Online ISSN: 0718-1957
RBMO

Revista de Biología Marina y Oceanografía
Vol. 57(2): 119-123, 2022
<https://doi.org/10.22370/rbmo.2022.57.2.3531>

Chafing behaviour from two carcharhinid shark species *Carcharhinus falciformis* and *C. galapagensis* on whale sharks *Rhincodon typus*

Comportamientos de frotamiento de *Carcharhinus falciformis* y *C. galapagensis* sobre tiburones ballena *Rhincodon typus*

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Abstract.- This report provides observations regarding chafing interactions from two carcharhinid species, the silky shark, *Carcharhinus falciformis* and the Galapagos shark, *C. galapagensis*, on whale sharks, *Rhincodon typus*, in the Revillagigedo National Park, Mexico. Four events were observed between 2013 and 2019 by means of SCUBA diving and drone aerial surveys. These interactions appeared to be casual and triggered by the large dimensions and slow swimming speed of the whale sharks.

Key words: Ecology, marine protected area, endangered species, Eastern Pacific Ocean

Introduction

Cleaning behaviour is frequently observed in marine fishes (Losey 1972, Araujo *et al.* 2020, Nicolás-Chávez 2022). This type of symbiosis usually occurs in well-defined areas known as cleaning stations, in which the interaction between two or more individuals is involved (Youngbluth 1968, Feder 1996, Quimbayo *et al.* 2016). During the symbiosis, the cleaner species can remove ectoparasites, bacteria, injured tissue, and unwanted food particles (Grutter 1997, Papastamatiou *et al*. 2007). However, the circumstances that favour cleaning behaviours may vary depending on the species, given that the mutual benefits or affectations are poorly understood (Losey 1972, Becerril-García *et al*. 2020a).

Previous observations of cleaning activities between sharks and bony fishes have been observed in the Revillagigedo National Park (RNP; Fig. 1), the largest marine protected area of North America, formed by four volcanic islands (Socorro, San Benedicto, Roca Partida, and Clarion; Fig. 1) and a total surface of 148,000 km^2 (CONANP 2017). This oceanic archipelago hosts 19 species of sharks and 235 species of reef fish, of which 13 are endemic of this region (Spalding *et al.* 2007, Fourriére *et al.* 2016, Becerril-García *et al.* 2020b, Saenz-Arroyo & Camacho-Valdez 2022). In this marine protected area, particular species such as the blacknose butterflyfish *Johnrandallia nigrirostris* and the Mexican hogfish *Bodianus diplotaenia* have been observed cleaning shark species such as the scalloped hammerhead *Sphyrna lewini* (Higuera-Rivas pers. obs.).

Each year, large numbers of silky sharks *Carcharhinus falciformis* are regularly observed swimming near "The Canyon", a popular diving site located in San Benedicto Island and a potential cleaning station for this species (Cortés-Fuentes 2018). Moreover, other carcharhinid species such as the Galapagos shark *Carcharhinus galapagensis*, the silvertip shark *Carcharhinus albimarginatus*, and the blacktip shark *Carcharhinus limbatus* are often observed getting cleaned by *B. diplotaenia* in San Benedicto Island (Higuera-Rivas pers. obs.). Other species such as the whale sharks (*Rhincodon typus* Smith, 1828) visit the RNP seasonally (Fourriére *et al.* 2016, Becerril-García *et al.* 2020b), in which mature females (> 9 m of total length (TL); Norman & Stevens 2007) are observed during November while the presence of juveniles has been reported during all year (Ramírez-Macías *et al.* 2017, Cortés-Fuentes 2018).

