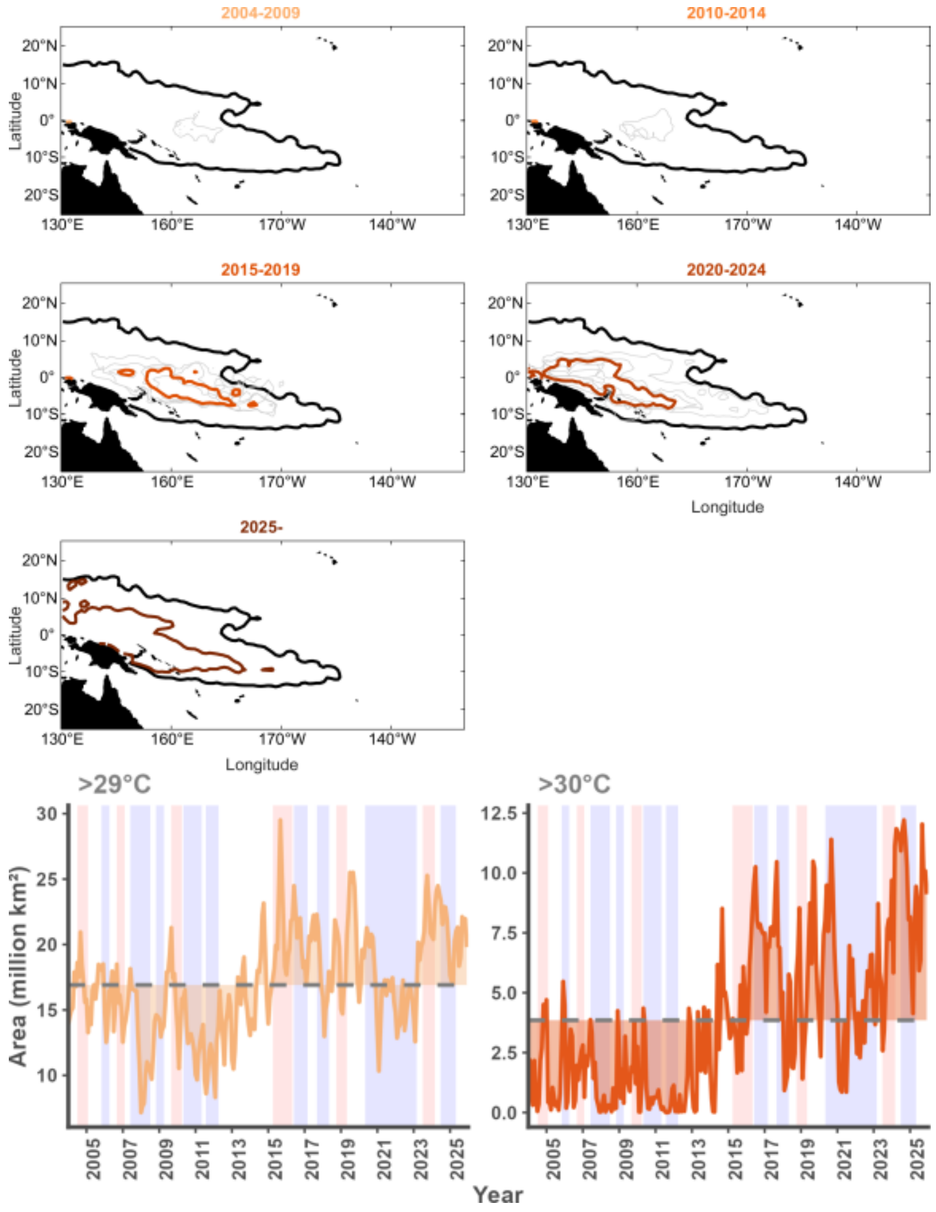


Encroaching thresholds

- Overall area of the western Pacific warm pool showed no overall increase in area across the observational period (2004-2025).
- However the area of water exceeding 30˚C increased, indicating a shift towards warmer conditions encroaching mortality thresholds.



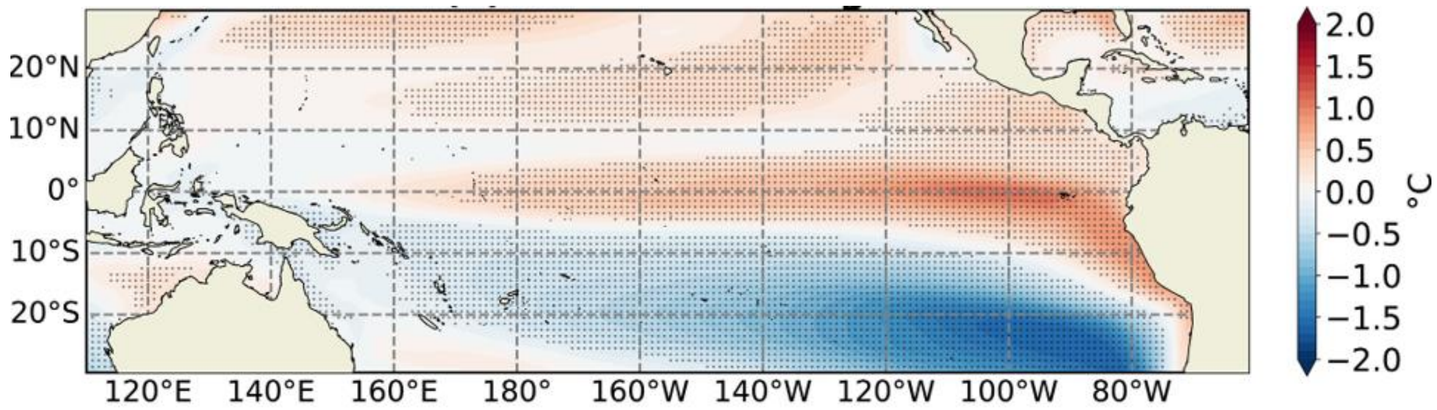
Fujioka et al (2024) DOI: 10.1111/jfb.15767



Impact of global warming on oceanography

RSST is the difference between the local SST and its average across the tropical belt (25°S–25°N). It is used to identify regions that are warming more or less than the tropical average.

