Mexico Baja California Sur blue and brown shrimp – bottom trawl/cast net]

Fishery Improvement Project (FIP)

Technical report on the status, productivity, and management recommendations for the Bahía Magdalena-Almejas shrimp fishery, B.C.S.

Elaborated by:

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INSTITUTO NACIONAL DE PESCA Y ACUACULTURA

DIRECCIÓN GENERAL DE INVESTIGACIÓN
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CENTRO REGIONAL DE INVESTIGACIÓN
ACUÍCOLA Y PESQUERA LA PAZ

Technical report on the status, productivity, and management recommendations for the Bahía Magdalena-Almejas shrimp fishery, B.C.S.

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

Geographic scope:
Pacific Ocean Littoral

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Content

Introduction

Importance of the fishery

The shrimp fishery is one of the most important in Mexico, occupying first place in the product's commercial value, number of large and small vessels involved in the fishery, and installed infrastructure. This biological resource is highly valued in domestic and foreign markets, and commercialization in the latter market represents an important source of foreign exchange (NOM- 002-SAG/PESC-2013; INAPESCA, 2020).

The shrimp fishery in the Mexican Pacific includes the area from the Upper Gulf of California to the border with Guatemala, including the western coast of Baja California Sur and practically all the lagoon systems along the coast (López *et al*., 2012; INAPESCA, 2019, 2020). Its catch is mainly composed of four species: *Penaeus stylirostris* (Stimpson, 1874), blue shrimp; *P. vannamei* (Boone, 1931), white shrimp; *P californiensis* (Holmes, 1900), brown shrimp; and *P. brevirostris* (Kingsley, 1878), pink shrimp (INAPESCA, 2017a). However, other species in smaller proportions of penaeid shrimp may have lower commercial value.

The genders *Litopenaeus* and *Farfantepenaeus* were changed in 2011 to the genus *Penaeus* (Ma *et al.,* 2011).*Penaeus stylirostris* is distributed from Baja California Sur, Mexico, to Peru, including the Upper Gulf of California (AGC) (Hendrickx, 1996). *P. vannamei is distributed* from Sonora, Mexico, to Peru. It also inhabits sandy and clay bottoms (Hendrickx, 1996). *P. californiensis* is present along the entire Mexican Pacific coast, on sandy and clay bottoms, from the United States of America (USA) to Peru, including the Gulf of California and the Galapagos Islands (Hendrickx, 1986). *P. brevirostris*, distributed from Sinaloa, Mexico, to Peru, inhabits sandy, silty, and clay bottoms (Hendrickx, 1996).

In Mexico, twelve states, including Sinaloa, Jalisco, Durango, and Baja California, stood out by aggregating 69.6% of the Gross Domestic Product (GDP) in primary activities (INEGI, 2016). Despite the relatively low importance in the national GDP, the share of fisheries in production is higher at the regional level; in 2004, Sinaloa (22.72%) and Sonora (22.23%) had 45% of the national fisheries GDP. Together with Baja California Sur (5.49%), Baja California (4.94%) and Nayarit (2.68%) occupied 52.57 of the fishing GDP (http://www.cedrssa.gob.mx/?doc=1757, accessed 02/23/2018).

In 2014, exports were 1,129,418 thousand dollars, of which "fisheries and aquaculture" ranked 23rd, 0.8% of total world exports, with shrimp as the main exported product. Shrimp is in third place in Mexico's fishery production in terms of volume; however, in terms of value, it is in the first place. The average annual production growth rate in the last ten years is 0.01%. In exports, it isfirst among fishery species, with the United States of America, Japan, and Italy as its main destinations. The number of fishing permits for small boats is 1,688, distributed among 9,019 vessels authorized for shrimp fishing on the Pacific coast. Fifty-eight percent of the smaller vessels registered to catch shrimp are located in Sinaloa, 17% in Chiapas, 11% in Sonora, 7% in Nayarit, 5% in Baja California Sur, and the remaining is distributed in the states of Baja

California, Colima, Jalisco, and Oaxaca. In addition, the number of large shrimp catching vessels is 834, 90% of which are concentrated in the states of Sinaloa and Sonora. The number of registered shrimp processing plants is 57; the states of Sonora, Sinaloa, and Baja California account for 82% of the plants, with a cold storage network that ensures an export-quality resource (SAGARPA, 2015).

The shrimp catching season lasts between six and seven months, generally beginning in September or October and ending between March and April. Only in the months of October, November, and December is approximately 70% of the total catch obtained; the rest of the time, it decreases to a third of the catch compared to the beginning of the season.

The shrimp fishery in the lagoon system of Bahía Magdalena-Almejas, B.C.S., as in other fisheries along the Mexican Pacific, is sequential, taking advantage of the different life stages in different habitats. It is also multispecific (Fig. 1), with species of other habits, including brown shrimp *P. californiensis* and blue shrimp *P. stylirostris*, as well as rock or Japanese shrimp (*Sycionia penicillata*, *S. ingentis,* and S. *disdorsalis)* (García- Borbón *et al*., 1996).

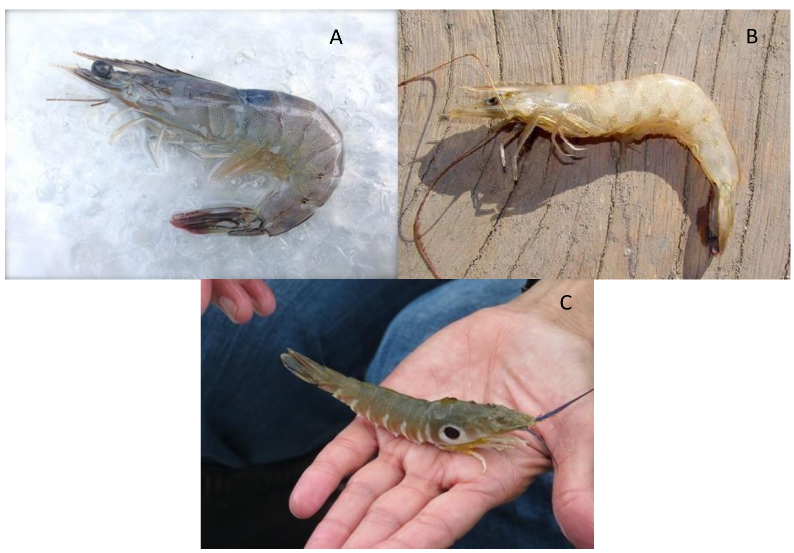

Figure 1. Shrimp species in the Bahía Magdalena-Almejas fishery, B.C.S. A) Blue shrimp (*Penaeus stylirostris*); B) Brown (*P. californiensis*); C) Rock (*Sicyonia penicillata*).

