Comparing Eastern Pacific Albacore and Yellowfin Tuna Abundances Across Strong El Nino and Strong La Nina Years

Matt Guanci

5/2/2022

Abstract

In this study averaged abundances for both Albacore and Yellowfin tuna are being compared across extreme El Nino Southern Oscillation year events in the eastern Pacific Ocean. Catch per unit of effort (CPUE) is being used as a proxy for abundance. it has been shown that Albacore prefer cooler temperate waters where Yellowfin prefer warmer waters and it is predicted that these species will respectively shift thier distribution and abundances in response to the warmer and cooler waters that respective strong El Nino and La Nina events bring to the eastern Pacific Ocean.

Introduction

The Eastern Pacific tuna fishery is one of the more economically important fisheries in terms of both economic value and international participation. Overall, 26 nations fish for tuna in this region. Annually 6.5 thousand metric tons of tuna from the Eastern Pacific are bought to the world markets with a value of $1.1 billion USD (Pew Charitable Trusts 2016).

Much of the productivity in the region is driven by coastal upwelling and the El Nino southern oscillation (ENSO) cycles. This oscillation is an irregular fluctuation that spans the whole of the tropical Pacific Ocean. El Niño events occur at two-to-seven-year intervals and vary in strength. They are characterized by weaker trade winds, deeper thermoclines due to increased stratification, and abnormally higher than normal sea-surface temperatures (SSTs) in the equatorial Eastern Pacific Ocean. The opposite phase, known as La Niña, is characterized by stronger trade winds, shallower thermoclines, and lower SSTs. These events likewise vary in strength. (Griffins and Fuller 2019). Of particular interest in the IATTC region is the Peruvian coast and adjacent high seas areas. Here, a strong seasonal upwelling drives productivity. The effects ENSO events affect the upwelling in this region however local effects may counter the sea surface anomalies characteristic of ENSO phases. These localized effects are only thought to extend to 100 km offshore. (Quispe-Calluari et al 2018).

Of the five species of tuna commercially caught in this region two were selected for study in this paper. These are the Albacore tuna (*Thunnus alalunga*) and the Yellowfin tuna (*Thunnus albacares*). These two species are commercially caught in the Eastern Pacific Ocean and have overlapping ranges and similar diets. They are also commercially harvested in the same manner; purse seining and longline sets being the most common methods of doing so (IATTC 2020).

Yellowfin tuna can often be found in large schools and are often intermixed with other species such as Skipjack. This species can be found across a wide range of latitudes; from 40 degrees N and S in the Western Pacific and narrowing slightly in the Eastern Pacific (Fishbase 2021). These fish prefer preference warmer waters and shallower depths above the thermocline and prefer water temperatures between 21-28 degrees C (Allain 2016). Unlike most other Pacific tuna species, Albacore tuna prefers temperate waters and eschew equatorial regions (Zhou et al 2020). They can be found at depths ranging from the surface to below 380 meters (Collette and Nauen 1983).

Because of the evident disparity in preferred environmental conditions between Yellowfin and Albacore, these two species, they were chosen as focal species for this study.

The hypothesis for this work is that there will be a visible difference in distribution and abundances between the two species as water temperatures in the equatorial Eastern pacific warm and cool in relation to ENSO cycles.

Data Sources and Methods

All catch data for this project was obtianed from the Inter_American Tropical Tuna Commission website at https://www.iattc.org/PublicDomainData/IATTC-Catch-by-species1.htm. EL-Nino Southern Oscillation data was obtained from the Golden gate Weather Service website at https://ggweather.com/enso/oni.htm. GGOceanMap data was downloaded from https://mikkovihtakari.github.io/drat“,”https://cloud.r-project.org. Data was processed and graphed using R version 4.1.1 (2021-08-10).

For this study, longline catch data ranging from 1953 to 2021 was obtained from the Inter-American Tropical Tuna Commission (IATTC) website. This data cataloged monthly longline catch between the described years for all regulated species including Yellowfin and Albacore. Data was listed by factors such as year, month, and location narrowed down to five degree latitude by five degree longitude. Longline data was chosen in lieu of purse seine data due to the fact that longline fishing methods can target fish at differing depths and do not rely on schooling behavior in order to catch fish. Purse seine vessels, which rely on fish schooling in a localized area, also use methods such as fish aggregating devices (FADs) in order to induce schooling (Ellis 2008). This may give a false picture of the actual abundances of target species present in an area.

