Ocean & Coastal Management 125 (2016) 1–7

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Emerging fisheries in subtropical coastal lagoons: *Sphoeroides annulatus* in Magdalena-Almejas Bay, BCS, Mexico (1998–2008)

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ARTICLE INFO

Article history:
Received 9 November 2015
Received in revised form
15 February 2016
Accepted 20 February 2016
Available online xxx

Keywords:
Magdalena-Almejas Bay
Botete diana
Bullseye puffer fishery
Sphoeroides annulatus
Emerging fisheries

ABSTRACT

Fishing is an important economic activity in Baja California Sur that creates thousands of jobs and provides high-quality food. Magdalena-Almejas Bay is a highly productive region that contributes an annual average close to 50% of state catches. It is the center of various small-scale fisheries that include the marine species commonly known as "finfish", for which information is scarce. To understand the operation of this multi-species fishery and its recent changes, operations of the coastal fleet were analyzed using a historical series of official capture landing reports for the period 1998–2008. Surveys were administered to fishers in order to record their local knowledge on aspects such as target species, associated species and bycatch, fishing gear currently used, and fishing seasons and areas. Primary (on-beach) buyers were surveyed to document the market. The information obtained revealed the existence of emerging fisheries, highlighting *Sphoeroides annulatus* (locally known as "botete diana") that ranks fifth in relative importance based on volume captured, production value, and number of capture landing reports. Fishing operations were documented on fishing trips with producers who use specific fishing gear locally called "*chinchorro botetero*" (puffer seine net). Due to the lack of published information about this particular fishery, this work attempts to set a foundation for the systematic documentation of this fishery, recording biological aspects of the species, fishing gear used, catch techniques, initial preservation, the prices of fish sold on the beach, the marketing channel, the target market, seasonality, and spatial distribution of the fishery.

1. Introduction

Fishing is a global productive activity that significantly impacts the economy and development of countries, especially in coastal areas, creating millions of direct and indirect jobs, both in industrial activities as well as in the so-called small-scale, artisanal, or coastal fishery (FAO, 2005; FAO, 2014).

According to a recent report on the global state of fisheries, Mexico ranks 16th among the most important nations in terms of fisheries production, showing a 1% increase between 2011 and 2012, with a 16.7% cumulative growth in catch during 2003–2012 (FAO, 2014). The country's northwestern region, which encompasses the states of Sonora, Sinaloa, Baja California and Baja California Sur (BCS), contributes 70% to national production (CONAPESCA, 2014).

In BCS, the region encompassed by the Magdalena-Almejas lagoon complex (BMA) has become the main fishing center. This is due to its high productivity associated with geographic, oceanographic, and environmental factors, all of which allow coastal fisheries and the industrial fishing of sardines. Together these contribute annually between 55% and 60% of state catches and over 40% of production value (Ojeda, 2012).

While fisheries of species of high commercial value such as abalone and lobster supported social development in this subtropical coastal lagoon (Cárdenas, 2014), the decline in catches, the reduction of natural banks, and the growth of the fishing sector jointly led to the diversification toward alternative resources. The relative importance of other fisheries consequently increased, raising the fishing pressure on a larger number of species.

A study coordinated by the FAO entitled *"El Potencial Pesquero y*

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http://dx.doi.org/10.1016/j.ocecoaman.2016.02.009
0964-5691/

Acuicola de Baja California Sur" includes reports on the major fisheries in the state based on records from the 1980s and early 1990s. The document defines the potential for development as appropriate. It includes traditional coastal fisheries, such as lobster, abalone, pacific calico, estuarine shrimp, shark, crab, snail, and finfish, among others. In the case of marine finfish fisheries, the study was divided into 3 resources for analysis: flounder, hake and finfish (the latter comprises other marine finfish captured, including *Sphoeroides annulatus* ("*botete diana*"). This structure was proposed in consideration to the potential of the flounder and hake fisheries identified at that time (Casas and Ponce, 1996).

