Regional Studies in Marine Science 18 (2018) 68–79

Contents lists available at ScienceDirect

Regional Studies in Marine Science

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

Participatory management in a small-scale coastal fishery—Punta Abreojos, Pacific coast of Baja California Sur, Mexico

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HIGHLIGHTS

- Participatory management promotes sustainable practices and economic security.
- A fisheries coop with clear management structure, membership obligations and benefits.
- Coop adaptive capacity has evolved through participatory management and stewardship.

ARTICLE INFO

Article history:
Received 25 December 2017
Accepted 30 December 2017
Available online 4 January 2018

Keywords:
Coastal fishing
Cultural
Target
Complementary resources
Participatory management
Punta Abreojos

ABSTRACT

We describe the structure and historic landings of the Punta Abreojos fishing cooperative (Baja California Sur, Mexico) for the period between 2001 and 2015 to understand the dynamics of an economically and ecologically successful coastal fishing community according to catches and the direct income of fishers. A total of 21 commercial species were classified into three major groups: cultural resources, target resources and complementary resources. The most important resource in terms of total biomass was *Paralabrax nebulifer* (58.4%), followed by *Panulirus interruptus* and *P. inflatus* (13.6%). *Seriola lalandi*, *Atractoscion nobilis*, *Caulolatilus princeps*, *Paralichtys californicus* and *P. woolmani* made up minor proportions of the total biomass contributing 7.0%, 5.7%, 3.4% and 3.2% respectively. *Haliotis fulgens* and *H. corrugata* represented just 1.1% of the total biomass caught. Lobsters were the most profitable source of direct income for fisherman (77.5%), followed by the green and pink abalone (10.4%), barred sand bass (5.6%), white seabass (2.7%), California and speckled flounder (1.2%), yellowtail (1%) and whitefish (0.4%). The rest of the catch was composed of six species of finfish that represented 4.1% of the total catch biomass and 0.4% of the revenues from fishing.

This work provides a first clear base-line description of the fisheries in Punta Abreojos which implements a management program that aims to ensure the wellbeing of the fishers and the fishery. The cooperative has been successful in maintaining catch at levels considered optimal to sustain revenues and continued annual landings. A management and cooperative structure that allows for adaptive change whilst maintaining revenues of the fishers is testament to the stewardship of the community and the participatory management upon which the community is built. For this reason, Punta Abreojos should be considered an example of a successful small-scale fishing cooperative that other, less successful fishing groups, can learn from.

1. Introduction

Northwest Mexico is the most important region for marine fisheries in the entire country. It includes the coasts of Baja California Peninsula and the Gulf of California, and supports between 40 to 50% of the national commercial fishing activity (artisanal and

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https://doi.org/10.1016/j.rsma.2017.12.014
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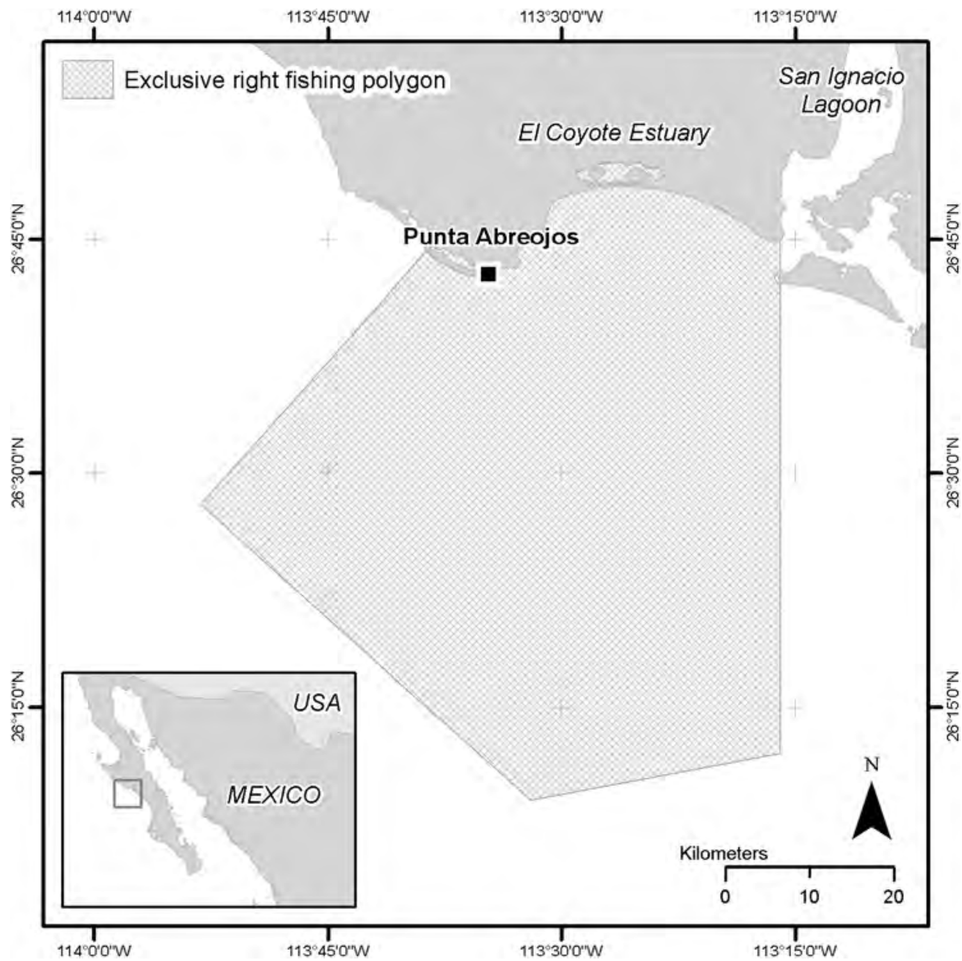

Fig. 1. Location of the exclusive concession area for fishing of 6 species for the fishers of the Punta Abreojos fishing cooperative, Baja California Sur, Mexico.

industrial fisheries) (OECD, 2006; Cisneros-Mata, 2010). This region is characterized by a complex set of oceanographic and physiographic characteristics that produce highly productive coastal ecological systems. These include wetlands, coastal lagoons, and mangroves that harbor large populations of fish, invertebrates, marine birds, turtles and mammals (Cliffton et al., 1982; Seminoff, unpublished; Aburto-Oropeza et al., 2008, 2009). These systems function as habitats for the development, protection and reproduction of marine species of commercial and ecological importance that sustain the fisheries in the region, such as snappers, breams, crabs and clams, among others (Gerard et al. 2015; Lluch-Cota et al. 2007; Aburto-Oropeza et al. 2008). The degree of exploitation of the commercial fisheries in Mexico has grown steadily through government investment and subsidy to commercial fleets (Cisneros-Mata, 2010). In 2003, Hernandez and Kempt (2003) estimated that 82% of target fisheries are completely exploited or overfished in Mexico. Trends of reduced stock abundance, fewer active fishing sites and reduced catches per unit effort have also been documented in the Gulf of California (Sala et al., 2004; Sáenz-Arroyo et al., 2005), which is estimated to be fished by approximately double the number of small-scale fishing vessels required to land maximum fish biomass (Johnson et al., 2017). Although much of the literature related to the marine fisheries around Mexico report failures in management (Cisneros-Mata, 2010; Mangin et al., 2018), the small fishing community of Punta Abreojos on the Pacific coast of Baja California Sur (26.717303 Latitude, −113.574338 Longitude, Fig. 1), approximately 350 miles from the southern tip of the Peninsula, tells a different story.