In Baja California Sur, the shrimp resource is in third place (in terms of the magnitude of its catch), after fisheries such as sardine and clams. In the case of industrial shrimp fishing, the participation of the fleet from other Mexican Pacific entities (mainly Sonora and Sinaloa) is currently more important than the State's own (with only two vessels), and the landing of the product in Baja California Sur is also scarce. The participation of a variable number of boats in the continental shelf of the western coast is recognized, depending on the abundance of the resource, mainly brown shrimp. Still, it can reach up to 200 and 300 boats. On the otherhand, the artisanal shrimp fishery in the lagoon system of Bahía Magdalena-Almejas is the most important in the State, with the direct participation of around 900 fishermen with 450 small boats and indirectly generating at least another thousand jobs. The importance of the employment generated by this fishery must also contemplate the magnitude of the time involved, which can reach up to 7 months, a time in which the economic benefit is also significant. Variably but unequivocally, given certain environmental conditions on the west coast of the peninsula and the success of various population processes (reproduction, growth, and recruitment), the distribution and abundance (mainly blue shrimp) extend northward (Fig. 4) from the Bahía Magdalena - Almejas system to Laguna San Ignacio; similarly, in the lagoon system of Guerrero Negro - Ojo de Liebre, brown shrimp can reach very high abundances when optimal environmental conditions are found.

Background

Studies on the shrimp resource in Baja California Sur carried out to date provide information on changes in population structure and dynamics, recruitment and reproduction seasons, distribution, and spatial and bathymetric abundance of the species that make up the catch (Cendejas, 1987; CIB *et al*., 1989; CIB *et al*., 1991; García-Borbón *et al*., 2015, 2018) for artisanal and industrial fisheries. The processes of change in the technical characteristics of fishing gear for shrimp capture in Magdalena Bay have also been monitored (García-Borbón *et al*., 1992). There are also technological studies that have led to the regularization of shrimp exploitation in the lagoon complex of Bahía Magdalena-Almejas, B.C.S., through the development of modified trawl nets, which include sea turtle and fish excluders, such as the Magdalena I net (DOF, 2001) that allow the capture of the resource in suitable proportions, reducing the impact on the communities where the resourceis found, as well as on the bottom (Fig. 2).

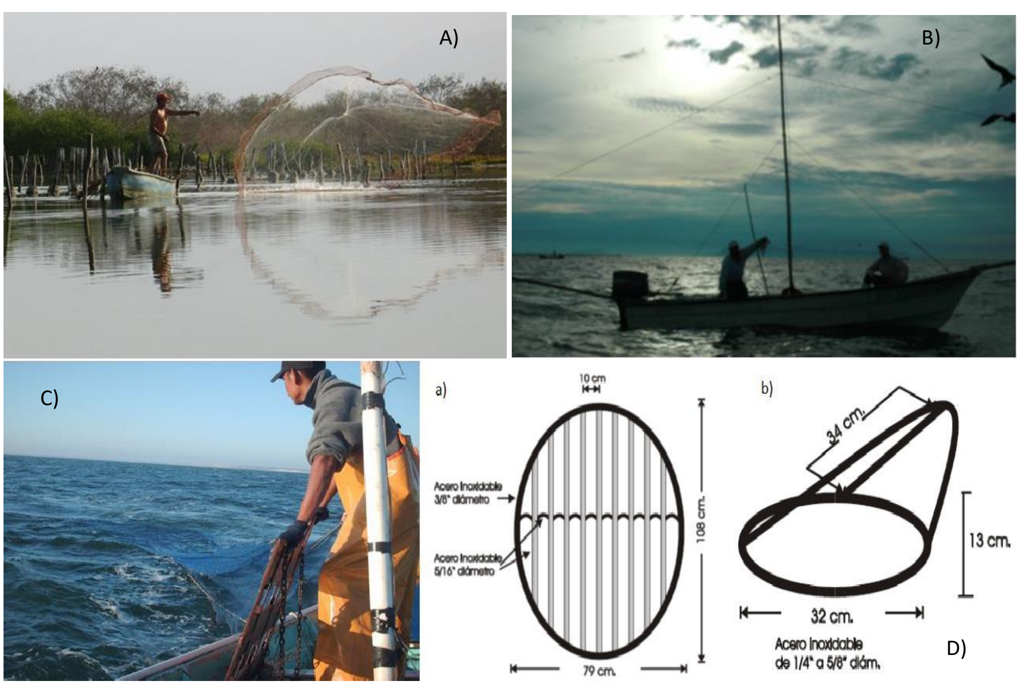

Figure 2. Shrimp fishing gear in Bahía Magdalena-Almejas, B.C.S. A) Atarraya, B) Suripera; C) Magdalena I; D) a) Rigid turtle excluder; b) Fish excluder "Ojo de Pescado".

The annual characterization of the population structure and dynamics of the species that compose the resource has allowed establishing the relevant recommendations for the management of their fisheries; they have also allowed appreciation of the variability of the relevant biological processes in the annual determination of the population size, through the estimation of parameters such as growth (Cendejas, 1997), natural mortality (García-Borbón, 2009; Aranceta-Garza *et al*., 2016), recruitment, reproduction (García- Borbón *et al*.,2018) and the parameters of the annual length-weight relationships.

On the other hand, the impact of environmental variability on the distribution and abundance of resources has been recognized as a fundamental factor in catch variations (López-Martínez et al., 2010; Magallón-Barajas, 1987; Mendo and Tam, 1993; Sheridan, 1996), which has been recognized in penaeid shrimp (López-Martínez et al., 2010). Variability in catches in invertebrate fisheries such as shrimp can be positive, with increases in abundance and availability, for example, in response to declining catches in other fisheries, particularly flake (Anderson et al., 2011). Or as suggested by Worm and Myers (2003), due to the release of predators of several previously abundant invertebrates.

