Correlation Between Existence of Reef Sharks with Abundance of Reef Fishes in South Waters of Morotai Island (North Moluccas)

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Abstract. Despite increasing academic research citation on biology, abundance, and the behavior of the blacktip reef sharks, the influence of reef fish population on the density of reef sharks: Carcharhinus melanopterus and Triaenodon obesus population in its habitat were largely unassessed. This present study examined the correlation between abundance of reef fishes family/species with the population of reef sharks in Southern Waters of Morotai Island. The existence of reef sharks was measured with the Audible Stationary Count (ASC) methods and the abundance of reef fishes was surveyed using Underwater Visual Census (UVC) combined with Diver Operated Video (DOV) census. The coefficient of Determination (R²) was used to investigate the degree of relationships between sharks and the specific reef fishes species. The research from 8th April to 4th June 2015 showed the strong positive correlations between the existence of reef sharks with abundance of reef fishes. The correlation values between Carcharhinus melanopterus/Triaenodon obesus with Chaetodon auriga was 0.9405, blacktip/whitetip reef sharks versus Ctenochaetus striatus was 0.9146, and Carcharhinus melanopterus/Triaenodon obesus to Chaetodon kleinii was 0.8440. As the shark can be worth more alive for shark diving tourism than dead in a fish market, the abundance of these reef fishes was important as an early indication parameter of shark existence in South Water of Morotai Island. In the long term, this highlights the importance of reef fishes abundance management in Morotai Island’s Waters to enable the establishment of appropriate and effective reef sharks conservation.

1. Introduction
The reef sharks (family: Carcharhinidae) are predominantly found in Indo-Pacific waters with three of its species most commonly sighted near shores [25-26]: Blacktip reef shark, Carcharhinus melanopterus; grey reef shark, Carcharhinus amblyrhinchos; and whitetip reef shark, Triaenodon obesus. Human activity affects the on-going collapse of coral reef ecosystem which further domino effect to lesser the reef sharks population. Recent estimation suggested the shark population has declined regionally by 90% or more in 30 years [9]. The observation on Cleveland Bay, Australia, showed the decline of 71% of juvenile Carcharhinus melanopterus within almost two years [36], while other examination in Great Barrier Reef indicated the reduction of whitetip reef sharks (Triaenodon obesus) population by 7% annually and gray reef sharks (Carcharhinus amblyrhynchos) population by 17% yearly [26].
Coral reefs are used by variety of shark species [35] as their unique habitat. Blacktip reef shark (*Carcharhinus melanopterus*) is known for its relatively high site fidelity by living in their coral reef’s home range (up to 21 km²) for 12.61% to 84.57% of their life [30]. Given this high residency of blacktip reef sharks, the change in this predator population has caused trophic cascading effect in their coral reef’s habitat [5]. Tropical lagoons or coral reefs have ten components of food chain [3]: macroalgae, planktons (zooplankton and phytoplankton), and coral reef at the base of food chain; omnivore (including corallivore), planktivore, and herbivore at the second level of trophic; piscivore and large carnivore at the trophic level three; mesocarnivore (reef sharks) at the trophic level four; and apex predator (pelagic sharks) at the top trophic level.

One indicator of a healthy coral reef ecosystem is the abundance of herbivore fishes - as well as omnivore and planktivore [21], as this means the reduced population of macroalgae [10]. The dynamic of the food chain in the coral reef ecosystem shows that the presence of reef sharks (mesopredator) may promote the abundance of herbivore [28], as this group are critical to the progress and outcome of coral recovery. In other study, herbivore abundance increases in the area protected from shark fishing were observed only after cyclone disturbance [27]. However, as a response, other study showed that during the recovery period, abundance of herbivorous fishes increased significantly on both fished and unfished reefs, but the magnitude of this increase where greater on reefs where shark was still present [28].

Morotai waters are located in the middle of world's coral triangle where three of the most common reef sharks (Blacktip reef shark, whitetip reef shark, and gray reef shark) are present [22]. Only 2% of the Morotai waters have been explored and these areas mostly lie in southern part of Morotai waters. There were fast declining of life coral reef coverage in Morotai Waters from 1996 to 2002 (41.1%) and 17.4% loss from 2002 to 2013 [33]. Other study on the research location showed that the life coral coverage in Niomi Point (flat), Blacktip Point (flat), Fariman (flat) and Eagle Ray Point (slope) were 48%, 52%, 22% and 45.95% respectively [13,22] Comparative study in south waters of Morotai Island shows the value of shark diving industry is 568 times higher than the value shark fishing/shark finning [11]. Thus, it is important to understand the correlation between the existence of reef sharks with the abundance of reef fishes in this area to establish effective conservation means as well as the tool for determining the reef shark existence.

