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

Darmawan Ahmad Mukharror[1] , Isnaini Tiara Baiti[2] , Muhammad Ichsan[1] , Niomi Pridina[1], Sanny Triutami[1]

[1]Shark Diving Indonesia Morotai, Kampung Yayasan, Daruba, Morotai
[2]Marine Science Department, FPIK, Universitas Padjdjaran, Jl. Raya Bandung-Sumedang KM 21, Bandung

Email: darmawan_ahmad_m@yahoo.com

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 (R^2) 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 amblyrhyncos*) 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 km^2) 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 01º 58' 29.1" E 128º 14' 13.9", Station B lies in N 01º 58' 13.4" E 128º 14' 03.6", Station C is located at N 01º 58' 29.5" E 128º 15' 01", and Station D is on N 02º 01' 35.5" E 128º 13' 12.2". Complete location of all observation stations on the Morotai Island's map is shown in Figure 1 below.

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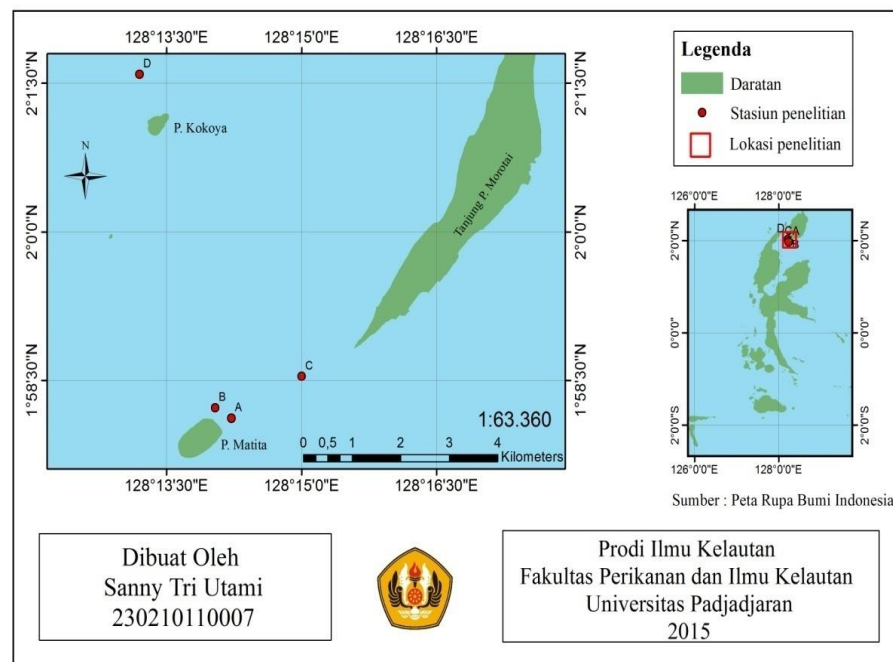
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Figure 1. Observation stations in south waters of Morotai Island

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^{TM} statistical software, Microsoft Excell^{TM} 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]:

$$R_1^2 = 1 - \sum(y - \hat{y})^2 / \sum(y - \bar{y})^2$$

$$R_2^2 = \sum(\hat{y} - \bar{y})^2 / \sum(y - \bar{y})^2$$

$$R_3^2 = \sum(\hat{y} - \bar{\hat{y}})^2 / \sum(y - \bar{y})^2$$

$$R_4^2 = 1 - \sum(e - \bar{e})^2 / \sum(y - \bar{y})^2, \quad e = y - \hat{y},$$

$$R_5^2 = \text{squared multiple correlation coefficient between the regressand and the regressors}$$

$$R_6^2 = \text{squared correlation coefficient between } y \text{ and } \hat{y}$$

$$R_7^2 = 1 - \sum(y - \hat{y})^2 / \sum y^2$$

$$R_8^2 = \sum \hat{y}^2 / \sum y^2$$

However, for the efficiency in analysis we used Microsoft Excell^{TM} to obtain the R^2 value through linear regression between two variables, the interpretation of the correlation values are as follows [38]:

0.00 - 0.19	=	very low
0:20 - 0.39	=	low
0:40 - 059	=	moderate
0.60 - 079	=	strong
0.80 - 1.00	=	very strong

