Shark species' inventory in Cabo San Lucas, using a touristic operations as methodology

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Abstract

Pelagic sharks include oceanic and semi-oceanic species, and are mostly represented by the orders Carcharhiniformes, Lamniformes, and Squaliformes. Due to their complex life cycle, research on these organisms can be difficult in terms of logistics and finance. Because of this, the use of touristic operations and citizen science has been seen as an effective method to study these organisms in areas where their abundance is quite significant. Due to the characteristics of the study area, we expect to find high species richness, as well as seasonal patterns regarding the relative abundance of sharks as a function of environmental factors. The main goal of this study was to create an inventory of pelagic shark species in Cabo San Lucas and identify seasonal patterns in their abundance, as well as contribute data that supports the use of touristic operations and citizen science on the study of pelagic species. To do this, submarine censuses were completed with the assistance of Cabo Shark Dive, registering shark species richness, relative abundance, sex and size of the individuals, as well as environmental factors such as sea surface temperature, wind speed, cloudiness and depth (if it was possible),. We observed 8 species during the censuses, with the most abundant species being *Carcharhinus falciformis, Sphyrna zygaena,* and *Isurus oxyrinchus*. Also, we identified seasonal patterns on the relative abundance of these three species, where *I. oxyrinchus* was the most dominant species during the cold season (December through March), *S, zygaena* during the transitional periods (April through June), and *C. falciformis* during the warm season (July through November). This is the first formal inventory of species done for the area, and we were able to demonstrate the viability of touristic operations and citizen science as tools used for the monitoring of these organisms and the establishment of baselines for these populations. This is especially important since these species are being taken advantage of by the growing nature tourism sector in Mexico.

Key words: citizen science, shark tourism, Baja California Sur, seasonal variability, relative abundance.

INTRODUCTION

Pelagic sharks include oceanic and semi-oceanic species, and they comprise a small group amongst the elasmobranchs as they only represent 6% of them. These organisms show low variations in terms of body plans if they're compared to coastal species, and are mainly represented by the orders Carcharhiniformes, Lamniforme, and Squaliformes (Camhi *et al.* 2009).

Due to their complex life cycles, their study is complicated in logistical and monetary terms. This is why over the last few years, touristic operations and citizen science have surged as an efficient method for their study, contemplating themes like basic biology, short and long term abundance, behaviour, dsitribution, horizontal and vertical movements, etc. (Meyer *et al.* 2009; Clua *et al.* 2010; Gallagher & Hammerschlag 2011; Brunnschweiler *et al.* 2014).

HYPOTHESIS

Due to the conditions of the study area, we expect to find a high species' richness, as well as seasonal patterns on the relative abundance of sharks, in terms of environmental factors.

OBJECTIVE

Our main goal was to create a species' inventory for pelagic sharks in Cabo San Lucas, Baja California Sur, Mexico, as well as identify seasonal patterns on the relative abundance of these species. Furthermore, we expect to collect data that will support the use of tourist operations and citizen science on the monitoring of pelagic species.

MATERIAL AND METHODS

Study Area

The observations were carried near Cabo San Lucas' Bay, in Baja California Sur, Mexico, comprising the period between February 2016 and December 2018 (476 tours, 1428 hours of effort). This area is important as it represents the union between the Gulf of California and the Pacific Ocean. The area lacks of a wide continental platform, so depths below 500 m are found close to shore (Aguilar-Palomino *et al.* 1998). The area is influenced by 3 superficial currents: the California Current, the North Equatorial Current, and the North Equatorial Countercurrent. They each vary greatly troughout the year as a

consequence of changes on the speed and direction of the dominant winds. Due to the fact that the bay is found inside a complex transitional area, the oceanic climate is affected by climatic phenomenons such as the Southern Oscillation El Niño effect. The surface temperatura varies greatly depending on the season, having temperatures as cold as 18-20ºC during winter and as hot as 30ºC during the summer (Zúñiga-Flores 2004; Figure 1).

