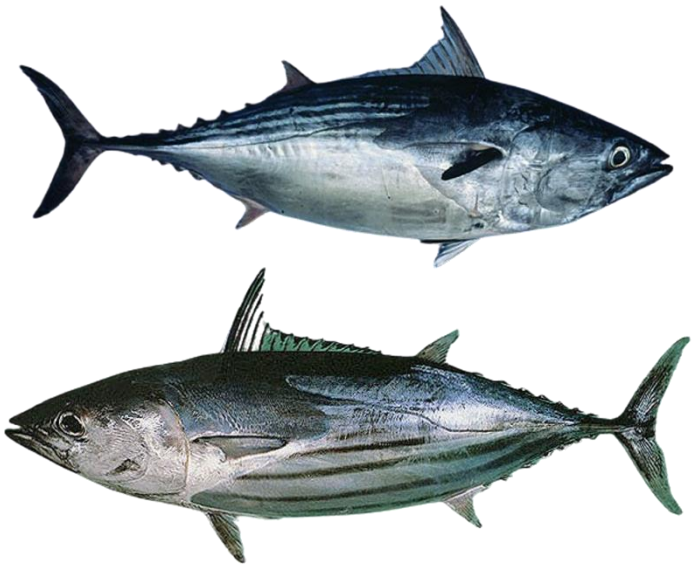
“ ANALYSIS OF THE KICKET RESOURCE FISHERY IN PUERTO, ÁNGEL, OAXACA”

RESCUE OF VALUE OF THE KICKET IN PUERTO ÁNGEL, OAXACA



Responsible institutions and organizations:

Oaxacan Fund for Nature Conservation (FOCN), Oaxacan Aquaculture Health and Safety Committee (COSIA), SmartFish AC, the Pochutla Technological Institute and the Punta Sacrificio SC de RL Fisheries Production Cooperative

Results of the Oaxacan Nature Conservation Fund consultancy for the black skipjack and the striped skipjack.

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Heroica Puebla de Zaragoza, Pue., Mexico, March 19, 2024

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1. SUMMARY

The tuna fishing industry in Mexico is experiencing constant growth, generating around 12 thousand direct and indirect jobs, and reaching an estimated annual production between 100 and 150 thousand tons. Although the focus is on yellowfin tuna, skipjack emerges as the second most caught and traded tuna in the country, representing between 10% and 20% of national catches. This species of small tuna is distributed in tropical and subtropical waters throughout the world, and has been caught in Mexico for a century, mainly on the Pacific coasts. In Oaxaca, skipjack stands out as the most relevant tuna species, occupying fourth place in terms of landed weight and thirteenth place in economic value. Puerto Ángel leads the state's production of skipjack, followed by Puerto Escondido and Salina Cruz. Through a size structure analysis, it was found that the average length of the black skipjack was 47.39 cm (± 2.56 cm), with an average weight of 1.75 kg (± 0.281 kg), while the striped skipjack reached an average length of 50.10. cm (± 3.43 cm), with an average weight of 2.02 kg (± 0.548 kg). The majority of fishing trips (97%), are completed in a single day, with travel time ranging between 1 and 3 hours. The average price per kilogram of black skipjack on the beach is $17.09 M/N (± $4.45 pesos) and for skipjack skipjack it was $74.03 pesos (± $36.58 pesos), with fishermen investing an average of $635.4 (± $267.14) pesos in gasoline per fishing trip.

KEYWORDS: Skipjack, artisanal fishery, Oaxaca, sustainability

2. INTRODUCTION

2.1 Fishing in Mexico

Fishing activity in Mexico is of great importance since it contributes to combating poverty and marginalization in the country's coastal and rural communities (CONAPESCA 2021), by generating employment and income, guaranteeing food security, and supporting the local and national economy (Tam *et al.* 2018). Currently, Mexico ranks 15th in fishing production worldwide (FAO 2020).

In Mexico there are 17,474 deep-sea fishermen, 230,307 coastal fishermen, 11,446 aquaculturists, 77,009 smaller vessels and 2,382 larger vessels (CONAPESCA, 2023), however, this figure could exceed two million people if all those who participate in the fishing supply network (CEMDA, 2021) since it is estimated that 86.2% are informal workers (Data México, 2023). 10.9% of the people who participate in fishing are women, the average age of the fisherman is 44.3 years and they have an average schooling of 7.04 years (Data México, 2023).

In 2023, industrial and artisanal fishing represented $1.01 billion Mexican pesos of the National Gross Domestic Product. In Mexico, the average monthly salary ranges between $6,640 - 7,370 pesos (M/N) working 4.61 days per week, equivalent to 18.44 days per month. The average weekly hours worked by the fisherman is 33.9 hours or 135.6 hours per month (Data México, 2023).

The states that stand out for their fishing production are located in the northwest region, mainly Sinaloa and Sonora, while the states with the lowest fishing production and population are Jalisco, Colima and Michoacán (CONAPESCA, 2020).

2.2 Biological data

Black skipjack, *Euthynnus lineatus*

The black skipjack is a pelagic species of small tuna that is characterized by having an elongated fusiform body with a dark blue color on the back with 5 – 6 horizontal black stripes that extend forward to the anterior part of the first dorsal fin. The underside and sides of the body are grayish or silvery, with several dark spots under the sides of the pelvic and pectoral fins (Fig. 1; Robertson *et al* ., 2024).

Figure 1. Photograph of the black skipjack, *Euthynnus lineatus* . Taken from FishBase , author: Béarez , P. (1998).

Sizes range between 39.4 cm – 62.1 cm, although the maximum recorded length is 92.5 cm (Ramos-Cruz, 2009; Robertson *et al.,* 2024). Regarding weight, the minimum value recorded is 0.38 kg during the month of December and the maximum is 3.41 kg in July, with an annual average of 1.59 kg (Ramos-Cruz, 2009). The maximum weight recorded worldwide is 11.8 kg (Robertson *et al.,* 2024).

Unlike other species of small tunas, the black skipjack has a marked prevalence in coastal waters and a restricted distribution to the Eastern Pacific Ocean ranging from California to Peru, including all oceanic islands (Velásquez Polanco, 2017). Mexico is the country with the greatest fishing exploitation of this species, being captured mainly in Baja California Sur, Jalisco and Oaxaca (Velásquez Polanco, 2017; Robertson *et al* ., 2024).

In Mexico, the coastal strip between Puerto Escondido and Puerto Ángel, Oaxaca, is an area of reproduction and growth of the black skipjack, the population presents the best state of well-being during the spring months, particularly March (Ramos-Cruz, 2009). . In the Eastern Pacific Ocean it reproduces constantly, different authors have pointed out reproductive peaks in January, April, May, August and October, although the consensus is that the black skipjack begins to reproduce during the spring, reaching the highest peak during the summer (Klawe , 1983; Nishikawa *et al.,* 1985, Schaefer, 1987).

The black skipjack is mainly piscivorous and a specialist; on the central Pacific coast of Mexico, 72% of its diet consists of yellowfin herring (*Pliosteostoma lutipinnis*), followed by 27% krill (Gamiz *et al* ., 2018). Pelagic crustaceans, as well as octopuses and squid, are also part of their diet (Sandoval *et al* ., 2020).

Skipjack, *Katsuwonus pelamis*

Skipjack is a pelagic species of small tuna that has an elongated fusiform body with a dark purple-blue coloration on the back. On the lower part of the body and sides they are silvery and have 4–6 conspicuous wavy stripes or discontinuous lines of dark spots, a distinctive characteristic of the species (Figure 2; Robertson *et al.,* 2024).

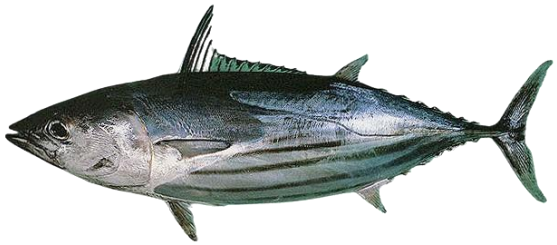

Figure 2. Photograph of the skipjack, *Katsuwonus pelamis. Taken* from FishBase , author: Randall, JE, (1997).

The skipjack skipjack is distributed in tropical and subtropical waters of the world, although its distribution is affected by convergence zones, oceanic fronts and upwellings (Sokolov 1967). There are records that the abundance of skipjack decreases during the hot phase of the “El Niño Southern Oscillation (ENSO)” phenomenon, while it increases in the cold phase, possibly due to the effect of the phenomenon on lobster, squid and smaller pelagic fish, some of which which are part of the skipjack diet (Alatorre-Ramírez, 2007).

Sizes range between 30 and 80 cm, with a maximum of 108 cm. The maximum weight recorded for the Eastern Tropical Pacific is 33 kg. It feeds mainly on euphasids (*Nyctiphanes sp .*) and small pelagic crustaceans (e.g. lobster, Alatorre-Ramírez, 2007). The size at maturity is 42 to 45 cm, equivalent to 3 years, although it has been reported that fecundity in female skipjack is very variable in relation to the geographical area and furcal length of the organism (Granados-Alcantar. 2002). In the Eastern Pacific Ocean, a slight predominance of males over females was identified, mainly in the winter months (Granados-Alcantar. 2002).

It has an asynchronous deviation, that is, not all individuals reproduce at the same time, and the period between spawning increases with distance from the equator (Collette & Nauen 1983). It reproduces from spring to early fall, spawning approximately 7 to 76

million eggs near coasts (neritic zone; Guevara-Rascado *et al.,* 2008). A wide dispersal of *K. pelamis eggs has been identified* in the Eastern Tropical Pacific, spanning from the Gulf of California to the Gulf of Tehuantepec.

Skipjack form shallow schools mixing with yellowfin tuna, blackfin tuna, floating objects and birds. Floating objects are an effective tool for locating schools of tuna (Collette and Nauen 1983). The association of the skipjack with larger organisms may be due to the protection they offer from predators, since when it is attracted by the size of the prey, the possibility of survival increases by having a smaller size than the other associated species. . And also because it offers more time for feeding given that its diet is similar to that of other tunas (Suyehiro , 1952 in Alatorre-Ramírez, 2007; Fréon and Dagorn , 2000).

2.3 Taxonomic classification

Animalia Kingdom

Phyllum : Chordata

Sub phullum : Vertebrata

Infra phyllum : Gnathostomata

Parvphylum : Osteichthyes

Giga class: Actinopterygii

Superclass : Actinopteri

Class: Teleostei

Order: Scombriformes

Family: Scombridae

Subfamily: Scombrinae

Genus: Euthynnus

Species: *Euthynnus lineatus* (Kishinouye , 1920)

Genre: Katsuwonus

Species: *Katsuwonus pelamis* (Linnaeus , 1758)

Genre: Sardinian

Taxonomic classification obtained from the World Register of Marine Species (WoRMS , 2024).

3. GENERAL OBJECTIVE

- Carry out a biological and fishing evaluation of skipjack in Puerto Ángel, Oaxaca for the year 2022-2023.