In the early 1930s the community of Punta Abreojos had a total population of 15 people with just two families living in the area at the time. The first people that further established themselves there were fishermen from the Sociedad Cooperativa de Producción Pesquera California (Fish Production Cooperative Society of California), which was made up of retired members of the marine infantry that came from Ensenada, Baja California, and San Ignacio in Baja California Sur (Cota-Nieto, 2010). This cooperative had a section of the coast reserved for their fishing activities from Bahia Asuncion to Punta Abreojos. From 1938, the fishing cooperatives had, by law, exclusive rights to exploiting the six most important resources: shrimp, abalone, lobster, oysters, pismo clam, and groupers. This decree was crucial in the development of the national cooperatives sector, including the Punta Abreojos cooperative (Arce and Sotero, 1998). This cooperative was consolidated in 1948 and named the Sociedad Cooperativa de Producción Pesquera Punta Abreojos (Fish Production Cooperative Society of Punta Abreojos). Lieutenant Nicolas Ramos Palacios was one of the chief promoters in the development of this cooperative, formed by a group of 80 people mostly from San Ignacio and surrounding areas (Cota-Nieto, 2010).

Today, Punta Abreojos is one of the most important fishing communities in Baja California Sur, with regards to marine resource use and management (Ramírez-Rodríguez and Ojeda-Ruíz, 2012). It is well known as a local fishing cooperative success story and continues to provide members of the fishing cooperatives with specific obligations in return for reliable incomes and additional benefits such as disaster payment and retirement plans (Table 1). This community, as well as La Bocana, Bahía Asunción and Bahía

Table 1
List of obligations of member of the Punta Abreojos cooperative and the benefits they receive being part of the cooperative.

Obligation	Benefits
Environmental conservation and stewardship	Social Security paid by the cooperative (Instituto Mexicano del Seguro Social)
Help at cooperative meetings and assemblies	Assistance with large expenditures (uncommon / extreme medical expenses)
To work honestly	Economic bonus at the end of the year
Maintenance and upkeep of work equipment and materials	1 month of vacation every year
Have the economic interests of the cooperative at heart	Permission for unlimited absence from work and justified absenteeism
	Economic bonus on the day of retirement relative to the amount of time spent as an active cooperative member.
	Regular pension (IMSS)
	Emergency financial assistance

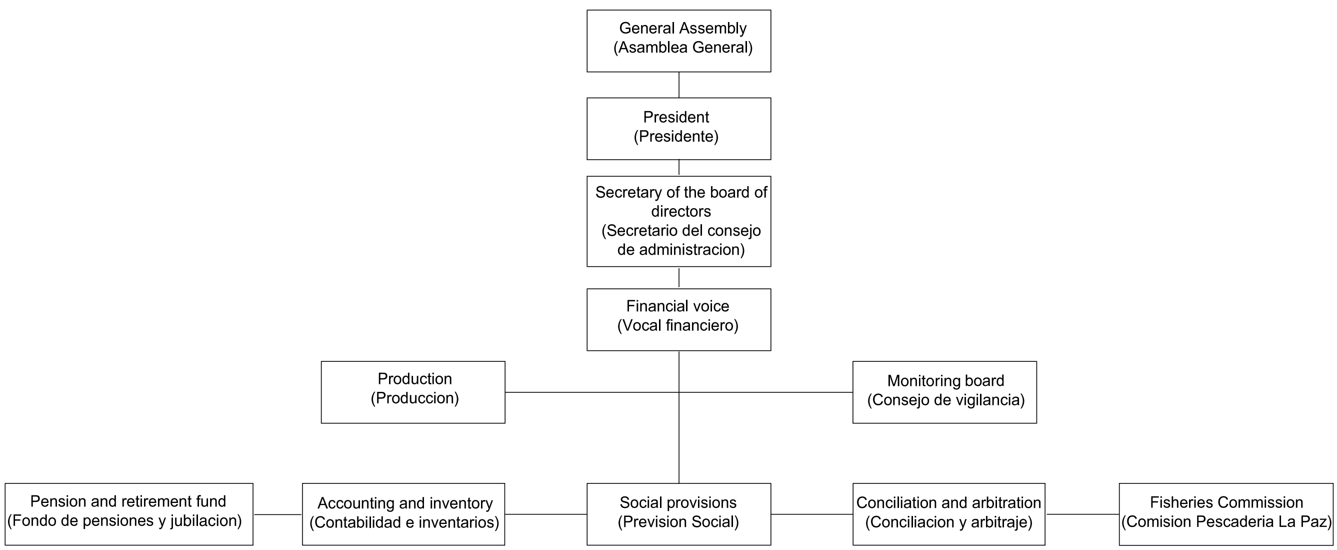

Fig. 2. Organizational chart of the Punta Abreojos fishing cooperative.

Tortugas, make up the Federación Regional de Sociedades Cooperativas de la Industria Pesquera de Baja California S.C.L. (FEDECOOP, or Regional Federation of Industrial Fishing Cooperative Societies of Baja California). The Punta Abreojos cooperative serves as a good case study of participatory fisheries management that has improved the production, and conservation of local fisheries resources, as well as the socio-economic status of the local community (Ponce-Díaz et al., 2009). The participative management system of this cooperative includes: inter-institutional collaboration (Fig. 2), evaluation actions, production of information on fisheries through monitoring programs, participatory and cautionary management that promote resource sustainability and/or recovery (Ponce-Díaz et al., 2009), and an exclusive right fishing polygon (also see Fig. 1) within which only members of the Punta Abreojos cooperative can fish for concession species. Within this area, the cooperative has a concession of 6 resources (abalone, lobster, blue crab, octopus, pismo clam and wavy turban snail) meaning only members of the coop can capture these fishery resources inside the fishing polygon. It should, however, be noted that although many fishers and fishery organizations in the region advocate for regulatory management, a lack of engagement in wider-scale, regional conservation initiatives has been blamed on limited government capacities to initialize them (Hill et al., 2015).

The role of the fishermen, technical personnel and the ability of the cooperatives to participate in the governance of both fisheries and fishing communities in the area, has yielded positive results in the management of the local fishery resources (Ramírez-Rodríguez and Ojeda-Ruíz, 2012). These management characteristics are the result of endogenous development wherein the community has developed their own management proposals and initiatives. In other words, the leadership comes from the community and the decisions are a result of this multiple, collaborative participation. These management characteristics, however, evidently are not widely replicated elsewhere in the rest of Mexico, (Lagunas-Vázquez et al., 2009) and rarely globally (e.g. Sabella, 1980; Makino and Matsuda, 2005).

The objective of this study was to document the fisheries of the most important resources in Punta Abreojos from 2001 to 2015 to make a first characterization as a baseline for considering participatory management as a potentially successful measure for artisanal fisheries in Mexico.

2. Materials and methods

2.1. Data collation

Fisheries data was provided by the Sociedad Cooperativa de Producción Pesquera Punta Abreojos S.C. de R.L. The raw data correspond to daily catch logs and the percentage or total economic revenues for each of the documented catches. We analyzed 24 species corresponding to 21 resources, since both species of abalone *Haliotis fulgens* and *H. corrugata*, two species of lobster, *Panulirus interruptus* and *P. inflatus*, as well as two species of flounder, *Paralichtys californicus* and *P. woolmani*, were grouped into single categories (Table 2). Each species managed by the cooperative is registered by its common name. To identify each species accurately and allow comparability with catch records from other areas/studies, we used fresh specimens and online databases such as FishBase (www.fishbase.org) and the Smithsonian Tropical Research Institute (www.neotropicalfishes.org), as

Table 2
Mean percentage of catch and direct income broken down by species and grouped by resource type, from the coastal fisheries in Punta Abreojos, Baja California Sur, Mexico (2001–2015). It should be noted that blue crab (*Callinectes sp.*), octopus (*Octopus sp.*), pismo clam (*Tivella stultorum*) and wavy turban snail (*Megastaea undosa*) are also caught by the cooperative but data on their catches was not available.

