The COVID-19 pandemic and the impact on the absence of
diver-shark interaction on blacktip reef shark’s agonistic
behavior: Morotai case

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Abstract. Prior to COVID-19 pandemic, Morotai waters was well known as one of the favorite
destination for shark watching tourism in Indonesia. Similar to other animal sighting tourism in
Indonesia, shark diving has been hit hard by the pandemic of COVID-19 and has been banned
since April 2020. However, the absence of tourist or diver on the shark dive site brings
opportunity to investigate the impact of prolonged absence of diver-shark interaction on the
blacktip reef shark’s agonistic behavior. The researches on blacktip reef shark’s agonistic
behavior were conducted using diver operated video technique in monthly basis from May to
October 2020. These data were compared with the previous diver-shark interaction videos from
January 2013 to February 2020. Comparison of both pre-COVID-19 pandemic and during
COVID-19 pandemic found that the blacktip reef shark’s agonistic behavior toward diver were
not affected significantly by the absence of diver.

1. Introduction
Shark diving has been introduced in Morotai at 2013, and since then it grows as one of the main shark
tourism destination with the value (2017 value) was estimated as 1,322,380 USD/year [1]. Among
approximately 771,171.07 (mean 2017 value) shark diver went to Indonesia to watch shark [1], 8,935
of them visit Morotai. As the country which sit in rank-4 of the most economically valuable shark
diving country [2], the increase of shark diver visit to Indonesia may potentially impact the shark
behavior during interaction between diver and shark underwater.

History of shark-human interaction in Indonesia can be tracked since the early Java kingdom era,
as can be seen on several pictures in Borobudur Temple (built at 824 AD) [3]. Further research
showed that shark pictures were also found at Prambanan Temple, Penataran Temple, and Surawana
Cave [3]. Apart from shark picture found on the temples, local belief on some families in Aru Island
showed that they thought that they are the descendant of the crocodile and shark [4]. However,
massive shark catching which has been growing since 19th centuries [5] change the image of shark as
an economical commodity. Self-contained underwater breathing apparatus (SCUBA) diving activities
in Seribu Islands since 1970s [6] increase the interaction between human and shark underwater. These
diver – shark interaction boosted commercially by the opening of whale shark watching in
Cenderawasih Bay since end of 1990s [7].

Albeit there are long histories of interaction between human and shark, complete behaviour
repertoire of sharks is largely unknown [8]. The behaviour of lemon shark (Negaprion brevirostris)
had been investigated since 1950s by treating them with a feed in exchange for their behavior
observation [9]. Investigation on grey reef shark (Carcharhinus menisorrah) and blacktip reef shark
Carcharhinus melanopterus) behavior on determining the target during observation were conducted in
1960s [10]. Shark behavior research in Eniwetok Atol [11] showed that grey reef shark (C. menisorrah) and blacktip reef shark (C. melanopterus) has ability to detect the smell of baited fish and their behavior responses were recorded as activity index.

For the purpose to interpret and understand shark behaviour, researcher must understand shark’s capabilities and how shark’s sense function underwater [8]. Agonistic displays of grey reef shark (C. amblyrhynchos) are the correct signals of their defensive behaviour when interact with diver [12]. In order to correctly measure the agonistic behaviour of sharks, presentation of ethogram which captures the discrete measurable agonistic display unit has to be recorded [13].

Shark agonistic behaviour and display element which have been reviewed are consisted of at least 29 discrete postures [14]. Despite, until 2007, only eight of them were observed on blacktip reef shark (C. melanopterus). Recent study in Morotai waters [3], Indonesia showed that blacktip reef shark (C. melanopterus) have up to 31 agonistic displays (however two of them, rapid turn right and rapid turn left may not related to agonistic displays), significantly more complex than previously observed. Figure 1 below shows the complete displays of blacktip reef shark in Morotai waters.