3.1 Specific objectives

- Carry out an exhaustive description of the skipjack fishery at the national level and its context within the state of Oaxaca.
- Analyze the age of the skipjack using indirect methods based on the size structure of the captured individuals.
- Evaluate the length-weight relationship of skipjack specimens.
- Describe the skipjack fishery based on data collected from landings, including monthly trends and catch per unit of effort.
- Identify the current status of the skipjack population in the Pacific area and propose specific conservation actions for its sustainable management.
- Propose recommendations for future biological-fishery evaluations of skipjack.

4. STUDY AREA

Puerto Ángel is a town of 2,991 inhabitants belonging to the coastal municipality of San Pedro Pochutla in the state of Oaxaca (INEGI, 2020). The main economic activity is fishing, followed by tourism and to a lesser extent, agriculture. It is an important tourist site for the state, receiving more than 25,000 people a year (SEMAR, 2008).

Puerto Ángel is located in the Gulf of Tehuantepec region, an area rich in upwellings resulting from strong winds that promote phytoplankton proliferation and trophic activity (Ojeda- Cárdenás and Ramírez-Ortiz, 2022). In Puerto Ángel, 487 fish have been reported, including sharks and rays (Ramírez, 2013), which represents 81% of the ichthyofauna recorded for Oaxaca (Del Moral-Flores *et al.,* 2016).

23 points were taken with a GPS along the coastline belonging to 10 fishing areas where black skipjack and skipjack are caught (Fig. 4).

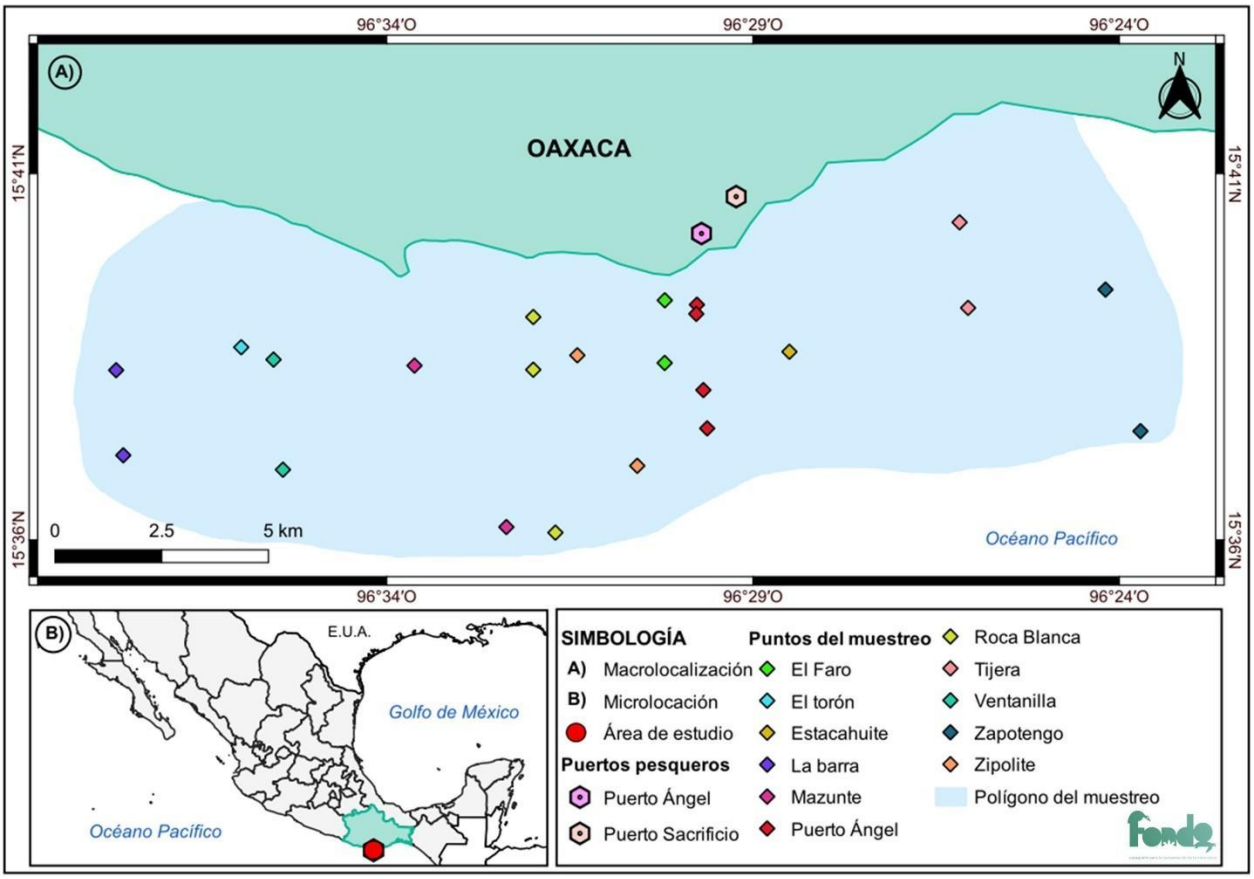

Figure 4. Map of the study area showing the monitored points in Puerto Ángel, Oaxaca. Prepared with layers downloaded from the Geoportal of the National Biodiversity Information System of CONABIO.

5. METHODS

5.1 Biological monitoring

Biological monitoring of 28 field trips on the beach for skipjack was carried out from February to November 2023 with students from the Pochutla Technological Institute and fishermen from the area.

On each outing, an average of 14 men and 10 women participated between one and two times a week in monitoring in the Bay of Puerto Ángel, Oaxaca, to record data on the name of the vessel, fishing area, reference location of the fishing, number of specimens caught, beachfront price, fishing time, species, weight in kilograms and length in centimeters of a random number of specimens.

The students were provided with a digital spring Roman scale, rechargeable batteries, tape measure, support table, recording sheets, pens and cell phone cameras to carry out measurements and records.

5.2 National and regional context

Through a review of government websites, specialized bibliography and technical documents, the national context, the tuna fishery on the coast of Oaxaca and, in particular, skipjack, were described. Power Bi Desktop was used for analysis in filters and data analysis in conjunction with Microsoft Excel.

The national and annual fishing production bases by species were downloaded from the official CONAPESCA website (Table I) covering the period 2006-2022. Fishing production bases classify species by common name, so the filter was applied for "skipjack." A filter was made to first exclude all non-tuna species, in order to identify the percentage that skipjack represents in national tuna production, and describe the pattern of skipjack production by state. A second filter was made to analyze only the skipjack in the state and municipalities of Oaxaca. The live weight and landed weight present in the national fishing production base are the same in both years, the landed weight category was used.

Propesca (2014-2019, Table I) and Bienpesca (2020-2022) databases were downloaded to identify the number of subsidies granted to the skipjack fishery since 2014. The Bienpesca database stopped including the species variable, therefore As of 2020, it was not possible to identify the number of beneficiaries by species.

To describe the fishing panorama in Oaxaca, the bases of economic units, large vessels, small vessels, aquaculture facilities and fishing population were downloaded from the page of the National Registry of Fisheries and Aquaculture (RNPA).

5.3 Global markets

The bases were obtained from the International Trade Database at the Product- level of the World Bank (Table I) from 1992 -2022. A first filter of imported and/or exported marine products was carried out, going from 5,000 to 102 products, subsequently an exclusive filter was made for products that were only or contained skipjack or black skipjack. It was identified that Mexico exported and imported skipjack from 1995 to 2012.

Table I. Sources and access links to the databases consulted.

Institution	Period	Information consulted	Access link to download page
CONAPESCA	2006-2022	National fishing production	https://www.gob.mx/siap/acciones-y-programas/roducton-pesquera
CONAPESCA	2014-2019	PROPESCA — Direct economic incentive for fishermen and aquaculturists	https://datos.gob.mx/busca/dataset/propesca—incentivo-economico-directo-al-pescador-y-acuacultor
CONAPESCA	2020-2022	BIENPESCA — Direct economic incentive for fishermen and aquaculturists	https://datos.gob.mx/busca/dataset/bienpesca—incentivo-economico-directo-al-pescador-y-acuacultor
CONAPESCA: National Registry of Fisheries and Aquaculture (RNPA)	2024	Economic Units Larger Vessels Small boats Aquaculture facilities Fishing population	https://www.gob.mx/conapesca/documentos/registro-nacional-de-pesca-y-acuacultura-rnpa
World Bank Group: CEPII Research and Expertise on the world economy	1992-2022	Trade Database at the Product-level (HS92-22)	http://www.cepii.fr/CEPII/en/bdd_modele/bdd_modele_item.asp?id=37
Data Mexico	2012-2022	Skipjack or Striped Belly Bonito “ *Euthynnus - Katsuwonus* ”, Fresh or Chilled.	https://www.economia.gob.mx/datamexico/es/profile/roducto/skipjack-or-belly-striped-euthynnus-katsuwonus-pelamis-fresh-or-chilled

5.4 Size structure

The size structure was analyzed from the data captured in the biological monitoring base for the two species of skipjack, black skipjack and striped skipjack. Frequency histograms were used to describe the weight and size of the organisms. Lengths and

weights were grouped into class intervals obtained from the Sturges Rule equation for both species.

$$K = 1 + 3.322 * (\ Log\ (n))$$

Where

- K: Number of classes
- N: Sample size

5.5 Weight to length ratio

The length-weight relationship for the black skipjack and the striped skipjack was analyzed using the least squares formula since it allows us to find the line that best fits and therefore describes the relationship between both variables. This method seeks to minimize the sum of the squares of the differences between the observed values and the values predicted by the fit line. The isometry test was performed to identify if length-weight growth is proportional, and if not, if it is negative and positive asynchronous . Linear regression was obtained for both species of skipjack.

5.6 Age and growth

Based on the lengths in millimeters, the organisms were classified into ages and the equation and growth rate for the kite set were obtained from the Von Bertalanffy equation.

$$L(t) = L\infty[1 - e^{-K(t-t_0)}]$$

Where

- L(t): Length of the fish at age t.
- L∞: Constante que representa la longitud asintótica o la longitud teórica máxima que el pez puede alcanzar cuando *t* tends to infinity.
- K: Growth constant.
- t: Age.
- t_0: Theoretical age at which the length of the fish should be zero.

5.7 Analysis of the skipjack fishery

From the SCPP fishing and production record base and the biological sampling database, a description of the skipjack fishery in Oaxaca was made, which included the monthly landing, production by species and by vessel, duration of the fishing trip, frequency of fishing gear, number of crew, product presentation and product cost. Chi square tests were performed to identify differences in the volume recorded by vessel, disembarkation by number of crew members.

5.7.1 Travel expenses

The cost of the fishing trip (gas, breakfast and transportation) was described based on the data collected in the biological monitoring base. The maximum, minimum, average and standard deviation costs are shown for each of these inputs.

5.7.2 Price per barrel piece

The price on the beach for black skipjack and tuna (skipjack) was described, listing the average price, standard deviation, maximum and minimum sales per kilogram. The six sales presentations are indicated only for the black skipjack and the weight frequency per presentation is shown from a late bar graph.

5.8 Conservation actions

The Red List of the International Union for the Conservation of Nature (IUCN), as well as NOM-059-SEMARNAT-2010, was consulted to identify the conservation status of black skipjack and skipjack tuna. Seven conservation actions are proposed. conservation for the sustainability of the skipjack fishery in the state of Oaxaca.

