Report on the annual variation of whiteleg shrimp abundance.

Mexico Marismas Nacionales artisanal whiteleg shrimp – trap / cast-nets

Yuliesky Garces | SmartFish AC | May 2023

Introduction

Shrimp fishing represents one of the most important fisheries in Mexico, with the Mexican Pacific being the region where the largest total shrimp catch is taken (~92%) in Mexico (SAGARPA, 2021). This fishery ranks third in terms of its volume of fish production, however, for its commercial value, it ranks first in Mexico. Shrimp catches in the Mexican Pacific are mainly made up of three species, the blue shrimp *Litopenaeus stylirostris* (Stimpson 1871), the white shrimp *L. vannamei* (Boone 1931) and the brown shrimp *Farfantepenaeus . californiensis* (Holmes (1900), in addition to other species of penaeid shrimp.

Shrimp of the genus *Litopenaeus* spend most of their time in areas influenced by or in close relationship with river deltas, estuaries, or coastal lagoons. The migratory movements obey the nature of their life cycle, which is dependent on estuaries or coastal lagoons, which are used as protection, feeding and growth zones. They prefer soft, sandy-muddy bottoms and feed on crustaceans, fish, molluscs, annelids, plants and organic detritus. Shrimp are species with a short life cycle (one to two years), rapid growth, early sexual maturity, high fecundity, and high mortality rates (Hendrickx , 1996, Hernández-Covarrubias *et al* ., 2012). Due to the currents and tides, the shrimp in its post- larval stage penetrates the estuaries and coastal lagoons (Macías-Regalado et al., 1982), where it virtually begins its growth (30 to 60 mm per month) with semi-benthic habits . Upon reaching the sub-adult state (approximately 140 mm in total length), they begin their migration towards marine waters to complete their reproductive cycle (Pearson, 1939, Cárdenas, 1951; Signoret , 1974). These organisms reach maximum size at about a year and a half, but are susceptible to capture as early as six months of age, therefore season yields will depend on year class strength, and this in turn will reflect success. or recruitment failure (García and Le Reste, 1981).

In Mexico, the use of the shrimp fishery is regulated by the Official Mexican Standard NOM-002-SAG/PESC-2013, which establishes the rights and obligations of users, as well as the conditions of access to the resource. As a shrimp management strategy, in addition to the regulation of fishing gear, temporary closures have been implemented with the purpose of limiting effort, protecting the reproductive period and maximizing yield. This ban, in recent years, has been established between April and September (with spatio-temporal variations), which ensures the recruitment of the species in the fishing area and therefore the conservation of shrimp species in the Mexican Pacific. .

The white leg shrimp fishery that takes place within the Biosphere Reserve Marismas Nacionales in Nayarit (from now on BRMN) is one of the most important economic activities within the federal protected area. Fishing activities are the main source of food and livelihoods for the local communities. According to Carvajal- Rascon *et al* . (2017) between 12 and 14 thousand fishers took part in fishing activities that generated up to $170 million pesos (~9 million USD). The average production of white leg shrimp ranged between 4 and 6 thousand tons that represented ~55% of the total annual fisheries' production in the region (Carvajal- Rascon *et al* . 2017).

The management program states that around 15 different areas for shrimp extraction exist within the BRMN which are used by ~20 fishing cooperatives that hold authorization for the extraction of different species. The three most important species groups are white leg shrimp (WLS), finfish (or Escama) and oysters (SEMARNAT-CONANP 2013). According to the head of the fishing technical office

The most important economic activity is the shrimp fishery, which is carried out by fishers who are divided into free fishers (those who can work with individual fishing permits or carry out the activity illegally) and members of one of the local cooperatives (Carvajal- Rascon et al. 2017). In addition to the authorized gear (castnets , see figure below), local producers in the region use a traditional system of wooden piles (mostly mangrove) that are placed at the sea bottom across the estuary channels, known as tapos.

