

Seasonal variation in the size structure of the black skipjack (*Euthynnus lineatus*) on the small coast of Oaxaca, Mexico

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Summary

The artisanal fishery for black skipjack (*Euthynnus lineatus*) takes place throughout the year on the small coast of Oaxaca. The objective of this work was to identify the seasonal changes in the size structure and determine the length-weight relationship, in order to provide information on the biology of this species. During the months of October 2022 to July 2024, 1,377 specimens were randomly collected from catches in the town of Puerto Ángel, Oaxaca. For each specimen, the furcal length (Lh) and the total weight (Pt) were measured. For the taxonomic identification of the species, specialized keys, guides and catalogs were used.

The size structure was analyzed with frequency histograms and the mean catch size (MCS) was compared with the mean length at maturity (MMM). The length-weight relationship was estimated using Ricker 's allometry equation . The black skipjack showed a range of fork length between 36.0 and 62.0 cm, where the most frequent sizes were between 46.5 and 48.5 cm. Although there is no defined pattern in the monthly average of the sizes, it was observed that February and March recorded the maximum sizes (~ 48.5 and 49.5 cm respectively), while October recorded the lowest values (~ 45.5 cm). The results of the length-weight relationship show that most of the species show isometric growth,

In this study, we would expect to observe capture sizes greater than the size at maturity and also an isometric type of growth of native fish.

Keywords: length-weight relationship, *Euthynnus lineatus*,

INTRODUCTION

The black skipjack (*Euthynnus lineatus*) is an epipelagic species of the Scombridae family , which is distributed in tropical and subtropical waters of the Eastern Pacific Ocean and forms large schools near the surface (Blackburn, 1965; Allen & Punsly , 1984). This species 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- Durá , 1978).

E. lineatus are very active pelagic fish with a great amount of energy that allows them to travel

long distances in a short time (Olson & Boggs, 1986). Therefore, food availability is a determining factor in the abundance and distribution of these species (Stretta , 1991). However, it is not considered within the group of tunas catalogued as "highly migratory", since its migrations are associated with continental shelves (FAO, 1994).

On the coasts of Oaxaca, the black skipjack fishery is an important component of artisanal 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 of the state of Oaxaca are close to 90 tons and represent an activity that significantly impacts the regional economy, since it represents a source of food, direct and indirect employment, trade and economic well-being both regionally and nationally.

For *E. lineatus*, different body lengths have been recorded from 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). In relation to the coast of Oaxaca, Velásquez-Polanco (2017) reports that the black skipjack has a negative allometric growth , since it grows first in length and then in weight. In addition, he found up to 10 age groups (2-11 years), which grow rapidly in the first six years of life, reaching a fork length of 42-43 cm, while after the seventh year until 11 years of age, the average fork length is very similar (47-49 cm).

The state of Oaxaca, particularly Puerto Ángel, is the most important producer of skipjack nationwide by artisanal fisheries (Ramos-Cruz, 2000; Ramos-Carrillo et al., 2011; DOF, 2012). *E. lineatus* is the most abundant scombrid species 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 shark fishing (DOF, 2012). However, to date, little is known about the size structure and length-weight relationship of skipjack catches. Therefore, the main objective of this study is to determine the size structure and the length-weight relationship, in order to generate information that will serve as a basis for the design of a conservation and fishery management strategy for black skipjack caught by coastal fisheries on the small coast of Oaxaca.