6. **RESULTS**

6.1 National context

The resource called skipjack includes the species of black skipjack (*E. lineatus)* and striped skipjack (*K. pelamis)* , which are small species of tuna that play an important role in fisheries worldwide due to their economic value and job creation. and be a source of animal protein. It represents between 45% and 49% of global tuna catches, although it is not the most economically important species, with yellowfin tuna (*Thunnus albacares*) being the most relevant in this regard (Botello-Ruvalcaba & Villaseñor-Talavera, 2008). In the Pacific Ocean, approximately 13% of global tunas are captured, with Mexico being one of the main producers (Botello-Ruvalcaba & Villaseñor-Talavera, 2008).

Tuna fisheries in Mexico had their beginnings in 1916 by the artisanal fleet, initially capturing yellowfin tuna and later incorporating skipjack on the coasts of Baja California (Botello-Ruvalcaba & Villaseñor-Talavera, 2008). By 1927, the commercial capture of tuna was established, formalizing especially in the late 1960s with the reconditioning of fishing vessels, going from bait to purse seine nets, and reaching its peak in the 1980s (Morán-Angulo, 2000).

Currently, the tuna fishery in Mexico continues to grow (CONAPESCA, 2015), occupying second place in the country's fishing production. This activity provides employment to more than 12 thousand fishermen and generates around 70 thousand direct and indirect jobs, with an estimated annual production between 100 and 150 thousand tons (CONAPESCA, 2018; Gómez-Mena, 2020). The main tuna producing states are Sinaloa, Colima, Chiapas and Baja California, although other states such as Baja California Sur, Veracruz, Oaxaca, Tabasco and Jalisco also participate to a lesser extent (CONAPESCA, 2015).

Tuna species caught in these fisheries include yellowfin, bigeye or bigeye tuna (*Thunnus obesus*), bluefin (*Thunnus orientalis*), and skipjack (DOF, 2023). However, the greatest fishing and legislative effort focuses on yellowfin tuna due to its large production volume and high commercial value (Solana- Sansores & Ramírez-López, 2006). Yellowfin tuna has come to represent between 70% and 90% of the total tuna catch in Mexico (Fig . 5). The other species are considered complementary or associated with yellowfin tuna, despite their importance at the national and regional level (DOF, 2023).

The skipjack resource has been caught off the Mexican coast for a century, but it was in the mid-1990s when the catch of *K. pelamis* began to increase, along with other tuna species, due to shipments from the United States. towards Mexico. Currently, skipjack has positioned itself as the second most caught and traded tuna species in Mexico (Fig. 5). The capture percentage has undergone significant changes; During the 90s it represented 11.3% of the tuna catches at the national level (Granados-Alcantar, 2002), currently remaining between 10% and 20% of the national catches (Fig. 4).

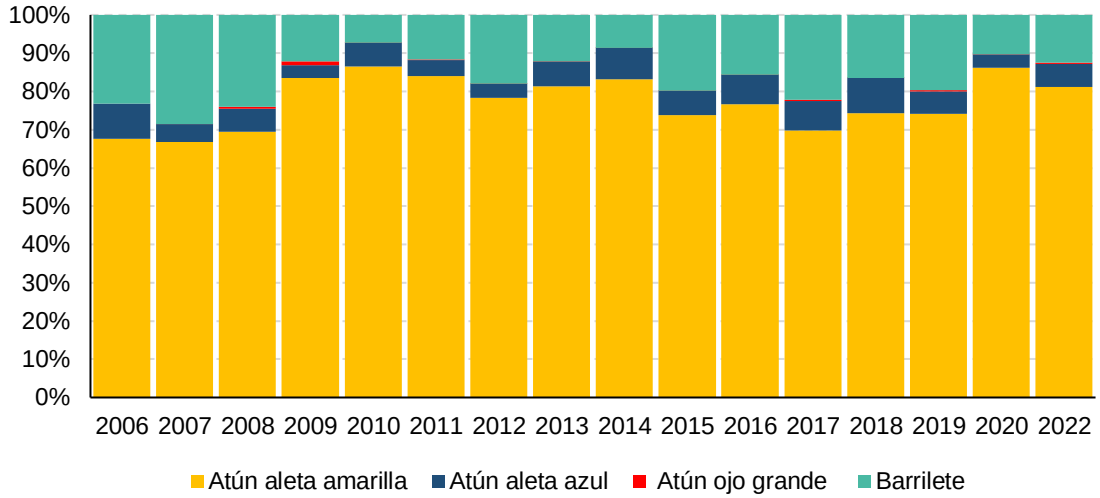

Figure 5. Proportion of fishing landings in kilograms for the four main species of tuna in Mexico from 2006 to 2022. Own elaboration based on the annual bases of CONAPESCA fishing production tables.

The status of the skipjack fishery varies depending on the fishing region in Mexico. Arreguín-Sánchez and Arcos-Huitrón (2011) carried out a study on regional changes in various commercial fisheries from 1956 to 2009. For skipjack, a diverse pattern was observed in different areas. In the Gulf of California, it was found that the fishery fluctuated between underdeveloped and developed states from 1979 to 1997, reaching its maximum exploitation between 1998 and 2009. On the other hand, on the central Pacific coasts, the fishery remained underdeveloped since 1977. until 1995, experiencing

development between 1996 and 2003, and reaching its peak in 2004. However, as of 2005, the fishery was classified as overexploited and in 2009 it was considered collapsed. In the Gulf of Tehuantepec, the situation was similar, with an underdeveloped phase from 1966 to 1998, followed by a period of development between 1999 and 2003. Starting in 2004, the fishery oscillated between maximum exploitation and overfishing. On the coasts of the Gulf of Mexico, from Tamaulipas to Tabasco, the skipjack fishery was analyzed since 1990. In that period, a combination of states of underdevelopment and development was observed until the year 2000, but from then until 2007 it remained low. maximum use, collapsing in 2009. For the Bank of Campeche, only the years 1998 and 1999 were analyzed, the first classified as developed and the second as maximum use.

The Gulf of California stands out as the largest producer of skipjack in Mexico, with 225,622 tons landed in 17 years (66.9%), followed by the Pacific (110,843 tons, equivalent to 32.9%), Gulf of Mexico (315 tons, which represents the 0.09%) and Caribbean Sea (7.7 tons or 0.002%; CONAPESCA, 2006-2022).

Skipjack catch and value have been highly variable for the 17 coastal states (Figure 6). However, in most states and years, the economic value line has followed a similar pattern to that of the landed weight. In Nayarit and Sinaloa, this pattern is broken, since the value of the skipjack has exceeded the weight landed (Fig. 6).

The highest national production for both species of skipjack was recorded in 2007, with 33,247,039 kg, which represented $188,131,947 pesos ($11,015,597 USD), while the lowest was observed in 2010, with 8,998,156 kg, with a value of $68,689,357 Mexican pesos. ($4,021,934 USD; Figure 6). The average landing of the skipjack fishery over 17 years is 21,049,333 kg, equivalent to $216,194,304 pesos ($12,658,719 USD, Table II).

Sinaloa is the state with the highest skipjack landings among all the coastal states (Figure 6), followed by Colima, Chiapas and Oaxaca, while Campeche, Yucatán and Tamaulipas have the lowest production (Table II). Quintana Roo only reported one year of skipjack capture, in 2020, with 1,081 kg and a value of $185,841 M/N. The same occurred for Tabasco, where the amount of 774 kg was reported only in 2010, with a value of $7,845 M/N (Table I). Although Tamaulipas appears at the bottom of the table, it has caught skipjack in small quantities for seven years.

Table II. Average, maximum and minimum weight landed for the two species of skipjack, black and skipjack in the period 2006 to 2022. Own elaboration based on the annual bases of CONAPESCA fishing production tables.

Federal entity	Average landed weight (kg)	Maximum		Minimum	
		Year	Landed weight (kg)	Year	Landed weight (kg)
Sinaloa	12,679,676	2007	26,807,481	2010	4,556,164
Colima	3,878,831	2017	8,846,562	2009	749,154
Chiapas	2,024,407	2019	3,817,747	2014	861,208
Oaxaca	899,807	2015	2,099,504	2008	246,654
Baja California Sur	367,296	2006	1,827,403	2019	3,075
Nayarit	666,266	2015	1,679,885	2007	5,568
Baja California	290,622	2019	1,019,418	2011	2,000
Jalisco	134,164	2014	581,965	2006	9,120
Sonora	89,674	2010	379,000	2007	1,000
Veracruz	19,331	2006	153,672	2019	125
Michoacan	15,250	2015	120,582	2006	23
Warrior	14,987	2017	43,297	2006	405
Campeche	1,697	2018	2,700	2010	694
Yucatan	958	2019	2,500	2014	200
Quintana Roo	1,081	2020	1,081	2020	1,081
Tabasco	774	2010	774	2010	774

Tamaulipas	184	2012	386	2019	1
NATIONAL TOTAL	**21,085,005**		**47,383,957**		**6,437,246**

During the period of the PROPESCA fishing subsidy program (2014-2019), a total of 98 fishermen dedicated to skipjack fishing submitted applications for this subsidy, however, only three of them received it, two in Oaxaca and one in Colima. in 2019 (CONAPESCA, 2020). It is important to note that the fishery subsidy program does not specify the fishery in which fishermen are involved, making it difficult to identify any fishery-specific increases. However, the exponential increase in the number of supports granted under the new operating rules of the BIEPESCA program (CONAPESCA, 2023) is notable.

