Mexico Baja California Sur blue and brown shrimp – bottom trawl/cast net]
Fishery Improvement Project (FIP)

Technical report of the 2022-2023 Shrimp Fishing Season and Recommendation for the Beginning of the 2023 Closed Season in Magdalena-Almejas Bay, B.C.S.

Elaborated by:

Instituto Nacional de Pesca y Acuacultura

INAPESCA
INSTITUTO NACIONAL DE PESCA Y ACUACULTURA

INSTITUTO NACIONAL DE PESCA Y ACUACULTURA

DIRECCIÓN GENERAL DE INVESTIGACIÓN
PESQUERA EN EL PACÍFICO

CENTRO REGIONAL DE INVESTIGACIÓN
ACUÍCOLA Y PESQUERA LA PAZ

Technical report of the 2022-2023 Shrimp Fishing Season and Recommendation for the Beginning of the 2023 Closed Season in Magdalena-Almejas Bay, B.C.S.

Shrimp Fishery in Magdalena-Almejas Bay,
Baja California Sur,México

Program/Project:
POA Pacific Shrimp La Paz

Authors:

Juan Antonio García Borbón - CRIAP-La Paz
Carlos Hiram Rábago Quiroz - CRIAP-La Paz.

Content

INTRODUCTION

Importance of the fishery

Shrimp is Mexico's most important fishery; in terms of volume, it is ranked fourth in Mexico's fishery production; however, in terms of value, it is in the first place, in addition to the number of people involved in its extraction. The average annual production growth rate over the last ten years is 0.15%. It is the first place in fishery exports, with the United States of America, Japan, and Spain as its main destinations (Anuario Estadístico de Acuacultura y Pesca, 2013).

The shrimp fishery is extraordinarily complex due to the multi-species composition of its catches, its wide geographic distribution, and the sequentiality of its exploitation, which involves different fisheries, gear, social sectors, and fishing strategies (Almendarez-Hernández, 2008).

The dynamics of this resource are directly related to its biological cycle: in the juvenile stage, they inhabit shallow marine waters, coastal lagoons, bays, and estuaries, areas made up of terrigenous material from the rivers from the washing of the continents, detritus, sea grasses and mangroves, which provide sufficient food for their growth. Their survival depends on the physical-chemical and climatic conditions, among others, where they remain until they reach three to four months of age, to later migrate to the sea and get the adult stage to complete their life cycle, although the latter is not a necessary condition since a good part of the population in its different stages remains in the open sea where they settle and continue their life cycle.

In the clear case of fishing, the main goal is to maintain a stable pattern of catches over time and, if possible, to increase it. It should be considered that temporary increases in catch, as a consequence of increased fishing effort, do not mean that there is potential for further intensification of the fishery, which could be a management mistake. The lower efficiency of effort when the population increases can be observed more clearly in the indicators of relative abundance.

The shrimp industry has the largest fleet in the country, made up of small and large vessels, which have brought the fishery to its maximum level of exploitation. Because of this, government authorities concentrate their efforts on maintaining biomass and recruitment at current levels to stabilize yields and reduce technological and environmental interactions (CNP 2012). As part of this policy, the fisheries administration recommends not increasing fishing effort and reducing fishing mortality in some strategic areas. Additionally, Mexican fisheries authorities, represented by the National Commission of Aquaculture and Fisheries (CONAPESCA) in 2005 to reduce the fishing effort of shrimp fishing vessels, initiated the Shrimp Fishing Effort Reduction Program, throughout the country (http://www.conapesca.gob.mx/work/sites/cona/resources/LocalContent/3168/2/bol220906reunion_tortug as.html). From 2005 to date, shrimp fishing effort in the country has decreased by 38.5%. In 2013, there were 850 large vessels and 40,663 coastal vessels in the Pacific that operated in protected waters and, in the case of Sinaloa and Sonora, also along the coast.

The National Institute of Fisheries and Aquaculture (INAPESCA) has programs to monitor the resource during the closed and catching seasons. Thanks to this, there is a time series of shrimp abundance records obtained during the closed season from 1992 to date. This has always been in expectation of the changes in abundance of shrimp populations, so the timing of the closed season is variable due to the fishing effort and the behavior of the oceanic climate, the diseases that the resource may present, its reproductive pattern, the sudden drops in abundance and the yield or catch per unit of effort. This information is also helpful for administrators (CONAPESCA), contributing to improving management, that is, to plan strategies when high abundance is observed or to protect the population when there are adverse effects due to biological or environmental variability that have a negative impact on the resource.

Based on the above, it is essential to maintain shrimp monitoring during the capture season so that with the evaluation of biomass through dynamic models, we can assess the condition of the reproductive stock for its maintenance and, thus, the fishery. The primary evidence that prevents overfishing recruitment in population terms is the presence of maturity in the females of the different stocks. In contrast, regarding the fishery, trends in relative abundance indicators should be observed, which may show a notable decline as the season progresses. Thus, management criteria based on these tactics should consider a seasonal and spatial closure, waiting for spawners to spawn, and eventual recruitment to the fishery over time.