Materials and methods

Description of the study area

Marismas Nacionales (hereafter Marismas) is one of the largest mangrove forests on the Pacific coast of North America, located on the western Mexican coastal plain, in the southern region of Sinaloa and northern border of Nayarit, bounding the eastern shore of the Gulf of California (Fig 1). The general climate for the region corresponds to the semi-warm sub-humid Aw1(h'), with annual rainfall of more than 150 mm and the influence of humid monsoon-type winds from the sea. The average annual temperature is from 26 to 28ºC; with an annual average maximum temperature of 30 to 34ºC.

The BRMN is one of the most important and largest mangrove ecosystems in Mexico, with its more than 133,000 Ha, this ecosystem hosts ~20% of the mangrove ecosystems in the country (SEMARNAT-CONANP 2013). However, several factors have impacted the status of the BRMN ecosystem. According to the management program, the main issues are related to physical changes in the drainage patterns due to the construction of protection walls, impacts of aquaculture and fisheries activities, reports of overfishing, coupled with the use of harmful extractive practices, and the absence of effective fishing management that have plunged the activity into a continuous crisis (SEMARNAT-CONANP 2013).
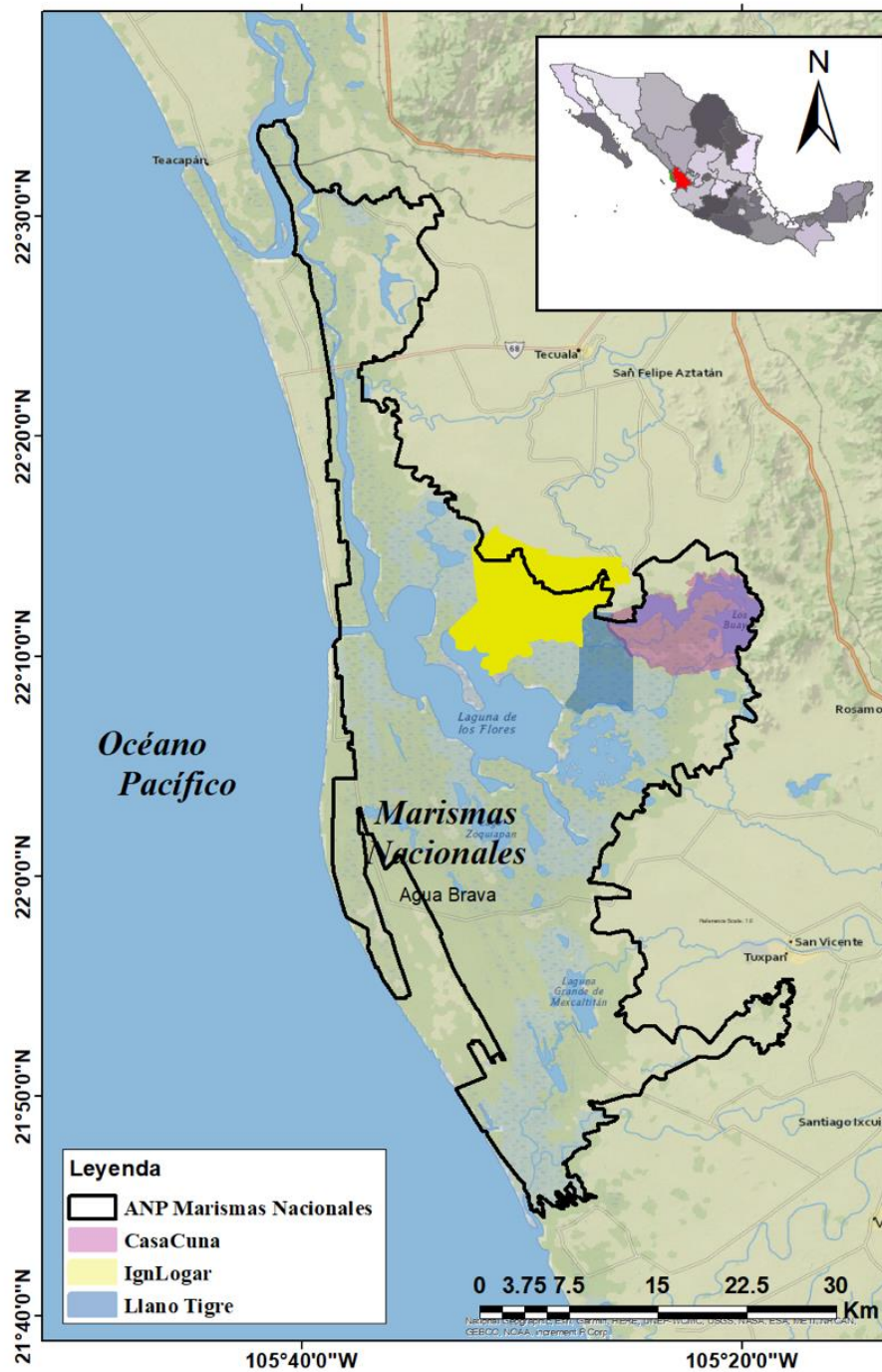
Figure 1. Location of Marismas Nacionales and the fishing areas of the fishing cooperatives participating in the FIP.

