Movement patterns and habitat use of the silver tip shark (*Carcharhinus albimarginatus*) at the Revillagigedo Archipelago

Gádor Muntaner López
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Dra. Mª Milagrosa Gómez Cabrera

Dr. Edgar Mauricio Hoyos Padilla

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El alumno

Fdo.: Gádor Muntaner López

Los directores

Fdo.: María M. Gómez Cabrera **Fdo: Edgar Mauricio Hoyos Padilla**

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ABSTRACT

The Revillegigedo Archipelago Biosphere Reserve is home to several shark species that spend at least part of their life history associated with oceanic islands associated with hotspots of pelagic biodiversity and in particular with apex predators. Silvertip sharks (*Carcharhinus albimarginatus*) are is commonly found in all the islands of the archipelago. However, very little is known about the spatial and temporal scales of their habitat use and associated ecological role. In this study, we employed passive acoustic telemetry to investigate the residency patterns and migration dynamics of 35 silvertip sharks tagged in three islands of the archipelago (San Benedicto, Socorro and Roca Partida) and monitored for a period of between 7 and 1165 (mean ± SD: 553.7± 354.2) days. Shark size ranged from 80 to 200 cm TL, and mean size did not vary significantly between males (105,4 ± 27,9 TL) and females (120,4 ± 42,9 TL; t test=1.0864, df = 30, p=0.2860). The island and the reproductive state had significant effects on the Residency Index (Linear Model: $F = 11.73$, p-value < 0.05) of the tagged sharks. Adult sharks showed its higher presence in Roca Partida, while juvenile and newborn sharks had a higher presence in Canyon, San Benedicto. General Linear Models revealed significant effects of reproductive stage and location on the daily number of sharks present, and their interaction, with a deviance explained by the model of 71%. Our results provide the first evidence that silvertip sharks use San Benedicto and Socorro as nursery areas. After they reach maturity, they start to migrate to Roca Partida for foraging and mating reasons. This study provides useful information that should be taken into account by the Mexican authorities and stakeholders for management conservation.

INTRODUCTION

Recent declines in populations and catches of many species of sharks have sparked considerable interest in the conservation biology of these fishes (Heithaus, 2007). The formation of marine protected areas (MPAs) is a common method used to preserve both targeted fishery species and non-targeted species alike. However, these areas are often designed with little prior knowledge of the spatial behaviour of the species they are designed to protect (Barnett *et al.* 2012). The spatial ecology of apex predatory shark species is important to understand when considering their role in structuring marine communities and proposing effective conservation strategies (Daly *et al*. 2014, Speed *et al.* 2012). Therefore, it is critical to identify key habitats that are essential to the maintenance of shark populations as they directly affect community composition by prey ingestion, and indirectly through predation risk (Heithaus *et al.* 2008).

The increased use of Essential Fish Habitat (NOAA 1996) in management plans has recognized that all stages in a species life cycle are important, not just those stages vulnerable to exploitation (Heupel *et al.* 2007). Thus better understanding of those habitats or regions that serve as nurseries should improve shark conservation and management (NMFS 2006).

Many authors have tried to define and identify nursery areas. Castro *et al.* (1993) stablished a criteria based solely on the presence of newborns, juveniles or both. Another definition was given by Beck *et al* (2001), who considered nursery as a region where juvenile fish occur at higher densities, avoid predation more successfully, grow at a faster rate than in other habitats and so provide a greater relative contribution to adult recruitment, than other areas. However, a more refined definition for shark nurseries was necessary to avoid labelling vast areas as nurseries and diluting the ability to protect the most valuable areas (Beck *et al.* 2001). In response, Heupel *et al.* (2007) outlined three basic criteria designed to standardize the classification of shark nursery areas and identify those of greatest importance: (1) sharks are more commonly encountered in the area than in other areas, (2) sharks have a tendency to remain or return for extended periods, and (3) the area or habitat is used repeatedly across years.

The Revillegigedo Archipelago Biosphere Reserve is home to several shark species that spend at least part of their life history associated with oceanic islands which provide structure to both ocean bathymetry and current patterns and are associated with hotspots of pelagic biodiversity (Worm *et al*. 2003) and in particular with apex predators (Stevenson *et al*. 2007). It represents a suitable scenario to identify potential nursery areas and hotspots for sharks.

The silvertip shark (*Carcharhinus albimarginatus*) is commonly found in all the islands of the archipelago. However, there are no current studies defining movements of silvertip sharks in the Eastern Pacific.

The silvertip shark is a large, slow-growing shark with a maximum recorded total length (TL) of 300 cm. Males and females reach maturity between 160–180 and 160–200 cm TL, respectively (Stevens, 2009). It presents a large and slender body with moderately long and broadly parabolic snout. It has conspicuous white tips at posterior margins on all fins. The first dorsal fin is large and triangular, originating above or slightly forward of the free pectoral fin tips, also presenting a dermal ridge between the first and second dorsal fins. The pectoral fins are long and falcate in shape, with pointed tips and the upper teeth are broadly triangular (Fig. 1) (Pillai *et al.* 2000).