This report presents the technical basis for establishing the end of the 2022-2023 commercial shrimp fishing season and the beginning of the 2023 closed season in the protected waters of Baja California Sur. These grounds are based on the historical analysis of catch and effort, reproduction cycles, fishing yield, and migration and recruitment of the two main shrimp species: *Penaeus stylirostris* (blue) and *P. californiensis* (brown).

OBJECTIVES.

General objective.

To analyze the performance of the 2022-2023 shrimp catching season in Bahía Magdalena-Almejas, B.C.S. and to propose the starting date of the 2023 closed season that will allow protection the shrimp reproduction, recruitment, and growth period for the 2023-2024 season.

Specific objectives.

- Guarantee the renewal of the populations, protecting the reproductive process.
- To monitor fishing yield as a function of relative abundance and fishing effort.

MATERIAL AND METHODS

Study Area

The shrimp fishery in the Mexican Pacific includes the area from the Upper Gulf of California in the Colorado River Delta to the border with Guatemala, including the western coast of Baja California Sur (BCS) and the lagoon systems along the Mexican Pacific. For study purposes, and based on the different population units, the fishing area has been divided into seven zones, which in turn are divided into subzones, which are studied by each Regional Center for Aquaculture and Fisheries Research (CRIAP) of INAPESCA: Zone 10, Ensenada, Baja California (BC); Zone 20, Guaymas, Sonora; Zones 30 and 40, Mazatlán, Sinaloa; Zone 50, La Paz, BCS; Zone 60, Bahía de Banderas, Nayarit; and Zone 90, Salina Cruz, Oaxaca. The primary study area of Zone 50 corresponds to the region of Bahía Magdalena-Almejas, B.C.S. (Fig. 1).

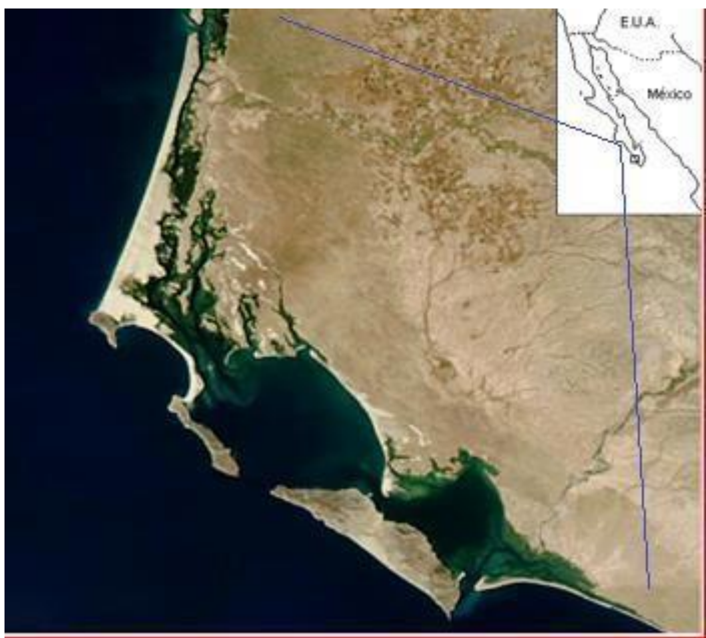

Figure 1. Bahía Magdalena – Almejas lagoon system, Baja California Sur, Mexico.

Biological Sampling Campaigns

Three formal sampling campaigns were carried out during September and October 2022 and February 2023; and informally, with personnel hired for this purpose (Biologist Martín González Garibay) during the rest of the season (November-December 2022 and January-February 2023). From the commercial catches, access was obtained to samples of 4,979 shrimp of both species.

The shrimp species composition (Pérez-Farfante, 1988; Pérez-Farfante and Kensley, 1997), their proportion in weight, and the corresponding number for each species were determined from the catch obtained from each vessel. The shrimp captured were separated by species, and depending on the number of specimens in each boat sampled, if it was less than 100, the total was considered for the analysis; otherwise, a subsample of 100 individuals was separated as the minimum sample size. The relative yield was determined for each boat. The average for the boats sampled in the five days of monthly sampling (kg/hour, kg/area or kg/set), sex ratio, size structure (total length, abdominal length), the weight of each organism (total and abdominal weight), and degree of gonadal maturity was obtained by morphochromatic evaluation. For the males of both shrimp species (brown and blue), two degrees of maturity are considered, I - Immature (separate petasma), II - Mature (united petasma); in the females, also of the two species, four stages are recognized: I - Immature, II - Developing, III - Mature, IV - Spawned, varying for each species the colors and their tonalities. From the data obtained, the species' size structure was established by graphs showing the monthly frequency distribution of the total length in intervals of 5 mm. Regarding the development of the reproductive process of the females of each species, the evolution of the cycle was evaluated by obtaining the relative frequency of each of the four degrees of maturity. As part of the sampling of each vessel, information was collected on catch per species and effort applied in trawling time to obtain indicators of relative yield and catch per unit of effort (cpue), both per vessel and per unit of time (kg/hr).

Another source of information used was CONAPESCA's arrival notices on daily total catch and effort in both fisheries. These indicators were reduced to the average every month. To evaluate the current season's performance, the indicators obtained were contrasted with their respective long-term trends, considering their corresponding confidence intervals.