Data and applied methodology

Annual precipitation data was downloaded from the National Meteorological Service (SMN) of Mexico (https://smn.conagua.gob.mx/es/) . Subsequently, the data was processed and analyzed in order to determine the seasonal variability of rainfall and its possible effects on the annual shrimp catch in the Marismas Nacionales region.

For its part, the data on national production and annual catch in Nayarit were obtained from the 2021 Aquaculture and Fisheries Statistical Yearbook (https://www.gob.mx/conapesca/documentos/anuario-estadistico-de-acuacultura-y-pesca). . Consecutively with the objective of knowing the annual variation of the catches, these data were processed and graphed.

On the other hand, the monthly shrimp catch data of the cooperatives participating in the Fisheries Improvement Project (FIP) were obtained from the fishing logs of each cooperative. This information made it possible to carry out studies of the monthly and annual variation of the shrimp catches and to determine their relationship with the meteorological variables.

Result

Precipitation variability

The highest rainfall reported for Nayarit occurs from June to October with maximums in July and August. The monthly mean precipitation minimums were obtained from November to May, mainly in April and May (Fig. 2). However, in the last decade the months with the highest rainfall have been August and September.
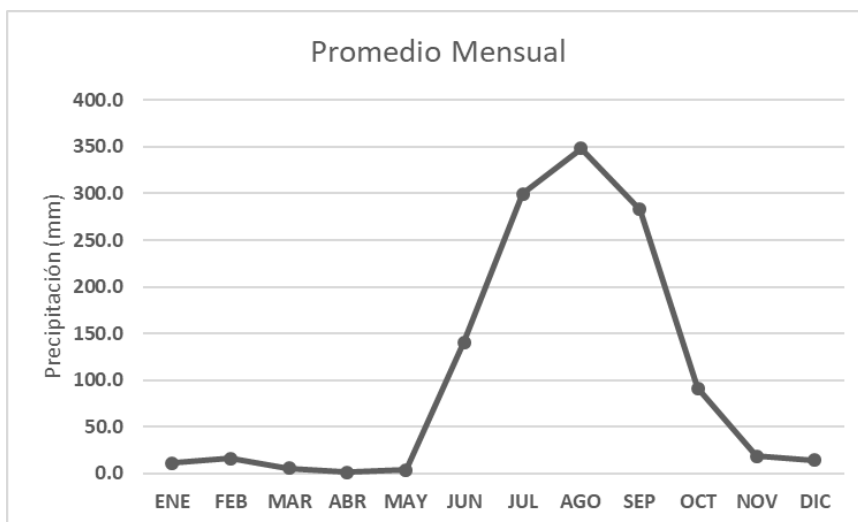

Figure 2. Historic monthly average of rainfall in the state of Nayarit, Mexico.