According to Ramírez (1996), the finfish fishery contributes between 5% and 7% of the BCS volume, with variations in the composition of annual catches. It has been the driving force of the growth of fishing activity in the latest years analyzed, associated with the decline in the production of resources of higher commercial value (including the catarina scallop) and the incorporation of workers displaced from other local economic activities (specifically from the agricultural sector).

An analysis of the statistics of finfish catches from 1984 to 1994 from both BCS littorals identified marked differences in the composition of catches. Caulolatilus spp ("*pierna*"), *Paralabrax nebulifer* ("*verdillo*") and Paralichthys spp *and* Pleuronichthys spp ("*lenguado*") catches stand out on the northern Pacific coast – the most productive area; *verdillo, pierna* and Mugil spp ("lisa"), in the southern Pacific; and *Lutjanus peru* (*"huachinango"*), in the Gulf (Ramírez, 1996). *Verdillo* and *pierna* were considered emerging fishing resources at that time.

As regards applicable legislation, the finfish fishery management approach includes several measures such as licenses, fishing gear, and no-fishing zones. However, the only marine fish species with specific regulation is Mugil spp, "Norma Oficial Mexicana"/ DOF, NOM-016-SAG/PESC-2014 (DOF, 2015). In addition, there was no basis for estimating the potential exploitation of finfish and this diverse and multi-species fishery. In Ramírez (1996) the first reports of *botete diana* catches appear, with important volumes in the southern Pacific — nearly 100 tons per year —, as bycatch from other fisheries (Ramírez, 1996).

1.1. Finfish fishery in Magdalena-Almejas Bay

An analysis of Official Catch Landing Reports (OCLRs) from 1998 to 2008 for BMA identified 14 small-scale fisheries. Considering the contribution of each in landed weight (kg), production value, and the number of OCLR reported, the relative importance was estimated with the index (RII) proposed by Ojeda and Ramírez (2012). As a result, the pacific calico, finfish, and shrimp were classified as the most relevant small-scale fisheries in the region (Ojeda and Ramírez, 2012).

In BMA, the marine fish potential comprises more than 22 families and over 100 species potentially suitable for fishing. The fishing activities take place mainly with small boats, using a wide range of fishing gear that includes nets, traps, longlines, and hand lines (De la Cruz et al., 1994; Ramírez, 2011).

The representatives of the Tetraodontidae family are fish of ecological, economic, and fishing importance. They are distributed mainly in marine and brackish waters (Walker and Bussing, 1996). This group comprises 193 species, some of which are exploited for local and regional consumption (Eschmeyer, 2014). In northwestern Mexico, and specifically in Magdalena Bay, there are 3 species belonging to the genus Sphoeroides (*S. annulatus, S. lispus* and *S. lobatus*) which are exploited commercially (Walker and Bussing, 1996; Aguirre et al., 2006). *S. annulatus* is by far the dominant species, accounting for nearly 95% (CONAPESCA, 2014) and with the potential to reach a high commercial value (Froese and Pauly, 2014).

As regards finfish fisheries, the DOF 2010 ("*Carta Nacional Pesquera*") includes only a minimum number of target species from this group, some living in the Pacific and others in the Gulf of Mexico. It does not contemplate specific management measures for each of the species that currently support the finfish fisheries in BMA, such as Caulolatilus spp and *P. nebulifer,* nor does it list *S. annulatus*. There are only general measures like a non-fishing zone, fishing gear, and licenses.

No publications were found regarding the operation of the bullseye puffer fishery (*botete diana*). However, a number of authors point to its importance in the northwest of Mexico, particularly in Sinaloa. Research work has been done on some reproductive parameters and on population dynamics that provide a deeper insight into this resource and set the basis for management strategies and actions (Sánchez et al., 2011; Díaz et al., 2013; Valdez et al., 2014).

When new species are incorporated into the catch series or the specific catch composition varies, this can lead to changes in the fishery regime, depletion of conventional resources, social changes, or market pressures (Maullil et al., 2013). Apparently, this is currently happening in BMA. Several species of serranid or sea bass (Mycteroperca spp, Epinephelus spp and *Hyporthodus acantisthius)* are less frequent on OCLR and exert a low impact on production volumes, while the contribution of other species such as Caulolatilus spp and *P. nebulifer* are on the rise. Species such as *S. annulatus*, listed in catches of recent years, are recognized as target resources for small scale fleets.