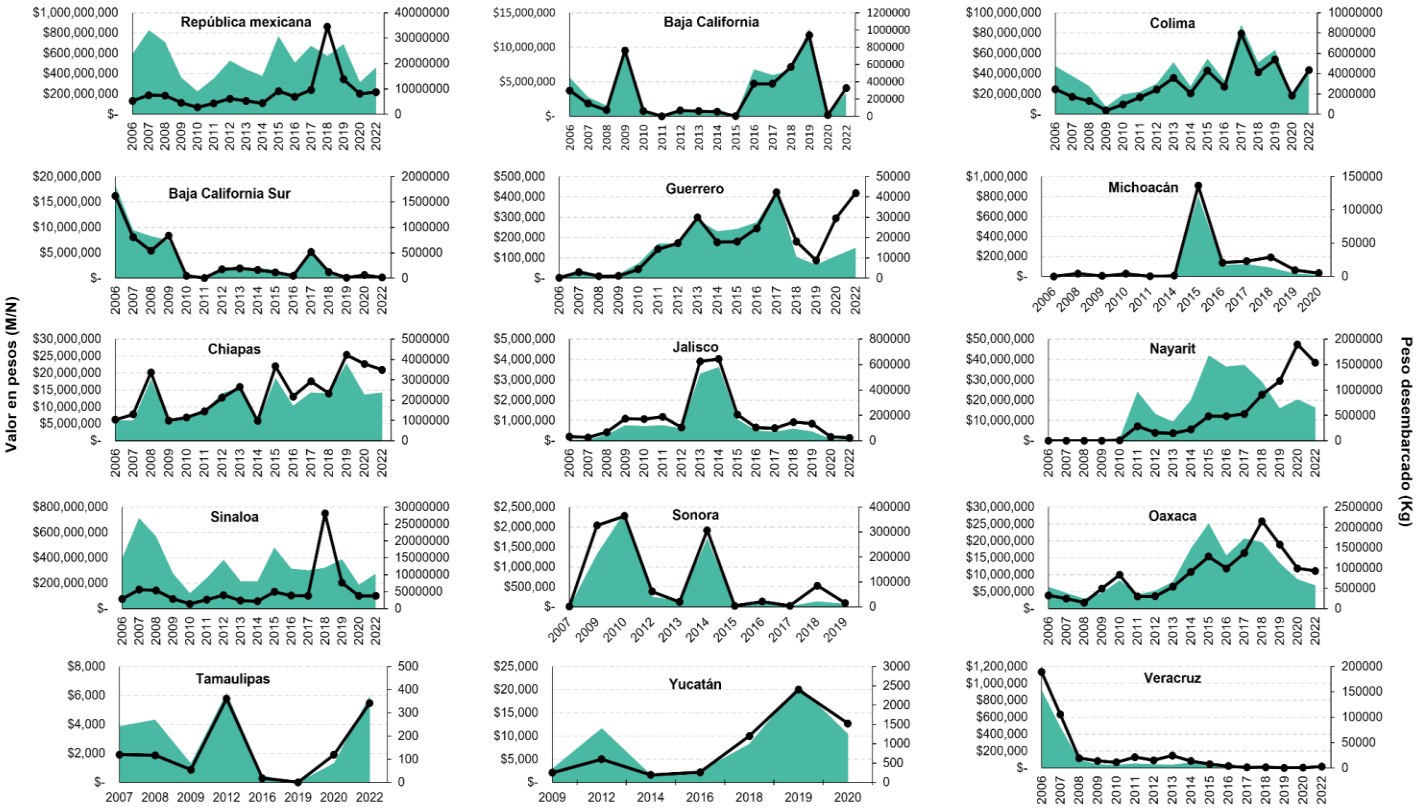

Figure 6. Economic value (black line) and landed weight in kilograms (green area) for the two species of skipjack, black skipjack *Euthynnus lineatus* and striped skipjack *Katsuwonus pelamis* by state from 2006 to 2022. Own elaboration based on annual databases CONAPESCA fishing production tables.

6.1.1 Regional context

Oaxaca occupies 15th place in the number of fishermen and boats, with 219 deep-sea fishermen, 6,219 coastal fishermen, 687 aquaculturists, 2,073 small boats and 39 large boats. 37.34% of the smaller vessels are in Juchitán, 17.32% in Pinotepa Nacional, 15.10% in Puerto Escondido, 14.66% in Puerto Ángel, 8.20% in Salina Cruz, 5.4% in Oaxaca and 1.98% in Temazcal. . All the larger vessels are in Salina Cruz.

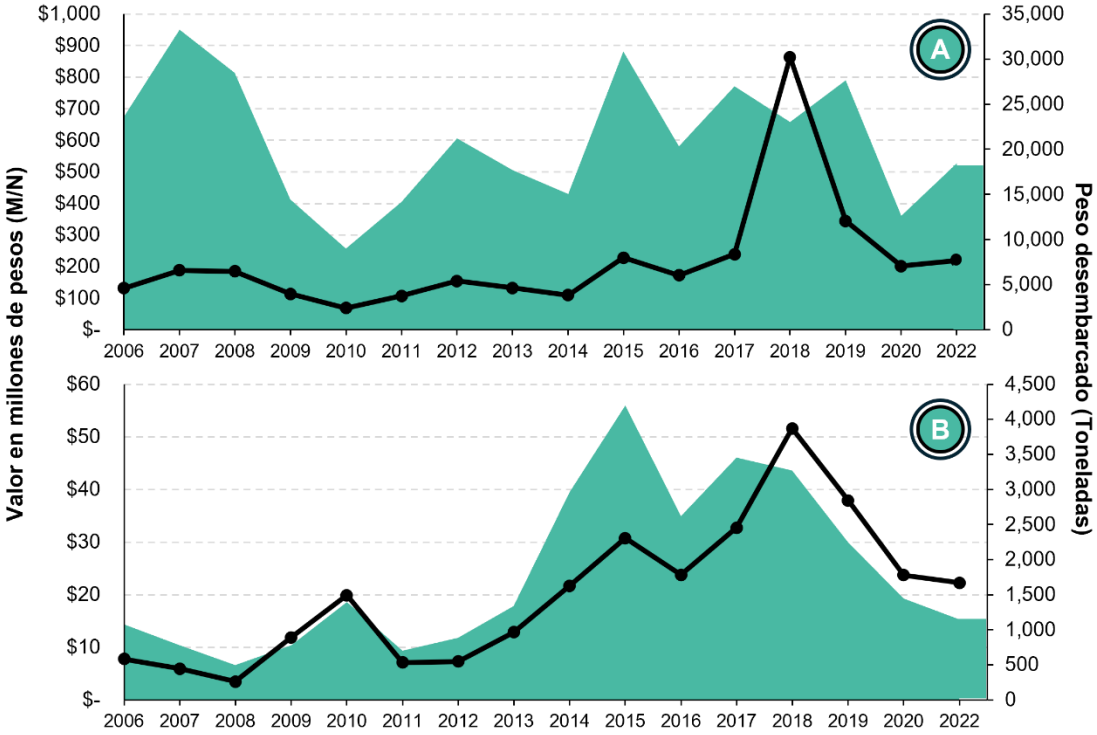

Figure 7. Fishing landings (areas) and economic value (lines) of the skipjack resource fishery from 2006 to 2022 at the national level (A) and in the state of Oaxaca (B). Own elaboration based on the annual bases of CONAPESCA fishing production tables.

The skipjack resource ranks 4th among Oaxaca's fisheries in terms of landed weight in kilograms, and 13th in economic value. However, black skipjack and skipjack are the most important tuna species in the state. At the national level, Oaxaca contributes 4% of the total national catch of the skipjack resource. In the period 2006-2022, the year 2015 had the record with 2,099,504 kg of skipjack landed (equivalent to $15,376,105 M/N), while in In 2008, the minimum value was recorded with 246,654 kg ($175,675 M/N). Although the 2018 catch was

lower than in 2015, that year it reached the highest economic value in the 16 years, at $863,099,449. (Fig. 7).

In the state of Oaxaca, the municipality of Puerto Ángel leads the production of the skipjack resource landed during the last 17 years (2006-2022), with a total of 11,006,549.8 kg, followed by Puerto Escondido with 2,692,946 kg and Salina Cruz with 355,599 kg. In Pinoteca Nacional, the catch of skipjack has only been recorded in four years, 2010, 2015, 2016 and 2022. The municipality of Oaxaca only has two records, one in 2019 with a landing of 3,581 kg and another in 2020 with 2,995 kg. In Juchitán, skipjack capture has not been recorded after 2015, and in Huatulco since 2018 (Fig. 8).

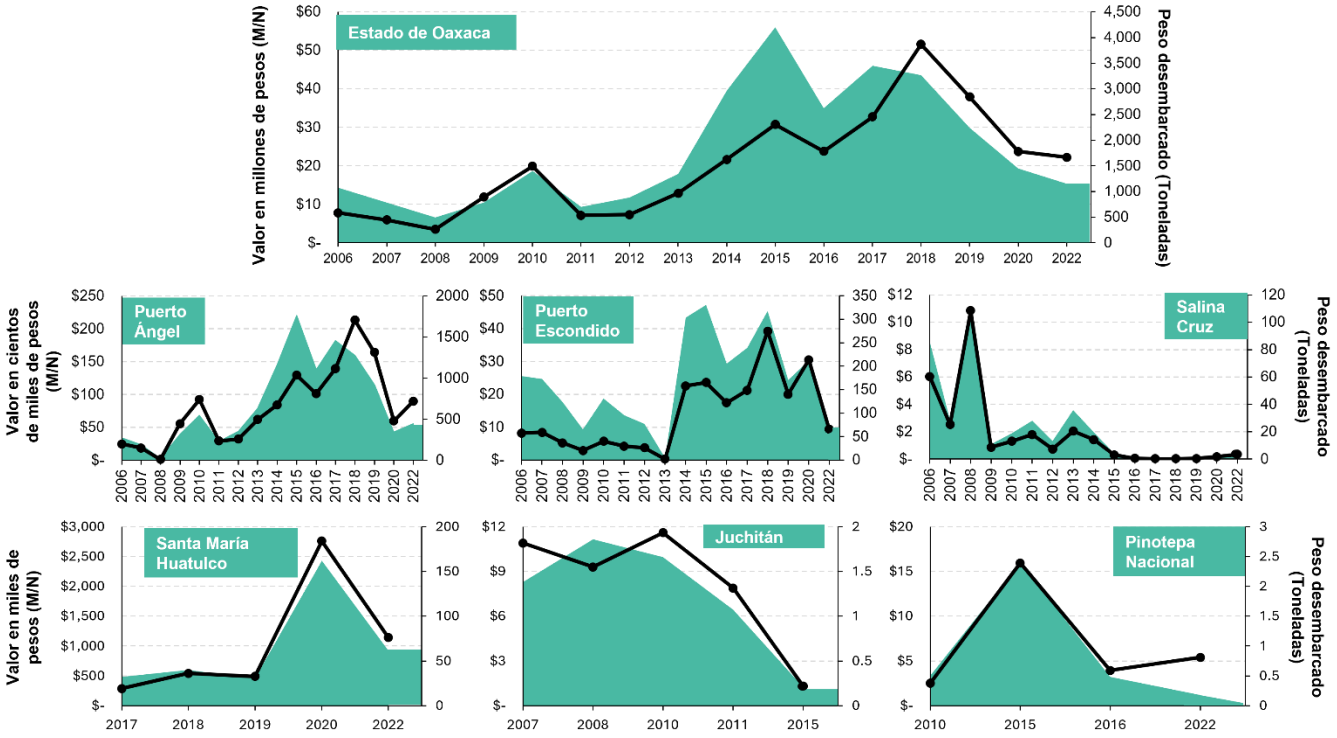

Figure 8. Economic value (black line) and landed weight in kilograms (green area) of the skipjack resource for the state of Oaxaca, and six of its municipalities from 2006 to 2022. Own elaboration based on the annual bases of fishing production tables of CONAPESCA.

Of the two species that make up the skipjack resource, the black skipjack represents 90.68% of the catches reported during biological monitoring in Puerto Ángel (Fig. 9). The dominance of the black skipjack may be due to the fact that the strip between Puerto Escondido and Puerto Ángel is a reproduction and growth area for this species.

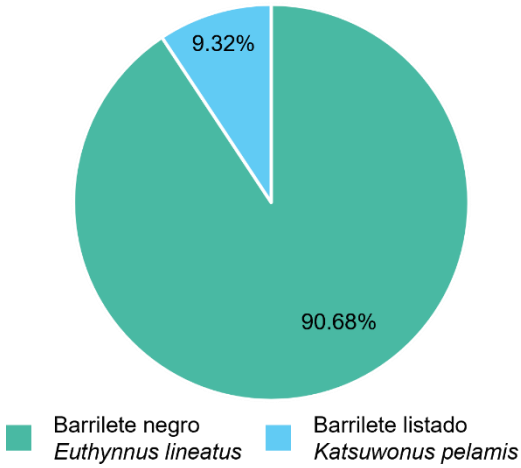

Figure 9. Proportion of catches of black skipjack and skipjack in Puerto Ángel, Oaxaca.