- Multi-Model Mean for 63 CMIP5/6 ESMs.
- Change in Relative SST (RSST) (difference between 2075-2100 and 1900-1925) for RCP8.5
- Dotted areas indicate regions where more than 75% of models agree on the sign of the MMM change.
- Less warming in SE Pacific
  - stronger winds increase evaporation, cooling the ocean surface.
- More warming in the eastern equatorial Pacific due to reduced evaporative cooling



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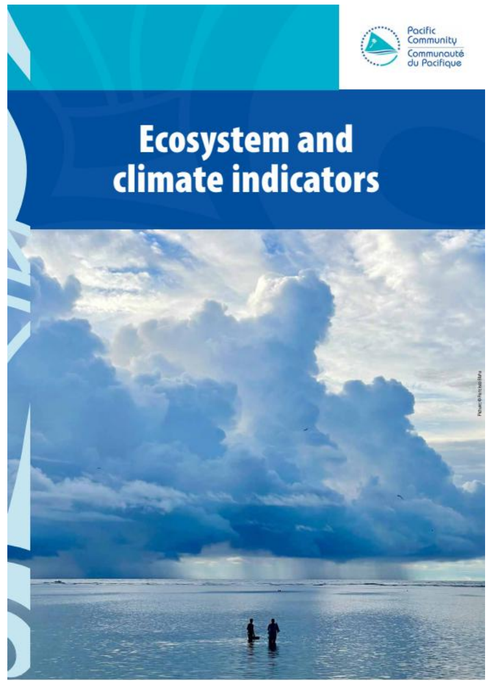
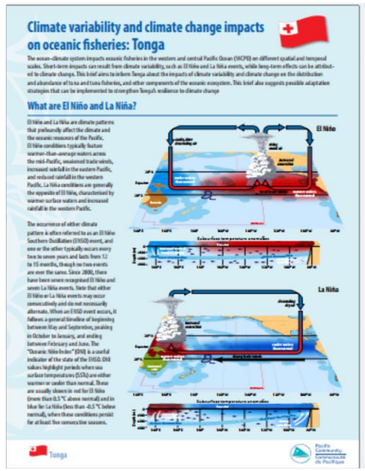
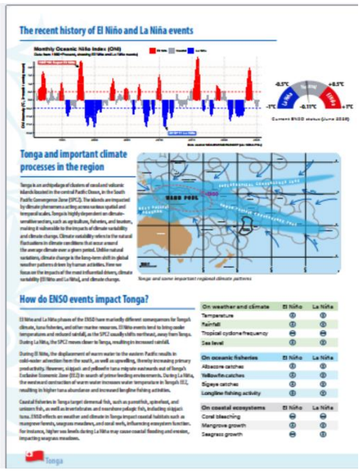
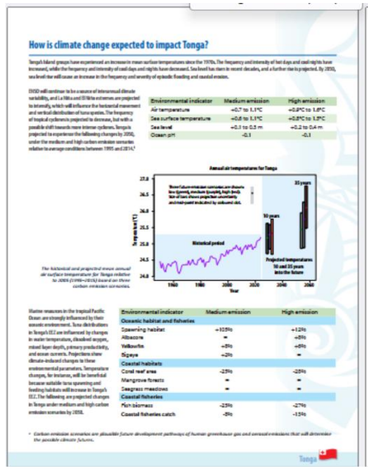
Ocean Climate Reporting

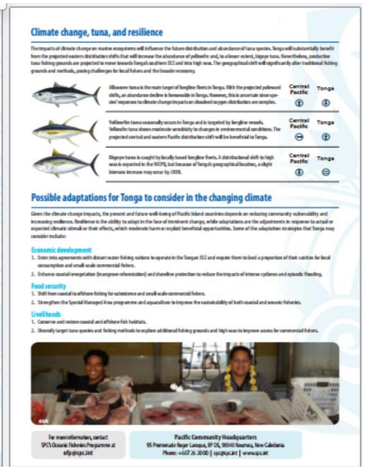
- WCPF Commission Report
- SPC member reports & policy briefs
- Dashboard trainings