Quantitative analysis

Relative abundance

Abundance indices (yield in kilograms per trawl hour, kg/h) were obtained from the catch data recorded by the biologically sampled vessels; the unbiased estimator that uses the delta distribution to calculate the mean and confidence intervals was applied to these abundance indices (Pennington 1983, 1986, 1996; Pennington and Stromme 1998). The minimum variance estimator of the mean (c) and variance (d) was calculated as follows:

The variance of the unbiased estimator (denoted as c and d) for the mean, and the variance of the abundance is calculated as follows (Pennington 1983, 1986, 1986, 1996, Pennington and Stromme 1998):

$$
c\begin{cases} \frac{m}{n}\exp(y)g_m\left(s^2/2\right), & m>1 \\ \frac{x_1}{n}, & m=1 \\ 0, & m=0 \end{cases}
$$

Where: n is the number of samples; m is the number of samples with non-zero values; the mean value and s^2 are the mean and variance of samples with non-zero values, expressed as log; xi is a (non-transformed) non-zero value when m=1, and; Gm (x) is a function of x and m expressed as:

$$
d\begin{cases} \frac{m}{n}\exp(2y)\left\{g_m\left(2s^2\right)-\left(\frac{m-1}{n-1}\right)g_m\left(\frac{m-2}{m-1}s^2\right)\right\}, & m>1 \\ \frac{x_1}{n}, & m=1 \\ 0, & m=0 \end{cases}
$$

$$
G_m(x)=1+\frac{m-1}{m}x+\sum_{j=2}^{\infty}\frac{(m-1)^{2j-1}x^j}{m^j(m+1)(m+3)..(m+2j-3)j!}
$$

The unbiased minimum variance estimator of the variance of c($var_{est}(c)$) is given by (Folmer and Pennington 2000):

$$
\mathrm{var}_{est}(c)\begin{cases} \frac{m}{n}\exp(2y)\left\{\frac{m}{n}g_m\left(\frac{s^2}{2}\right)-\left(\frac{m-1}{n-1}\right)g_m\left(\frac{m-2}{m-1}s^2\right)\right\}, & m>1 \\ \left(\frac{x_1}{n}\right)^2, & m=1 \\ 0, & m=0 \end{cases}
$$

When n=m, the estimator assumes a normal distribution (Smith, 1990, McConnaughey y Conquest, 1992; Lo et al. 1992, Conquest et al., 1996; Smith y Gavaris 1993).

Cohort identification

To know the theoretical monthly size structure for the optimal characterization of the dynamics of the population structure, the different components or size cohorts were identified by using the multinomial model of the organisms recorded in the sample grouped in intervals of total length of 5 mm. The model has the following form:

$$F' = \sum_{a=1}^{n} f_i * (\frac{1}{\sigma\sqrt{2\pi}} \exp(-[\frac{(x_i - \mu_i)^2}{2\sigma_a^2}])) * P_a$$

where *a* corresponds to the cohort, *i*= total length interval, P_a is the cohort weighting factor.

Reproduction

A description of the reproductive process of the females of the two shrimp species during the fishing season was obtained, in the context of the long-term trend of the maturity and spawning stages, to locate the development of the reproductive process in terms of its minimum, maximum, and average values, as well as its confidence interval.

RESULTS AND DISCUSSION

Catches

Shrimp catches in the lagoon system of Magdalena Bay - Almejas, B.C.S., counted up to January of each year, to homogenize the comparison from the 2022-2001 season to the current 2022-2023 season, can be seen in Figure 2. The average total catch (blue and brown) in this period amounts to 916 tons in weight. Several peaks of abundance are recognized throughout this period, with the 2013-2014, 2019-2020, and 2006-2007 seasons standing out. In general, the average catch of brown shrimp (645 t) is above the corresponding average of blue shrimp (241 t), mainly due to the persistence of the abundance of brown shrimp throughout each fishing season and the year; however, the peaks of higher catches are primarily due to significant upturns in the abundance of blue shrimp, especially in the last two peaks observed in Figure 2; the same occurs in the periods of minimum abundance. Regarding the performance of the 2022-2023 fishing season, the catch of both species is below that recorded for the previous season (2021-2022) by 13% for blue whiting and 46% for brown whiting. However, outside of the catches recorded to date and not shown in Figure 2, sampling conducted in January and February shows a rebound for February, particularly for blue shrimp.

