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Tuna fisheries bycatch and climate change in the western tropical Pacific Ocean

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Tuna fisheries bycatch and climate change in the western tropical Pacific Ocean

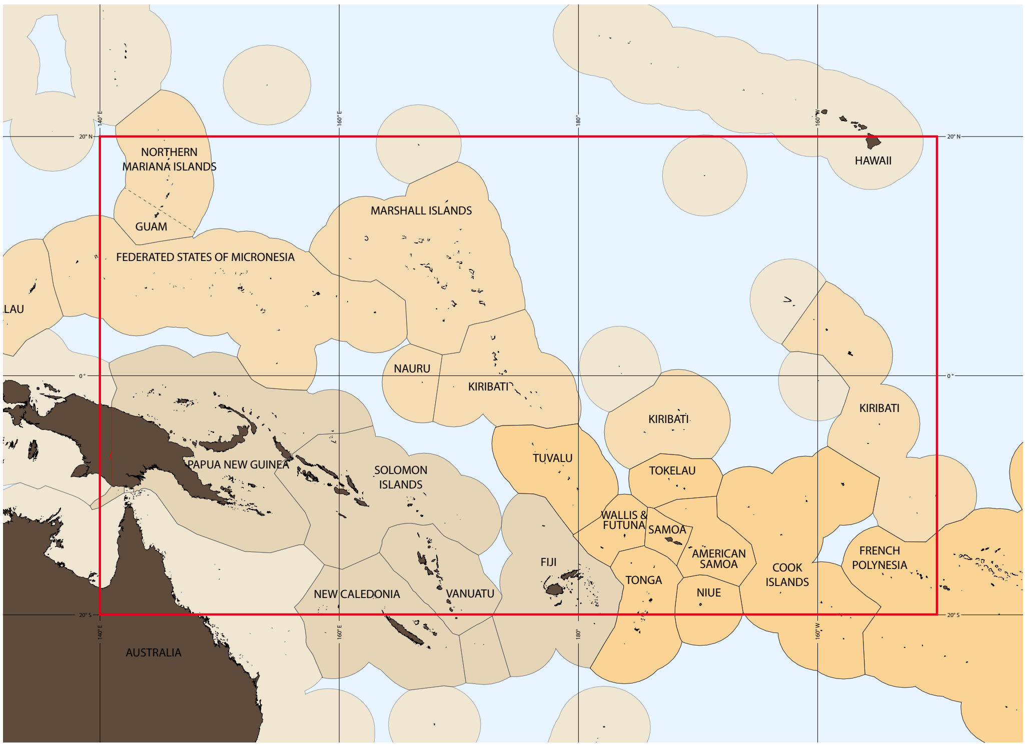
Project purpose: to inform Pacific Island countries and territories of the potential effects of climate change and tuna fishing on tropical western and central Pacific Ocean edible bycatch species.

Context

Employing an ecosystem approach to fisheries management that considers climate change is a crucial step towards the sustainable management of tuna resources and their wider ecosystem in the western and central Pacific Ocean. Purpose-built ecosystem models can provide a holistic view of the system and be used to explore the potential impacts of climate change and fishing on target and other species. This document summarizes the results of the application of such an approach to the tropical western and central Pacific Ocean with a focus on edible bycatch species caught within tuna fisheries (marlins, swordfish, wahoo, mahi mahi, rainbow runner, barracuda, and opah). These findings may inform regional decision-making around ecological sustainability and food security in the region.

Key messages

- Climate change has a negative impact on edible bycatch species biomass with the strongest effects predicted after 2050;
- Climate change and fishing effects interact. The ecosystem food web is sensitive to the synergistic effect of both factors, and for most species, climate change exacerbates the negative effect of any increase in fishing mortality;
- Long-lived species are particularly sensitive to climate change and fishing mortality;
- Ecosystem models are useful tools to support sustainable fisheries management as they allow the evaluation of the effects of interactions by multiple drivers. In many cases, these effects are indirect and modified by food web connections that are not represented in single species models.