Catch data was converted catch into Cost per Unit of Effort (CPUE). CPUE is an indicator of how much work is being put forth to catch fish. It has no set units, rather the parameters are dictated what data is being sought. CPUE may take the form of man hours worked per unit of catch, fishing vessels used, or number of casts or sets performed as compared to their resulting catch. In this study we are looking at the number of fish caught as compared to the number of hooks set as a measure of both CPUE and an indicator of abundance This is not the best measure as it assumes uniform effort across the Eastern Pacific and accurate reporting by all vessels. However, given the vastness of the area ans scarcity of other relevant data, it is a relatively easy analysis to perform to give an idea of tuna species abundances.

Because ENSO years are offset from calendar years by six months, it was necessary to converted calendar catch years into ENSO event years. ENSO years start June 1st and end May 31st of the following year. Therefore, calendar years were advanced six months in order to accurately capture ENSO years. For example, ENSO year 1972 was originally calendar year June 1971-May 1972. The overall catch data was then grouped by ENSO event years. For example, 2010 was a year featuring a strong La Nina. Catch data for the ENSO year 2011 was grouped with other Strong La Nina years. In addition to the strong El Nino/La Nina event year groups, a third group was also used. Years identifying with weak El Nino events were also included. This was done to give a idea of what Albacore and

Yellowfin abundances are in the absence of strong ENSO events. The following ENSO event year groups were used:

Strong El Nino: 1958, 1966, 1973, 1983, 1988, 1992, 1998, 2016
Strong La Nina: 1974, 1976, 1989, 1999, 2000, 2008, 2011
Weak El Nino: 1953, 1954, 1959, 1970, 1977, 1978, 1980, 2005, 2007, 2015, 2019

CPUE for individual species was averaged by 5x5 degree Lat/Long grid square across all like ENSO event years. This average CPUE was multiplied by 1000 to give an adjusted number. All CPUE averages were plotted as contour lines by species and ENSO event year group on baseline maps using the GGOceanPlot R package. A multiple regression analysis was done for each set of data to determine r(squared) and p values.

Results and Conclusion

Results overall showed differing distributions for each species across ENSO events. For Albacore, during strong El Nino years (Figure 1) this species was generally found far to the south with some apparent abundance around the Cook Islands (approx 10 South, 140 West) and off central Mexico SW of Socorro Island. The higher concentrations in the southern temperate waters were expected owing to the influx of warm waters into the eastern Pacific. As previously stated, Albacore prefer cooler deeper waters.These fish have also been observed to have two separate populations, one on either side of the equator with little mixing between them (Zhou et al 2020). The reason for the remaining populations around the Cook Islands and Socorro Island is unclear however the prey availability associated with these locations may outweigh temperature preference for some populations of this species.

This is contrasted with Albacore abundances during strong La Nina years (Figure 2). Here it is apparent that the tuna have moved closer to the equatorial regions as well as closer to the coastline likely to take advantage of the stronger coastal upwelling and cooler sea water temperatures. However, the separation between the northern and southern populations remains readily observable with little reported catch within ten degrees north or south of the equator. Figure 3, the Albacore distribution of abundance during “normal” years also readily shows this separation. It also shows these tuna being, in some cases, further offshore but still remain close to coastal upwelling zones with similar distributions as those of strong La Nina years.

Though this seems to readily confirm the split in Albacore populations cited by Zhou et al and other authors, this study may not be an accurate picture of the actual abundances. The data presented is based on CPUE by location which is a measure how much effort fishing vessels are cumulatively putting into catching albacore at any given place in the eastern Pacific. Being interested in earning a healthy profit, most fishermen will selectively fish in areas they know their target species are likely to be (Hu et al 2018). Therefore, vessels targeting Albacore may tend to put more effort into temperate areas ignoring likely small but present populations in more tropical regions.

The data as a whole does suggest that Albacore are responding to changes in sea conditions caused by differing ENSO events. However, this is far from conclusive. Multiple regression analysis for strong El Nino showed a r(sq) value of 0.11 and a p value of zero. Likewise, the strong La Nina analysis showed a r(sq) value of 0.025 and a p of 0.065. Finally, weak El Nino showed a r squared value of 0.138 and a p value of 0. Overall, this means almost no explanation in variance between these variables. However, p values are also low so there was some fit of the data to the model.

