The jack mackerel fishery in the southeastern Pacific (1973–2025): environmental variability, yield, and habitat projections under climate change

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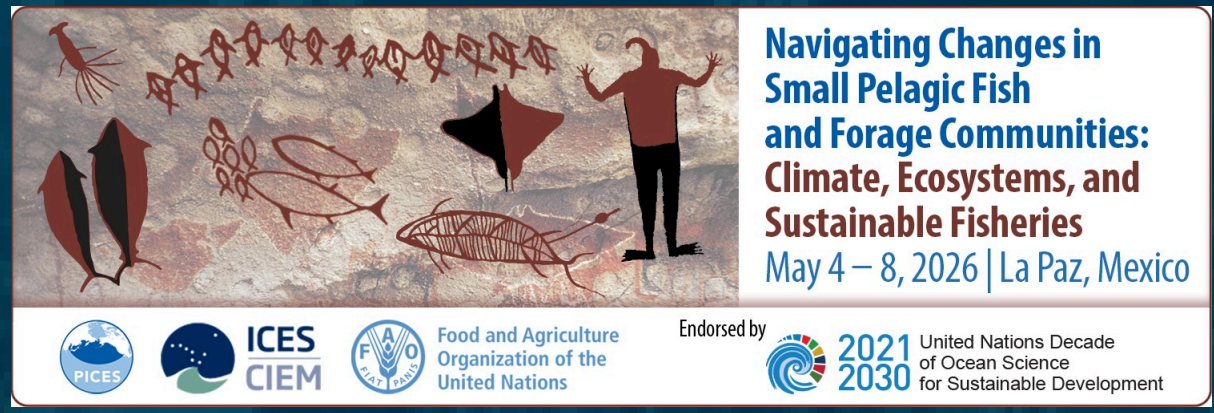


Roadmap

- **Context.** Jack mackerel dynamics are shaped by fishing pressure, interdecadal thermal variability, and habitat availability.
- **Question.** Can environmentally informed models connect changes in expected yield with changes in suitable habitat?
- **Approach.** CLIMPROD for annual yield-oriented reference points, deep learning for monthly catch dynamics, and Maxent for seasonal habitat suitability.
- **Message.** Warmer conditions increase simulated catch or yield in these models, but the ecological interpretation is mainly about **availability, distribution, and catchability**, not biomass alone.

Why jack mackerel, and why environment?

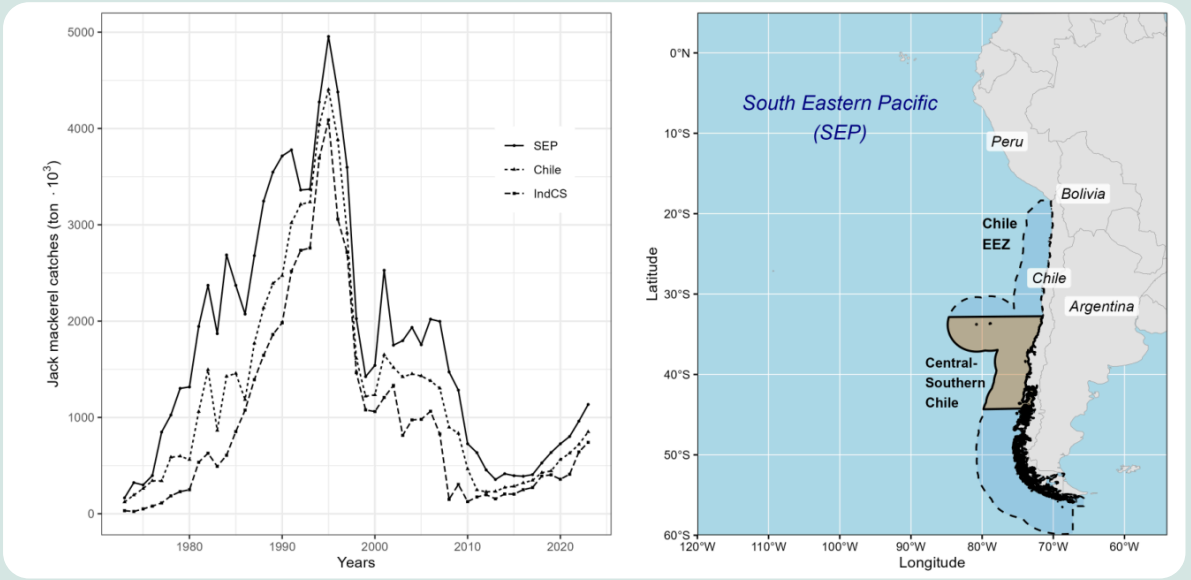
- *Trachurus murphyi* is a highly migratory pelagic resource of the southeastern Pacific.
- Its distribution and catchability respond to SST, productivity, oxygen structure, and ENSO-related variability.
- Environmental variability is not yet fully integrated into management-oriented reference points.

