# Interannual variability of skipjack abundance in Puerto Angel, Oaxaca, Mexico

***Mexico Oaxaca artisanal skipjack and black skipjack tuna – handline***


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## Thanks

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**Index**

### *List of figures*



### *List of tables*

# INTRODUCTION

Tuna are a group of marine fish of the Scombridae family , which have pelagic habits and are found mainly in the epipelagic zone and rarely below 200 m depth. The fish of this genus have a fusiform, streamlined body and a lunar tail end, common to all tuna-like fish. Young tunas form large schools near the surface; while adults prefer deeper waters, although they are also found near the surface ( Blackburn, 1965 ).

The genus *Euthynnus* includes three species, *E. affinis* , *E. alletteratus* and *E. lineatus* , distributed mainly in tropical waters. *E. lineatus* lives in the epipelagic, neritic and oceanic zones, it is distributed in tropical and subtropical waters of the Eastern Pacific Ocean ( Allen & Punsly , 1984 ). It has a wide distribution, from California to the Galapagos Islands and Northern Peru, being found most frequently along the coasts of Mexico and Central America ( Ruíz- Dura , 1978 ). The genus *Euthynnus* can be distinguished from *Katsuwonus* , by the presence of a series of oblique or longitudinal black marks on the lateral line. The dorsal fins are contiguous or very close to each other. This last characteristic distinguishes *Euthynnus* from the genus Auxis , whose dorsal fins are widely spaced.

Although *E. lineatus and K. pelamis* carry out large-scale migrations, it is not considered within the group of tunas classified as “highly migratory”, since their migrations are associated with continental shelves ( FAO, 1994 ). However, they are very active pelagic fish with a large amount of energy that allows them to cross long distances in a short time ( Olson & Boggs, 1986 ), therefore, the availability of food is a determining factor in the abundance and distribution of these species ( Stretta , 1991 ). For *E. lineatus,* different body lengths have been recorded for organisms from the coastal zone, captured by coastal fisheries ( Espino-Barr et al., 1990; Ramos-Cruz, 2009; Ramos-Carrillo et al., 2015; Ruis -Pérez et al., 2016 ). The total lengths reported have been found from 29.40 to 69 cm, with a multimodal distribution ( Espino-Barr et al., 2003; Hernández-Covarrubias et al., 2016 ). For its part, the total weight has been found in the range of 0.28 to 5.48 kg, with averages of 1.40 to 1.80 kg ( Espino-Barr et al., 2003; Ramos-Carrillo et al., 2015; Hernández-Covarrubias et al. ., 2016 ). Regarding relative growth, Velásquez-Polanco (2017) reports that skipjack has negative allometric growth , since it grows first in length and then in weight. In addition, this author found, by using the first spine of the dorsal fin, he estimated the age of the skipjacks on the coast of Oaxaca, finding up to 10 age groups (2-11 years). In general, *E. lineatus* grows rapidly in the first six years of life, reaching a furcal length of 42-43 cm, while after the seventh year until 11 years of age, the average furcal length is very similar (47-43 cm). 49 cm) ( Velásquez-Polanco, 2017 ).

In Mexico, the tuna fishery is the second most important in commercial value and volume, after shrimp and sardine respectively. Tuna fishing represents a source of food, direct and indirect employment, trade and economic well-being both regionally and nationally. The main species caught are yellowfin

tuna ( *Thunnus albacares* ) and bluefin tuna ( *T. thynnus* ), and associated species include skipjack ( *Katsuwonus pelamis* ), bigeye tuna or bigeye tuna ( *T. obesus* ). albacore ( *T. alalunga* ), and black skipjack ( *Euthynnus lineatus* ).

On the coasts of Oaxaca, the skipjack fishery ( *E. lineatus and K. pelamis)* is an important component of artisanal pelagic fishing, since it is fished throughout the year. It is a small-scale fishery, which is developed with greater intensity in the coastal strip located between Puerto Escondido and areas surrounding the bays of Huatulco ( **Fig. 1** ). The monthly catches in the state of Oaxaca are close to 90 tons and represent an activity that significantly impacts the regional economy, since its exploitation has a very important social role by contributing to jobs and food security, being in some cases the only source of income for family support.