Common name	Scientific name	Catch (%)	Revenue (%)
	Cultural resources		
Lobster	*Panulirus interruptus* *Panulirus inflatus*	13.31	75.32
Abalone	*Haliotis fulgens* *Haliotis corrugata*	1.08	11.2
	Subtotal	*14.39*	*86.52*
	Target resources		
Barred sand bass	*Paralabrax nebulifer*	60.42	6.11
Yellowtail	*Seriola lalandi*	6.64	1.20
White seabass	*Atractoscion nobilis*	6.10	3.80
Whitefish	*Caulolatilus princeps*	3.19	0.40
Flounder	*Paralichtys californicus* *Paralichtys woolmani*	3.06	1.30
	Subtotal	*79.41*	*12.81*
	Complementary resources		
Pacific bonito	*Sarda chiliensis*	2.23	0.15
Mackerel	*Scomber japonicus*	0.78	0.06
Guitarfish	*Rhinobatos productus*	0.74	0.11
Smooth-hound	*Mustelus californicus*	0.63	0.11
Blue shark	*Prionace glauca*	0.56	0.05
California sheephead	*Semicossyphus pulcher*	0.26	0.04
Mako shark	*Isurus oxyrinchus*	0.24	0.04
Cownose ray	*Rhinoptera steindachneri*	0.20	0.02
Hammerhead shark	*Sphyrna sp.*	0.15	0.01
Pacific porgy	*Calamus brachysomus*	0.15	0.01
Giant seabass	*Stereolepis gigas*	0.12	0.04
Thresher shark	*Alopias vulpinus*	0.12	0.02
Angel shark	*Squatina californica*	0.01	0.002
Roosterfish	*Hyporthodus acanthistius*	0.01	0.002
	Subtotal	*6.20*	*0.664*
	Total	100	100

well as reference materials published in scientific journals, to identify each to species level (e.g. Allen and Robertson, 1994; Fisher et al., 1995; Thomson et al., 2000).

With permission of the cooperative, catch records for each species were compiled from 2001 to 2015. This data included: the day, month and year of landing (from all single boat trips in the cooperative), the common (local) name of the species, the equipment used to catch the species, the capture volume and price per kg of the landed species, and the direct earnings for the fishers by catch volume. Each species was classified into one of the following resource groups: (1) Cultural resources: pioneering fisheries that drove the development of the fishing industry in the community and those that currently have a concession for extraction with well-defined gear (Table 3) within the exclusive fishing area (Fig. 1); (2) Target resources: those species of great importance for the volumes in overall landings that have clearly defined fishing gear and catch methods and, (3) Complementary resources: incidental catches for which additional economic benefit is obtained (Table 2).

2.2. Description of catches and fisheries effort

For the cultural and target resources, we describe mean total annual catches and economic incomes from each, their mean monthly catches, the number of boat trips required to make those catches, and time series of annual catches, effort (as number of boat trips) and catch per unit effort (CPUE). To describe potential, significant linear trends in the annual catch and CPUE time series, we used Ordinary Least Squares regression across the time series of each species (2001–2015) and for segments of each time series for which potential trends were visually evident (e.g. an overall steady increase between 2003 and 2009 or a decline between 2005 and 2012 for example), using a minimum of 5 data points in these "potential-trend" regressions. All regressions were run with an alpha significance value of 0.05 using R software (version 3.4.2) and the *lm* (linear models) package. We also include a description of the complementary Bonita (*Sarda chiliensis*) catches as this species is the most important bait species used in several of the other fisheries, particularly the lobster and the barred sandbass.

2.3. Economic assessment of resources

The income from fishing was divided into two components following an administrative model from the Punta Abreojos Cooperative: (a) the payment rights to each fisherman-partner, and (b) the fund used by the cooperative to meet operational costs from fishing activities. The economic percentage is the reflection of what is obtained in the first level of the fishing process. The earnings were calculated using the prices per kg of catch (defined by the market and used by the cooperative) and the proportion of the total catch, and were represented in percentages for each species. For privacy reasons, the economic incomes are presented as the proportions that the volumes of catch represent with respect to the income of the fishers.

Table 3
Fishing gears associated with each species caught in the coastal fisheries in Punta Abreojos, Baja California Sur, Mexico.

Common name	Resource type	Fishing gear	Description
Lobster	Cultural	Lobster trap	The traps are rectangular and made from coated wire. They contain bait compartments. By law, they have to have an escape window for under-size lobsters (carapace length <82.5 mm) as well as ecological (oxidizable) joint staples.
Abalone	Cultural	Hookah	Diving assisted by an air compressor (hookah) connected to a hose with a mouth piece that gives divers the ability to work in shallow waters (up to 12 m) for long periods (most commonly up to 2 h).
Barred sand bass	Target	Finfish trap	These are rectangular traps measuring 1.22 × 0.81 × 0.46 m, made from coated wire with a mesh size of 2 in. to avoid the capture of small and under-size bass (<11 in.).
Yellowtail & White seabass	Target	Gill net	This is a net with variable lengths from 100 to 500 m with a mesh size of 6.5 or 8 in. These nets move with the currents, standing vertically in the water column. In the Winter, trawling nets are used to catch the seabass. These nets have an 8-inch mesh size, have lengths between 109 to 500 m.
Whitefish	Target	Finfish trap	This species is often captured incidentally in Barred sand bass traps but landed as it is marketable.
Flounder	Target	Flattened net	This is a net that is placed on the seabed on sandy, nearshore habitats. The net is between 100 and 500 m long and has a mesh size of 8 in.
Pacific bonito & Mackerel	Complementary	Gill net	These species are captured using the same gear as that of the yellowtail and White seabass. This catch is, however, only used as bait in the Lobster and Barred sandbass traps.
Guitarfish, Giant seabass, Angel shark & Roosterfish	Complementary	Flattened net	These species are incidental, marketable catch in the flounder fishery. In rare circumstances, the giant seabass and Roosterfish has been caught in the Yellowtail and White seabass fisheries.
Smooth-hound, Blue shark, Mako shark, Cownose ray, Hammerhead & Thresher shark	Complementary	Gill net	These species are incidental, marketable catch from the Yellowtail and White Seabass fishery.
California sheephead	Complementary	Finfish trap	This species is an incidental, marketable catch mainly from the Lobster fishery and to a lesser degree from the barred Sand bass fishery.
Pacific porgy	Complementary	Gill net	This species is an incidental, marketable catch in the Barred sand bass and Yellowtail fisheries.