2. Methodology

Sampling was conducted on 4 different coral reefs (stations) around south waters of Morotai Island in April – June 2015. Selection of the stations is based on previous research location with additional stations in Niomi Point and Eagle Ray Point are selected based on report of shark sighting records by Shark Diving Indonesia (Ichsan et al., 2015). Station A is located at N 01° 58’ 29.1” E 128° 14’ 13.9”, Station B lies in N 01° 58’ 13.4” E 128° 14’ 03.6”, Station C is located at N 01° 58’ 29.5” E 128° 15’ 01”, and Station D is on N 02° 01’ 35.5” E 128° 13’ 12.2”. Complete location of all observation stations on the Morotai Island’s map is shown in Figure 1 below.
Figure 1. Observation stations in south waters of Morotai Island

Materials used for this research are: two (2) sets of basic SCUBA diving gear for one researcher and her buddy, one (1) underwater slate, one (1) transect meter, one (1) squeezable empty mineral water bottle, one (1) GPS locator, one (1) underwater camera. For analysis purposes, following tools were used: SPSS™ statistical software, Microsoft Excel™ 2007 version, Reef Fish Identification Books. Survey is conducted in each station every week between April to June 2015, eight (8) weeks in total, except in Station C which has one survey canceled out due to weather condition (safety reason).

We measured the existence of reef sharks with the Audible Stationary Count (ASC) method. ASC method is developed since 1970s using low-frequency sound (such as continuous squeezing of empty plastic bottle) to attract reef sharks to a stationary point [6]. It was demonstrated that ASC could be reliable to attract reef sharks at 80 m from the stationary point [16], with average response up to 250 m away [37]. Attracted reef sharks came by the stationary point were counted and recorded on underwater slate. Visibility during surveys was reliable enough (between 10 – 20 m) to reduce the counting error during census.

We surveyed the abundance of herbivore and carnivore reef fishes using Underwater Visual Census (UVC) surveys with a combination of Diver Operated Video (DOV) census. UVC has been used to estimate the densities of the reef fishes since 1950s [4]. There are two methods of UVC: transect count (an experienced diver swam at constant speed along the transect and noted the reef fish species observed on a slate) and point count (an experienced diver stayed at a vantage point and noted the surrounding reef fish species observed on a slate). UVC with transect and point count have relatively similar significance \( p = 0.054 \) and \( 0.048 \) for 10 hectare count respectively, therefore both censuses is deemed reliable [32] to be selected for small area of survey. Novel method, combination of UVC and diver operated video (DOV) presents great potential to count the abundance of reef fishes in a research station (Tessier et al., 2013).

Identified reef fishes were then classified based on classification on www.fishbase.org. Set of data of the number of reef sharks sighted during ASC and abundance of reef fishes based on their diet category were then analyzed using \( R^2 \) coefficient of determination to examine the degree of relationship between two variables. The coefficient of determination must represent a goodness-of-fit and it must be unit free, should range from 0 to 1, where 1 represents a perfect fit. There are eight expressions for \( R^2 \) appears as [13]:
However, for the efficiency in analysis we used Microsoft Excel™ to obtain the $R^2$ value through linear regression between two variables, the interpretation of the correlation values are as follows [38]:

\[
R_I^2 = 1 - \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} \\
R_r^2 = \frac{\sum(y - \hat{y})^2}{\sum(y - \bar{y})^2} \\
R_0^2 = \frac{\sum(y - \bar{y})^2}{\sum(y - \bar{y})^2} \\
R_1^2 = 1 - \frac{\sum(e - \hat{e})^2}{\sum(y - \bar{y})^2}, \quad e = y - \hat{y}, \\
R_x^2 = \text{squared multiple correlation coefficient} \\
\text{between the regressand and the regressors} \\
R_y^2 = \text{squared correlation coefficient} \\
\text{between } y \text{ and } \hat{y} \\
R_3^2 = 1 - \frac{\sum(y - \hat{y})^2}{\sum y^2} \\
R_4^2 = \frac{\sum \hat{y}^2}{\sum y^2}
\]

