The influence of the natural climate variability of La Niña and El Niño events on tunas. Natural until when?[1]

El Niño is the warm phase of the El Niño Southern Oscillation (ENSO) climate pattern, originating from the tropical Pacific Ocean but influencing the world's climate. This phenomenon, which occurs every three to seven years, leads to physical and ecological impacts throughout the Pacific basin, with important connections to other oceanic basins. A typical El Niño event was first scientifically described (Bjerknes 1966)[2] as being triggered by a weakening of the trade winds leading to an eastward expansion of warm equatorial waters accumulating in the western equatorial Pacific, a region called the warm pool, with a sea surface temperature above 29°C. These warm waters reach the eastern Pacific first, and then propagate poleward along the coasts of North and South America where they replace the typically colder and more productive surface waters. The name El Niño (which refers to the Christ child in Spanish) was first linked to the time of year (around December) during which the warm waters reach the Peruvian coast with dramatic consequences on the anchovy population. When the situation reverses – with strong trade winds exceeding their average intensity and pushing the warm equatorial waters far to the west – the productivity of coastal Peruvian and Californian waters reaches a maximum intensity as does the productivity in eastern and central equatorial waters. This cold phase of ENSO is called La Niña.

We now know that the profound changes driven by ENSO – at the scale of the whole Pacific Ocean – have an impact on many ecosystems and marine resources, including changes in the distribution of tunas. El Niño or La Niña directly affect the horizontal movements and vertical distributions of the main exploited tuna and tuna-related species (e.g. skipjack, yellowfin, bigeye, albacore, swordfish and marlins). Purse-seine tuna catches and tagging data in the central western Pacific have clearly demonstrated a spatial shift in skipjack abundance that follows the eastward extension of the warm pool during El Niño, or conversely a concentration in the west during La Niña. These large east–west displacements of skipjack in the equatorial region associated with ENSO can be simulated with the spatially explicit ecosystem and fish population dynamics model SEAPODYM, which is used by the Pacific Community's Oceanic Fisheries Programme. Model results are consistent with observed changes in purse-seine fishing grounds and tagging data (Fig. 1). These results suggest that the eastward extension and westward contraction of tunas and tuna-like fish and their fisheries during El Niño and La Niña phases, are driven by changes in temperature, prey distribution (under the influence of currents), and dissolved oxygen concentration. However, not all ENSO events are equal. Despite several classical phases of development, each ENSO event is unique in terms of its intensity and impact, and the sequence of cold, neutral and warm phases. The complexity of these patterns is the focus of intense research efforts because it is the key to improving our predictive capacity for climate and for ecosystem and fisheries management. Analyses of the spatial patterns of El Niño events reveal two main types – an eastern Pacific El Niño and a central Pacific (sometimes called Modoki) El Niño. The largest El Niño event in 2015–2016 was a central Pacific event, and despite it being a strong one (Fig. 1), it did not significantly impact primary production in eastern Pacific waters as had other western Pacific El Niño events. To add to this complexity, the interannual natural ENSO variability is modulated by another natural climate signal, the Interdecadal Pacific Oscillation (IPO), which seems to be responsible for multi-decadal regimes dominated by higher frequencies of El Niño or La Niña events.

Through its various applications since the 2000s, the SEAPODYM simulations consistently pointed to a positive effect of El Niño events on skipjack larvae recruitment, and the spatial redistribution of juvenile and adult fish. Unfortunately, there are no sufficient and direct abundance surveys, such as eggs and larvae sampling, to monitor large-scale variability of tropical tuna species' larval densities. However, this variability propagates through the population structure and can be detected (with some delay) in the exploited stock, either through the analysis of catch rates and size frequencies of catch, or inferred from model and stock assessment analyses based on these datasets. The skipjack link between ENSO and larvae recruitment is confirmed by an independent estimate of recruitment (Fig. 2) of the Western and Central Pacific Fisheries Commission, which uses the standard stock assessment model MULTIFAN-CL. In that case the recruitment series is estimated from catch and tagging data, without any oceanographic information.

[1] Summarised and updated from: Lehodey P., Bertrand A., Hobday A., Kiyofuji H., Mc Clatchie S., Menkes C. E., Pilling G., Polovina J. and Tommasi D. 2020. ENSO impact on marine fisheries and ecosystems. In: McPhaden M.J., Santoso A. and Cai W. (eds). El Niño Southern Oscillation in a Changing Climate. Book Series: Geophysical Monograph Series. https://agupubs.onlinelibrary.wiley.com/doi/10.1002/9781119548164.ch19

[2] Bjerknes, J. 1966. A possible response of the atmospheric Hadley circulation to equatorial anomalies of ocean temperature. Tellus 18(4):820–829. doi: 10.3402/tellusa.v18i4.9712

