CORAL HEALTH INDEX OF GILI MATRA

MARINE RECREATIONAL RESERVE

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Summary

The current study reports the findings of an extensive coral reef health survey conducted in the Gili Matra Marine Recreational Reserve (GMMRR), providing a valuable measurement for the long-term monitoring of these reefs. Using the Coral Health Index (CHI) protocol of Giyanto et al. (2017), which is widely used throughout Indonesia, the current study reports that the majority of dive sites within the GMMRR have a CHI score of 3/10, indicating low reef health. Compared with the index scores calculated in 2014 (Giyanto et al. 2017), it is evident that the health of the reef at Turtle City has severely declined, with the CHI score dropping from 6 to 3. The reef health has also declined, although less severely at Halik and Shark Point. The only site at which the CHI score has increased, is Sunset Point, increasing from 2 to 3. The benthic community is dominated by dead coral smothered in algae (38.4% ± 3.4 SE). Hard coral constitutes 20.4% ±2.8 SE of the reef, and sponges constitute 16.6% ±3.9 SE. The benthic community has a low percentage cover of soft coral 4.4% ±1.3 SE and fleshy seaweed 0.1% ±0.1 SE. The biomass of target fish families throughout the GMMRR was classified as low, ranging from 17kg/ha ±7.4 SE at Turtle City, to 129kg/ha ±20.1 SE at Shallow Turbo.

Introduction

Coral reefs provide a crucial foundation for numerous ecological, social and economic systems. Not only are they a vital ecological resource for over 25% of all marine species, a physical barrier that protects coastlines from storm damage, a natural phenomenon with immeasurable social value and their worth is an estimated $29.8 billion annually to the global economy (Spalding et al., 2001; Cesar, Burke and Pet-Soede, 2003). This is particularly true for the coral reefs of the GMMRR, which are a major source of tourist income, coastal protection and food supply. Unfortunately, these reefs have shown signs of degradation through a combination of threats such as; overfishing, pollution and bleaching events (Bakti et al., 2012). The protection of these coral reefs and their resources relies upon effective management, which is itself dependent upon the availability of sufficient data to increase our understanding of the health of these reefs. The current report details the findings of a comprehensive ongoing study conducted from monitoring 10 sites within the GMMRR from January 2019 – April 2019. This study was completed in adherence to the COREMAP-CTI Coral Health Index (CHI); a national monitoring guideline that is applied throughout Indonesia, allowing data at various spatial and temporal scales to be comparable. This is extremely valuable in its ability to highlight how reef health is changing spatially and temporally, thus providing an insight into where and how management actions would be best applied.

The current study uses an index for coral reef health (Figure 1) that constitutes a variety of parameters; Benthic recent condition, benthic recovery potential, and fish biomass. Thus allowing the index to provide a more accurate measurement of reef health, rather than provided by a single parameter such as coral cover.

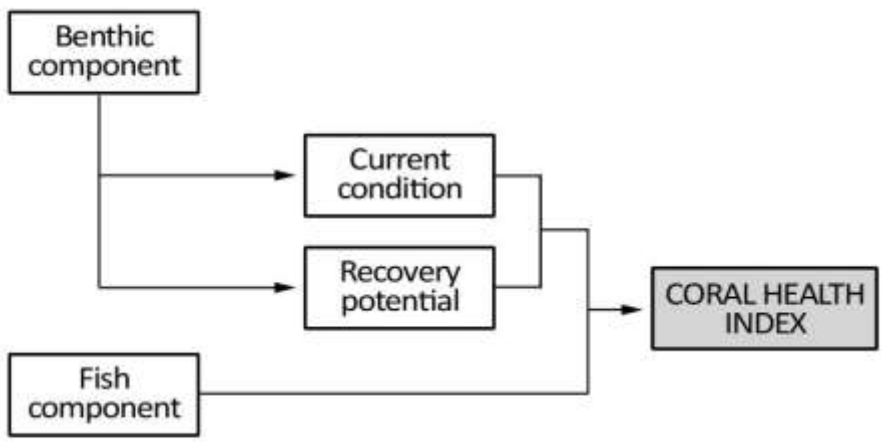

Figure 1. The parameters used to determine CHI. (Giyanto et al., 2017).

The value of the benthic component of the CHI, focuses on two factors: the recent condition and the recovery potential (Table 1). The recent condition is defined by the live coral cover percentage, which is categorized as either *high, medium* or *low.* The recovery potential represents the ability of the reef to recover from disturbance. This is defined according to the cover percentage of two variables, which are negatively associated with coral reef recovery, fleshy seaweed and coral rubble. The recovery potential of a reef is defined as *high* if it meets the following two conditions:

1. Fleshy seaweed cover is less than 3%.

2. Rubble cover is less than 60% *or* live coral cover is more than 5%.

The value of the benthic component is then determined by combining the live coral cover percentage and recovery potential values.