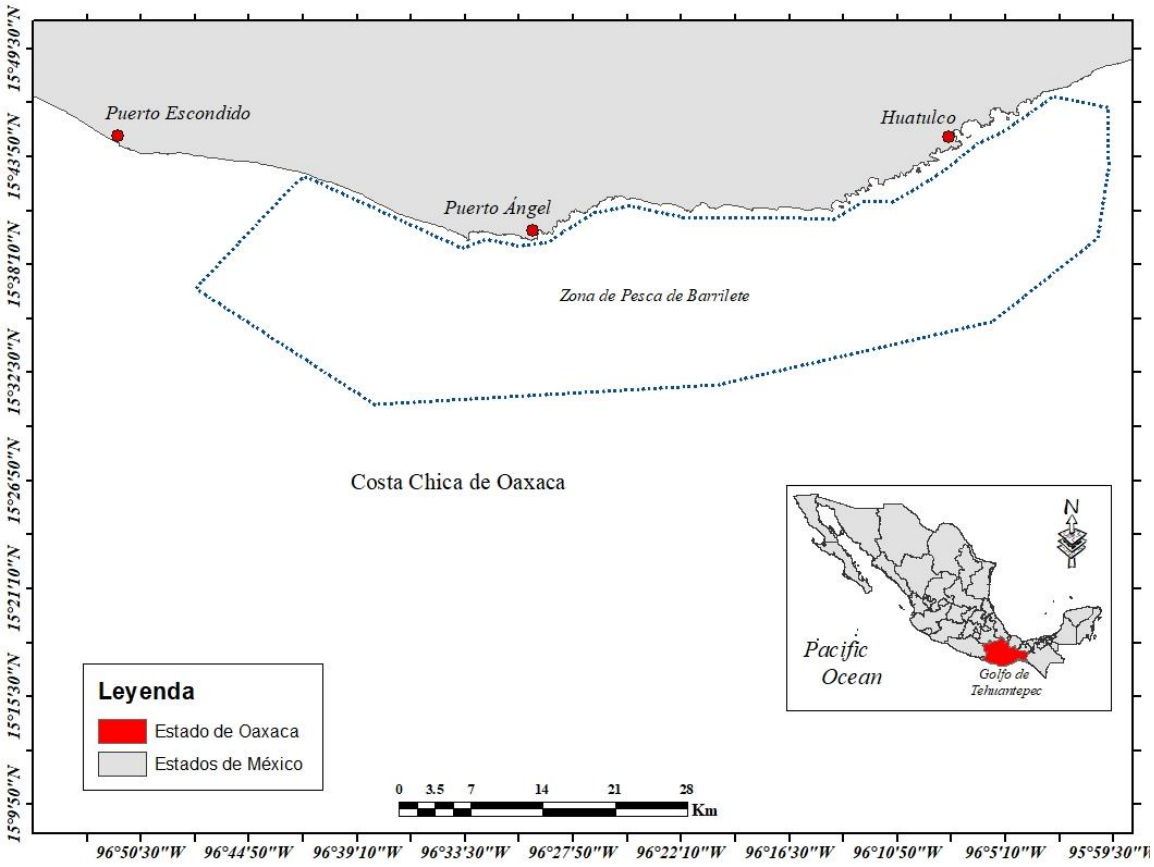


Figure 1. Location of the study area on the coast of Oaxaca. The dashed line indicates the fishing zone of the Puerto Ángel artisanal fishing fleet.

The state of Oaxaca, particularly Puerto Ángel, is the most important producer of skipjack nationally through artisanal fishing ( Ramos-Cruz, 2000; Ramos-Carrillo et al., 2011; DOF, 2012 ). *E. lineatus* is the most abundant species of scombrid on the Oaxacan coast ( Ramos-Cruz, 2000 ; Ramos Carrillo *et al* ., 2011 ), and its main use is for direct human consumption, local trade and to a lesser extent as bait in the shark fishing ( DOF, 2012 ). Therefore, the general objective of the present study is to determine the

interannual variation in the abundance of skipjack captured in the community of Puerto Ángel, Oaxaca.

## STUDY AREA

The study area is located in the Pacific Ocean, south of Mexico, typically known as the small coast of Oaxaca ( **Fig. 1** ). This area belongs to the Gulf of Tehuantepec and is characterized by having a very narrow continental shelf (4-6 km). In addition, it has a pronounced slope, reaching depths greater than 4000 m (in front of Puerto Ángel) near the coastline, which allows access to larger pelagic resources that are present in the area. The study area includes the landing zone for artisanal fishing in Puerto Ángel, Oaxaca, and the marine limit is determined by the spatial dynamics of the coastal fishing fleet that captures skipjack, which is between 1 and 7 nautical miles ( **Fig. 1** ).