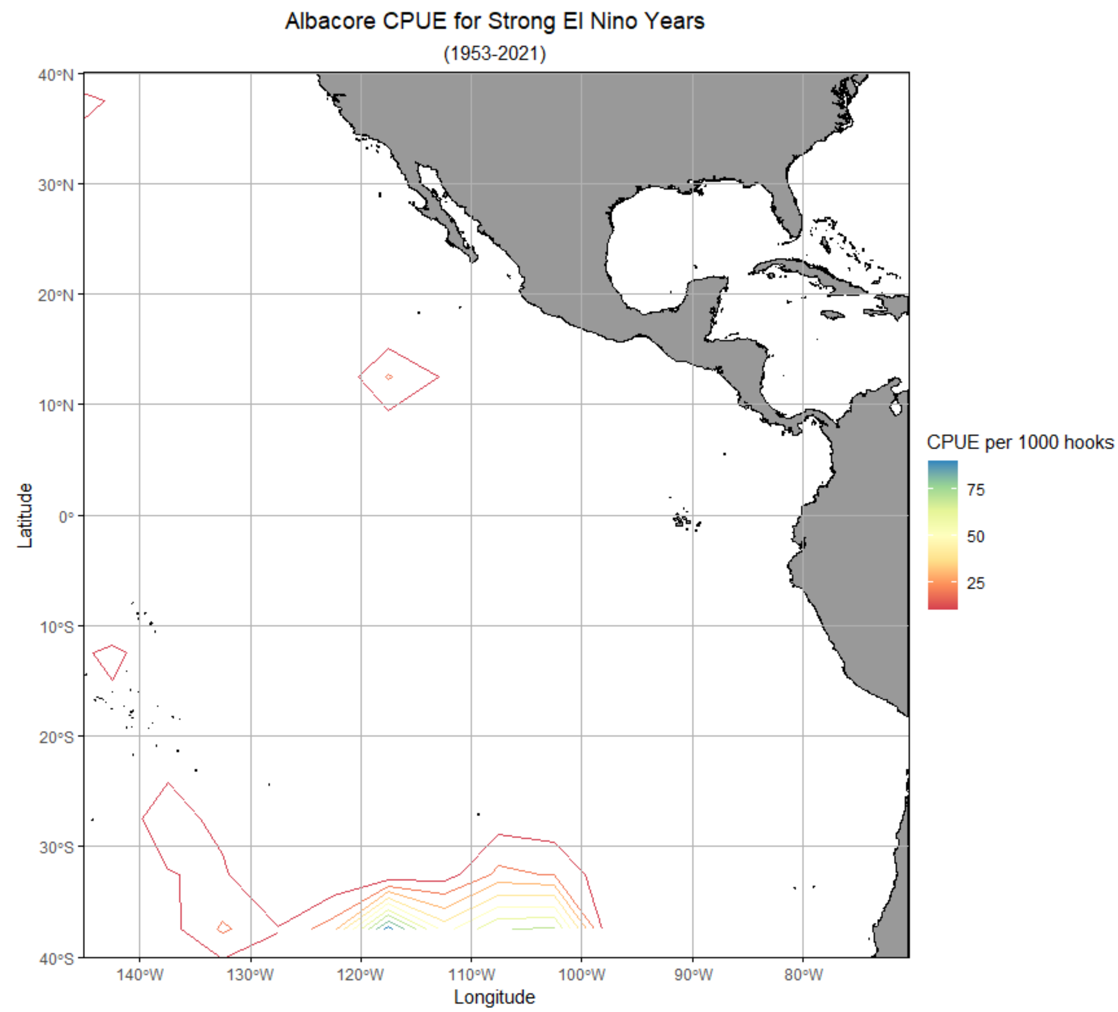

Figure 1: **Albacore CPUE for Strong El Nino Years:** This figure shows the Albacore being found primarily well south of the equatorial region. This is seemingly consistent with the hypothesis that these fish will avoid the warmer equatorial waters that strong El Nino years bring and congregate in cooler temperate waters. These abundances are also found well off the coast away from the lessened upwelling. However a multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of only 0.11 and a P value of close to zero.