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.
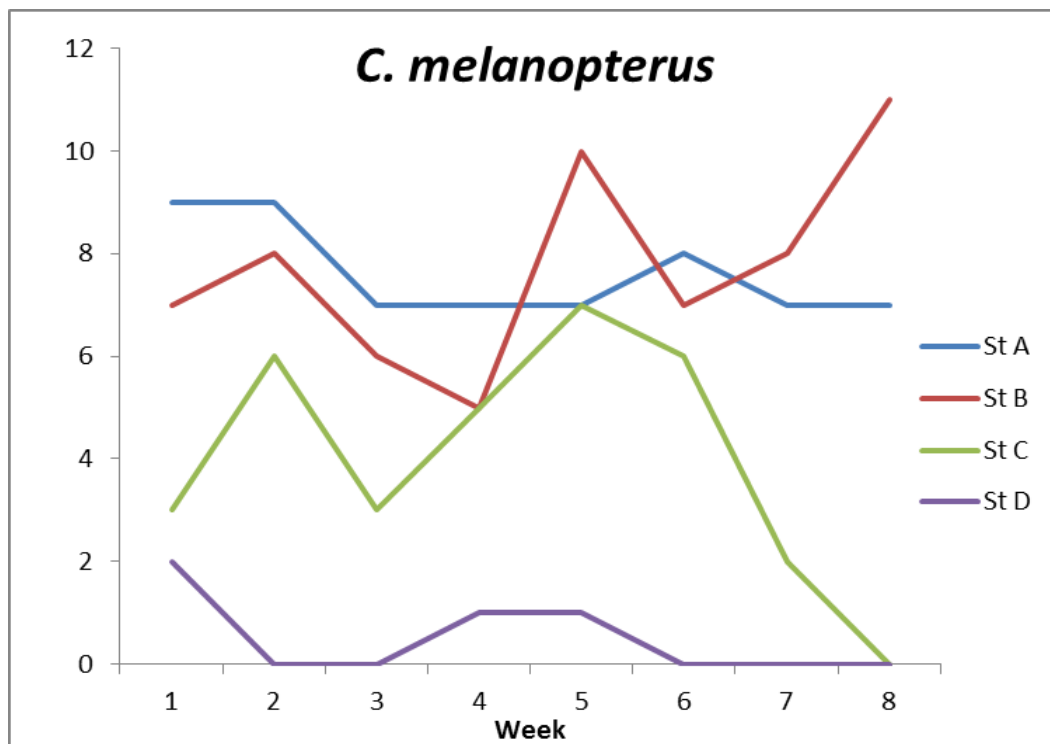
Figure 2 Existence of Blacktip Reef Shark in four observed stations

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.
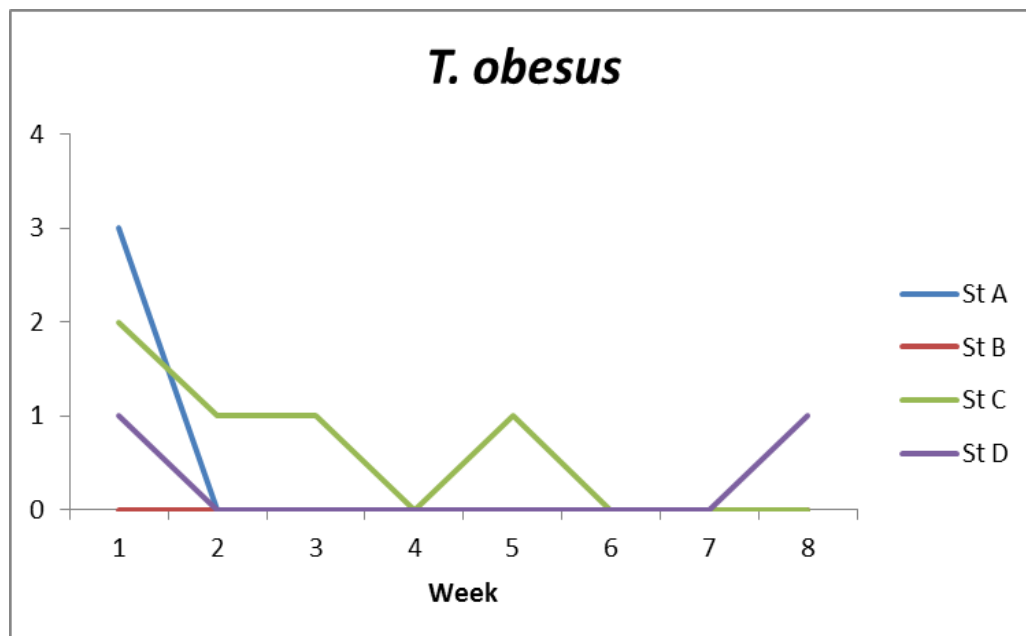