The climate in the region is tropical, specifically warm-subhumid ( Aw ) with an annual temperature range of between 26º and 30ºC . Climatic seasonality is mainly marked by two seasons, a dry one, which covers the months of November to April, and a rainy season that runs from May to October.

During the dry season, the Tehuano winds, a cold air mass from North America, cause a rise in the thermocline in the Gulf of Tehuantepec, which produces an intense upwelling of nutrient-rich waters ( Lavín *et al* ., 1992 ; Fiedler, 2002 ). Once the winds decrease, the coastal circulation is reestablished and a plume of cold water progressively extends out of the gulf ( Ortega-García *et al* ., 2000 ). For this season, the direction of the coastal current is determined mainly by the California Current with southward flow ( Kessler, 2006 ). For its part, when the Tehuano winds decrease and circulation is restored in the Gulf of Tehuantepec and adjacent waters, the Costa Rica Coastal Current has greater influence in the area, which causes a decrease in the thermocline and the presence of warm waters. warmer surface areas (30°C) and lower productivity ( Hernández-Becerril *et al* ., 2015 ).

During the rainy season, there is a natural contribution of nutrients to the sea, due to the drainage of rainwater into the marine environment, which increases the amount of organic matter and nutrients, mainly in the coastal zone ( Martínez-Santos 2014 ; Cabrera-Núñez , 2016 ). The surface circulation in this season is governed by the Costa Rica Coastal Current with a flow towards the north which carries waters of low salinity and rich in nutrients along the Oaxacan coast ( Lavín *et al* ., 1992 ; Kessler, 2006 ). In the coastal zone, the thermocline occurs between 10 and 15 meters deep, where the mixing layer is very shallow and favors the abundance of fishing resources ( Araico -Gonzáles, 2012 ).

## MATERIALS AND METHODS

*Sampling and biological data*

The information and samples were taken from the artisanal fishery of Puerto Ángel, Oaxaca ( **Table 1** ). Sampling was carried out weekly, during the period from October 2022 to October 2023 ( **Table 1** ). The sample size was a function of local catches, since the fishing gear used by the fishing fleet is trolling and

hand line. In general, the fleet's catches correspond to an average distance of 5 miles from Puerto Ángel and the effective fishing time per day averages two hours of work.

**Table 1** . Total number of individuals, average furcal length and average monthly weight of the samples collected in the arrival area of Puerto Ángel, Oaxaca.

| *Month* | Year | Length (cm) | Weight (kg) | Number of individuals |
|---|---|---|---|---|
| *October* | 2022 | 45.7 | 1.6 | 18 |
| *November* | 2022 | 46.0 | 1.9 | 23 |
| *February* | 2023 | 48.4 | 1.7 | 35 |
| *March* | 2023 | 49.6 | 1.6 | 37 |
| *April* | 2023 | 48.6 | 2.0 | 89 |
| *May* | 2023 | 48.2 | 1.9 | 97 |
| *June* | 2023 | 48.5 | 1.8 | 119 |
| *July* | 2023 | 48.1 | 1.8 | 148 |
| *August* | 2023 | 46.0 | 1.6 | 26 |
| *September* | 2023 | 47.0 | 23 | 99 |
| *October* | 2023 | 45.7 | 1.6 | 115 |

The biological data recorded were: furcal length *( Lh* ), total weight of the organism ( *Pt* ) and when possible, gonads and stomachs of different individuals were collected, which were separated, labeled and preserved until treatment in the laboratory. A total of 10 stomachs of E. lineatus were analyzed *,* where a cross section was made and opened from each stomach. From this, a sample of the stomach contents was taken and analyzed in the stereoscope to later determine its contents. Monthly and annual skipjack catch data for the state of Oaxaca were obtained from the statistical yearbook of Aquaculture and Fishing (CONAPESCA) ( *https://www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca* ). Meanwhile, the monthly skipjack catch data from the Punta Sacrificio cooperative were obtained from the logs that are being implemented in the Fisheries Improvement Project (FIP). This information allowed studies of monthly and annual variation in skipjack catches to be carried out, as well as determining its relationship with meteorological variables.

*Environmental variable data*

Annual precipitation data were downloaded from the National Meteorological Service (SMN) of Mexico ( *https://smn.conagua.gob.mx/es/ )* . For temporal analysis, the data were processed and analyzed with the objective of determining the seasonal variability of precipitation and its possible effects on the annual catch of skipjack in the small coast region of Oaxaca. On the other hand, the Southern Oscillation (ENSO) data were downloaded, which were obtained from the Physical Database. Sciences NOAA Laboratory ( *https://psl.noaa.gov/enso/* ). This information was processed and graphed with the objective of observing the El Niño and La Niña periods, and thus determining their relationship with the

abundance and seasonal variation of skipjack catches on the Oaxacan coast.