6.2 Global markets

In Mexico, exports and imports of skipjack to the international market lasted 17 years, starting in 1995 and ending in 2012. Since 2013, Mexico has not recorded any exports or imports of skipjack according to the 1995-2022 bases of the International Trade Database at the Product-level of the World Bank.

Mexico made 315 exports to 51 countries, mainly the United States (15.24%), Spain (6.35%), Belize and Honduras (5.71%), Cuba 5.40%; Figure. 10A). 78,705.73 tons were exported, which represented $20,415.42 USD. The modes of presentation were prepared or preserved (74.92%), frozen (18.73%), and fresh or refrigerated (6.35%).

At the national level, 314 imports were made, equivalent to 249,926.55 tons and with a value of $465,338.79 USD, coming mainly from the United States (11.11%), Spain (6.98%), Ecuador (6.67%) and Indonesia (6.03%; Figure. 10B). The presentations were prepared or preserved (62.86%), frozen (34.92%), and fresh or refrigerated (2.22%).

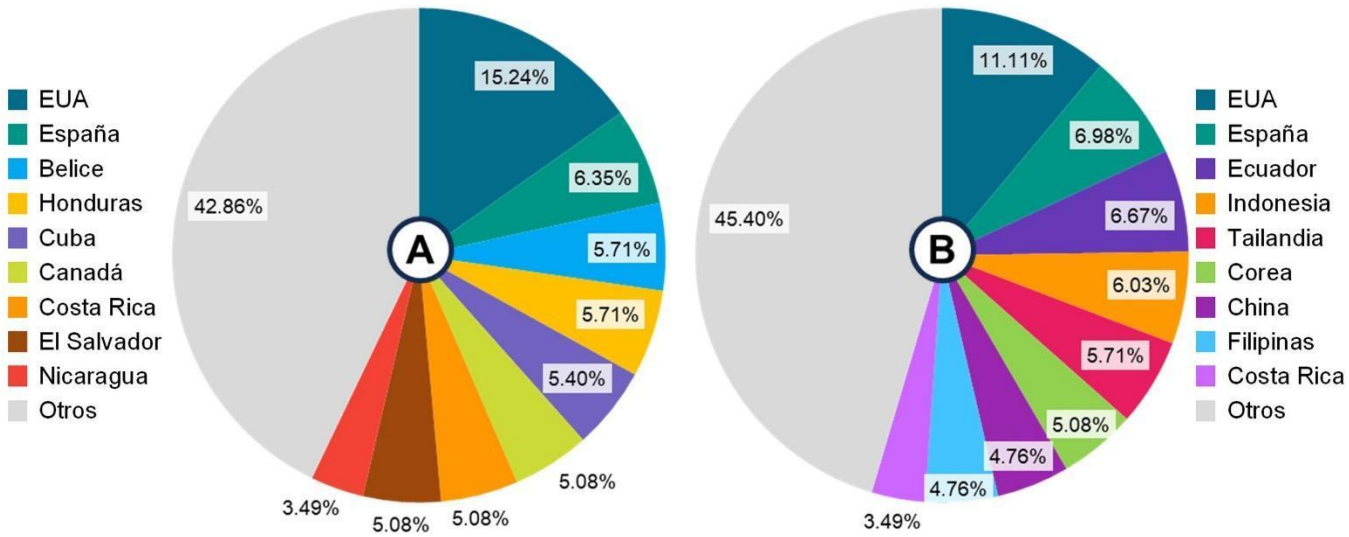

Figure 10. 17-year average proportion of exports (A) and imports (B) of Mexico in the world. Own elaboration with data from the International Trade Database at the Product- level .

In 2021, the main skipjack exporting countries were Sri Lanka, China and Spain, reaching values of $3.91, $1.63 and $1.58 million USD. While the United States, Fiji and France were the main importers during the 2020-2021 period, importing $3.86, $1.63 and $1.36 million USD (Data México, 2021).

6.3 Size structure

General

Within the FIP base, a total of 869 individuals were recorded, 788 black skipjack and 81 striped skipjack. The average length for the two species of skipjack was 47.60 cm (± 3.17 cm, Figure 9) with a maximum of 62 and a minimum of 36 cm.

In March the longest individuals were recorded (49.6 cm) and in October the smallest ones (45.7 cm). Sizes above 48 cm are maintained from February to June. Weights vary little throughout the year. The highest weight was in September (2.3 kg) and the lowest in March (1.5 kg, Fig. 11).

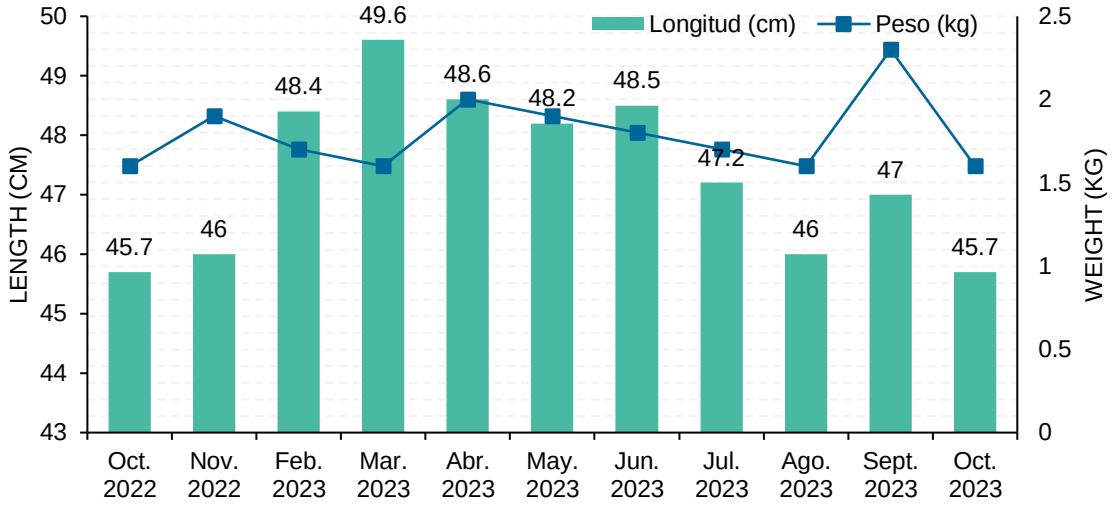

Figure 11. Monthly variation in length (bar) and weight (line) for the two species of skipjack, black skipjack and striped skipjack.

Black skipjack, *Euthynnus lineatus*

The average length of black skipjack was 47,393 cm (± 2,565 cm), with a minimum of 36 cm and a maximum of 56 cm. There is a greater concentration in the range of 44 cm to 49 cm, with frequencies ranging from 17 to 113 (Fig. 12A). The less frequent lengths appear only once or very rarely in the sample, such as 36, 38, 39 and 39.5 cm. Six class intervals were identified for length, with a range of 20 and a width of 3.26 cm between intervals. More than 50% of the individuals are between 45.8 - 49.05 cm (Table III).

The average weight was 1,757 kg (± 0.281 kg) with a maximum of 2.8 kg and a minimum of 0.730 kg. The highest concentration of weights is between 1.3 kg to 1.8 kg, with frequencies ranging from 5 to 114. The lowest frequencies were 0.73, 0.9 and 1,050 kg, among others. Eight class intervals were identified for length, with a range of 2.07 and a width of 0.260 kg between intervals. 87.8% of the individuals are concentrated in three weight ranges, 1.26 - 1.51 kg, 1.52 - 1.77 kg and 1.78 - 2.03 kg (Table III).

Table III. Length (cm) and weight (kg) class intervals for black skipjack.

Length (cm)			Weight (kg)		
Interval	**Frequency**	**Percentage**	**Interval**	**Frequency**	**Percentage**
36 - 39.25	4	1 %	0.73 - 0.99	2	0.3%
39.26 - 42.52	32	4 %	1 - 1.25	19	2.40%
42.54 - 45.79	129	16%	1.26 - 1.51	159	20.2%
45.8 - 49.05	462	59%	1.52 - 1.77	232	29.40%
49.06 - 52.31	150	19%	1.78 - 2.03	301	38.20%
52.32 - 56	eleven	1 %	2.04 - 2.29	47	6%
			2.3 - 2.55	22	2.80%
			2.56 - 2.81	6	0.80%

Skipjack, *Katsuwonus pelamis*

The average length of skipjack skipjack was 50.106 cm (± 3.43 cm), with a maximum of 62 cm and a minimum of 41 cm (Fig. 12B). There is a concentration of lengths between 47 to 52 cm. The less common lengths are 41, 44, 45, 58 cm among others. Six class intervals were identified for length, with a range of 21 and a width of 3.76 cm between intervals. 77.7% of skipjack individuals are between 44.77 - 48.52 cm and 48.53 - 52.28 cm (Table IV).

The average weight was 2.02992 kg (± 0.548 kg) with a maximum of 5 kg and a minimum of 1.33 kg. There is a concentration of weights in the range of 1.5 to 2 kg, with frequencies ranging from 3 to 20. Some extreme weights are observed in this sample, such as 5, 4, 3.5 and 3 kg, although they are less common. Seven class intervals were identified for length, with a range of

3.67 and a width of 0.571 kg between intervals. 83.95% of the individuals are concentrated in two weight ranges, 1.33 - 1.90 kg and 1.91 - 2.47 kg (Table IV).

Table IV. Length (cm) and weight (kg) class intervals for listed kite.