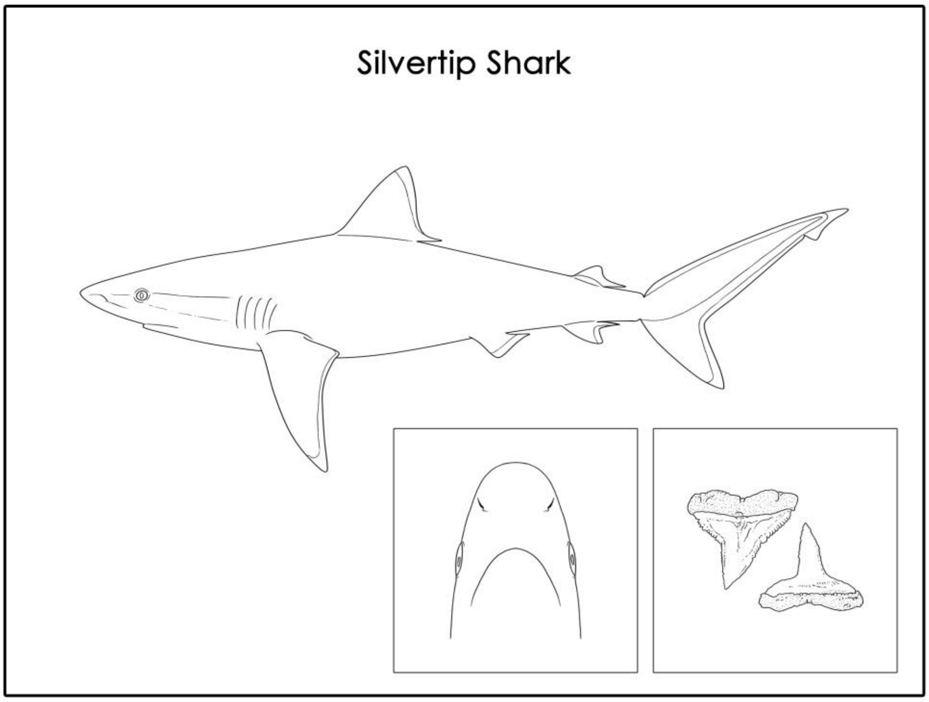

Figure 1. Diagnostic features of the silvertip shark (Modified from Compagno 2005)

This species has a wide but fragmented distribution throughout the tropical Indian and Pacific Oceans (reports in the western central Atlantic are as yet unconfirmed). They are commonly found over continental and insular shelves at a depth of 30–800 m, occupying all levels of the water column. They are most common around isolated islands, coral banks, and reef drop-offs (Compagno, 1984). Juveniles frequent coastal shallows or lagoons to avoid predation, while adults occur in deeper water, with little overlap between the two age groups (Ferrari, 2002). It appears to be relatively site-specific, possibly with limited dispersion. This species is subjected to bycatch in high seas fisheries and in artisanal longline, gillnet and trawl fisheries throughout its range, and the number of pelagic sharks landed by fishing fleets in all oceans has become increasingly important in recent years (Pillans *et al*. 2009). Silvertip shark is currently Red-listed and classified as 'Near threatened' by the International Union for Conservation of Nature (IUCN).

Little is known about the spatial dynamics of silvertips around the Revillagigedo Archipelago. Without this understanding, it is difficult to assess their value as conservation tools for the pelagic community. Also understanding silvertip shark movements is important for assessing the effectiveness of protected areas such as The Revillagigedo Archipelago Biosphere Reserve. The development of passive acoustic telemetry technology has enabled long-term investigations of movement patterns by multiple individuals (Voegeli et al. 2001). In 2008, a regional network of scientists (Pelagios Kakunja A.C.) deployed arrays of listening stations at different sites around the archipelago and began a study to understand local and regional movement patterns of several shark species, including silvertip sharks. The objective of the present study is to determinate the movement patterns, use of habitat and nursery areas of the silvertip shark in the Revillagigedo Archipelago in order to provide useful information to the Mexican authorities and stakeholders for their management and conservation.

MATERIAL AND METHODS

Study area

Located approximately 350-650 km south and southwest of the southern tip of the Baja California peninsula, Mexico, and about 580 km west of the coast of Colima (Brattstorm, 1990), the Revillagigedo Archipelago consist of a group of four volcanic oceanic islands (Socorro, Clarion, Roca Partida and San Benedicto) rising independently from the ocean floor along the Clarion Fracture Zone (Fig. 2a,b). The islands are located just west of the junction of the Pacific, Rivera and Cocos plates, the East Pacific Risa and the Middle America Trench (Silver & Valette-Silver, 1987).