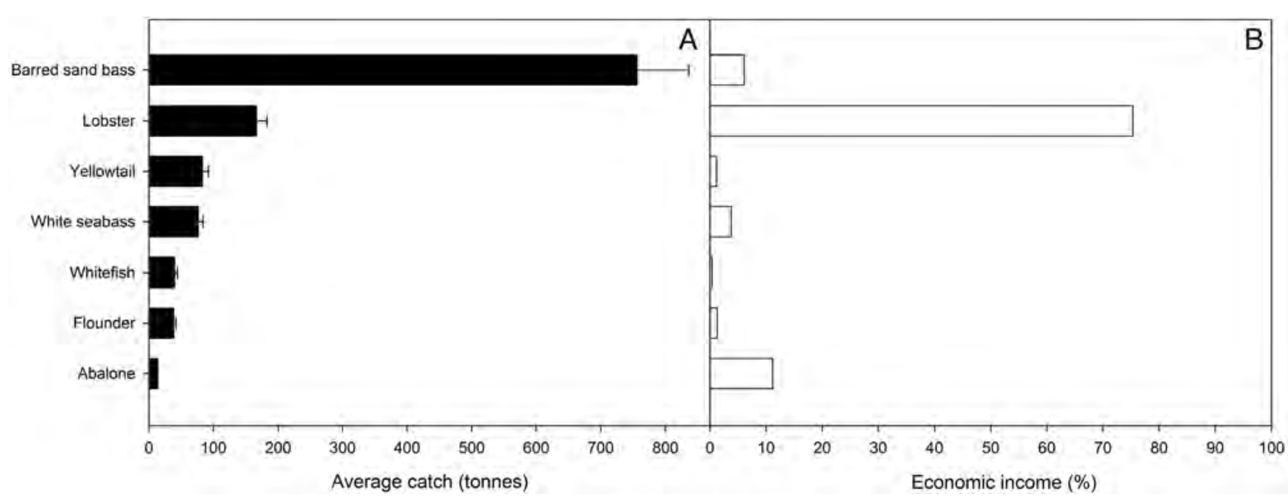

Fig. 3. (A) Average catch (tonnes ± SE) and (B) % Income for the seven most important fishing resources between 2001 and 2015.

3. Results

3.1. Total catch volumes and economic assessment

A total of 24 species (21 resources) are fished within the exclusive fishing zone of the Punta Abreojos cooperative. Lobster is the most economically important species providing the cooperative with 75% of its revenues, followed by abalone (11%). The barred sand bass contributed the highest proportion of catches in terms of biomass (60%) followed by the lobster (13%). Overall, the cultural resources were more important to the cooperative in terms of percentage of catch and revenue than the target resources with the complementary resources contributing comparatively little to the cooperative (6% catch and 0.66% revenue). Seven resources (cultural and target) made up 93.8% of registered catches and 99.33% of the direct revenues of the cooperative. Below we describe each of the cultural and target resources landed by the Punta Abreojos cooperative. We note any management regulations, describe seasonal patterns in their catch and note linear trends in the total landings and Catch Per Unit Effort (CPUE) from 2001 to 2015. All statistics related to the trends described can be found in Tables 4 and 5. The average catch and income from the seven most important fishing resources between 2001 and 2015 can be seen in Fig. 3.

Table 4
Linear regression (OLS) results of Total Catch and Catch Per Unit Effort (CPUE) over time (2001–2015) for the cultural and target resources of the Punta Abreojos fishing cooperative.

Species	Measure	OLS regression statistics			
		P	R^2	$F_{1,13}$	Trend
Lobster	Catch	0.028*	0.28	6.36	Increasing*
	CPUE	<0.001*	0.69	23.2	Decreasing*
Abalone	Catch	0.228	1.68	1.60	NA
	CPUE	0.640	−0.058	0.23	NA
Barred S	Catch	0.002*	0.51	15.80	Increasing*
	CPUE	<0.001*	0.574	19.9	Increasing*
Yellowtail	Catch	0.482	−0.035	0.53	NA
	CPUE	0.461	−0.031	0.58	NA
White Seabass	Catch	0.184	0.065	1.97	NA
	CPUE	0.364	−0.008	0.88	NA
Whitefish	Catch	0.145	0.091	2.41	NA
	CPUE	0.9515	−0.0766	0.0038	NA
Flounder	Catch	0.731	−0.067	0.12	NA
	CPUE	0.7806	−0.07027	0.081	NA

Table 5
Linear regression (OLS) results of Total Catch and Catch Per Unit Effort (CPUE) over time for the cultural and target resources of the Punta Abreojos fishing cooperative. These regressions were not run over the entire time series (2001–2015) but run over periods in which distinct trends were apparent by visualizing the time series. Those results in italics should be taken with caution as their degrees of freedom equal <5.

Species	Measure	Period	OLS regression statistics				
			P	R^2	F	DF	Trend
Lobster	Catch	2001–2010	<0.001*	0.699	24.32	1,9	Increasing*
	CPUE	2003–2015	0.002*	0.561	16.31	1,11	Decreasing*
Abalone	Catch	2001–2008	0.004*	0.745	21.18	1,6	Increasing*
	Catch	2008–2015	0.079	0.33	4.45	1,6	Decreasing
	CPUE	2001–2015[a]	0.818	−0.078	0.055	1,12	NA
Barred Sandbass	Catch	2001–2009	<0.001*	0.899	72.29	1,7	Increasing*
Yellowtail	Catch	2005–2011	0.0027*	0.83	30.23	1,5	Increasing*
	CPUE	2001–2010	0.029*	0.399	6.97	1,8	Increasing*
	CPUE	*2010–2015*	*0.029* *	*0.670*	*11.15*	*1,4*	*Decreasing* *
White Seabass	Catch	2001–2007	0.038*	0.531	7.80	1,5	Decreasing*
	Catch	2007–2013	0.001*	0.883	46.13	1,5	Increasing*
Whitefish	Catch	2005–2015	0.021*	0.410	7.842	1,9	Decreasing*
Flounder	*Catch*	*2001–2006*	*0.156*	*0.291*	*3.049*	*1,4*	*Decreasing*
	Catch	*2006–2011*	*0.009* *	*0.810*	*22.29*	*1,4*	*Decreasing* *

[a] All years apart from 2010.

* Significant regression assuming an alpha of 0.05.

3.2. Cultural fisheries

Spiny and blue spiny lobster (*Panulirus interruptus* and *P. inflatus*)

The management policy for lobster, as a concession and eco-certified (by the Marine Stewardship Council (MSC)) species (in the case of the species *Panulirus interruptus*) is regulated by the Mexican Official NORM 006-PESC-1993. Through the Regional Centre for Fisheries Research (CRIP), the Cooperative and CONAPESCA monitor this fishery on a seasonal basis. The implementation of a minimum landing size (carapace length 82.5 mm) and a closed season comprising seven months (March to September) helps to regulate catches and avoid over exploitation of the local populations. The catch of lobster also involves bycatch of whitefish (*Caulolatilus princeps*), California sheephead (*Semicossyphus pulcher*) and occasionally, California scorpionfish (*Scorpaena guttata*), all of which are commercially exploited. Most of the lobster catch is recorded in October and decreases towards the end of the season in January and February (Fig. 4A). During 2001–2007 the average annual catch was 144.9 tonnes while during 2008–2015 an average of 185.59 tonnes was recorded, representing an increase of 28% over the first period (Fig. 5A). Overall, there has been a significant increase in the catch of lobster by the cooperative but a decrease in the CPUE for the species (Tables 4 and 5).

Green and pink abalone (*Haliotis fulgens* and *H. corrugata*)

The abalone fishery is regulated by the Mexican Official NORM 005-PESC-1993 in which catch limits (quotas) are set by previous evaluations from specific sites. A minimum catch size (140 mm and 130 mm for *Haliotis fulgens* and *H. corrugata* respectively) and a complete closure from September to January is used to manage this fishery. The season consists of seven months (January to July) but depending on the assessments and environmental issues such as red tides and weather, the season can start up to two months later (March) and last for only five months (March to July) (Fig. 4B.). During the period 2001–2015 the capture of abalone was highly variable (±40% of the highest catch recorded), with the maximum catch recorded in 2008 (16.5 tonnes). From 2001 to 2007 the average annual catch was 13.87 tonnes but from 2008 to 2015, it was 12.65 tonnes, representing an 8.8% reduction in total catch. Between 2001 and 2008 there was a significant increase in the catch of abalone followed by a large decline between 2008 and 2010 (Fig. 5B). However, over the full 15-year time series, there was no significant increasing or decreasing trend in the catch or CPUE in the abalone fishery at Punta Abreojos (Fig. 6B, Tables 4 and 5).