Central problem

The same stock can appear more or less available to the fishery depending on the environmental background.

Context based on habitat and fishery-environment studies for jack mackerel (**Bertrand et al. 2016**; **Lima et al. 2020**; **Parada et al. 2013**).

Study system and data domains



Annual southeastern Pacific series and central-southern Chile monthly fishery domain.

- Annual SEPO/SEP series: total catch, CPUE, fishing effort, and NOAA SST.
- Monthly central-southern Chile series: catch, effort, SST, and lagged temporal structure.
- Habitat component: georeferenced fishery records linked to seasonal SST and chlorophyll-a fields.

The annual and monthly components are complementary, not directly interchangeable (**Plaza-Vega et al. 2026**; **Yáñez et al. 2026**).

Scientific question and modelling logic

Can environmental variability help interpret **interdecadal changes in expected yield** and **seasonal changes in habitat suitability** for jack mackerel under climate change?

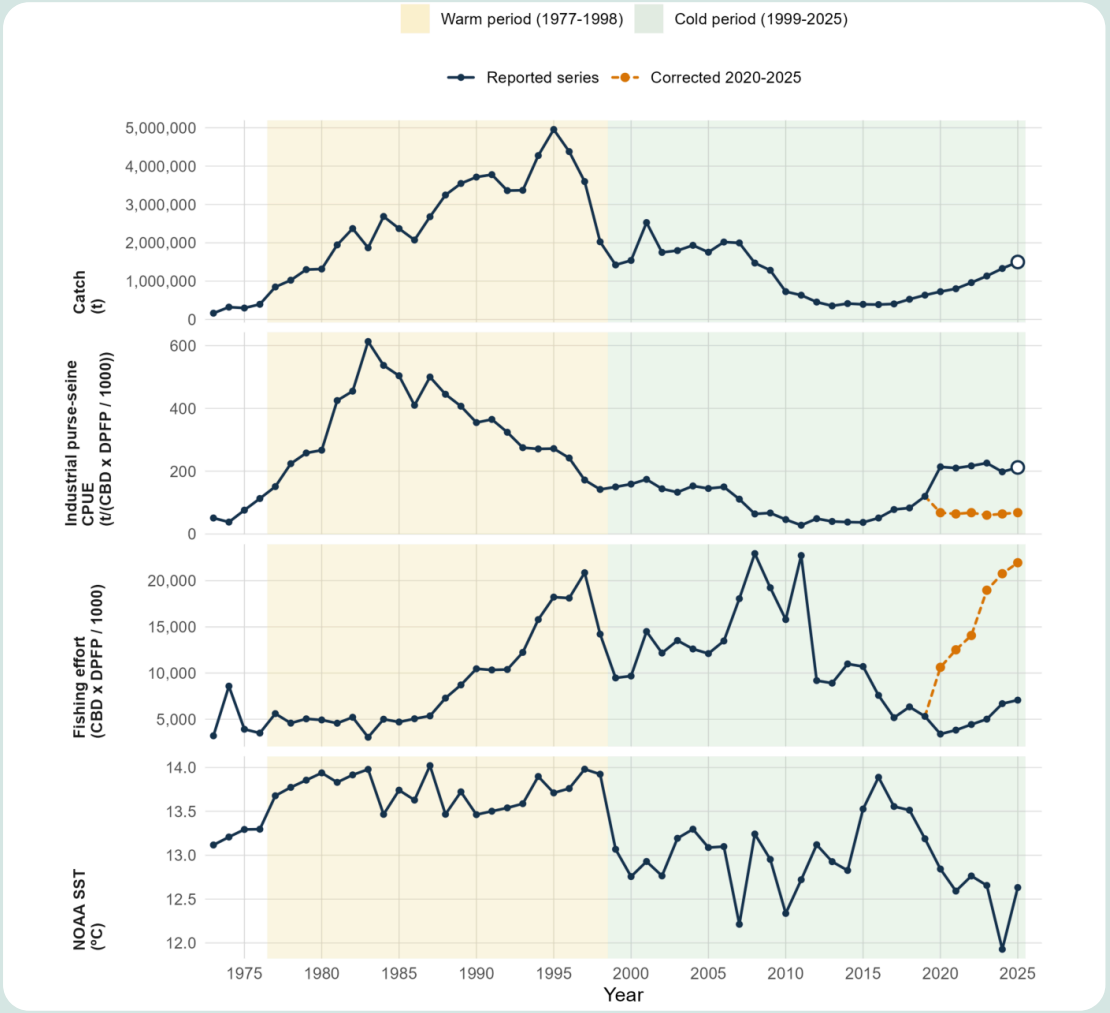
CLIMPROD
Annual, equilibrium-oriented, management quantities.

