



## RESEARCH ARTICLE

# How to Kill Another Shark: A First Inside Look at a Potential Hunting Strategy of the Galapagos Shark

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### Abstract:

#### Background:

Close-up videos of sharks foraging on other live sharks are rare, especially when it comes to footage of the entire duration of an event.

#### Objective:

Our goal was to present an in-depth analysis involving a Galapagos shark, *Carcharhinus galapagensis*, foraging on a whitetip reef shark, *Triaenodon obesus*.

#### Method:

A frame by frame video examination was used to highlight the different aspects of this bout.

#### Results:

Several behavioral characteristics, including the somewhat cryptic approach, the extensive shaking once the Galapagos shark had the whitetip reef shark between its jaws, and devouring tail-first, stand out in this event.

#### Conclusion:

The entire act appeared very smooth, indicating that this bout, or at least parts thereof, may represent a common hunting strategy for Galapagos sharks.

**Keywords:** Behavior, Galapagos shark, Hunting strategy, Selachivorous, Whitetip reef shark, Videos.

## 1. INTRODUCTION

It is commonly accepted that sharks occasionally forage on other live sharks [1 - 3]. Although video-sharing websites and TV channels have occasionally offered insights into potential selachivorous bouts in the past [4 - 6], the videos were either taken from too far away, were incomplete, reflected kleptoparasitism during shark fishing, or did not show the actual kill but merely a clash between two sharks without any observable consequences for either of them [7]. Thus, none of those videos are particularly useful for reaching an understanding of the potential behavioral characteristics underlying a bout between two sharks. As a consequence, existing data primarily stems from stomach content analyses [8 - 10] without any indications of how the shark pursued, killed and devoured the other shark.

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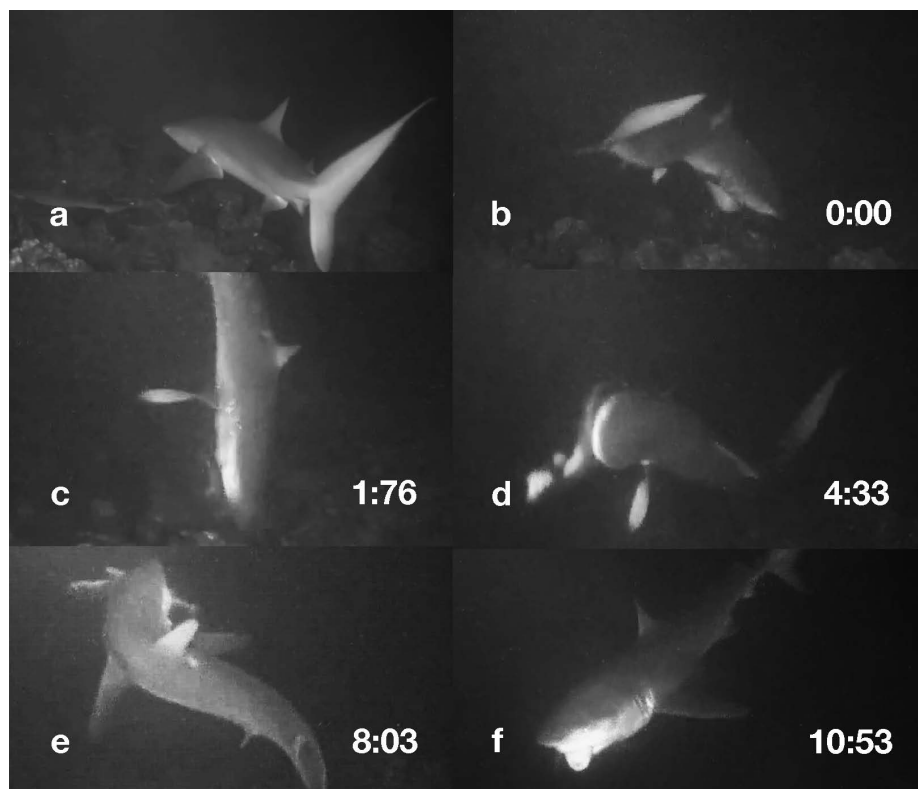
Here, we describe a close-up video sequence of the first documented predatory bout of a Galapagos shark, *Carcharhinus galapagensis*, a fairly common species [11 - 13], killing and swallowing a whitetip reef shark, *Triaenodon obesus*. We discuss the different parts of the bout regarding the potential influence of the external circumstances where the kill took place. The incident was observed during a night dive; thus the kill was probably affected to some extent by the proximity of the divers as well as the lights they used. Still, the bout appeared rather fluid and effective, suggesting that at least some sections of it reflect general characteristics of a Galapagos shark's potential hunting strategy.