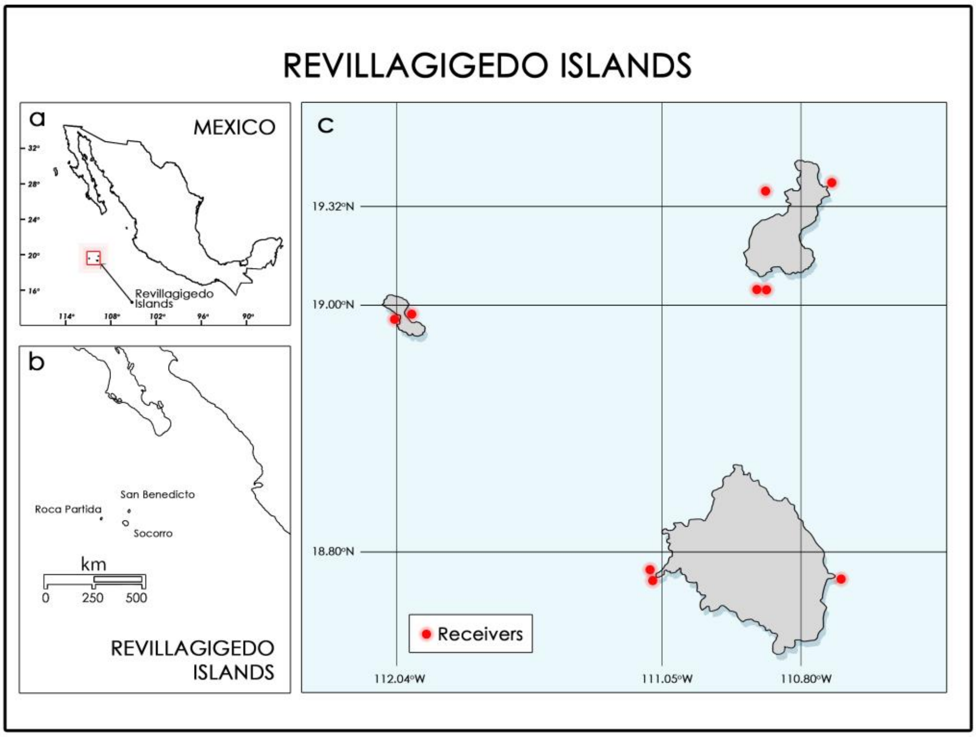

Figure 2. Location of the study area and listening stations

The Revillagigedo Archipelago was declared Biosphere Reserve by the Mexican government in 1994 (CONANP, 2004), due to its high biological and geological richness. The marine environment surrounding these islands has a particularly rich biodiversity and it constitutes an important habitat for marine top predators, having one of the richest faunas of tropical eastern Pacific sharks (Hoyos-Padilla and Ketchum in prep.)

Acoustic array and shark monitoring

A total of 30 juvenile silvertip sharks were caught using hook and line and brought on-board to be measured, sexed and internally tagged with V16 acoustic-coded transmitters (Vemco, Ltd., 95 mm long, 36 g in air, 16 g in water, 157–160 dB, < 3 years battery life) while running water was pumped over their gills to keep them oxygenated. The tagging procedure consisted of making a 2 to 3 cm incision along the ventral surface using a scalpel, implanting the transmitter into the body cavity and closing the incision using surgical suture. All instruments and the transmitter were sterilised prior to use and individuals were returned to the water within 5 minutes.

Five adult individuals were externally tagged underwater. The transmitters were fitted with stainless steel tag heads, fitted to a pole spear and shot the transmitter into the dorsal region of the sharks by scuba diving.

Sharks were tagged between 28th April 2010 and 27th November 2014 at five locations: Canyon and Boiler (San Benedicto Island), Punta Tosca and Cabo Pearce (Socorro Island), and Roca Partida, where only adult sharks were tagged as no juvenile silvertip sharks were observed. Tagged individuals were monitored from April 2012 until July 2015 using an array of 9 tag-detecting receivers (Vemco, Ltd., VR2W) or listening stations deployed at 3 different islands of the archipelago. Four receivers were placed at San Benedicto, two at Roca Partida, and three at Socorro (Fig. 2c). All receivers were covered with duct tape to avoid biological fouling and attached to mooring floats at depths between 20 and 40 m in strategic locations known to be frequented by different species of sharks and pelagic fish.

Listening stations recorded the identity, time and date sharks fitted with acoustic transmitters swam within range of the unit. These data were stored in flash memory until the unit was downloaded to a laptop computer. Swapping of receivers was conducted every 6 months to download the information, clean the receivers and change their batteries.

Data analysis

Detection data from the different study sites was downloaded and initially analysed using the software package VUE version 2.0.6 (Vemco, 2013). Data from all receivers were combined to investigate overall presence and absence at each site.

A residency index (RI) was used to examine shark presence at the three different islands. The residency index for each island was defined as the number of days a shark was detected at this location divided by the number of days monitored (i.e., number of days from the tagging date to the last day of detection.

$$RI = \frac{days\ of\ detection}{days\ of\ monitoring\ time}$$

Shark detections were tested for normality prior to statistical analysis resulting in a non-normally distributed data set (Lilliefors Test: $p > 0.05$). In count data, the variance and the mean value are related, therefore residuals won't be normally distributed. Furthermore, the fact that the data are whole numbers (integers) affects the error distribution. To deal with all these issues, generalized linear models (GLM) with Poisson distribution error were used to examine the influence of site and reproductive stage on the daily number of sharks present. Generalized linear models were implemented using R version 3.0.2 (R Development Core Team 2014).

A general network analysis was used to study how the sharks moved between the different stations and islands. Network analysis is traditionally used to quantify relationships between individuals but has recently been applied to animal movement data (Jacoby et al. 2012). The network consists of a series of nodes (receivers) that are linked by edges (i.e. an individual detected moving from one receiver to another) (Papastamatiou *et al*. 2015). Individuals were separated by reproductive stage, and Chord Diagrams were performed with R Studio to investigate the links formed between stations and islands.

RESULTS

Temporal residency patterns

A total of 35 silvertip sharks (12 males, 22 females, 1 unknown) were acoustically tagged between April 2010 and November 2014. Individuals were tagged at San Benedicto (n = 24), Socorro (n=6) and Roca Partida (n = 5). Shark size ranged from 80 to 200 cm TL, and mean size did not vary significantly between males (105,4 ± 27,9 TL) and females (120,4 ± 42,9 TL; t test=1.0864, df = 30, p=0.2860). Following the criteria stablished by Compagno *et al*. (2015), tagged individuals were classified by reproductive stage, resulting in a total of 6 adults, 26 juveniles and 3 newborns. Individual tag detection totals ranged between 141 and 94.000 detections. However, considering that every transmitter emits a coded pulse at 69 kHz with a random delay of 40–140 s (Hearn *et al*. 2010), data were transformed into daily presence or absence in order to avoid any potential bias.

Data from all nine receivers at the archipelago were combined to investigate the temporal habitat use of individual silvertip sharks. Except for shark T29, no juvenile or newborn individuals were detected in Roca Partida (Fig. 3). Conversely, all adult sharks spent most of its monitoring period in Roca Partida. Shark T32 showed the longest period of continuous presence (absences ≤ 1 day), being registered in Roca Partida during 2.8 years. Adult female sharks T1 and T10 were tagged at the same date and location (Roca Partida) while pregnant, and showed a similar migratory pattern, moving from Roca Partida to Socorro and San Benedicto, respectively, at the same period of the year (Fig. 3).