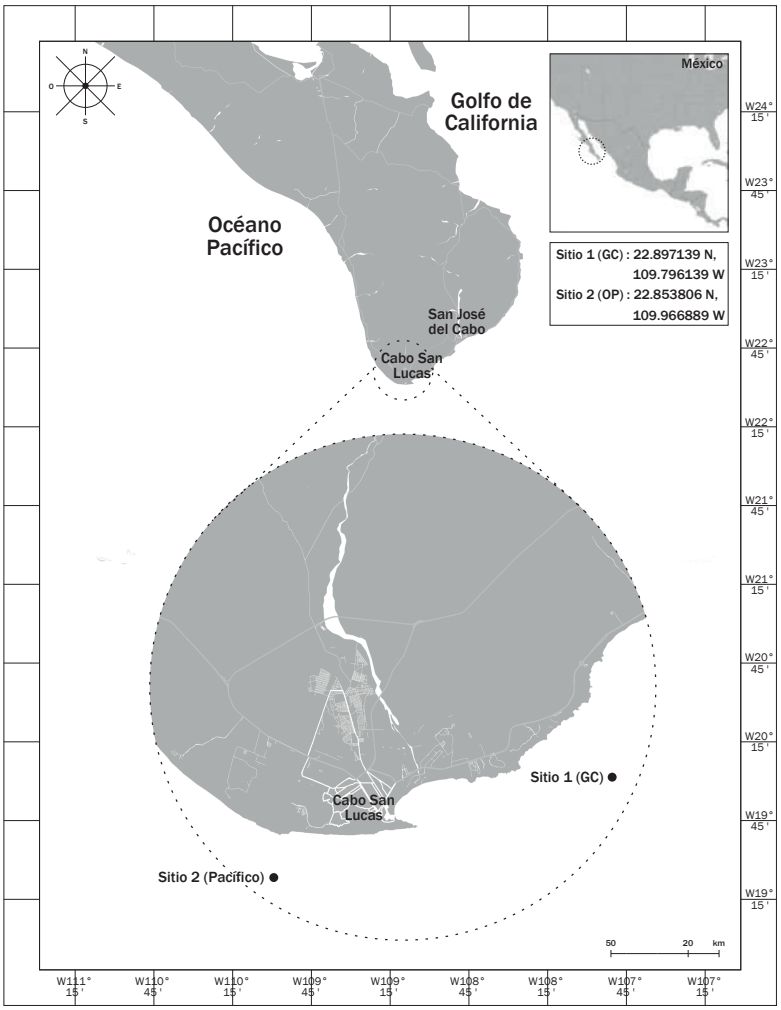

Figure 1. Study area.

Underwater monitoring

A boat ("*panga"* type) was used to get to the observation spots. Once there, provisioning was used to create a smell current and attract the sharks. The most used fishes were: skipjack tuna (*Katsuwonus pelamis),* yellowtail kingfish *(Seriola lalandi),* yellowfin tuna *(Thunnus albacares),* and during season, mahi mahi (*Coryphaena hippurus*). Sea surface temperature, wind speed, depth, and

water color was collected *in situ*, if possible. Once a shark appeared, the observer jumped into the water, and while snorkeling, registered the amount of sharks in the area, their species, sex, and size (visual estimation using people or objects with known heights).

Data analysis

Firstly, histograms representing the relative abundance of all species and effort (hours) were done for each year. Secondly, sightings per unit of effort were calculated for the most abundant species. The latter were graphed through histograms. Finally, the sea surface temperature profile per year (monthly composite) was graphed as well, and compared with the SPUE graphs, in order to observe seasonal patterns on the relative abundance in terms of this environmental factor.

RESULTS

During 2016-2018, we observed 8 species of pelagic sharks in Cabo San Lucas: Shortfinned mako *Isurus oxyrinchus*, smooth hammerhead *Sphyrna zygaena,* silky shark *Carcharhinus falciformis*, blue shark *Prionace glauca*, dusky shark *Carcharhinus obscurus*, blacktip shark *Carcharhinus limbatus*, Galapagos shark *Carcharhinus galapagensis*, and scalloped hammerhead *Sphyrna lewini* (Table I).

Table I. Shark species' inventory in Cabo San Lucas.