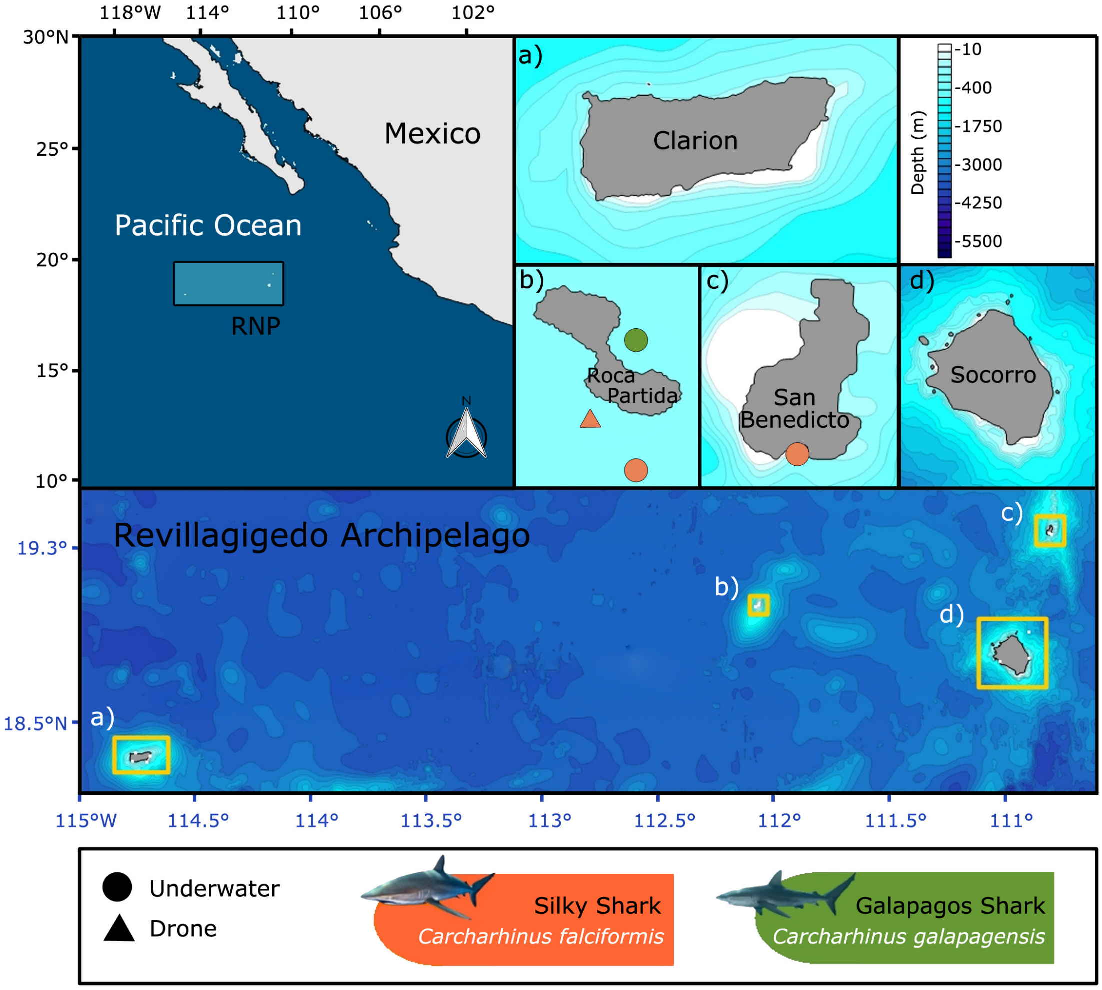

Figure 1. Location of the Revillagigedo National Park (RNP), Mexico and its respective islands (a-d). b-c) Recorded events of chafing behaviors by *Carcharhinus falciformis* (orange) and *C. galapagensis* (green) performed underwater (circles) and by drone (triangle) / Ubicación del Parque Nacional Revillagigedo, México y sus respectivas islas (a-d). b-c) Eventos registrados de conductas de rozamiento por *Carcharhinus falciformis* (naranja) y *C. galapagensis* (verde), realizados bajo el agua (círculos) y utilizando un dron (triángulo)

Previous studies have reported cleaning behaviours between whale sharks and bony fishes in Malpelo Island, Colombia, where a single animal was being cleaned by a king angelfish *Holacanthus passer* (Quimbayo *et al*. 2017). Other cleaning events performed by the blue-streak cleaner wrasse *Labroides dimidiatus* and the moon wrasse *Thalassoma lunare* on whale sharks has also been observed in Cebu Island, Philippines (Araujo *et al*. 2020). Within cleaning interaction, chafing is identified as the behaviour of an organism to curve a part of its body and rub it against a rough surface of another organism (Berthe *et al*. 2017; Williams *et al*. 2022).

In this study, chafing behaviour from the silky and Galapagos sharks were evidenced on the whale sharks in the RNP.

Materials and methods

A total of four interactions between whale shark and carcharhinid sharks (silky shark and Galapagos shark) were observed within the RNP between 2013-2019 (Fig. 2). Whale sharks' photo-identification pictures were taken by photographing key areas including the gills and the pectoral fin on the left side of the body (van Tienhoven *et al*. 2007). These opportunistic interactions were recorded during SCUBA® dives (0-40 m) using a Canon® 5D Mark III and a Canon® 1DX Mark II mounted in a Nauticam© underwater housing, with one of these events being recorded during an aerial survey using a drone DJI® Mavic Pro (Suppl. Mat.; Video S1, S2, S3 and S4).

