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Fisheries

Relationship between, and prediction of, the annual catch of bigeye tuna and climate factors

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The trend between predicted values and actual values of the model used is generally consistent, with good performance supporting the management of bigeye tuna fisheries

Study evaluated the relationship between the annual catch of bigeye tuna and climate factors and its prediction. The trend between predicted values and actual values of the model used is generally consistent, with good performance supporting the management of bigeye tuna fisheries, providing scientific evidence for the sustainable development of bigeye tuna fisheries and improved understanding of the long-term impact of climate change on bigeye tuna. Photo by Marc Taquet (CC BY 4.0, https://creativecommons.org/licenses/by/4.0, via Wikimedia Commons).

The bigeye tuna (*Thunnus obesus*) is widely distributed in the deep waters of tropical and subtropical regions across the three major oceans and represents a significant economic species for pelagic fisheries. Current global research on bigeye tuna primarily focuses on analyzing the spatial distribution of fishing grounds and resource abundance in relation to marine environmental and climatic factors. **Various researchers** (https://doi.org/10.3389/fmars.2024.1344966) have identified key marine environmental factors affecting the distribution of bigeye tuna fishing grounds yet failed to consider the impact of climate change. However, other climate factors besides El Niño, such as the Pacific Decadal Oscillation, also influence bigeye tuna catch rates.

Several studies have developed models to predict bigeye tuna distribution based on environmental factors; however, these models are limited by the quality of the data and the challenges of handling long-term climate trends. Traditional models for sequence prediction in existing research have high data quality requirements, and inappropriate historical values can lead to significant prediction errors. Most machine learning methods employed in these studies use single learning models, which struggle with nonlinear and unstable long-term periodic time series, offering only rough trend estimations. Given that climate change typically spans several decades or longer, current **research on bigeye tuna** (https://epic.awi.de/id/eprint/37530/) primarily focuses on marine environmental factors rather than regional or global climate variables.

Most studies cover short-term periods of <10 years, limiting their ability to reveal the impacts of climate change on fisheries. A comparative study of the predictive capabilities of various existing models for bigeye tuna catch volumes based on climate factors has yet to be conducted. This study fills this gap by employing long-term series data of low-frequency climate change parameters for correlation analysis.

This article – **summarized** (https://creativecommons.org/licenses/by/4.0/) from the **original publication** (https://doi.org/10.3389/fmars.2024.1344966) (Ding, P. et al. 2024. The relationship between the annual catch of bigeye tuna and climate factors and its prediction. *Front. Mar. Sci.* 11:1344966) – reports on a study that developed a prediction model to explore the long-term impacts of climate change on bigeye tuna catch rates, to provide scientific references for the sustainable development of bigeye tuna fisheries in the open ocean.

Study setup

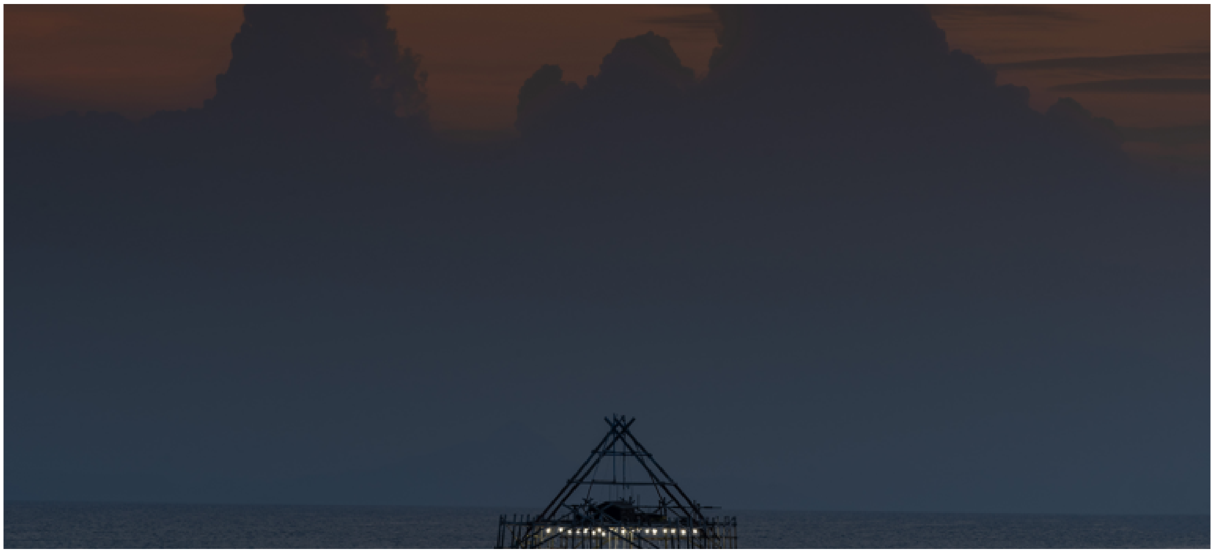
To explore the impact of climate factors on bigeye tuna catch, monthly data of several climate factors – including El Niño-related indices (Niño1 + 2, Niño3, Niño4, and Niño3.4), Southern Oscillation Index (SOI), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), North Pacific Index (NPI), and global sea–air temperature anomaly index (dT) – were combined with the annual data of global bigeye tuna catch. The data was used to study the relationship between low-frequency climate factors and bigeye tuna catch using various prediction models.