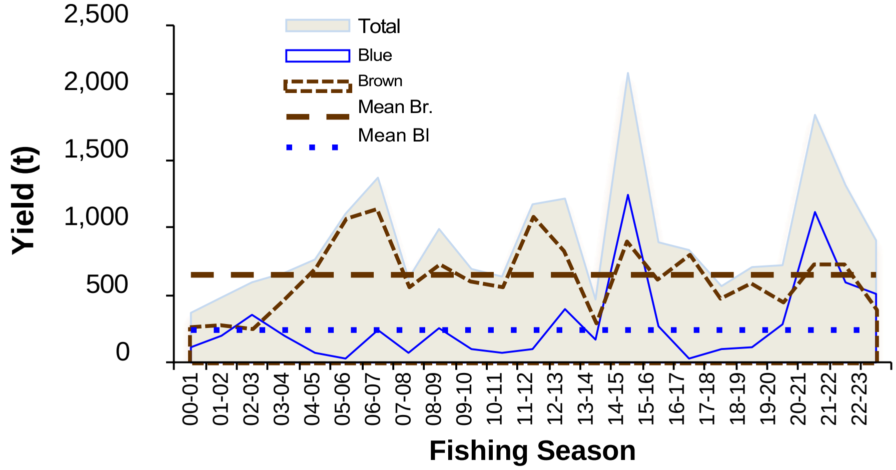

Figure 2. Historical catches (Sep - Jan) of shrimp landed in Bahía Magdalena-Almejas, Baja California Sur.

Proportion of species in the catch

Figure 3 shows the percentage share of blue and brown shrimp in the total catch of both species. In the average of the last five seasons, the participation of coffee is the majority, with 54% and 46% for blue shrimp; however, in the current season, blue shrimp increased its participation to 57% and 43% for coffee. This is without considering the relative contribution of the catch during the rest of the season. The predominance of blue shrimp in this season denotes a change in the alternation of the abundance of the fishery's component species.

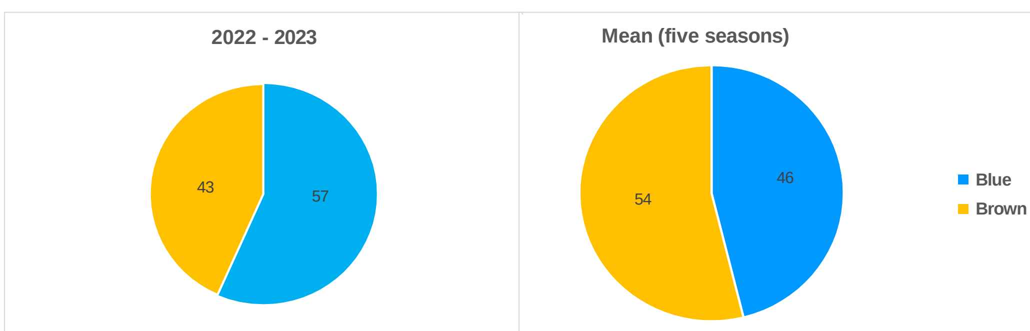

Fig. 3. Percentage of the catch by species landed in Baja California Sur, during the 2022-2023 fishing season and the average of the last 5 seasons.

Seasonality of catch

Blue shrimp

The mean seasonality, confidence interval, and extreme values of the blue shrimp catch throughout its history is shown in Figure 4, where in addition to the monthly catch of the current season, the data for the 2021-22 season are presented for comparative purposes. In the current season (2022-2023), the catch records are lower from September to November than in the 2021-2022 season. Still, in December and

January, the magnitude of the blue catch is above its corresponding period last season. Both last season and this season, the monthly catch records are higher than the historical average, and from November to January, they are even higher than their calculated confidence interval. Considering that catch records for February and March 2023 have yet to be available and observing the trend of the historical average, it is expected to have significant catch records for this remaining period of the season.

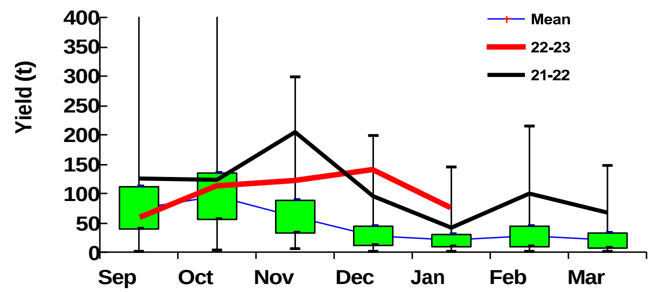

Figure 4. Seasonality of blue shrimp catches from Bahía Magdalena-Almejas, B.C.S. Fishing season 2022-2023.

Brown shrimp

For brown shrimp, the participation of this species in the catches was below the 2021-2022 season. Even below the average and its confidence interval, except for September when it was above the indicators mentioned above (Fig. 5). The downward trend in the records from November to January denotes the continuation of the decline in catches for the rest of the season. Therefore, it can be accepted for this date that the catch of this species in this season was very poor in terms of production.

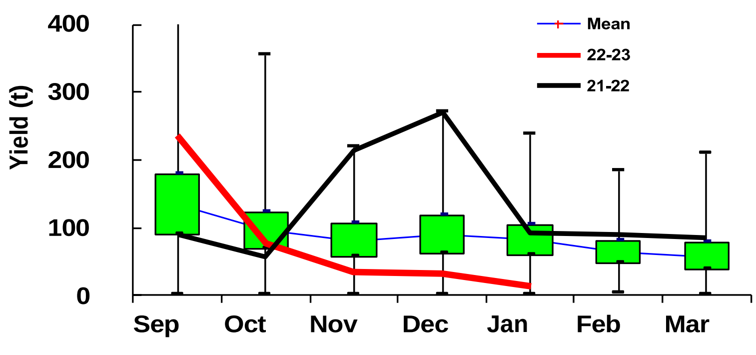

Figure 5. Seasonality of brown shrimp catches from Bahía Magdalena-Almejas, B.C.S. Fishing season 2021-2022.