Ecosystem model of the tropical western and central Pacific Ocean (140°E–150°W and 20°N–20°S)

Recommendations

- Ongoing and representative fisheries monitoring programmes that include data collection for bycatch species are key to support ecosystem approaches to fisheries management.
- Fisheries management measures are key tools for mitigating and adapting to climate change impacts and supporting the sustainable use of marine resources. However, the synergistic effects of climate change, and changes in fishing mortality through regulation of different fisheries can lead to unexpected outcomes for edible bycatch species. Careful consideration will be required when developing management measures to ensure they achieve objectives for the target species, edible bycatch and the ecosystem at large.

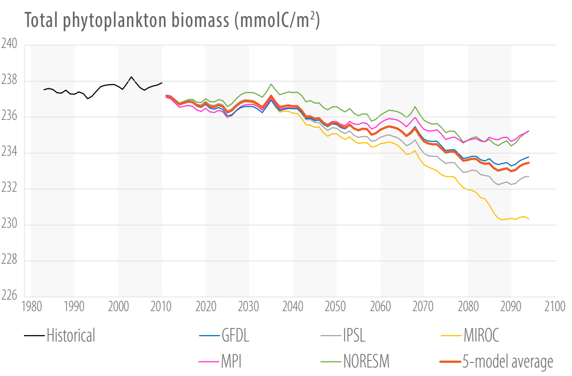
Caveats / Uncertainties

- Climate change impact was simulated only through variations in the biomass at the base of the food web (phytoplankton). Other changes, such as increasing water temperature or decreasing oxygen, and their direct impacts on species were not considered.
- Current climate simulations only accounted for a limited set of uncertainties. Future analyses should consider uncertainty in biogeochemical and trophic processes to fully capture the likely impacts of climate change on edible bycatch.
- Fishing scenarios tested were designed to identify trends in trophic structure changes. Next steps should consider fishing scenarios co-developed in partnership with stakeholders as well as additional considerations around catch efficiency and bycatch mitigation measures.

How may climate change and fishing levels impact bycatch?

Changes in the biomass of edible bycatch species in the tropical western and central Pacific Ocean by the end of the century were simulated by forcing the ecosystem model using i) phytoplankton biomass projections (from five climate models and the average of these models) to represent climate change impacts and ii) four fishing scenarios to illustrate the impact of differing fishing mortalities on trophic responses (see methods at the back of the leaflet).

Climate forcing

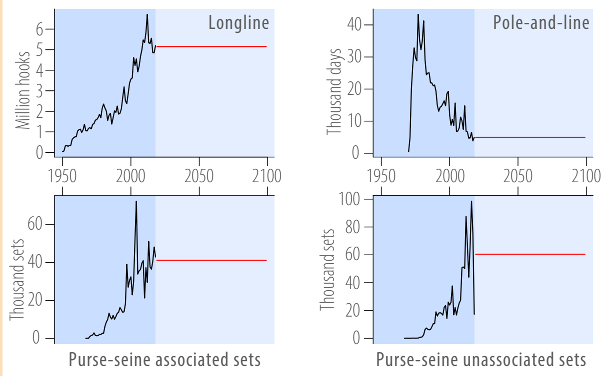


Across all climate models, phytoplankton biomass is projected to decrease, suggesting that the region will become less productive. The decline gets stronger after 2050 and this is a major driver in food web changes. However, only one biogeochemical model was available to estimate phytoplankton biomass in this study. Consequently, the magnitude of this change is uncertain, and results should be interpreted with the understanding that this change may plausibly be either larger or smaller than that considered.