Length (cm)			Weight (kg)		
Interval	**Frequency**	**Percentage**	**Interval**	**Frequency**	**Percentage**
41 - 44.76	2	2.5%	1.33 - 1.90	32	39.51%
44.77 - 48.52	27	33.3%	1.91 - 2.47	36	44.44%
	36	44.4%	2.48 - 3.04	9	11.11%
48.53 - 52.28	eleven	13.6%	3.05 - 3.61	1	1.23%
	5	6.2%	3.62 - 4.19	2	2.47%
52.29 - 56.04			4.20 - 4.76	0	0%
			4.77 - 5.33	1	1.23%
56.05 - 59.8					

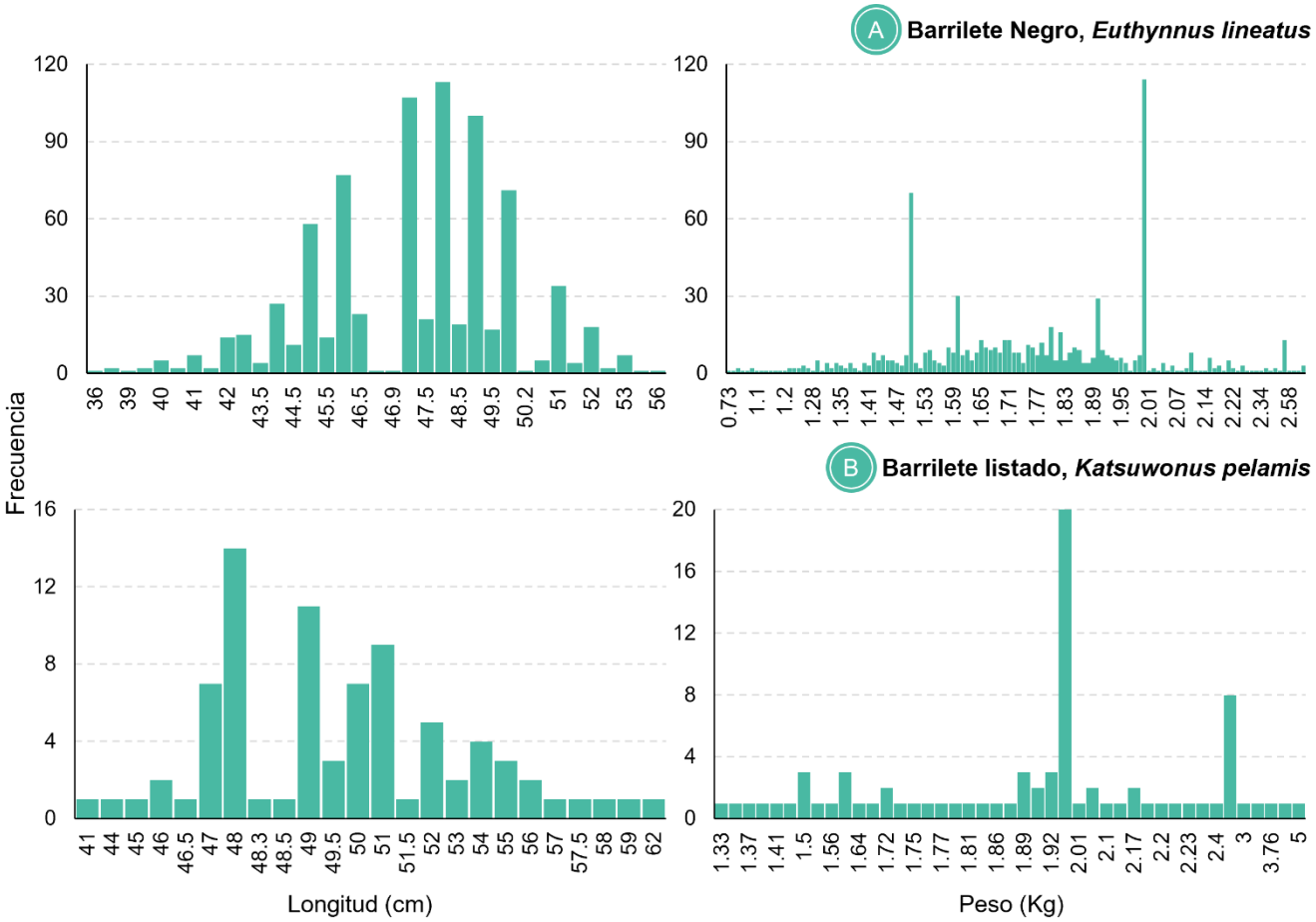

Figure 12. Size histogram of length (cm) and weight (kg) for the black skipjack, *Euthynnus lineatus* (A) and the striped skipjack, *Katsuwonus pelamis* (B).

6.4 Weight – Length Ratio

Black skipjack, *Euthynnus lineatus*

allometric growth , that is, it grows in length, and subsequently in weight. The slope (beta) of the linear regression indicates that, for each unit increase in length, a growth of 1,977 g is expected. The coefficient of determination (r^2) was 0.458, indicating that about 45.8% of the variability in weight can be explained by length using the linear regression model (Fig. 13). The negative allometry of black skipjack in the Oaxaca area was previously reported by Ramos-Cruz (2009) and Velásquez (2017).

Results of the analysis of the weight-length relationship by least squares:

- α= 0.0089
- β= 1.977
- Adjusted R^2= 0.458
- Degrees of freedom = 978
- Log10(Length)= 0.023
- Log10(Weight)= 0.0708

Isometry test results:

- Absolute of B-3= 1.022
- T-calculated= 13.17
- *p* = 5.60 E-36

The linear regression equation for the kite is: *Weight (gr) = 0.009 +1.978 * (Ln10 (Length (mm))*

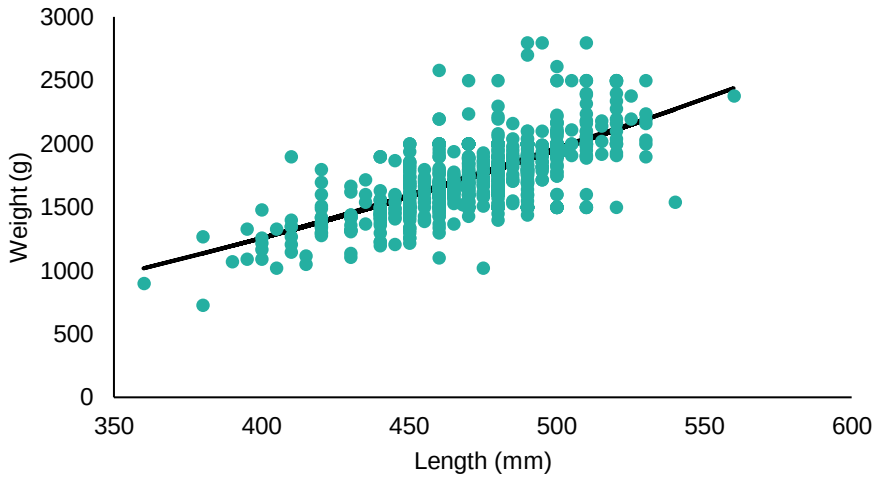

Figure 13. Linear regression of the weight-length relationship of the black skipjack, *Euthynnus lineatus* .

Skipjack, *Katsuwonus pelamis*

The skipjack shows isometric growth, that is, the weight grows proportionally and at the same time as the length. The slope of the regression line is 2.938, so for each increase in length, an increase in weight of 2.938 g is expected. The coefficient of determination (r^2) is approximately

0.519, which indicates that 51.9% of the variability in weight can be explained by length using the linear regression model (Fig . 14).

Results of the analysis of the weight-length relationship by least squares:

- α= 2.33257E-05
- β= 2.938
- Adjusted R^2= 0.5190
- Degrees of freedom = 77
- Log10 (Length)= 0.029
- Log10 (Weight)= 0.0969

Isometry test results:

- Absolute of B-3= 0.0617
- T-calculated= 0.235
- *p* = 0.814823

The linear regression equation for the kite is: *Peso (gr)= 2.33257E−05 +2.938 * (Log10 (Longitud(mm))*

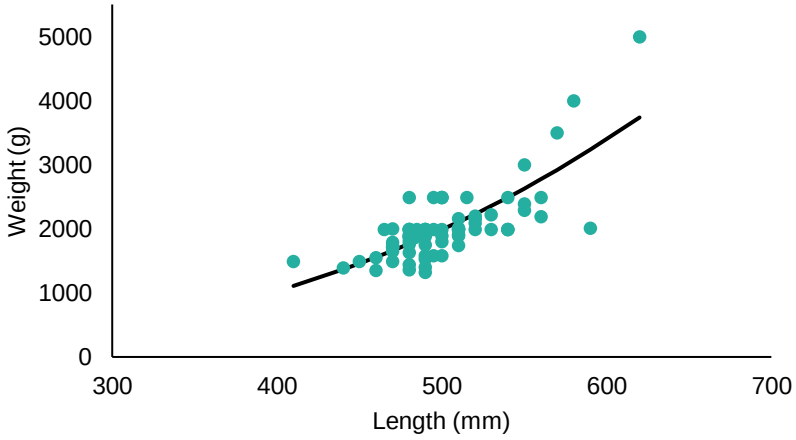

Figure 14. Linear regression of the weight-length relationship of the skipjack skipjack, *Katsuwonus pelamis* .

6.5 Age and growth

Black skipjack, *Euthynnus lineatus*

Se identificaron 10 intervalos de edad donde se clasificaron los 781 individuos de barrilete negro. A partir de la ecuación de Von Bertalanffy, se determinó una tasa de crecimiento moderada (Figura 15). El valor L∞ fue de 48.78 cm, el valor de k fue de 0.6 y T_0 out of 0.03.

There was an upward trend from the first years until reaching a peak in the seventh year of age, with 242 individuals (Figure 15). This progressive increase may be the result of a probable accumulation of individuals in the older age group, possibly due to a higher survival rate or favorable environmental conditions (FAO, 1993). Although age eight had the second highest concentration of individuals, it is shown that from that age the frequency begins to decrease.

The total biomass of black skipjack was 1,387. 12 kg. A gradual increase in biomass is observed from the first years until reaching a maximum in the eighth year, with a notable value of 429.17 kg. This progressive increase suggests continuous growth and biomass accumulation over time, possibly due to an increase in size and the number of individuals in the population (Gómez et al., 2020).

Skipjack, *Katsuwonus pelamis*

Se identificaron siete intervalos de edad donde se clasificaron los 81 individuos de barrilete listado. A partir de la ecuación de Von Bertalanffy, se determinó una tasa de crecimiento moderada (Fig. 15). El valor L∞ fue de 54.64 cm, el valor de k fue de 0.76 y T_0 out of 0.51. The skipjack has a higher growth rate compared to the black skipjack.

The highest concentration of skipjack individuals is between three and four years old, with 37 and 22 observations respectively. The presence of a significant number of individuals at younger ages could suggest a healthy reproduction rate or the existence of favorable conditions for early survival (FAO, 1993).

There is a significant increase in biomass from the second to the third year, reaching a peak in the third year with 67.67 kg. However, from that point on, biomass gradually decreases as

age advances (Fig. 15). This pattern suggests a life cycle marked by rapid growth in early stages followed by a period of stability or decline in later stages.