It is important to document the results and changes in the country's fishing activities with the aim of including new fisheries at the right time in public policy instruments such as the national fishing chart or regional management committees. Thus, the objective of this study is to set the foundation for the systematic documentation of the puffer fishery (*S. annulatus*) emerging in BMA. This can be achieved through holistic approach that investigates about the resource, fishing gear, fishing operations, onboard handling, marketing channels, and prices on the beach.

2. Materials and methods

2.1. Study area

Magdalena-Almejas Bay is a subtropical lagoon complex located on the Pacific coast of Baja California Sur, between the municipalities of La Paz and Comondu. Physiographically it consists of three major water bodies: estuaries to the north, Magdalena Bay in the central area, and Almejas Bay to the south (Fig 1). The climate and oceanographic conditions in BMA create conditions of high primary productivity. The influence of the California current together with prolonged upwelling effects sustain abundant populations that support intense fishing activity in the area, considered the center of several coastal and even some industrial fisheries (Ojeda, 2012).

From the environmental standpoint, the region is highly valued for the diversity and richness of its ecosystems. Mangrove forests are notable, since these include abundant areas of seagrass, macroalgae, and rhodolite, which serve as a source of energy and shelter for species of commercial importance. This has given rise to conservation interests in the area and led to the promotion of sustainable development (Funes et al., 2007).

Official censuses estimate a population of around 8942 inhabitants in the region, with the communities of Puerto San Carlos, Puerto Adolfo Lopez Mateos, and Puerto Chale as the main population centers (CONAPO, 2010). The local population is dedicated mostly to fishing activities, tourism and trade, or work in the Federal Electricity Commission power plant located near Puerto San Carlos, BCS (Ojeda, 2012).

2.2. Methods

The present study compared the OCLR data (reported by legally organized coastal fishers to the authorities through the state's Federal Fishery Offices) to local knowledge (gathered through interviews and using instruments designed to meet specific information needs). Considering the diverse and multi-species nature of the "finfish fishery", an analysis of the activity was undertaken in the first place using the literature available for the study region, in order to set the basis for analyzing and interpreting statistical information and data gathered through local knowledge.

Using OCLR data for small vessels for the period 1998 to 2008, the relative importance of fish families was determined according to the index proposed by Ojeda and Ramírez (2012). This analysis identified the 10 most important families related to finfish production in BMA, which in turn allowed analyzing the behavior of the Tetraodontidae fishery according to its results for the study period.

As regards *botete diana* catches, a space-time analysis was conducted based on data reported in OCLRs that allow relating the volume captured, the number of landing reports in which the resource is recorded, to production value, with the locality and month of capture. It should be noted that localities of capture are recorded in OCLRs as they appear in the BCS Atlas of Fishing localities (Ramírez et al., 2005).

In order to confirm the trends derived from trip tickets and determine how the finfish fishery operates in the region, two instruments were administered systematically to gather local knowledge.

Survey A was designed considering the diversity recorded for the finfish fishery — more than 20 families and 70 species in catches. Its main purpose was to identify the target species that drive the fishing efforts of fleets in the region, the species associated with target species, species considered as bycatch, fishing gear used, and destination of the fishing production. This instrument was intended for legally constituted finfish producers registered with the National Fishing Register and achieved 29% coverage. 40 of a total of 133 organizations completed the instrument, and hence the sample is deemed significant. This instrument was previously tested and fine-tuned with local contacts and academic experts. It was initially administered to sector leaders, but was subsequently completed using the "snowball" strategy where the survey starts with one fisherman who at the end of the interview suggests other fishermen to be considered on the study.