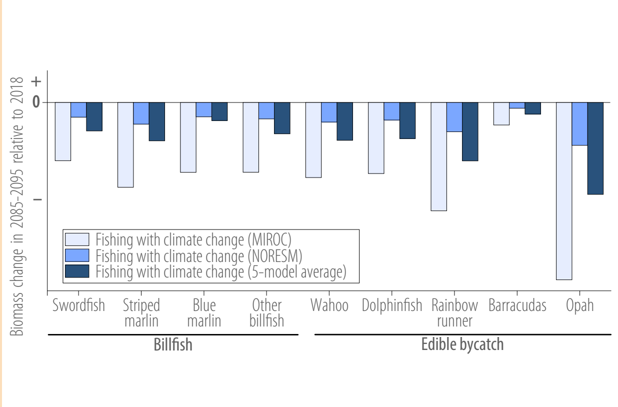
Fishing effort forcing

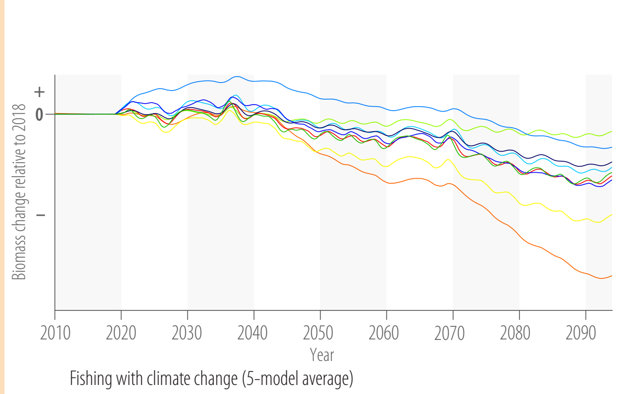
Predicted bycatch biomasses

+ scenario a Climate change and current fishing mortality



Average 2014-2018 effort was maintained for each fishery.

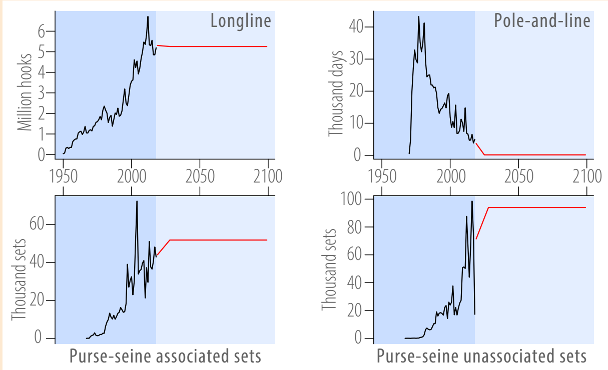




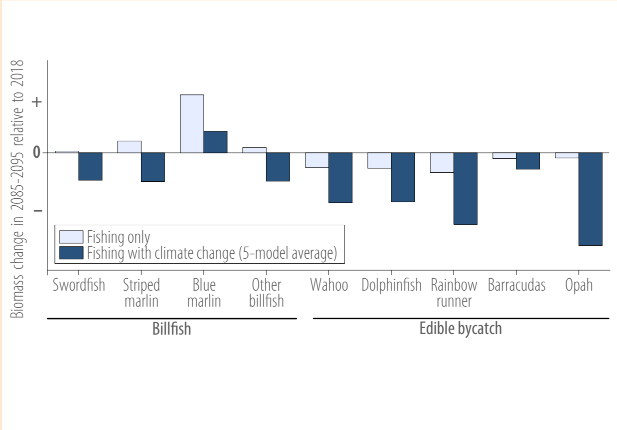
Declines in phytoplankton biomass led to a decrease in the biomass of edible bycatch species as evident in the 5-model average. Biomass levels for most stocks remained stable until ~2050 and declined thereafter.

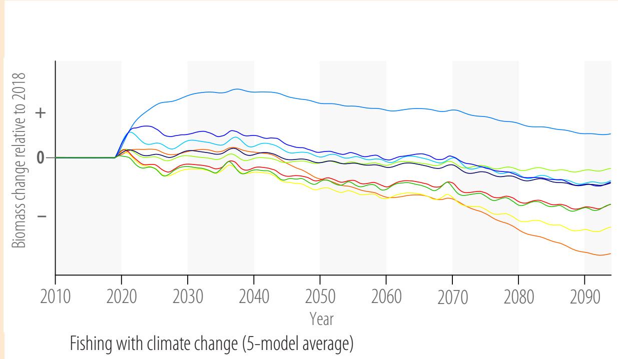
While the magnitude of biomass changes for bycatch species differed across climate models, they all indicated a similar trend: a decrease in biomass by the end of the century. The most pessimistic climate model (MIROC) yielded the strongest negative impact and the least pessimistic model (NORESM) showed smaller biomass changes.

+ scenario b Climate change and recent trends in fishing mortality



Recent trends in effort for each fishery (2007–2018) were maintained for 10 years (2019–2028), and then assumed constant.