The monitoring period ranged from 7 to 1165 days (mean ± SD: 553.7± 354.2). Three RI were calculated for each shark (Table 1), corresponding to the different islands of the study: San Benedicto, Roca Partida and Socorro. The island and the reproductive state had significant effects on the IR (Linear Model: $F = 11.73$, p-value < 0.05). Adult individuals had highest IRs at Roca Partida. The island which presented higher IRs (corresponding to juvenile and newborn sharks) was San Benedicto (Fig. 4)

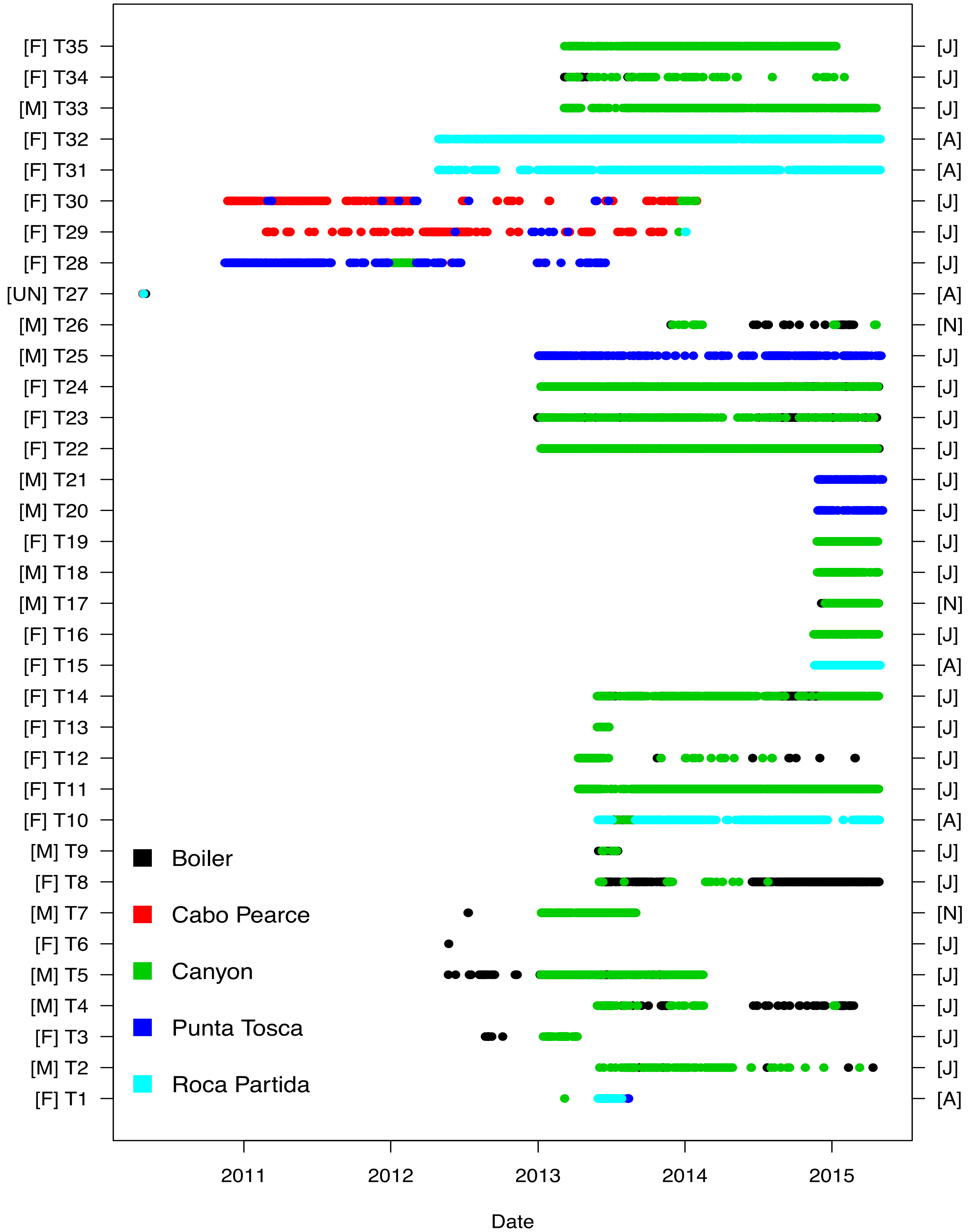

Figure 3. Timeline of the daily detections of sharks at the Revillagigedo Archipelago from April 2010 to July 2015, where each dot represents detection and colour is coded for location. Horizontal axis shows the timeline in years. Vertical left axis represents sex and ID of the sharks (F=female and M=male), while vertical right axis represents the reproductive stage (N=newborn, J=juvenile and A=adult)

Table 1. Summary of the tagged silvertip sharks and their Residency index in each island (RP: Roca Partida, C: Canyon, PT: Punta Tosca, CP: Cabo Pearce)