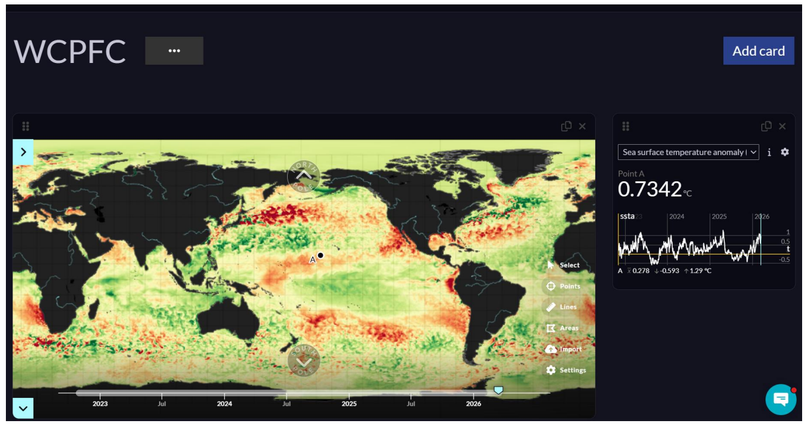






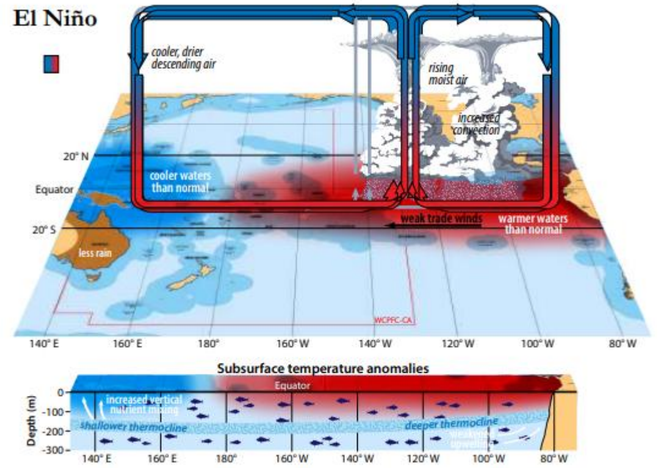


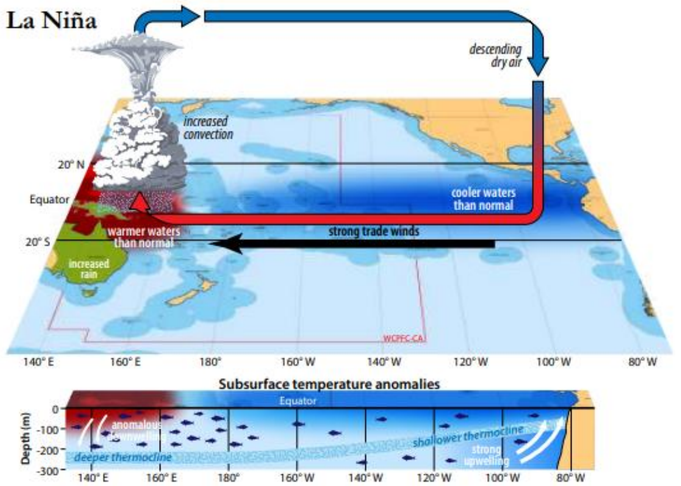




Impacts of Climate and Climate Change: *Climate Variability*

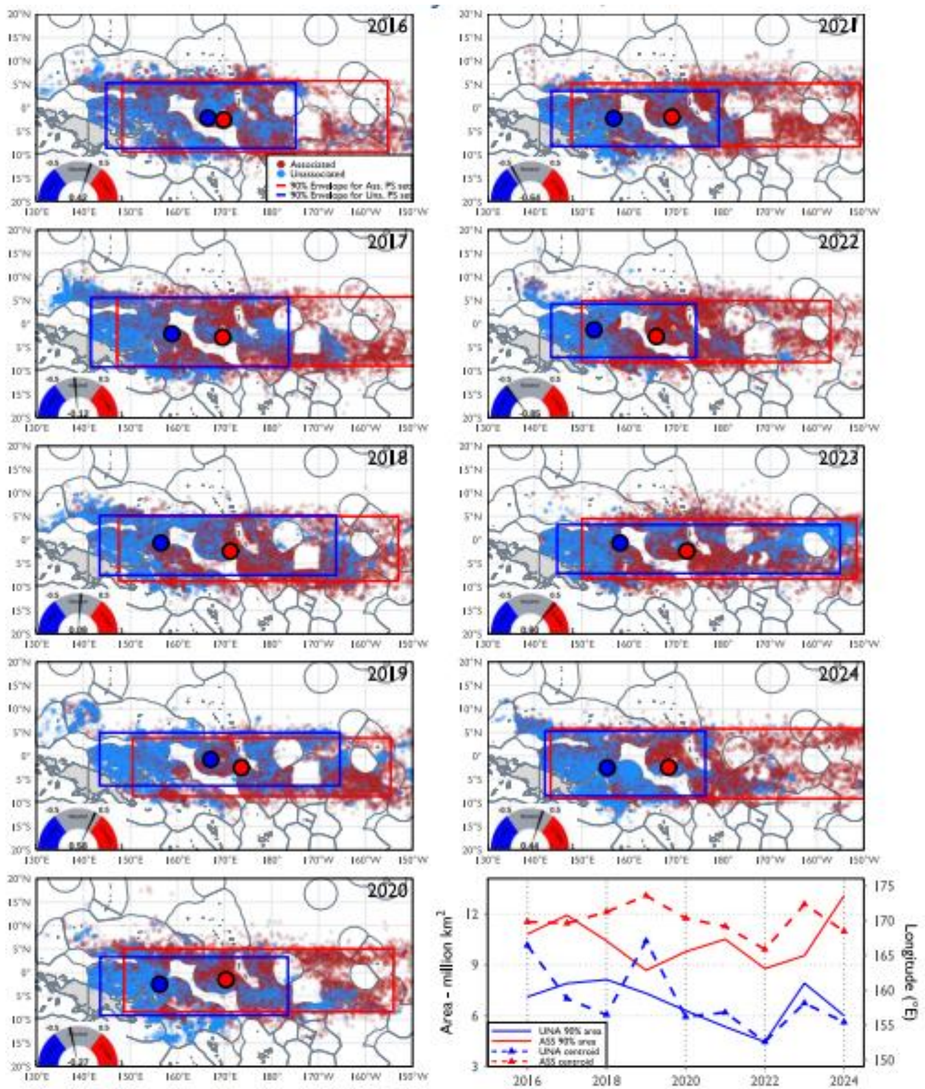
- Oceanic conditions are modulated by multiple, overlapping modes of climate variability.
- El Niño–Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) are the most influential drivers.
- ENSO events occur over interannual time frames (typically 4-7 yrs) with events occurring over the austral summer
    - El Niño warms the central and eastern Pacific
    - La Niña amplifies the pooling of warm waters in the west.
- The IPO pre-conditions the Pacific towards periods of more frequent El Niño-like or La Niña-like conditions and operates over decadal periods (15-30 yr phases).
- Both phenomena alter surface currents, thermal profiles, oxygen concentrations, and biological productivity.





Climate Variability

- ENSO impact on purse-seine fishing
- Shifting distribution
- Increased spatial variability

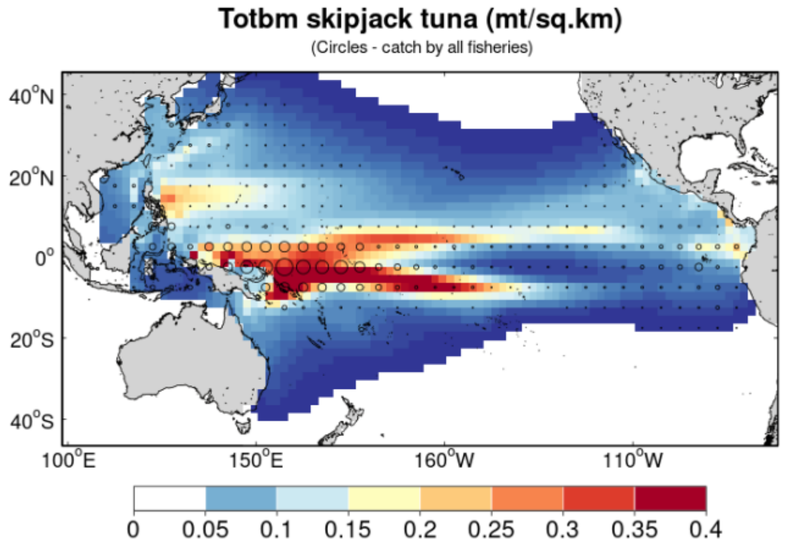


Skipjack tuna model

- Full CLTE (catch, length, tagging and early-life) data likelihood;
- Early-life history data were used to inform model parameters for the first time;
- Fits better to observations than previous (INTERIM) model;
- Estimated total skipjack population biomass in line with the stock assessment model.