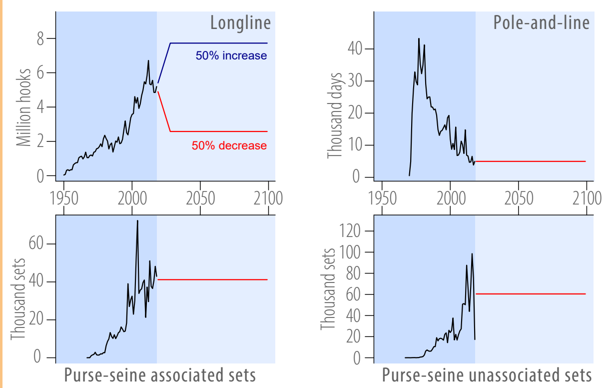




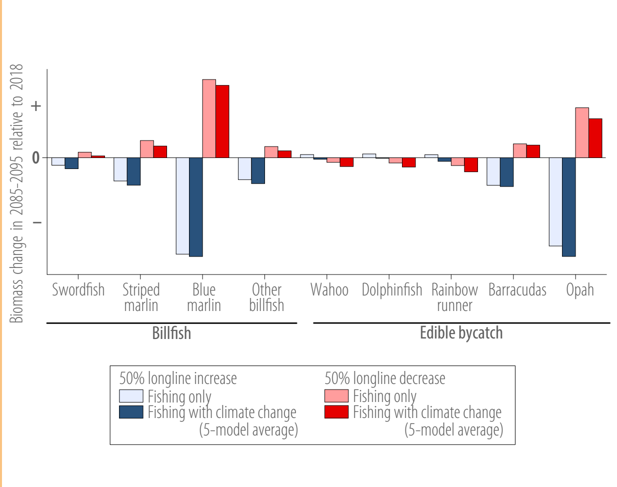
The combined effect of increased fishing and climate change showed a positive effect on billfish species, particularly on blue marlin, until 2050. By the end of the century, combined impacts remain positive for blue marlin, but other billfish and all edible bycatch species declined. These responses, however, were sensitive to the degree of fishing mortality imposed.

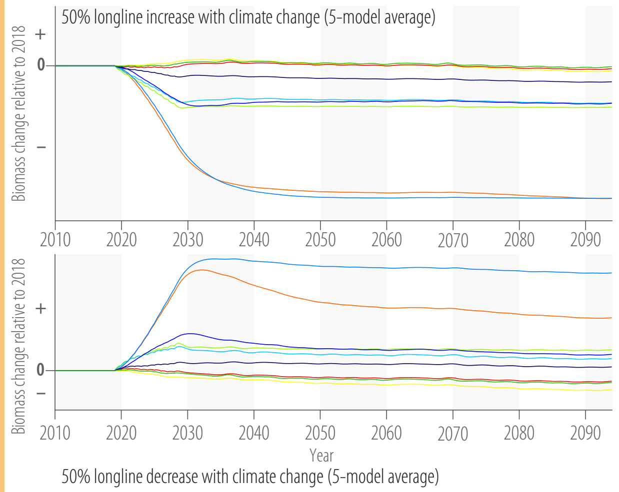
In another variation of this scenario, overall level of fishing mortality was increased further to account for increased catch efficiency (+2% for longline fisheries and +3% for both purse-seine fisheries for the period 2019-2023 and then constant thereafter). This resulted in a decrease for all billfish species and predation release on wahoo, dolphinfish and rainbow runner leading to an increase in the biomass of these species.

+ scenario c Climate change and large changes in fisheries strategies: Modifying longline fishing mortality



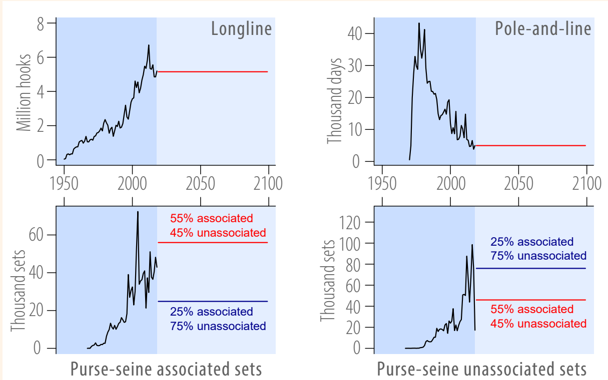
Longline effort was increased or decreased by 50% from 2014-2018 levels, progressively, over the period 2019–2028 and then assumed constant. Average 2014-2018 effort was maintained for other fisheries.