The minimum sample size for finite populations was determined at the 85% confidence level, with an estimated error of ±0.15 (Daniel, 2002), and resulting in a minimum size of 40 surveys. The formula used was:

$$E = Z_{\alpha/2}\sqrt{\frac{\widehat{p}\widehat{q}}{n}}$$

Where:

- E is the error range
- z is punctual value of normalized standard distribution with alpha equal to 0.95
- p is the proportion of the population that responds to the survey
- q is the proportion of the population that does not respond to the survey
- n is the number of surveys conducted

Survey B aimed at determining some features of marketing on landing sites and identifying destination markets of BMA production. It was administered to the commercial agents identified by finfish producers in survey A. This work only reports the results related to management, marketing, prices, and destination markets of the *botete diana* (*S. annulatus*).

The information recorded through surveys by fishers was used to locate those who fish *S. annulatus* as a target resource. They were asked to provide additional information on fishing gear and fishing techniques, as well as access to document their fishing operations. The information obtained confirms the existence of a fishery targeting *botete diana* with fishing gear specifically designed for the capture of this finfish species.

3. Results

According to the OCLRs of finfish at the family level for the period 1998–2008, the index of relative importance (RII) showed that 97% of catches involve 10 of the 22 families identified in catch reports (Table 1). Among them, the family Tetradontidae ranks fifth in relative importance, with 4.96% of total catches, 9.35% of production value and 5.60% of the OCLRs, giving a RII of 19.91.

To analyze the variations in relative importance of the Tetradontidae fishery, the evolution of RII was estimated for this family from 1998 to 2008. Our findings reveal that this index ranged between a minimum of 15 in 2002 and a maximum of 28 in 2006, with a clear tendency to increase in importance among the families of marine fishes exploited. Fig. 2 shows a minor variation in catches and fishing intensity measured through OCLRs. The rise in RII is due to the increase in the value of catches, evident in the separation between catch and production value. This finding evidences a steady rise in product prices on landing sites in recent years.

According to the Fishing Office's official data, the majority of production landings from small vessels in BMA report three different species under the generic name puffer. However, these point out that the bullseye puffer *S. annulatus*, locally named *botete diana*, accounts for 95% of Tetraodontidae catches in BMA, being the species with market demand.

OCLRs submitted by fishers state the catch date and location. This information was used to undertake a space-time analysis that revealed that the puffer is captured year round, with a peak season from March to August in which cumulative catches from May to June account for 60% of the total produced in the study period (Fig 3).

Of the 144 catch locations in the Atlas of Fishing Localities for BMA, from Puerto Chale, to the south, to San Jorge, to the north of the Lopez Mateos estuaries, *botete* catches have a limited dispersion, being reported in less than 15 localities as per the OCLRs (Fig. 4). According to information provided by fishers, 84% of total catches take place in the localities named Magdalena Bay, Almejas Bay and Puerto Chale, the former being the most important locality in terms of its contribution to the fishery (65%).

B-type interviews were conducted with seven commercial agents identified by fishers through survey A; of these, only three claimed to market *botete diana*. This species is handled fresh and stored on ice. It is separated from other species by sections or plastic bags due to the amount of mucus on its skin. It is purchased headless at $2.00 US dollars/kg, being more expensive than other target species in the region such as bass and tilefish, which are sold for around $0.60 to $0.80/US dollar kg and $1.20 to $1.60 US dollars/kg, respectively. *Botete diana* fillets sell for up to $5 US dollars/kg in consumer markets. The three commercial agents agreed that local consumption is low, and almost all the production is transported to Culiacan, Sinaloa. Sánchez et al. (2007) point out that the kilogram of this species is sold for up to $10 US dollars/kg in the U.S. market.

