The Adverse Impact of Anthropogenic Activities on Coral Reef

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Abstract: Coral reefs are one of the main habitats for marine organisms, located in the coastal areas, fostering around 35,000 to 60,000 species of animals. They provide protection and economic services to humans, generating millions of dollars per year from tourism and other uses. However, 50% of the world's coral was lost in the last 30 years due to global warming and other anthropogenic activities. Its annihilation process is swift from the fast coral bleaching that the coral undergoes from healthy to dead as a result of combined human activities of garbage disposal, illegal trading, chemical pollution, unsustainable overfishing, intensive tourism, and global warming. There are multiple cases of mass coral bleaching worldwide, such as the 1998 cases that struck Sabah, Borneo. Sipadan is an example of an area that sustains a great variety of coral reefs, well protected by legislation and agreements. However, its methods have their deficiencies when viewed from a larger scale, such as driving fishermen to other islands nearby and destroying other coral reefs. More solutions regarding this issue should be discussed, with consideration of different stakeholders. The article analyze the anthropogenic activities' impacts from two points of view: direct and indirect. Later on, it will focus on the applicable solutions for the future of this issue concerning the case of Sipadan.

1 INTRODUCTION

Coral reef, the underwater wonders supported by calcium carbonate construction secreted by coral, is the home to 35,000 to 60,000 species in the marine ecosystem. In addition to shielding the shore areas from ocean waves, it serves as a haven for a diversity of aquatic life. It is sustained through a symbiotic relationship with the algae zooxanthellae, where the zooxanthellae obtain needed shelter, carbon dioxide, and nutrients from the coral and then provide oxygen and remove waste for the coral. Due to the need for photosynthesis of its symbiotic algae zooxanthellae, coral reefs are often located up to 100m in depth and generally in coastal areas, making them susceptible to human activities. As a result, the depletion of coral reefs is increasing due to different human activities, such as overfishing, global warming, tourism, etc., which will eventually lead to the habitat annihilation of 25% of the marine organisms (El-Naggar and Hussein, 2020). Although there is a lack of quantitative information on the effects of anthropogenic activities, it is estimated that almost 60% of coral reefs are affected by these activities (Wilkinson, 2008). There is multiple research that show the correlation between the quantity of certain human activities and the health of coral reefs, yet few researches offer discrete solutions to the mass coral bleaching that is happening worldwide. It is noteworthy that a particular action may have a number of diverse effects, all of which when combined might result in coral bleaching and the coral disease spreading.

The coral reef is an important component biologically and economically of the Southeast Asian region, yet no systematic research has been conducted on the long-term anthropogenic stressors and the effectiveness of the various legislation that is being applied to the area. However, there is extensive research into the coral reef biodiversity and the coral reef cover throughout Malaysia, offering footstone into the research about human activities and coral degradation. To some extent, the establishment of coral-protected areas is crucial to the preservation of coral reefs in Malaysia as its economic growth and coastal population continue to rise.

Although there are some actions taken worldwide, focused on the different organizations that are trying to encourage people to put action into coral protection actions such as Coral Watch, governments and companies need to put more effort and investments into these projects. Laws such as the Environmental Quality Act (1974) and the Customs (Prohibition of Exports Amendment No. 4) Order (1993) safeguard

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coral reefs in Malaysia (Praveena et al., 2012). However, the effectiveness of these legislations has remained to be questioned. Aside from law enforcement, awareness is also an issue to be addressed as research on coral conservation awareness in the Terengganu community of Malaysia shows that 55.3% of the sample have acceptable knowledge of coral reefs and only 29.0% of the sample had good coral reef protection practices (Marzo et al., 2023).

Therefore, the objective of this article will focus on how anthropogenic stressors may directly and indirectly affect the coral reef population, and hence how these impacts can be mitigated through different socioeconomic and political restrictions.

2 CASE DESCRIPTION

Sipadan is Malaysia's only oceanic island, formed by coral reefs growing on top of a volcanic cone. It is famous for its turtle and coral reef, especially among scuba divers and snorkelers, classified as one of the world's top 10 diving sites. It was described as "an untouched piece of art" as it is in the coral triangle and consists of over 600 different coral species and nearly 3,000 different fish species (Musa and Ghazali, 2002). Dr. Elizabeth Wood from the British Marine Conservation Society began her ongoing monitoring of Pulau in 1992 and saw a noticeable decline in the number and quality of the coral reefs. Furthermore, the shallower parts of Sipadan's reef were completely destroyed by the tropical storm Greg in 1996. And because of global warming and rising ocean temperatures, the reef is impossible to regenerate and recover. Of Malaysia's variety of coral reefs, 97% were classified as threatened in 2011, and 50% as highly vulnerable to severe degradation (Burke et al., 2011). Later on, there are several policies established to restrict the proficiency and number of tourists that are allowed on the island to effectively protect the coral reefs. Sabah Parks declared on September 22, 2022, that starting on October 1, 2022, only ones who possess Advanced open water level certificates and Sipadan permits will be able to dive at Sipadan, with a maximum of two dives permitted (Musa and Ghazali, 2002).