![Figure 1. Shark agonistic display element in Morotai waters, Indonesia [3]](image)

Lorenzini ampullae is electromagnetic sensory organ which only exists on the shark and ray’s head [15]. This sensor consists of vesicle sensor which communicate the sea water through the narrow canal, which is filled with jelly, to the shark’s skin surface [16]. Kalmijn [17] described that Lorenzini ampullae is not only sensitive to heat and mechanical stimulation, but also responded to the weak electromagnetic field. Study on bamboo shark (Scyliorhinus canicula) and ray (Raja clavata) showed that elasmobranch utilizes the Lorenzini ampullae significantly to detect the electromagnetic wave transmitted by their prey.

2. Materials and Method

2.1. Field work

This research project is the continuation of previous work [3] on black tip reef shark behaviour in the same location (primary and secondary observation from 2013 to 2019). On this project, shark behaviour display elements were measured in Blacktip Point, Pulau Mitita, Morotai, Maluku Utara (Figure 2) during COVID-19 pandemic from May 10th, 2020 to October 10th, 2020. Geographically, Blacktip Point is situated on 1°58’12” N-128°13’54” S, northward Mitita Island, Morotai, North Mollucas, Indonesia. Location is selected since it is in the proximity of shark diving site in Morotai, which has highest population of blacktip reef shark [18]. Hence, it is considered as the place with highest likelihood to encounter blacktip reef shark (C. melanopterus).
Blacktip reef shark behavior (*C. melanopterus*) observation is conducted using diver operated video (DOV) method – or video recording operated by self-contained underwater breathing apparatus (SCUBA) diver to capture the specific agonistic display of shark behavior. DOV is recognized as having high potential as research method – especially for teleost research on the coral reef habitat [19]. Hand feeding is employed to attract the blacktip reef shark as well as to reveal the agonistic behavior of the shark during feeding frenzy. A protective clothing of Shark Armor™ – which is made of chained stainless steel – is worn by the professional feeder to ensure safety during observation.

**Figure 2.** Map of observation site (green: land, blue: sea, red dots: dive sites)

**Figure 3.** Professional feeder using fish to attract the shark during observation
Figure 3 showed the professional feeder using Shark Armor™ lured blacktip reef shark. Feed given by professional shark feeder to attract the shark is limited by no more than 100 g per shark individual per diving (once a month) as to not impair the normal diet of the blacktip reef shark.

In order to record the behavior displays of blacktip reef shark, a checklist which register the observed behavior element of the C. melanopterus is prepared (as the basis, 31 display element of blacktip reef shark behavior were enlisted). Kawulich [20] did not suggest to observe all of the behavior of sharks in series, albeit it is recommended to focus on evaluated behavior display elements. Ideally, observation (on blacktip reef shark agonistic display) should be taken each month or within the certain periodic time. However, this not the case for Morotai waters since there are some delay or rearrangement due to bad weather or heath protocol restriction due to COVID-19 pandemic.

Carcharhinus melanopterus is selected as the species to be observed since it is commonly found across Indonesia and it is abundant in observation point [21]. Previous study [18] showed that at least 21 of different blacktip reef shark individuals are found in the observation point (blacktip point). No diving activity were found on location between end of March 2020 and early May 2020, when the research was commenced. This situations (absence of diving activities) were maintained until the last observation data was taken on October 10th, 2020. The absence of divers on observation location is critical to ensure the result of the shark behaviour study as a comparison to those shark – diver interaction prior to COVID-19 pandemic.

Morotai waters is characterized as having mild to strong current (0 to 3 knots) and warm temperature (27 to 31°C) [22]. Other study showed that other water parameter in Morotai are as follow: pH between 8.13 – 8.44 [23], salinity between 34 – 36 PSU [23], and visibility varies between 5 to 17 meters [24].

2.2. Data Analysis
Basic 31 agonistic behavior element display of blacktip reef shark (Carcharhinus melanopterus) as shown in Figure 1 above will be used to compare the behavior before and during COVID-19 pandemic. The number of agonistic behavior element display during the present and absence of tourist-divers is then compared in order to evaluate whether the blacktip reef shark (Carcharhinus melanopterus) behavior is changed when their interaction with the human is significantly reduced or absence. Study is also aimed to record any new blacktip reef shark behavior display element which may not displayed previously in the pre-COVID-19 pandemic time.