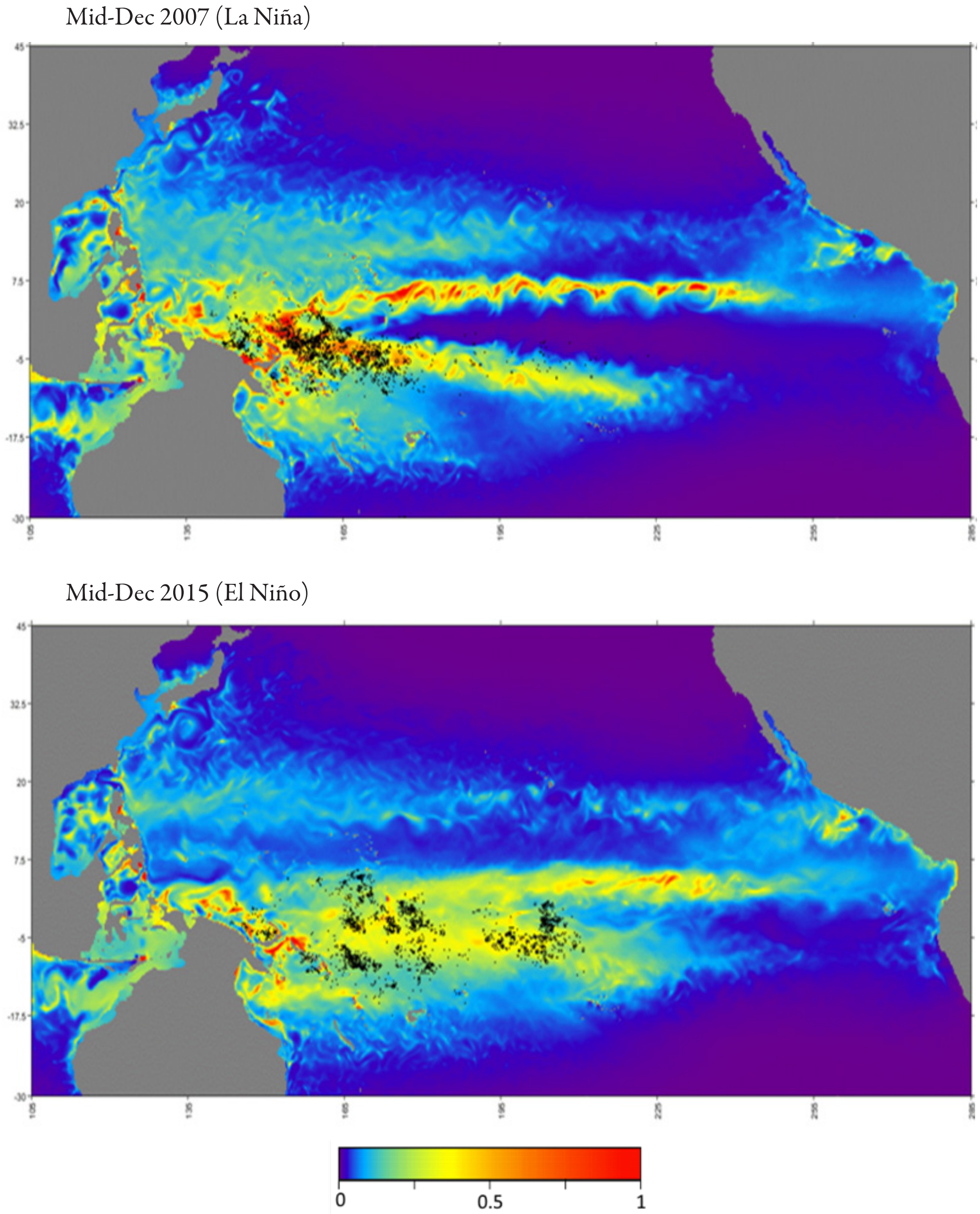

Figure 1: Impact of ENSO on distribution of Pacific skipjack tuna population and fisheries. Biomass distribution of skipjack tuna predicted with SEAPODYM (t per km^2) and observed catch (black circles) during typical La Niña and El Niño situations.

It is worth noting that the correlation between the series of skipjack recruitment and the ENSO indicator (SOI: Southern Oscillation Index) is achieved after the recruitment series has been detrended (i.e. the increasing linear average trend is removed to keep only the interannual variability). Is this tendency due to the influence of climate change? Increasing amplitudes of El Niño events since the 1980s in the central equatorial region has been reported, and the last El Niño event (2015–2016) generated an unprecedented warm temperature anomaly in this region. Its extreme intensity has been attributed in part to unusually warm water conditions in 2014 and to long-term background warming. Also, unlike in previous strong El Niño events, the 2015–2016 event was not followed by a strong La Niña phase, depriving this region of a strong subsequent recovery of the equatorial upwelling and high productivity associated with it. However, given the relatively limited period of modern observations of climatic and oceanographic conditions, it is possible that such an extreme event, and the absence of a subsequent La Niña event is still within the range of natural variability that occurred for ENSO in the last few centuries. The latest projections of ENSO under the International Panel on Climate Change business-as-usual emission scenarios suggest more frequent and more extreme and eastern Pacific El Niño events, and extreme La Niña events associated with the mean-state changes under greenhouse warming. These