Size structure

Blue shrimp

Figure 6 shows the frequency distribution of the total length of blue shrimp during the 2022-2023 fishing season and the corresponding fit to a multinomial model, proper to distinguish both the component cohorts of the size structure observed in the catch as well as to obtain an adjustment of the expected proportions in these cohorts. There were no specimens of this species in December 2022 and January 2023; however, the modal progression due to growth and the influence of total mortality is recognizable. For September 2022, the importance of the recruitment of this species at the beginning of the season and the decrease in the range of sizes available for fishing in the rest of the season can be distinguished. The size structure recorded in February 2023 is essential not only because of the magnitude of the yields registered but also because of the economic value represented by the participation of large sizes during this last month. It also highlights the persistence of the cohorts over time since it is difficult for fishermen to locate the areas and depths where they are distributed throughout their life cycle since, during December and January, they could not identify concentrations of this species. The advantage is that with these "spikes" in abundance, the profitability and continuity of the fishery are maintained for a significant amount of time.

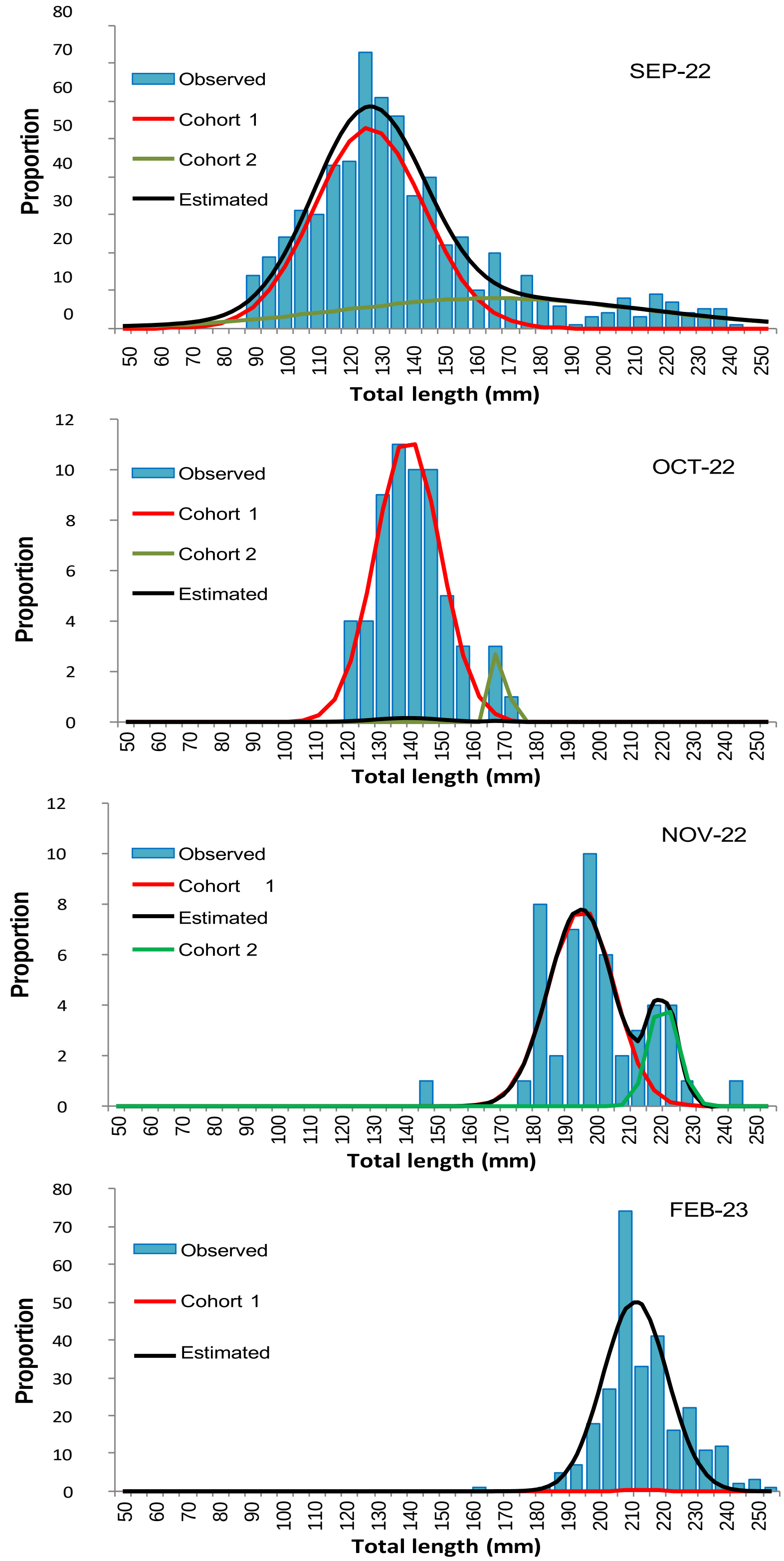

Figure 6. Frequency distribution of total length of blue shrimp in Bahía Magdalena-Almejas, B.C.S. and multinomial model fit, during the 2022-2023 fishing season.