Data	Metric	Prev.	Upd.
Catch (C)	r^2	0.93	**0.95**
	VR	0.88	**0.92**
	err	0.27	**0.23**
Length (L)	$\text{NRMSE}_{\bar{x}}$	0.40	**0.39**
	SMD	0.11	**0.00**
Tagging (T)	NRMSE_{σ}	0.57	**0.52**
	KGE	0.73	**0.77**
	PC	0.86	**0.89**
Early-life (E)	NRMSE_{σ}	—	0.45

Previous



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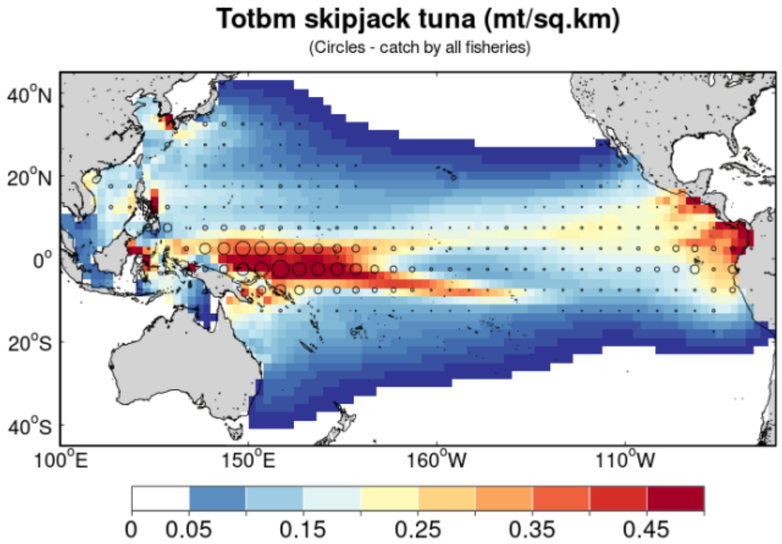
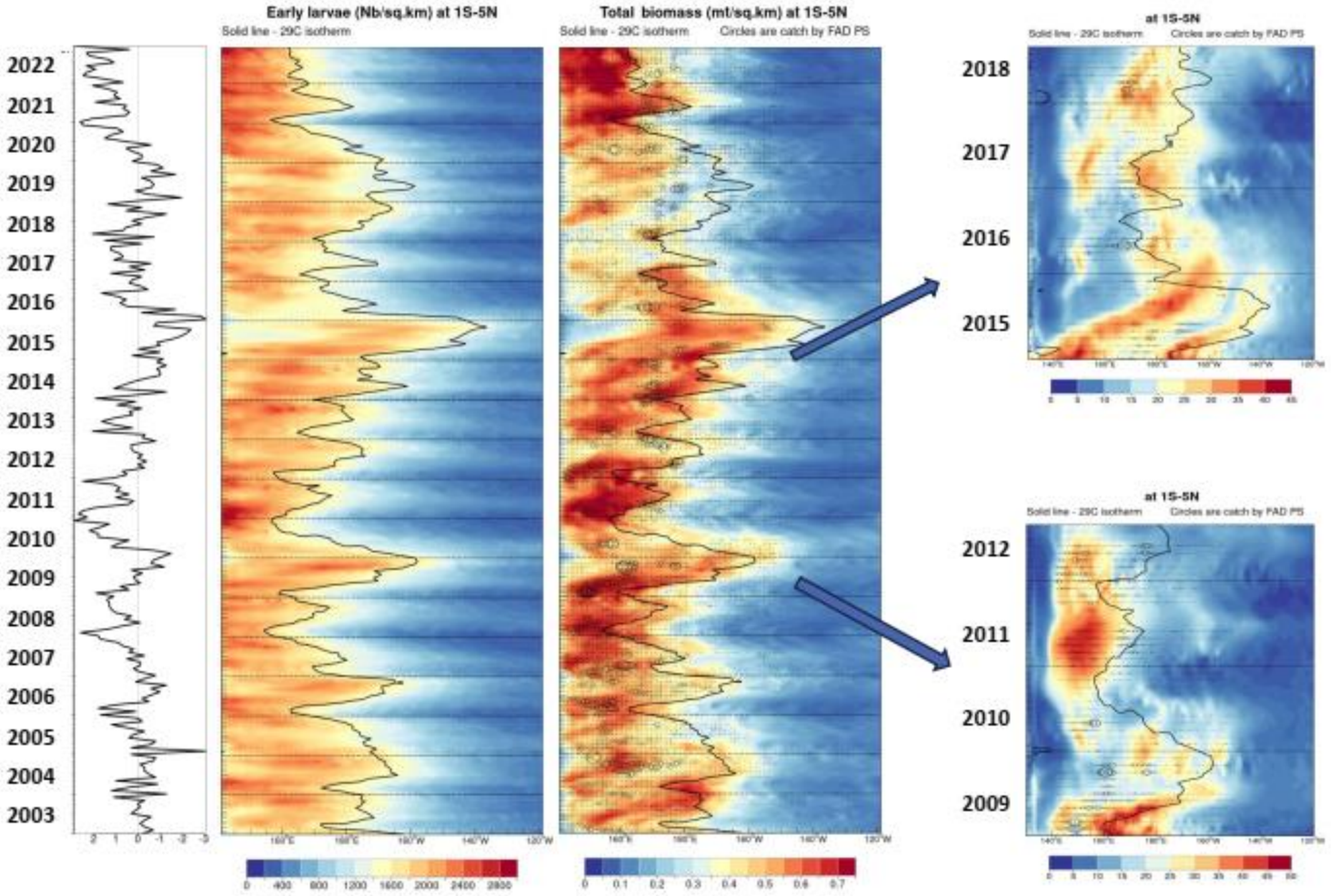