Table 1. Benthic component value (Giyanto et al., 2017)

LIVE CORAL COVER	RECOVERY POTENTIAL	BENTHIC CATEGORY	VALUE OF BENTHIC COMPONENT
High	High	Good reef with high recovery potential	6
High	Low	Good reef with low recovery potential	4
Medium	High	Moderate reef with high recovery potential	5
Medium	Low	Moderate reef with low recovery potential	2
Low	High	Poor reef with high recovery potential	3
Low	Low	Poor reef with low recovery potential	1

The fish component of the CHI, is a measure of the biomass of selected fish species. This is divided into three categories; *high, medium* or *low*. The current study estimated the biomass of the selected fish families; Snapper, Grouper, Parrotfish, Rabbitfish, Surgeonfish and Butterflyfish. By comparing their length measurements to known length:biomass ratios (Froese et al., 2013).

The CHI value is then determined by combining the values of the benthic component and the fish component as shown in Table 2. These values are ranked from 1 (lowest coral reef health) to 10 (highest coral reef health).

Table 2. Combination of benthic and fish component making up the CHI (Giyanto et al., 2017)

BENTHIC COMPONENT			FISH COMPONENT		TOTAL VALUE	CORAL HEALTH INDEX
Live coral cover	Recovery potential	Value	Fish biomass	Value		
High	High	6	High	6	12	**10**
High	High	6	Medium	4	10	**8**
High	High	6	Low	2	8	**6**
Medium	High	5	High	6	11	**9**
Medium	High	5	Medium	4	9	**7**
Medium	High	5	Low	2	7	**5**

High	Low	4	High	6	10	**8**
High	Low	4	Medium	4	8	**6**
High	Low	4	Low	2	6	**4**
Low	High	3	High	6	9	**7**
Low	High	3	Medium	4	7	**5**
Low	High	3	Low	2	5	**3**
Medium	Low	2	High	6	8	**6**
Medium	Low	2	Medium	4	6	**4**
Medium	Low	2	Low	2	4	**2**
Low	Low	1	High	6	7	**5**
Low	Low	1	Medium	4	5	**3**
Low	Low	1	Low	2	3	**1**

Methodology

Study site

The current study was conducted on the reefs of the Gili Matra archipelago (8°21'S; 116°4'E), which consists of three islands; Gili Air, Gili Meno and Gili Trawangan. Located on the north west coast of Lombok, Indonesia (Figure 2). The three islands are a popular tourist destination, attracting many travellers from the neighboring islands of Bali and Lombok. All data was collected from January 2019 – April 2019 via SCUBA at a depth less than 10 meters. Average sea surface temperature was 28°C, with visibility ranging from 5-30 meters.