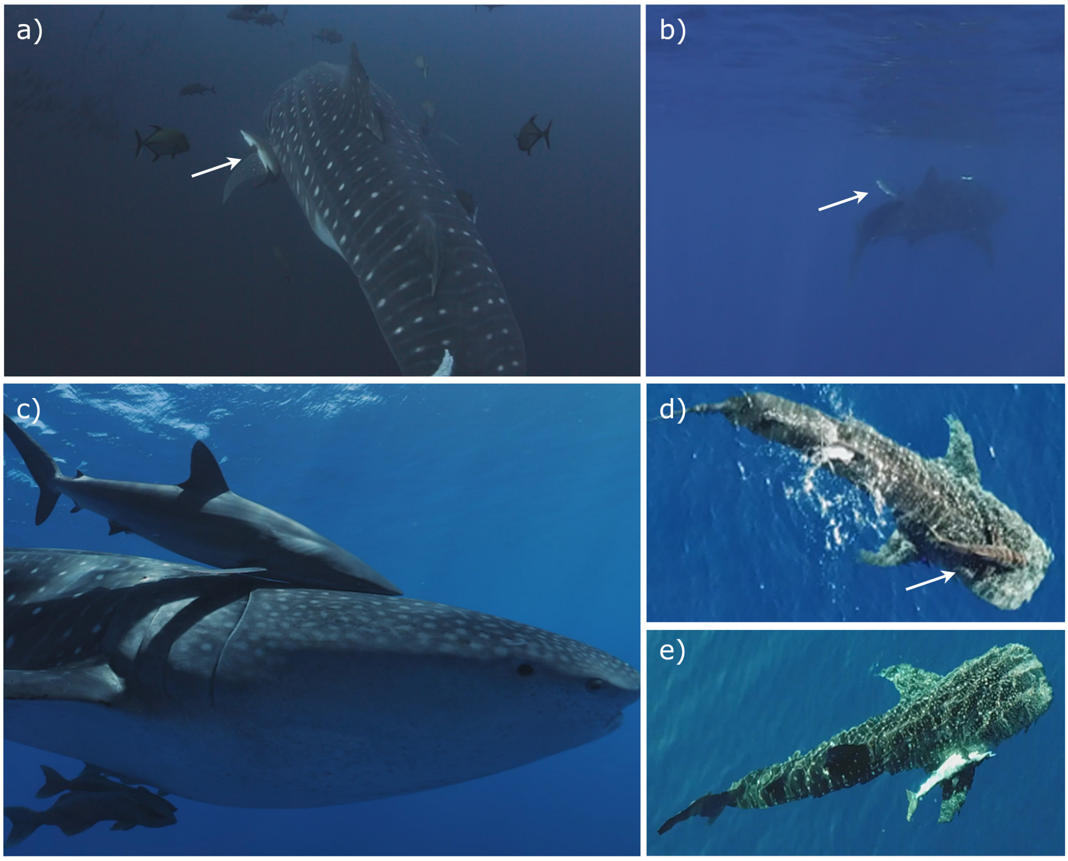

Figure 2. a) Galapagos shark *Carcharhinus galapagensis* chafing on a whale shark *Rhincodon typus* at Roca Partida (white arrow); b) Chafing by a silky shark *Carcharhinus falciformis* on a whale shark *Rhincodon typus* at Roca Partida; c) Silky shark chafing on a whale shark at San Benedicto. d-e) Drone screenshots of a silky shark chafing on a whale shark at Roca Partida. a-c) Photos by Jesús Erick Higuera-Rivas; d-e) Photos by Rodrigo Friscione / a) Rozamiento de un tiburón Galápagos *Carcharhinus galapagensis* en un tiburón ballena *Rhincodon typus* en Roca Partida (flecha blanca); b) Rozamiento de un tiburón sedoso *Carcharhinus falciformis* en un tiburón ballena *Rhincodon typus* en Roca Partida; c) Rozamiento de un tiburón sedoso sobre un tiburón ballena en San Benedicto; d-e) Capturas de pantalla tomadas por un dron en que un tiburón sedoso roza sobre un tiburón ballena en Roca Partida. a-c) Fotos de Jesús Erick Higuera-Rivas; d-e) Fotos de Rodrigo Friscione