Figure 3. Existence of Whitetip Reef Sharks in four observed stations

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.

Table 1. Abundance of Reef Fishes in four observed station in south waters of Morotai Islands

Station ID	Total No. of Obsereved Fishes	No. of Species	Abundance (ind/m^2)	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.

Table 2. Correlation between reef sharks, herbivore and carnivore

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 Moratai 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/m^2 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 *Triaenodon 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.

Triaenodon 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
Pomacanthidae	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.

References

[1]   Andersson, Karin. 2002 A Study of Coral Reef Fishes along a Gradient of Disturbance in the Langkawi Archipelago, Malaysia. Undergraduate Thesis, Uppsala University

[2]   Bornatowski H., et al. 2014 Ecological Importance of Sharks and Rays in a Structural Foodweb Analysis in Southern Brazil. *ICES J. Of Mar. Sci..* 71: 1586-1592.

[3]   Bozec, YM, et al.., 2004 Trophic Model of Lagoonal Communities in Large Open Atoll. *Aquat. Liv. Res.* 17: 151-162

[4]   Brock VE., 1954 A Preliminary Report on a Method of Estimating Reef Fish Populations. *Wildl. M'ment.* 18: 297-308

[5]   Dulvy NK., et al. 2004 Coral Reef Cascades and the Indirect Effects of Predator Removal by Exploitation. *Ecol. Letters.* 7: 410-416.

[6]   Frisch, Ashley J. 2013 The Dr. Dorothea Sandars and Irene Lee Churchill Fellowship to Develop Robust Methods for Measuring and Monitoring Reef Shark Populations. Fellowship Report No. 158, Winston Churchill Memorial Trust of Australia.

[7]   Frisch, A., et.al. 2016 Reassessing the Trophic Role of Reef Sharks as Apex Predator on Coral Reef. *Coral Reefs.* 35: xxx-xxx

[8]   Goldman, B and FH. Talbott., 1976 Aspect of the Ecology of Coral Reef FIshes. In: Jones, OA and R. Endean (eds) Biology and Geology of Coral Reefs VII. Academy Press, New York.

[9]   Heithaus, MR. et al. 2007 Predicting Ecological Consequences of Marine Top Predator Declines. *TREE.* 913: 1-9.

[10]   Hughes, TP. et al. 2007 Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change. *Curr. Bio.* 17: 360-365.

[11]   Ichsan, Muhammad, et al. 2015 Shark Diving Tourism in Morotai, North Maluku, Indonesia. Sharks and Rays Symposium Proceeding. WWF Indonesia, Jakarta, pp 183-188.

[12]   Karimah, Ashma, et al. 2017 Status of Coral Reef Ecosystem and Indication of Coral Bleaching Event in Morotai Island Waters, North Mollucas. The 4th International Marine and Fisheries Symposium, Makassar.

[13]   Kvalseth, Tarald O. 1985 Cautionary Notes About R^2. *The American Statistician.* 39:4: 279-285.

[14]   Marshell, A., P.J. Mumby 2012 Revisiting Functional Roles of Surgeon Fishes *Acanthurus nigrofuscus* and *Ctenochaetus striatus*. *Coral Reefs.* 31: 1093-1011.

[15]   Mourier, Johann and Serge Planes, 201. Direct Genetic Evidence for Reproductive Phylopatry and Associated Fine-Scale Migrations in Female Blacktip Reef Sharks in French Polynesia. *Mol. Ecol.* 22: 201-214.