Over 70% of Indonesia's reefs have suffered significant damage from natural causes and anthropogenic activities, according to the Ministry of Marin Affairs and Fisheries (Tuwo, 2011). However, due to the variety of protection acts in Sipadan, the coral reef condition in Sipadan was found to be in the finest condition in the Sibah islands.

3 ANALYSIS OF ANTHROPOGENIC STRESSORS' IMPACT ON CORAL REEF

3.1 Direct Impact of Human Activities

3.1.1 Traffic Boat

Because of its propeller string and anchoring mechanism, boats have the potential to harm the marine environment, particularly coral reefs, physically or mechanically (El-Naggar and Hussein, 2020). According to research conducted in the British Virgin Islands, the coral coverage, especially hard coral coverage differs significantly from low anchoring sites to high anchoring sites (Flynn and Forrester 2019). The research result by the team is shown in the table 1 below:

Table 1. Anchoring Level's Impact on Coral's Percentage Cover (Flynn and Forrester 2019)

Taxonomic Group	Low anchoring sites (percentage over)	Medium anchoring sites (percentage cover)	High anchoring sites (percentage cover)	Proportional change in cover (H-L)/L
Hard coral	17.05 ± 2.4	16.06 ± 2.3	9.91 ± 1.9	-0.42
Sea Fan	12.78 ± 5.9	4.71 ± 3.9	5.00 ± 0.4	-0.61
Soft Branching Coral	18.58 ± 6.3	19.15 ± 6.4	13.20 ± 5.7	-0.29
Dead coral	2.57 ± 2.0	2.80 ± 3.7	6.47 ± 3.55	1.52

The different levels of anchoring sites (low, medium, and high) are classified by different densities of anchoring activities as observed by the satellite imagery, with no obvious differences in proximity in land-based factors. As shown from the research, at high anchoring sites, coral coverage is approximately 39% smaller than that of low or medium anchoring sites, showing a strong correlation between the coral colony sizes and the amount of anchoring activities. Furthermore, mound corals and branch corals are most severely damaged, indicating coral loss is mainly the result of anchor chain

sweeping and other physical damages (Flynn and Forrester 2019).

However, the impact of traffic boats is an inevitable destruction of coral reefs because it's the only method of inter-island transportation and it is necessary for the economic development of a certain island. Aside from the physical damage, most of the boats that connect Semporna to other islands are fueled by oil, inevitably causing oil and toxin leakage into the ecosystem and the noise from ships may cause disruptions to the fish living in the coral reef (El-Naggar and Hussein, 2020).

3.1.2 Garbage Disposal

In Malaysia, more than 80 percent of people reside 50 kilometers or less from the coast, and they are overexploiting the country's natural resources (Asian Development Bank, 2014). An assessment was conducted on the Malaysian islands of Mamutik, Manukan, and Sapi, showing an abundance of marine debris, mainly consisting of plastic bags, plastic bottles, polystyrene, and plastic cups, in the intertidal zones (Zahari et al., 2022). The most prevalent marine debris found in the Malaysian islands is plastic bottles and plastic cups, which take up to 450 years and 50 years, respectively, to fully break down (Zahari et al., 2022). These plastic debris have a direct impact on the coral reef as they create openings to pathogens like ciliates or introduce pathogens directly such as Rhodobacterales carried in polyvinyl chloride (PVC) (a very common material used in children's toys and building materials). In fact, common coral diseases, such as skeletal eroding bands, white syndromes, and black bands, are more prevalent in corals that are greatly impacted by plastic wastes, leading to a higher mortality rate. In addition, microplastics are eight times more likely to be trapped in the more complex and branched corals, causing a greater impact on the structurally complex corals. Such a result may lead to macroplastic debris blocking out light for photosynthesis and resulting in a low-oxygen condition that favors the growth of microorganisms, leading to coral diseases such as the black band (Lamb et al., 2018).

There is usually poor waste management on small islands because the daily wastes do not have an efficient disposal method except for being thrown into the ocean. Especially for poor islands, cannot afford the high cost of transporting or breaking down the waste through artificial methods as the transportation is inconvenient on the island. To address this issue, more efficient and convenient garbage disposal methods should be researched and developed.