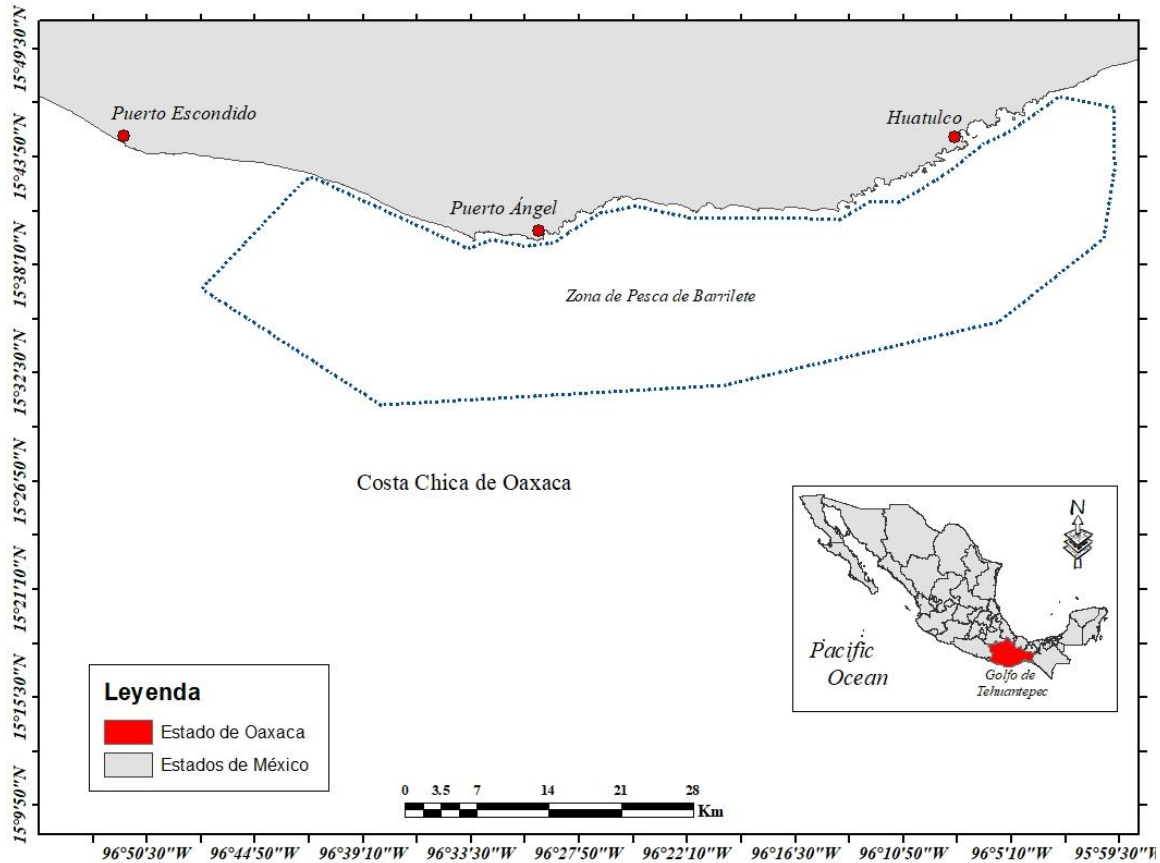


Figure 1. Location of the study area on the coast of Oaxaca. The dashed line indicates the fishing area of the artisanal fishing fleet of Puerto Ángel.

Materials and methods

Area of study

The study area is located in southern Mexico in the Pacific Ocean, a region known as the Costa Chica of Oaxaca (Fig. 1). This area It belongs to the northwestern end of the Gulf of Tehuantepec and is characterized by a very narrow continental shelf (4-6 km) and a steep slope, reaching depths greater than 5000 m near the coastline (Lara-Lara et al., 2008). The study area includes the landing zone of the artisanal fishery of Puerto Ángel, Oaxaca and the marine limit is determined by the spatial dynamics of the coastal fishing fleet that captures black skipjack, and that works at a distance between 1 and 7 nautical miles from the coast (Fig. 1).

The climatic seasonality is mainly marked by two seasons, a dry one, which covers the months of November to April and a rainy one that runs from May to October. During the dry season, the Tehuano winds, a cold air mass coming 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). For this season, the direction of the coastal current is mainly determined by the California

current with a southerly flow (Kessler, 2006). On the other hand, when the Tehuantepec winds decrease and circulation is reestablished in the Gulf of Tehuantepec and the adjacent waters, the Costa Rica Coastal Current has a greater influence in the area, which causes a decrease in the thermocline and the presence of warmer surface waters (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 to the north which carries low salinity waters 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 mixed layer is very shallow and favors the abundance of fishery resources (Araico -González, 2012).

Sampling and biological data

Data were collected from artisanal skipjack fishing in Puerto Ángel, Oaxaca, during the period from October 2022 to July 2024 (Table 1). Sampling was carried out four times per month and was based on daily catches, since the fishing gear used by the fishing fleet is trolling and handline. In general, the fleet's catches correspond to an average distance of 5 nautical miles from Puerto Ángel and the effective fishing time per day averages two hours of work.

Species identification was performed using keys, guides and specialized catalogs for species identification from FAO for Pacific fishery resources (FAO, 2002). Subsequently, the fork length (*Lh*) of each organism was measured with an actinometer and the total weight (*Pt*) with a scale. The composition of the size structure of each species was analyzed using Sturges' rule (1926), which allows determining the number of size intervals in a frequency histogram. Subsequently, the average sizes of catches were compared with the average sizes at sexual maturity published for the species in the Mexican Pacific region.