In addition, species with different life histories respond differently to changes in environmental conditions. Thus, a species with a short life history will exhibit a response in a short period if there is a change in its environment, particularly in fundamental biological processes such as reproduction, growth, abundance, and natural recruitment (Longhurst, 2002). In this sense, it has been pointed out that the variability of abundance in penaeid shrimp is related to the physical environment (Arreguín-Sánchez et al., 2015; Castro-Ortíz and Lluch-Belda, 2008; Galindo- Bect et al., 2000; López-Martinez et al., 2002, 2010; Santamaría-del-Ángel et al., 2010). The variability of the climate-ocean system has been shown to affect marine life strongly, and has been considered in fisheries, wildlife, and ecosystem management studies (Beaugrand et al., 2003; Cury et al., 2008). These local and regional fluctuations are identified through the variability of physical factors such as temperature, rainfall, river discharge, and winds, which in turn are related to large-scale changes associated with oceanic and atmospheric circulation dynamics.

Fishing zones

The shrimp catch zone is along the Mexican Pacific coast, divided into protected waters and the high seas. Fishing in protected waters occurs mainly in lagoon systems, estuaries, and bays of Baja California Sur, Sonora, Sinaloa, Nayarit, Oaxaca, Chiapas, and to a lesser extent, Jalisco and Colima. Fishing in marine waters is conducted at a depth greater than five fathoms with larger and smaller vessels, in the Mexican Pacific Ocean, including the Gulf of California (except for protected areas that stipulate) (INAPESCA, 2017a). On the high seas, research on the state of the resource in the Mexican Pacific is divided into seven study zones. The Mexican Pacific zones were divided during a meeting held in 1985 based on aspects such as river mouths, bathymetry, distribution, and specific abundance, among others (Fig. 3).

- Zone 10 includes the AGC, between 29°45' N and 114°15' W to 28°44' N and 111°56' W, excluding the vaquita protection zone polygon (DOF: 20/04/2018) and the Upper Gulf of California Biosphere Reserve. The fishery is supported by *P. stylirostris.*
- Zone 20 includes the coastal front of the State of Sonora, from south of Isla Tiburón to the mouth of the Río Fuerte, on the border with Sinaloa, between 28°44' N and 111°56' W to 25°57' N and 109°26' W. P. californiensis mainly support the fishery.
- Zone 30 includes from north of Mazatlan to Punta Ahome, on the border with the state of Sonora, between 25°57' N and 109°26' W to 23°11' N and 106°27' W. The fishery is supported mainly by *P. californiensis* and, to a lesser extent, *P. stylirostris* and P. *vannamei*.
- Zone 40 includes from Mazatlan to Boca de Teacapan on the border with Nayarit, between 23°11' N and 106°27' W to 22°11' N and 105°38' W. The fishery is supported by *P. californiensis*, *P. vannamei,* and *P. stylirostris.*
- Zone 50 includes the strip between La Paz and Cabo San Lucas in the Gulf of California, as well as the west coast of the Baja California Peninsula, between 28°30' N and 114°05' W to 24°18' N and 110°17' W, excluding the polygon of the refuge area zone for the loggerhead sea turtle (*Caretta caretta*) (DOF: 05/06/2018) The fishery is supported mainly by brown shrimp, *P. californiensis*.
- Zone 60 Off the coast of Nayarit, from the mouth of Teacapán to the mouth of Custodios, between 22°11' N and 105°38' W to 21°30' N and 105°13' W. The fishery is supported by *P. vannamei* and, toa lesser extent, *P. californiensis* and P. *brevirostris*.
- Zone 90 includes the Gulf of Tehuantepec, corresponding to the States of Oaxaca and Chiapas, the area from Punta Chipehua, Oaxaca, to Puerto Madero, Chiapas, between 16°00' N and 95°21' W to 14°32' N and 92°14' W. *P. vannamei, P. californiensis and P. brevirostris* are caught. In general, *P. californiensis* is the most abundant species in marine fisheries and is present throughout the Mexican Pacific; however, due to the size each species reaches, *P. stylirostris* and *P. vannamei are the* most economically valuable.

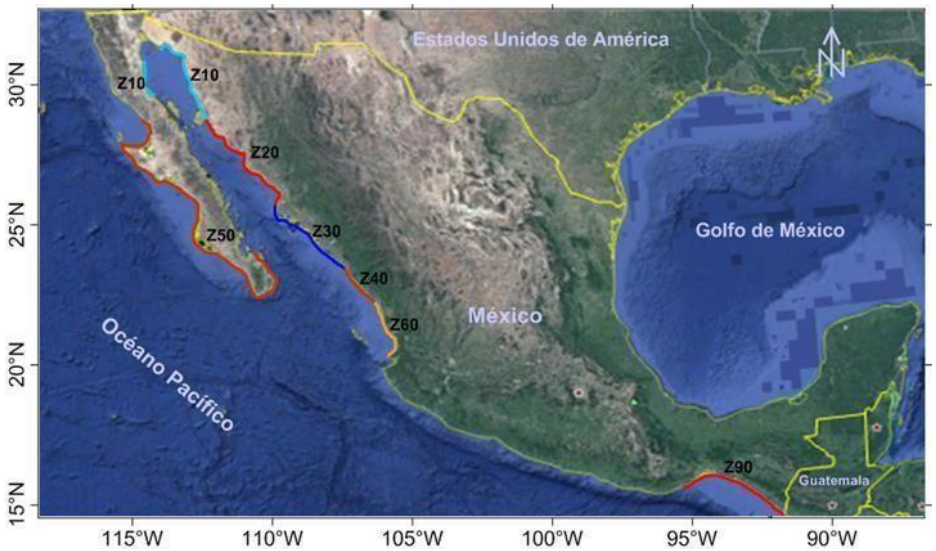

Figure 3. Location of the regions defined for the study of the high seas shrimp fishery in the Mexican Pacific.

The shrimp fishery in protected waters of Baja California Sur takes place mainly in the lagoon complex formed by Magdalena and Almejas Bays, in San Ignacio Lagoon, San Hipolito Bay, San Juanico Bay, as well as in the Ojo de Liebre - Guerrero Negro lagoons. Of these areas, the Bahía Magdalena - Almejas complex is the most crucial in terms of shrimps stocks in the State (Fig. 4).