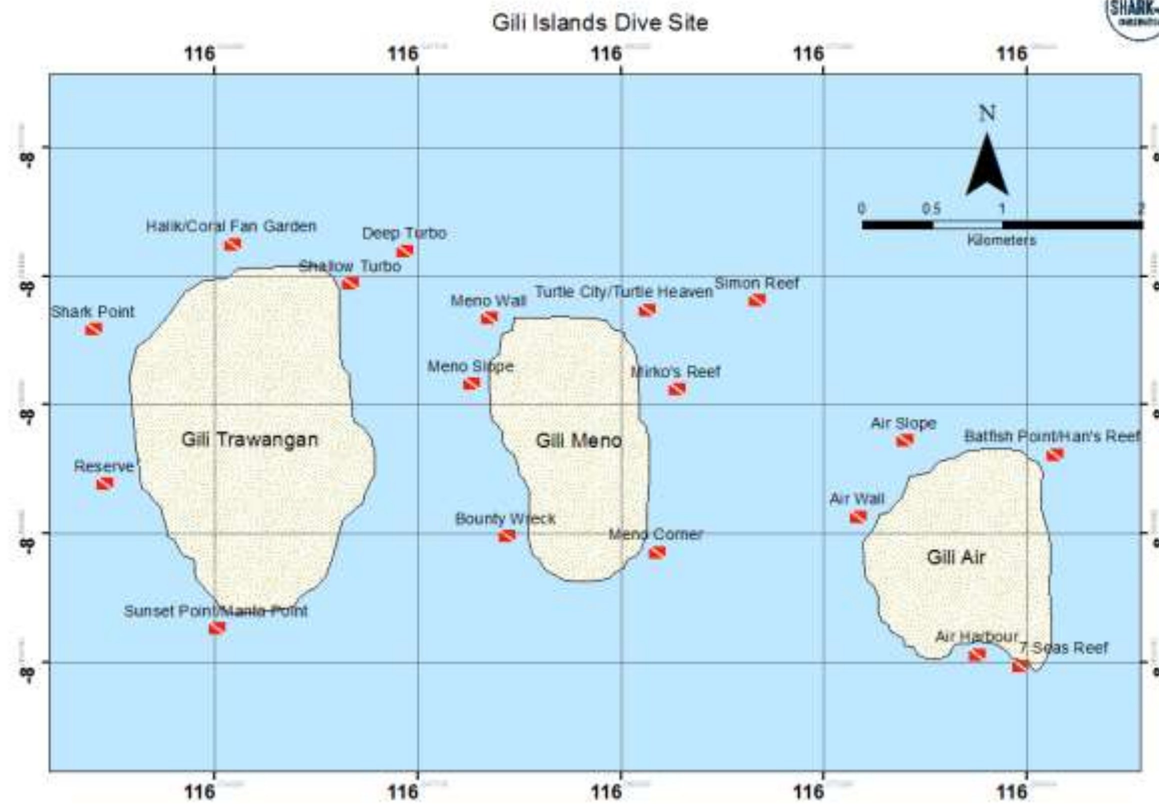

Figure 2. The GMMRR consists of three islands off the north east coast of Lombok, Indonesia

Sampling design

Underwater Photo Transect (UPT) methodology was used to measure the benthic community composition at 11 sites in the GMMRR at a depth less than 10m. Measurements were replicated three times at each site. At each site, a 50m transect was laid parallel to the shore and a quadrat was placed on the reef at the 0 m mark. Using an underwater camera, a photo was then taken of the quadrat perpendicular to the reef and at a distance of 1m. Using the exact same technique photos were taken at each meter of transect, providing 50 photos for each transect, and thus representing 50m^2 of reef.

At the end of the transect after the final photo taken, divers waited 5 minutes for the fish to acclimatize to their presence. Then proceeded to conduct an Underwater Visual Census (UVC) to measure the fish biomass and diversity. Divers swam back along the transect recording the occurrences and estimated the total fish length of the targeted fish families that were present within 2.5m either side of transect. Each UVC represents $250m^2$ of reef.

Data analysis

Coral Point Count with Excel extension (CPCe) software version 4.1 was used to analyze the photos taken from each UPT (Figure 3). In CPCe, benthic categories were identified using 'KODE KARANG COREMAP' classification. A total of 30 random points were used for analyzing each image, thus cover percentage of benthic categories was quantified.

Fish component data was analyzed using Microsoft Excel software. Abundance, biomass, and diversity of the six targeted families, were determined by summing up the number of species per family sighted, converting length to biomass of each species sighted and finally, calculating the number of individual species per family.

The cover percentage of benthic categories and fish biomass were then used to generate the Coral Health Index (CHI) as outlined by Giyanto *et al*. (2017).