For its part, the length-weight relationship was estimated using the potential allometry equation $W = aL^b$ of Ricker (1975), where *W* is the weight, *L* the length, *a* is the origin ordinate and the slope *b* (allometry coefficient), is used to describe the type of growth exhibited by the species. Isometric growth (*b*=3) is considered when weight and length grow in the same proportion over time, if *b*>3, the growth is considered positive barometric, that is, individuals have increased their weight in a greater proportion than their length. On the other hand, if *b*<3, the growth is negative allometric and is when individuals increase their relative length more than their weight (Froese 2006).

Table 1. Statistical parameters of the size and weight structure of the artisanal black skipjack fishery on the small coast of Oaxaca, during the months of October 2022 to July 2024. Number of individuals (N), Average catch size (ACS), Average catch weight (AWW).

Month	N	TMC	Range	PMC	Range
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October 2022	18	45.7	40.5-48.5	1.6	1.3-1.9
November 2022	23	45.5	39.5-50.0	1.8	1.3-2.6
February 2023	32	47.8	44.0-51.0	1.6	1.3-2.0
March 2023	37	49.4	46.0-53.0	1.5	1.3-2.0
April 2023	75	47.8	42.0-52.0	1.9	1.5-2.5
May 2023	98	48.2	45.0-53.0	1.9	1.1-2.5
June 2023	118	48.5	39.5-56.0	1.8	1.0-2.5
July 2023	148	47.2	40.0-52.5	1.7	1.0-2.8
August 2023	26	46.0	38.0-51.0	1.6	1.0-2.1
September 2023	99	47.5	41.0-54.0	1.8	1.2-2.8
October 2023	115	45.7	36.0-53.0	1.6	0.9-2.8
February 2024	83	47.6	42.0-57.0	1.9	1.4-3.0
March 2024	31	46.3	43.0-49.0	1.8	1.4-2.0
April 2024	83	44.8	34.0-55.0	1.6	1.0-2.1
May 2024	101	46.6	34.0-54.5	1.7	1.0-2.6
June 2024	30	46.9	36.0-55.0	1.5	1.0-1.9
July 2024	132	44.9	31.0-52.0	1.5	0.5-2.2
Total	1249	46.8		1.7	

Results and discussion

The information collected in this study was obtained from the landings of black skipjack caught with hooks and trolls by the coastal fleet of Puerto Ángel, Oaxaca. The size structure, for the 1249 *E. lineatus* organisms analyzed, presented an average capture size of 46.8 cm, and an average weight of 1.7 kg, with a range from 31.0 - 57.0 cm and 0.5 - 3.0 kg for the fork length and total weight respectively (**Table 1**).

E. lineatus, showed differences in the average monthly catch size, with temporal variations in the composition of the organisms landed by the artisanal fleet of Puerto Ángel. In addition, it was observed that the average monthly size of the black skipjack did not present a seasonal pattern, revealing the population dynamics of the resource on the small coast of Oaxaca (**Fig. 2**). In general, the average monthly size showed the lowest values in July 2024 (44.9 cm) and April 2024 (45.2 cm), while the maximum *Lh* values were reached in March (49.6 and 49.0 cm) of 2023 and 2024 respectively. Regarding the average monthly catch weight of *E. lineatus*, although it also had temporal variations, no patterns are identified in the weight behavior in the skipjack catch. For their part, the average minimum values were 1.5 kg in the months of March 2023, June and July 2024, while the maximum values recorded were 1.9 kg during the months of April and May 2023 and February 2024 (**Fig. 2**).