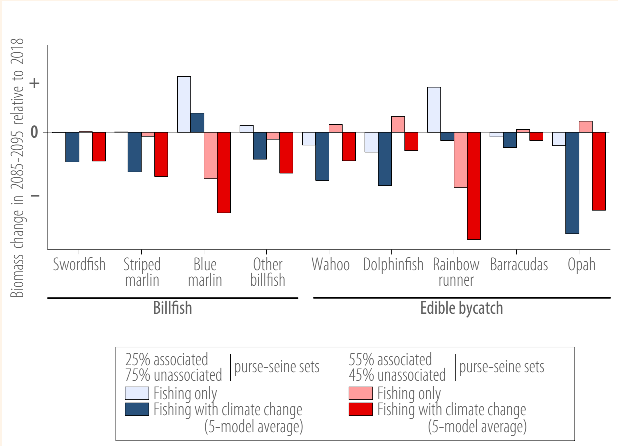


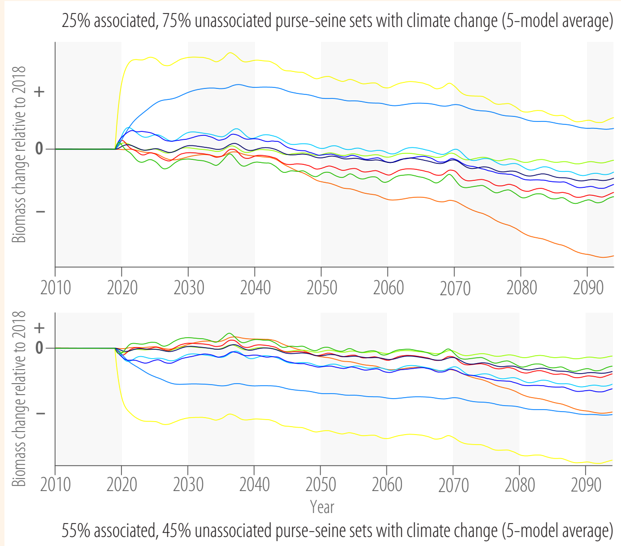
Changes in longline effort showed the strongest impacts of all fishing scenarios tested. Simulations show comparatively large decreases in opah and blue marlin biomass in response to longline effort increases and correspondingly smaller increases of these species biomasses under reduced longline effort. Impacts on striped marlin, other billfish and barracudas were less pronounced, and negligible for all other species. Because of the strength of the underlying prey-predator relationships, some species showed unexpected trends. For example, when longline effort decreased, blue marlin biomass increased but that of rainbow runner decreased. This effect is due to increasing predation by blue marlin on rainbow runner when fishing pressure on blue marlin declines.

+ scenario d Climate change and large changes in fisheries strategies: Modifying purse-seine fishing strategy



For purse seine, the proportion of fishing mortality linked to associated and unassociated sets was increased or decreased while maintaining the total purse seine fishing effort constant at the 2014-2018 average level (changes in proportion between the two types of sets could be achieved by manipulating the duration of the FAD closure for instance). Average 2014-2018 effort was maintained for other fisheries.

