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New Nursery Area for White Sharks (*Carcharodon carcharias*) in the Eastern Pacific Ocean

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Abstract

The white shark is a worldwide protected species and nevertheless coastal nursery grounds and juvenile aggregation areas have been reported, the actual information about birth or nursery areas for this species is still lacking. So, is necessary to focus research effort to identify new aggregation site, especially for young stages. During 2015 to 2017 we obtained data of 12 neonates and juveniles around Isla Cedros, in the western coast of Baja California, Mexico suggesting this island as important nursery area for white sharks. This information will help in management plans for conservation in aggregation habitats of young white sharks.

Introduction

White Sharks (*Carcharodon carcharias*) are distributed globally in subtropical and temperate waters and positioned as apex predators. This species of shark is known to have a long-life span, low reproductive potential and fecundity rate (Compagno, 2002; Bruce, 2008) and are listed in the Appendix II of the 2004 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the International Union for Conservation of Nature (IUCN) (Fergusson, Compagno & Marks, 2009). Furthermore, in Mexican waters the white shark is protected by a permanent fishing ban prohibiting its capture (NOM-029-PESC-2006). Therefore, the early stages are ecologically important for understanding the species populations and generating adequate management plans for species conservation (Castro, 1993; Simpfendorfer & Heupel, 2004). Both juvenile and adult white sharks are caught as by-catch in commercial and sports fisheries over the world using gillnets, longlines and handlines. In the coastal waters of Baja California, white sharks are reported to be incidentally caught in the artisanal fisheries (Cartamil *et al.* 2011; Santana-Morales *et al.* 2012; Ramírez-Amaro *et al.* 2013; Castillo-Géniz, Godinez-Padilla, Ajás-Terriquez, & Gonzaléz-Ania, 2014; Oñate-González *et al.* 2017), which may be due to the intensity of fisheries activities in coastal areas that overlap nursery grounds (Dahlgren *et al.* 2006; Heithaus, 2007).

The aim of this information is to assess the presence of young of the year (YOYs) and juvenile white sharks in Isla Cedros, using capture records from artisanal fisheries in the area.

Our study area of Isla Cedros in the western coast of Baja California have depths of up to 200 m and has

been previously documented to support a strong upwelling of cool waters, which sustain a complex trophic chain (Hernández-Rivas, Jiménez-Rosenberg, Funes-Rodríguez & Saldierna-Martínez, 2000). These productive waters allow the development of a rich marine community, incorporating a range of elasmobranchs species (*Mustelus* spp., *Squatina californica*, *Triakis semifasciata*, *Pseudobatos productus*, *Zapterix exasperata*), targeted by artisanal fisheries (Des Lauriers, 2009).

Materials and Methods

The white shark captures were recorded from local fishermen, when they fish around the Isla Cedros **(**28º 10' 58" N; 115º 13' 04" W, Fig. 1). Local fishermen were previously trained by members from the Fish Ecology Laboratory of Centro Interdisciplinario de Ciencias Marinas (CICIMAR) to identify different shark species. The training of fishermen consisted to teach them to use morphological features (teeth shape, body shape, skin color, fin position and fin shape), identification guides and photographic material to identify white sharks and distinguish them from other species. This training was necessary because the majority of artisanal fishermen in Baja California do not distinguish the white sharks from other species, like shortfin mako sharks (*Isurus oxyrinchus*) or porbeagle (*Lamna nasus*) especially in their juvenile stages. Furthermore, the artisanal fishery of Baja California commonly classify the elasmobranchs in: tiburón (TL>150 cm), cazón (TL<150 cm) and rays (Ramírez-Amaro *et al.* 2013). We also trained them to record biological data such as total length (TL) and sex by the presence or absence of the reproductive organs (claspers) (Compagno 2002). Fishermen recorded capture date with GPS position and biological data for each shark capture or observation. However, in some cases, they were not able to estimate the TL, so an estimation of the total weight (TW) from captured sharks was registered. Then TL was obtained by using the converter length-weight relationship of NEFSC Apex Predators Program from the National Oceanic and Atmospheric Administration (NOAA) web site. (https://www.nefsc.noaa.gov/nefsc/Narragansett/sharks/calc.html), allowing the conversion of shark weight to fork length (FL) and TL (Kohler, Casey, & Turner, 1996).

