Transactions on Environment, Energy and Earth Sciences
ISSN: 2960-1924, eISSN: 2960-2300 | Volume 3
GRET 2024

Analysis of Unbearable Pressures on The Great Barrier Reef Ecosystem

Motong Wang *

College of Agricultural and Environmental Sciences, University of California, Davis, Davis, China

* Corresponding Author Email: viwang@ucdavis.edu

Abstract. Under the trend of global warming, coral reef ecosystems are under stress beyond the scope of the system to repair itself. The Great Barrier Reef (GBR) ecosystem, as the most representative coral reef ecosystem, is facing difficulties such as coral bleaching and reduced coral abundance due to excessive stressors. Based on the existing scientific research results and relevant experimental data, the existing stressors and their consequent impacts in the GBR ecosystem were reviewed. At present, the coral reef ecosystem in the GBR can be surveyed and clearly affected by three human-induced stressors: water quality, overfishing, and climate change. Water pollution from agriculture, industry and tourism surrounding the GBR ecosystem has led to a decrease in the ecosystem's energy supply and an increase in the prevalence of Marine life. Overfishing has resulted in the removal of vital roles that maintain the GBR ecosystem from the GBR ecosystem, limiting the productivity of the reef ecosystem. Climate change is hitting calcium-dependent Marine life in the GBR ecosystem and reducing the reproductive success of Marine life. The better understanding of the stressors coral reef ecosystems is facing can help us in our efforts to protect coral reef ecosystems in the future and help the organisms in the coral reef ecosystems adapting environmental changes brought by global warming, while bring down the influence of human activities on the ecosystem through policies.

Keywords: The Great Barrier Reef, global warming, coral reef ecosystems.

1. Introduction

The topic of global warming has gained prominence in international treaty negotiations, cooperation between countries, and summit meetings of governments. As a result, the various influence of global warming often cause widespread concern among government policymakers, scientist and the general public [1]. Climate change driven by global warming is mainly caused by carbon dioxide and other greenhouse gases released by human activities [2]. One of the central regions of the world that has experienced strong warming during this decade is northern Asia, ranging from Siberia to the Far East, according to studies conducted between 1999 and 2008[1]. The effects of global warming are hard to ignore, Becasuse of the widely report through news and media. The public appealing to researcher and government around the world and forced them launching campaigns to against global warming. However, the massive amounts of greenhouse gases brought on since the age of industrial revolution have pushed global warming to the point where it cannot be stopped. What researchers and governments have done so far in a short period of time is like throwing an ice cube into boiling water, and it pales in comparison to the greenhouse gas emissions caused by human in long history. The potential threat to coastal cities from rising sea levels caused by global warming gets most of the attention and makes the ocean becoming the most visible victim under the trend of global warming. The dependence of the economies of coastal cities on Marine ecosystems is another reason for researchers to focus on the oceans, because coral reef Marine ecosystems can provide a large supply of resources. When the resources generated by the coral reef Marine ecosystem decrease and cannot meet the needs of the coastal urban economic system, it is likely to cause the collapse of the coastal urban economic system and the lack of resources. The stress on coral reef Marine ecosystems caused by global warming is causing the ecosystems themselves to fail to function well, and not only are coral reef Marine ecosystems unable to provide resources for coastal cities, but coral reefs themselves are in steep decline.

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The Great Barrier Reef (GBR) holds the title of being location of the largest coral reef ecosystem on earth and approximately 20,000 square kilometers are covered by 2,900 coral reefs and 900 coral cays, making up a total area of 345,000 square kilometers in the GBR Marine Park [3]. In the past decade, more and more reserches and news reports have begun to pointcoral reef bleaching events that GBR is experiencing. The increasingly frequent occurrence of coral reef bleaching has been more and more frequent in the public eye. Between 1997 and 1998, records indicate that mass coral bleaching affected 42 to 60 percent of the GBR, and 31 other countries around the world reported coral bleaching and loss of coral cover [3]. The rising temperature due to human activation may be the reason. Coral bleaching is a coral disease that occurs when external stressors stimulate individual corals and exceed individual adaptive ability, resulting in damage and loss of symbiotic bacteria and photosynthetic pigments in coral cells. [4]. About 400 species of hard coral can be found in the GBR ecosystem, which is inhabited by a diverse group of organisms[3]. There are over 1500 varieties of sponges, around 4000 varieties of mollusks, approximately 800 varieties of echinoderms, and including over 1,500 varieties of fish [3]. If the climate change brought by human activities is unable to be adapted, all the creatures that habit The GBR ecosystem will face catastrophe.