In this region, there is a fishing phase in estuaries at depths between 0.5 and 6 m, where mainly juvenile blue shrimp are caught and, to a lesser degree, brown shrimp in seasons of high abundance. Another fishing stage occurs at greater depths, between 6 and 50 m, where blue shrimp are caught after migrating from the estuaries to the deeper bays, from juvenile to adult, and brown shrimp from juvenile to adult. In addition to the fishing stages in protected waters, there is exploitation on the continental shelf. Each of these stages has different capture systems; other fishing gear is used due to differences in the developmental stages of the species being harvested. There is also the capture in the channel zone, which can be considered an intermediate zone between the estuary zone in the northern region of Magdalena Bay lagoon system, and the high seas, in which practically all the variety of regional fishing gear is used; in this stage, both species are captured in juvenile and sub-adult stages in the process of migration, either to the high seas or to the deep zone of the bays.

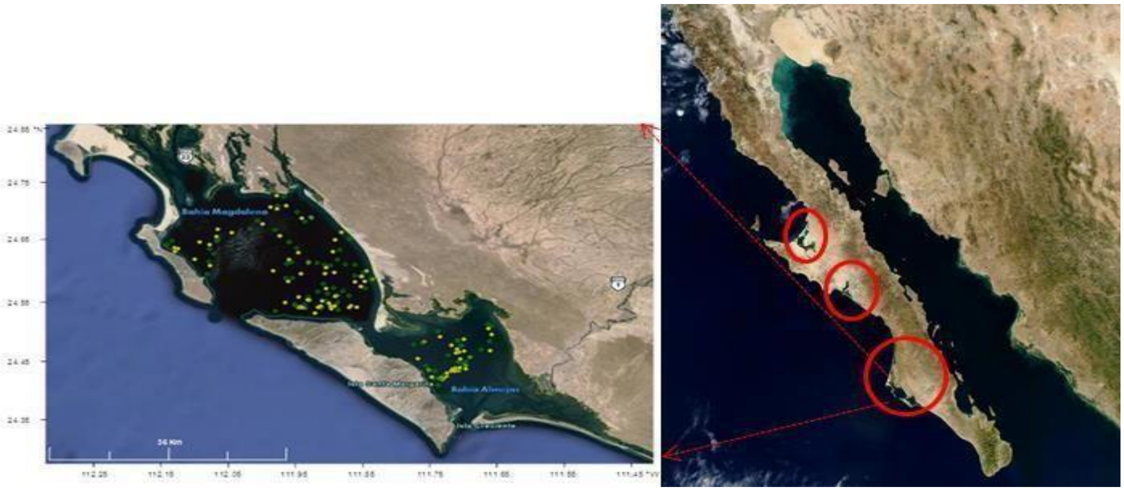

Figure. 4. Main shrimp catch areas in Baja California Sur (Zone 50 of the Pacific Shrimp Program). Guerrero Negro-Ojo de Liebre (upper circle), Laguna San Ignacio (center circle), and Bahía Madalena-Almejas (lower circle and left inset).

Fishing methods and gear

Harvesting is carried out by a fleet of variable size of small boats (450 authorized vessels) with outboard motors of between 60 and 115 Hp (2 and 4 strokes) and artisanal fishing gear (atarraya, suripera, cast net, and Magdalena net), whose origin goes back to those created in the states of Sinaloa, Sonora, and Nayarit.

Due to the magnitude of the abundance, biological complexity, and physiognomy of the lagoon complex of Bahía Magdalena-Almejas, there are three sequences in the exploitation, mainly due to the natural dynamics of the two species presented here. One line corresponds to fishing in estuaries where blue and brown shrimp are caught in the juvenile stage using cast nets and suriperas; another is fishing for blue and brown shrimp, eventually, rock shrimp (also known as Japanese or rock) from juveniles to adults in the bay area using trawls (Magdalena I); the last is deep-sea fishing, on the contiguous continental shelf where mainly brown and marginally blue shrimp are caught using larger vessels with trawls. The use of gillnets is illegal in these lagoon systems.

In San Ignacio Lagoon, blue and brown shrimp, from juveniles to adults, are caught using the cast nets, the only gear permitted for this system. In the Guerrero Negro and Ojo de Liebre lagoons, brown shrimp are caught with the cast nets while waiting for the introduction of the suripera net. Fishing activity in these regions depends mainly on resource availability, and its contribution can be considered small.

Table 1. Shrimp species mainly exploited and associated with the fishery:

Target species	
Common name	**Scientific name**
Brown shrimp	*Penaeus californiensis*
Blue Shrimp	*Penaeus stylirostris*
Associated species	
Common name	**Scientific name**
Rock shrimp (rock, Japanese)	*Sicyonia penicillata, S. ingentis, S. disdorsalis.*

1. Fishery indicators

The volume of shrimp catches corresponds to blue shrimp (P*. stylirostris*) and brown shrimp (P*. californiensis*);however, the abundance of rock shrimp (*S. penicillata*) is important, particularly during the closed season and during the fishing season when the volume of catches of the first two species is low. The variability of total shrimp catches (blue and brown) is quite evident (Fig. 5), with values ranging from 401 to 2,526 t, with an average of 1,116 t. The highest catches were recorded in the 2014-2015 and 2020-2021 seasons. The lowest catches occurred during the 2000-2001 and 2013-2014 seasons. On the other hand, it is observed that the CPUE is quite faithful to the catch trends, demonstrating the flexibility of the fishery to adapt to the availability of the resource, mainly if the participation of two main species in the catch is considered.