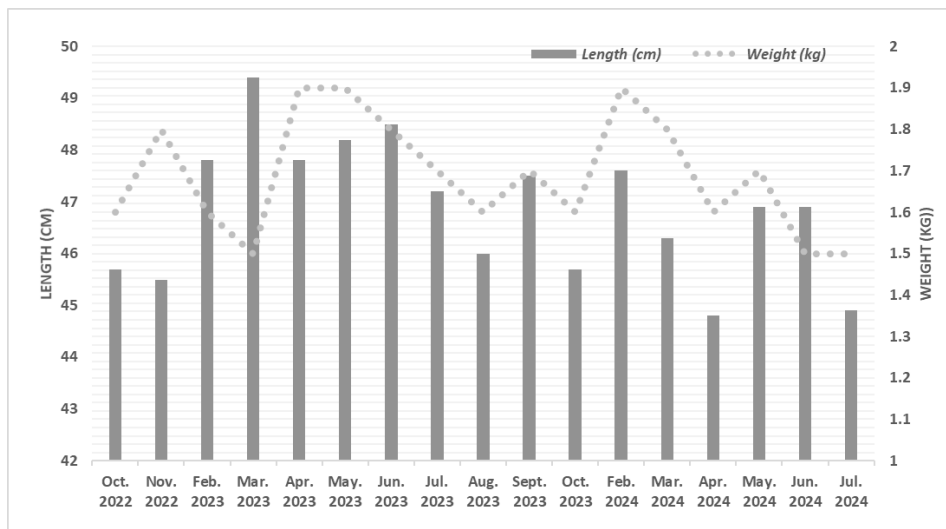


Figure 2. *E. lineatus* caught during October 2022 to July 2024 in Puerto Ángel, Oaxaca.

The monthly and seasonal variation in the average catch size and total weight of *E. lineatus*, found in this study, could be related to the migration and seasonality of the schools, which coincides with what was found by Schaefer (1982), who indicated that skipjack commonly swim in schools of similar sizes, stomach contents and maturity stages. 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) skipjack between 5 and 7 years of age transit the region, while the rest of the year (February-July 2023) older skipjack (8-10) years of age are found.

On the other hand, it was found that the average catch sizes registered a difference between the years analyzed, registering an average maximum value of 47.5 cm during the year 2023, while the year 2024 registered the lowest catch sizes with an average of 46.2 cm (Fig. 2). This interannual variation in average catch sizes could be given by seasonal changes in the El Niño Southern Oscillation (ENSO), since changes in sea surface temperature (warmer or colder) influence food availability (Stretta , 1991) and in turn the growth of this species.

Lh interval was found from 31.0 to 57.0 cm. The sizes with the most frequent class interval were 46-47 and 47-48 cm (Fig. 3). On the other hand, according to the multinomial analysis, the size frequency histogram showed a unimodal structure, with a median of 47.0 cm and a standard deviation of 3.1. The average monthly capture sizes of *E. lineatus* recorded were higher than the size at first maturity for black skipjack on the small coast of Oaxaca (Fig. 3). Therefore, the recruitment of the skipjack fishery occurred at an optimal age and size in which the captured organisms have already spawned and contributed new individuals to the population. The above reflects that the artisanal fishery of *E. lineatus* on the small coast of Oaxaca does not present overfishing at recruitment and growth because it is supported by large and mature individuals.

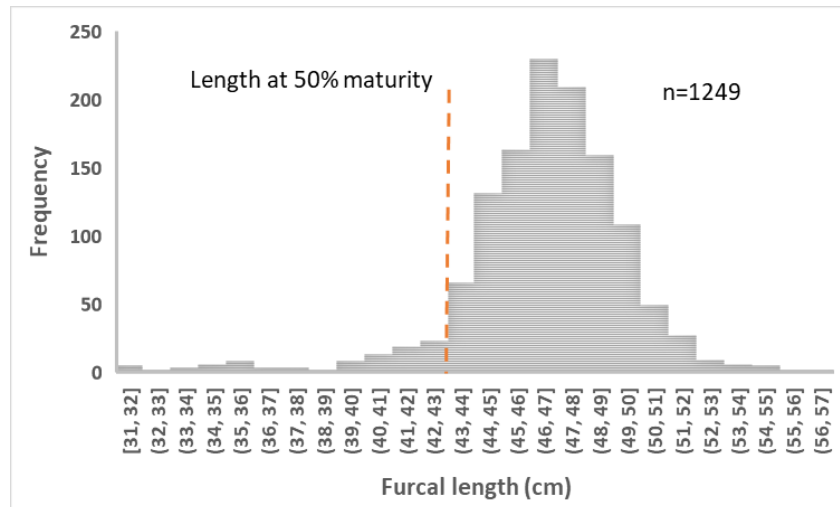


Figure 3. Fork length frequency histogram for *E. lineatus* captured during the period October 2022 - July 2024 on the Costa Chica of Oaxaca, Mexico. The red dotted line corresponds to the length at 50% maturity for *E. lineatus*.

The fork length-total weight relationship for combined sexes of *E. lineatus* showed negative isometric growth (Fig. 4). However, this length-weight relationship could differ between years, as skipjack populations vary between years, since the growth coefficient depends on food and environmental conditions in the region.