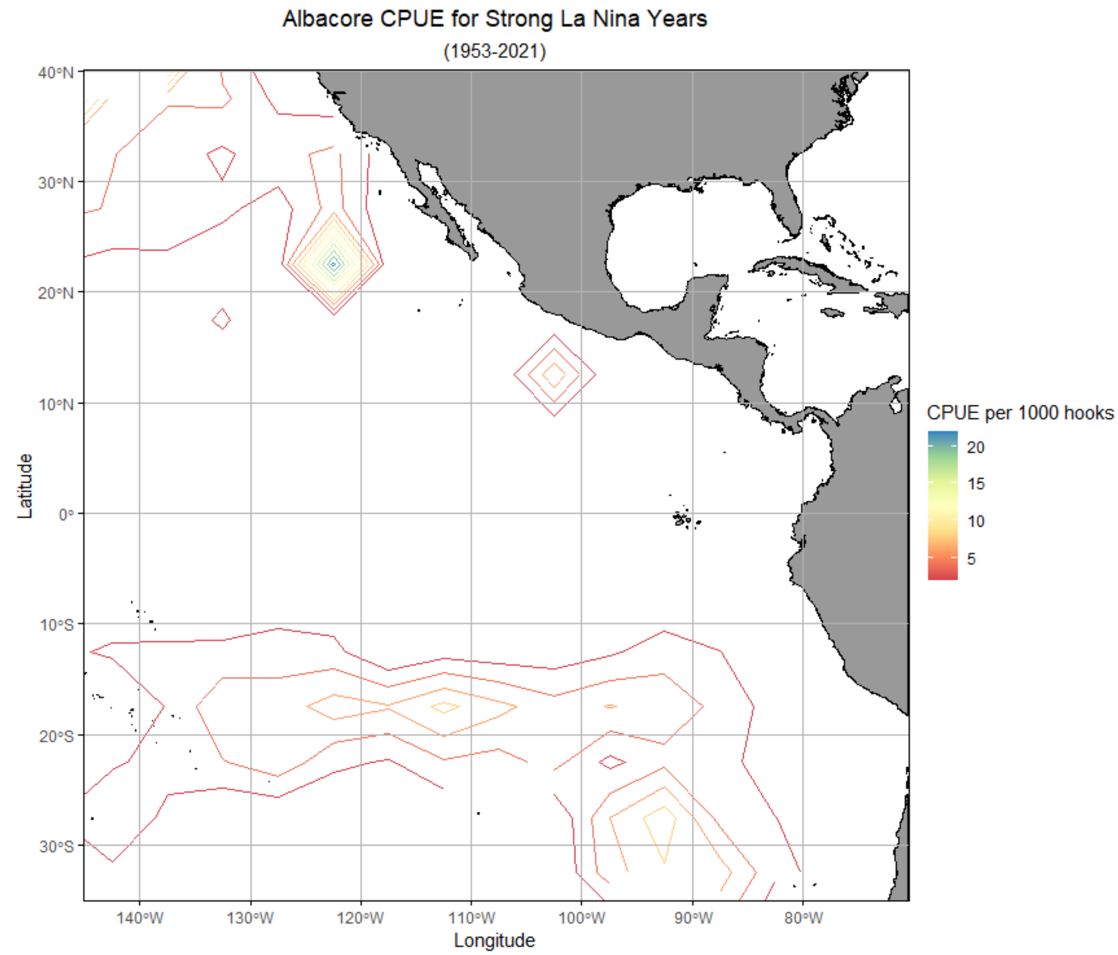

Figure 2: **Albacore CPUE for Strong La Nina Years:** This figure shows the Albacore abundances during strong La Nina years. Populations are found closer to equatorial regions. This is again consistent with the hypothesis that the cooler tropical waters resulting from increased upwelling and increasing trade winds resulting from strong La Nina phenomena will bring Albacore to lower latitudes. Again, a multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of only 0.025 and a P value of 0.065.