Species	Date for first observation	References
Isurus oxyrinchus  Shortfinned mako Foto: Francisco Mascareño	February 2016	González-Armas *et al.* (2012); CONAPESCA (SA); this study
Sphyrna zygaena	March 2016	This study

Smooth hammerhead

Foto: Miguel Ángel Eliceche

Carcharhinus falciformis	March 2016	CONAPESCA (2018); this study

Silky shark

Foto: Francisco Mascareño

Prionace glauca	February 2017	CONAPESCA (2018); this study

Blue shark

Foto: Benjamín Fernández

Carcharhinus obscurus	November 2017	This study

Dusky shark

Foto: Andy Murch

Carcharhinus galapagensis	September 2016	This study

Galapagos shark

Foto: Kori Garza

Sphyrna lewini	September 2018	CONAPESCA (2018); Klimley (1983)

Scalloped hammerhead

Foto: Andy Murch

Carcharhinus limbatus  Blacktip shark Foto: Andy Murch	July 2017	CONAPESCA (2018); this study

During 2016, the most abundant species was the silky shark, followed by the shortfinned mako, the smooth hammerhead shark, and finally, with only one sighting, the Galapagos shark. For 2017, we observed higher relative abundances for all the species, being the most abundant species the silky shark, followed by the smooth hammerhead shark, the shortfinned mako, the blue shark, and finally, with one sighting only, the blacktip shark and the dusky shark. Finally, for 2018, the most abundant species was the shortfinned mako, followed by the smooth hammerhead shark, and the silky shark, while we only had one sighting for the blue shark and the scalloped hammerhead (Table II, Figure 2).

Table II. Relative abundance of the observed species in Cabo San Lucas, during the period comprising February 2016-December 2018.

Species	**2016**	**2017**	**2018**	**Total**
Isurus oxyrinchus	25	44	146	215
Sphyrna zygaena	13	86	65	164
Carcharhinus falciformis	129	189	68	386
Prionace glauca	-	6	11	17
Carcharhinus galapagensis	1	-	-	1
Carcharhinus obscurus	-	1	-	1
Carcharhinus limbatus	-	1	-	1
Sphyrna lewini	-	-	40	40

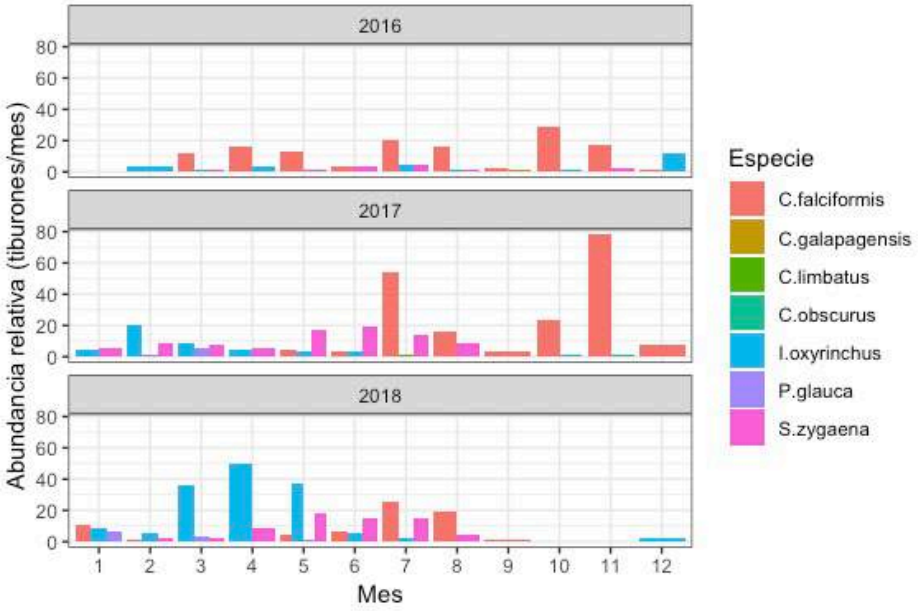

Figure 2. Relative abundance (sharks/h) of pelagic sharks in Cabo San Lucas

The highest SPUE for the mako shark in 2016 and 2017 was found during February, followed by December, March, and April during 2016, and January, March, and April for 2017. During 2018, the highest values were observed during March, April, and May. The highest SPUE for this species concurrs with the cold season in the area, with low sightings during the warm season (Figure 3).