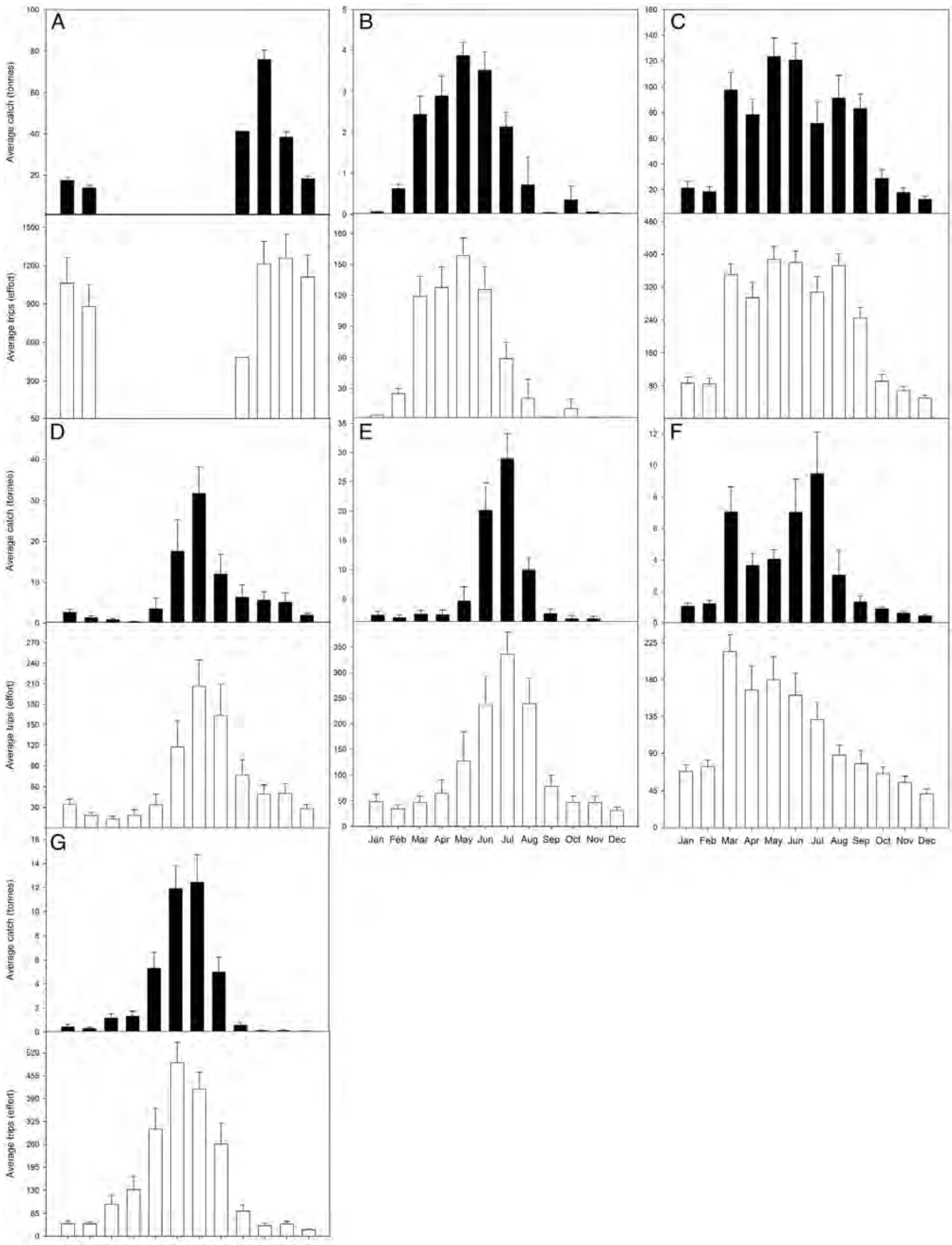

Fig. 4. Monthly average catch (tonnes) and effort (average trips ± SE) for the seven most important fishing resources between 2001 and 2015. A) Spiny and blue spiny lobster B) Green and pink abalone C) Barred sand bass D) Yellowtail E) White seabass F) Whitefish G) California and speckled flounder.

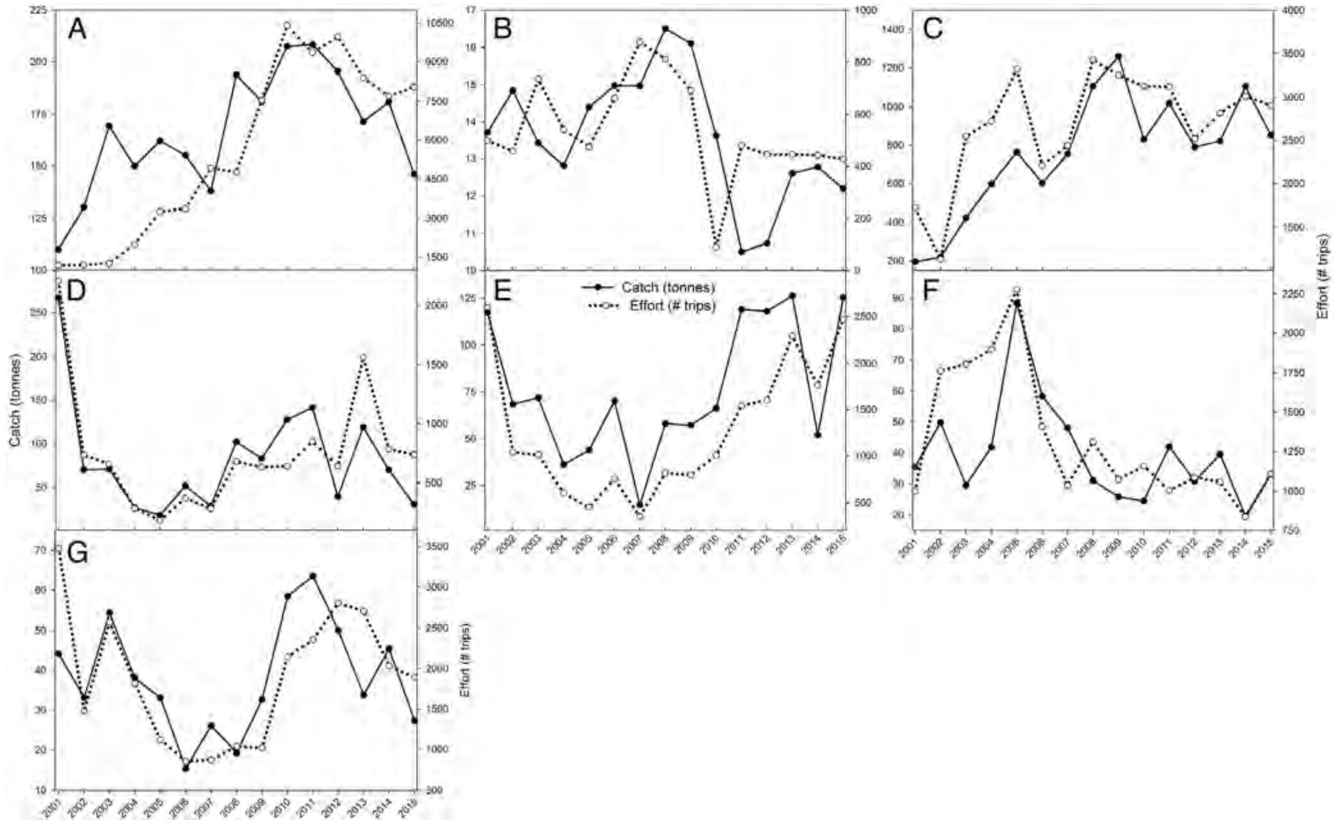

Fig. 5. Annual catch (tonnes) and no. of fishing trips for the seven most important coastal fisheries in Punta Abreojos B.C.S., México, between 2001 and 2015. A) Spiny and blue spiny lobster B) Green and pink abalone C) Barred sand bass D) Yellowtail E) White seabass F) Whitefish G) California and speckled flounder.