3. Result and Discussion
3.1. Agonistic behavior element display in the reduced or absence of tourist-shark interaction
In total, observation of blacktip reef shark (C. melanopterus) were conducted seven times between May 10th – October 10th 2020. No tourism activities were observed in Blacktip Point during this period, as the local government applied strict regulation to ban any tourism activities in Morotai between March to October 2020. Results of the blacktip reef shark (C. melanopterus) behavior observation showed that there are slightly decreasing in the number of agonistic behavior element display during absence of tourism activities compared to pre-COVID-19 era.

As shown in the Table 1 below, there are 6 out of 29 agonistic behavior element displays (approximately 20%) of blacktip reef shark (melanopterus) were absence during COVID-19 pandemic. They are: head shaking, ritualistic jaw snapping, open jawed tooth raking, gill pouch billowing, torso thrusting, and Palatoquadrate protrusion. However, there were four new agonistic behavior element displays became clearly observed during absence of tourism activities in Blacktip Point (rapid right sideway snap, rapid left sideway snap, snout depression, and touch responding). In overall, there are only approximately 6% of blacktip reef shark (C. melanopterus) agonistic behavior element displays decreasing during absence of tourism activities in Blacktip Point, Morotai.
Table 1. Comparison of blacktip reef shark agonistic behavior element display pre and during COVID-19 pandemic.

| No | Shark Agonistic Behavior Element Display | Before COVID – 19 Pandemic | During COVID – 19 Pandemic |
|----|----------------------------------------|-----------------------------|--------------------------|
| 1  | Stiff or Jerky Movement                | Yes                         | Yes                      |
| 2  | Pectoral Fin Depression                | Yes                         | Yes                      |
| 3  | Back Arching                           | Yes                         | Yes                      |
| 4  | Tail Flexure                           | Yes                         | Yes                      |
| 5  | Tail Depression                        | Yes                         | Yes                      |
| 6  | Sniut Elevation                        | Yes                         | Yes                      |
| 7  | Head Shaking                           | Yes                         | No                       |
| 8  | Jaw Geping                             | Yes                         | Yes                      |
| 9  | Jaw Closing                            | Yes                         | Yes                      |
| 10 | Ritualistic Jaw Snapping               | Yes                         | No                       |
| 11 | Open Jawed Tooth Raking                | Yes                         | No                       |
| 12 | Gill Pouch Billowing                   | Yes                         | No                       |
| 13 | Torso Thrusting                        | Yes                         | No                       |
| 14 | Palatoquadrate Protrusion              | Yes                         | No                       |
| 15 | Tail Slapping                          | Yes                         | Yes                      |
| 16 | Flank Displaying                       | Yes                         | Yes                      |
| 17 | Body Shivering                         | Yes                         | Yes                      |
| 18 | Body Tilting / Rolling                 | Yes                         | Yes                      |
| 19 | Rapid, Tight, Pattern Swimming         | Yes                         | Yes                      |
| 20 | Laterally Exaggerated Swimming         | Yes                         | Yes                      |
| 21 | Looping                                | Yes                         | Yes                      |
| 22 | Corkscrewing                           | Yes                         | Yes                      |
| 23 | Reduced Swimming Efficiency            | Yes                         | Yes                      |
| 24 | Charging                               | Yes                         | Yes                      |
| 25 | Ramming With Snout                     | Yes                         | Yes                      |
| 26 | Give Away                              | Yes                         | Yes                      |
| 27 | Follow Give Away                       | Yes                         | Yes                      |
| 28 | Stand Back                             | Yes                         | Yes                      |
| 29 | Rapid Withdrawal                       | Yes                         | Yes                      |
| 30 | Right Sideway Snap                     | Unclear                     | Yes                      |
| 31 | Left Sideway Snap                      | Unclear                     | Yes                      |
| 32 | Snout Depession                        | No                          | Yes                      |
| 33 | Touch Responding                       | No                          | Yes                      |

