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EFFECTS OF CORAL CONTACT RATE ON THE CORAL COVER (PRE AND POST COVID-19'S PANDEMIC MOVEMENT CONTROL ORDER) IN TUNKU ABDUL RAHMAN PARK, MALAYSIA

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ABSTRACT

Covid-19 pandemic lockdown has affected all activities worldwide, including the tourism sector in Tunku Abdul Rahman Park (TARP). This study has spanned since pre-MCO in July 2019, hence it can be investigated to observe the impact of tourism on coral cover, before and after the MCO. The study was conducted from July 2019 to July 2020 and divided into three intervals. A total of 4 permanent transect coral survey were carried out at every beginning of the interval and at the end of the study period. MCO that was enforced during Interval 3 (I3) recorded a significant drop of more than 90% in the number of visitors. Even with the drop in number of tourists, coral contact rate recorded a quite similar trend throughout the 3 interval ranging between 1.66 to 1.82. Coral cover in TARP after 1 year recorded an increase of 1.17%. The negative correlation between number of tourists and changes in coral cover proved that the concept of resting period is neded for coral reefs to recover from the constant stress and daily coral contact with visitors.

Keywords: *Tourism, Marine Protected Area, Carrying capacity, Coral recovery, Covid-19.*

INTRODUCTION

Tunku Abdul Rahman Park (TARP) is the first gazetted MPA in Sabah. They were gazetted separately in a different year; in 1974 (two islands) and 1979 (three islands) with a combined area of 4,929 ha. The gazettement aims to ensure that all marine flora and fauna are protected from mass destruction due to coastal development and human activity. Tunku Abdul Rahman Park is very popular among tourists as it is only 15 minutes boat ride away from the capital city of Sabah, Kota Kinabalu (Somaskanthan & Rosmalina, 2016), flooded with a large number of visitors coming from all over the world, and has contributed considerable revenue to the Park Authority and offered a lot of job opportunities in the tourism sector in the state.

In the year of 2013, TARP recorded its first five hundred thousand (500,000) of tourists arrival in a year, and the number was achieved again for three consecutive year from 2017 to 2019. However, a drastic drop of more than 90% was recorded in 2020 since March 18th because of the implementation and enforcement of a lockdown or Movement Control Order (MCO) nationwide due to the uncontrollable spread of the Covid-19 pandemic worldwide. All international borders are closed, and every movement of the people were limited to essential purposes only.

The unexpected enforcement of MCO during this research has presented itself a unique opportunity to study the impact of the tourism-free period on the MPA's coral reefs. In this study, which spanned during pre-MCO and the MCO, assessment on the coral cover and CCR are available from these two types of scenarios (before and after MCO), allowing the researchers to determine the model of resting period effectiveness of an MPA in TARP. The results from this study will indicate how hard coral cover and CCR were affected by tourist arrivals.

LITERATURE REVIEW

Tourism Impact on Coral Reefs

Tourism has been a strong and main player in the Malaysian economy with good support from the government since the 90s. The booming of Malaysia's tourism industry started in the 1990s during the Seventh Malaysian Plan (1995-2000) in order to increase its tourism industry by popularising natural attractions.

However, tourism has a major effect on host destinations, as well as areas of transit and origin and the extent to which this impact is positive or negative depends on whether tourism is managed appropriately. Management and planning involve intentional efforts to control tourism development for a destination in order to help fulfil the long-term economic, social, cultural and environmental aspirations and strategic objectives of the people living in that destination (Weaver & Lawton, 2014).

In term of the marine environment, although the actual impact of tourism has not been measured, it has been suggested that tourism activities have contributed to the pressure on the reefs (Pilcher & Cabanban, 2000). Diving industry significantly impacts different types of damage to various coral forms (Zhang et al., 2016). At frequently snorkelled or dived areas, the coral reefs, particularly in branching species, often experienced skeletal breakage due to close contact from snorkelers and divers who may inadvertently cause physical harm to corals (Paradis et al., 2019). In some cases, this type of contact can also lead to tissue abrasion in coral reefs, thus lowering coral metabolism and impairing the energy balance.

A study by Roche, et al., (2016) reported areas that heavily being used for recreational purposes tend to develop a higher incidence and rate of coral diseases among reefs. These indicators support the claim that the degree of reef disruption in Sabah is high and that greater attention should be paid to reef health and impact management to conserve ecosystem services, which are very important to the local communities who are dependent on them.