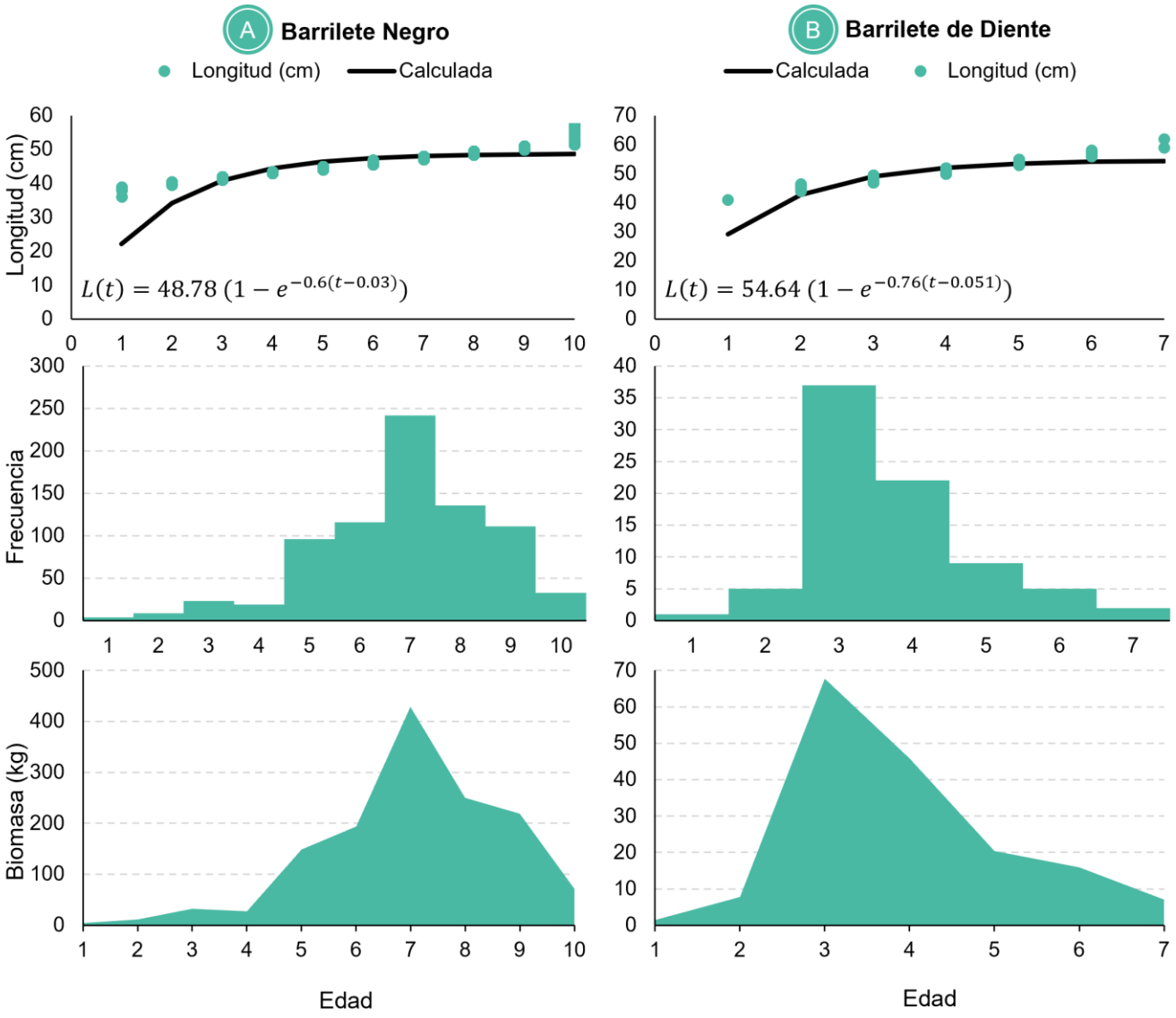

Figure 15. Linear relationship of the Von Bertalanffy equation, histogram of age and biomass by age for the black skipjack, *Euthynnus lineatus* (A) and the striped skipjack, *Katsuwonus pelamis* (B).

6.6 Skipjack fishery in Puerto Ángel, Oaxaca

In the Excel Base of the SCPP Punta Sacrificio Fishing and Production Registry, a total of 157 fishing observations were made for the black skipjack and striped skipjack from September 2022 to August 2023. A volume of 9,928.88 kg was reported between both species, 9,643.88 kg

for black skipjack and 285 kg for skipjack, the latter was only caught four times, in April, July and twice in August. The average catch of black skipjack is 63.03 kg, with a maximum of 116.04 kg in July, and a minimum of 23.44 kg in September (Figure 16). In July 2023, the largest catch was obtained with 2670.35 kg and the smallest in August 2023 with 175 kg (Fig . 16).

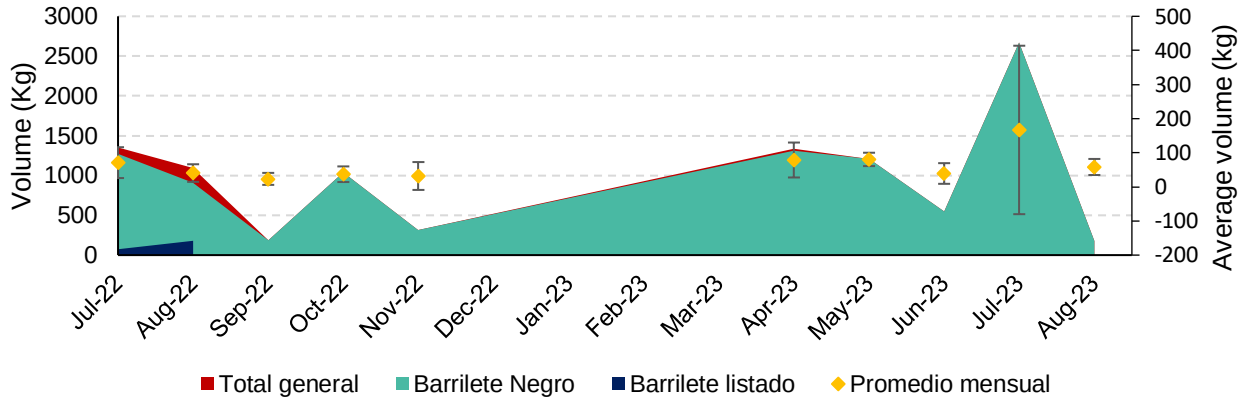

Figure 16. Volume in kilograms landed of the monthly catch of black skipjack *Euthynnus lineatus* and skipjack skipjack *Katsuwonus pelamis* for 2022 to 2023.

Six boats are used, Arcángel, Cinthia, Juquilita, La Odisea, The Seven Drops and Sofi . Of these, three are employed more than 90% of the time, Juquilita (64.33%), Arcángel (15.29%), Cinthia (12.74%). Juquilita had the highest production with 5,371.96 kg, and La Siete Gotas had the lowest with a single record (Fig. 17). There are no significant differences in the volume per vessel (α 0.05, p= 0.074).

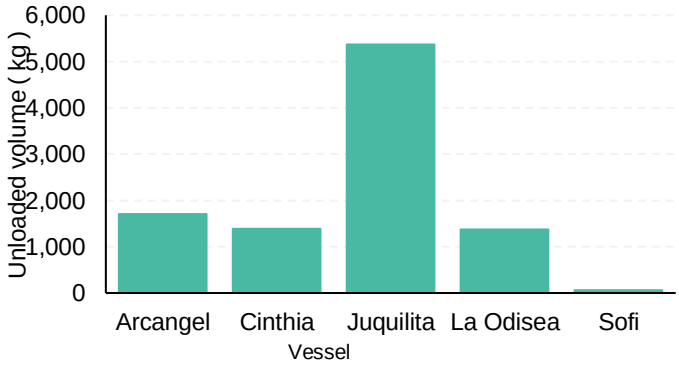

Figure 17. Volume in kilograms landed by vessel from the fishing registry base.

97% of fishing trips are round trips on the same day, with a time range between 1 and 3 hours of travel, although 76.62% of trips are 2 hours. Only trolling was used as fishing gear on all two-hour fishing trips.

The number of crew members ranged from just the captain to the captain with one to three crew members. 44.59% of the trips were made with one crew member, 30.57% with two, 22.93% without any other member apart from the captain, and 1.91% with three crew members. There are differences in volume due to the number of crew members (α 0.05, p= 0.0068). 79% of the product is presented whole with viscera, while the rest is whole-eviscerated. For skipjack tuna (skipjack) 100% of the presentation was whole, while for blackskipjack 78.7% was whole and 21.3% was whole-gutted.

In the FIP Biological Sampling base, the capture of 5,739 skipjack individuals was recorded from October 2022 to October 2023, May had the largest capture with 1,465 individuals and an average per fishing trip of 112.69 skipjack, while November had the smallest amount with 76 individuals and an average per trip of 12.67 skipjacks (Figure 18).

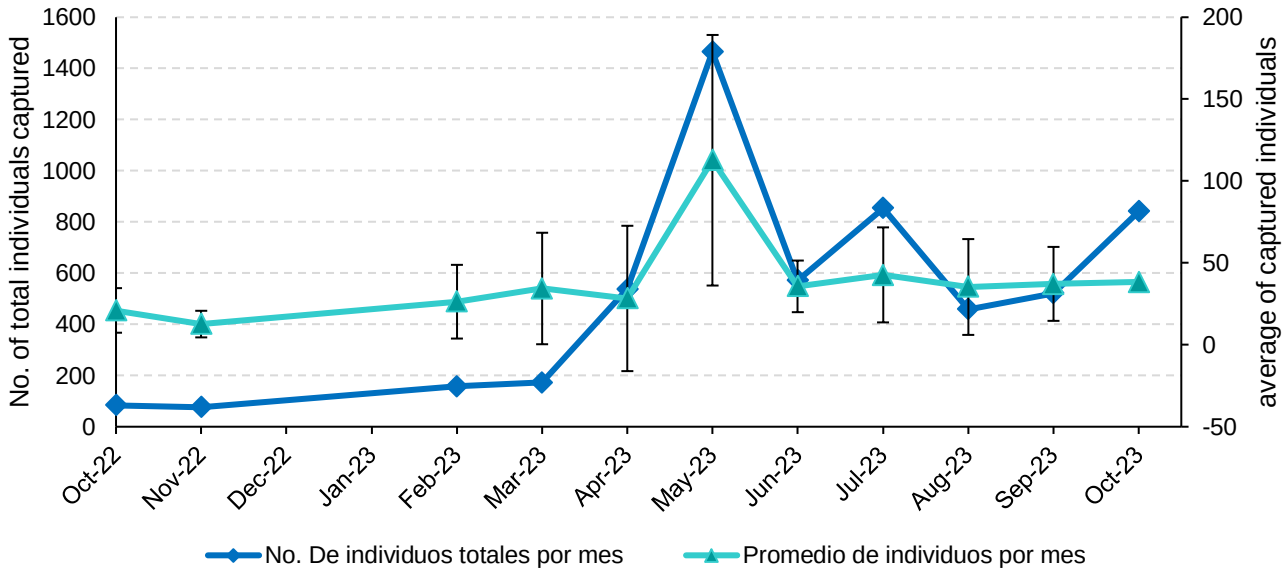

Figure 18. Total and average number of individuals captured per month from the biological sampling base.

There are 32 vessels registered within the FIO Oaxaca Biological Sampling base, of these, Lichito obtained the largest capture with 844 individuals, followed by La Odisea with 744, while Juquita and Capris only had 2 captures each (Figure 19A). Two fishing gears are used: trolling, which is used on 68.42% of the trips, and hand line (31.58%). Trolling appears to have a greater volume of skipjack catch than handline (Figure 19B), this is notable for Arcángel, Yami and Juquilita.