As the Global Biodiversity Outlook 2024 report shows, the influence of climate change are generating negative trends in overall habitat conditions it is more pronounced in coral reef habitats than in other habitats [2]. Although coral cover has risen in comparison to the 2019 assessment, overall, the cumulative pressures from climate change, crown of thorns starfish (COTS) outbreaks and poor quality of water in offshore areas continue to negatively impact coral reefs [2]. Over the past three decades of recorded coral bleaching, mechanisms that mitigate coral bleaching have also gradually lost their effectiveness in the face of rising temperatures. [4]. Therefore, the disturbances that reefs are facing and their ability to resist deserve continued attention, which can help protect coral reef ecosystems. In this paper, the stressors facing by the GBR ecosystem and the impacts of stressors is going to reviewed by combining the scientific research results and relevant data from various aspects.

2. Influence of Water Quality on Coral Abundance in the GBR

The GBR, the most famous holiday destination in Australia, was established in 1975 as a Marine Park managed as a zoned, multi-use habitat protection area and the multi-use zoning is managed in a way that provides a high level of protection for the habitat while also allowing commercial activities to take place in other areas [2]. However, increased human activity is putting increasing pressure on the GBR ecosystem, in the decline in water quality caused by human activities poses a threat to the long-term health of the coral ecosystem of the GBR [5]. According to the international consensus, Marine pollution caused by human activities mainly comes from agriculture, cities and industry, and the impact of these human activities can also be observed in the coral ecosystem of the GBR [5]. Previous data monitoring has shown that the coral ecosystem of the Great Barrier Reef tends to contain higher concentrations of pollutants closer to human activity [6]. These locations close to human activity are usually harbors, seaports, urban centers, and areas with intensive agricultural activity [6]. Because of frequent human activities are followed by large amounts of wastewater discharge and agricultural runoff, which flow from polluted water into nearby waters and increase the concentration of pollutants in local waters. [6]. According to estimation, an approximation of 16 million tons of sediment, 6,300 tons of nitrogen and 1,100 tons of phosphorus are imported into the GBR through rivers each year [7]. The massive influx of nutrients into the reef's coral ecosystem is the result of agricultural expansion, with fertilizer use by the agricultural industry more than tripling [6].

2.1. Marine Pollution Caused by Agriculture

Dissolved inorganic nitrogen (DIN) is widely used in fertilizer products [5]. The concentration of DIN in seawater is usually associated with tropical cyclones and monsoon rains, which flow into the ocean through land erosion [6]. The organic substances in plankton and sediments are enriching by DIN, resulting in reduced calcification and elevated concentration of photopigment and conducting to higher coral morbidity [5]. DIN provides rich nutrition to larvae of COTS and enhance the chances of COTS’s larvae to survive [7]. As coral predators, a surge in COTS populations can cause huge damage to coral reefs [3]. The GBR has experienced the greatest external pressure from COTS outbreaks over the past 50 years, leading to the death of coral [2].

Pesticides are also widely applied in human agriculture and enter the ocean through land erosion and other substances [5]. During the rainy season, the reef's offshore waters close to human agricultural activities are highly exposed to weeding runoff from agricultural fields [5].