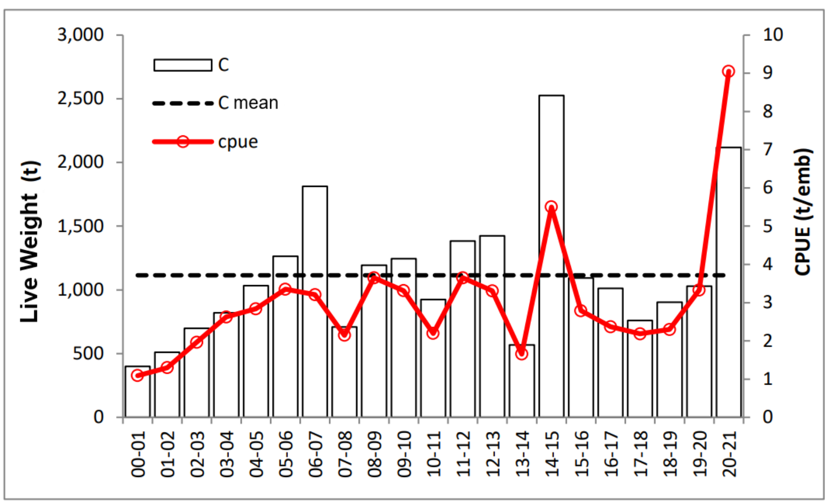

Fig. 5. Indicators of the shrimp fishery of Bahía Magdalena-Almejas, B.C.S. Capture (C), Capture mean (Cmean) and catch per unit of effort (CPUE).

The participation of the two main shrimp species in total catches is variable (Fig. 6), and on rare occasions, the catches of both species tend to be high together. Still, the contribution of brown shrimp to the total is important in practically all the observed seasons. During the period 2004-2007, 2008-2013, and in the 2014-15 and 2016-17 seasons, the production of brown shrimp exceeds its average. Only in the 2014-2015 and

2020-2021 seasons did it show a share above the average in blue shrimp. 2021 denoted participation above the average of brown and blue, but the occasions in which the catches exceed their average are lower concerning the case of brown shrimp. Until the 2020-2021 season, the average catch is 323 t for blue shrimp and 793 t for brown shrimp.

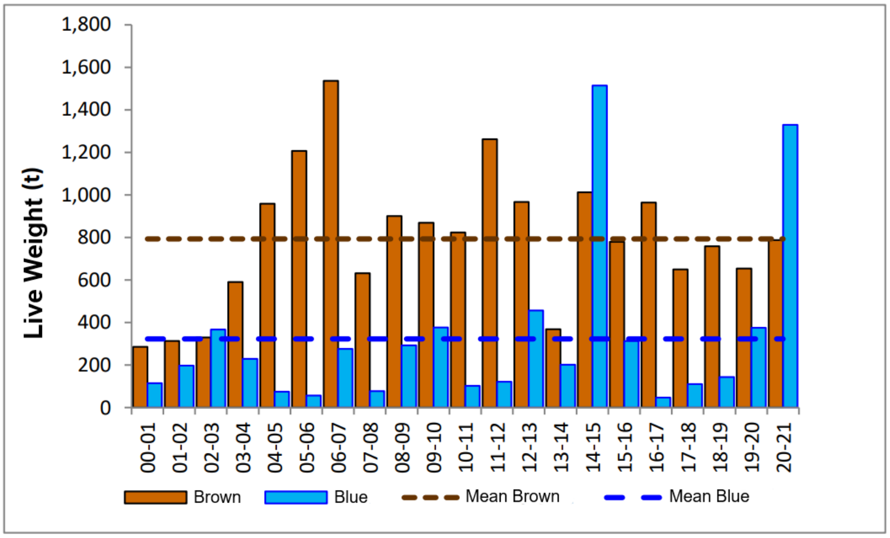

Figure 6. Total and average catch of blue and brown shrimp in Magdalena Bay - Almejas, B.C.S.

2. Objectives

General

Determine the status, productivity and management options for the Bahía Magdalena-Almejas t shrimp trawl fishery.

Particular

a) Update the National Fishing Chart as an instrument for the administration of the shrimp fishery.

c) Evaluate the shrimp resource through the use of useful reference points for the administration of the resource.

d) Characterization of the accompanying fauna of shrimp in the fishery of Magdalena Bay- Almejas, B.C.S.

3. Method

Based on the information from the analysis of catch data and biological sampling in the field, models were applied to evaluate the resource.

Stock Assessment

Catches (t) for blue, white and brown shrimp by fishing season and CPUE (t per number of boats) were analyzed. The seasons analyzed were from 2000-01 to 2018-19, catch data were obtained from SIPESCA, CONAPESCA.

CPUE was analyzed using the dynamic biomass model of Schaefer, 1954, modified by Pella and Tomlinson, 1969 (Haddon, 2001).

$$\boldsymbol{B_{t+1} = B_t + \frac{r}{p} B_t \left[1 - \left(\frac{B_t}{K}\right)^p\right] - C_t}$$

Where: t = year (fishing season); B_t= stock biomass at time t; B_{t+1}= stock biomass at time t + 1; r is the intrinsic growth rate, K is the carrying capacity, *p* is related to the asymmetry and C_t is the catch at time t, which is defined as:

$$\boldsymbol{C_t = q * f_t * B_t}$$

Where: **q** is the catchability coefficient and $\boldsymbol{f_t}$ is the fishing effort at time t. Parameter estimation (r, k and B_0) consisted of fitting catch per unit effort as an index of abundance estimated by the model versus observed CPUE. The model parameters were estimated by maximizing the likelihood function with the following equation(Haddon, 2001):

$$\boldsymbol{lnL = -\frac{n}{2}[ln(2\pi) + 2ln(\sigma) + 1]}$$

The Excel Solver function was used for maximization using the Generalized Reduced Gradient (GRG) algorithm (Lasdon *et al*., 1978).

Biological Reference Points

Once the parameters were estimated, the biological reference points were calculated. A thousand random samples were taken from the best residual fit of the data using the Monte Carlo method, in this way the uncertainty of the reference points used to define the state of the fishery can be obtained.

Maximum Sustainable Yield (MSY) was calculated by: $MSY=r*K/4$.

The stress (*fMSY*) at the level of maximum sustainable yield is $f\,MSY=r/2*q$

The *FMRS* at the level of maximum sustainable yield or optimum exploitation rate (Punt and Japp, 1994) is:

$FMSY=r/2$ and the *F0.1*: 10 % of the original slope in the *F* versus Catch relationship (Sparre and Venema, 1997; Chen and Montgomery, 1998).

Abundant species in the FAC

According to the Relative Abundance Index (*RAI*), species were grouped into four categories based on this index (Rodríguez-Romero *et al*., 2008). Abundant species (A): those with a relative abundance greater than 1.0%. Frequent species (F): species with a relative abundance of between 1.0% and 1.0%.