3. Results

3.1. Shark existence

There are two reef sharks species found during the survey: blacktip reef shark (*Carcharhinus melanopterus*) and whitetip reef shark (*Triaenodon obesus*), none of the grey reef shark is observed during the survey. Figure 2 and Figure 3 below shows the existence of blacktip reef sharks and whitetip reef sharks respectively each week in four observation stations. None of the grey reef shark (*Carcharhinus amblyrhinchos*) was found in all research stations during the period of observation. The maximum blacktip reef shark aggregation in one station is 11 individual recorded in station B (blacktip point), while station D (eagle ray point) showed that averagely low blacktip shark sighting.
Figure 2. Existence of Blacktip Reef Shark in four observed stations

The frequency of sighting of white tip reef shark is between 0 – 3 sharks/dive, with the maximum aggregation is 3 at Niomi Point (Station A). No sighting of *Triaenodon obesus* in blacktip point (station B) was ever recorded.

Figure 3. Existence of Whitetip Reef Sharks in four observed stations
3.2. Abundance of reef fishes in south waters of Morotai Island

There are 117 - 121 species from 32 families of reef fishes recorded in four observed stations in south waters of Morotai Island with abundance variety from 1.11 individuals/m² in station D to 1.59 individuals/m² in station C. *Pomacentrus auriventris* and *Chromis margaritifer* were two species of reef fishes that most abundant in Southern Waters of Morotai Islands. The most common reef fishes families found in Morotai Island’s Southern Waters were pomacentridae, labridae, balistidae, and acanthuridae.

| Station ID | Total No. of Observed Fishes | No. of Species | Abundance (ind/m²) | Abundance of Dominant Species (%) | Abundance of Reference Species (%) |
|------------|-----------------------------|----------------|-------------------|-----------------------------------|-----------------------------------|
| A          | 11,455                      | 119            | 1.39              | Xanthichthys caeruleolineatus (14.84%), Chromis margaritifer (7.49%) | Ctenochaetus striatus (1.99%), Chaetodon kleinii (2.08%), Chaetodon auriga (0.22%) |
| B          | 13,737                      | 119            | 1.57              | Chromis margaritifer (8.23%), Pomacentrus burroughi (7.41%) | Ctenochaetus striatus (2.02%), Chaetodon kleinii (2.42%), Chaetodon auriga (0.17%) |
| C          | 13,025                      | 117            | 1.59              | Xanthichthys caeruleolineatus (15.15%), Pomacentrus auriventris (13.58%) | Ctenochaetus striatus (0.96%), Chaetodon kleinii (1.57%), Chaetodon auriga (0.12%) |
| D          | 10,012                      | 121            | 1.11              | Pterocaesio pisang (13.31%), Neoglyphidodon crossi (5.50%) | Ctenochaetus striatus (0.55%), Chaetodon kleinii (0.73%), Chaetodon auriga (0.11%) |

3.3. Correlations between reef sharks and reef fishes

Analysis result of the observed data of the existence of sharks and abundance of reef fishes in four stations are shown in the Table 2 below.

| Fish          | Shark | C. auriga | C. kleinii | C. striatus |
|---------------|-------|-----------|------------|-------------|
| Shark         | 1     | 0.9405    | 0.8440     | 0.9146      |
| C. auriga     | 0.9405 | 1         | 0.7430     | 0.9277      |
| C. kleinii    | 0.8440 | 0.7430    | 1          | 0.9148      |
| C. striatus   | 0.9146 | 0.9277    | 0.9148     | 1           |

3.4. Shark existence

The existence of reef sharks in south waters of Morotai Island was confirmed during eight (8) weeks observations. Two of the main reef sharks that were observed exist in Morotai Island’s south water are: blacktip reef sharks (*Carcharhinus melanopterus*) and whitetip reef sharks (*Triaenodon obesus*) with the density of 0-11 individuals and 0-3 individuals respectively. As previous research [16] hypothesised that reef shark could reliably use their hearing sensory at 80 m (2 ha of area) to approach the low frequency emitted sound from ASC method, then the density of reef sharks could be assumed as follow in Table 3.
Table 3. Reef sharks density (individuals/hectare) in observed stations with ASC

| Station ID | Blacktip reef shark | Whitetip reef shark | Combined |
|------------|---------------------|---------------------|----------|
| A          | 3.5 – 4.5           | 0 – 1.5             | 0 - 6    |
| B          | 2.5 – 5.5           | 0                   | 2.5 – 5.5|
| C          | 0 – 3.5             | 0 – 1               | 0 - 4    |
| D          | 0 – 1.5             | 0 – 0.5             | 0 - 2    |

Comparative study between this research results with other reef sharks census [25] in Great Barrier Reef shows that the existence of sharks in Morotai Island's south water was considered as higher (up to 2.61 sharks/ha in GBR compared to 6 sharks/ha in Morotai Island).