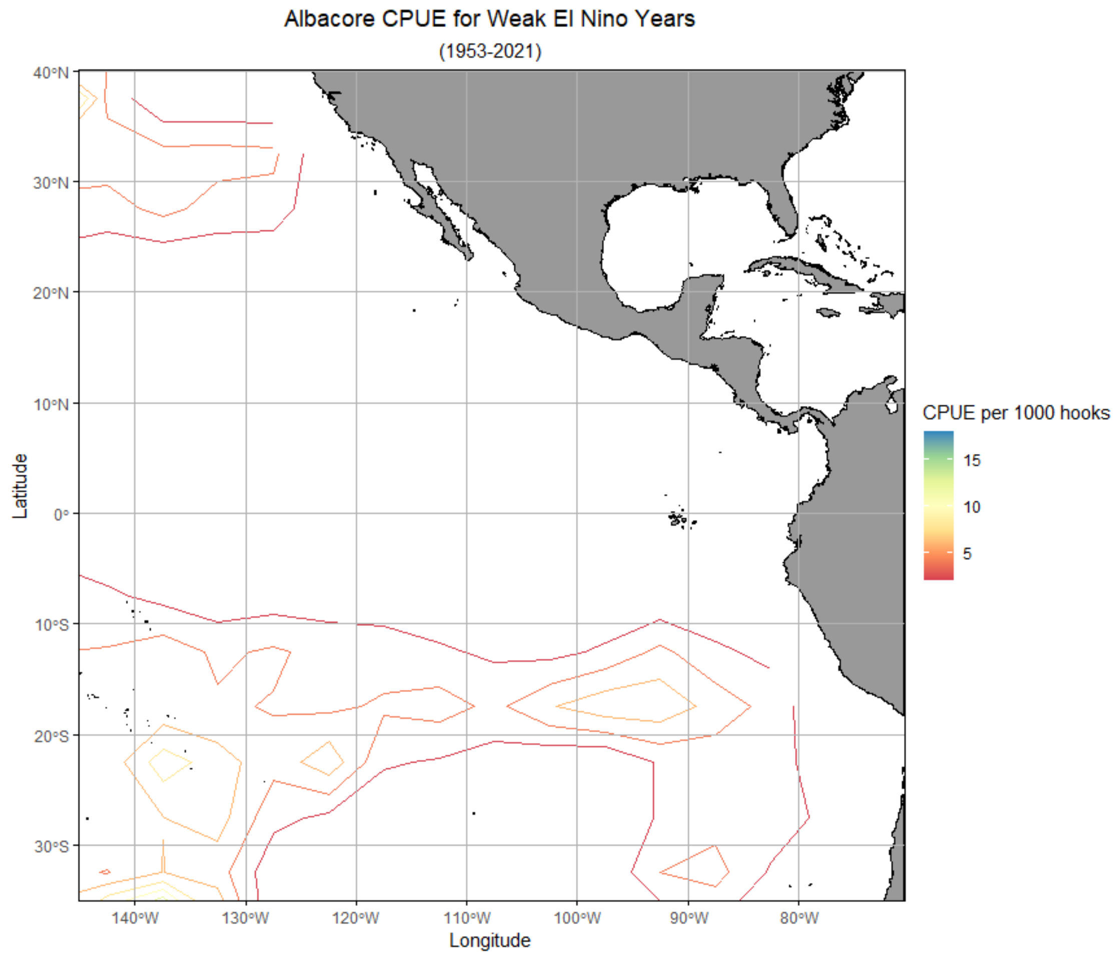

Figure 3: **Albacore CPUE for Strong La Nina Years:** This figure shows the Albacore being more normally distributed in the temperate waters North and South of the equator close to upwelling regions with slightly smaller abundances than strong La Nina years. Multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of 0.138 and a P value of 0.

Yellowfin tuna also showed marked differences in distribution and abundance across ENSO events. For strong El Nino years (Figure 4), there was a fairly strong abundance of this species across the eastern Pacific equatorial region. One strong concentration is in the upwelling region off the coast of Peru. This a little surprising as Strong El Nino years tend to be catastrophic for production at all trophic levels (Espinoza-Morriberón et al 2017). However, this is an average across all Strong El nino years with some variation in conditions between them, some upwelling was likely in evidence for at least part of the year and productivity remained high enough to support apex predators such as Yellowfin. In addition to the upwelling region off Peru, noted concentrations include the area close to position 12N 112W, the already noted area near Socorro island that Albacore also congregate, and an area near position 5N 104W. This latter area coincides with a seamount, not shown in Figure 4. These areas are where both food items would readily be available, and, not incidentally, fishing vessels are likely to target giving the high CPUE shown for these spots.

For Strong La Nina years, Yellowfin abundance and distribution becomes patchy with a large concentration near 23N 123W (Figure 5). Other than the presence of some relativity shallow seamounts in this region, it is unclear why this spot had such a high concentration in strong La Nina years. There is also an increased concentration around the Peruvian upwelling zone. This is expected as there will be increased upwelling during strong La Nina years with accompanying increased productivity.

For weak El Nino years (Figure 6), the abundances for Yellowfin are, like Albacore, more evenly distributed across their expected waters. In this case, the warm water preferring Yellowfin are distributed acorss equatorial waters with a high concentration near the Peruvian upwelling zone. Overall the abundance and distribution of these fish agree with the hypothesis that there are marked differences in these variables across strong ENSO event years.

Multiple regression analysis shows a slightly different take. Strong El Nino showed a r(sq) value of 0.011 and a p value of 0.314. Strong La Nina analysis showed a r(sq) value of 0.059 and a p of 0.001. Finally, weak El Nino showed a r squared value of 0.014 and a p value of 0.233 Overall, this means almost no explanation in variance between these variables and some to no model fit.