The precipitations show a constant tendency and an accumulated annual average of approximately 1230 mm. In general, every six years there is a maximum peak of the accumulated rainfall, although in the last decade it has been observed that the peaks occur every three years and have lower accumulated rainfall. The highest accumulated annual rainfall was observed in 2008 and 2010, while the lowest values correspond to the years 1996 and 2006 (Fig. 4). When divided into two stages (1993-2013 and 2014-2022) and compared with each other, a change in the precipitation trend was observed, especially in the annual accumulations. The first stage shows a growing trend, with alternating periods of maximums and minimums, while the second stage shows a decreasing trend, although it does not present periods lower than the annual historical average.

Current status of the fishery

In Mexico, in the 1993-2021 order, an average of ~60 thousand tons of wild shrimp was registered, registering the historical maximum in the 2015 season with approximately 84 thousand tons of shrimp. In general, it is observed that in the 1990s the shrimp catch fluctuated between 46 thousand tons per year. While, since the 2000s, the shrimp catch has an upward trend, exceeding 50 thousand tons per

year, possibly as a result of the expansion of the fleet and fishing areas. However, from its historical maximum reached in 2015, the catch shows a decreasing trend (Fig. 3).

As is to be expected in a multi-species fishery , the stability observed in total shrimp catches presents different patterns when the catch is studied by fishing area and shrimp species.

The catch in estuaries and bays is mainly given by the *Litopenaeus species* (white and blue shrimp). The period studied registers an average of ~25,000 tons of shrimp per year, with historical maximums of approximately 45,000 tons in 2018. Note that the capture in estuaries and bays, despite presenting two seasons above the historical average (2005 and 2011), always maintained an interannual variability oscillating around the historical average. However, as of 2013, an upward trend is observed, registering its historical maximum in 2018 to later show a drop in the catch to approximately 400 tons in 2021 (Fig. 3). However, this reduction in the catch was possibly determined by the impact of three hurricanes (Rick, Pamela and Nora) and one Tropical Storm (Dolores) in the main fishing areas in estuaries and in the main months of capture.
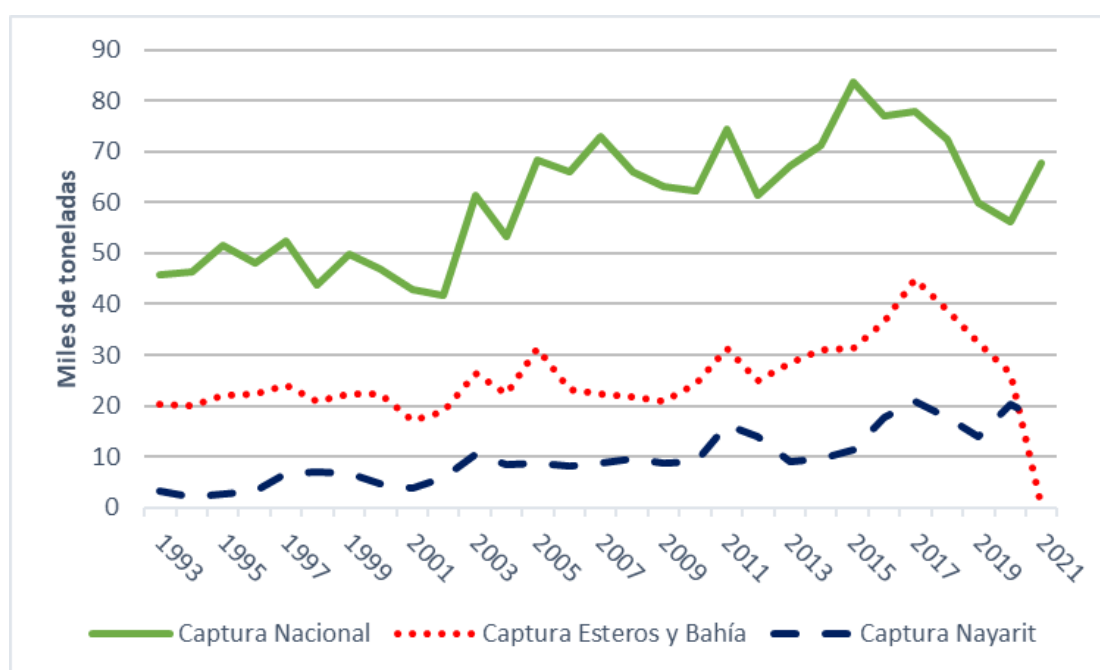