3.3. Target fisheries

Barred sand bass (*Paralabrax nebulifer*)

The Barred sand bass (locally known as verdillo) fishery runs throughout the year (Erisman et al., 2017). It is the most important of the finfish fisheries in terms of revenue and is the most important species of all the resources based on biomass. Although the traps used to capture this species are in the process of being recognized by CONAPESCA, to date they have worked efficiently because of their selectiveness of individuals >30 cm. The largest catches of Barred sand bass are registered in May and June (Fig. 4C). The catch trend during the period 2001 to 2009 increased with an average annual catch of 658 tonnes. From 2010 to 2015 the average catch was 903 tonnes, increasing by 37% compared to the first period. Overall catches and the CPUE of this species have increased significantly, with the largest increase in catch between 2001 and 2009 (Figs. 5C and 6C, Tables 4 and 5).

Yellowtail (*Seriola lalandi*)

There are two main catch peaks for Yellowtail, usually in June and July, with months outside of these showing comparably low catches (Fig. 4D). An average catch of 76.2 tonnes between 2001 and 2007 and 98.6 tonnes between 2008 and 2015, shows a 23% increase in catch during in the second period. Overall there was no significant trend in catch or CPUE for this fishery (Tables 4 and 5). There was, however, a significant increase in catch between 2005 and 2011 as well as a longer period of increasing CPUE between 2001 and 2010 (Figs. 5D and 6D).

White seabass (*Atractoscion nobilis*)

The most important monthly average catch for White seabass was recorded every July between 2001 and 2015. For the remaining months, catches were substantially lower (Fig. 4E). Annual catches declined significantly overall from >110 tonnes in 2001 to <15 tonnes in 2007 (Table 5), during which time the average catch was 60.37 (SE ± 8.49) tonnes. After 2007, there was a significant linear increase to the highest catches in 2013, followed by a dramatic drop in 2014 only to recover to 2013-levels in 2015 (Fig. 5E). Until the sharp decline in 2014, the period from 2008 to 2015 registered an average catch of (90.27 tonnes ± 15.4), a 49.5% increase from the previous period (Fig. 5E). There was no significant trend in the CPUE of White seabass overall between 2001 and 2015.

Whitefish (*Caulolatilus princeps*)

The three major average catch peaks of Whitefish occur in March, June and July, the latter being the largest (Fig. 4F). Average catches remained relatively similar during April, May and August between 2001 and 2015. From 2001 to 2005 the average catch was 49 tonnes ± 10.4 SE, the largest catch occurring in 2005. Later (2006–2015) the average catch dropped to 35.32 tonnes ± 5.26 SE, representing a 27.5% decrease in total catch compared to the previous period (Fig. 5F.). Between 2005 and 2015 there was a significant decline in catches of Whitefish (Table 4) but no obvious trend in the CPUE of the species (Table 5).

California and speckled flounder (*Paralichtys californicus* and *P. woolmani*)

For the flounder fishery, the most important months are June and July, when two major peaks in landed catch occur. During the autumn and winter months, catches are lower, as well as the number of boats catching these species (Fig. 4G). In the first half of the period (2001–2006) catches averaged 36.3 tonnes ± 5.81 SE, increasing in the second period (2007–2015) to 39.64 tonnes ± 6.88 SE (Fig. 5G). Overall there are no significant trends in the catch or CPUE of flounder between 2001 and 2015 (Tables 4 and 5).

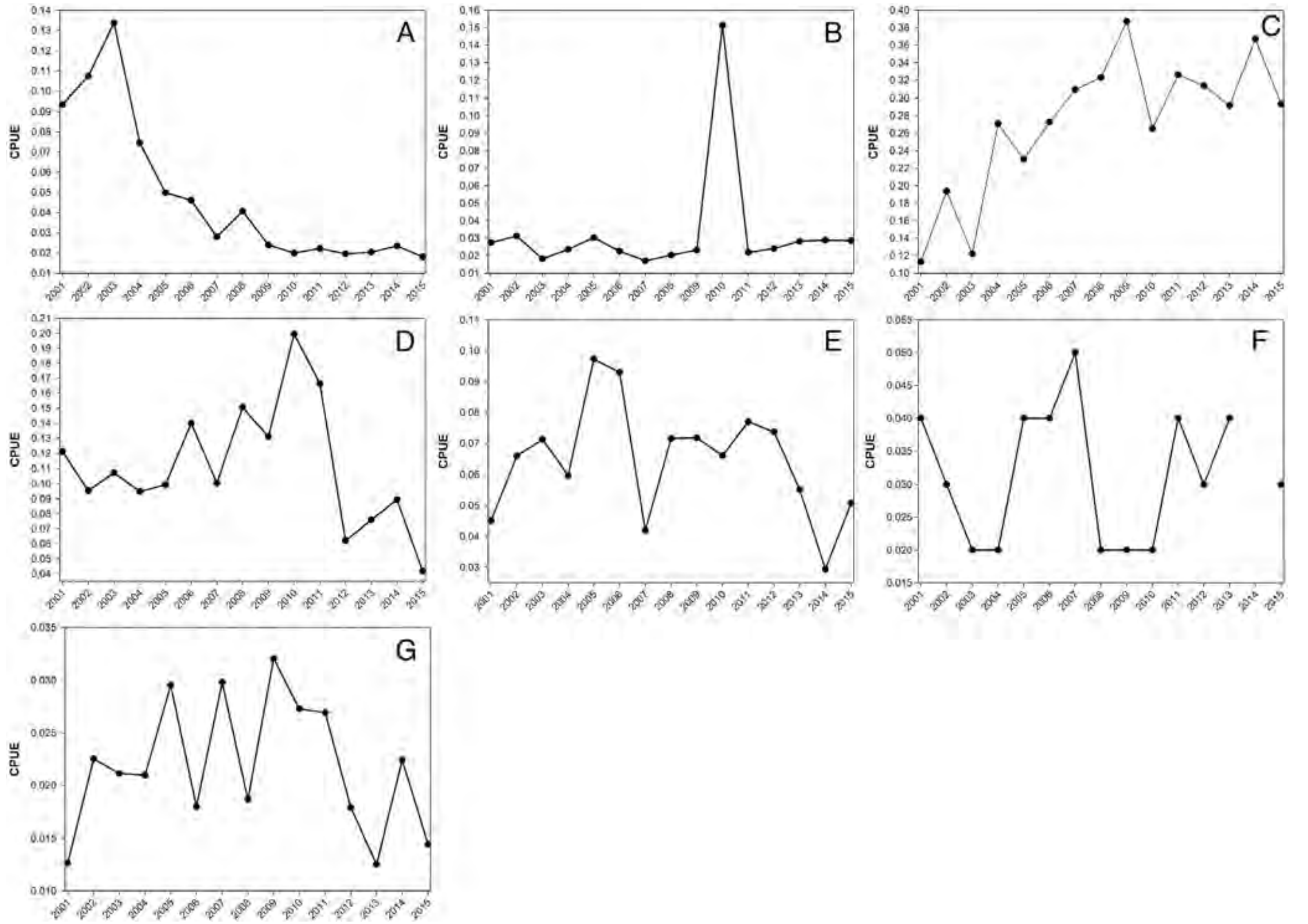

Fig. 6. Annual Catch (total) Per Unit Effort for the seven most important coastal fisheries in Punta Abreojos B.C.S., México, between 2001 and 2015. A) Spiny and blue spiny lobster B) Green and pink abalone C) Barred sand bass D) Yellowtail E) White seabass F) Whitefish G) California and speckled flounder.