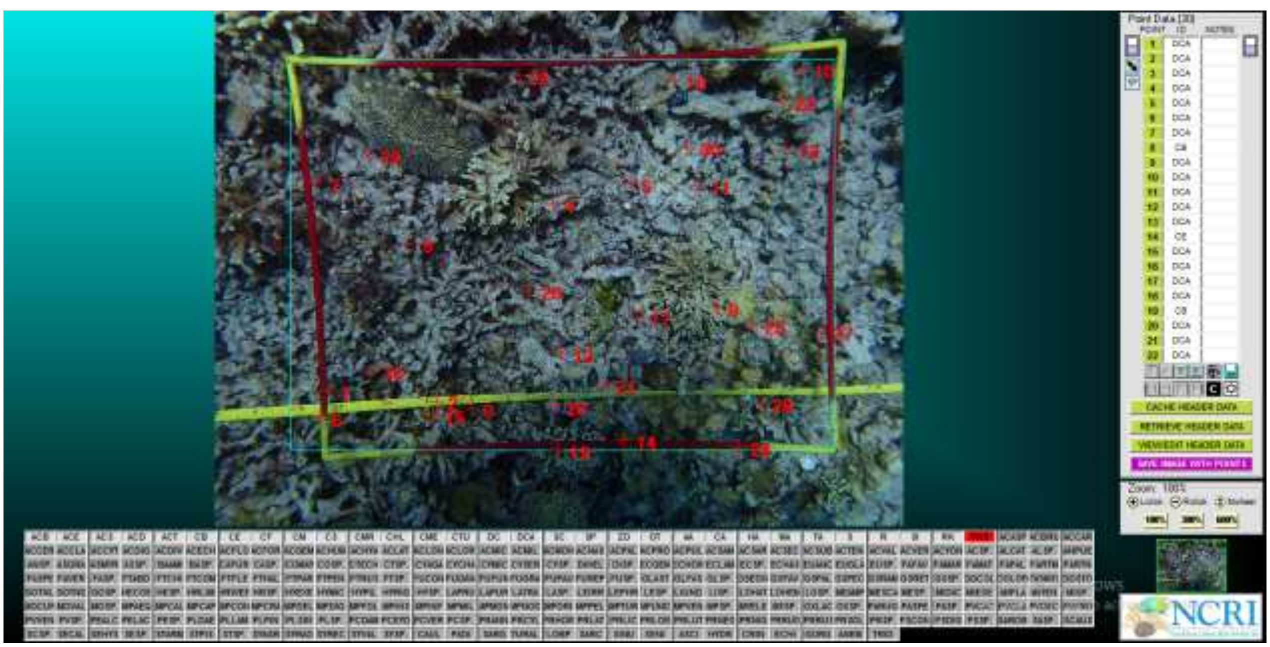

Figure 3. Screenshot of CPCe during UPT data analysis

Results

Coral Health Index

Within the GMMRR the majority of dive sites had a CHI of 3 (Figure 4). The healthiest sites were Halik (6), Shark Point (5) and Sunset Point (5). With comparison to the CHI scores calculated in 2014, by Giyanto et al. (2017), it is evident that the health of the reef at Turtle City has severely declined with the CHI score dropping from 6 to 3 (Figure 5). The reef health has also declined, although less severely, at Halik and Shark Point. The only site at which the CHI score has increased, is Sunset Point, going from 2 to 3. The 2014 survey only indexed 6 of these sites, therefore the current study provides a valuable baseline measurement for the health of the following four dive sites: Bounty Wreck, Shallow Turbo, Statue Garden and Meno Wall.

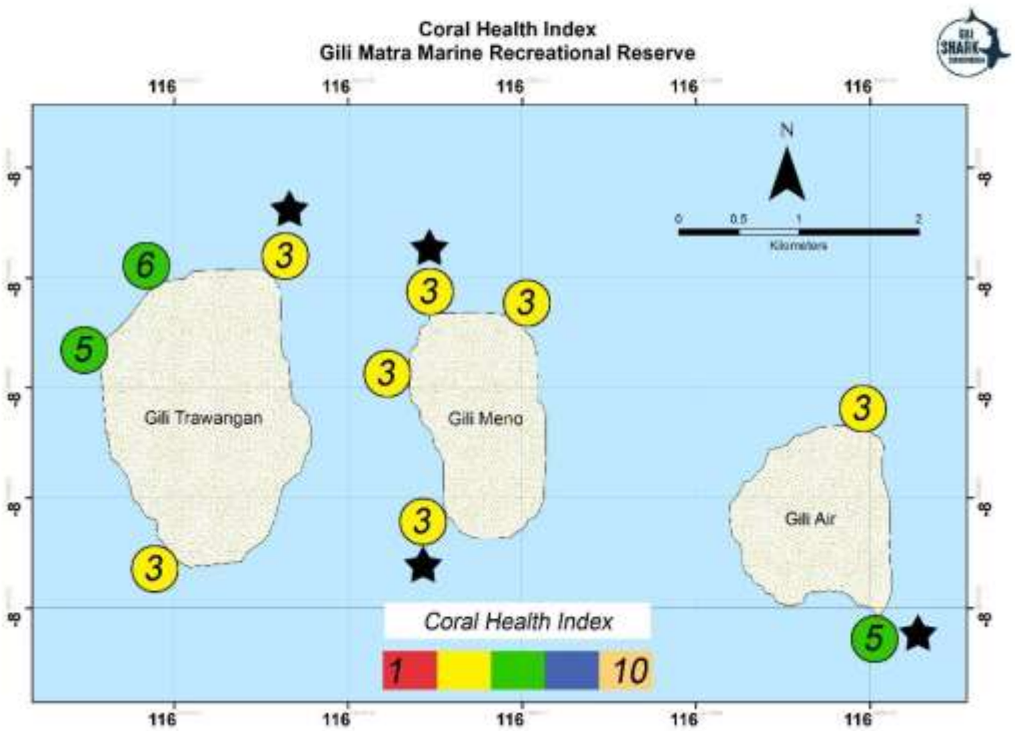

Figure 4. CHI scores of 10 dive sites within the GMMRR. 4 of these sites, marked with a star – Bounty Wreck, Shallow Turbo, Statue Garden and Meno Wall – have not been indexed before, and thus these scores provide a valuable baseline measurement.