CNN / LSTM
Monthly nonlinear temporal dependence and lagged SST–effort effects.

Maxent
Seasonal habitat suitability from SST and chlorophyll-a.

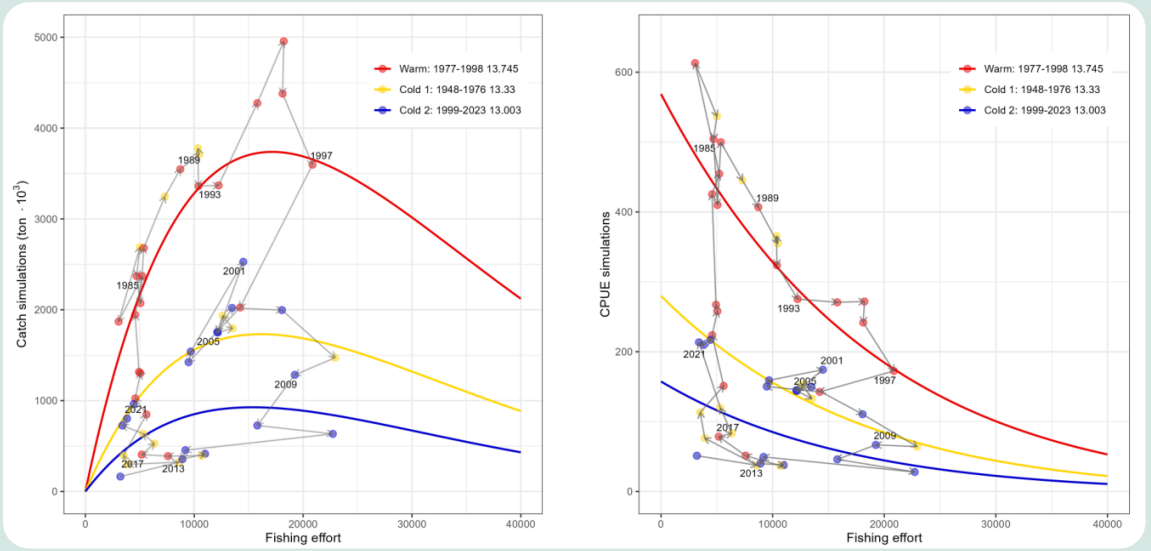
CLIMPROD incorporates environmental forcing into surplus-production analysis (**Fréon 1993**; **Fréon and Yáñez 1995**). Maxent follows occurrence-based habitat modelling (**Phillips, Anderson, and Schapire 2006**; **Phillips and Dudík 2008**).