## RESULTS

### *Capture analysis*

The skipjack catch for the period from 2005 to 2022 in the state of Oaxaca showed an annual average of ~ 886 tons ( **Fig. 2** ). The highest catches were recorded in the years 2015, 2017 and 2018 respectively, while the historical minimum recorded catches correspond to 2008. In general, it is observed that at the beginning of the 2000s (2005-2013), the catch is below the historical average and ranges between 500 tons on average. While, as of 2014 (2014-2020) the skipjack catch has registered an upward trend, exceeding 1,000 tons of annual catch. However, starting from its historical maximum reached in 2015, the catch shows a decreasing trend, where as of 2020 the annual catches are below the historical average ( **Fig. 2** ).

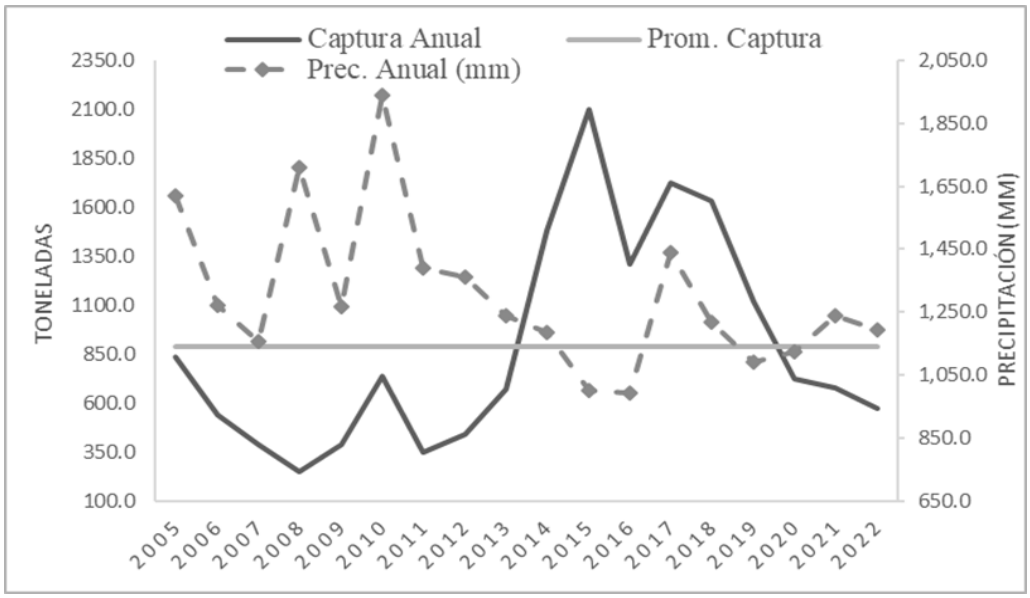


Figure 2. Historical series of annual skipjack production in Oaxaca. The dashed line is the accumulated annual rainfall for the coast of Oaxaca.

This variation in annual skipjack catches presents an inverse relationship with the annual average rainfall, as seen in Figure 2. In general, it is observed that the period in which the highest accumulated rainfall is recorded (2008 and 2011) corresponds to the years where the lowest historical catches of skipjack were recorded on the coast of Oaxaca. While, the years of maximum historical capture correspond to periods where the minimum accumulated precipitation is recorded ( **Fig. 2** ).

For its part, it was observed that the average historical monthly catches of skipjack showed seasonality and monthly variability for Puerto Ángel, Oaxaca ( **Fig. 3** ). The average historical catch is approximately 73 tons per month, where the months between April and September record the highest catches of

skipjack during the year, with April and July being the months with the highest catch (~90 tons). For its part, the second half of the year is the month with the lowest average catches (August-December), with December being the month where the lowest catches are recorded (~50 tons).