Figure 3. Shrimp catch in tons: national, Esteros and Bahía and Nayarit by season.

In relation to the annual captures of the shrimp fishery in Nayarit, these presented an average of approximately 5 thousand tons, with a historical maximum of approximately 11,500 annual tons of capture in 2017 (Fig. 3). In general, during the period studied, an ascending pattern of catches was observed, although some periods show catches of less than 2 thousand tons per year (Fig. 3). This decrease in catches is directly related to precipitation in the region, as shown in figure 3. In general, it is observed that in years where annual precipitation is lower than the historical average, shrimp fisheries show a decrease in their annual catches.

On the other hand, the highest recorded annual shrimp catches correspond to the years where annual rainfall was close to the historical average (Fig. 4).
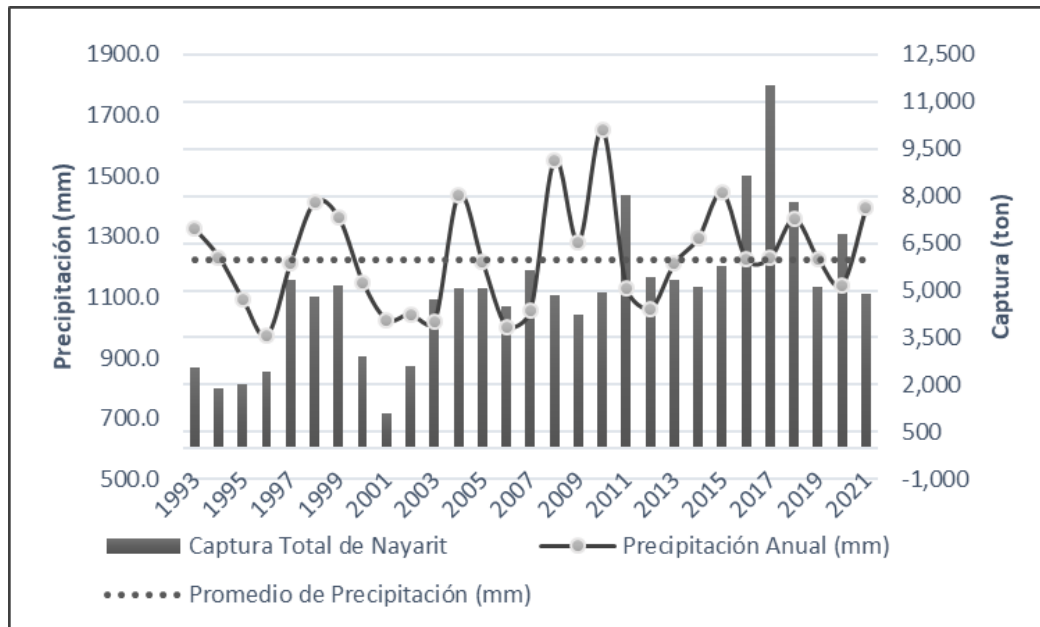
Figure 4. Relationship between the shrimp catch in tons and the annual average rainfall for the state of Nayarit. The bar corresponds to the annual shrimp catches; the black line corresponds to the annual rainfall average and the dashed line to the historical rainfall average for Nayarit.