The results obtained in this study show that the average catch size and total weight of *E. lineatus*, caught by the coastal fleet on the small coast of Oaxaca, present an interannual variation, which coincides with what was reported by Ramos-Cruz (2009) and Velásquez-Polanco, (2017), who indicate that sizes and weight vary significantly on a monthly and seasonal basis. The monthly variation found in size and weight could be related to the presence of various schools of *E. lineatus* of homogeneous sizes that move according to the temporality of their biological cycle, since this species commonly swims in schools of similar sizes and maturity stages (Schaefer, 1982).

On the other hand, this study identified a seasonal period in the weight increase in *E. lineatus*, which spans from April to May 2023 and from February to March 2024, results similar to those obtained by Ramos-Cruz (2009), who found an increase in the condition of the fish during the period from November 1997 to April 1998. This increase in weight at the beginning of the year could be related to the increase in upwelling and availability of zooplankton in the Gulf of Tehuantepec, due to the northern season (Ayala-Duval et al., 1998; Trasviña and Andrade, 2002), which allows the feeding and fattening of *E. lineatus*. Considering that Schaefer (1987) reported that black skipjack spawn from October to June on the coast of Central America, and that prior to spawning, the fish accumulate fat and their gonads increase in weight (Guerra-Sierra & Sánchez- Lisazo, 1998), the results obtained in this work allow us to assume that the highest values of total weight recorded by *E. lineatus* during the period from February to May are associated with the spawning period of the species.

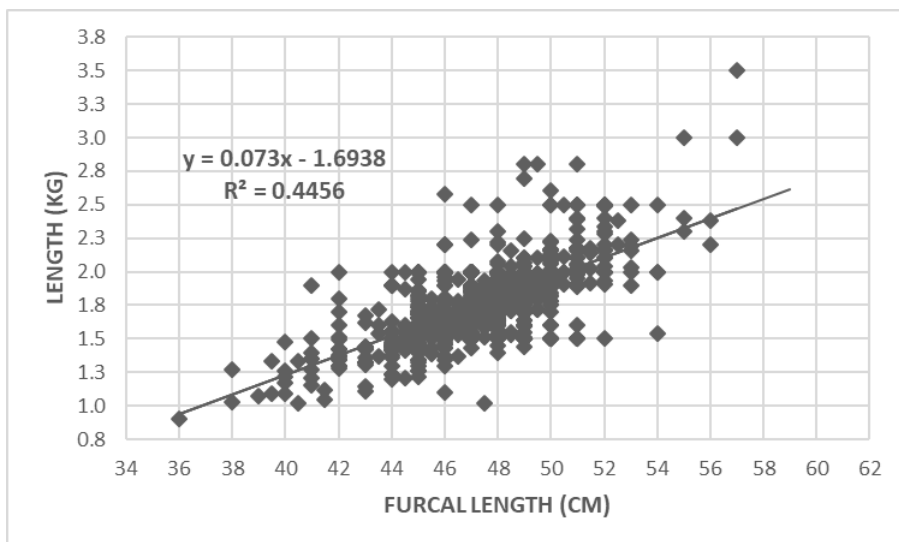


Figure 4. Furcal length - total weight relationship for combined sexes of *Euthynnus lineatus* captured on the small coast of Oaxaca.

In this study, a size range of 31.0 to 57 cm and a total weight range of 0.5 to 3.0 kg were recorded, which differ from other reports for catches from the Oaxaca coastal fishery (Guevara *et al.*, 2003; Ramos-Carillo *et al.*, 2015). This difference may be determined by the fishing gear (line and trolling) used by the Puerto Ángel fishing fleet, which has established management measures for black skipjack under the fishery improvement project existing in the region (<https://fisheryprogress.org/fip-profile/mexico-oaxaca-artisanal-skipjack-and-black-skipjack-tuna-handline>). On the other hand, the furcal length and total weight ranges reported in this study were collected weekly (October 2022 to July 2024), which contains the range of sizes and weights possible to obtain by the fishing fleet, therefore, they are considered representative of the *E. lineatus* population within the study area.

Conclusion

E. lineatus showed a temporal and seasonal variation in the average size of the catch, with a range of fork length between 31.0 and 57.0 cm, where the most frequent sizes were between 46.5 and 47.5 cm, being larger than the sizes at first maturity recorded for the species on the small coast of Oaxaca. On the other hand, based on the sizes found, which make up the catches of the artisanal fleet, the organisms are between 7-10 years old, which reveals that the fishing gear used is selective and that the fishery does not have a negative impact on the recruitment of the resource's population stock.

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