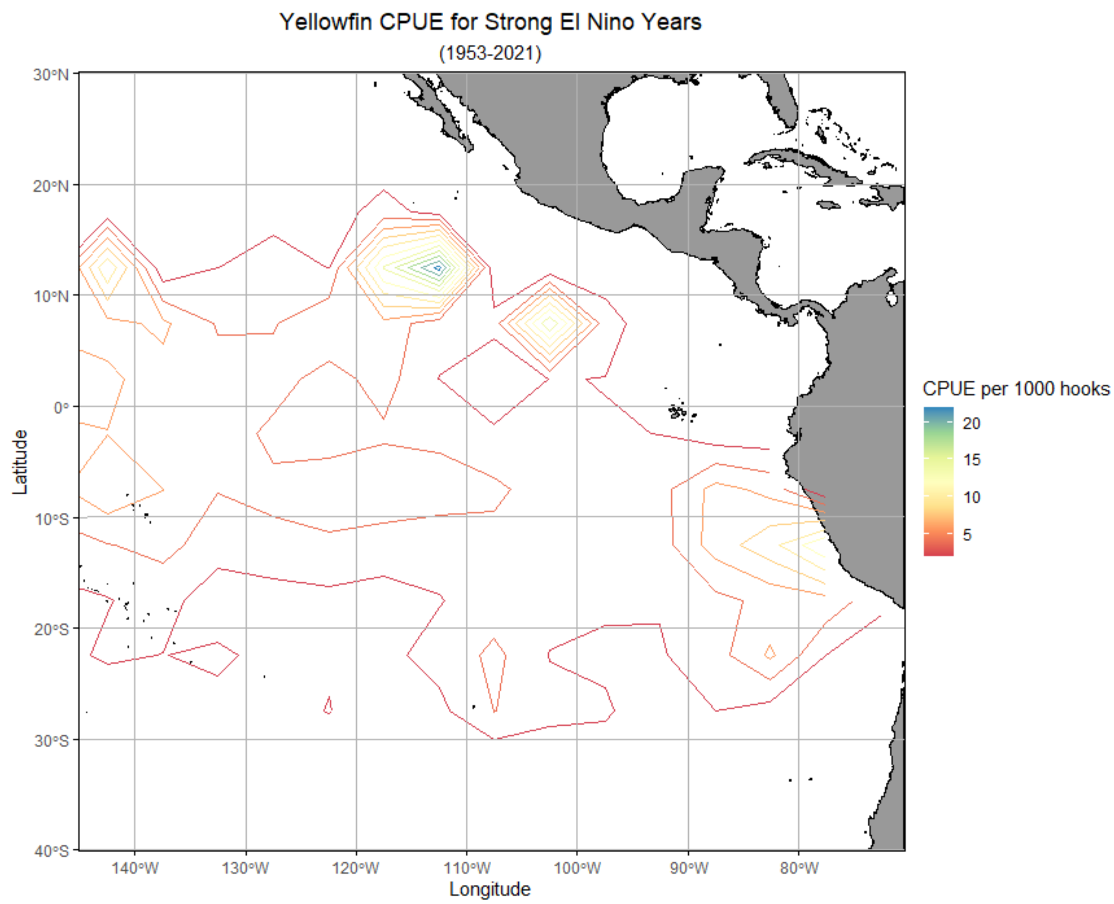

Figure 4: **Yellowfin CPUE for Strong La Nina Years:** For strog El Nino years, Yellowfin show a strong concentration in topical waters coinciding with the warmer waters resulting from strong El Nino events. There is also a noted concentration off the coast of Peru, a famous upwelling zone. Multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of 0.011 and a P value of 0.314.