Results and discussion

All chafing interactions occurred between 12 and 17:30 h, with the duration of each interaction lasting for a few seconds (1-3 s). In the first interaction recorded on December 2013 at Roca Partida (19.01203; -112.06678), a Galapagos shark (3.0 m TL) was observed at 40 m of depth chafing twice on one adult female whale shark (estimated TL of 13 m) (Fig. 2a). The second event was recorded in June 2014 at the south side of Roca Partida Island (19.01171; -112.06712), where one silky shark (1.9 m TL) was observed chafing twice against the left side of a juvenile whale shark (estimated TL of 6.0 m) that was swimming between 0-5 m of depth (Fig. 2b). The third event was recorded in November 2017 at San Benedicto (19.29899; -110.80817) at a depth of 5 m, where a silky shark (2.X m TL) was observed once rubbing its ventral part of the body on the head of a juvenile whale shark (TL 6 m). (Fig. 2c). Lastly, the fourth event was recorded in April 2019 at the south side of Roca Partida (19.01207; -112.06727). The drone recorded a silky shark (2.0 m TL) near the surface, chafing three times on a juvenile whale shark (estimated TL 5.5 m). The first time the silky shark chafed on the right side of the whale shark, near the beginning of the right pectoral fin (Suppl. Mat.; Video S1, S2, S3 and S4), the second time it chafed and turned on the same side (right of the whale shark; Fig. 2d), while the third time it chafed on the head of the whale shark (Fig. 2e). Only on one occasion, the whale shark had an evasive reaction. In the other events the whale shark responded with no reactions. All the events recorded in Roca Partida occurred in a pelagic zone, periodically visited by whale sharks, that presents a typically rocky substrate (Fig. 1b). The event recorded at San Benedicto occurred 300 m from the island in which sandy bottoms are also present (Fig. 1c). In all events, the swimming direction of the sharks when they chafed over the whale shark occurred from the tail toward the head of the whale sharks.

Cleaning symbiosis involving elasmobranch and bony fishes has been previously reported (Keyes 1982, Papastamatiou *et al*. 2007, Araujo *et al*. 2020, Becerril-García *et al*. 2020a, Nicolás-Chávez 2022). In the RNP, cleaning interactions involving pelagic marine taxa such as carcharhinid sharks are periodically observed in Roca Partida and San Benedicto islands, due to the high abundance of cleaner fish (Fourriére *et al*. 2016). These interactions involve species such as the Galapagos shark and the bluefin trevally (*Caranx melampygus*; Papastamatiou *et al*. 2007); the grey reef shark (*Carcharhinus amblyrhynchos*) and the rainbow runner (*Elagatis bipinnulata*); and the giant Pacific manta *Mobula birostris* with the common remora *Remora remora*, among others (Becerril-García *et al*. 2020a). Cleaning stations in these two islands could influence the presence of several species of sharks, such as silky shark and Galapagos shark, which provide benefits on the health of both species by removing ectoparasites from their skin (Araujo *et al*. 2020, Williams *et al*. 2022).

The seasonal presence of whale sharks at Roca Partida and San Benedicto islands is likely a favourable factor for this kind of events. The large dimensions of the whale sharks might embody an efficient cleaning surface, while its slow swimming, could favour an effective access by the carcharhinid sharks (Meekan *et al*. 2015). According to the images taken in the RNP, both silky and Galapagos sharks appeared to scrub their body against different areas of the whale shark's body (left side, right side, and dorsal area of the head). This behaviour suggests that specific areas of the whale sharks could be more efficient in removing ectoparasite from the sharks compared to others, probably because of the dermal denticle structures. Recent studies show that the dermal denticles of the whale shark have three ridges with different degrees of tightness depending on the area of the animal's body where they are found (Becerril-García *et al*. 2021). Chafing against a specific area rather than a different one could also have an implication on lower predation: as reported by Williams e*t al*. 2022, our observations also indicated that silky sharks prefer to chafe on the whale sharks head (Fig. 2c and d), a position that does not put the chafer at risk. The swimming direction of the cleaning sharks (always towards the head of the whale sharks) might indicate that the friction generated by the dermal denticles could benefit the cleaning (Papastamatiou *et al*. 2007, Feld *et al*. 2019). Lastly, the evasive behaviour of the whale shark, even if it was observed only on one occasion, could indicate that some kinds of negative implications are incurring during the interaction: the touch itself could be a factor of disturbance and/or the transfer of parasites and microbes might be occurring (Pratte *et al*. 2022).

Further studies should focus on the assessment of the ecological implications occurring after opportunistic cleaning interactions (Feder 1996, Cheney & Côté 2001). The role of the whale shark's dermal denticles, which include shape and density in different body parts, as well as the possibility that the whale shark represents a vector in the spread of microbes, should be evaluated in the future given that it could reveal ecological aspects regarding the benefits and affectations from this interaction.

Acknowledgments

The authors thank Rodrigo Friscione for the images provided. Additional thanks to the National Commission of Natural Protected Areas (CONANP) Revillagigedo National Park**.** Photos of the analyzed individuals can be requested from the corresponding author.

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Received 19 October 2021

Accepted 20 May 2022

Supplementary material

Video S1. See: <https://rbmo.uv.cl/images/Videos Material Suplementario 57(2)-119/SI1.mp4>

Video S2. See: <https://rbmo.uv.cl/images/Videos Material Suplementario 57(2)-119/SI2.mp4>

Video S3. See: <https://rbmo.uv.cl/images/Videos Material Suplementario 57(2)-119/SI3.mp4>

Video S4. See: <https://rbmo.uv.cl/images/Videos Material Suplementario 57(2)-119/SI4.mp4>