3.1.3 Illegal Trading

The commercial coral harvesting industry persists despite global legislation that limits the exploitation of coral reefs governed by the Convention on International Trade in Endangered Species. According to the NMFS analysis, the international trade of corals and live rocks has increased at a rate of 12 to 30 percent per year since 1990. Certain species such as the red coral have high economic value and culture, tempting the merchants to acquire them illegally to make money. In fact, red coral has been collected for 5,000 years as Ancient Egyptians, Romans, and Greeks used them as jewelry, and people in the Middle Ages used them to ward off witches. The CITES Trade Database states that between 2011 and 2015, around 210 tons and 80,000 pieces of raw Corralium corals that were listed under the CITES were imported worldwide (Tsounis et al., 2010). Large businesses also collect coral reefs as souvenirs or aquarium trade. Furthermore, the general population is unaware of how crucial coral is to the ecology, particularly dead and bleached coral. Therefore, it is common for tourists to take dead and stony corals as souvenirs or ornaments from trips to the ocean sides.

3.1.4 Chemical Pollution

Fertilizers and pesticides may result in the marine ecosystem through runoffs from farmlands. The harmful pesticides will accumulate inside the coral reef and even pass down along the food chain, causing a greater impact on the ecosystem and humans. Studies are conducted on H.micronos, F. speciosa, and P. lobata in the Sabah islands to measure the concentration of heavy metals. It was found that the amount of iron and nickel is significantly higher than that of other metals, but the chemical pollution condition in Sabah islands is not as severe as it is in other islands (Mokthar et al., 2011). Chemical leaks and spills, which are mostly the result of oil tanks, pipelines, and harbors, affect coral reefs' ability to grow, feed, defend themselves, reproduce, and organize their cells (El-Naggar and Hussein, 2020).

The concentration of different chemicals in the coral reef may lead to different implications of the contamination that the coral is exposed to. For example, a high concentration of zinc in coral species shows a high value of zinc in the seawater as the inclusion of zinc in the coral is mostly due to the

consumption of seawater-soluble metal through respiration and coral polyp feeding. A high nickel concentration, originating from fishing boats, crude oil in oil production fields, and harbors associated with organic matter, can significantly decrease the survival of coral larvae. In Sipadan specifically, the concentration of zinc in seawater is 0.070 ± 0.020 μg/L and the concentration of zinc in sediment is 13 ± 0.41 μg/g, a low number compared to the concentration elsewhere, but still concerning (Mokthar et al., 2011).

3.1.5 Fishing and Overfishing

In Malaysia, nearly all citizens reside within 100km of the coast and 53.4% of the fishers live in Sabah (Asian Development Bank, 2014). In Eastern Malaysia, destructive fishing practices have been prevalent, such as cyanide usage in killing reef fish, which causes the deterioration of valuable fish species like groupers, snappers, and wrasses due to its lack of specificity. In fact, about 68% of the coral reefs in Sabah have been destroyed or harmed by cyanide, which is a concerning number regarding the coral reef status worldwide (Government of Malaysia, 2010).

The removal of herbivore species may be just as impactful to the large-scale reef ecosystem as the removal of predators. The algae will quickly take over and dominate when marine grazers are eliminated, this is especially true when the ecosystem is also threatened by organic pollution and eutrophication. As algae spread, the water's dissolved oxygen content drops and sunlight is unable to reach deeper below the surface, which results in the death of more underwater organisms (El-Naggar and Hussein, 2020).

3.1.6 Tourism

Tourism increases the recreational constructions and demand for services from the ecosystem. Specifically, tourism related to coral reefs produces 35.8 billion dollars annually and draws almost 70 million visitors worldwide (Lamb et al., 2014). Unmindful tourists may cause great harm to the coral reefs during the scuba diving and snorkeling processes, especially by inexperienced divers. Some researchers show that there is a higher possibility of coral-damaging actions, such as touching the coral and kneeling on the coral, in inexperienced divers and tourists, which may indicate a needed proficiency level to get into contact with the coral is an approachable solution (Lamb et al., 2014). Research shows that around 90% of divers have one or more contact with corals during their diving experiences, with the most damage from accidental kicking of corals when they lose their buoyancy (58%) (Barker and Roberts, 2004).

Diving too close to the coral may unavoidably cause some of the nearby sediments to be disturbed, causing increased sedimentation loads from rocky coralligenous assemblages that will lead to a reduction in coral growth rate and health (Barker and Roberts, 2004). This results in the abundance decrease of massive corals and branch corals in diver-heavy sites. In research conducted by Kalyan De and Mandar Nanajkar, it is shown that the high-density diving sights have a significantly higher amount of coral damage than non-dive sites and low-density diving sight, reaching an amount of 20% of the coral being physically damaged by the year 2019 (Kalyan et al.,).