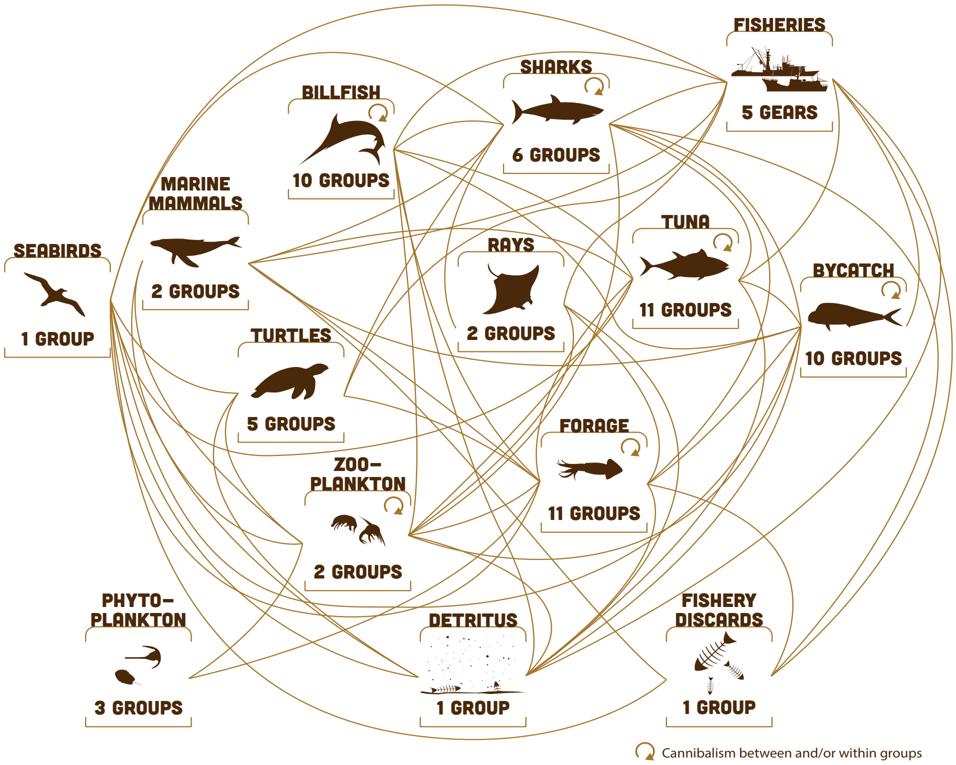




Shifting a greater proportion of purse seine fishing mortality to associated sets had a negative impact under climate change on edible bycatch species, particularly for rainbow runner, blue marlin and opah. Opah also responded strongly and negatively to a greater proportion of unassociated sets in combination with climate change. Rainbow runner and blue marlin biomasses were positively impacted when unassociated sets increased. Overall, the magnitude of change was relatively minor in comparison to the longline scenarios as total purse seine effort remained unchanged – only the proportion between associated and unassociated sets varied.

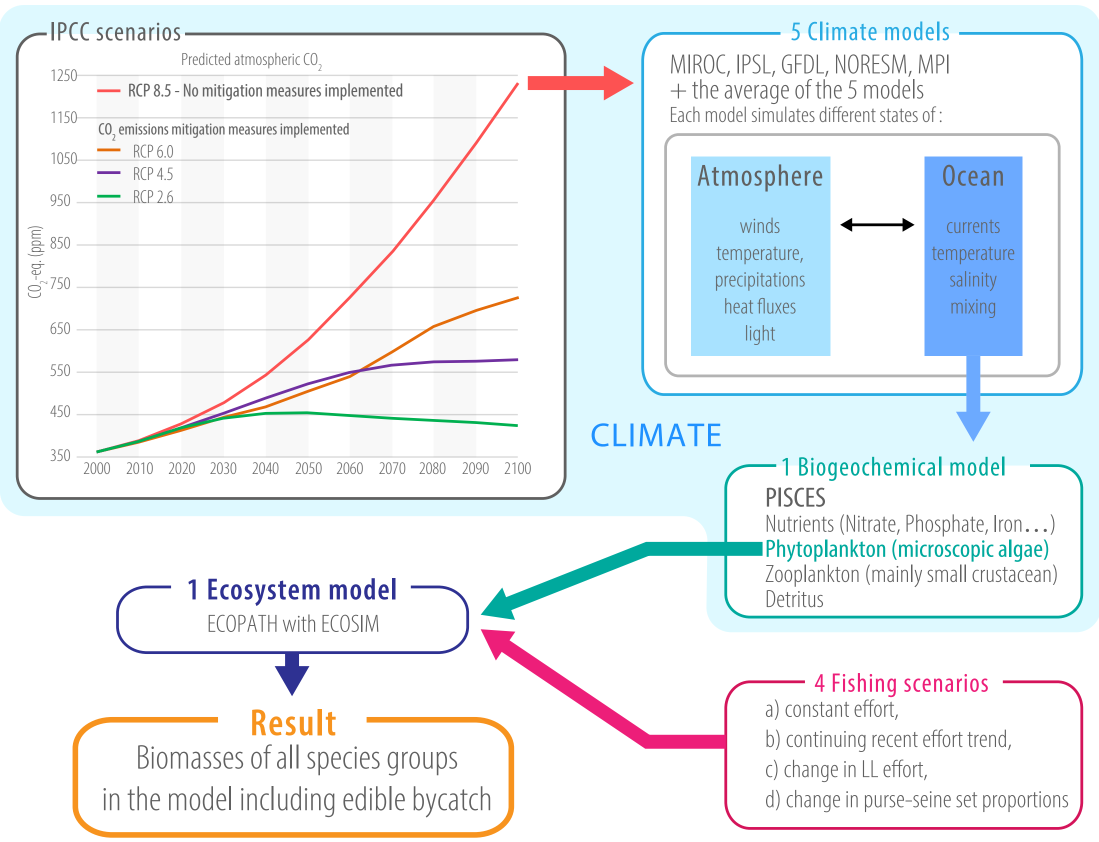
Climate forcing + Fishing effort forcing = Predicted bycatch biomasses