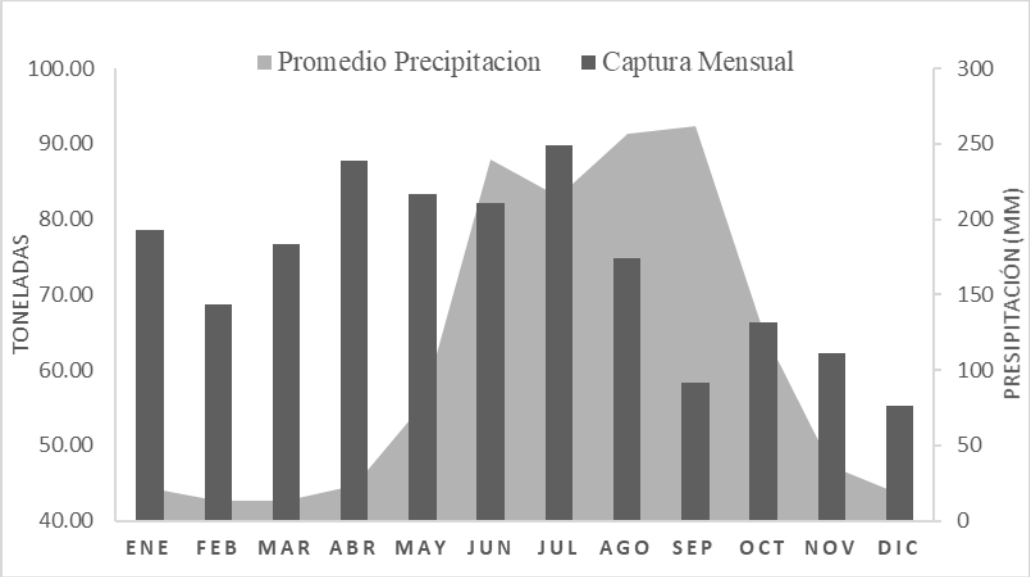


Figure 3. Monthly average of skipjack catches from 2005 to 2022 in Puerto Ángel, Oaxaca. The shaded line corresponds to the monthly average rainfall.

In relation to the seasonality of precipitation, an inverse relationship was also observed between the average skipjack catches and the accumulated monthly precipitation. The months with the highest accumulated precipitation correspond to the summer period (June-September), with September being the month with the highest accumulation values (~260 mm). While, in winter there are the months with the lowest accumulated rainfall (January-April), mainly in the months of February (12 mm) and March (13 mm). In general, in Figure 3, it is observed that the period of lowest accumulated precipitation (winter) corresponds with the highest monthly average catch values, which decrease with the increase in precipitation ( **Fig.3** ).

For its part, skipjack catches for the small coast of Oaxaca registered interannual variability in relation to seasonal changes in ENSO ( **Fig. 4** ). In general, negative anomalies in skipjack catches were observed when the La Niña phenomenon dominated, while in times of positive anomalies in catches they were recorded in the El Niño period. At the beginning of the 2000s (2005-2009), when the La Niña phenomenon dominated, the lowest values of the anomaly of skipjack catches were observed by the artisanal fleet of the small coast of Oaxaca, mainly in the 2008 when an intense period of La Niña was recorded. This behavior also occurs in the period 2011-2014, where negative anomalies in skipjack capture were observed during the La Niña event ( **Fig. 4** ).

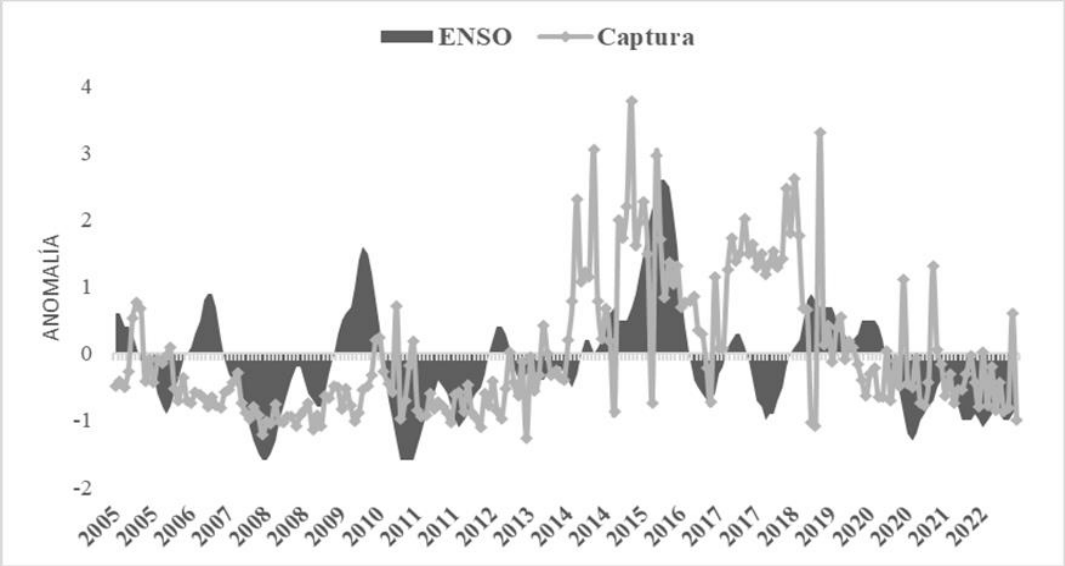


Figure 4. Relationship between El Niño Southern Oscillation (ENSO) and the interannual catch of skipjack on the small coast of Oaxaca.