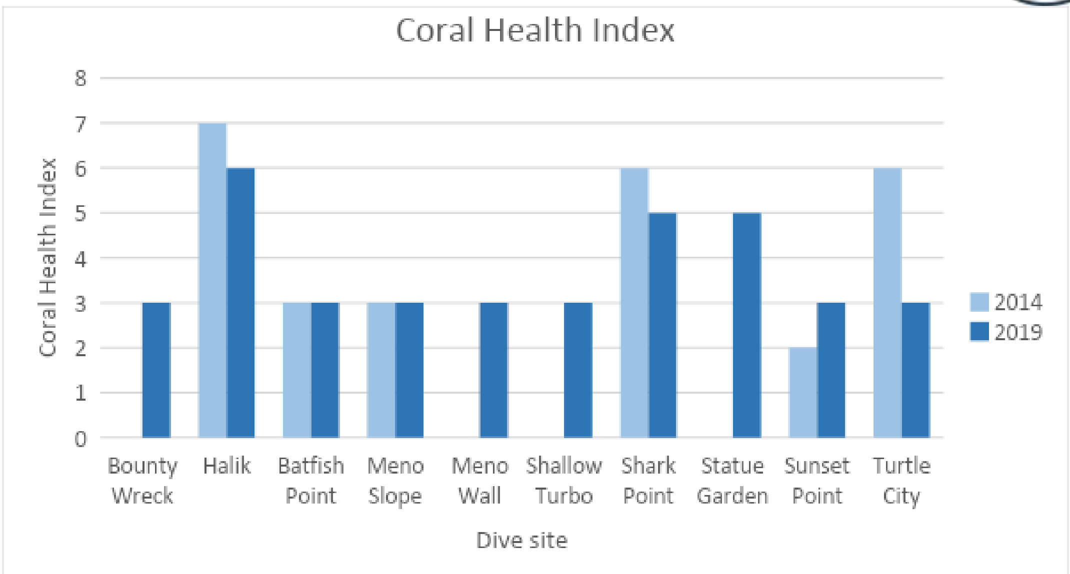

Figure 5. CHI scores of 10 dive sites within the GMMRR, compared with the scores calculated by Giyanto et al. in 2014.

Benthic community

The benthic cover within the GMMRR is dominated by dead coral smothered in algae, 38.4% ± 3.4 SE (Figure 6). Hard coral constituted 20.4% ±2.8 SE of the reef and sponges constituted 16.6% ±3.9 SE. The benthic community has a low percentage cover of soft coral 4.4% ±1.3 SE and fleshy seaweed 0.1% ±0.1 SE. Figure 7 is showing example of two UPT dominated by dead coral with algae and hard coral as the most dominant substrate in the GMMRR.

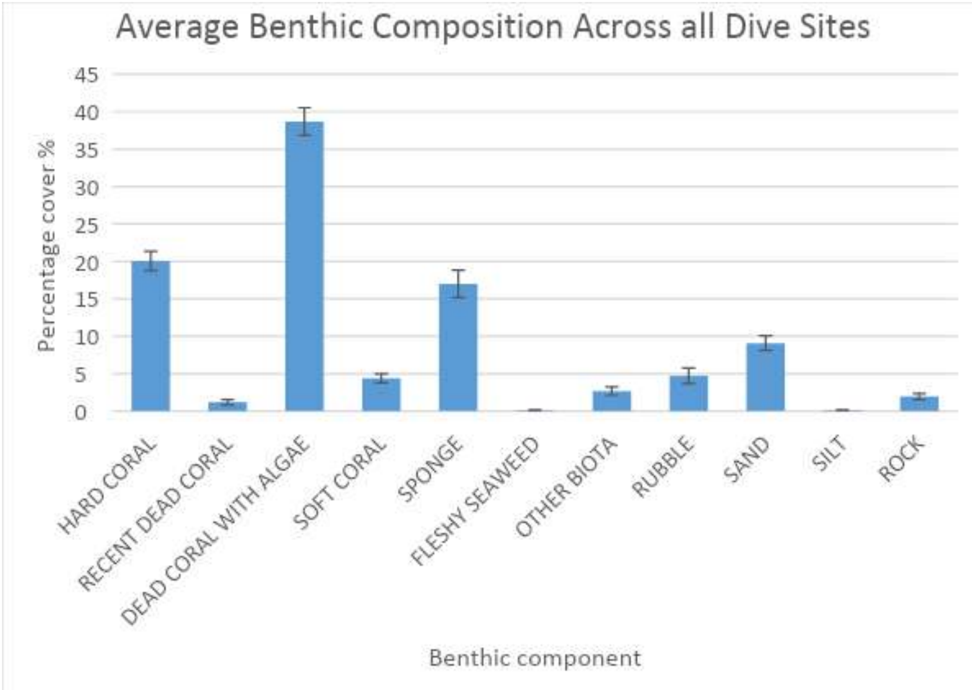

Figure 6. Benthic community composition, averaged across all dive sites within the GMMRR

There was notable variation between dive sites in their percentage cover of hard coral (Figure 8). The highest cover was found at Halik 37.8% ±4.6 SE, Shark Point 31.4% ±9.9 SE and Statue Garden 32.1% ±3.2 SE. The hard coral cover at the other sites ranged from 11.5% ±3.6 SE to 18.1% ±3.1 SE.