The decreasing of the agonistic behavior element displays may be related to the convergent properties of showing honest information to the diver (instead of rivals, in term of shark – human interaction) about the magnitude and fighting capacity of the signaler [25]. Human presence in the proximity of the shark habitat are providing stimuli to elicit shark agonistic behaviour [14], therefore the more diver presence in the shark habitat, the number agonistic behaviour may be increased. A dense group of divers or large disperse group of divers (which usually were presence in Blacktip Point...
prior to COVID-19 pandemic) is suspected to be more provocative to sharks (hence, they display more agonistic behaviour elements) and this situation may be considered as supernormal stimulus [26].

3.2. Rapid Side-way Snaps
Even though they were found prior to the COVID-19 pandemic [2], the rapid right sideway snap and the rapid left sideway snap were not clearly understood and observed. In the absence of frequent shark – human interaction during COVID-19 pandemic, blacktip reef shark showed clear agonistic behaviour element displays of sideway snaps in each of observation data collection between May 10th, 2020 to October 10th, 2020. Figure 4 showed the clear right sideway snap and left sideway snap of blacktip reef shark when they quickly ambush the feed from the professional feeder’s hand.

![Figure 4. Rapid right-side and left-side sideway snaps of blacktip reef shark](image1)

Despite were not enlisted in Martin’s agonistic display elements [14], sideway snap behaviour elements were observed on other shark species, e.g. grey reef shark (*C. amblyrhynchos*) [27], great white shark (*Carcharodon Carcharias*) [13], and great hammerhead shark (*Sphyrna mokarran*) [28]. Unique fact is also found that blacktip reef shark is having tendency to snap the feed in the right sideway snap movement (compared to ramming with snout and left-sideway snap). Figure 5 showed the proportion between ramming with snout, right sideway snap and left sideway snap.

![Figure 5. Comparison of ramming with snout, right sideway and left sideway snap movement](image2)
As found by Kalmijn [17], shark can use their Lorenzini ampullae to correctly locate the prey by sensing its electromagnetic wave transmitted by the prey. However, the number of Lorenzini ampullae pores between left side and right side of the shark head are never been evaluated. Random checking on four black tip reef shark heads on Tobelo fish market (Tobelo is approximately 24 km westward Morotai) showed that number of Lorenzini ampullae pores in right side of the head are higher than of left side of the head. Figure 6 below showed the difference of Lorenzini ampullae pores between left and ride of the blacktip reef shark’s head on four individual in Tobelo Market.

![Figure 6. Lorenzini ampullae pores between left and ride of the blacktip reef shark’s head on four individual in Tobelo Market](image)

The difference of the Lorenzini ampullae pores between left side and right side of the blacktip reef shark head may contributes on why the blacktip reef shark have tendency to prefer right sideway snap to ambush the feed provided by professional feeder during observation.

4. Conclusion
It is found that approximately 20% (head shaking, ritualistic jaw snapping, open jawed tooth raking, gill pouch billowing, torso thrusting, and Palatoquadrate protrusion) of blacktip reef shark (C. melanopterus) agonistic behavior element display were absence during COVID-19 pandemic. Instead, there were four new agonistic behavior element displays became clearly observed during absence of tourism activities in Blacktip Point (which are: rapid right sideway snap, rapid left sideway snap, snout depression, and touch responding). As the result, there are only approximately 6% of blacktip reef shark (C. melanopterus) agonistic behavior element displays decreasing during absence of tourism activities in Blacktip Point, Morotai, which indicates that the behavior of blacktip reef shark may not be significantly affected by the absence of the diver in their habitat. New fact was also found that blacktip reef shark has tendency to snap the feed in right sideway snap mode. This may be contributed by the number of Lorenzini ampullae pores of right side of the blacktip reef shark head which higher...
than the left side. Further study is required to confirm the effect of difference number of *Lorenzini ampullae* pores of both side of blacktip reef shark head to their sideways snap preference.

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