For their part, the positive anomalies in skipjack catches were mainly associated with the El Niño event. During the period 2014-2016, the maximum values of positive capture anomalies were observed, which occur during intense periods of El Niño ( **Fig. 4** ).

### *Sampling analysis*

The data and samples collected were obtained from organisms captured with hooks and trolls by the coastal fleet of Puerto Ángel, Oaxaca. The skipjack catch in the area is mainly composed of black skipjack ( *E. lineatus* ), however, during the sampling the presence of skipjack ( *K. pelamis* ) and, to a lesser extent, horse mackerel ( *Seriola) was observed. lalandi* ). The number of samples analyzed ( **Table** 1) is in relation to the abundance of skipjack caught by the fleet.

During the sampling period, 870 skipjacks were analyzed, where it was found that the furcal length showed an average of 47.6 cm. The *Lh* interval It was found from 36.0 to 62.0 cm, where the most frequent sizes are between 46.0 and 50.0 cm ( **Fig. 5** ). According to the multinomial analysis, the frequency histogram shows a symmetrical structure (unimodal), since they are centered around the median (48.0 cm).

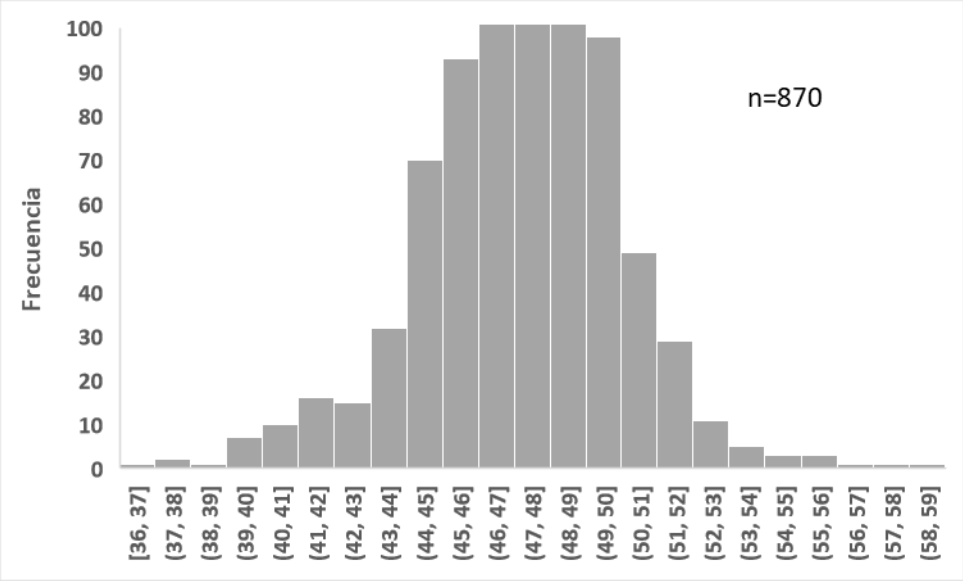


Figure 5. Frequency histogram of furcal length for skipjack ( *E. lineatus* and *K. pelamis* ) captured during the period October 2022 - October 2023 on the small coast of Oaxaca, Mexico.

On the other hand, significant differences were observed between the *Lh* per month of sampling ( **Fig. 6** ), which reveals temporal variations in the composition of the catches of the artisanal fleet of Puerto Ángel. The highest median value of *Lh* was reached in the month of March 2023 with 49.6 cm, while the lowest value was recorded in October (45.7 cm) of 2022 and 2023 ( **Fig. 6** ). In general, two groups of months can be observed with differences in the average monthly sizes, the first group is made up of the months from September to November, presenting average values between 45.7 and 46.0 cm. The second group is made up of the months from February to July, with average *Lh values* ranging between 48.1 to 49.6 cm ( **Fig. 6** ).