According to the survey and interviews of fishers who exploit *botete diana* as a target species, the most common fishing gear used

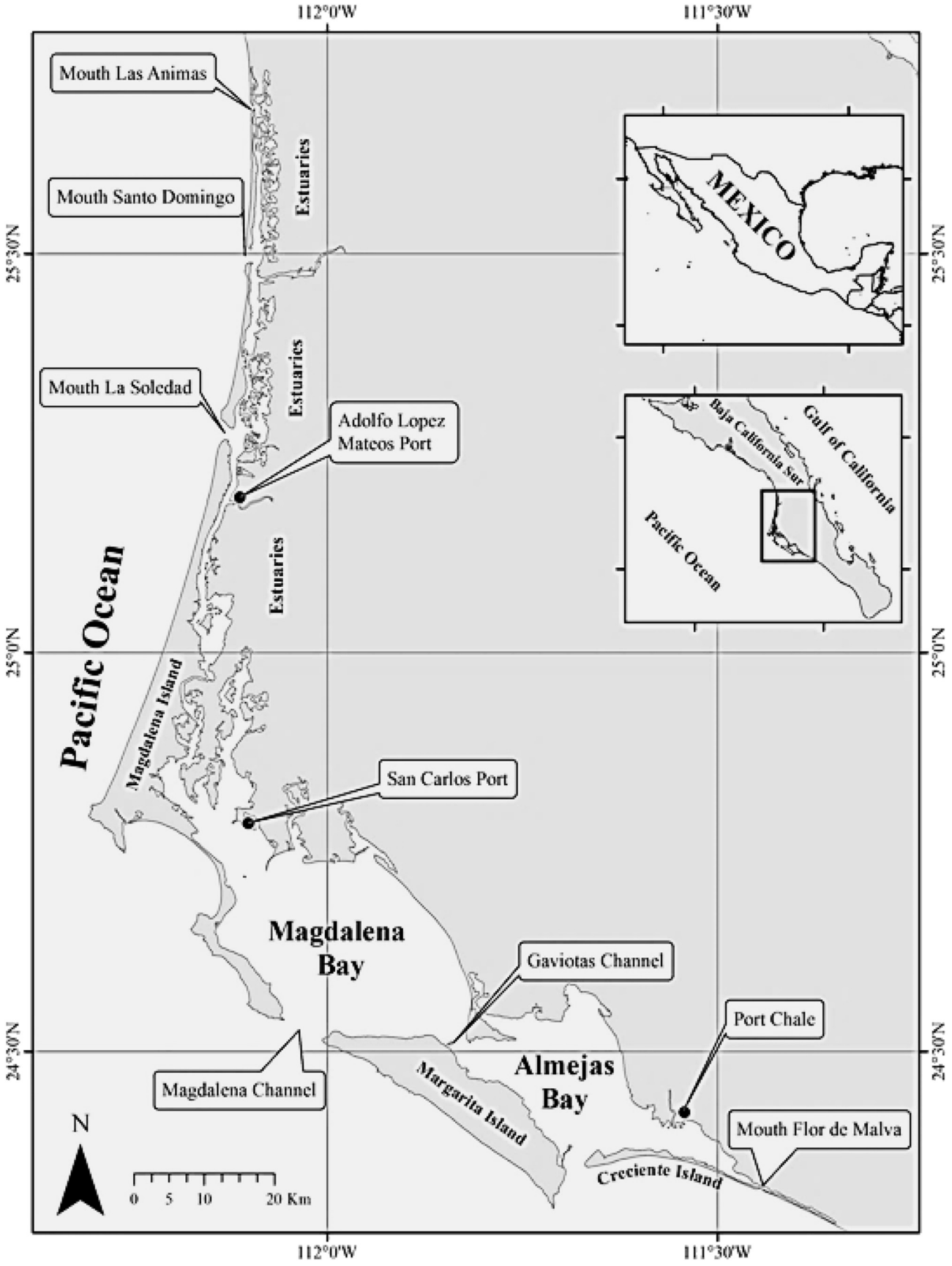

Fig. 1. Magdalena-Almejas Bay, Baja California Sur, Mexico.

Table 1
Relative Importance Index for the main finfish families reported in the 1998–2008 OCLRs, at BMA, México.