Thermal regimes and scenario logic



- Warm period: **1977–1998**, mean annual SST **≈ 13.745°C**.
- Recent cold period: **1999–2025**, mean annual SST **≈ 12.949°C**.
- Recent coastal concentration was explored through a **CPUE correction** for 2020–2025.
- Climate-change sensitivity: linear **+0.8°C** SST increase by 2045.

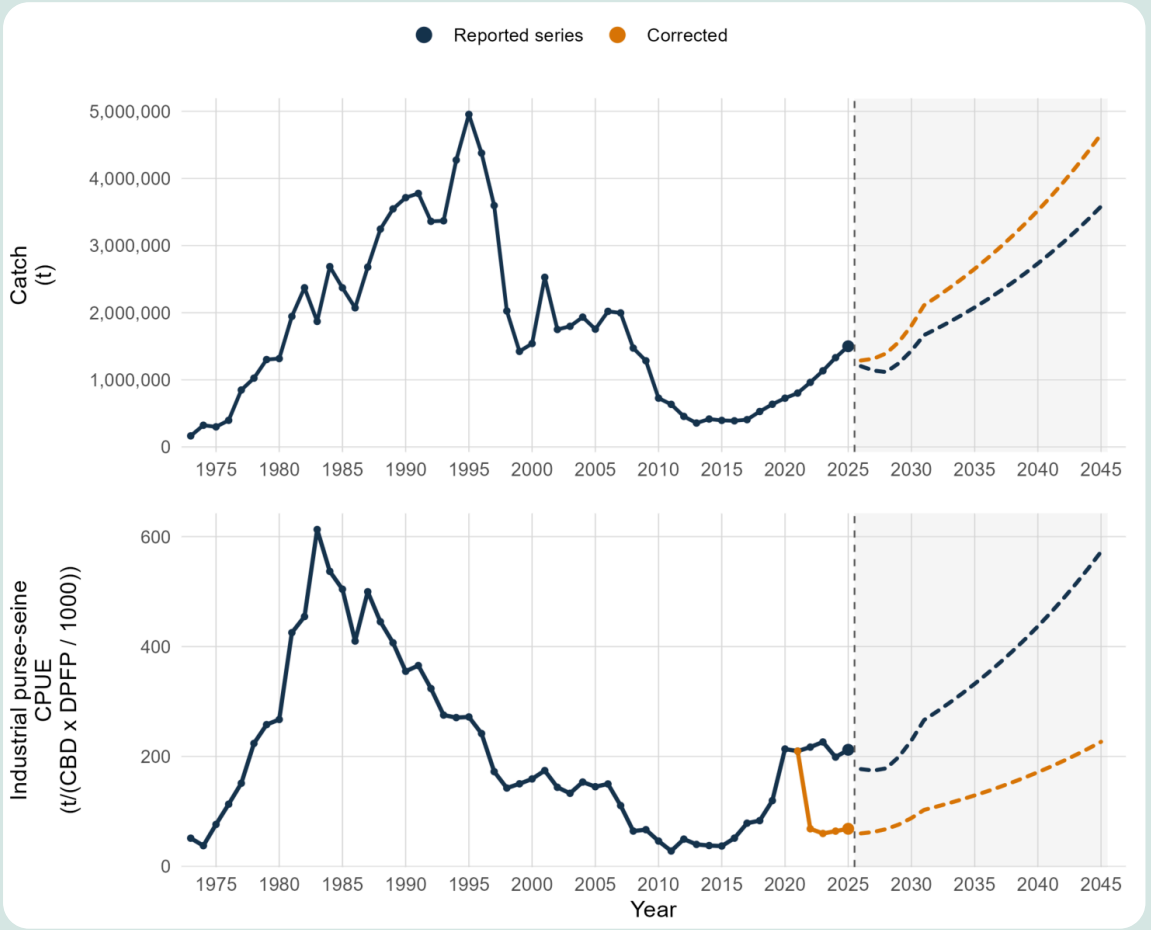
Result 1: interdecadal changes in MSY