Movement Control Order (MCO)

As the Covid-19 became a global pandemic, the Movement Control Order (MCO) was unexpectedly declared by the Malaysian government starting from 18 March 2020, for an initial period of 2 weeks. On 4 May 2020, restrictions were gradually lifted under Conditioned MCO (CMCO) with the reopening of selected sectors, which include the soft opening of TARP on 16 May 2020. Recovery MCO (RMCO) replaced CMCO on 9 June 2020 where more restrictions were lifted as part of an exit and relief strategy due to economic impact from the MCO to the people. This RMCO involves relaxing interstate travel restrictions and allowing more economic sectors to restart operations. However, it also does not allow bars, clubs, reflexology, karaoke, religious events, theme parks, and open houses to operate (Majlis Keselamatan Negara, 2020).

METHODOLOGY

This study was carried out from July 2019 to July 2020 and was divided into three intervals, namely Interval 1 (I1), Interval 2 (I2), and Interval 3 (I3). Tourist arrival statistics over one year of the study period were obtained from every entry point in TARP, which is in the islands of Manukan, Mamutik, Sapi, and Gaya ticket counter. A permanent transect was set up in each islands for coral survey of the mostly occupied snorkeling reef area (Map 1). The coral survey was done 4 times, the beginning and end of study, and in between the intervals. In each interval, 200 random CCR samples were collected from tourists/snorklers. This number was selected due to the limited sample during I3 (Interval 3), which was only successfully collected during March (early March), June and July (the start of Recovery MCO). 200 random samples were selected and compared in term of their CCR (refer Table 1).

Table 1: The Field Data Collection Schedule

Intervals	11				12				13				
Date	Jul 19'	Aug 19'	Sept 19'	Oct 19'	Nov 19'	Dec 19'	Jan 20'	Feb 20'	Mar 20'	Apr' 20	May 20'	Jun 20'	Jul 20'
MCO									MCO	MCO	MCO	MCO	RMCO
Coral Surveys	1st	-	-	-	2nd	-	-	-	3rd	-	-	-	4th

CCR Sampling	200 samples	200 samples	200 samples

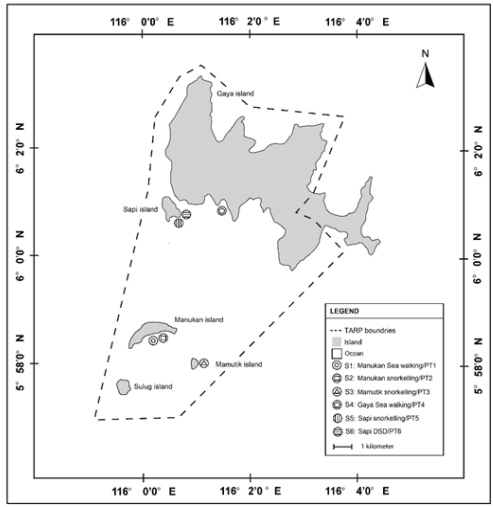
Source: Author

Trampling, fin contact, standing on corals, and resuspension of sediment are an example form of direct diver or snorkeler impacts to the marine environment, especially the coral reefs (Chabanet et al., 2005). The researchers assessed using direct observation of random and anonymous snorkelers and sea walking activity. Any data collection related to the tourist activity was part of the daily monitoring duties of the Park Authority staff for random purposes. As we are in a public location, it is legal to record them (Carman, 2018). Besides, the faces of the tourist were not recorded, and the identity of them are confidential and will not be exposed. A total of 10 minutes of observation for each snorkeler and sea walking activity was conducted to assess their CCR. Details such as the weather, current speed, time of observation, visibility, and gender were also recorded. Table 2 provides a desciption on the contact type.

Table 2: Description of Type if Interaction Made by Snorkelers

No.	Contact Type	Description
1.	Fin/Kick	Any contact by fin or a kick to the corals from a snorkeler.
2.	Touching	Deliberate touching of the corals by a snorkeler.
3.	Kneeling/Standing	Snorkeler kneeling or standing on corals/reef substrate.
4.	Clutching/Holding	Snorkeler holding the coral for more than 2 seconds to gain stability due to wave action
5.	Equipment Contact	Any contact from a camera, toy, life jacket, or any other equipment.
6.	Other(s)	Any contact occurred other than the above. Harassing marine animals, collecting souvenir (pieces of corals, seashells, or any other marine animals)

Source: modified from Rouphael & Inglis, (2001).