The global annual catch data of bigeye tuna were obtained from the Western & Central Pacific Fisheries Commission (**WCPFC** (https://www.wcpfc.int/doc/wcpfc-tuna-fishery-yearbook-2021)) for the period from 1960 to 2021. While the data are considered global, it is essentially derived from the three major oceans (Pacific, Atlantic and Indian Oceans).

Climate change characterization factor data, including El Niño-related indices (Niño1 + 2, Niño3, Niño4, and Niño3.4), Southern Oscillation Index (SOI), North Atlantic Oscillation (NAO), Pacific Decadal Oscillation (PDO), and North Pacific Index (NPI), were obtained from the National Oceanic and Atmospheric Administration (**NOAA** (https://www.esrl.noaa.gov)).

The global sea–air temperature anomaly index (dT) was obtained from the Hadley Centre of the UK **Meteorological Office** (https://www.metoffice.gov.uk). All climate factor data were monthly data for the period from 1960 to 2021.

For detailed information on the experimental design, data collection and models used, and data analyses, refer to the original publication.



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Results and discussion

In this study, the Spearman rank correlation analysis – a measure of statistical dependence between two variables – was used to select six independent climate change characterization factors, including Niño1 + 2, SOI, NAO, PDO, NPI and dT. The optimal lag years (usually there is a lag, regularly of several years, between the year of fisheries data being collected and when it becomes available to fisheries managers) of these factors in relation to the catch of bigeye tuna were found to be 15 years, 12 years, 12 years, one year, 14 years and four years, respectively. The longest lag year was for Niño1 + 2 (15 years), while the shortest was for PDO (1 year).

This is different from the three-month lag years of ENSO observed by other researchers, which might be due to the long duration and wide range of the catch of bigeye tuna used in this study. This also confirms the **lag effect of climate change** (https://www.cabidigitallibrary.org/doi/full/10.5555/20220303149) on fisheries, which may be due to the indirect impact of climate change on fisheries through changes in the marine environment.

The lag phenomenon may be attributed to the lag effects of climate change on marine and climate factors, food supply, survival rate of larvae and habitats, which subsequently influence the spawning and recruitment of bigeye tuna), thus affecting their catches. Furthermore, studies have found that the distribution, reproduction, catch yield, and spatial distribution of fish populations are closely related to these factors.

The three main climate change characterization factors that affect the catch of bigeye tuna are Niño1 + 2, dT, and SOI, accounting for approximately 70 percent of the six climate change characterization factors. These findings are generally consistent with the results of other scholars, indicating that the El Niño-Southern Oscillation phenomenon has a significant impact on the bigeye tuna fishery. This may be attributed to the fact that bigeye tuna is a warm-water species that is greatly influenced by temperature, having specific requirements for water temperature during their habitat and spawning periods. During El Niño, the upper boundary of the thermocline (distinct layer based on temperature within the ocean, with a high gradient of distinct temperature differences associated with depth) is shallower and weaker compared to La Niña, resulting in a smaller suitable habitat, which leads to higher catch of bigeye tuna in La Niña years.

During El Niño, the reproduction of plankton decreases, reducing the nutrient content in the water column, resulting in less nutrition for bigeye tuna and lower catches. Conversely, in La Niña years, the proliferation of plankton increases, improving the nutrient content of the water column, allowing bigeye tuna to obtain more nutrition, and leading to higher catches. In terms of the sea-air temperature anomaly index (dT), climate change affects the recruitment of fish populations by **influencing sea water temperature** (https://doi.org/10.4319/lo.2001.46.7.1774). The lag phenomenon may be due to the indirect effects of climate factors on the catch of bigeye tuna through influencing marine and climate factors, recruitment, habitats, and spatial–temporal distribution, thus exhibiting a certain degree of lag.

The climate factors selected in this study – including Niño1 + 2, SOI, NAO, PDO, NPI and dT – have significant impacts on fisheries, as reported by previous studies, including the a significant impact of the ENSO phenomenon on the spatial distribution and resource abundance of Chilean jack mackerel; the NAO effects on the recruitment of cod by influencing sea water temperature; the strong correlation between the migration duration of red salmon and NPI; and others.

This study explored the impact of climate change characterization factors as the only influencing factors on the catch of bigeye tuna, highlighting the importance of climate factors in fisheries. This is consistent with the proposal by **some scholars** (https://doi.org/10.5194/adgeo-42-83-2016) to use climate factors to help manage fisheries and plan for the industry in the long term. Overall, the results of this research provide valuable insights into the integration of different regression models for fisheries prediction and presents a novel approach to modeling fisheries data.

Perspectives

This study investigates the effect of climate change factors as the sole influencing factor on the catch of bigeye tuna, highlighting the climatic reasons behind the variations in the abundance of bigeye tuna resources and fishing grounds. This approach differs from those that consider climate change characterization factors as one of the influencing factors or discuss the issue during climate transitions. Moreover, the use of long-term (low frequency) climate change parameters to study the impact on bigeye tuna is distinct from short-term research focusing on marine environmental factors.

By discussing the long-term impact of climate change on the catch of bigeye tuna from the angle of climate change with a long time series, this study can provide scientific evidence for the sustainable development of the bigeye tuna fishery and understand the long-term impact of climate change on bigeye tuna.

The findings of this study can provide a reference for developing scientific and effective fishery management measures for bigeye tuna. However, it is worth noting that due to the lack of data such as fishing gear information and operating hours, there are limitations in calculating catch per unit effort

(CPUE). Future research could continue to delve deeper into this area after supplementing relevant data.

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