- Warm thermal conditions yield substantially higher equilibrium production curves.
- Published 1973–2022 estimates: Warm **≈ 3.74 million t**, Cold2 **≈ 0.93 million t**.
- Updated 1973–2025 analysis: recent cold-period MSY **≈ 1.0 million t**, or **0.725 million t** with CPUE correction.

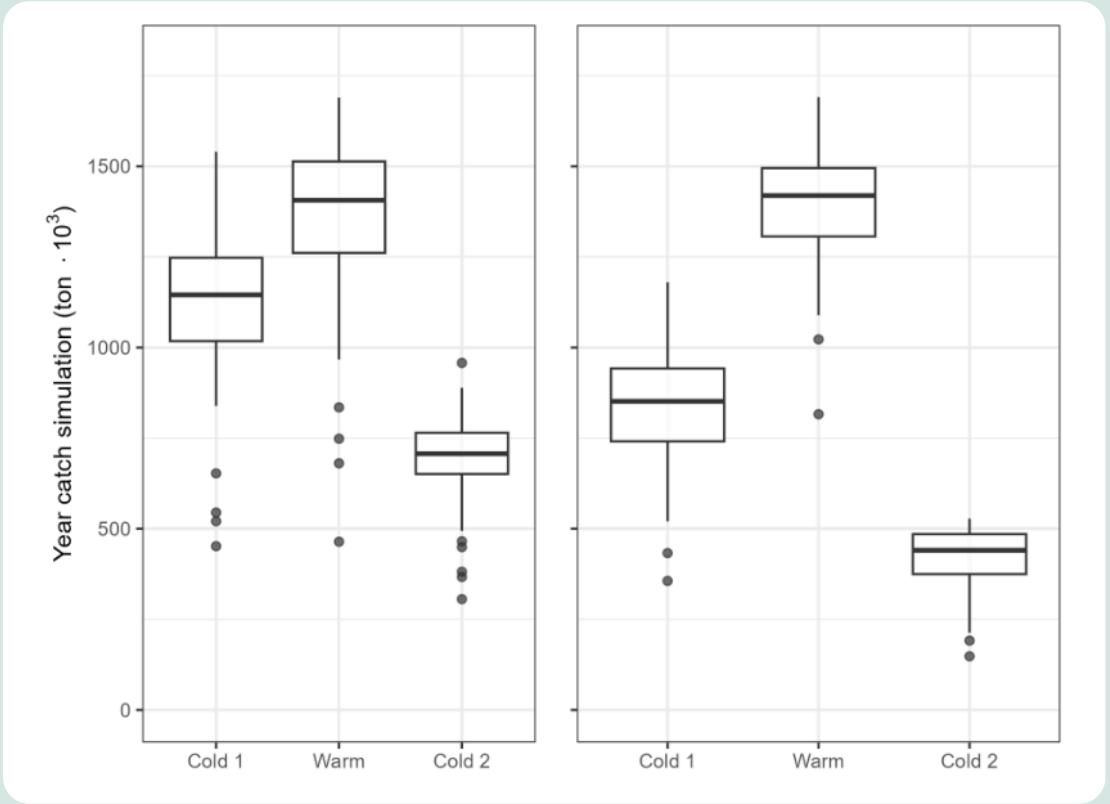
The contrast is strong, but it should not be read as a direct climate-change harvest recommendation.