0.1 y 0.99%. Common species (C): a relative abundance between 0.01 and 0.099%. Rare species (R): with a relative abundance of less than 0.01%.

The *RAI* was determined with the following expression:

$$RAI = \left(\frac{N}{TN}\right) * 100$$

Where: *N*= Number of individuals of each species captured and *TN*= Total number of individuals of all species.

4. Results

Stock assessment

Figure 7 shows the state of the blue shrimp (P*. stylirostris*) population for the period from the 2000- 2001 to 2020-2021 fishing seasons, evaluated through A) the estimated catch and biomass versus theoptimum biomass (K/2), as a limit reference point, and B) the catch versus the maximum sustainable yield (MSY), as a target reference point. In the first case (Fig. 7A), the estimated biomass for blue shrimp shows wide variability, ranging from 585 to 1,955 t, with catches very close to the biomass present in each season. The MSY was located on average at 409 t, with a confidence interval (95%) of 404 and 425 t, while the limit reference point estimated as K/2 (1,896 t) is only reached in the season of maximum catch (2014-15) with a catch of 1,514 t. Figure 7B shows catch versus MSY, as a target reference point, where it is recognized that catches only exceed MSY in three seasons (2014-15, 2020-21, and 2012-13), occurring in circumstanceswhere the biomass of blue shrimp shot up significantly between 2 and 5 times the immediate previous abundance; outside of these times of high catches, the mean oscillates around 200 t.

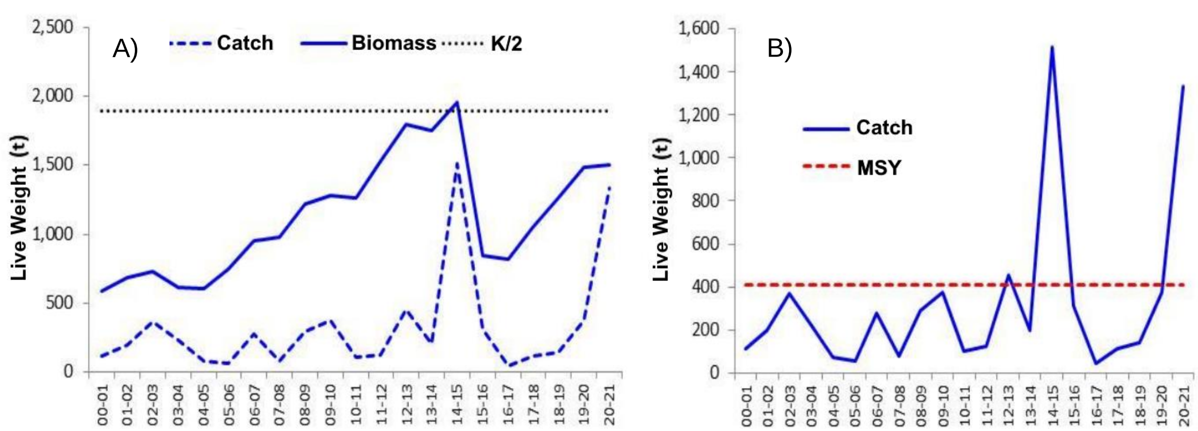

Fig. 7. Reference points of the *P. stylirostris* fishery in Bahía Magdalena-Almejas, B.C.S. A) Catch and biomass trajectory; limit reference point (K/2). B) Catch and target reference point (MSY).

For brown shrimp, the estimated total biomass ranged between 630 and 2,049 t, with catches also around the biomass (Fig. 8A). Although variability in biomass and catches is observed, this variability is not as pronounced as in blue shrimp, where drastic changes in biomass and catches are observed. For this species, the limiting reference point (K/2 = 2.408 t) is not exceeded at any time. On the other hand, Figure 8B shows thecatches versus MSY as a target reference point, where it is observed that only twice in the reference period is the MSY exceeded (1,068 t), with a confidence interval (95%) of 1,067 - 1,070 t, occurring in the 2006-07 and 2011-12 seasons.

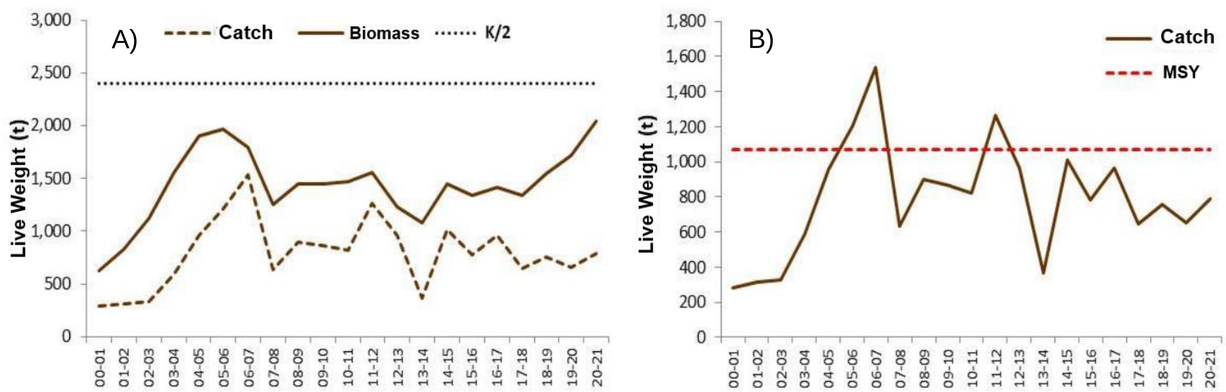

Fig. 8. Reference points of the *P. californiensis* fishery in Bahía Magdalena-Almejas, B.C.S. A) Catch and biomass trajectory; limit reference point (K/2). B) Catch and target reference point (MSY).