Shrimp capture in fishing cooperatives

The annual capture of shrimp is carried out during the fishing period that goes from August to March, being the greatest abundances in the months of September and October. This period coincides with the rainy and hurricane seasons in the Mexican Pacific region. The studied stage of the shrimp fishery in Marismas Nacionales is located in the last decade where the shrimp catch shows differences in annual abundances.

The average annual shrimp capture of the cooperatives participating in the FIP is approximately 522 tons, with maximum abundance values recorded in 2016 and 2015 (~800 tons), while the minimum annual abundance of shrimp was ~200 tons and corresponds to to the year 2021 (Fig. 5). The capture in the first stage (2013-2017) shows an upward trend with abundances above 500 tons of shrimp reaching the maximum values for 2017, while in the following years there is a rapid decrease in the captures, decreasing to the order of the ~400 tons per year (Fig. 5).
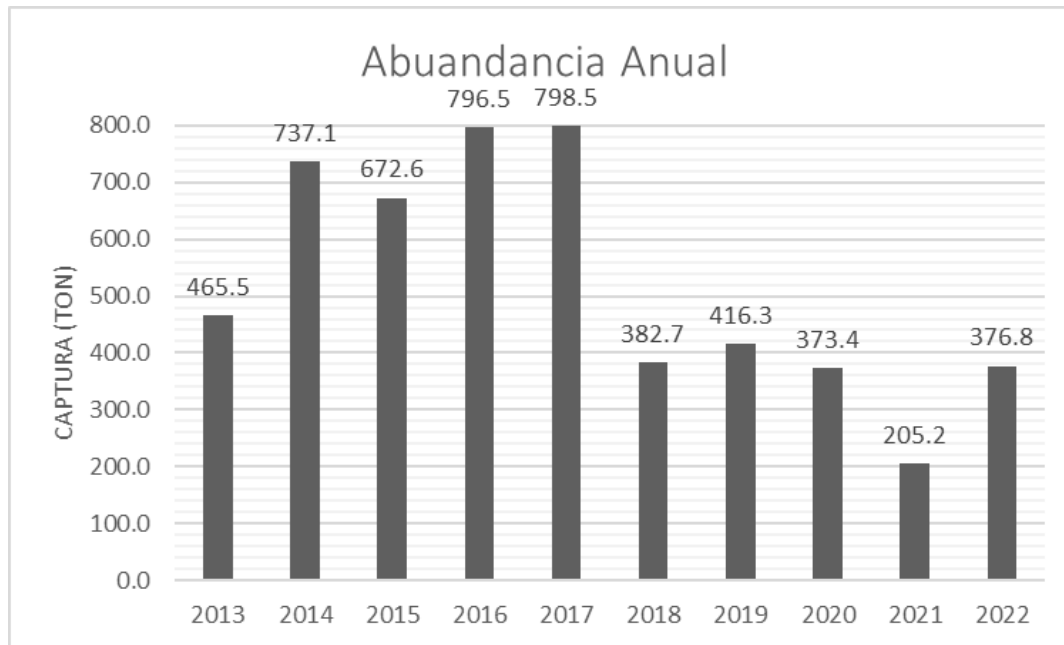
Figure 5. Annual shrimp catch registered by the cooperatives participating in the FIP.