3.2 Indirect Impact of Human Activities

3.2.1 Global Warming

Coral bleaching is one of the most direct presentations of anthropogenic climate change's severe damage to a biological system, and global warming is also the major threat that coral reefs are facing currently. The symbiotic zooxanthellae depart the coral skeleton during coral bleaching because the algae are unable to adjust to the increasing temperature. Without the symbiotic algae, the coral is incapable of growing, feeding, and reproducing, which eventually leads to death. If the environment recovers to the normal level in time, then the zooxanthellae will come back and the coral can sustain. Therefore, there is research conducted to evaluate the impact of anomaly exposure time and magnitude of temperature change on the coral's ability to recover from anomalies (Strong et al., 1996). This is measured using "degree heating weeks," or DHW, which is calculated using the formula DHW = anomaly size-length of exposure. If DHW is greater than 4, then the coral can recover from bleaching without lasting damage. If DHW is greater than 8, then the coral will bleach with a lasting impact, causing possible mortality. If DHW rises above 12, then it usually will cause mass destruction of coral reefs, such as the mass bleaching incident in the Western Indian Ocean in 1998, leading to the death of 50% of the corals in the region (Strong et al., 1996).

3.2.2 Ocean Acidification

Ocean acidification is closely connected with the rising concentration of CO2 across the world. It

occurs when carbon dioxide enters water and creates carbonic acid, which will then turn into bicarbonate ions that will react with calcium carbonate, the main composition of coral skeletons. Research in 1999 shows that the existence of high concentrations of bicarbonate ions will be able to reduce up to 40% of the coral and other marine calcifier's ability to produce calcium carbonate skeletons (Kleypas et al., 1999). These factors will eventually lead to coral's inability to grow and sustain the reef.

3.2.3 Outbreaks of Crown-of-Thorns

Crown-of-Thorn is a species of starfish that typically feeds on coral, causing a decrease in coral population. Under natural processes, they can effectively control the population of coral to maintain ecological balance. However, outbreaks of crown-of-thorn starfish may also lead to massive destruction of coral reefs that would take 30-50 years to recover, and maybe even longer considering the current ocean acidification status. In worse cases, the coral reefs may never recover as their habitat is being overtaken by sponges, algal cover, or other coral species (El-Naggar and Hussein, 2020).

The mass outbreaks of crown-of-thorn are indirectly caused by humans as they thrive in poor water quality and hazardous natural phenomena such as tropical cyclones, which are increasing due to chemical pollution and climate change. Moreover, humans overharvest the crown-of-thorns' natural predator Triton Trumpet, which offers space and opportunity for their population to thrive (Forbes, 2006).

4 SUGGESTIONS

4.1 Marine Protected Areas

Marine-protected areas can take different forms, where some should restrict human entrance in general and some can allow well-trained and professional tourists to minimize the harm to the coral reefs, such as in Sipadan. According to research conducted in 2019, the awareness of coral protection and quality diving experience increases as the proficiency of the diver increases, and the well-protected area will further attract more experienced divers to maintain the economy needed by the area (Barker and Roberts, 2004).

Sipadan has prohibited blast and cyanide fishers due to concerns about overfishing and dynamite fishing. However, by forcing these fishermen to Mabuh Island, this action has caused more devastation elsewhere. This shows that the marine-protected areas are efficient in protecting the biodiversity of a single area, but it is hard to apply to a greater scale as socioeconomic needs still exist.

4.2 Funding of Different Action Plans

Currently, there are a variety of action plans in Malaysia that are collected in Malaysia's National Plan of Action (NPOA), formed to inform all the stakeholders to be aware of all the projects that are undertaking actions. It includes 134 action plans, headed by 16 government departments and agencies, 1 research institute, and 1 non-governmental organization, that are either in progress or have been submitted to appropriate agencies and organizations (Asian Development Bank, 2014). However, these action plans are suffering from multiple implementation issues, including but not limited to insufficient funding and inadequate permanent and experienced experts. Therefore, only a few actions are funded and commenced, while most of the action plans remain proposed and unfunded (Asian Development Bank, 2014).

5 CONCLUSION

Anthropogenic activities have impacted coral reefs for years both directly and indirectly, causing detrimental impacts to the reef ecosystem. Sipadan as an individual diving site with a variety of precious coral and fish populations is successful from its control over divers and fishermen; however, its strategy cannot be applied to a large scale due to socioeconomic needs worldwide. The direct and indirect interactions between humans and coral may harm the coral from different aspects that vary by species, limiting their growth, eliminating their branches, and suppressing the chemical reactions required. Due to the fast-paced destruction of coral reefs, maintaining the current coral population is not enough, restoration is also crucial to their survival; therefore, the participation of different ocean initiatives and actions needs to be noted by the mass public. This paper gives a holistic view of the various impacts of each anthropogenic action in depth and can effectively inform the public about the correlation between human activities and coral reef deterioration. In the future, hopefully, there will be more research conducted on the restoration process of coral reefs and building coral reef resistance against global warming.

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