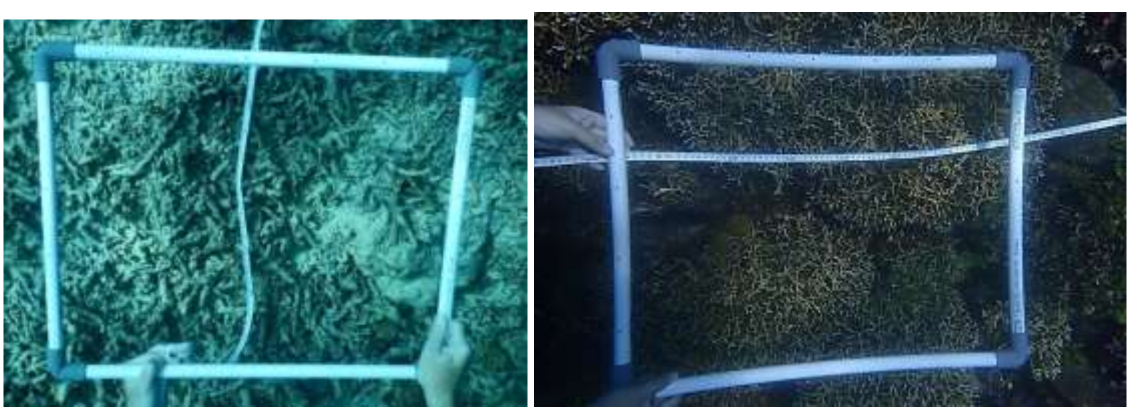

Figure 7. Two dominant categories of substrate: dead coral with algae (left) and hard coral (right) in GMMRR.

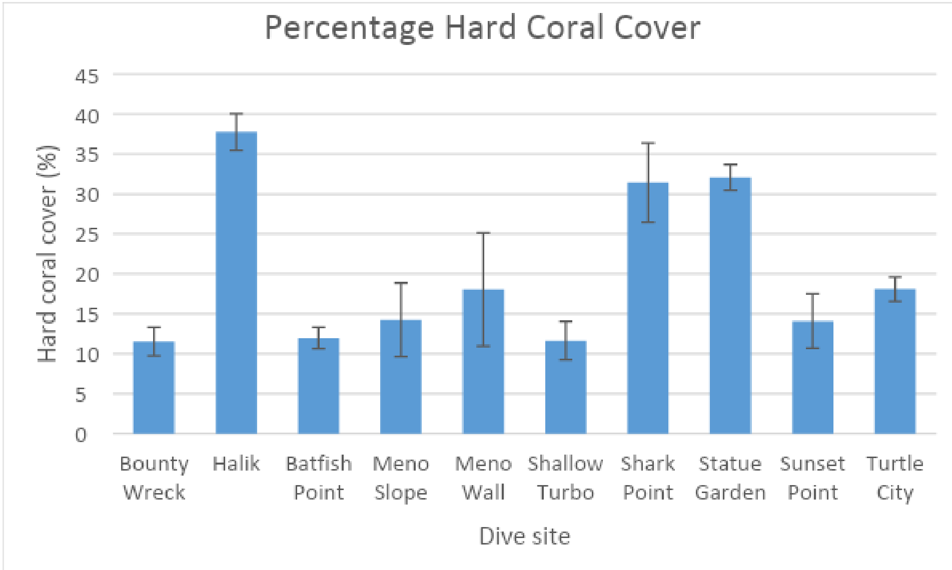

Figure 8. Percentage of hard coral cover at 10 sites within the GMMRR

Fish community

The density of the targeted fish families (Snapper, Grouper, Parrotfish, Rabbitfish, Surgeonfish, Butterflyfish) ranged from 42.0 ±14.0 SE at Sunset Point to 121.7 ±40.9 SE at Turtle City. The density of butterflyfish, which are considered a reliable indicator of reef health (Hourigan, Timothy, Reese., 1988), was highest at Halik, which is consistent with the current study's CHI index scores. Interestingly, the biomass of the target fish families was lowest at Turtle City 17.3kg/ha ±7.4, and highest at Shallow Turbo 129.1kg/ha ±20.1 (Figure 10). Across all dive sites, there was a large variation in fish density between the target fish families, with a notably low density of Snappers, Groupers, Rabbitfish and Parrotfish relative to Butterflyfish and Surgeonfish (Figure 11). The most common fish was the Lined Bristtletooth, *Ctenochaetus striatus* from the Surgeonfish family (Figure 9) and the least common fish were from the Snapper family.

Figure 9. Lined Bristtletooth, *C. striatus* as the most abundant fish species (IUCN Red List of Threatened Species, 2019)