Result 2: +0.8°C sensitivity by 2055



- The selected CLIMPROD relationship produces increasing CPUE and catch trajectories.
- By 2045, projected catches are near the upper historical range: about **3.5–4.6 million t**.
- This is an **exploratory sensitivity analysis**, not a coupled climate–population forecast.

Result 3: monthly simulations show the same direction



- CNN and LSTM models used monthly catch, effort, and SST with a **60-month lookback**.
- Both architectures produced higher annual summaries under the **Warm** scenario and lower values under **Cold2**.
- The monthly models support the same directional interpretation, but at a different temporal and spatial scale.

These are yearly summaries of monthly one-step-ahead simulations for the central-southern Chile industrial fishery (Plaza-Vega et al. 2026).

Result 4: habitat model performance and drivers

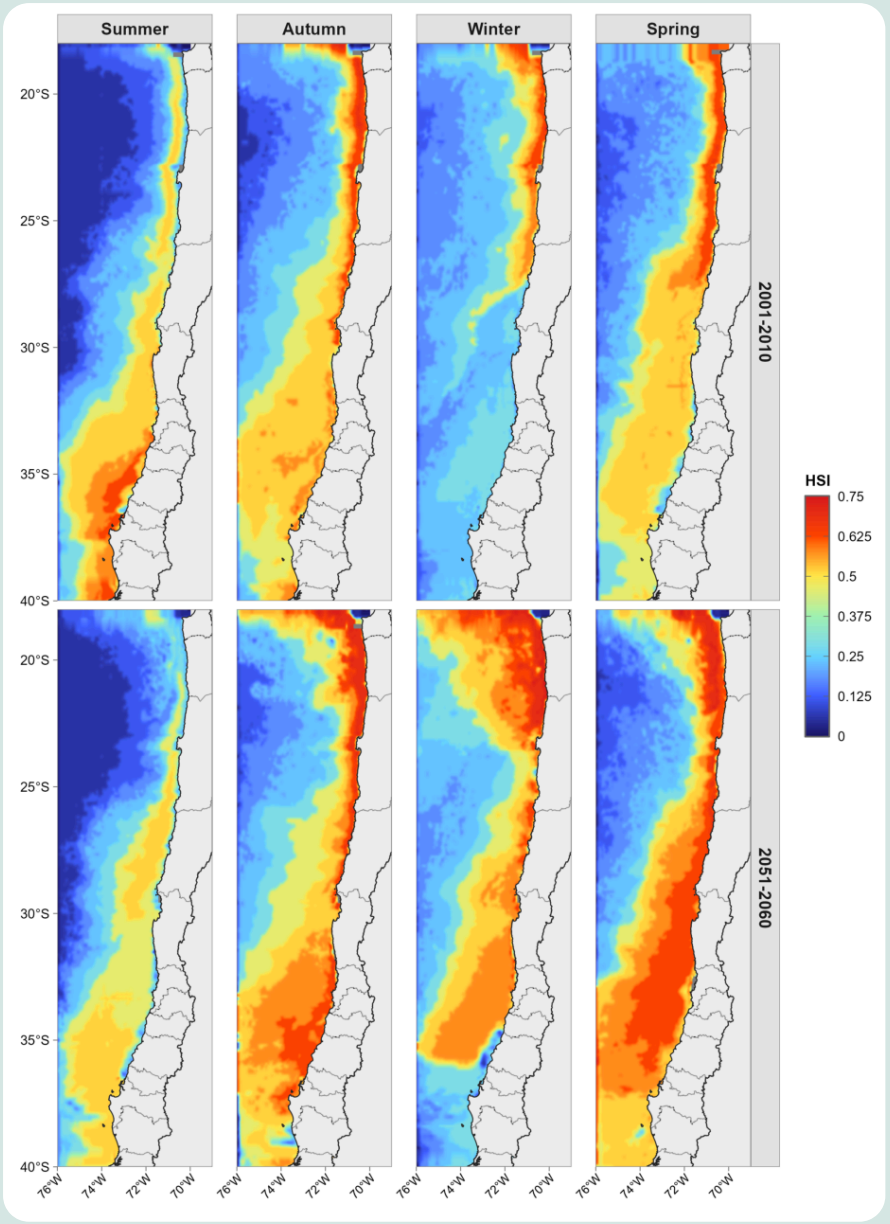
Data
10,966 monthly georeferenced fishery records for 2001–2012 on a 4 × 4 km grid off Chile.