Because of the particularity of insecticides, the mobility and solubility of insecticides threaten the downstream freshwater and Marine ecosystems, especially by affecting the algae with which corals are symbiotic and affecting coral coverage [5]. Photosynthesis in Marine plants can be inhibited by prolonged exposure to herbicides [5]. Herbicides deprive plants of energy sources by inhibiting photosynthesis and respiration, forcing plants to die because they do not have enough energy to maintain their own machinery. When the algae that having symbiosis relationship with coral, which also rely on photosynthesis and respiration to provide energy for the coral reef ecosystem and the individuals, are exposed to high levels of herbicides, it will result in a large population decrease due to the inhibition and destruction of energy sources. Because of the symbiotic relationship between coral reefs and algae, when the algae decrease in large numbers, coral reefs do not get enough help from the dinoflagellates to cope with the pressure of survival, resulting in a decrease in coral cover and population. In addition, algae act as producers in coral reef ecosystems, and the reduction in the number of producers or the absence of producer roles due to herbicides can lead to a breakdown in the energy supply chain of the entire coral reef ecosystem. When exposed to herbicide-rich environments, algae cannot provide enough energy for the entire coral reef ecosystem compared to flagellate because of the inhabitation of photosynthesis. In the absence of a guarantee that the entire coral reef ecosystem has enough energy to function, the coral reef ecosystem is unlikely to have more energy to resist other external stressors.

Heavy metals also enter the reef's coral ecosystem through weathering and erosion [6]. The GBR ecosystem is dependent on many heavy metals, but if the safe range of living organisms is exceeded, the GBR ecosystem can suffer devastating damage [6]. Unnatural amounts of metals are released into the terrestrial environment in high concentrations because of agricultural activities and persistently released into the GBR ecosystem through rainwater seeping from farmland and domestic wastewater discharge during periods of continuous rainfall [6].

2.2. Marine Pollution Caused by Industrial

Coral reef ecosystems have been contaminated with petroleum products and heavy metals by industrial activities around the GBR, although some of the pollution itself is present in the environment, but they are fatal to biota due to unsafe concentrations of pollutants [6]. As a natural component of crude oil, polycyclic aromatic hydrocarbons (PAH) account for 20% of the integrated hydrocarbons in raw petroleum, and more PAH can be produced in the process of high-temperature combustion [8].

Fuel combustion, waste and rainwater discharge, oil spills, and cruise ship accidents are all sources of PAH in the GBR ecosystem [8]. The oceans around the world are forced to received an roughly 6.1 million tons of petroleum products every year, with the majority of these emissions coming from man-made sources [9]. PAH is the most toxic class of compounds in petroleum, and because of its volatile and short-lived characteristics, its acute toxicity can be greater than chronic toxicity [8]. PAH works by interfering with an organism's metabolism and is more likely than other hydrocarbons to be retained in the body by biological tissues [6].

Therefore, when petroleum products containing PAH are leaked into the Marine environment, they can threaten the growth process of Marine organisms and become a carcinogen [9]. Once PAHs are deposited in sediments, filter-feeders and benthos suffer from an inability to metabolize toxic compounds, genetic mutations, and cell atrophy [9].

2.3. Marine Pollution Caused by Tourism

As one of the world wonders, the GBR is Australia's most popular tourist and entertainment destination. However, due to large number of human activities brought by tourism and entertainment industry, a large amount of Marine litter is generated in GBR. Marine debris is artificial solid waste that enters the Marine ecosystem in various ways [10]. The majority of marine litter worldwide is consist of plastic, which accounts for up to 70% of the litter and can have physical and physiological effects on marine organisms, eventually leading to disease or death. [10]. The cause of death is more than just intestinal obstruction, but also the heavy metals and other toxins from floating plastic debris that absorb from the ocean and those toxins being absorb by animals tissues [10]. Marine organisms may be attracted not only by the appearance of plastic debris but also by the difficulty of distinguishing between food and the smell of biofilm plastic [11].

On the GBR, the highest concentration of human activity areas overlaps with the habitat of local organisms. High levels of human activity make plastic inevitably infiltrate the diets of local organisms. According to the study on Heron Island, a significant number of wedge-tailed shearwater (Ardenna pacifica) were found to have absorbed plastic debris, with each wedge-tailed gull consuming an average of 3.2 pieces of plastic, which weighed 0.056 grams each [12].