						Residency Index (RI)		
Shark ID	Tagging location	Total Length (cm)	Sex	Rep. stage	Monitoring period (days)	San Benedicto	Socorro	Roca Partida
T1	RP	200	F	Adult	159	0,006	0,031	0,375
T2	C	166	M	Juvenile	679	0,145	0,000	0,000
T3	C	93	F	Juvenile	228	0,245	0,000	0,000
T4	C	86	M	Juvenile	637	0,211	0,000	0,000
T5	C	89,5	M	Juvenile	633	0,650	0,000	0,000
T6	C	89	F	Juvenile	1	1,000	0,000	0,000
T7	C	81	M	Newborn	417	0,676	0,000	0,000
T8	C	87	F	Juvenile	695	0,546	0,000	0,000
T9	C	150	M	Juvenile	48	0,479	0,000	0,000
T10	RP	200	F	Adult	699	0,063	0,000	0,648
T11	C	111	F	Juvenile	746	0,906	0,000	0,000
T12	C	87	F	Juvenile	688	0,128	0,000	0,000
T13	C	89	F	Juvenile	30	1	0,000	0,000
T14	C	86	F	Juvenile	699	0,777	0,000	0,000
T15	RP	200	F	Adult	164	0,000	0,000	1,000
T16	C	105	F	Juvenile	161	0,937	0,000	0,000
T17	C	85	M	Newborn	142	0,936	0,000	0,000
T18	C	102	M	Juvenile	152	0,756	0,000	0,000
T19	C	97	F	Juvenile	151	0,967	0,000	0,000
T20	PT	113	M	Juvenile	161	0,000	0,484	0,000
T21	PT	89	M	Juvenile	160	0,000	0,706	0,000
T22	C	108	F	Juvenile	840	0,947	0,000	0,000
T23	C	124	F	Juvenile	842	0,402	0,000	0,000
T24	C	97	F	Juvenile	839	0,972	0,000	0,000
T25	PT	102	M	Juvenile	851	0,000	0,357	0,000
T26	C	80	M	Newborn	510	0,109	0,000	0,000
T27	C	175	UN	Adult	7	0,286	0,286	0,143
T28	PT	152	F	Juvenile	945	0,046	0,348	0,000
T29	CP	111	F	Juvenile	1043	0,001	0,158	0,003
T30	CP	129	F	Juvenile	1165	0,015	0,271	0,000
T31	RP		F	Adult	1097	0,000	0,000	0,699
T32	RP		F	Adult	1097	0,000	0,000	0,859
T33	C	121	M	Juvenile	775	0,589	0,000	0,000
T34	C	133	F	Juvenile	695	0,155	0,000	0,000
T35	C	110	F	Juvenile	674	0,846	0,000	0,000

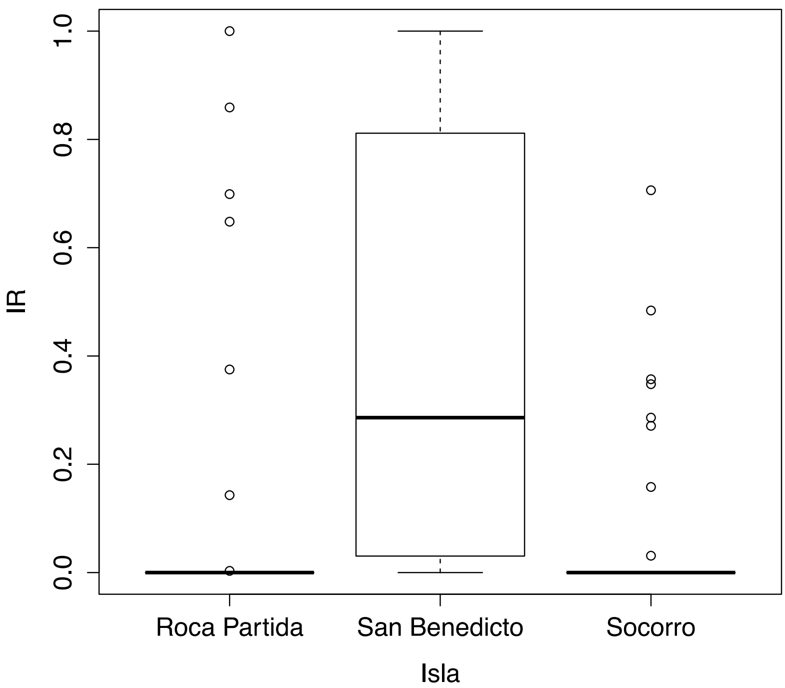

Figure 4. Sharks IR among the different islands

In general, adult sharks showed its higher presence in Roca Partida, while juvenile and newborn sharks had a higher presence in Canyon, San Benedicto (Fig.5). No newborn and juvenile individuals were detected in Roca Partida.