Finfish families	Catch	Value	Number of OCLRs	RII
Serranidae	28.94%	29.54%	17.14%	75.62
Sciaenidae	15.36%	13.54%	21.73%	50.63
Branchiostegidae	8.80%	7.79%	7.90%	24.49
Carangidae	7.46%	6.45%	7.62%	21.53
Tetraodontidae	4.96%	9.35%	5.60%	19.91
Scombridae	8.07%	7.42%	4.08%	19.57
Pleuronechtidae	3.97%	7.72%	7.54%	19.23
Gerreidae	6.16%	3.41%	8.40%	17.96
Mugilidae	8.19%	4.37%	4.86%	17.42
Lutjanidae	2.94%	6.33%	6.02%	15.28

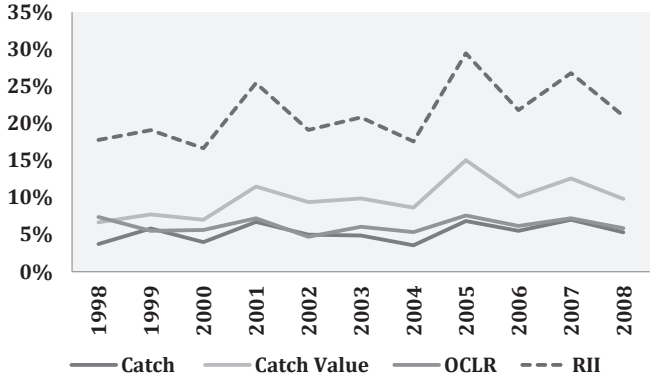

Fig. 2. Evolution of RII for the Tetradontidae fishery at BMA, 1998–2008.

is the one locally known as "*chinchorro botetero*" (puffer seine), a type of gillnet of approximately 320 m long, fitted with a fishing net bag at one end and similar to the codend of the coastal trawl nets used in the region for shrimp fishing.

Due to their morphological characteristics, puffers are rarely caught in gillnets. Instead, the net serves as a path that herds the fish to the bag where they are trapped. This fishing gear is used in inland waters, in channels with strong water currents during the turning tides, using a small vessel less than about 6.7 m long. Fishers use a tide calendar to determine the time of peak current velocity, at either high tide or low tide, to start their fishing operations.

The fishing operation starts by throwing out an anchor fixed with straps to the end opposite the codend where the leading net is attached. Then the codend is set with the tide and the net is hauled

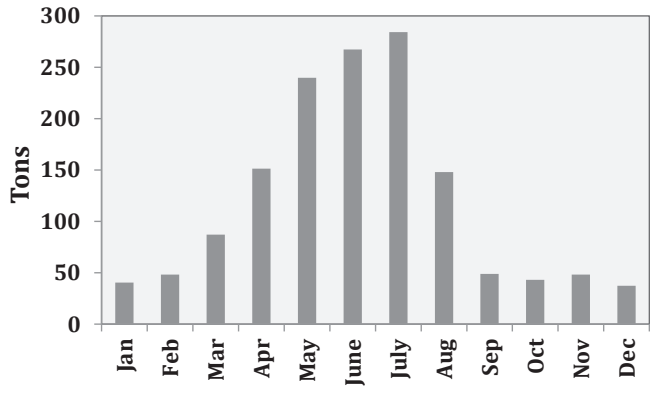

Fig. 3. Monthly cumulative catch for Tetradontidae at BMA from 1998 to 2008.

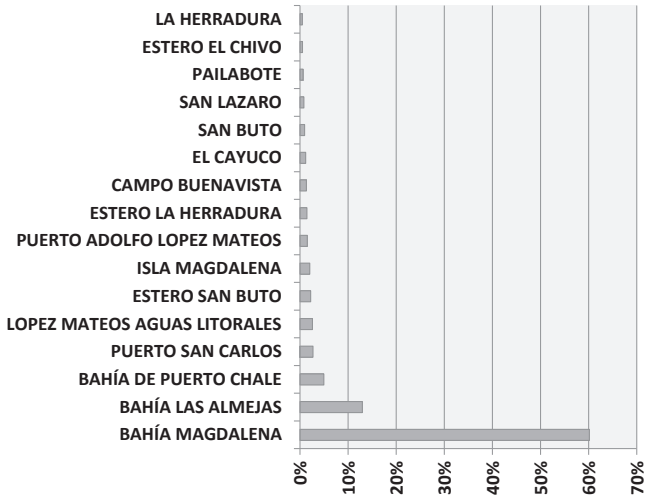

Fig. 4. Sphoeroides annulatus catches per fishing localities at BMA, according to 1998–2008 OCLRs.

against the current in a slightly oblique direction. The end is anchored to the bottom with the codend entrance facing the current, the force of which keeps the entrance open (Fig. 5).