3.5. Abundance of reef fishes
Comparing the density of reef fishes in south waters of Morotai Island to Koh Phangan and Koh Tao in Thailand (Pusch, 2011) shows that they were almost similar (1.59, 1.77, and 1.4 individuals/m² respectively). However, abundance of reef fishes from four observed stations in Morotai Island showed the very strong correlation with the abundance of the reef fishes in Pulau Langkawi [1] with the coefficient of determination of 0.9578. This very strong correlation between Morotai Island and Pulau Langkawi may be affected by the average life coral cover in both islands that is not too different (42% and 35%, respectively).

In most area, the damselfishes (Pomacentridae spp.) were the most abundant, with the percentage varies from 18.10% in Nha Trang Bay to 93.51% in western area of Biawak Island [39], as it shown in Table 4 below. Some fish family such as Balistidae spp. That were abundant in Morotai is not exist in all another area. This may relate with the geographical factor which shows that Morotai is further east compared to other area and it is affected directly by the Pacific Ocean current.

Table 4. Abundance of Reef Fishes Comparison between Morotai and Other Area in Indo-Pacific

| Fish Family | Morotai (%) | Tapanuli Selatan (%) | Nha Trang Bay (%) | Langkawi (%) | West Biawak (%) |
|-------------|-------------|----------------------|-------------------|--------------|-----------------|
| Pomacentridae | 42.64 | 30.09 | 18.10 | 65.62 | 93.51 |
| Labridae | 12.90 | 3.52 | 19.10 | 8.82 | 2.88 |
| Balistidae | 11.44 | N/A | N/A | N/A | N/A |
| Acanthuridae | 9.31 | 0.998 | 4.40 | N/A | N/A |
| Caesionidae | 5.94 | 3.46 | N/A | 6.64 | 0.72 |
| Chaetodontidae | 4.59 | 3.18 | 5.90 | 3.47 | 1.08 |
| Anthinnae | 3.38 | N/A | N/A | N/A | N/A |
| Holocentridae | 1.49 | N/A | N/A | 0.58 | N/A |
| Nemipteridae | 1.47 | N/A | N/A | 0.98 | 1.08 |
| Pomacanthidae | 1.40 | 1.94 | 1.10 | 0.12 | N/A |
| Mullidae | 1.19 | 0.15 | N/A | 0.02 | N/A |
| Scaridae | 0.37 | 2.26 | 1.70 | 5.82 | 0.36 |
| Siganidae | 0.14 | 0.59 | 6.20 | 1.27 | N/A |
| Apogonidae | 0.02 | 52.85 | N/A | 1.61 | N/A |
| Zanclidae | 0.56 | N/A | N/A | 0.29 | N/A |

3.6. Correlation between reef shark and reef fishes
The correlation value between reef sharks vs Chaetodon auriga, Chaetodon kleinii and Ctenochaetus striatus in south waters of Morotai suggested that the relation between the existence of reef sharks as predator were very strong (value = 0.9405, 0.8440, 0.9146 respectively). All of the survey locations are categorized as outer reef flats except station D (Eagle Ray Point), which is slope. The previous
study shows that *Ctenochaetus striatus* have been observed foraging on the outer reef flats [14, 20] and prefer areas of high water motion [19]. Another study also shows that *Ctenochaetus striatus* were more abundant on outer reef slope rather than inner atoll rim reef slopes [29]. These were consistent with the *Carcharhinus melanopterus* that was heavily relied on their feed (site fidelity of 67%) in the outer reef [18].

It has been long hypothesised that butterfly fishes (Chaetodontidae) could be used as bio-indicator of coral health [24]. Strong correlation between chaetodontidae and life coral coverage has been studied in Buton, Sulawesi Tenggara and resulted in coefficient of determination of 0.73 [40], while other examination in Nusa Penida waters showed strong correlation of 0.6628 [49] and surveyed in Batam, Riau Islands Province showed the coefficient of determination of 0.5625 [41]. In reverse, the extensive life coral coverage depletion was strongly decline the abundance of the butterfly fishes [21]. Hence, the strong relationship between reef shark in Morotai with the butterfly fishes (represented by *Chaetodon kleinii* and *Chaetodon auriga*) may indirectly indicate strong bonding between reef sharks and its coral habitat.