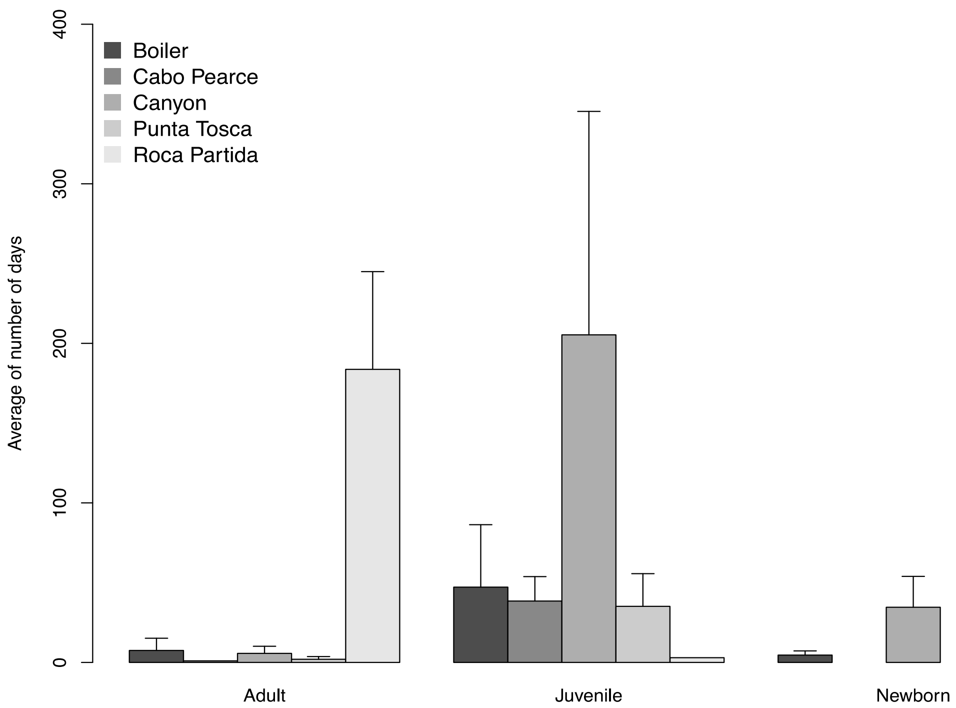

Figure 5. Average number of days present for adult, juvenile and newborn sharks, respectively, at the different locations. Error bars representing standard deviation

A GLM was fitted to evaluate the effect of the location and reproductive stage on shark presence, and a second model was performed including the interaction between both factors. The small sample-corrected Akaike's information criteria (AIC_c) was used to assess model performance. The best-fit model was the second one, revealing significant effects of reproductive stage and location on the daily number of sharks present, and their interaction (Fig. 6). The deviance explained by the model was 71%.

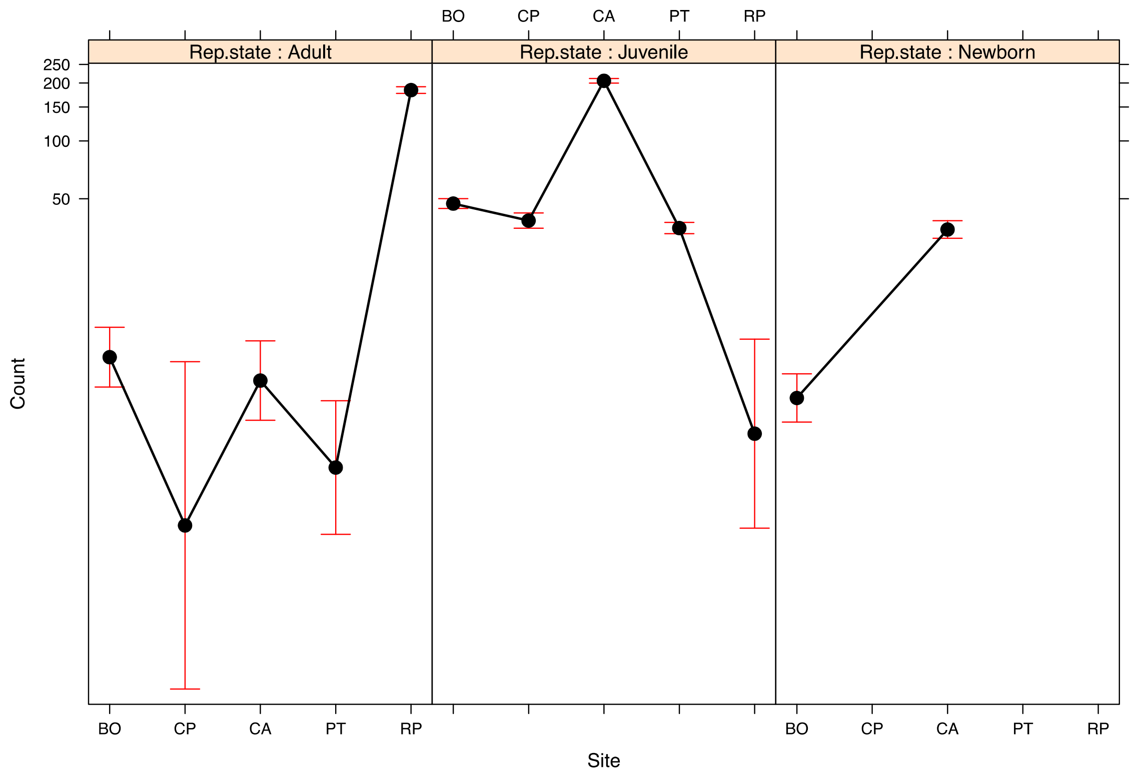

Figure 6. Graphic representation of the GLM. Vertical axis represents the count of days of shark presence. Horizontal upper axis represents the reproductive stage and horizontal down axis is coded for locations (BO: Boiler, CP: Cabo Pearce, CA: Canyon, PT: Punta Tosca, RP: Roca Partida

Inter-island connectivity

The network analysis showed no inter-island movements for newborn individuals. They stayed always near their tagging location, showing movements between the two listening stations located in Boiler and Canyon (San Benedicto Island). On the other hand, juvenile sharks moved around the different stations within the island where they were tagged (San Benedicto and Socorro), and three individuals migrated between both islands, which are separated by 83,3 Km. Only one juvenile, tagged in

Socorro (T29), was detected in Roca Partida 2.9 years after being tagged. All adults were tagged in Roca Partida and they were detected in the three islands with receivers (Fig. 7).