After some 20 min of setting, fishers lift the net from half its length, advancing toward the codend, making it pass through the center of the boat and dropping it again. This maneuver forces the advance of fish toward the bag. When the codend is reached, is it uploaded to the boat and the catch is removed. Afterwards, the codend is thrown into the water and the gear is set in the fishing position again. This maneuver is repeated two or three times until the current intensity decreases, after which the gear is picked up and the fishing session ends.

Botete diana is processed by fishers as soon as the vessel lands by removing the head without tearing the organs and the ventral cavity, to avoid contamination with enzymes and toxins. Subsequently, fishes are handled fresh on ice. In the process, fish are preserved by piling them up using an equal proportion of ice.

4. Discussion

One of the most relevant challenges for understanding the coastal or small-scale fisheries in order to improve management practices is the lack of information on various aspects of this activity (Salas et al., 2007). Given this situation, we propose the use of the information available in Mexico, i.e. OCLR, which despite its weaknesses compared to log books, allows obtaining trends and indicators. This information has been managed along with a number of strategies that mainly seek to improve the data, highlight site surveys, conduct sampling, and use local knowledge (Moreno et al., 2010; Sáenz et al., 2005; Ramírez and Ojeda, 2011; Ojeda, 2012).

The knowledge gathered by resource users has been revalued by several authors, who acknowledge that it is a key tool that not only provides information and allows validating academic research, but also contributes to design management schemes that are easier to accept by fishers - the ultimate resource users- (Maullil et al., 2013). To note, this document uses both local knowledge and information about fleet operations reported by fishers to the authorities in OCLRs.

Production trends were estimated with information included in OCLRs to determine the relative importance and to detect changes through time in the behavior of catches, the number of OCLRs, and production value. It was possible to determine the fishing season,

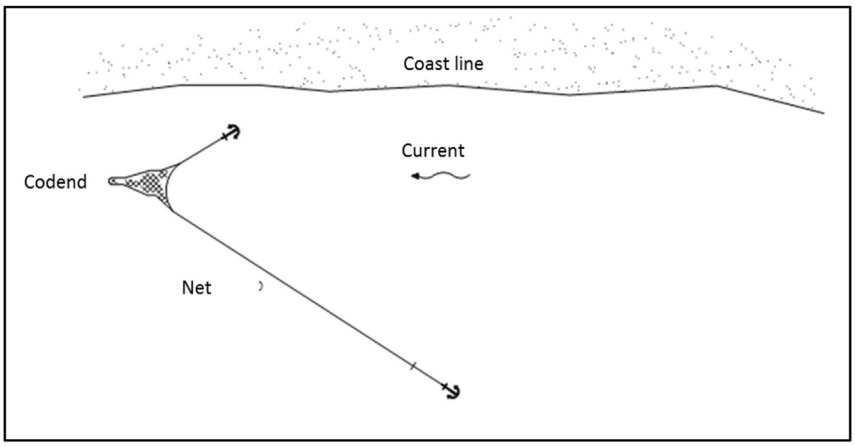

Fig. 5. Top view of the seine net locally named *chinchorro botetero* used for catching *botete diana* at BMA.

the peak of the main season, and the spatial distribution of this activity in catch localities. Altogether, these data provide a close and relevant approximation on the behavior of fishing fleets that capture *botete diana* in BMA.