Several previous studies have suggested that the habitat use or site fidelity of predators may reflect a relationship to prey abundance in that area (e.g.; [42-44]). The primary characteristic of the nursery area that included abundant food has been focused in the several shark nursery studies [45-47]. Earlier diet study showed that *Carcharhinus melanopterus* feed mostly on teleost (bony fish) with the percentage of 56.8% at Northern Australia [48], 99.7% at Queensland, Australia [50], and 44.44% at Palmyra Atoll, Polynesia [51], 52% at Great Barrier Reef [52], and 56% at Alaska [54]. Detailed diet analysis of *Carcharhinus melanopterus* and *Triakisodon obesus* has been examined by the research at Great Barrier Reef [52], while the Grey reef shark (*Carcharhinus amblyrhinchos*) was studied in the Hawaiian Island [34]. Composition of the blacktip reef shark and whitetip reef shark diet and Morotai’s reef fish abundance shows in Table 5 below.

*Triakisodon obesus* is well suited for feeding on reef animals, as indicated by the study at Hawaii [53] which suggest that whitetip reef shark feed on surgeon fish (acanthuridae). Table 5 also shows that all of the common prey for the reef sharks (blacktip reef shark, whitetip reef shark and grey reef shark) mostly are available in Morotai. Dominant prey such as pomacentridae, acanthuridae, labridae, and caesionidae were also found as abundant in Morotai waters. This showed that Morotai waters are the suitable ecosystem for the reef sharks.

### Table 5. Comparison of Blacktip/Whitetip Reef Fish Diet and Abundance of Reef Fishes in Morotai

| Fish Family | Blacktip reef shark (%)\(^1\) | Whitetip reef shark (%)\(^1\) | Grey reef shark (%)\(^2\) | Abundance in Morotai (%)\(^3\) |
|-------------|-------------------------------|-------------------------------|--------------------------|---------------------------|
| Labridae    | 23.0                          | 16.69                         | 0                        | 12.90                     |
| Fistulariidae | 23.0                          | 0                             | 0                        | 0.04                      |
| Atherinidae | 15.38                         | 0                             | 0                        | 0.00                      |
| Scaridae    | 7.69                          | 50.00                         | 6.15                     | 0.37                      |
| Muraenidae | 7.69                          | 0                             | 18.80                    | 0.00                      |
| Pomacentridae | 7.69                          | 0                             | 0                        | 1.40                      |
| Lutjanidae | 7.69                          | 0                             | 0                        | 0.38                      |
| Synodontidae | 7.69                          | 0                             | 0                        | 0.14                      |
| Acanthuridae | 0                             | 16.67                         | 12.69                    | 9.31                      |
| Caesionidae | 0                             | 16.67                         | 0                        | 5.94                      |
| Apogonidae | 0                             | 0                             | 0                        | 0.02                      |
| Holocentridae | 0                             | 0                             | 18.80                    | 1.49                      |
| Pomacentridae | 0                             | 0                             | 6.15                     | 42.64                     |

[6, 34]
4. Conclusion

The existence of reef sharks represents the density of predator in south waters of Morotai Island was confirmed and even higher than that of another area (such as Great Barrier Reef, Australia). The correlation between reef sharks and bio-indicator fishes (Chaetodon auriga, Ctenochaetus striatus, and Chaetodon kleinii) suggested that they are strongly positive interrelated. Strong correlation between reef sharks and chaetodontidae may represent strong indirect effect of the live coral coverage with the reef sharks.

As the economic value of the recreational shark diving is 568 times higher than the extractive economic value of shark finning, the presence of Chaetodon auriga, Ctenochaetus striatus, and Chaetodon kleinii are important as the initial indicator of the shark abundance in the dive site. This highlights the importance of these reef fishes abundance management in south waters of Morotai Islands to enable the establishment of appropriate and effective reef sharks conservation.

Since there was very limited reef shark's diet study, especially in Indonesia, it is suggested that further studies should focus on the reef shark diet to examine the relationship between the stomach content and the prey (reef fishes) abundance.

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