For its part, for the same number sampled (n=870), it was found that the average weight of kites was 1.8 kg. The *Pt interval* obtained for all records was found from 0.9 to 4.0 kg, where it is observed that the most frequent class interval was 1.89-2.00 kg ( **Fig. 7** ). For its part, the frequency histogram of total weight also showed a unimodal structure, with a median of 1.78 kg and a standard deviation of 0.19. The highest average weight observed was 2.3 kg in the month of September 2023, while the lowest average weight was recorded in March and August 2023 with 1.6 kg ( **Fig. 6** ). In general, the annual analysis does not present significant differences between the average weights and furthermore, no patterns are identified in the behavior of the weight in the skipjack catch in Puerto Ángel, Oaxaca ( **Fig. 6** ).

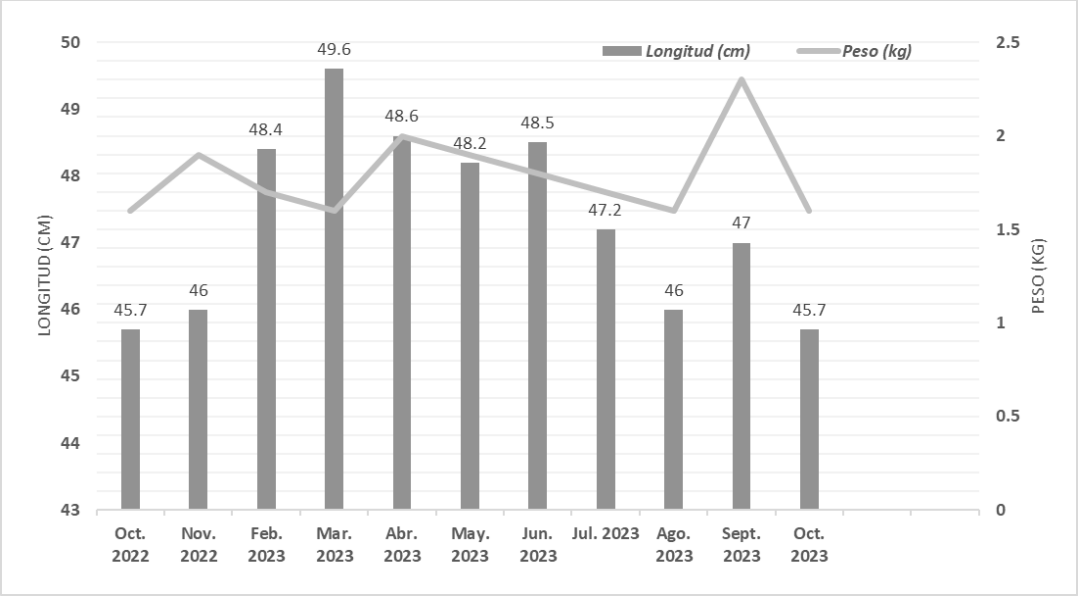


Figure 6. Monthly average of weight (kg) and furcal length (cm) data of skipjack individuals analyzed in Puerto Ángel, Oaxaca.

In relation to the analysis of the stomach contents, a total of six fish were found with organic matter, that is, the stomach contents could not be analyzed because they were already in a high degree of decomposition. In addition, a total of three fish were recorded with empty stomachs, while one showed a fish in its stomach contents, but the species could not be determined because it was in very poor condition. For its part, the relationship between furcal length-total weight for skipjack in Puerto Ángel, Oaxaca, presented a linear relationship ( **Fig. 8** ).