Brown shrimp

Even though the catch of brown shrimp during this season can be considered one of the lowest in the last eight seasons, it was possible to record the monthly distribution of length frequencies, including those calculated for the various component cohorts, in each of the sampling campaigns carried out (Fig. 7). The first aspect to note in the length frequencies is the continuity of the recruitment process throughout the season to maintain a monthly size structure that considers young individuals at practically every moment of the study period. Although it should be noted that a significant fraction of the small sizes is composed of males, who tend to be smaller than females at the same age. It is also common to find more than one cohort in the monthly distribution of size frequencies precisely because of the continuity of the recruitment process. Although it should not be overlooked that the capture process, which involves using nets with different mesh openings in fishing areas and variable depths, allows the inclusion of a wide range of cohorts and age and sex components present in the population in different periods. One aspect to be recognized throughout the time series included in the present study is that after identifying two cohorts in one month, September, for example, the large size mode disappears in October due to fishing mortality; by November, two cohorts are again recorded, which enter the fishery due to recruitment and growth, so that in December the large size mode group is lost again as a result of fishing, and so on.

.

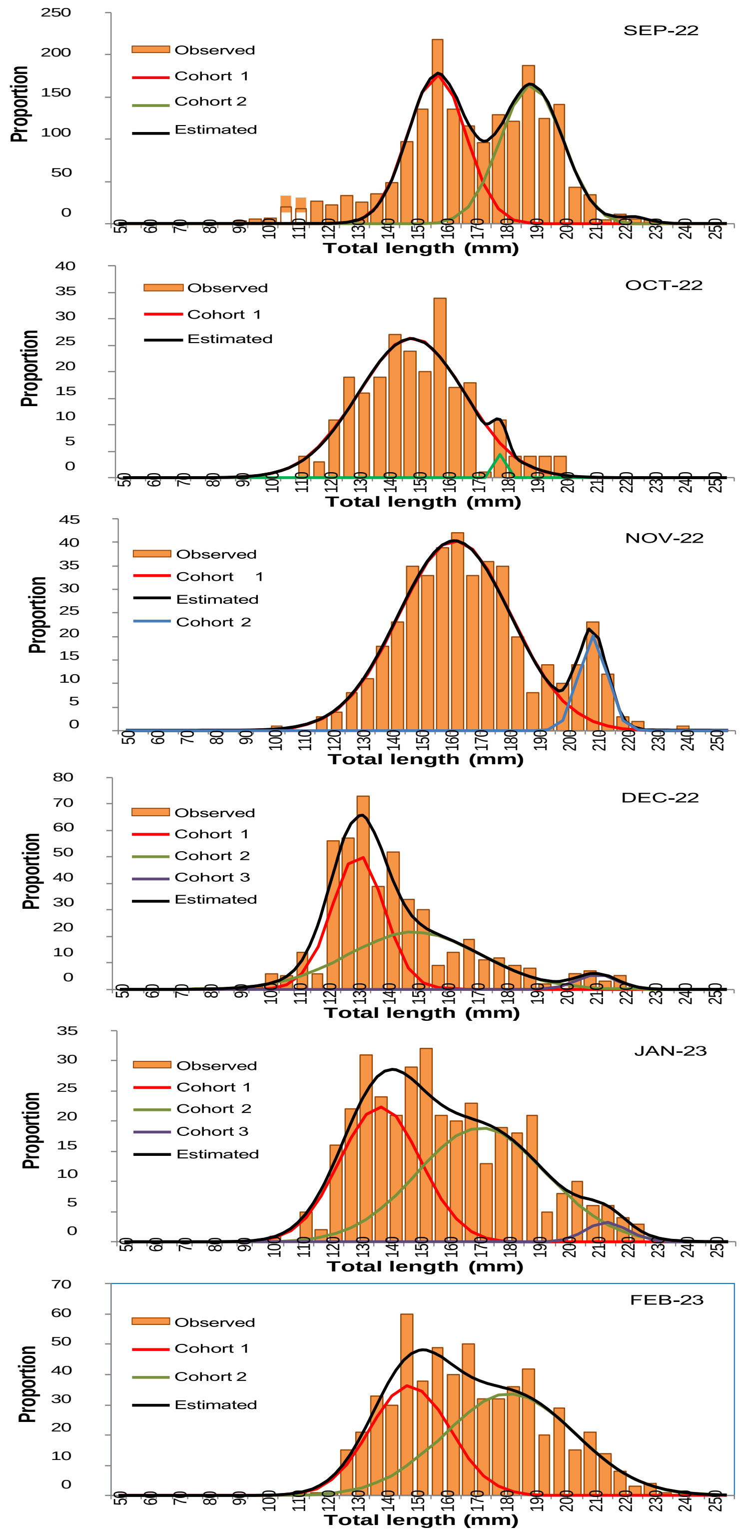

Figure. 7. Frequency distribution of total length of brown shrimp in Bahía Magdalena-Almejas, B.C.S. and multinomial model fit, during the 2022-2023 fishing season.