On the other hand, the seasonality of the catches in the fishing years shows a monthly variability (Fig. 6). The monthly average catch is approximately 75 tons and in general, the months of September and October record catches of more than 100 tons. From 2013 – 2017, the monthly catch follows a similar pattern from September to December, with the maximum catches in September and October, with catches gradually decreasing towards the end of the year. This period registers a monthly average of approximately 100 tons, with catches of more than 300 tons in the months of September and October. During the period 2018 - 2022, in general, a sharp decrease in monthly shrimp catches is observed, with a monthly average of approximately 50 tons. Although September and October continue to record the highest catches, it was observed that they do not exceed 250 tons. In addition, a decrease in catches was observed in the remaining months of the fishing season, for example, in the 2021 fishing season, the monthly catch for the months of September and October corresponded to approximately 92% of the overall catch of the fishing season. Although it is necessary to mention that this year, the region was affected by two hurricanes, which caused a decrease in fishing days and possibly an effect on shrimp migration to the surrounding maritime area.
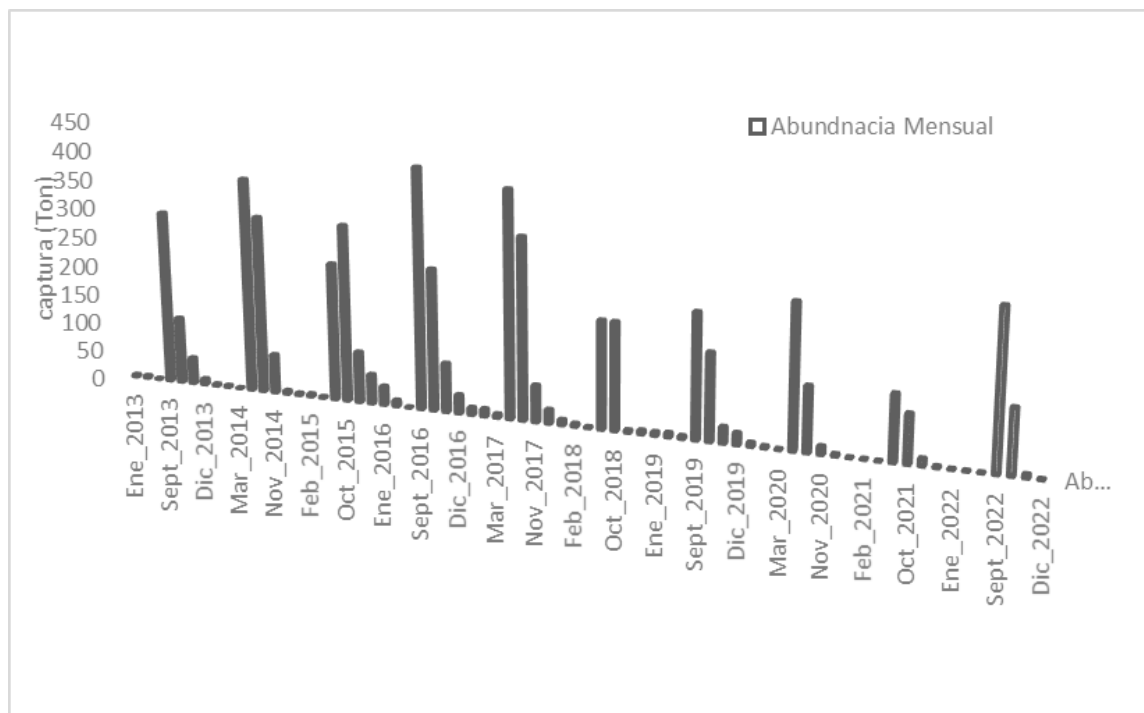
Figure 6. Monthly abundance of shrimp catches for the fishing cooperatives that participate in the FIP.

Next studies

Monthly sampling is being carried out in the fishing area corresponding to each cooperative, where information is being collected on fishing effort, size structure and weight of shrimp and accompanying fauna, in addition to shrimp genetic studies. These studies will make it possible to determine the main seasons of shrimp recruitment, the Catch per Unit of Effort (CPUE), as well as the abundance and densities of the resource and the current state of shrimp in Marismas Nacionales.

On the other hand, at the same time, sampling of physical-chemical variables is carried out in the area of the resource's habitat, which will allow, in addition to characterizing the region, to carry out analysis of spatio-temporal variability and correlation with biological data.

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