Map 1. Location of all the study sites in TARP

Source: Sabah Parks, (2020)

The coral survey of 50 meters transect was done using a permanent transect protocol. For every five meters, PVC pipe (1 x 2 inch) with a small marker buoy was hammered to act as a marker for the next survey. After the permanent transect was established, a quadrate with the size of 1 x 1 meter was placed, and the photo was taken using a camera at every two meters of the transect line. The camera set-up protocol followed Hill and Wilkinson (2004), to ensure that the best quality photos were taken analysis purposes. During this study, underwater visibility was in good condition, and therefore full quadrate photos were taken. The photos were analysed using the Photo Quadrat Analysis Software (Trygonis et al., 2012) and were presented in percentage (%) of living coral cover. The status of reefs was measured following the standards developed by the Australian Marine Science Institute (AIMS) (English et al., 1997). The status of coral range from; 'Excellent': 76-100%, 'Good': 51-75%, 'Fair': 26-50% and 'Poor': 0-25% according to the coverage of living coral cover on the 50 meters survey.

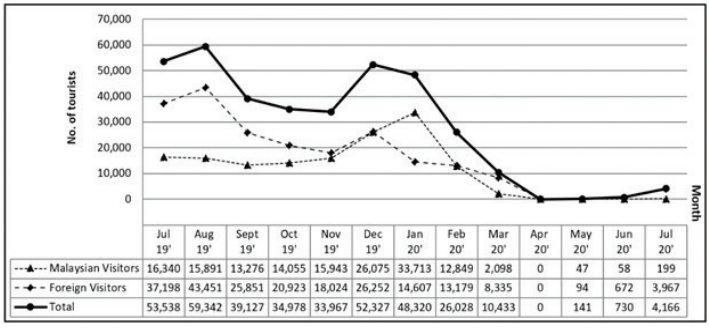
To get the CCR, The total number of coral contacts were divided by the total number of snorkelers observed for each interval.

$$CCR = \frac{Frequency\ of\ contact}{Total\ snorkelers \times 10\ minutes}$$

The CCR of different interval was tested whether the differences were significant.

RESULTS

A total of 363,097 tourists visited the study area during the study period (from July 2019 to July 2020). Overall, the number of tourists from foreign countries recorded a higher number every month compared to Malaysian visitors, and the highest was in August 2019 with 43,451 tourists. Only one month a higher Malaysian visitor (33,713) was recorded, which was during January 2020 with more than half of foreign visitors (14,607). The total number of Malaysian visitors comprised of 41.46%, while foreign tourists with 58.54%. Months of July, August, and December 2019 recorded the highest number of tourists with more than 50,000, where the highest number of tourists was in August 2019 with 59,342 tourists. MCO was enforced on 18 March 2020 and has affected the total number of visitors ever since. The number of tourists dropped to 10,433 in March and have recorded zero tourists in April before gradually increasing afterwards. The average number of tourists before MCO was 43,453.4 tourists/month and dropped 95.89% ($p<0.05$) after MCO to only 2,826 tourists/month. The trend of tourists arrivals, as shown in Figure 1.



	Jul 19'	Aug 19'	Sept 19'	Oct 19'	Nov 19'	Dec 19'	Jan 20'	Feb 20'	Mar 20'	Apr 20'	May 20'	Jun 20'	Jul 20'
Malaysian Visitors	16,340	15,891	13,276	14,055	15,943	26,075	33,713	12,849	2,098	0	47	58	199
Foreign Visitors	37,198	43,451	25,851	20,923	18,024	26,252	14,607	13,179	8,335	0	94	672	3,967
Total	53,538	59,342	39,127	34,978	33,967	52,327	48,320	26,028	10,433	0	141	730	4,166

Figure 1. Trend of the Number of Tourists from July 2019 to July 2020
Source: Author

Based on Figure 2, out of 600 samples snorkeler, 77% of them made contact with the coral reefs at least once, and only 23% did not make any contact.