Reproduction

Blue shrimp

This species has a more defined reproductive process than the brown shrimp, which usually shows all stages of maturity continuously throughout the year. Reproduction in blue shrimp usually occurs from February to August, with variations that imply a delay or advance around this period. It may be shorter or longer, depending on environmental conditions, whether favorable or unfavorable. Figure 8 shows the evolution of the reproductive process of females, particularly in phases III (maturity) and IV (spawning) from September 2022 to February 2023. From the samples obtained from September to November, blue shrimp remained below average in terms of maturity and spawning, barely reaching the average for the spawning stage in November. However, when a cohort of adult individuals was located in February, spawning values were above average and above the confidence interval. This implies that, even though no adults were recorded in December and January due to spatial dispersion issues, blue shrimp females must have started to reproduce in January 2023 or started to reproduce in February in a very intense way.

.

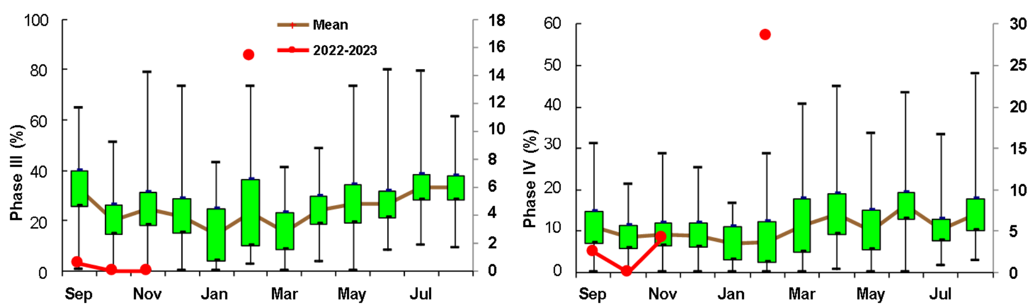

Figure 8. Reproductive cycle of blue shrimp in Bahía Magdalena-Almejas, B.C.S.

Brown shrimp

Figure 9 shows that at the beginning of the 2022-2023 fishing season, particularly in September and October, the reproductive process (maturity and spawning) was still taking place. Still, it was already declining since July. The lowest proportions of mature and spawned females were observed in November and December. For January, mature females are below the average, but by February, they exceed both the average and the confidence interval. Meanwhile, for brown shrimp spawned females and during January and February, the values were slightly above the average but within the confidence interval.

.

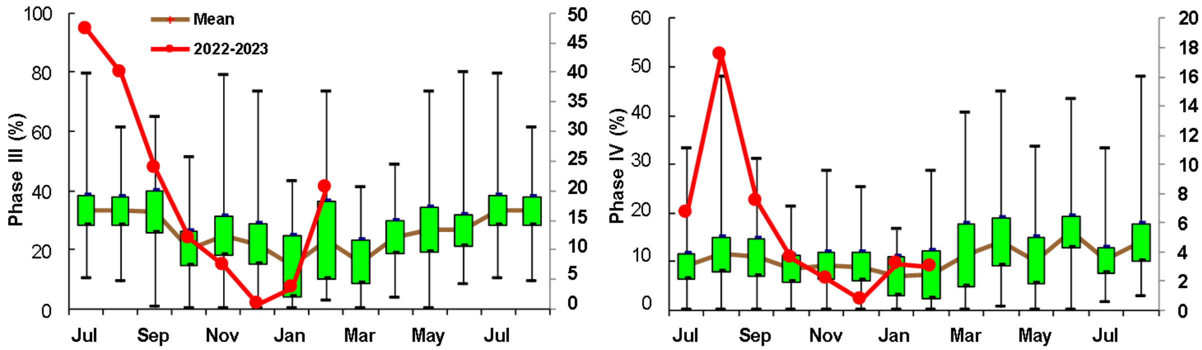

Figure 9. Reproductive cycle of brown shrimp in Bahía Magdalena-Almejas, B.C.S.

Yield

Regarding the performance of the fishery in terms of catch and effort exerted, Figure 10 A shows the results of the sampling campaigns where the estimates of relative abundance (kg/h) of the two species subject to exploitation throughout the period September 2022 to February 2023 are presented, as well as the average daily total catch obtained by a fishing vessel. Even though the brown shrimp was the species with the lowest yield this season in the final official count, the estimated relative abundance was relatively stable and homogeneous (3.2 kg/h), except in December, when the abundance increased to 9.7 kg/h. For blue shrimp, relative abundance seems to have decreased from September (3.9 kg/h) to February (1.7 kg/h). And concerning the average catch per vessel per trip (working day), average monthly yields were between 29 and 45 kg of shrimp (both species and headless); an increasing trend in catch was observed, with a significant decrease only in December, recovering the movement in February.

On the other hand, the performance in the fishery, in terms of the catch of the total number of vessels that operated and registered the product, Figure 10 B shows the catch per vessel (cpue) for the September-January period. The trend of the total considering both species is similar to the direction of the relative abundance previously mentioned; however, the catch records denote essential differences in the species composition of the total catch, with the blue shrimp catch predominating in this case. And the trends are evident in Figure 10 B, where brown shrimp start the season with high cpue values and decrease throughout the season; conversely, blue shrimp start the season with a low cpue, increasing as the season progresses. Considering the total number of vessels and for the September-January period, the average catch per vessel was estimated at around one ton of headless shrimp.