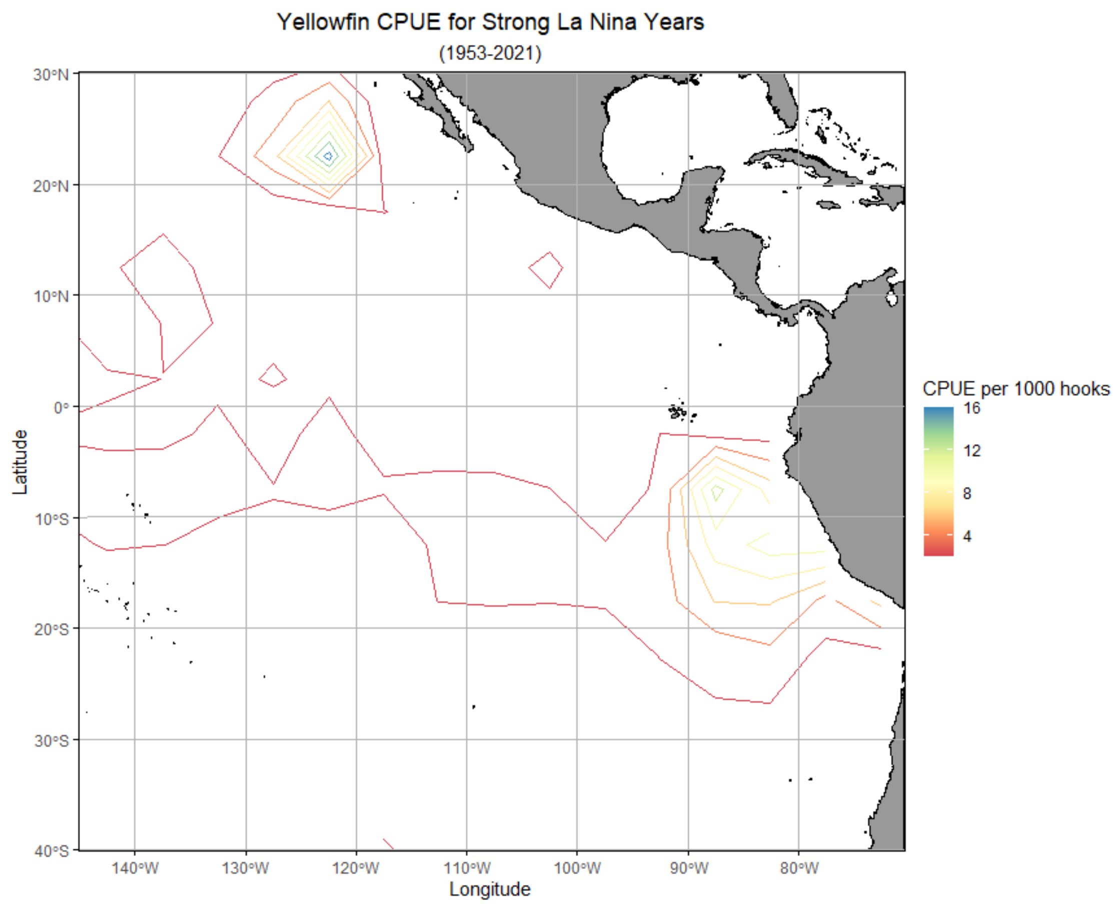

Figure 5: **Yellowfin CPUE for Strong La Nina Years:** This figure shows Yellowfin abundances during strong La Nina years. Here, there is a patchier distribution of Yellowfin with notably strong concentrations in or adjacent to coastal upwelling zones. Multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of 0.059 and a P value of 0.001 again shows almost no correlation between geographic position and CPUE.