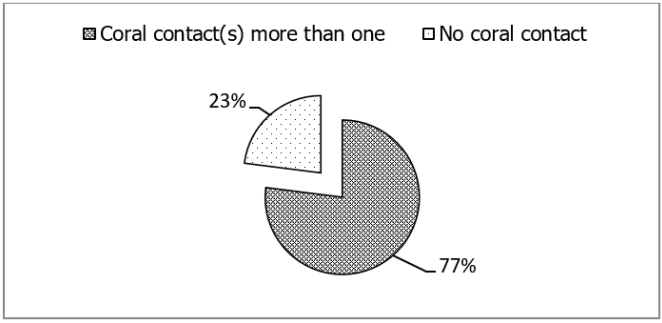


Figure 2. Total Snorkelers that Made Contact with Coral Reefs
Source: Author

Overall coral contact by snorkelers based on a type of contact in the study area is shown in Figure 3. Touching coral reefs was the highest type of contact with 422 recorded touches from 600 snorkelers. Fin/kick and clutching/holding recorded mid-range contact with 198 and 225 respectively. Kneeling/standing was recorded 107 contacts mostly on reef structure or boulder corals, which could cause severe damage to the corals (Nestor et al., 2017; Plathong et al., 2000; Zakai et al., 2000; Otto et al., 2016; Hawkins & Roberts, 1993; Rodgers & Cox, 2003). Equipment contact recorded the lowest number of contacts with only 91. Most of the contacts from this type were obtained from snorkelers with cameras, where the snorkelers were too focused on recording or taking photos before accidentally collided with the corals.

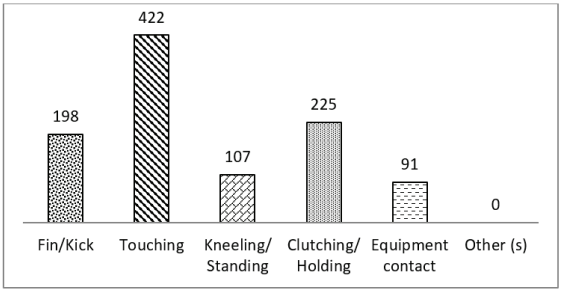


Figure 3. Types of Coral Contact(s) Made by Snorkelers
Source: Author

The average CCR at every interval has no significant difference ($p>0.05$) and Figure 4 shows that every interval recorded a relatively consistent number, where I1=1.74 contact 10minutes-1 ±0.65; I2=1.82 contact 10 minutes-1 ±0.64; and I3=1.66 contact 10 minutes-1 ±0.66. Despite the drop in tourists arrival, the rate of coral contact was quite similar (the biggest difference was only 0.16 contact 10 minutes-1). This shows that the pattern of CCR was the same throughout the study.

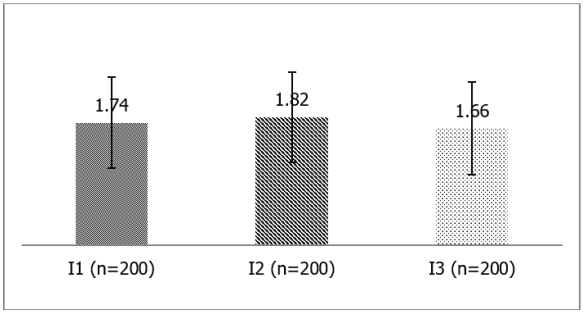


Figure 4. Average CCR per 10 Minutes of Each Interval in All Study Sites
Source: Author

Figure 5 shows that S5 recorded the highest coral cover among all study sites throughout the study period. The coverage of living coral at the beginning of I1 was 72.67%. Snorkelling area in S5 is marked with a buoy with rope and was guarded by the Parks Authority and lifeguards. During low tides, this area will be closed, and snorkelers are not allowed to enter the coral reefs area. However, coral cover in S5 recorded a steady declination through I2 (70.29%) and I3 (69.4%) before showing a positive inclination to 73%.

S2 was the only study site in which did not surpass the initial coral cover where it decreased from 43.92% (I1) to 43.27% (I2) and 42.88% (I3) before having a slight increase after MCO was enforced to 43.67%. The growth rate of coral in this site is slower than other sites as S2 mostly comprised of the massive/boulder type coral (Anthony, 2013). Both sea walking areas in S1 and S4 recorded the highest difference compared to their initial coral cover with an increase of 1.93% and 1.97% respectively. This increment could be possible because these sites are significantly more in-depth than other snorkelling sites, thereby reducing the risk of damaging the reefs (Selkoe et al., 2009). Therefore, in contrast, S3 and S5 recorded

the highest declination with 4.37% and 3.27% respectively from I1 to I3 as they have the most shallow sites compared to other sites.