## 2. METHODS AND RESULTS

On the evening of April 29, 2015, a group of divers did a night dive at the “Manuelita Coral Garden” site within the Archipelago of Cocos Island, Costa Rica. An area of about 100 m<sup>2</sup> was illuminated during the dive. While observing whitetip reef sharks, a Galapagos shark moved into the illuminated area, milled around for a few seconds, then killed and consumed one of the whitetip reef sharks. The entire bout lasted around 15 seconds from the initial contact to the last gulp and was filmed in 720p HD at 30 frames/second. The size of the two sharks could not be measured accurately, but the Galapagos shark was estimated by one of the authors (AM) to be close to 2.5m in length, not uncommon around Cocos Island [14], whereas the whitetip reef shark, based on comparison to the Galapagos shark, seemed to be about a quarter of that length.

To better describe the bout, the event was divided into four phases: prowl, contact, manipulation, and devouring.

**Prowl**—During the moments before the kill, the Galapagos shark lowered its head twice towards a whitetip reef shark swimming in front and one swimming beneath its position (see supplemental video). However, it didn't pursue either of them any further. How long the Galapagos shark was on the prowl prior to the recorded bout remains unknown (Fig. 1a).



**Fig. (1).** Galapagos shark forages on a whitetip reef shark. (a) Galapagos shark prowls prior to the attack. (b) Frontal body area torques towards prey, begin of the actual contact with the prey. (c) Vertical position to enhance pressure onto the whitetip. (d) Shaking prey and moving grip posteriorly. (e) Aligning with whitetip shark to swallow tail-first. (f) Devouring whitetip shark. Numbers reflect duration in fraction of seconds from the beginning of first contact (Fig. 1b).

### 2.1. Contact

Immediately before the hit, the Galapagos shark appeared to turn in accordance with the swim pattern of the chosen whitetip reef shark, directly below. The predator then torqued its frontal body area towards the seafloor (Fig. 1b) and pinned down its prey. This motion was immediately followed by shifting its entire body into a vertical position, pushing the prey into the reef (Fig. 1c). The initial bite was aimed at the gill area of the whitetip reef shark. The duration of this phase was less than three seconds.

### 2.2. Manipulation

Once the whitetip reef shark was caught square between the jaws of the Galapagos shark, the predator shook it for about six seconds (Fig. 1d). During this phase, the Galapagos shark changed its hold from mid-body to the tail of the whitetip reef shark. Despite the continued shaking, neither gouging nor ripping of the prey apart occurred.

### 2.3. Devouring

The onset of this phase transpired seamlessly after the final head shake (Fig. 1e). Although the Galapagos shark gulped six times to swallow the entire whitetip shark, after the first three gulps that took around two seconds, only parts of the whitetip's head remained visible. It could not be determined if the whitetip reef shark was already dead when being swallowed or just immobilized (Fig. 1f). The entire act of devouring took around six seconds.

## 3. DISCUSSION

The hunting strategies of most shark species are poorly understood since direct observations are rare, except for white sharks, *Carcharodon carcharias* [15 - 17], tiger sharks [18] and a few other species [19 - 21]. But even among those species, selachivorous bouts are poorly described or not documented at all, and any potential hints primarily stem from stomach content analyses [22 - 24].

Although the video presented is a single event and should be interpreted with caution, especially since it happened within the range of divers holding flashlights, the fluid execution and the smooth transitions between the individual phases suggest that this is potentially a general strategy for Galapagos sharks around Cocos Island.

It is likely that the dive lights increased the numbers of fish gathering which could then have attracted more whitetips [25 - 27]. Although an advantage for the Galapagos shark is possible and the lights may have facilitated the shark's foraging behavior, the opposite could also be true, and the predator was blinded by the lights and thus moved away from them. This potential drawback, however, would then raise the question of why the Galapagos shark swam into the lights in the first place. Since the potential effect of the divers and their lights can't be determined, it can also not be established which parts of the bout transpired by chance due to those influences and which ones reflected genuine characteristics of this predator's hunting strategy. Some of the better-known shark species show an array of strategies when going after prey, ranging from laying in wait to stalking and actively chasing prey down [28 - 30]. The recorded strategy could be interpreted as stalking or stealth and indeed appeared cryptic to the milling whitetips. Outwardly, the Galapagos shark seemed just to cruise along but was indeed searching for a suitable whitetip reef shark to attack, highlighted by its head motions while on the prowl. It is most plausible that the targeted whitetip was unaware of the imminent attack since the Galapagos shark was directly above the whitetip when striking. The Galapagos shark only had to torque its body downward to capture its prey without an actual forward motion, indicating that the attempt was intentional. Intent to strike is further supported by the observation that the Galapagos shark aimed for the gills, the most unprotected and exposed part of a shark's body regarding the location of the heart.