The different age classes, such as neonates, YOYs and juveniles, were determined based on birth and maturity sizes reported in literature (Francis, 1996; Uchida, Toda, Teshima, & Yano, 1996; Bruce & Bradford 2012). The reported range for birth length for white sharks is from 120 to 150 cm TL, and previous studies classified individuals < 175cm as YOY (Bruce & Bradford 2012). The TL for mature white sharks is 350 cm for males and 480 cm for females (Francis 1996; Uchida *et al.,* 1996; Bruce & Bradford 2012). We estimated white shark´s age using the inverse of the von Bertalanffy model, with species-specific parameters (Cailliet, Natanson, Welden, & Ebert, 1985), to classify white sharks as newborns, YOYs, juveniles and adults, based on their TL.

Results

During 2015 to 2017 we obtained twelve white shark´s records (Table 1). In most cases, sharks were captured in gillnets and they were still alive, so fishermen were able to release them after data collection. Captured white sharks: three females, three males and six undetermined individuals (Table 1) ranged in size from 110 to 500 cm TL. Based on the birth and maturity sizes, the sharks were classified as: 6 neonates, 3 YOYS, 2 juveniles and 1 adult. All captured individuals were reported during March to November, with the peak of captures during the summer months.

Discussion

All age classes of white sharks are known to occur in the western coast of Baja California, particularly around Sebastian Vizcaino Bay, with the highest frequency of neonates and YOY white sharks recorded during the summer months (Weng *et al.*, 2007; Cartamil *et al.*, 2011; Santana-Morales *et al.*, 2012; Weng *et al.*, 2012; Domeier & Nasby-Lucas, 2013; Oñate-González *et al.*, 2017) because this season is possibly related to parturition and births of this species (Francis, 1996; Uchida *et al.*, 1996).

High rates of by-catch, mainly in juvenile white sharks are common in Laguna Ojo de Liebre, which is considered the core area of this nursery region (Santana-Morales *et al.,* 2012). In fact, Sebastian Vizcaino bay was previously reported as nursery area for this species by Oñate-González *et al.* (2017), basing on whit white shark incidental catch records. Santana-Morales *et al.* (2012) reported the highest records of young white sharks in Laguna Ojo de Liebre, describing 111 white sharks over 11 years, with 80% of the YOY captured in this core of the nursery area. Meanwhile Oñate-González *et al.* (2017) reported a total of 390 white shark incidentals catch records along the western coast of Baja California, mentioning that the highest incidental catch rates of newborn and YOY sharks were inside the Sebastian Vizcaino bay, without related them to a specific area.

Nevertheless, Sebastian Vizcaino was defined a nursery area for white sharks, no records or data about juvenile and YOY white sharks have been reported for the outer region of Sebastian Vizcaino bay and Isla Cedros till the date (Fig. 1). Our capture records are mainly close to Isla Cedros, which would be a parturition area for white shark, as previously hypothesized from Domeier and Nasby-Lucas (2013). We were able to collect data from such remote area, compared with Ojo de Liebre lagoon, because we trained artisanal fishermen to identify white sharks to specie-specific

level, developing a teaching methodology based on their empirical experience. This kind of training and collection of biological data with the fishermen is a methodology to obtain data across large time periods, taking advantaged that artisanal fishermen spend a lot of time into the sea as previously documented (De la Parra-Venegas *et al.*, 2011).

Our results showed that not only the YOYs are caught by fisheries, because also neonates are the most affected age category. The aggregation of juvenile and YOY white sharks around Isla Cedros provides an indication of the ecological importance of this region for WS conservation. In fact, they could use this area for birth purposes, once they reached the sexual maturity.