Using the standard set by AIMS, the status of coral cover at the end of this study for S5, S1, S3, and S4 was in 'Good' condition with 73%, 63.6%, 54.33%, and 53.4% respectively. However, S2 (43.67%) and S6 (39.21%) were only in 'Fair' condition. These data relate to the overall coral cover in Sabah for the past ten years, where a fair condition has been consistently reported (Reef Check Malaysia, 2017).

Overall, a similar trend occurred in all study sites where coral cover decreased until the third survey (before MCO) and increased in the last survey (during RMCO). On average, the live coral cover started from 53.37% (survey 1) to 52.33% (survey 2) and 51.38% (survey 3) before increased to 54.54% in survey 4. A previous study shows that a significant threat to coral reefs could be coral contact (Nestor et al., 2017). According to Medio et al. (1997), as an ecological impact affecting coral reefs, damaged corals caused by tourists and visitors are becoming extremely relevant. In this study, every interval recorded a consistent CCR and did not show a significant difference ($p>0.05$).

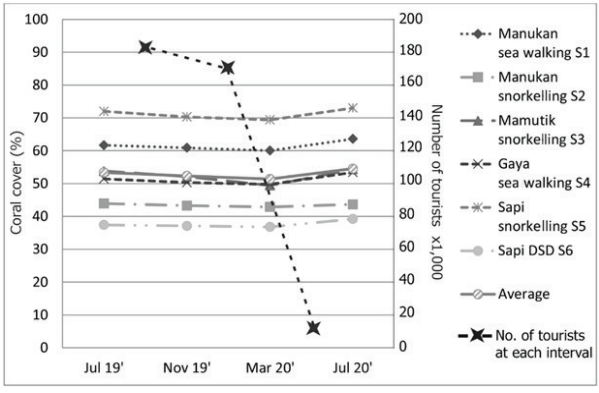


Figure 5. Live Corals Coverage Compares to the Number of Tourist in Study Sites through the Study Period

Source: Author

DISCUSSION

Based on the results, a similar trend occurred in all study sites where coral cover decreased until the third survey before the MCO implemetation. This trend was also found in another study by Bak, Nieuwland, and Meesters, 2005. In their study, the rate of coral cover and number of coral colonies suffered a decrease. This trend follows the process in areas somewhere in the Caribbean basin and other primary coral reef domains. A similar pattern also happened in Akumal Bay, Mexico. There, the stony coral cover rate undergoes a significant decrease while macroalgal cover, on the other hand, increased (Renfro & Chadwick, 2017).

The fact that study sites S3 and S5 which are considered shallow compared to other sites, recorded the highest declination of coral cover due to damage, can also be supported by Bak et al. (2005), where shallow coral reefs are more vulnerable compared to deep reefs due to destruction and deterioration factors that mostly took place within the shallow regions. This pattern was also found in another study where shallow coral reef areas that are easily accessible recorded the highest damage. This is because snorkelers tend to explore this region higher, considering that it is closer to the shore, leading to more snorkelers, possibly doing more damage than deeper parts (Hannak et al., 2011).

Other study sites, S1, S4 and S6, which recorded lower declinations, are slightly deeper than S3 and S5. Coral reefs in deeper areas, where sunlight can still penetrate, are more resilient than those in shallow and exposed regions because they are further connected to the deeper ocean environment. Thus, demonstrating lower damage. The relative importance of coral reefs with the deeper ocean is established by considering the temperature where certain damage like coral bleaching can be caused by maximum seawater temperature that is manifested in shallow waters where corals are almost exposed to the surface.

Unlike the other sites, S6 is an area where scuba diving activities took place. Despite the decreasing coral cover rate, it experienced a lower declination compared to S3 or S5. This is probably due to lesser tourists who dived rather than snorkelling; thus, less damage was done. However, the fact that the corals here suffered damage still cannot be denied. In scuba

diving sites, there are a few common reasons for how divers possibly harm the corals. Firstly, it is due to inexperienced divers. It is a known fact that a non-certified may do more harm to corals, mainly due to lack of knowledge on corals which leads to unintentional reef contact.