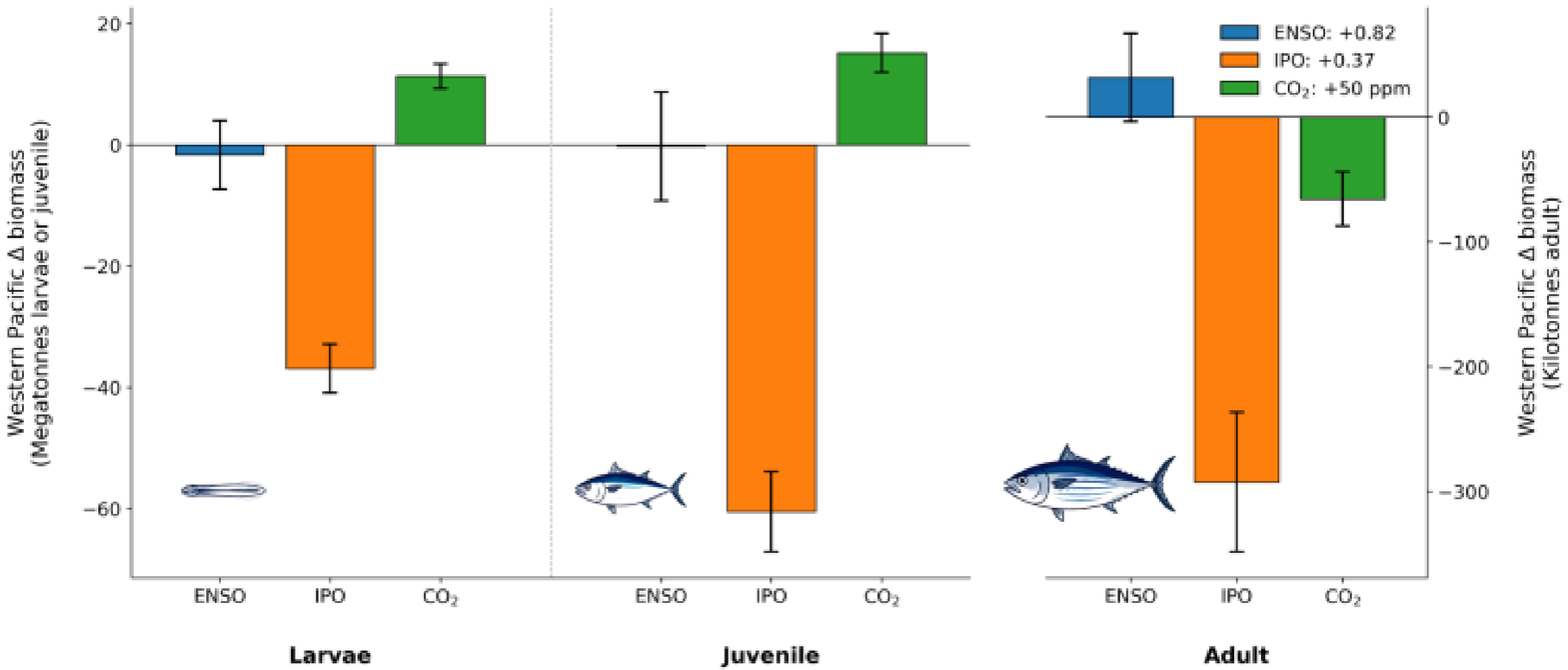
Climate Variability

- ENSO impact on skipjack recruitment and movement



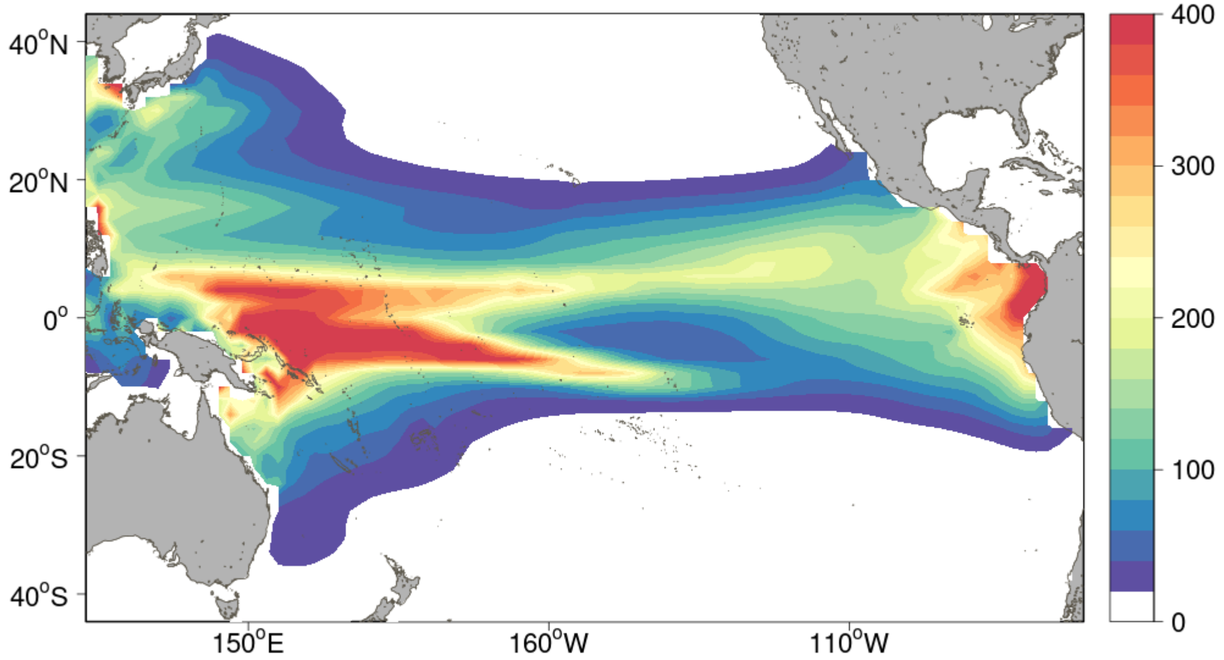
Climate Variability

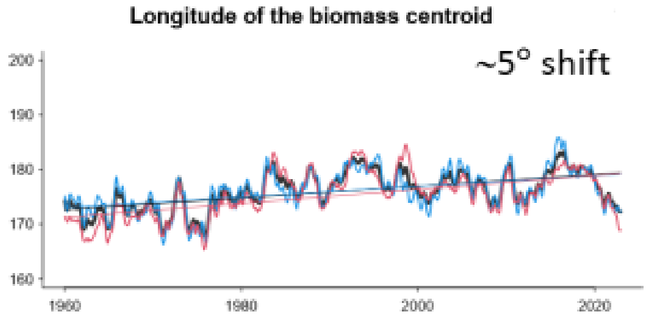
- Western Pacific changes in the biomass of skipjack larvae, juveniles and adults associated with climate modes.