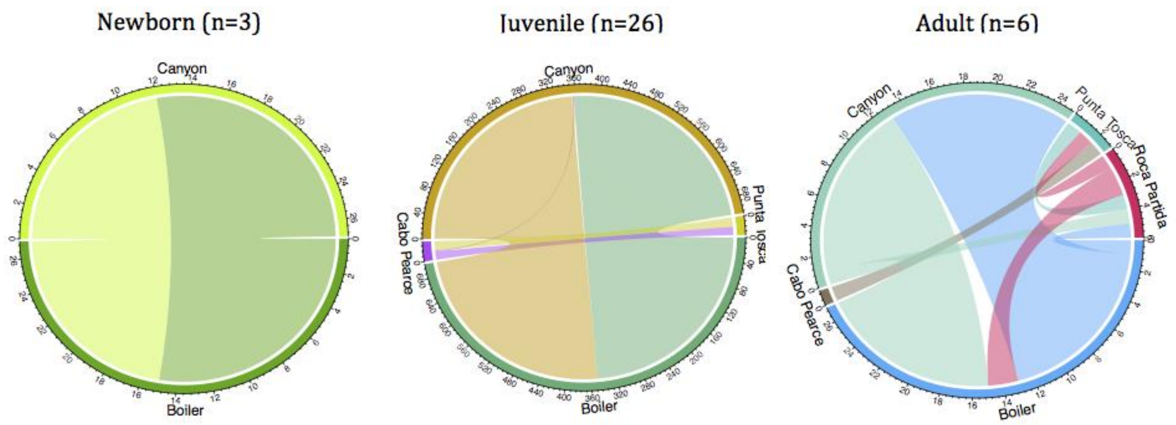

Figure 7. Chrod Diagrams representing links between the different locations for newborn, juvenile and adult sharks, respectively. Colours are coded for locations. Outside numbers correspond to the number of times the link was given

DISCUSSION

This study provides the first detailed examination of habitat use and movement patterns of the silvertip shark in the Tropical Eastern Pacific. Individuals near the birth size were tagged at Canyon, and our data shows a high site fidelity for newborn and juvenile sharks at San Benedicto and Socorro islands. This could be explained by the fact that all the locations in both islands where listening stations were deployed, share similar characteristics: shallow and calm water areas with topographic features providing refuge, and where potential prey occur at higher densities and abundance of predators is low. All the mentioned features represent favourable conditions for young sharks. These areas also fit the criteria stablished by Heupel *et al.* (2007) which suggest that in nursery areas: (1) sharks are more commonly encountered in the area than in other areas, (2) sharks have a tendency to remain or return for extended periods and (3) the area is used repeatedly across years.

By contrast, Roca Partida is a small pinnacle with a near vertical 40-fathom dropoff to the shelf (Richards, 1964). No shallow areas are found all over the area, and upwelling and downwelling currents occur frequently. In general, our data shows no juvenile and newborn sharks present in Roca Partida, only adult sharks have been observed and tagged in this island. Therefore, the absence of young individuals at Roca Partida suggest that this area does not provide favourable conditions for growing, and that is being used by adult sharks for other purpose. However, there is one juvenile shark (T29) detected at Roca Partida after 2.9 years of monitoring period. Kato *et al*. reported a maximum growth rate for silvertip sharks of 30.1% of their body length. According to this, in 2.9 years, shark T29 could have reached its adult size so that would explain the detection at Roca Partida.

Variation in movement and residency of the monitored sharks depending on the reproductive stage could be due to differences in energy requirements. Larger sharks generally have higher energetic requirements than smaller ones (Carlson *et al*. 2004), and consequently, their activity space tends to increase as they grow (Papastamatiou *et al*. 2009). Inter-island movements of the tagged sharks are likely strategies for maximizing foraging opportunities, while reducing the degree of intra-specific competition for resources (Papastamatiou et al. 2013). This could explain the differences in habitat selection between juvenile and adult sharks. Silvertip shark predation events on Whitetongue Jacks (*Uraspis helvola*) have been observed during early morning in Roca Partida (Hoyos-Padilla, personal communication).

The purpose of migrations to Roca Partida other than feeding is unknown, but it may be for reproductive reasons. Adult individuals of our study showed high site fidelity to Roca Partida, and the presence of adult males and females of this species forming schools and several females in a late pregnancy stage (two of them tagged during this study) have been recorded. According to Hearn et al. (2011), foraging and reproduction areas should present high density of prey, high exposure to current, deep waters, and high productivity (associated to upwelling currents). Therefore, Roca Partida could constitute a suitable scenario for silvertip sharks to find potential mates and food resources enough to cover the energy requirements during pregnancy.

Furthermore, acoustic tagging of female scalloped hammerheads in Malpelo, Colombia, has revealed that many female sharks leave oceanic islands during the months of March-April each year to presumably move to pupping grounds located on mangrove forest in mainland areas (Bessudo et al. 2011). In our study, two pregnant females (T1 and T10), which were tagged at the same date at location migrated from Roca Partida to San Benedicto and Socorro for a short period of time, and returned to Roca Partida, which suggests that they could be using San Benedicto and Socorro as pupping grounds. Therefore, the inter-island connectivity may be attributed to reproductive reasons.

This study provides a better understanding of those regions that serve as nurseries for silvertip sharks. Despite being part of a Biosphere Reserve, these areas are popular dive sites which have been subjected to a high pressure by ecotourism activities during lasts years (e.g. high number of divers every day,continuous presence of boats anchoring, etc.). While nursery area protection should remain a component in shark management strategies within the reserve, it will be critical to link early life stage conservation with management strategies that encompass older individuals residing outside nurseries if effective management is to be achieved.

CONCLUSIONS

1- This study provides the first evidence of nursery areas for the silvertip shark in Mexico, at San Benedicto and Socorro islands.
2- Juvenile silvertip sharks remain at nursery areas due to the favourable conditions for foraging and protection against predation. Once they reach maturity, they start to migrate to Roca Partida in order to find food resources with higher energetic value and potential mates.
3- Roca Partida represents a “hotspot” for adult silvertip sharks which spend most of their life there for foraging and mating reasons.
4- This study links early life stage conservation with management strategies that encompass older individuals residing outside nurseries, which should be taken into account by the Mexican authorities and stakeholders if effective management is to be achieved.