Secondly, damage can happen due to certified dive guides with poor buoyancy skills, consequently increasing the rate of coral contact (Zakai & Chadwick-Furman, 2002). Besides, uncontrolled underwater buoyancy will often lead to detachment causing divers to topple on top of the entire coral colony (De et al., 2020). In some cases, divers damage can be quite similar to anchors but on a much lower scale. Divers may crush or break corals as well as stirring clouds of sediment with their fins, body parts or other equipment (Saphier & Hoffmann, 2005).

At an increasing rate, sedimentation caused by divers can potentially act as a tremendous stressor towards corals by reducing coral cover. The coverage will be reduced by shading adult corals and inhibiting their recruitment (Hanafy, 2012). Nevertheless, the reduction of coral cover in S6 is still considered fair compared to other diving sites globally, which suffered damage up to four times worse (Zakai & Chadwick-Furman, 2002).

From this study, we have found that from I1 to I3, hard coral cover recorded a significant decrease for all study sites. At the same time, CCR per person maintained a steady value. A similar study by Roche et al., 2016 in the Philippines also recorded a comparably smaller value of 1.20/10 min, while our average CCR is 1.74/10 min. In their study, a lower value of CCR was recorded mainly due to their observed divers being more aware of conservation, making their dive more environmentally friendly and avoided contact with corals. The human contact rate with corals is further minimised as many dive operators participated in green diving programmes.

This kind of green programme's efficiency can be proven because divers in Hong Kong have a significantly higher CCR due to most of them having little to no diving experience. Therefore, they tend to make a lot of contact with corals. Besides, pre-dive briefing too plays an essential role in influencing a diver contact rate. Just like the programme, a diver who listened to a briefing before diving will record a lower CCR compared to those who did not. Toyoshima and Nadaoka (2015) also agreed that CCR

is heavily related to the pre-dive or environmental briefing.

Furthermore, the number of tourists decreased to more than 90% during MCO (I3). The damage and anthropogenic disturbance reduced, and it gave the coral reefs some time and space to recover. Although the recovery is small, this may prove many things in the resting period concept. Human intervention towards the environment does impact the environment itself, the impact usually in a negative way and leave a long term 'scar' to it. Snorkelling and diving were practices that directly impacted the reefs (Chabanet et al., 2005).

However, the reef may not be directly affected by certain leisure activities provided in TARP. Still, intense tourism activity may cause stress reefs and surrounding marine organisms (Lamb et al., 2014) such as scuba doo (underwater scooter), parasailing boat, banana boat, and jet ski. This study shows that coral cover has a very close relationship with the number of tourists. Eventually, the tourist will enjoy the coral reef as a tourism product and directly contact it. Previously, findings from Nestor et al. (2017) results indicate that broken coral fragments were relatively higher, which was twice the amount at a site with more snorkelers than a non-visit site.

Corresponding with our study, the results showed that coral cover has a close relationship with the number of tourists. A study in Mexico found a comparable correlation. It was revealed that intensive rates of tourism, primarily snorkelling, do affect the coral cover negatively. Extreme rate of snorkelling of more than 1,000 tourists daily, can destructively impact many of reef-building corals causing them to shift to a new phase, where they will be dominated by macroalgae, just like how it happened to many other reefs which are exposed to human intervention (Renfro & Chadwick, 2017).

Tourists who step carelessly on coral colonies or those who collected corals for fun will cause destruction towards the reef and other associated habitats. It is confirmed that increasing tourists is one of the dominant factors that lead to a drop in coral cover throughout the globe (Liu et al., 2012). However, not all tourism activities can be severely damaging to coral reefs. For instance, supposedly snorkelling and diving are carried out below the carrying capacity, the damage is likely to be minimal, thus contributing to a little decline in coral cover (Cupul-Magana & Rodriguez-Troncoso, 2017).