How did we obtain our results ?



Ecosystem model: The pelagic ecosystem was modelled using the freely available platform Ecopath with Ecosim. The current model, representing the average annual situation in 2013 for the tropical western and central Pacific Ocean (140°E–150°W and 20°N–20°S), constitutes a substantial update to a previous version (Griffiths et al. 2019). It includes 65 biological groups and 5 fisheries (including «other fisheries»). Predator-prey relationships in the model were parameterised based on stomach content analyses from fish sampled by regional fisheries observers. Other parameters such as catch, biomass, natural and fishing mortality were derived from stock assessments, fishery data and the scientific literature.

Simulating climate change and fishing impact: Climate change effects were introduced through modelled future phytoplankton biomass time series (microscopic algae at the base of the food web) as obtained from a combination of five climate models (MIROC, IPSL, MPI, GFDL, NORESM) and the biogeochemical PISCES model under RCP8.5 carbon dioxide (CO_2) emission scenario. RCP8.5 simulates the accumulation of CO_2 in the atmosphere in the absence of mitigation measures.
Fishing scenarios representing changes in effort across different gears were developed to reflect current trends, or the implementation of new management measures. Ecosystem effects were investigated by running simulations of individual fishing scenarios on their own and in combination with changes in phytoplankton biomass (climate change).



Further readings:

Allain, V., Phillip Jr., N.B., Griffiths, S., Macdonald, J., Scutt Phillips, J., Nicol, S., and Smith, N. 2020. EcoSEA workshop: Ecosystem modelling in the WCPO: current status and future directions. 16th Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission, WCPFC-SC16, 12-20 August 2020 EB-IP-04: 23. https://meetings.wcpfc.int/node/11742

Griffiths, S.P., Allain, V., Hoyle, S.D., Lawson, T.A., and Nicol, S.J. 2019. Just a FAD? Ecosystem impacts of tuna purse-seine fishing associated with fish aggregating devices in the western Pacific Warm Pool Province. Fish. Oceanogr. 28(1): 94–112. doi:10.1111/fog.12389.

Contributors: concept and outline of the Ecopath model: participants in the EcoSea workshop and survey (Allain et al 2020); **data provision:** Valerie Allain[1], Nicholas Ducharme Barth[1], Cyril Dutheil[3], Thomas Gorgues[3], Shane Griffiths[2], Patrick Lehodey[1,4], Jed MacDonald[1], Christophe Menkes[3], Thomas Peatman[1], Inna Senina[4], Matthew Vincent[1], Peter Williams[1]; **Ecopath model development:** Shane Griffiths[2], Colette Wabnitz[5,6]; **result analyses and report:** Valerie Allain[1], Thomas Gorgues[3], Shane Griffiths[2], Jed MacDonald[1], Simon Nicol[1], Graham Pilling[1], Colette Wabnitz[5,6]; **layout:** Boris Colas[1]

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