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VALORACIÓN PERSONAL (PERSONAL ASSESSMENT)

1. Actividades desarrolladas

Para la realización del presente Trabajo de Fin de Título, se han llevado a cabo diversas actividades que comprenden tanto trabajo experimental como análisis de datos y redacción. A continuación, se describen al detalle dichas actividades:

1.1. Búsqueda bibliográfica de información

Con el fin de ampliar mis conocimientos en el ámbito de trabajo, así como de familiarizarme con la situación y estudios actuales referentes al mismo ámbito, fue necesaria una intensa búsqueda bibliográfica de información sobre aspectos biológicos de la especie a tratar, estudios previos publicados, y otros estudios referentes a técnicas de telemetría acústica, patrones de movimiento y uso de hábitat de especies pelágicas y áreas de crianza de tiburones.

Esta búsqueda de información fue la tarea predominante durante las primeras semanas. Sin embargo, se prolongó durante todo el período de temporalización del trabajo, ya que para el desarrollo del manuscrito, ha sido necesaria una continua consulta y referenciación bibliográfica.

1.2. Trabajo de campo

Se llevaron a cabo dos expediciones científicas al Archipiélago de Revillagigedo. En ellas se realizó el marcaje interno de tiburones punta plateada, durante el cual puse en práctica los conocimientos recibidos con respecto a la cirugía necesaria para la implántación de transmisores acústicos (procedimiento detallado en el apartado "Material and methods").

Además también llevé a cabo la recogida de los receptores colocados en años anteriores para obtener los datos registrados, y el reemplazamiento por nuevos receptores, siendo necesario también reemplazar todo el sistema de cadenas, boyas y cabos. Para ello se hizo uso del equipo de buceo autónomo y de diversas herramientas de trabajo.

1.3. Análisis de datos y redacción del manuscrito

Una vez obtenida la información codificada de todos los receptores acústicos, fue necesario un proceso de tratamiento, filtrado y análisis de los datos con el uso de distintas herramientas informáticas como VUE, Microsoft Excel y R Studio.

Finalmente, se procedió a la redacción del presente manuscrito.

2. Formación recibida

La formación recibida durante el desarrollo de este trabajo ha sido muy extensa. He recibido formación para la identificación y determinación de sexo y estado de madurez de especies de elasmobranquios mediante la asistencia a varias charlas formativas en Pelagios Kakunjá. Asímismo, he recibido formación referente a la tecnología de la telemetría acústica, incluyendo el manejo de marcas acústicas y receptores, así como el marcaje interno de especies de tiburones y la realización la cirugía y sutura necesarias. Asímismo, he sido instruida en el tratamiento de datos con el uso de los programas Excel y R Studio, y he asistido a talleres formativos para el uso de éste último.

Nivel de integración y relaciones con el personal

Mi nivel de integración desde el primer momento fue mucho mejor de lo esperado. Todos los integrantes de Pelagios Kakunjá se mostraron siempre dispuestos a ayudarme en los primeros días y facilitaron mucho mi comodidad en el nuevo entorno y nuevo país. Asimismo, me proporcionaron la oportunidad de poder asistir a dos expediciones de campo y realizar también la parte experimental del trabajo. Mi gran vocación por lo que hacía hizo que todo fluyera con éxito. Debido al poco conocimiento previo en este campo de estudio, tuve que invertir algo más de esfuerzo en lectura de bibliografía sobre telemetría y biología de elasmobranquios. Sin embargo, en pocos días logré alcanzar el ritmo de trabajo adecuado y dominar las técnicas necesarias para pasar a formar parte del equipo.

4. Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT

De entre los aspectos positivos del desarrollo de este trabajo, destaca el gran aprendizaje que ha supuesto para mí. He obtenido conocimientos y formación en una área de aplicación desconocida hasta el momento, lo cual me ha servido para tomar decisiones de cara al futuro. Asimismo, los requerimientos exigidos por la ULPGC para este trabajo se aproximan mucho a los de las publicaciones científicas en revistas, lo cual ha aportado al trabajo una gran utilidad y un muy buen acercamiento al mundo de la investigación científica.

Los aspectos negativos más notables han sido, en primer lugar, las dificultades que conlleva el trabajo con animales vivos, ya que implica que no siempre se dan las condiciones favorables para disponer de la calidad y cantidad de individuos necesarios para el estudio. Además, el manejo de tiburones a bordo para la realización de la cirugía de marcaje es complicado debido a su naturaleza de depredadores acuáticos. Durante este tipo de procesos, el equipo científico sufrió algunos accidentes de leve importancia. En segundo lugar, mi falta de conocimiento en el ámbito de la estadística supuso grandes dificultades a la hora de analizar y trabajar los datos.

A pesar de todo, los aspectos negativos también han supuesto un aprendizaje importante.

5. Valoración personal del aprendizaje

Podría afirmar que, de todo el transcurso de mi Grado en Ciencias del Mar, este último semestre ha supuesto el mayor aprendizaje. La realización de este trabajo es, en mi opinión, una síntesis de todo el conocimiento recibido hasta la fecha, aplicada a un área de trabajo real. Se trata de un ejercicio de recopilación de las herramientas de conocimiento que se nos han proporcionado y el uso de estas para un caso muy cercano a lo que podría ser nuestra futura vida laboral. En mi caso, puedo decir que he resuelto mis dudas en el ámbito profesional, y que gracias a este trabajo ya sé hacia dónde gustaría orientar mi futuro laboral.