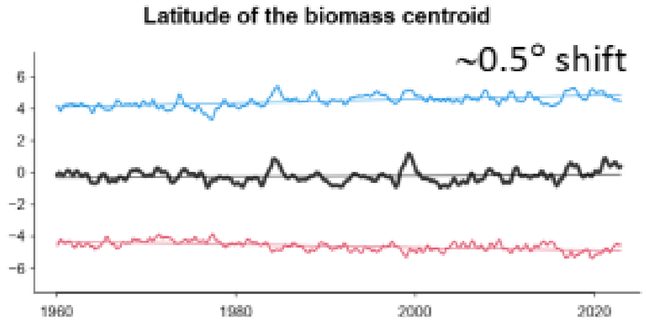


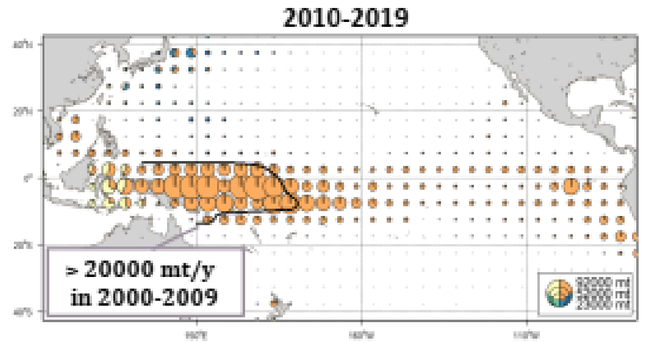
Impact of global warming on skipjack tuna

- Real-time restructuring of Pacific Ocean skipjack biomass due to climate!