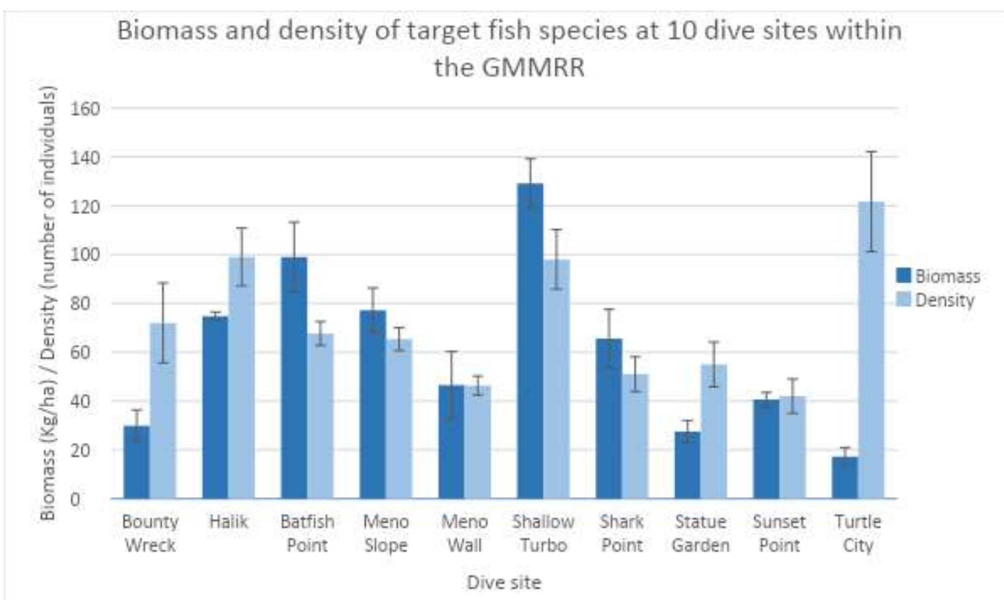

Figure 10. Biomass (kg/ha) and density (number of individuals) of target fish families (Snapper, Grouper, Parrotfish, Rabbitfish, Surgeonfish, Butterflyfish) at 10 sites within the GMMRR

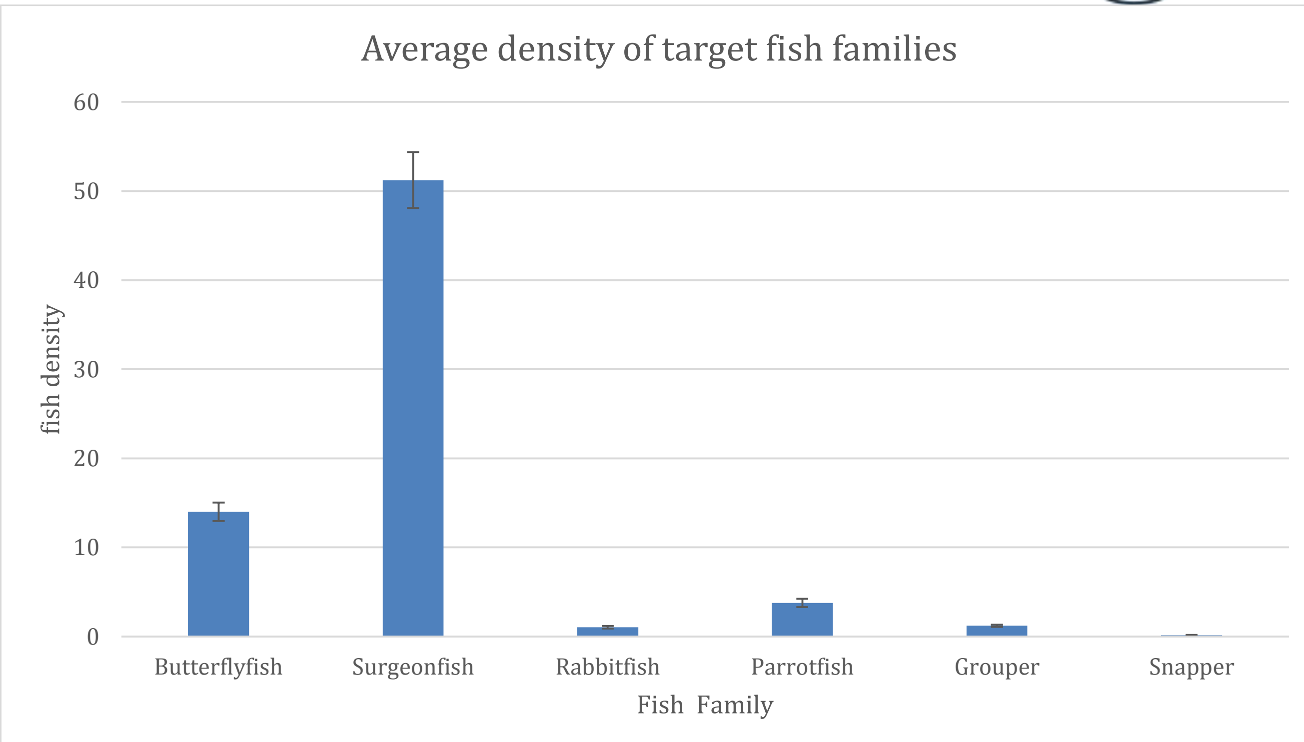

Figure 11. Density of the six target fish families, averaged across all dive sites within the GMMRR.

Discussion

Coral Health Index

Not only should a healthy reef have a high live coral cover, but they should be resilient against disturbance and sustain an abundant population of commercially valuable reef fish. These parameters engender an index that not only reflects the current state of the reef, but also encompasses the recovery potential and the economic/ecological value of the reef. The coral reef health index constitutes a selection of such parameters which provide a holistic measure of reef health.