Recent advances in fishing technology, coupled with the growing demand for fish products and rapid population growth, have led to steady depletion of fish stocks on a global level. Recent estimates suggest that more than 60% of global fisheries are currently overexploited, as the catch rate has exceeded the growth of exploited populations (Maullil et al., 2011; FAO, 2014). As regards the changes in ecosystems resulting from overexploitation, two effects of overfishing are worth noting: the fall in annual catches and the disappearance of certain target species, mainly top predators, and the appearance of emerging fisheries, generally based on resources of lower commercial value (Arreguín et al., 2004; Carocci et al., 2009; Maullil et al., 2013).

According to Ramírez (1996), fishing efforts initially focused on target species with the highest acceptance and market value, which included serranid and sea bass species such as Mycteroperca spp, Epinephelus spp and *H. acantisthius*. They subsequently broadened their scope by fishing other target species considered second- and third-class in terms of quality, such as Caulolatilus spp, *P. nebulifer*, small species of sharks "*cazón*" (*Carcharinus* spp), *Scomberomorus sierra* ("*sierra*"), *Gerres cinereus,* Diapterus spp and Eugerres spp, ("*mojarras*") among others.

In addition to economic aspects, anthropogenic factors may be influencing the emerging fishery of *S. annulatus* in BMA, from the need to diversify the fisheries resources in search of alternative or emerging resources, to addressing the demands of first-level buyers in the marketing chain. They could also relate to the adoption of fishing techniques associated with cultural aspects like migration patterns; the composition of the fishing community in BMA includes nearly 50% of persons from other states, particularly from Sinaloa, Sonora, and Michoacán (Ojeda, 2012).

The decline and change in the composition of catches have fostered changes in fishing, including the search for new target species of potential market value. This could be the case of the *botete diana* in BMA, a species reported as bycatch with values up to 100 tons per year according to Ramírez (1996), and which during 1998–2008 recorded a minimum of 84 tons in 2006 and a maximum of 214 tons in 2007, with an average of 140 tons per year. This finfish species is currently recognized by local fishers as a target catch species for which a specific type of fishing gear is used.

According to the RII during the study period, the Tetraodontidae is the fifth most important marine fish family caught in BMA. For this reason, it is essential that the product be incorporated into marketing chains that offer a higher price relative to other target species, above the prices paid for second- and third-class species in terms of product quality.

The scarce information published about the *botete diana* fishery relates to the neighboring state of Sinaloa, where its exploitation was reported a few years earlier than BMA. Although there are no published studies on how the fishery operates, some authors agree that it is an important activity worth being documented. In particular, there is interest in determining population parameters and aspects of its reproductive biology that will make it possible to establish management criteria for the species and support a basic management scheme that broadens benefits and fosters the sustainable use of the resource (Moreno et al., 2009; Sánchez et al., 2011; Díaz et al., 2013; Valdez et al., 2014).

In previous research, aspects of local knowledge in BMA were addressed. It was detected that the fishers' population comprises the same proportion of persons born in Baja California Sur and elsewhere, where fishers from Sinaloa make up a majority group of nearly 36% (Ojeda, 2012). Three of the seven finfish buyers interviewed are from Sinaloa and represent companies from that state.

All the above suggests that the *S. annulatus* fishery may involve a cultural influence related to both the experience of non-native fishers and commercial networks that include this as a species of commercial interest. This inference is strengthened by the identification of the target market of the *botete diana*: according to survey B, 100% of the product caught in BMA is transported to Culiacan, Sinaloa.

Currently, the Regional Center for Fisheries Research coordinates efforts to develop a Management Plan for the *P. nebulifer* fishery, an emerging species of high importance according to Ramirez (1996). However, important information gaps still remain nearly 20 years later. For this reason, we deem it necessary to document the *S. annulatus* fishery, currently an emerging resource, to set foundations that will involve a systemic approach, addressing various aspects of the fishery. This will provide basic information needed to support specific management strategies and actions. Mexican legislation requires details on various topics, including biological aspects of the species, fishing operations, processing, markets and prices, all of which are addressed in this document.

Acknowledgments

We would like to thank to the Autonomous University of Baja California Sur, the PRODEP program of the Ministry of Public Education of Mexico, and coastal fishermen respondents, for their

financial contributions and knowledge needed to finalize this document.

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