[16]   Myberg et al. 1976 Attraction of Free Ranging Sharks by Low Frequency Sound. In: Schuijf A, A.D. Hawkins (eds) Sound Reception in Fish. Elsevier, Amsterdam. Pp 205-228

[17]   Nanami, Atsushi and Moritaka Nishihara. 2003. Effects of Habitat Connectivity on the Abundance and Secies Richness of Coral Reef Fishes. *Mol. Ecol.* 22: 201-214

[18]   Mc Cauley, D.J., et.al.. 2012 Assessing the Effect of Large Mobile Predator on Ecosystem Connectivity. *Ecol. Application* 22(6): 1711-1717

[19]   Nelson, S.G., S. DeC. Wilkins. 1988 Sediment Processing by Surgeon Fish *Ctenochaetus Striatus* at Moorea, French Polynesia. *J. Fish Biol.* 32: 817-824

[20]   Polunin, N.V.C., D.W. Klump, 1989 Ecoligial Correlates Foraging Periodicity In Herbivorous Reef Fishes in teh Coral Sea. *J. Exp. Mar. Biol. Ecol.* 126: 1-20

[21]   Pratchett, MS. et al. 2014 Reef Degradation and the Loss of Critical Ecosystem Goods and Services Provided by Coral Reef Fishes. *Curr. Op. In Env. Sus..* 7: 37-43

[22]   Pridina, Niomi. 2015 Distributions of Reef Shark based on the Characteristic of Habitat on Morotai Waters, North Maluku. Undergraduate Thesis, Universitas Padjadjaran.

[23]   Pusch, Susanne. 2011 Effect of Tourism on Herbivore Community Compositions in Coral Reefs in the Gulf of Thailand. Diploma thesis, Universitat Muenchen

[24]   Reese, E.S., 1981. Predation on Coral by Fishes of the Family of Chaetodontidae, Implication and Management of Coral Reef Ecosystem. *Bull. Mar. Sc.* 31: 594-604

[25]   Rizzari, J.R. et al. 2014 Impact of Conservation Areas on Trophic Interactions between Apex Predators and Herbivores on Coral Reefs. *Cons. Bio.* 0: 1-12.

[26]   Robbins, W.D. et al. 2006 Ongoing Collapse of Coral-Reef Shark Populations. *Curr. Bio.* 16: 2314-2319.

[27]   Roff, George, et al. 2016 The Ecological Role of Sharks on Coral Reefs. *TREE.* 2075: 1-13.

[28]   Ruppert, J.W.L., et al. 2013. Caught in the Middle: Combine Impacts of Shark Removal and Coral Loss on the Fish Communities of Coral Reefs. *PlosOne.* 8: 1-8.

[29]   Sluka, R.D. and Margareth W/ Miller. 200. Herbivorous Fish Assemblages and Herbivory Pressure on Laamu Atoll, Republic of Maldives. *Coral Reefs.* 20: 255-262.

[30]   Speed, JWL., et al. 2012 Trophic Ecology of Reef Sharks Determined using Stable Isotoph and Telemetry. *Coral Reefs.* 31: 357-367.

[31]   Tull, Malcolm. 2009 The History of Shark Fishing in Indonesia. Working Paper No. 158, Murdoch University.

[32]   Watson, RA and TJ. Quinn II., 1997 Performance of Transect and Point Count Underwater Visual Census Methods. *Ecol Model.* 104: 103-112.

[33]   Wahidin, Nurhalis, 2015 Morotai Coral Reef Ecosystem Classification Based on Objects and Pixels. Postgraduate Thesis, Institut Pertanian Bogor.

[34]   Wetherbee, BM., et al. 1997. Distribution, Reproduction and Diet of Gray Reef Shark Carcharhinus ambhlyrhyncos in Hawaii. *Mar Ecol Prog Ser.* 151: 181-189.

[35]   White WT, Sommerville E. 2010 Elasmobranchs of Topical Marine Ecosystems. In: Carrier JC, Musick JA, Heithaus MR (eds) Sharks and Their Relatives II: Biodiversity, Adaptive Psychology and Conservation. CRC Press, Boca Raton, Florida.