CONCLUSIONS

In conclusion, disturbance by tourists in a coral reef community is indeed damaging where the effects are varied – depending on the severity of the damage. The coral cover will decrease when there are more human disturbances but will bounce back when corals are let to recover on their own during the Park's closure. On the other hand, the CCR recorded a steady value regardless of tourist arrival, possibly due to the sample size not being large enough. Although MCO has affected both tourists number and the total revenue, it benefited the coral reef community. According to Nestor et al. (2017), to prolong our rich coral reefs survival and their wealth, practices on shallow reefs must be handled carefully. To reduce the effects of tourism and give coral reefs more time and space to recover due to stress from human activities, it is suggested to implement a resting period in TARP. The lack of revenue during the resting period would not be a factor affecting TARP as a previous study showed that coral reefs have a high value in the tourism sector; it is estimated to have revenue of more than US$ 30 billion (Spalding, 2017). The increased demand for coral reefs/islands tourism will allow TARP to bounce back from the resting period quickly. Therefore, we can conserve and protect coral reefs for the long term and continue earning revenue for an extended period.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Anthony, T. (2013). *Fieldwork verification using a satellite image of coral reef and land cover of Manukan, Mamutik and Sulug island,* Tunku Abdul Rahman Park. Presentation slide of Internal Research Presentation, 21 April 2013. (Unpublished report to Sabah Parks).

Bak, R., Nieuwland, G. & Meesters, E. (2005). Coral Reef Crisis in Deep and Shallow Reefs: 30 Years of Constancy and Change in Reefs of Curacao and Bonaire. *Coral Reefs*, 24, 475-479.

Carman, A. (2018). *The Verge*. You can keep recording people in public, but don't capture their faces. Retrieved from https://www.theverge.com/2018/10/ 24/18015374/whyd-you-push-that-button-record-stranger-public.

Chabanet, P., Adjeroud, M., Andréfouët, S., Bozec, Y. M., Jocelyne, F. J., Garcìa-Charton, J. A. & Schrimm, M. (2005). Human-induced physical disturbances and their indicators on coral reef habitats: a multi-scale approach. *Aquatic Living Resource,* 18, 215–230.

Cupul-Magaña, A. L. & Rodríguez-Troncoso, A. P. (2017). Tourist Carrying Capacity at Islas Marietas National Park: An essential tool to protect the coral community. *Applied Geography,* 88, 15–23.

De, K., Nanajkar, M., Mote, S. & Ingole, B. (2020). Coral damage by recreational diving activities in a Marine Protected Area of India: Unaccountability leading to 'tragedy of the not so commons'. *Marine Pollution Bulletin,* 155, 1-10.

English, S., Wilkinson, C. & Baker, V. (1997). *Survey manual for tropical marine resources.* Australian Institute of Marine Science.

Hanafy, M. (2012). Effects of recreational scuba diving and snorkelling on coral reefs of the sheltered bays of the Red Sea, Egypt. Egypt. *Journal of Aquatic Biology & Fish, 16*(4), 1110-1131.

Hannak, J., Kompatscher, S., Stachowitsch, M. & Herler, J. (2011).

Snorkelling and trampling in shallow-water fringing reefs: Risk assessment and proposed management strategy. *Journal of Environment Management, 92* (10), 2723-2733.

Hawkins, J. P., & Roberts, C. M. (1993). Effects of recreational scuba diving on coral reefs: Trampling on reef-flat communities. *Journal of Applied Ecology, 30*(1), 25-30.

Hill, J. & Wilkinson, C. (2004). Methods for ecological monitoring of coral reefs: a resource for managers. Version 1. Australian Institute of Marine Science (AIMS).

Lamb, J. B., True, J. D., Piromvaragorn, S. & Willis, B. L. (2014). Scuba diving damage and intensity of tourist activities increase coral disease prevalence. Biological Conservation, 178, 88-96.

Liu, P. J., Meng, P. J., Liu, L. L., Wang, J. T. & Leu, M. Y. (2012). Impacts of human activities on coral reef ecosystems of southern Taiwan: A long-term study. *Marine Pollution Bulletin*, 64, 1129-1135.

Medio, D., Ormond, R.F.G. & Pearson, M. (1997). Effect of briefings on rates of damage to corals by SCUBA divers. *Biological Conservation,* 79, 91–95.

Nestor, V., Otto, E. I., Gouezo, M., Marino, L., Mereb, G., Olsudong, D., Jonathan, R., Swords, J. & Golbuu, Y. (2017). Impact of snorkelers on shallow coral reefs in the Rock Island Southern Lagoon.