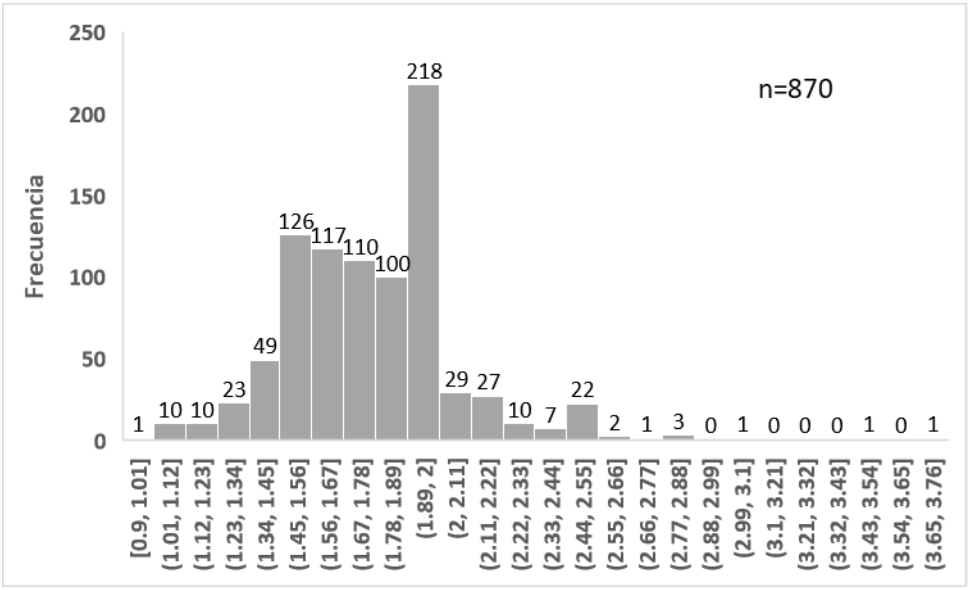


Figure 7. Total weight frequency histogram for skipjack ( *E. lineatus* and *K. pelamis* ) captured during the period October 2022 - October 2023 on the small coast of Oaxaca, Mexico.

The results obtained in this study show that the furcal lengths and total weights of the skipjack caught by the artisanal fleet in Puerto Ángel, Oaxaca present a temporal variation, which coincides with what was reported by Ramos-Cruz (2009) and Velásquez-Polanco, (2017). Like these authors, it was found that the sizes and weight of skipjack for this region vary monthly and seasonally. The monthly variation in sizes and weight could be related to the migration and seasonality of the schools, which coincides with what was found by Schaefer (1982), who indicated that skipjacks commonly swim in schools of sizes, stomach contents and stages of similar ripeness. Based on the above and what was found by Velásquez-Polanco, (2017), it is possible to intuit that in the autumn months (October and November 2022) kites between 5 and 7 years of age transit in the region, while the rest of the year (February-July 2023) older skipjacks (8-10) years old are found.

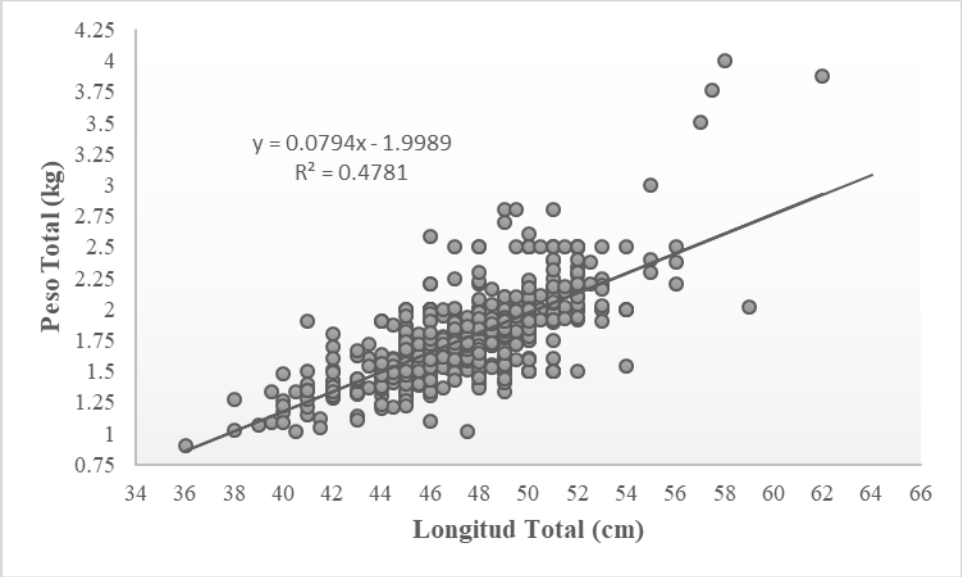


Figure 8. Total weight - furcal length relationship of the skipjack samples analyzed in Puerto Ángel, Oaxaca.

## CONCLUSION

- The skipjack catch in Oaxaca is approximately 890 tons annually and the maximum monthly values are recorded in the months of April and July, with approximately 88 and 90 tons respectively of historical average catch.
- The skipjack from Puerto Ángel, Oaxaca showed a temporal variation in sizes, with an interval of furcal length between 36.0 and 62.0 cm, where the most frequent sizes were found between 46.0 and 50.0 cm.
- Based on the sizes found, which make up the catches of the artisanal fleet, the fish are between 7-10 years old, which reveals that the fishing gear used is selective and that the skipjack fishery on the small coast of Oaxaca It does not have a negative impact on the recruitment of the

population stock of the resource.

- There is a direct relationship between skipjack catches on the coast of Oaxaca and the ENSO event, since the maximum catch values of the artisanal fleet are during the periods when El Niño predominates.

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