The subsequent shaking by the Galapagos shark seemed excessive bearing in mind the rather small size of the whitetip reef shark. The much larger size of the Galapagos shark would suggest a single, well-placed bite could immobilize the prey and thus be sufficient to begin the devouring process; hence the extended shaking may have been a deliberate strategy. Neither of the two most apparent potential strategies, either gouging or severing the prey's body into two parts, occurred. A third possibility is that the actual shaking was part of the intended strategy to either immobilize or kill the prey. This last option has some merit considering the fluid transition from shaking to the actual devouring phase. Assuming the shift between shaking and the start of devouring was deliberate, then it would be easy to understand why a tail-first swallowing of the whitetip reef shark occurred.

Examination of the manipulation phase shows that the way the Galapagos shark swallowed the prey appeared to be methodical; thus it is a likely possibility that this form of devouring is a common strategy for Galapagos sharks. This

does not exclude head-first swallowing. However, such swallowing would require facing potential prey before an attack, or then manipulating prey while holding on to it. Head-first swallowing is often preferred, especially among teleosts, where such orientation prevents a prey's body parts like opercula, fin rays, or spines from flaring outward during swallowing [31 - 33]. Since a large portion of a Galapagos shark's diet includes teleosts [12], head-first swallowing therefore seems most likely. Interestingly, when great hammerheads, *Sphyrna mokarran*, swallow stingrays, *Dasyatis americana*, they do it in a head-first fashion as well, although their initial attack occurs from behind [34]. For hammerheads, the most likely reason for this strategy is that the ray's tail barb could flare in a tail-first swallowing scenario.

In addition to teleosts, mollusks, crustaceans, and even certain mammals belong to the Galapagos shark's diet, suggesting this species to be an opportunistic hunter [11, 12, 35]. A more stationary population along Cocos Island, where food availability remains less diverse, could have a more specialized diet than more broadly ranging populations of this species. In this case, it is likely that whitetip reef sharks belong to the regular diet for the Cocos population. However, without detailed stomach content analyses for members of the population from Cocos Island, the content of their usual diet cannot be accurately known. Bearing in mind how frequently Galapagos and whitetip reef sharks are observed around Cocos Island (personal observation, EKR), it is likely that whitetips are common prey which is also consistent with the bite volume of the larger Galapagos shark. The bite volume reflects the maximum dimension of a single bite a shark can gouge from a larger animal [36] and is comparable to gape size [3, 37, 38]. Bite volume for average-sized Galapagos sharks thus may be an indicator of the maximum size of prey that could be consumed whole. Using the size and width of the whitetip reef shark and the estimated bite volume of the Galapagos shark seen in this video suggests that prey selection and devouring it whole did likely not happen by chance. Assuming that the particular prey size was aimed for by the Galapagos shark, the location for the attack could also have been deliberately chosen. The fewer obstructions that an environment has, the less restricted the pursuit of prey will be. The reef structure in this bout offered whitetip reef sharks some protection, which likely contributed to the early abortion of the two prior possible attempts to go after whitetip reef sharks before the actual bout. The selection of this particular whitetip reef shark could indicate primarily that the Galapagos shark saw an appropriately sized whitetip move into a favorable position and took the chance.

The two initial attempts prior to the real bout could indicate that a fitting prey may indeed have to be in a specific location where it could be pinned down, but also in a favorable body orientation, such as perpendicular to the predator's main body axis and by extension its jaws, and not exceeding a certain size. This would suggest some form of foraging plasticity to take into account the environment and body form [39 - 41]. However, such a choice may simply reflect a situational artifact when being presented with several prey species rather than being an indicator of natural steps taken during a bout when going after a single prey.

Whitetip reef sharks are a typical reef dwelling species. Should Galapagos sharks indeed hunt for them occasionally, they would likely have adapted their strategy to the point where structural reliefs matter. Therefore the hunting success recorded in this video would likely reflect such an adaptation.

#### **ETHICS APPROVAL AND CONSENT TO PARTICIPATE**

Not applicable.

#### **HUMAN AND ANIMAL RIGHTS**

Not applicable.

#### **CONSENT FOR PUBLICATION**

Not applicable.

#### **CONFLICT OF INTEREST**

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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