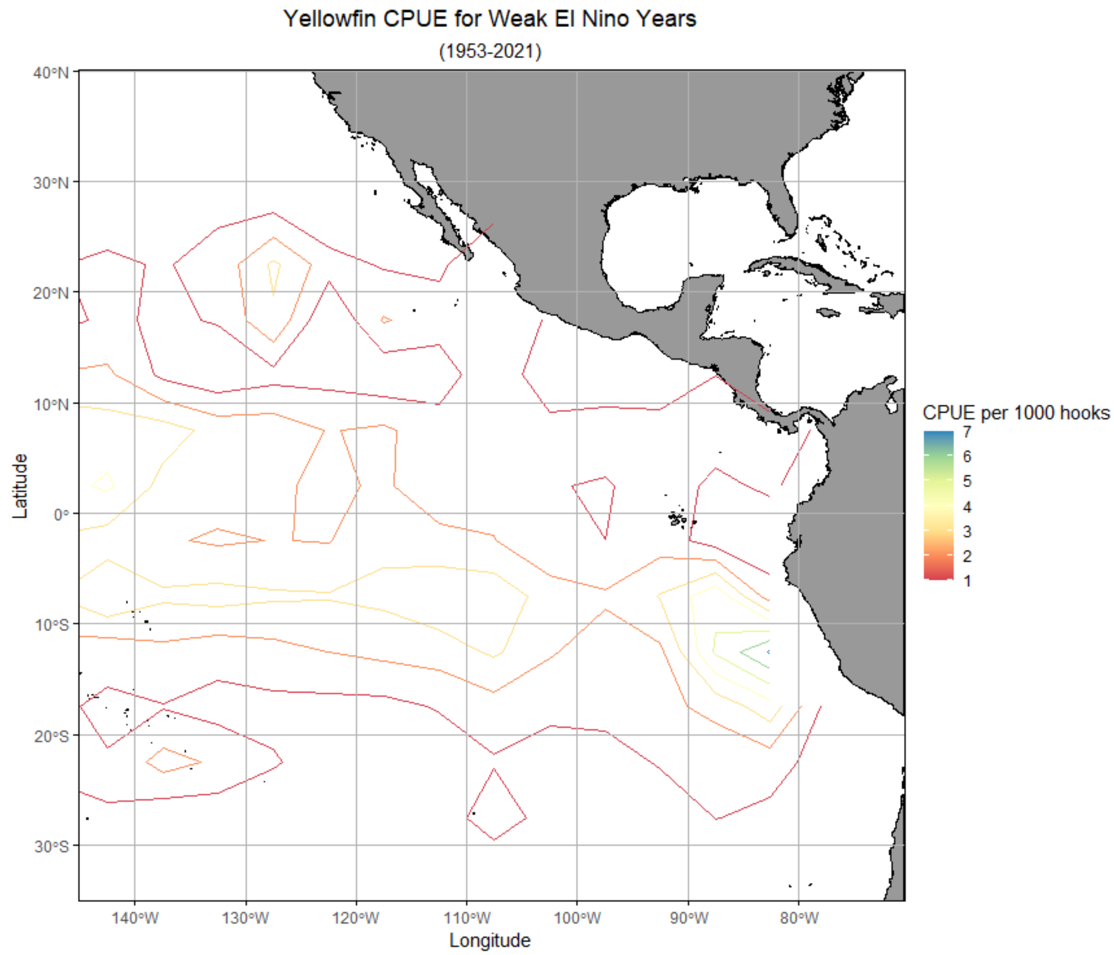

Figure 6: **Yellowfin CPUE for Strong La Nina Years:** This figure shows Yellowfin being more normally distributed in their preferred habitat, the tropical waters North and South of the equator. Smaller abundances can likely be accounted by the wider distribution of these fish across the region. Multiple regression analysis between latitude, longitude, and CPUE shows a multiple r squared of 0.014 and a P value of 0.233.

In conclusion, the plotted contours shown in Figures 1 to 6 tended to agree with the hypothesis that there would be differing distributions across extreme ENSO event years for Albacore and Yellowfin tuna. However the statistical analysis was far from backing this up with very little to no correlation shown between geographic location (lat/Long) and CPUE in most cases. This may be a product of the simplistic approach to this analysis or because of the variances in data form location to location. Overall, the two species do appear to respond to ENSO events by shifting abundances and distribution across the eastern Pacific. This is particularly true if the weak El Nino distributions are what would be normal or near normal distributions for Albacore and Yellowfin. Despite this, further work should be done to reconcile the statistics with the overall picture of how these fish respond to ENSO events.

References

Collette, B. and Nauen C. (1983). FAO Species Catalogue. Vol. 2. Scombrids of the World. An Annotated and Illustrated Catalogue of Tunas, Mackerels, Bonitos and other Related Species known to date. FAO Fisheries Synopsis. Accessed 01Nov21 at: http://www.fao.org/3/ac478e/ac478e00.pd

Ellis, R. (2008). Tuna. Love, Death, and Mercury. Vintage Books. 183-214.

Espinoza-Morriberón, D., Echevin, V., Colas, F., Tam, J., Ledesma, J., Vásquez, L., and Graco, M. (2017), Impacts of El Niño events on the Peruvian upwelling system productivity, J. Geophys. Res. Oceans, 122, 5423– 5444, doi:10.1002/2016JC012439.

Fishbase. (2021). https://www.fishbase.se/Summary/ SpeciesSummary.php?ID =142&AT=albacore+tuna. Accessed on 01Nov21.

Griffins, S. and Fuller. L. (2019) Inter-American Tropical Tuna Commission Scientific Advisory Committee Tenth Meeting San Diego, California (USA) 13-17 May 2019 Document Sac-10-14 Ecosystem Considerations. Inter-American Tropical Tuna Commission.

Golden Gate Weather Service (2022). El Nino and La Nina Years and Intensities. https://ggweather.com/enso/oni.htm. Accessed on 4/23/2022.

Hu, Harrison, D. P., Hinton, M. G., Siegrist, Z. C., & Kiefer, D. A. (2018). Habitat analysis of the commercial tuna of the Eastern Tropical Pacific Ocean. Fisheries Oceanography, 27(5), 417–434. https://doi.org/10.1111/fog.12263

Inter-American Tropical Tuna Commission. (2022). IATTC - Public domain data files for download. https://www.iattc.org/PublicDomainData/IATTC-Catch-by-species1.htm. Accessed on 4/23/2022.

Quispe-Calluari, Tam, J., Demarcq, H., Chamorro, A., Espinoza-Morriberón, D., Romero, C., Dominguez, N., Ramos, J., & Oliveros-Ramos, R. (2018). An index of coastal thermal effects of El Niño Southern Oscillation on the Peruvian Upwelling Ecosystem. International Journal of Climatology, 38(7), 3191–3201. https://doi.org/10.1002/joc.5493