.

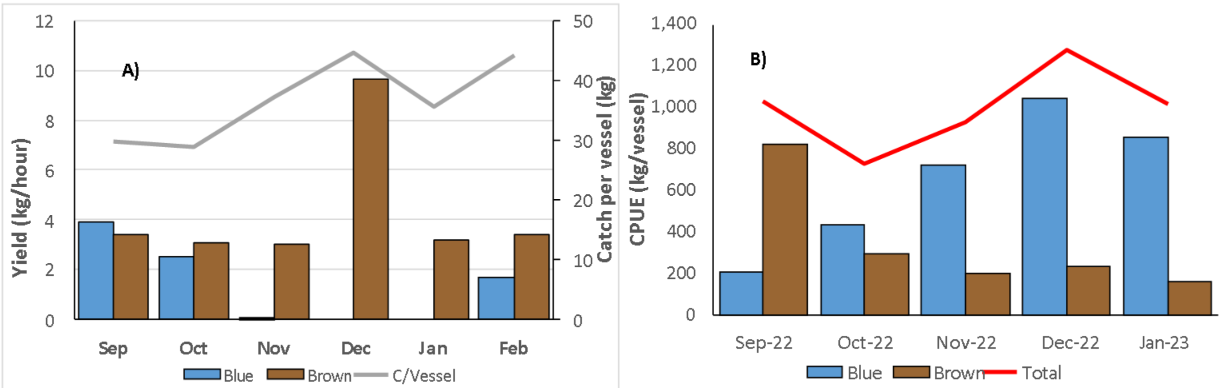

Figure 10. Yield of the shrimp fishery of Bahía Magdalena - Almejas, B.C.S., during the 2022-203 fishing season. A) Relative abundance (kg/hour) and catch per boat per working day observed in the samplings. B) Catch per unit effort (kg/vessel) from arrival notices throughout the fishing season.

CONCLUSIONS

Based on the studies carried out by the INAPESCA shrimp program in La Paz and the best scientific information available on biological, population, and fishing processes, we conclude the following:

The reproductive process in both species (maturity and spawning) was below-average historical indices. Only in February 2023 did blue shrimp show a significant spawning increase, but not maturity.

According to official records of catch and effort during the current season, its performance was below that of the previous season (2021-2022); however, both species showed catches above their historical average.

Significant differences were observed in the species composition of the total catch, with blue shrimp predominating. In the last five seasons, brown shrimp has dominated its share of the total. The trends observed in both species' catch per unit effort (cpue) were the opposite. Brown shrimp started the season with high cpue values, decreasing throughout the season; conversely, blue shrimp started the season with a low cpue and increased as the season progressed.

RECOMMENDATIONS

To protect the reproductive stock of commercially essential shrimp species in Bahía Magdalena-Almejas, B.C.S., and due to the decrease in catches and fishing yields, it is recommended to start the protection period for the natural populations that sustain the fishery no earlier than March 15, 2023.

To establish the adequate monitoring of the populations during the closed season 2023 and to be able to estimate the population dynamics in real-time and evaluate the migration and fishing recruitment processes, it is recommended to start the corresponding sampling program as soon as possible.

REFERENCES

Lo, N.C.H., Jacobson, L. D., and J.L. Squire. 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. *Can J Fish Aquat Sci* 49:2515-2526.

McConnaughey, R. A. and Conquest, L.L. 1992. Trawl survey estimation using a comparative approach based on lognormal theory. *Fish. Bull*. 91:107-118.

Pennington, M., 1986. Some statistical techniques for estimating abundance indices from trawl surveys. *Fish. Bull*. 84:519-525.

Pennington, M. 1996. Estimating the mean and variance from highly skewed marine data. *Fish. Bull*. 94:498-505.

Pennington, M, and Stromme, T. 1998. Surveys as a research tool for managing dynamics stocks. *Fish. Res*. 37:97-106.

Pérez - Farfante, I., 1977. American solenocerid shrimps of the genera Hymenopenaeus, Haliporoides, Hadropenaeus new genus and Mesopenaeus new genus. *Fish. Bull*. 75: 262-346.

Pérez - Farfante, I. 1988. Illustrated key to penaeoid shrimps of commerce in the Americas. U.S. Dept. Comm. *NOAA Tech Rep. NMFS*. 64: 1 - 32.

Pérez - Farfante, I. and B. Kensley, 1997. Penaeoid and sergestoid shrimps and prawns of the world. Keys and diagnoses for the families and genera. *Memories du Muséum National D'Histoire Naturelle. Tome 175. Zoologie*. París.

Smith, S.J., 1990. Use of statistical models for the estimation of abundance from groundfish trawl survey data. *Can. J. Fish. Aquat. Sci*. 47:894-903.

Smith, S.J. and S. Gavaris, 1993. Improving the precision of abundance estimates of eastern Scotian Shelf Atlantic cod from bottom trawl surveys. N. Amer. *J. Fish. Manag*. 13:35-47