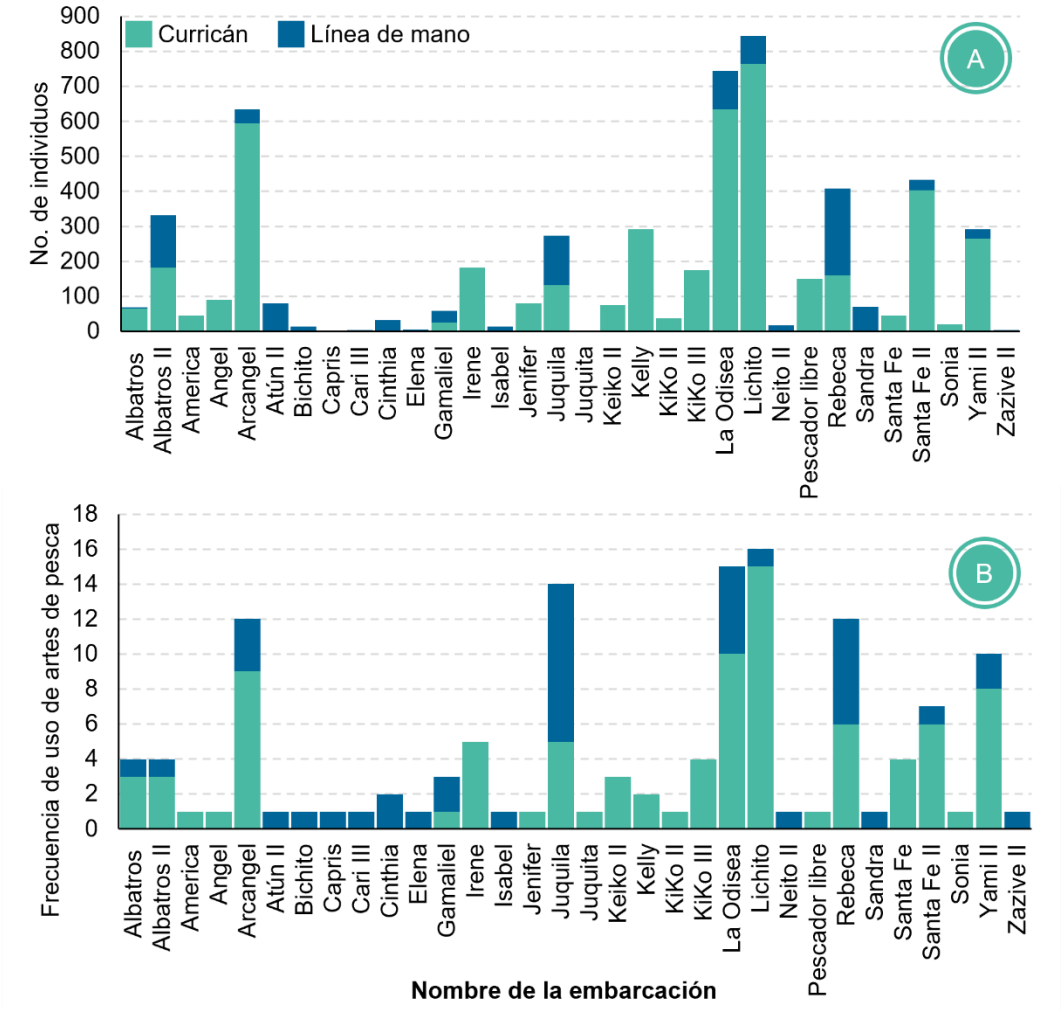

Figure 19. Number of individuals captured (A) and frequency of use (B) for each of the fishing gears, trolling (navy blue) and hand line (light green) by boat.

The price per piece of kite ranges between $15 – 50 Mexican pesos, the average is $33.78 M/N (± $9.24 M/N). The highest price is between July and September, with August being the

one with the highest average with $42 M/N per piece, (Figure 20). Only in May was paid $15 pesos per piece.

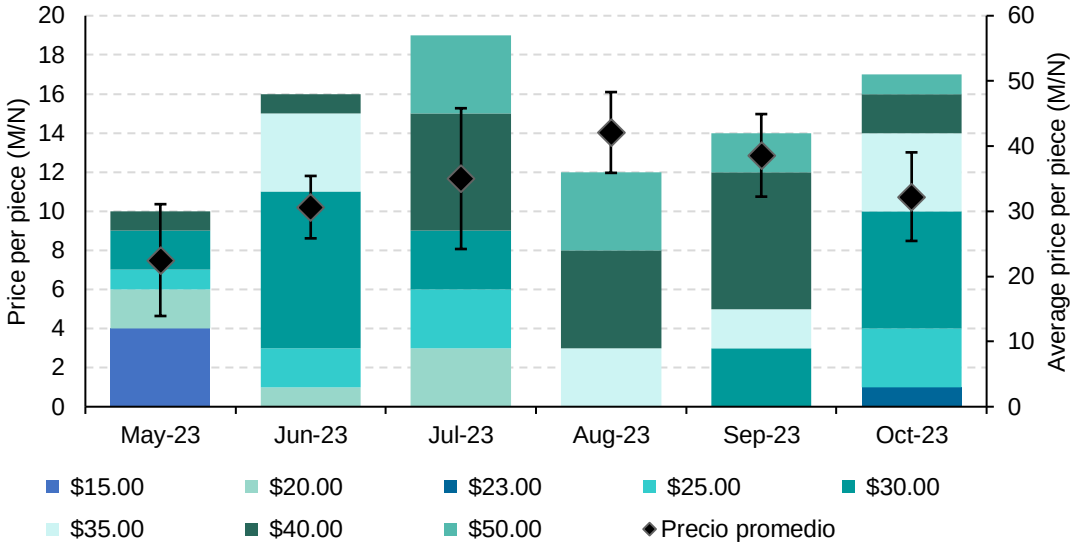

Figure 20. Average and monthly price per piece of kite.

6.6.1 Fishing trip expenses

From October to November 2002, fishermen invested an average of $635.4 pesos (± $267.14) in gasoline, with a maximum of $1,400 pesos and a minimum of $300 pesos. The average cost for breakfast was $30.35 pesos (±$16.15 pesos) with a maximum of $50 and a minimum of $14 pesos. Only on two occasions was the cost of the ticket reported and on both occasions with a value of $30 pesos. No bait or ice costs were reported. 90% of fishermen use their own vehicle to travel to the port, although some may use a taxi. Of the five boats, Juquilla has the highest gas expense of $709.8 pesos, followed by Cinthia with $775 pesos, La Siete Gotas with $500 pesos, Arcángel $350 and La Odisea $500.

The average cost of gasoline varies depending on the range of skipjack organisms captured. For 10 or less than 10 organisms captured, the average gas cost is $329; for 11 to 20 individuals it is $725. The average decreases slightly for the ranges of 21 to 30 organisms captured ($692.9) and 31 to 40 organisms captured ($466.7). Despite these fluctuations, the Spearman correlation reveals that there are no significant differences between the cost of gasoline and the number of organisms captured (p=0.439068).

6.6.2 Local market

In the fishing registry database, the beachfront price of 20 black skipjack and three skipjack listed during the months of October and November 2022 was noted. The price of the black skipjack was $17.09 (± $4.45) Mexican pesos, reaching a maximum of $26.66 pesos and a minimum of $9.20 pesos. The average price per kilogram for the 3 individuals of skipjack skipjack was $74.03 pesos (± $36.58 pesos), with a maximum of $116.3 pesos and a minimum of $52.6 pesos.

The price on the beach per piece of black kite varies depending on its approximate weight. For pieces weighing between 1 and 1.5 kg, the average price was $35 pesos; for those weighing between 1.6 and 2 kg, the price was $28.75 pesos; for those from 2.1 to 2.5 kg, the price was $85 pesos; and for those weighing between 2.6 and 3 kg, the price was $30 pesos. The Spearman correlation does not reflect significant differences between the approximate weight per piece and the price of the piece (p=0.271148).

7. **CONSERVATION ACTIONS**

Populations of skipjack *Katsuwonus pelamis* in the world are declining, but it is still listed on the IUCN red list as least concern. The black skipjack *Euthynnus lineatus* has stable population levels around the world, and is also categorized as least concern by the IUCN. None of these species is part of NOM-059-SEMARNAT-2010.

Some measures that could be taken to promote the conservation of black skipjack and skipjack skipjack

- *Management measures to regulate capture:* Establishment of fishing quotas based on the stock population. Quotas must be reviewed and adjusted regularly to ensure sustainable fishing and avoid overfishing.
- *Promote the use of selective fishing gear:* Promote the use of selective fishing gear through workshops and training, such as circle hooks and catch-and-release hooks, that reduce bycatch of unwanted species or impermissible sizes and that minimize the impact on juvenile skipjack.

- *Strengthening fishermen's cooperative societies* : Facilitate the strengthening of fishermen's cooperatives, providing them with training in business management, access to markets, and certifications. Establish economic incentives and recognition for fishermen and cooperative societies that comply with fishing agreements and laws.
- *Promote and encourage economic diversification activities* : Support the search and development of alternative and/or secondary economic activities, for example, by promoting ecotourism, e.g. sport fishing.
- *Development of participatory fishery management plans* : Facilitate the creation of fishery management plans in collaboration with local communities, which include regulations on minimum catch sizes, closed periods and restricted fishing zones.
- *Implementation of participatory and community monitoring and surveillance programs* : Establish community monitoring and surveillance programs to regulate fishing activity, which includes regular patrols by fishermen. Train local fishermen to carry out skipjack population monitoring and surveillance programs, including collecting data on catches, individual sizes, and behavioral observations.
- *Promote responsible fishing practices:* Train fishers on responsible fishing practices, including proper handling of catches, releasing juveniles, and adopting fishing methods that are less destructive to marine habitat, such as the use of lead-free lures. .

8. RECOMMENDATIONS FOR FUTURE EVALUATIONS OF THE SKIPKEY FISHERY

- Carry out an analysis of the reproductive cycle of the skipjack skipjack *Katsuwonus pelamis* and the black skipjack *Euthynnus lineatus* , where the gonadic index is obtained. If possible, validate the results through histological studies that consider the diameter measurements of the oocytes and are adjusted to the size of each individual (Scheafer , 1987). Being a species with asynchronous spawning , it is advisable to identify the stages of maturity of the gonads throughout a year and perform the analysis of partial fecundity and relative fecundity (Hunter & Leong, 1984).

It is suggested to use the criteria of Báez-Hidalgo and Da Costa (1989) for the classification of female gonads for teleost fish, and the scale proposed by Ratty. *et al* . (1984) for the gonads of male bony fish, in this way the five phases of gonadal development by sex will be obtained.

- Analysis of the feeding habits and diet of the skipjack *Katsuwonus pelamis* and the black skipjack *Euthynnus lineatus* . It is recommended to use the numerical, gravimetric, frequency of occurrence and relative importance index methods. To determine the breadth of the trophic niche, use the standardized index of Levin (1999).
- Conduct a study of age and growth of the two species of skipjack, striped skipjack *Katsuwonus pelamis* and black skipjack *Euthynnus lineatus* using direct methods such as counting marks within otoliths.
- Carry out the analysis of the length-weight relationship and monthly condition factor for the two species of skipjack, striped skipjack *Katsuwonus pelamis* and black skipjack *Euthynnus lineatus.* The condition factor will allow us to estimate the period in which both species reach their maximum degree of robustness or well-being. Consult the article by Ramos-Cruz (2009) as a reference.

- Analyze the capture and landing of the skipjack, *Sarda orientalis* , given that there are records of its fishing importance for Puerto Ángel, Oaxaca. Although this species is not included in the resource called “skipjack,” it is a species of small tuna of local importance, so it is necessary to address it in future analyzes of the skipjack resource fishery for Puerto Ángel.
- Conduct a population and stock study of the skipjack *Katsuwonus pelamis* and the black skipjack *Euthynnus lineatus* or , in order to provide a complete scientific assessment of their populations, identify possible threats and establish conservation measures. To date there is no study for any of these species.
- Carry out field and laboratory verification of the skipjack species in the area.

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