Otto, E. I., Gouezo, M., Koshiba, S., Mereb, G., Jonathan, R., Olsudong, D., & Golbuu, Y. (2016). Impact of Snorkelers on Shallow Coral Reef Communities in Palau. Palau International Coral Reef Center.

Paradis, B. T., Henry, R. & Chadwick, N. (2019). Compound Effects of Thermal Stress and Tissue Abrasion on Photosynthesis and Respiration in The Reef-Building Coral Acropora Cervicornis (Lamarck, 1816). *Journal of Experimental Marine Biology and Ecology*, 521, 1-11.

Plathong, S., Inglis, G. J. & Huber, M. E. (2000). Effects of self-guided

snorkelling trails on corals in a tropical marine park. *Conservation Biology, 14*(6), 1821-1830.

Pilcher, N. & Cabanban, A. S. (2000). The status of coral reefs in eastern Malaysia. In: Global Coral Reef Monitoring Network (GCRMN) Report. Australia Institute of Marine Science, Townsville, pp 81.

Reef Check Malaysia. (2017). *Status of Coral Reefs in Malaysia, 2016*. Reef Check Annual Survey Report. Retrieved from https://www.reefcheck.org.my/ resources.

Renfro, B. & Chadwick, N. (2017). Benthic Community Structure on Coral Reefs Exposed to Intensive Recreational Snorkelling. *PloS One, 12*(9), 1-22.

Roche, R., Harvey, C., Harvey, J., Kavanagh, A., McDonald, M., Stein-Rostaing, V. & Turner, J. (2016). Recreational Diving Impacts on Coral Reefs and The Adoption of Environmentally Responsible Practices Within The SCUBA Diving Industry. *Environmental Management,* 107-116.

Rodgers, K. S. & Cox, E. F. (2002). The effects of trampling on Hawaiian corals along a gradient of human use. *Biological Conservation,* 112, 383-389.

Rouphael, A. B., & Inglis, G. J. (2001). Take Only Photographs And Leave Only Footprints?: An experimental study of the impacts of underwater photographers on coral reef dive sites. *Biological Conservation,* 100, 281–287.

Sabah Parks. (2020). Map of Tunku Abdul Rahman Park (unpublished).

Saphier, A. & Hoffmann, T. (2005). Forecasting models to quantify three anthropogenic stresses on coral reefs from marine recreation: Anchor damage, diver contact and copper emission from antifouling paint. *Marine Pollution Bulletin,* 51, 590-598.

Selkoe, K. A., Halpern, B. S., Ebert, C. M., Franklin, E. C., Selig, E. R.,

Casey, K. S., Bruno, J. & Toonen, R. J. (2009). A map of human impacts to a 'pristine' coral reef ecosystem, the Papahanaumokuakea Marine National Monument. *Coral Reefs,* 28, 635-650.

Somaskanthan, M. & Rosmalina, A. R. (2016). Determining the relationship of tourist satisfaction and loyalty. *Journal of Advanced Research in Social and Behavioural Sciences, 2*(1), 93-101.

Spalding M., Burke L., Wood S. A., Ashpole J., Hutchison J. & Ermgassen P. (2017). Mapping the global value and distribution of coral reef tourism. *Marine Policy,* 82, 104-113.

Toyoshima, J. & Nadaoka, K. (2015). Importance of environmental briefing and buoyancy control on reducing negative impacts of SCUBA diving on coral reefs. *Ocean and Coastal Management*, 116, 20-26.

Trygonis, V. & Sini, M. (2012). photoQuad: a dedicated seabed image processing software, and comparative error analysis of four photo quadrat methods. *Journal of Experimental Marine Biology and Ecology*, 424-425, 99-108.

Weaver, D. B. & Lawton, L. (2014). *Tourism management.* John Wiley & Sons.

Zakai, D. & Chadwick-Furman, N. E. (2002). Impacts of intensive recreational diving on reef corals at Eilat, northern Red Sea. *Biological Conservation*, 105, 179-187.

Zakai, D., Levy, O. & Chadwick-Furman, N. E. (2000). Experimental fragmentation reduces sexual reproductive output by the reef-building coral Pocillopora damicornis. *Coral Reefs*, 12, 185-188.

Zhang, L. Y., Chung, S. S. & Qiu, J. W. (2016). Ecological Carrying Capacity assessment of diving site: A case study of Mabul Island, Malaysia. *Journal of environmental management,* 183, 253-259.