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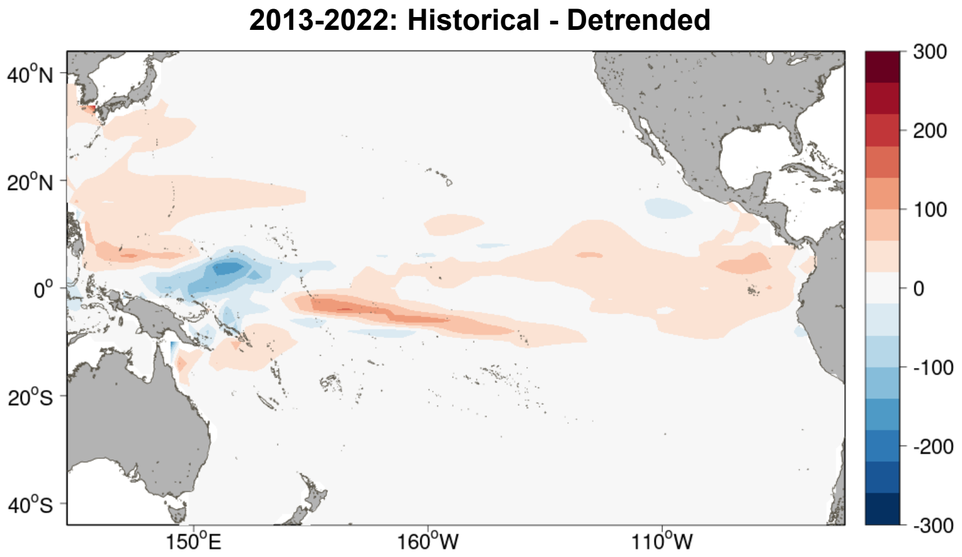
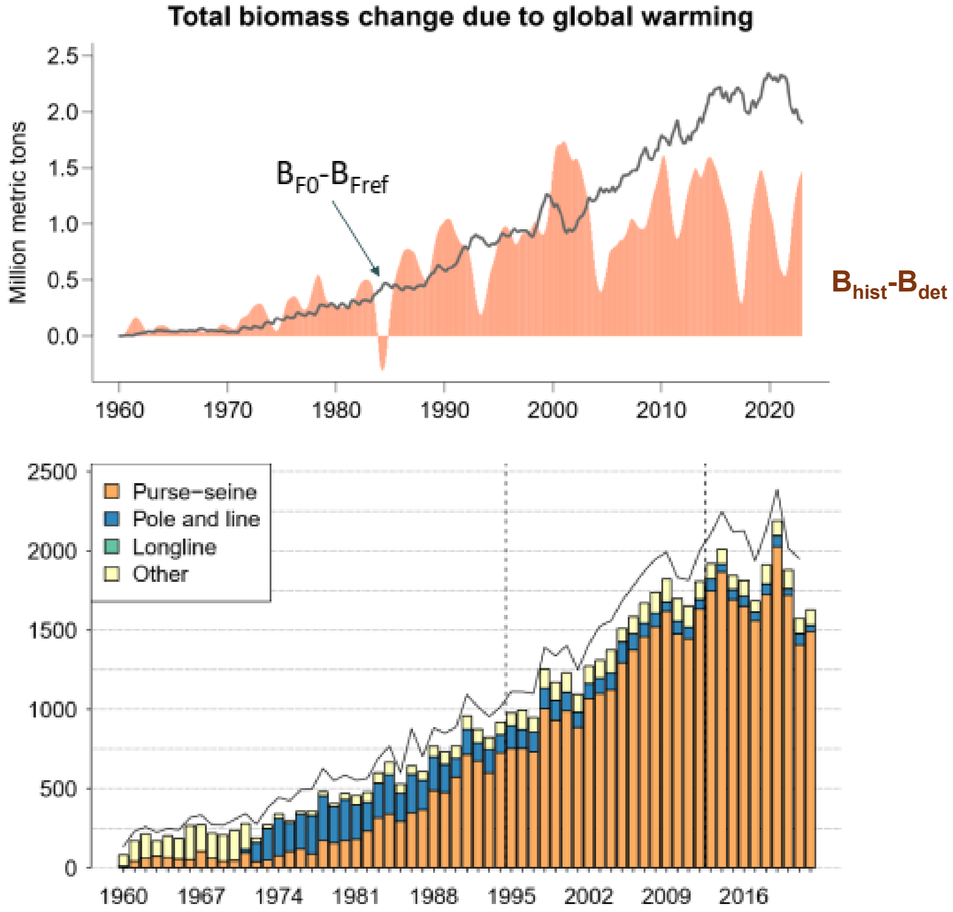
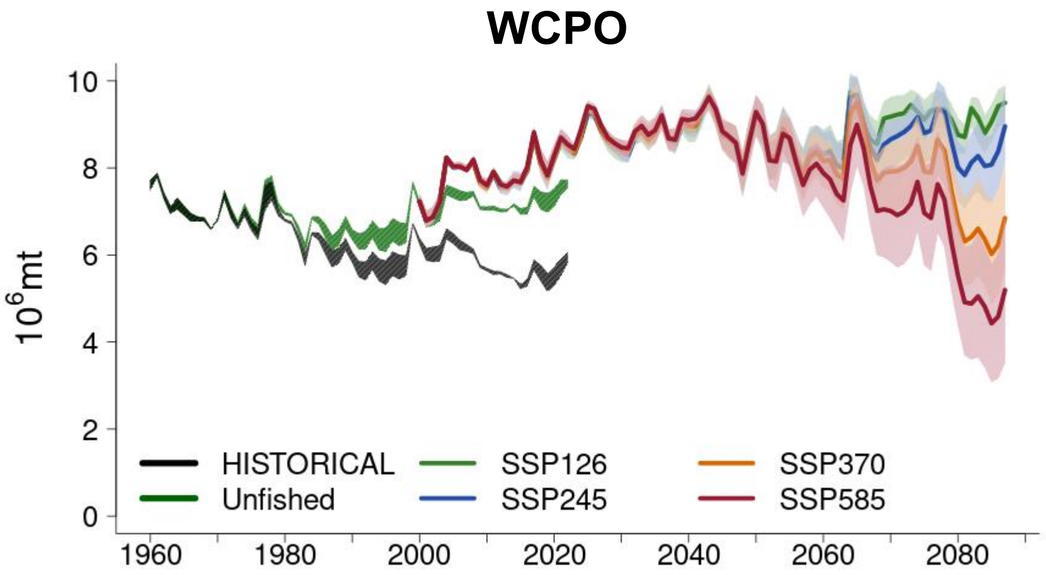
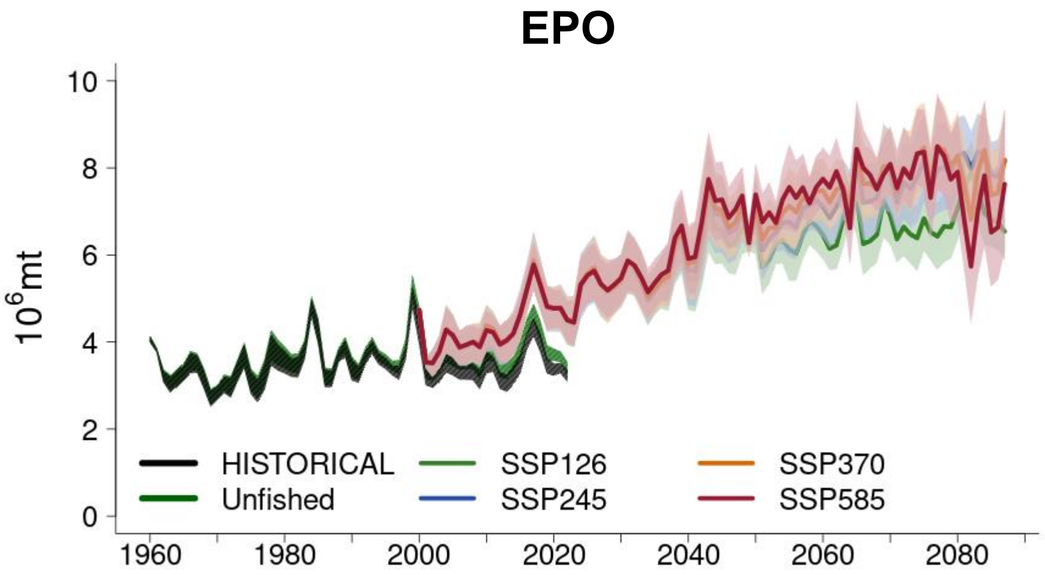




Impact of global warming on skipjack tuna

- Skipjack biomass projections under four SSPs, two ESMs and three SEAPODYM models (24 ensemble members)

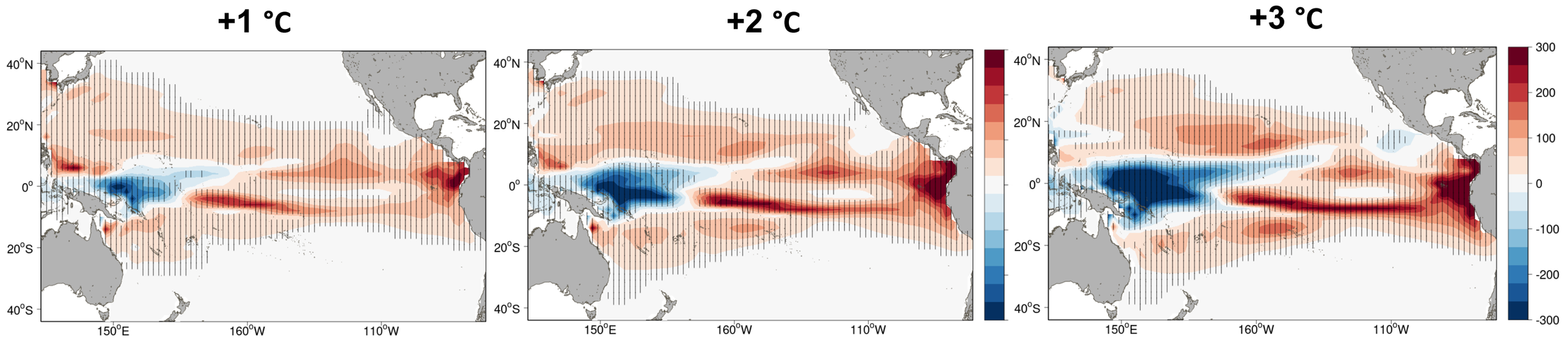




Climate impact by warming level

- Let's measure climate impact by warming level: 1C, 2C, etc.