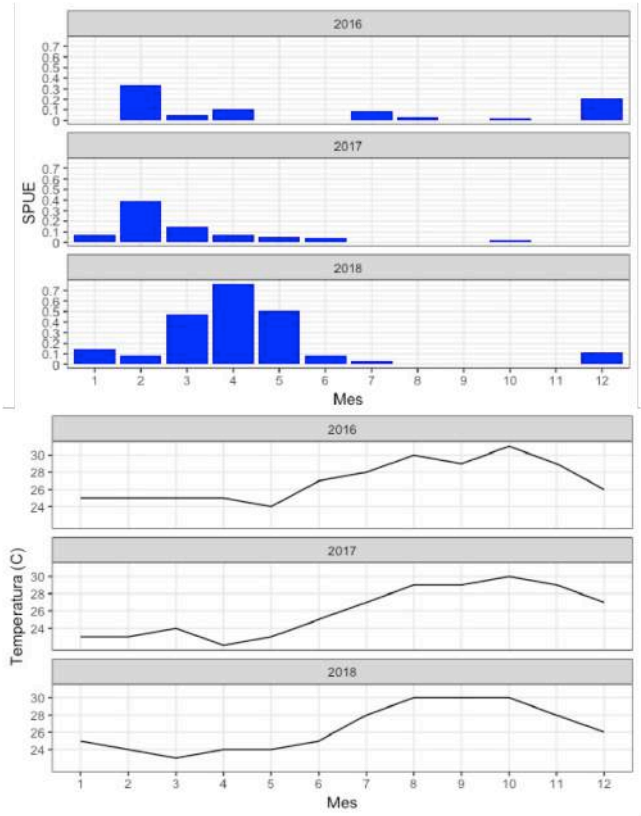

Figure 3. SPUE of the mako shark in Cabo San Lucas (2016-2018) and temperature profile.

For the smooth hammerhead, the highest SPUE values during 2016 weres found on June and July, while in 2017, we observed more sharks in February, May, June, July, and August. During 2018, the highest SPUE values were found from April til July. High temperatures seem to be a limiting factor for the abundance and presence of this species, as we had low sightings during the warm season. Overall, the relative abundance of this shark is higher during the transitional season, which goes from April til July (Figura 4).

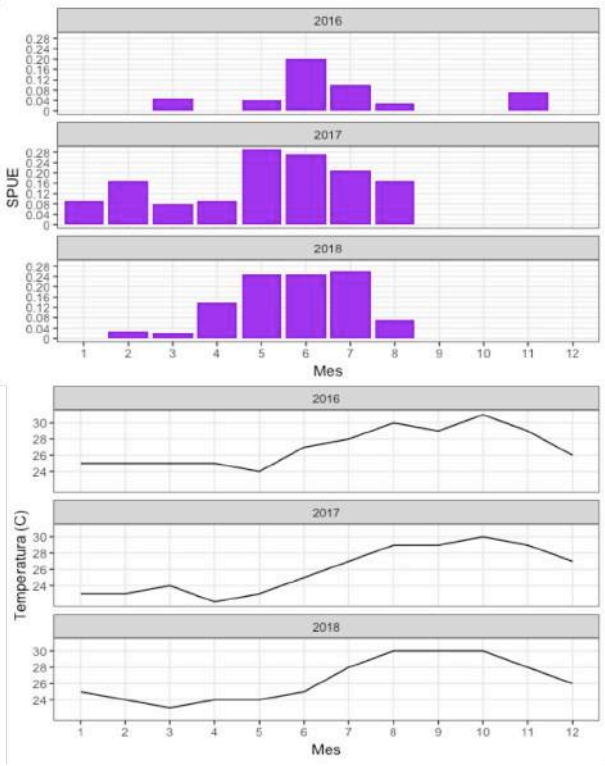

Figure 4. SPUE of the smooth hammerhead shark in Cabo San Lucas (2016-2018) and temperature profile.

Although the silky shark was observed throughout all the seasons during the three years of monitoring, the presence and abundance of this species seem to be limited by low temperatures (22-23ºC). As the temperature rose on the area, we observed an increase of the SPUE for this shark, reaching the highest values during the warm season (end of July til November). The low relative abundance during 2018 is explained by the low effort during the last months of the year (Figura 5).