[36]   Chin, A., Tobin, A. J., Heupel, M. R., and Simpfendorfer, C. A. 2013 Population structure and residency patterns of the blacktip reef shark Carcharhinus melanopterus in turbid coastal environments. *Journal of Fish Biology*, 82(4), 1192-1210.

[37]   Myrberg Jr, A. A 2001 The acoustical biology of elasmobranchs. In The behavior and sensory biology of elasmobranch fishes: an anthology in memory of Donald Richard Nelson (pp. 31-46). Springer Netherlands.

[38]   Sugiyono, M. P. P. (2007). Pendekatan Kuantitatif. Kualitatif, dan R&D, Bandung: Alfabeta.

[39]   Rasdiana, H 2010 Studies on Coral Reefs Condition and Reef Fishes Community at the Biawak Island and its Surrounding Marine Tourism and Conservation Area, Indramayu District, West Java Province.

[40] Utomo, S. P. (2010). Study the Correlation of Coral Reefs Condition with the Abundance Chaetodontidae's Fish in Local Marine Conservation Areas Liwutongkidi Island, Buton Regency.

[41] Maharbhakti, H. R. (2009). Hubungan kondisi terumbu karang dengan keberadaan ikan Chaetodontidae di perairan Pulau Abang, Batam.

[42] Boyd, I. L 1996 Temporal scales of foraging in a marine predator. Ecology, 77(2), 426-434.

[43] Howell, P. T., Molnar, D. R., and Harris, R. B. 1999 Juvenile winter flounder distribution by habitat type. *Estuarie*s 22, 1090–5

[44] Gotceitas, V., and Colgan, P 1990 The effects of prey availability and predation risk on habitat selection by juvenile bluegill sunfish. *Copeia* 1990, 409–17.

[45] Branstetter, S 1990 Early life-history implications of selected carcharinoid and lamnoid sharks of the northwest Atlantic. NOAA Technical Reports NMFS 90, 17–28

[46] Castro, J. I 1993 The shark nursery of Bulls Bay, South Carolina, with a review of the shark nurseries of the south-western coast of the United States. Environmental Biology of Fishes 38, 37–48.

[47] Springer, S 1967 Social organization of shark populations. In 'Sharks, Skates and Rays'. (Eds P. W. Gilbert, R. F. Mathewson and D. P. Rall.) pp. 149–74. (Johns Hopkins University Press: Baltimore, MD).

[48] Lyle, J. M. 1987 Observations on the biology of Carcharhinus cautus (Whitley), C. melanopterus (Quoy & Gaimard) and C. fitzroyensis (Whitley) from northern Australia. Marine and Freshwater Research, 38(6), 701-710.

[49] Lazuardi, M. E. 2000 Struktur Komunitas Ikan Karang (Famili Chaetodontidae) dan Keterkaitannya dengan Persentase Penutupan Karang Hidup di Ekosistem Terumbu Karang Perairan Nusa Penida, Bali.

[50] Salini, J. P., Blaber, S. J. M., and Brewer, D. T 1992 Diets of sharks from estuaries and adjacent waters of the north-eastern Gulf of Carpentaria, Australia. Marine and Freshwater Research, 43(1), 87-96.

[51] Papastamatiou, Y. P., Lowe, C. G., Caselle, J. E., and Friedlander, A. M 2009 Scale-dependent effects of habitat on movements and path structure of reef sharks at a predator-dominated atoll. *Ecology*, 90(4), 996-1008.

[52] Frisch, A. J., Ireland, M., Rizzari, J. R., Lönnstedt, O. M., Magnenat, K. A., Mirbach, C. E., and Hobbs, J. P. A 2016 Reassessing the trophic role of reef sharks as apex predators on coral reefs. *Coral Reefs*, 35(2), 459-472.

[53] Randall, J. E. 1977 Contribution to the biology of the whitetip reef shark (Triaenodon obesus).

[54] Cortés, E. 1999 A stochastic stage-based population model of the sandbar shark in the western North Atlantic. In American Fisheries Society Symposium (Vol. 23, pp. 115-136).