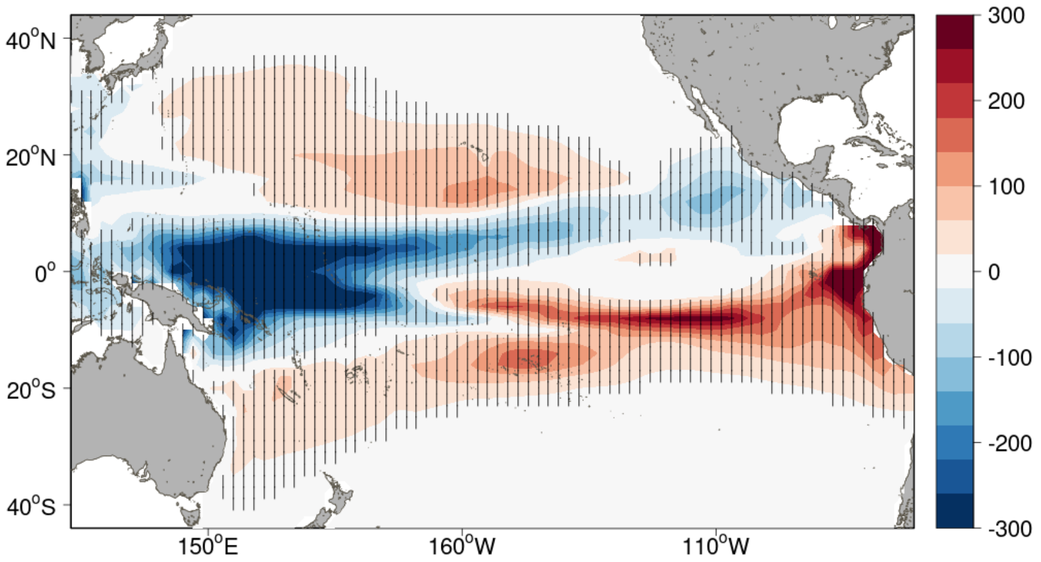
	+1 °C	+2 °C	+3 °C	+4 °C	max warming, 2078–2087 (ensemble mean)
SSP1-2.6	2054 (2050–2059)	—	—	—	1.19 °C
SSP2-4.5	2044 (2040–2049)	2079 (2075–2084)	—	—	2.09 °C
SSP3-7.0	2043 (2039–2048)	2065 (2061–2070)	—	—	2.92 °C
SSP5-8.5	2041 (2037–2046)	2058 (2054–2063)	2076 (2072–2081)	—	3.59 °C

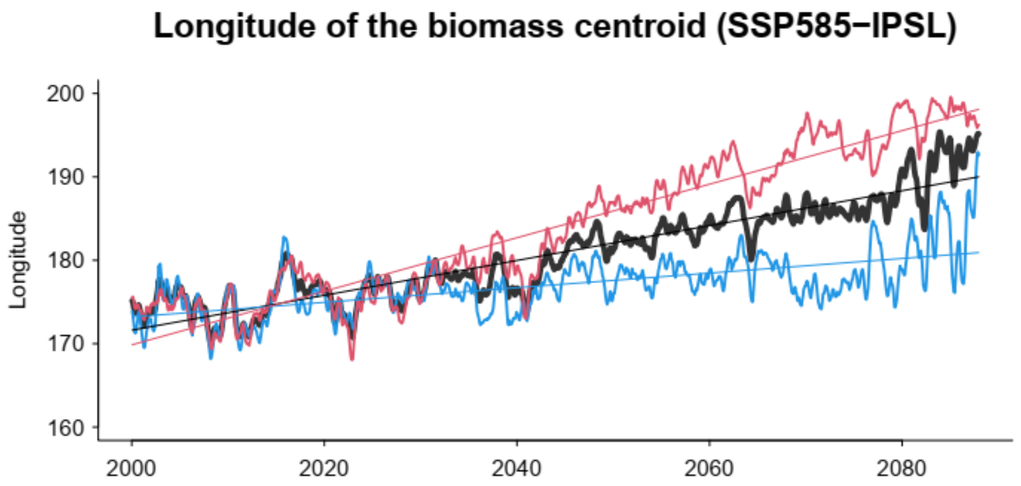


Climate impact by warming level

Warming level	WCPO			EPO		
	20 °N/S	45 °N/S	adult map	20 °N/S	45 °N/S	adult map
+1 °C	+15.5 %	+20.1 %	+18.3 %	+57.4 %	+57.1 %	+56.8 %
+2 °C	+10.7 %	+17.6 %	+12.6 %	+86.3 %	+86.1 %	+83.8 %
+3 °C	−17.3 %	−7.6 %	−15.7 %	+99.0 %	+99.5 %	+92.9 %
+3.8 °C	−47.9 %	−36.7 %	−44.5 %	+48.9 %	+50.1 %	+39.1 %

+3.8 °C
IPSL-SSP585





Where to from here

- Organise a side event in the margins of WCPFC23
  - Provide a high-level summary of climate impacts and climate change projects for the four tuna species

- Climate Awareness Workshop II (CLAWII)
  - 15-19 February 2027, Port Villa Vanuatu
  - In depth presentation on latest results for oceanic and coastal fisheries
  - Loss and damage and adaptation training
  - Supported by the FAO Common Oceans II and the GCF-RTP
  - Attendance support for Pacific Island Countries available (and potentially Territories and other on request)
  - Circular to be provided in October 2026

SC22 Advice

- Warming thresholds or IPCC SSP scenarios?
- If warming thresholds which are most relevance for WCPFC
  - 1º C (approximates the 1.5º C atmospheric warming), 2º C, 3º C SST warming levels proposed

HEADS OF FISHERIES MEETING 2025

Pacific Community
Communauté du Pacifique

Thank you!