Bonita (*Sarda chiliensis*)

This species is caught incidentally whilst fishing for mackerel and weakfish and is used exclusively for bait in other fisheries. There is a brief description of this species because of the role it plays in baiting of both the lobster and barred sand bass fishery. A capture peak was observed in July with an average of 18.9 tonnes. Catches remained between 0.12 and 4.6 tonnes during the rest of the months while autumn and winter were the least productive seasons. During the study period, two major peaks were observed, the first in 2001 with 75.1 tonnes and the second in 2009 with 62.3 tonnes. There were two periods with a minimum capture; 2005 with only 5.9 tonnes and 2013 with 3.84 tonnes.

4. Discussion

Studies over the last decade in Mexico show that the current situation of the artisanal fisheries is in a fragile state; overfished in many cases and facing potential collapse for some heavily exploited fish populations (Hernandez and Kempt, 2003; Sala et al., 2004; Sáenz-Arroyo et al., 2005; Rodríguez-Valencia et al., 2008; Winter, 2009; Cisneros-Mata, 2010; Cinti et al., 2010). The dependence on fishing for sustenance and local economies for most coastal communities, high levels of illegal fishing in various regions, including the Northwest, and new market opportunities have all driven Mexico's continued fisheries overcapacity (Environmental Defense Fund de México, 2013; Mangin et al., 2018). The dynamics of many fisheries in the Mexican Pacific and Northwest are defined by a combination of cultural, socio-economic and management structures. Due to the often-unclear structure of many management rules and control policies, conflicts between neighboring fishers often arise adding to the dynamics within the fisheries (Young, 2001; González-Becerril et al., 2006; Lluch-Cota et al., 2007; Cinti et al., 2010).

Our description of the fisheries in Punta Abreojos and the economic success of the local cooperative highlights co-management and participatory management as keys to achieving both economic and ecological sustainability. A fundamental aspect of the community's success is hinged on good monitoring and evaluation systems that are in place (Ponce-Díaz et al., 2009). It is, however, important to note the geographic isolation of the community and the low population density within Punta Abreojos, characteristics described by Ostrom (2009) that allow successful Socio-Ecological Systems, and characteristics that make management of local resources easier (fewer fishers and lower overall fisheries effort). The classification of cultural, target, and complementary resources includes elements corresponding to different levels and needs of fisheries management. For example, surveillance of the exclusive fishing polygon has enabled the protection and control, not only of the concession (cultural) resources, but also the rest of the resources occurring within the polygon.

Fortunately, in recent years there have been simultaneous efforts by the scientific community to generate, analyze, synthesize and communicate information about the status of exploited resources, for the improvement of fisheries management and policy in Mexico (Ponce-Díaz et al., 2009). Institutional examples driving these efforts include the Escuela Nacional de Ciencias Biológicas del Instituto Politécnico Nacional (Nacional Biological Sciences School of the National Polytechnic Institute) (e.g. Guzmán del Próo et al., 1991; Guzmán del Próo and Pineda, 1992), the Centro Interdisciplinario de Ciencias Marinas of the IPN (Interdisciplinary Center of Marine Sciences of the IPN), (e.g. Casas-Valdez et al., 1985; Hernández-Carmona et al., 1989; Hernández-Carmona et al., 1991), the Instituto Nacional de Pesca (INAPESCA, National Fisheries Institute) and its regional leadership, the Centro Regional de Investigaciones Pesqueras (CRIP, Center for Fisheries Research) and many Civil Society Organizations (CSOs or OSCs for their Spanish acronym).

The two cultural resources, lobster and abalone are managed in accordance with the Mexican official standards, fisheries laws, concessions, specific capture sites, closures, minimum catch size and/or quotas. While catches have not recently reached the levels of historical production for these fisheries (Jamienson and Campbell, 1998), the cooperative has managed to maintain and/or increase their catch to levels considered optimal for the fishery. The volume of annual catch of lobster has increased gradually whilst the CPUE has decreased from initial levels (early 2000's) and now remains relatively stable since 2009. The initial decline in CPUE is attributed to a reduction in the local abundance of lobsters following several severe red tide events (pers. comms), but the sustained levels of CPUE highlight successful maintenance of commercially viable populations. A study by Shester (2010) analyzing fishing production of lobster in Bahía Tortugas and Punta Abreojos in 2006 found that the successful production of these fisheries was the result of self-management by cooperatives of their resources in the monitored concession polygon, and because of the spatial relationship of lobster habitats within the area. In 2008, Morales-Bojórquez and colleagues conducted an analysis of the decline of the two species of abalone (*H. fulgens* and *H. corrugata*) using data from 1991 to 2001. They found a consistent pattern of dramatic declines observed periodically since 1975 for the area. To reverse this trend, fishery concession fees were implemented by CONAPESCA which meant fishers had to pay for the rights to fish the species every 20 years. The fees and renewal of the concessions is determined by the result of an assessment by the CRIP and the Cooperative at the beginning of each season. Auto-regulation and compliance of fisheries regulation has been an efficient management system that has helped maintain a relatively stable level of average catch of Abalone in Punta Abreojos since 1998. In turn, these results have encouraged the development of sustainable fisheries for other resources elsewhere in the region (Micheli et al., 2012).

The 5 target resources are captured throughout most of the year, as is the case with barred sand bass, and other resources only for a few specific months. There is no regulation for the "finfish" fisheries on volumes and seasons for harvesting defined by some biological-demographic characteristics (e.g. size, breeding seasons), as in the case of cultural resources. The target resources have been favored in their protection from an umbrella effect, as in the case of barred sand bass, provided by the presence of concession resources. The annual increase in catches and fishing effort for the commercialization of this resource has not shown fluctuations and/or decreases as evident as the rest of the resources. The increase in catches in the order of 6.5 times greater than those recorded in 2001 provoked closer scrutiny on the management of this fishery. Due to the increase in the volume of catch and considering historical events in the region, the cooperative has implemented a minimum catch size for barred sand bass (12 in.) to protect smaller sizes and ensure the survival of new recruits. We consider this a reasonable measure; however, it is necessary to complement efforts with biological studies of growth and reproductive biology for the barred sand bass population. This can help define the size at first maturity and fecundity, and estimate the time it takes for a species to achieve these sizes, thus enabling the fishery to more precisely define the minimum catch size and identify the reproductive period and specific areas where this phenomenon occurs (Erisman et al., 2012). The large variability in catches of Yellowtail, White seabass and Whitefish could be explained by the trophic reliance of these species on small pelagic fishes (predominantly sardine and anchovy), populations which are known to vary widely based on water temperature and primary productivity (Kim, 2010; Ishimura et al., 2013). Confirming this is the case for Punta Abreojos would, however, require extensive further study.