Across all dive sites within the GMMRR, the average CHI score is 3.7, which suggests "low-medium" reef health on the CHI scale of 1 to 10. According to these CHI scores, the healthiest sites within the GMMRR are Halik (6), Shark Point (5) and Statue Garden (5). With respect to the zonation of the GMMRR, it appears that the three healthiest reefs all exist within 'No Fishing' zones (Figure 12). However, it must be noted that the higher health of these reefs may not necessarily be attributable to the protection status of their zone. For these reefs may have been prescribed protection because they were *already* the healthiest reefs when the zones were being decided. Nevertheless, the value of no-take zones for the conservation of reef health is well documented and therefore we can assume it has a role to play in the increased health of the reefs in the 'No Fishing' zones in the GMMRR.

Figure 12. CHI value overlaid on top of GMMRR zonation map

With comparison to the CHI scores collected in 2014, reported by Giyanto et al. (2017), it is evident that over the past 5 years there have been marked changes in reef health within the GMMRR (Fig. 6). Halik has dropped from 7 to 6, Shark Point has dropped from 6 to 5, and the most concerning Turtle City has fallen from 6 to 3. The only dive site at which the CHI score has increased, is Sunset Point, moving from 2 to 3. This decline in reef health could be attributed to many factors, including those on a global scale such as increased sea surface temperature and those on a local scale, such as overharvesting. Human development on the Gili islands has increased significantly over the past 5 years, with an associated increase in pollution, boat traffic and fishing pressure. This, combined with the increased frequency of bleaching events noticed worldwide, could help to explain the reported changes in reef health within the GMMRR.

Benthic cover

The benthic community within the GMMRR is dominated by dead coral which has been smothered in algae (38.4% ± 3.4 SE), followed by live hard coral (20.4% ±2.8 SE) and sponge (16.6% ±3.9 SE). Other biota such as soft coral and seaweed are at low abundance (<5%) (Fig. 7). The relatively high abundance of dead coral indicates high coral mortality, which could itself be attributable to a variety of abiotic factors such as; sedimentation, pollution, storms, bleaching and boat anchor damage. Also biotic factors such as; disease and reduced herbivores. It is unclear which factors are most to blame; however it is likely that numerous factors are involved, perhaps at different spatial and temporal scales.

Fish abundance, biomass, and diversity

The biomass of the targeted fish families (Snapper, Grouper, Parrotfish, Rabbitfish, Surgeonfish, Butterflyfish) is classified as "low" across all dive sites within the GMMRR, ranging from 17.3kg/ha ±7.4 at Turtle City, to 129.1kg/ha ±20.1 at Shallow Turbo (Fig. 9). At some dive sites, the most notable example being Turtle City, there was a marked difference between fish biomass and density. Turtle City has the lowest fish biomass yet the highest fish density, of all the dive sites within the GMMRR. This indicates that the fish community at Turtle City consists of a high abundance of small fish, which is a potential indicator of a high fishing pressure which has removed large fish from the ecosystem. This theory is supported by the finding that the two families that were virtually absent from the shallows in this study, Snappers and Groupers, are highly targeted by fishermen (Figure 11). The lack of these families may thus be accountable for the relatively low fish biomass in the GMMRR.

Conclusion

Indonesian coral reefs represent 18% of coral reefs worldwide, provide a primary food source for millions of people and contribute an estimated US$1,000,000 km^2 /year to the tourism economy of Indonesia (Cesar, Burke and Pet-Soede, 2003; UNEP, 2006). However, like all coral reef ecosystems, they exist in a delicate balance. Excessive abiotic (pollution, temperature increase) and biotic threats (overfishing, invasive species) can quickly tip this balance, and lead to declines in reef health. While reefs do have a certain recovery potential or resilience, there is critical threshold beyond which their recovery is unlikely, leading to ecological cascades that can turn a healthy reef into destitute system, with diminished biodiversity and ecosystem products.

As reported by the current study, reef health within the GMMRR is generally low, and at certain dive sites reef health is rapidly declining. It is therefore of vital importance that these reefs are effectively managed. Coral restoration projects, which have proved successful on coral reefs around the world, are a simple approach to increasing hard coral cover and subsequent coral reef community health. Further applications and monitoring of coral restoration projects within the GMMRR, such as the one being created by Gili Shark Conservation, may prove useful in the conservation of these reefs. With respect to directly managing the fish populations, the application of a minimum legal size for commercial species, could also be a valuable strategy in the improvement of the low fish biomass found in the GMMRR. Furthermore, an effective management strategy should consider the presence and redundancy of functional groups within the coral reef ecosystem, especially those which are known to promote reef health, and thus the protection of herbivorous reef fish such as Parrotfish could be an effective strategy within the GMMRR (Bellwood, Hughes, Folke and Nyström, 2004).

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