Until now the coastal water of Southern California Bight (USA), the Gulf of California and Sebastian Vizcaino bay are reported as nursery area, however there are not specific conservative measures ongoing on those regions, because of white shark is already protected in Mexico and US. The common strategy to manage a nursery area is to establish marine protected areas, not always necessary. Carefully identification of the nursery ground or critical biological hotspots for a specie will improve our ability to manage and conserve nearshore habitats (Dahlgren *et al.*, 2006; Heupel, Carlson, & Simpfendorfer, 2007), which are also critical for supporting fisheries and provide human livehood. Our findings highlight that also the offshore and outer regions are important, because young white sharks can aggregate in shallow coastal water around islands like Cedros, which offer a protected site in open water. This research represents the first data of a new putative nursery area from the outer regions Sebastian Vizcaino bay, providing evidence that suggests that waters off Isla Cedros, could be an important habitat for young white sharks and their reproduction early stages. This kind of data can will provide more valuable information for shark biology, critical habitat and fisheries managers. In conclusion, we need to continue doing research of the frequency of juvenile and YOY white sharks in Isla Cedros to better understand the role of this region in the ecology of white sharks.

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Table 1: White sharks recorded, including their biological data and capture dates. Each symbol in the first column represent a shark recorded with the corresponded biological data and recorded and date. The recorded location for each individual is showed in Figure 1, where the different symbols are reported in the record location for all the different white sharks.

Symbol*	WT (kg)	LT (cm)	Sex	Age Class	Date	Kind of Record
	400	330	?	juveniles	3/5/15	captured
	18	139	?	Neonate	8/21/15	captured
	28	110	F	Neonate	4/19/16	captured
	60	190	F	Young of the Year (YOY)	5/17/16	captured
	-	130	F	Neonate	Middle of June 2016	captured
	-	300	M	juveniles	Middle of June 2016	captured
	-	150	M	Neonate	10/19/16	captured
	-	150	M	Neonate	10/11/16	captured
	-	180	?	Young of the Year (YOY)	First week of July 2017	captured
	-	500	?	Adult	7/29/18	observed by free diving
	-	180	?	Young of the Year (YOY)	8/1/17	captured
	-	140	?	Neonate	7/22/17	captured

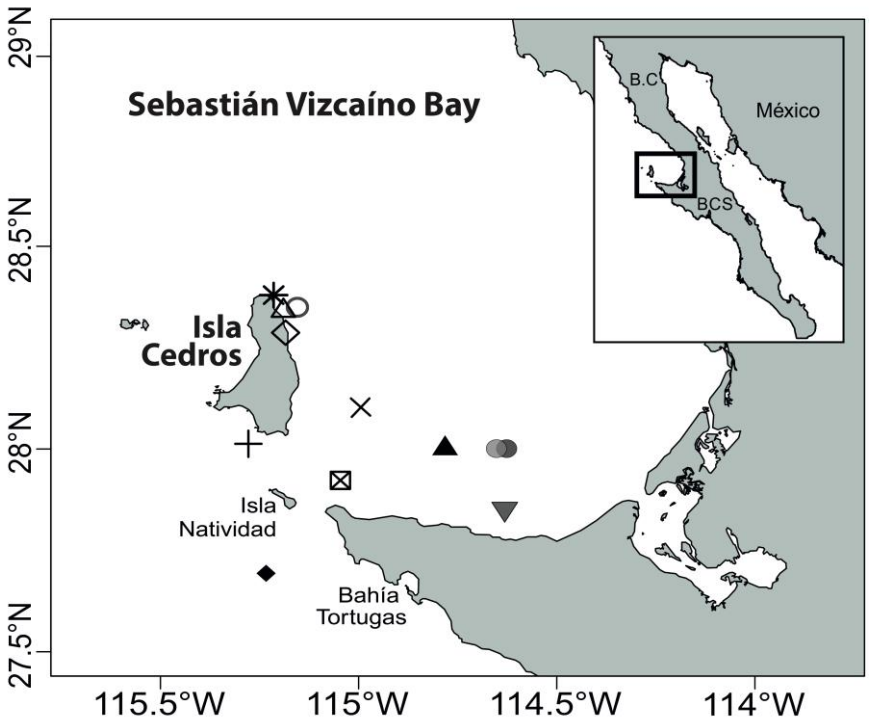

Figure 1. Isla Cedros, México as pupping ground for young white sharks (*Carcharodon carcharias*). Symbols represent location of white shark records.