To avoid undesirable situations for shrimp stocks, it is necessary to propose and implement protective measures that will result in the reduction of fishing effort, in the understanding that the environmental and biological processes responsible for the variability of abundance are not entirely under the control of those responsible for the administration of the fishery. This is particularly noticeable in the case of brown shrimp, whose fishery is in a critical situation mainly characterized by high fishing intensity. In practice, this type of measure would be referred to as the reduction of both the effective effort present in the fishery, as well as the reduction of the length of the capture season by delaying the start and/or bringing forward the closure of the fishing season. For this purpose, information on abundance indices and indicators of the proportion of spawners will be needed, both during the closed season before the start of fishing as well as throughout the catching season, to establish the temporal limitation of the catching season. Although the biology of blue and brown shrimp populations differs in terms of relative abundance, reproductive cycles, and recruitment mechanisms, fishing systems are not necessarily selective for a particular species, so the measures to be taken to reduce effort should be the same. Therefore,it is also necessary to establish the corresponding relationships between spawners and recruits, as well as how environmental dynamics influence the different biological processes of the two species.

Environmental effects and climate change

In a multiple regression analysis where the relationship between variables of the biological origin of brown shrimp from Bahía Magdalena-Almejas, B.C.S. with oceanic-atmospheric variables or indicators was evaluated, García-Borbón (2019) found that the most common and critical environmental variables in the relationship with reproductive aspects of brown shrimp (*P. californiensis*) were the upwelling index (S) and the meridional (north-south) component of the V. wind.

It can be considered that the multiple regression models for the fraction of mature females (FHM) and length at first maturity (L50) denoted significant goodness-of-fit and were significant, apparently because they correspond to a biological process (reproduction) that responds relatively directly to environmental variability, even when mediated by other processes at the individual (hormonal), population and other levels such as predation, dense dependence, and intra- and inter-specific competition (Andersen et al., 2017).

The multiple linear regression models established between biological and environmental variables in brown shrimp that were significantly appropriate were the frequency of mature females (FMF) and the lengthat first maturity (L50), with 67% and 56% of the variance explained, respectively. The environmental variables that were significant for FMF were: atmospheric pressure (AP), Pacific Decadal Oscillation (PDO), and time (T);while for L50 were: the meridional component of the wind, north-south (V,) and the Surge Index (S).

5. Fisheries policy and management regulations and instruments

Management Control	Y/N	Provisions	Supporting Document
Mexican Official Standard	Yes	NOM-002-SAG/PESC-2013	DOF: 11/07/2013
Management Plan	No		
Fishing			
Type of access	Yes	Commercial shrimp fishing permit or concession	Technical opinion of INAPESCA
Minimum size	Yes	The minimum size is not formal, but a minimum mesh opening in the nets is established. A minimum mesh size of 37.5 mm (1½ inches). Suripera net with a minimum mesh size of 32 mm (1.26 inches). "Magdalena I" with minimum mesh size of 44.45 mm (1 ¾ inch). inch) on the body and wings, and 41.28 mm (1 5/8 inch) on the bag.	DOF: 7/09/2001

Fishing gear and capture method	Yes	NOTICE announcing the authorization to use the Magdalena I and Suripera nets as fishing equipment for shrimp catching in the Magdalena-Almejas Bay Estuarine Lagoon System, located in the State of Baja California Sur. The "Magdalena I" net is operated from small boats with an outboard motor of up to 75 horsepower for shrimp catching. It may only be used in the lagoon system Bahía Magdalena-Almejas in areas deeper than 16m (60 ft). The net must have a maximum dimension of 13.5 m (44.3 feet) headrope length, cloth of polyamide (PA) or polyethylene (PE) mono and multifilament yarn, with a minimum mesh size of 44.45 mm (1 ¾ inch) in the body and wings, and 41.28 mm (1 5/8 inch) in the bag. The net must be fitted with a rigid sea turtle excluder and a fish excluder of the "fisheye"type. Only small boats up to a maximum of 7.62 m (25 ft) in length, equipped with an outboard motor up to 75 horsepower, and a single net may be used. The "Suripera" is a fishing gear (trawl type) operated with little or no mechanical propulsion. It is used in shallow areas of coastal lagoons or estuarine channels. It is made up of the main body known as a skirt or sweeper attached to the footrope with weights; bags or flakes, also known as caps that go on the upper part; blades, weights, and rings. The headrope shall have a maximum dimension of 13.0 m (50 ft) dragline length. The netting must have a minimum mesh size of 32 mm (1.26 inches) in any section. Only smaller vessels with a maximum length of 7.65 m (25 feet), equipped with an outboard motor of up to 75 horsepower, and one footrope or pair of footropes (each with a maximum of two bags or caps) may be used. Atarraya net with a minimum mesh size of 37.5 mm (1½ inches).	DOF: 7/09/2001
Closed Season	Yes	Temporary closure protects reproduction and growth with variable dates, generally between March and September of each year.	Item 4.4, DOF, 2013 INAPESCA's Technical Opinion.
Quota	No		
Unit of fishing	Yes	Artisanal boats	INAPESCA's Technical Opinion.
Effort	Yes	450 artisanal boats	INAPESCA's Technical Opinion.

No fishing zone	Yes	In no case may shrimp fishing be carried out in front of the mouths that communicate the sea with coastal lagoons, the mouths of estuaries, and rivers that communicate with the main body of the bay.	DOF,2001
		For the offshore fleet and, in all cases, in the Mexican Pacific, the regulatory guidelines established in the management programs of the Pacific Islands of the Baja California Peninsula Biosphere Reserve and the El Vizcaino Biosphere Reserve should be considered.	DOF, 2013 DOF, 2016 DOF, 2000 DOF, 2009 DOF, 2005

Abundant species that are associated with shrimp bycatch. (FAC)

Fish are the most representative group (95% of the total abundance) in the accompanying fauna of the shrimp in the lagoon complex Bahía Magdalena-Almejas, B.C.S., followed in abundance by crustaceans, mollusks, and echinoderms. Within the fish group, 48 families, 74 genders, and 106 species are represented. The families with the highest number of species were: Paralichthyidae (8), Haemulidae (8), Serranidae (6), Sciaenidae (5), Carangidae (5), Gerreidae (5) and Tetraodontidae (5). According to the index of relative abundance (RAI) and the biological value index (BVI) in the appendix, the most abundant and frequent species were: *Paralabrax maculatofasciatus, Eucinostomus gracilis, Etropus crossotus, Diplectrum pacificum, Etropus peruvianus and Eucinostomus dowii*. These 6 species were considered the most important, because they represent 68% of the total abundance and are the most recurrent in shrimp trawls.