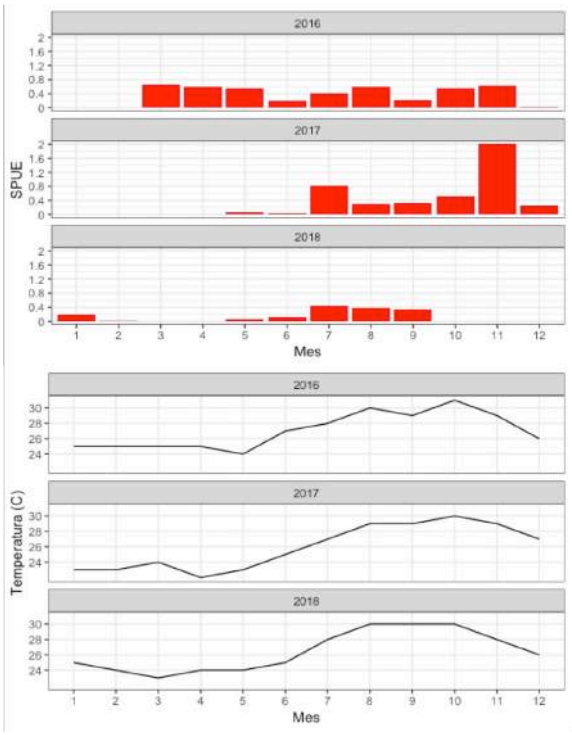

Figure 5. SPUE of the silky shark in Cabo San Lucas (2016-2018) and temperature profile.

DISCUSSION

This is the first systematic study to describe the species richness and relative abundance of pelagic sharks in Cabo San Lucas. Throughout 3 years of monitoring, we observed 8 species in the area, while three of them were the most abundante: mako shark, smooth hammerhead shark, and silky shark. Of all the species we observed in the region, only two of them have previous reports: mako shark (González-Armas *et al.* 2012; González-Armas *et al.* 2013) and scalloped hammerhead (Klimley 1983; Klimley & Butler 1988).

Although they lack of previous formal reports, the silky, blue, and blacktip sharks have previous reports by the Mexican authority on fisheries (CONAPESCA 2018). However, these reports are not trustworthy due to the uncertainty generated by the site of capture and misidentifications (Baum & Blanchard 2010).

Referring to the relative abundance of the mako shark, this species was most abundant during the cold season. This has been reported before by Bizzarro *et al.* (2007), who identified this species as one of the most abundant on the winter and spring landings in the state of Baja California Sur, along with the blue shark. The high frequency during the cold season suggests a clear thermal

preference, inhabiting waters of about 17-22ºC (Carrier 2017); however, Vaudo *et al.* (2016) found mako sharks had the capacity to inhabit waters with temperatures oscillating between 25-27ºC in the Gulf of Mexico, explaining our low sightings during the warm season.

There's not much information about the smooth hammerhead shark, both in Mexico and globally, in spite of the fact that the species is common in the Gulf of California and Pacific Ocean (Ochoa-Díaz 2008). However, Couto *et al.* (2018) registered sightings of this species in southern Portugal during the warm season there, which has similar sea surface temperature to the transitional season in Cabo San Lucas. This could suggest the influence of sea surface temperature and seasonal upwellings over the relative abundance of this species. It's important to point out that the abundance seen on this study was considerably higher than the one in Portugal, so we suggest the existence of a smooth hammerhead hotspot in Cabo San Lucas.

Finally, the silky shark showed the highest relative abundance throughout the whole study. Furthermore, the highest values were observed during the warm season, coinciding with previous reports by the fisheries in the state of Baja California Sur (Bizzarro *et al.* 2007). The presence and abundance of this species could be related to the area's bathymetry, the availability of food, and the sea surface temperature, which seems to be a limiting factor for the species below 23ºC (Bonfil 2008).

CONCLUSIONS

- Throughout 3 years, we observed 8 species of pelagic sharks in Cabo San Lucas, being the most abundant species the silky shark, the mako shark, and the smooth hammerhead shark.
- This study suggests a replacement of the most abundant species throughout the year, being the mako shark the most abundant during the cold season, the smooth hammerhead shark during the transitional season, and the silky shark during the warm season.
- Our results show the efficiency of touristic operations and citizen science as a tool to study pelagic populations.

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