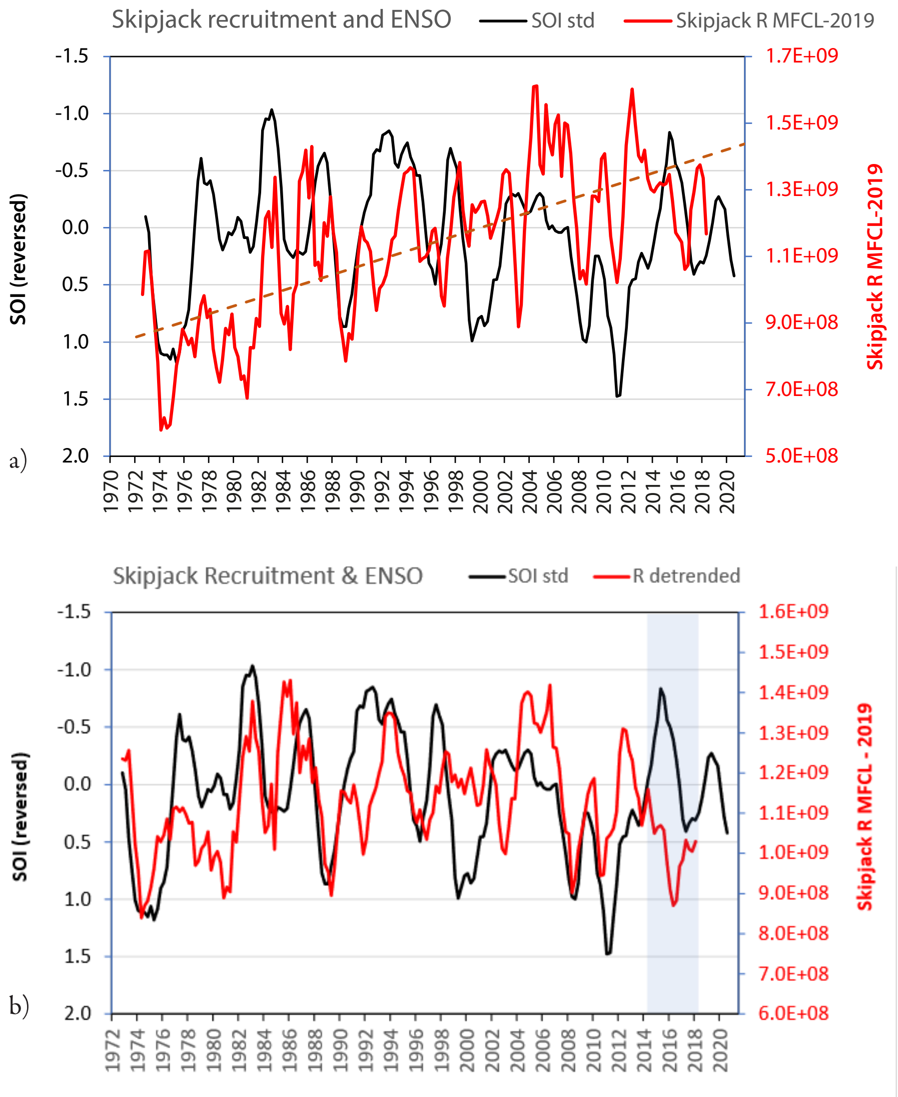

Figure 2. The impact of ENSO on Pacific skipjack tuna recruitment. Comparison of skipjack tuna recruitment index estimated in 2019 with the model MUTIFAN-CL for the Western and Central Pacific Fisheries Commission stock assessment study and the Southern Oscillation Index (SOI reversed axis). A high negative (positive) SOI index indicates El Niño (La Niña). The series are presented before (a) and after (b) detrending of the recruitment time series. Note that typically, standard stock assessment models hardly estimate the last years of recruitment (shaded area) due to the absence of information on what will become the future adult stock.

projections, however, still include many uncertainties due to model biases.

New simulations are currently being carried out with SEAPODYM to analyse recent changes in the dynamics of tuna populations and fisheries, and to compare these results with stock assessment results. The focus of the analyses is not just on the highly tropical skipjack species that seem to thrive in a warming ocean, at least so far, but also more subtropical to temperate tunas, especially albacore. This species might have the most to lose from the warming of the ocean, which would impact its subequatorial spawning grounds.

The recent La Niña that has been experienced in recent months will also provide another good benchmark to test the model's predictive skills.

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