6. Management strategies and tactics

Strategies: Presence of a temporary and spatial closed season, in which the conclusion of the maximum reproductive process is ensured, as well as the consequent recruitment of juveniles to the fishery; propitiating that the beginning of the fishing season occurs with the presence of optimal sizes and catch volumes, according to the information obtained during the closed season. To conserve economic profitability and optimum spawning biomass at the end of the fishing season.

Tactics: Control of effective fishing effort; reproductive and spatiotemporal variable growth closure; regulationson the types and characteristics of fishing gear.

7. Management recommendations

1. To maintain the healthy biomass of deep-sea shrimp in the Pacific, it is not recommended to increase effort and to reduce it as much as possible to reach the optimum effort to achieve maximum sustainable yield.
2. It is recommended that NOM-002 SAG/PES-2013 be modified to include the suripera network in all lagoon systems in Baja California Sur.
3. Increase vigilance to prevent illegal fishing, particularly during the closed season.
4. Facilitate access to statistical information on catch and effort in real time to INAPESCA (CRIAP La Paz) during the fishing season.

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Annex I

List of fish species in the FAC in the lagoon system Bahía Magdalena-Almejas, B.C.S. The classification is based on the criteria of the Relative Abundance Index (RAI) and the Biological Value Index (BVI). A= abundant; F= frequent; C= common.

Gender	Species	RAI	BVI
Paralabrax	*maculatofasciatus*	A	202
Eucinostomus	*gracilis*	A	191
Etropus	*crossotus*	A	172
Diplectrum	*pacificum*	A	169
Etropus	*peruvianus*	A	154
Eucinostomus	*dowii*	A	134
Achirus	*mazatlanus*	A	86
Haemulopsis	*axillaris*	A	43
Orthopristis	*reddingi*	A	40
Haemulopsis	*nitidus*	A	30
Balistes	*polylepis*	A	28
Occidentarius	*platypogon*	A	26
Orthopristis	*chalceus*	A	26
Porichthys	*analis*	A	21
Urolophus	*halleri*	A	20
Pleuronichthys	*ritteri*	F	31
Pseudupeneus	*grandisquamis*	F	19
Syacium	*ovale*	F	16
Haemulopsis	*elongatus*	F	15
Calamus	*brachysomus*	F	12
Sphoeroides	*lobatus*	F	11
Anchovy	*nasus*	F	11
Prionotus	*stephanophrys*	F	10
Chaetodipterus	*zonatus*	F	10
Synodus	*scituliceps*	F	9
Prionotus	*ruscarius*	F	8
Sphoeroides	*lispus*	F	8
Synodus	*lucioceps*	F	6
Sphoeroides	*annulatus*	F	5
Symphurus	*fasciolaris*	F	5
Zapteryx	*exasperata*	F	4
Urotrygon	*rogersi*	F	3
Hippoglossine	*bollmani*	F	2
Hippocampus	*ingens*	F	2
Anchovy	*ischana*	F	2
Paralichthys	*californicus*	F	1
Ophidion	*galeoides*	F	1
Elattarchus	*archidium*	F	1
Diplobatis	*ommata*	F	0

Hypsopsetta	*guttulata*	F	0
Cynoscion	*parvipinnis*	F	0
Heterodontus	*francisci*	F	0
Urobatis	*maculatus*	F	0
Scorpaena	*sonorae*	F	0
Ariosoma	*gilberti*	F	0
Sphoeroides	*sechurae*	F	0
Mustelus	*henlei*	F	0
Gymnura	*marmorata*	F	0
Xystreurys	*liolepis*	F	0
Mustelus	*lunulatus*	F	0
Porichthys	*margaritatus*	C	9
Catfish	*panamensis*	C	5
Lutjanus	*guttatus*	C	5
Bothus	*leopardinus*	C	3
Carangoides	*otrynter*	C	3
Oligoplites	*saurus inornatus*	C	3
Trachinotus	*paitensis*	C	3
Symphurus	*sp*	C	2
Myrophis	*vafer*	C	1
Alectis	*ciliaris*	C	0
Chaetodon	*humeralis*	C	0
Myliobatis	*californica*	C	0
Pleuronichthys	*verticalis*	C	0
Diodon	*holocanthus*	C	0
Paralichthys	*woolmani*	C	0
Mustelus	*californicus*	C	0
Prionotus	*birostratus*	C	0
Deckertichthys	*aureolus*	C	0
Eucinostomus	*entomelas*	C	0
Heterodontus	*mexicanus*	C	0
Heterodontus	*mexicanus*	C	0
Caulolatilus	*affinis*	C	0
Pleuronichthys	*ocellatus*	C	0
Scomber	*japonicus*	C	0
Selene	*peruvian*	C	0
Pomadasys	*branickii*	C	0
Sardinops	*sagax*	C	0
Eucinostomus	*currani*	C	0
Rhinoptera	*steindachneri*	C	0
Diplectrum	*eumelum*	C	0
Diplectrum	*euryplectrum*	C	0
Hippoglossine	*tetrophthalma*	C	0
Rhinobatos	*leucorhynchus*	C	0
Sphyraena	*ensis*	C	0

Apogon	*pacificus*	C	0
Opisthonema	*libertate*	C	0
Symphurus	*atricaudus*	C	0
Fistularia	*bugle*	C	0
Haemulon	*maculicauda*	C	0
Xenichthys	*xanti*	C	0
Halichoeres	*semicinctus*	C	0
Lophiodes	*caulinaris*	C	0
Narcine	*entemedor*	C	0
Opistognathus	*punctatus*	C	0
Pristigenys	*serrula*	C	0
Bathyraja	*sp*	C	0
Cheilotrema	*saturnum*	C	0
Cynoscion	*reticulatus*	C	0
Menticirrhus	*elongatus*	C	0
Menticirrhus	*elongatus*	C	0
Scorpaena	*guttate*	C	0
Scorpaena	*mystes*	C	0
Hyporthodus	*niphobles*	C	0
Paralabrax	*nebulifer*	C	0
Peprilus	*simillimus*	C	0
Synodus	*lacertinus*	C	0
Sphoeroides	*sp*	C	0
Bellator	*gymnostethus*	C	0