Although the complementary resources of Punta Abreojos are non-target/bycatch by nature, together these fisheries generate significant economic benefits for the cooperative fishers. The stewardship and conservation-mindedness of fishers within the coop is illustrated when considering the bycatch of grouper (*Mycteroperca jordani* and *M. xenarcha*) that often will be released by fishers based on a social conscience to conserve this resource when it occasionally appears in catches. Grouper populations decreased considerably in recent decades (Pondella II and Allen, 2008) and the cooperative has actively encouraged and promoted the protection of this species since 2012. Likewise, there is also by-catch of sharks and rays, whose populations are also considered greatly depleted in northwestern Mexico (Sala et al., 2004; Sáenz-Arroyo et al., 2005; Cartamil et al., 2011). Thus from 2012 a fishing regulation became effective for them through the enforcement of a closed season (NOM 029-PESC-2006) (Cartamil et al., 2011).

By putting the average annual catches in Punta Abreojos in an economic context and when compared to the volumes and earnings estimated by Ramírez-Rodríguez and Ojeda-Ruíz (2012) for the Gulf of Ulloa, located ~150 km south, the importance of fisheries productivity of the community as part of the North Pacific transition zone versus the Gulf of Ulloa is highlighted. In the study period (2001–2015), 1251.60 tonnes $\pm$ 80.06 SE of annual average catch were recorded for the 21 resources, and from south of Punta Abreojos up to Punta Entrada in Bahia Magdalena, 8450 tonnes per year were recorded corresponding to the period 1998-2009 (Ramírez-Rodríguez and Ojeda-Ruíz, 2012). Therefore, catch volumes of Punta Abreojos represent 14.8% of the Gulf of Ulloa (from Punta Abreojos to Punta Entrada, Bahía Magdalena) and comparing the community with zone 1 (from Punta Abreojos to San Juanico) (see Ramírez-Rodríguez and Ojeda-Ruíz, 2012) it represents 9.69% with respect to the communities of San Juanico to Bahía Magdalena. In other words, the North Pacific is one of the most productive areas at a regional level (Cota-Nieto, 2010; Ramírez-Rodríguez and Ojeda-Ruíz, 2012). The high value generated in the international market for resources such as lobster and abalone provide better profits to fishermen. However, proper administrative management of the cooperative enables the creation of commercialization guidelines to obtain a better price for the benefit of employees. Other studies show that cooperatives are a good system for sustainable fisheries if effort to work efficiently in terms of administration and surveillance is carried out (Cinti et al., 2010; Fujita et al., 2010). It is important to note that these values, as they are to be paid directly to the fisherman, correspond to a percentage of the total value of the commercialized resource. The rest is administered by the cooperative for operational costs, payroll of staff for each council (administration, monitoring, production, etc.), purchase of equipment and accessories, gear and fuel, as well as for the payment of permits, assessments and the maintenance of a processing plant, which in turn includes: canning, cold rooms and vacuum packing. Partner fishermen have medical insurance and other employment benefits (bonuses, etc.), that the rest of coastal fishermen generally do not have and that commonly characterize impoverishment of this sector. The scheme in Punta Abreojos encourages participation and compliance with regulations for the protection of resources (Arce and Sotero, 1998; Cota-Nieto, 2010), which also represent characteristics of successful Socio-Ecological Systems (Ostrom, 2009).

The ability of the cooperative to adapt has been very important in its long-term success and can be seen at multiple scales. For example, at the fisher level, adaptation comes in the form of the safeguards that are in place to entitle fishers to leave with pay and financial support in longer-term situations in which a fisher may not be able to work due to illness or for retirement. The cooperative is set up in such a way that both financing and substitute fishers are available to compensate for temporary losses in labor due to sickness or leave of individuals from the fishery. Adaptive capacity can also be seen in the management of the resources fished by the cooperative. For example, during periods of significant red-tides that are known to adversely affect many of the species fished by the cooperative (Sanseverino et al., 2016), the cooperative is active in conversing with scientific researchers and community members about strategies of moving forward during times in which catches may be lower than normal. This helps ensure that species affected by the red tides are not overfished leading to poor recruitment in the following seasons. This engagement with scientific personnel has also lead to a long-term monitoring program at Punta Abreojos in which water quality is checked regularly and reported back to the cooperative to foresee situations in which the coop will need to adapt their practices during natural phenomena that affect the landings.

During 2014 and 2015, Sea Surface Temperature (SST) monthly anomalies around Punta Eugenia (200 km northwest of Punta Abreojos) were the highest recorded in the previous 15 years (Leising et al., 2015). This unusual warming period, known as the blob, has had considerable impacts on many fisheries and marine species up the west coast of the United States (Cavole et al., 2016). Although at the southerly end of the blob, some of the target fish species of the cooperative at Punta Abreojos appear to have been affected by the warm water anomaly. Lobster, abalone, barred sand bass and flounder all showed similar patterns between 2013 and 2015 in their catch and CPUE. Between 2013 and 2014, there was an increase in catch and CPUE for each followed by a subsequent decline between 2014 and 2015. Yellowtail showed similar patterns but only in CPUE during the same period. The blob began in 2014 and was at its most severe in 2015. The declines seen in catch and CPUE of these species may well reflect the warm water anomaly impacting these fisheries. Although no active response was made by the cooperative during the warming period, it is important to note that cooperative members were aware of the anomaly and discussions regarding the fate of the fisheries under sustained high temperatures were had.

The fishing cooperative at Punta Abreojos represents a good example of successful participatory management in small-scale fisheries. The voluntary participation and engagement of the fishers with the local community, scientists and government is testament to a management system that has evolved following consideration of the many parties involved. As such, it is neither an example of top-down or bottom-up management as the divide between ‘top’ and ‘bottom’ is blurred due to consistent engagement between all stakeholders from managers to individual fishers. Relatively stable CPUEs (number of boats tracking the amount of catch) for the targeted resources at Punta Abreojos, as well as the sustained revenues gained by the fisheries, demonstrates how responsible resource management has removed the race to fish mentality and instead promoted marine stewardship among the coop members and wider community. Although the coop is actively engaged with scientific personnel, there is still considerable benefit in increasing this engagement through improved and wider scale monitoring programs. We believe this would be particularly fruitful for the finfish resources targeted by the cooperative. More scientific data collection and analyses will mean coop members will be even better positioned to make informed decisions balancing the social, ecological and economic needs of the fishers and community (Ponce-Díaz et al., 2009). This is particularly important considering recent environmental stressors/anomalies such as the warm blob of 2014/2015. Future environmental anomalies and market fluctuations that have the potential to cause significant problems for the cooperative in terms of sustaining catches and income will be a test for the cooperative and its Socio-Ecological System, as with any fishing community. Based on our experience with the community and cooperative at Punta Abreojos, however, we believe they are better poised than many adjacent communities to sustain the livelihoods of fishers following unpredictable downturns from anomalous climatic phenomena such as the blob or significant and prolonged red tides. For this reason, Punta Abreojos serves as a useful case study for other fishing communities aiming for sustainability and longevity in their fishing practices and livelihoods.

Acknowledgments

The authors thank the support of the Soc. Coop. de Prod. Pesquera Punta Abreojos S.C. de R.L. committees, the community, fishermen, The Scripps Institute of Oceanography UCSD, Centro para la Biodiviersidad Marina y la Conservación A.C. and the Fondo Mexicano para la Conservación de la Naturaleza A.C. (M-FG-C-PA11-12-03) for the financial support. AFJ was supported by NSF grant DEB-1632648 (2017).

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