Predictors
Seasonal SST and chlorophyll-a fields for present-day and future climate conditions.

- Maxent evaluated seasonal adult jack mackerel habitat suitability.
- Test AUC values were above **0.90** in all seasons.
- Chlorophyll-a dominated variable contribution: **82.4%** in winter to **97.0%** in autumn.

Future habitat fields are based on seasonal 2051–2060 conditions under the climate scenario described in the submitted manuscript (Silva et al. 2016; Yáñez et al. 2026).

Result 5: seasonal habitat projections



- Favourable habitat expands in **autumn (+28%)**, **winter (+427%)**, and **spring (+386%)**.
- Summer shows a strong contraction (**−87%**).
- The most favourable areas are projected to move **closer to the Chilean coast**.

The habitat result changes the interpretation of higher projected catches: increased availability may arise from spatial redistribution.

Integrated interpretation

Production axis
SST modifies the equilibrium production curve in CLIMPROD.

Prediction axis
Monthly CNN/LSTM simulations preserve a warm-versus-cold contrast.

Habitat axis
Maxent projects seasonal redistribution of suitable habitat.

A plausible synthesis is that future increases in simulated catches may reflect a joint effect of environmental forcing on **productivity, distribution, accessibility, and catchability**, rather than a proportional increase in total stock biomass alone.

What is demonstrated, and what remains interpretative?

Supported by the analyses

Warmer SST backgrounds are associated with higher simulated yield/catch values. Habitat suitability is projected to expand in autumn, winter, and spring.

Plausible interpretation

Part of the increase may arise from greater availability to the fishery through coastward/southward habitat shifts and higher spatial overlap with fishing grounds.

CLIMPROD is not an age-structured stock assessment, and the deep learning component is not a demographic population model (Plaza-Vega et al. 2026; Yáñez et al. 2026).

Limitations and next steps

- CPUE-based analyses remain sensitive to changes in fishing power, recent coastal concentration, and the assumption that CPUE tracks abundance.
- The CLIMPROD projection is conditional on the retained positive SST effect, the assumed effort level, and the +0.8°C trajectory.
- Habitat projections should incorporate improved horizontal and vertical distribution data, oxygen structure, and stronger links with population dynamics.
- Future work should integrate environmental, biological, fishery, and acoustic indicators into ecosystem-informed assessment workflows.

CPUE standardization and fishing-power effects are a known limitation in fishery-dependent indices (**Bishop 2006**; **Payá 2025**).

Take-home messages

- Jack mackerel fishery dynamics in the southeastern Pacific are strongly structured by environmental variability.
- CLIMPROD, deep learning, and Maxent provide complementary—not interchangeable—views of yield, catch dynamics, and habitat suitability.
- Warm conditions consistently produce higher simulated catch or yield in the models, while recent cold conditions produce lower reference values.
- Climate-change projections should be interpreted cautiously as changes in availability and habitat overlap, not as direct sustainable harvest advice.

Thank you

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Acknowledgements: IFOP data support; FONDECYT de Iniciación en Investigación 2025 (ANID-FONDECYT-11251120); collaborators and coauthors.

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