Marine debris is also a stressor that reduces coral reef abundance [13]. In coral reef ecosystems, microplastic pollution increases the likelihood of coral bleaching and disease [13]. And because consuming suspended particles such as microplastics requires energy-intensive tissue contractions to actively remove these pollutants, the corals' energy consumption increases [13]. Microplastics also have the potential to block the entire stomach cavity of the coral or to give the coral a false sense of fullness and an inability to meet the required energy intake [13].

Fishing lines from Marine debris wrap around corals, causing tissue damage and bone wear, and providing surfaces for pathogens to come into contact with, increasing coral morbidity [13]. In addition to damaging the coral structure, large pieces of plastic wrapped around the coral structure can prevent the coral from photosynthesis and oxygen exchange [13].

3. Influence of Overfishing on the Abundance of Marine Organisms in the GBR Ecosystem

In recent year, the ecological collapse caused by overfishing is no less severe than the disruption caused by other human activities to coastal ecosystems. Some of the commercial fish are an integral part of the GBR ecosystem. and when these commercial fish are overfished it can affect the overall productivity of the reef [14]. Sea cucumbers (Holothuroidea, order Aspidochirotida) most common members of the Marine benthic community, and they occupy a large commercial value in the Chinese market, therefore a large amount of dried and smoked sea cucumber products are sold to China [14]. Concerns have been raised about overfishing in the GBR ecosystem due to their significant role in the ecosystem and the dramatic decline in the species' density due to overfishing [15]. In 1999, the density of Holothurian nobilis (black teat fish) on the reefs of the GBR ecosystem had fallen to about 25%, forcing local authorities to shut down the H. nobilis fishery [14]. Of the 70 sea cucumber species currently in market circulation, at least 12 species have the habit of regular embedment in sand, which taking an role of great concern in sediment bioturbation [15]. It is estimated that sea cucumbers in tropical regions sift through large amounts of sediment each year, increasing coral productivity and promoting coral growth in nutrient-poor coral waters [15]. About 4,600 kg of dry sediment is turned over every year by Holothuria atra and Stichopus chloronotus in the GBR ecosystem [16]. In the process of feeding on sediment, sea cucumbers can reduce the organic load and convert the sediment into inorganic N and P in the body, which can improve the productive forces of the terrestrial biota [15]. In addition, sediment feeding by sea cucumbers can also affect the carbonate chemistry of seawater, locally slowing ocean acidification caused by human activities [15].Sea cucumbers can suppress coral disease in the process of consuming sediment [17]. Marine sediment-related coral disease is one of the reasons for the dramatic decline in coral cover, and sea cucumbers can suppress pathogens associated with coral disease in the process of feeding [17].

4. Influence of climate change on coral calcification rates in the GBR

The rise of the Industrial Revolution led to an increase in atmospheric carbon dioxide and absorbed by the surface oceans, resulting in lower pH and carbonate levels in the upper waters [3]. This process, known as ocean acidification, has a serious impact on Marine organisms in Marine ecosystems that rely on calcium carbonate to form their shells and skeletons [3].

Coral reefs are at risk from ocean acidification as it decreases the saturation of aragonite minerals, which are primarily responsible for the coral skeleton, and decreases the concentration of carbonate ions required to preserve carbonate reefs, and coral calcification can be the indicators of coral reef ecosystem health [3].

Experimental data models predict the growth trend of coral reefs within the GBR following the rise of atmosphec carbon dioxide [18]. Experimental data show that the growth and calcification of Porites in the GBR decreased with the rise of carbon dioxide, and the rate of calcification declined more rapidly than historically [18].

The fertilization process of Marine organisms depends on the specific aquatic environment, and the change of Marine environment by ocean acidification will potentially affect the breeding process and success rate of Marine organisms. Many Marine organisms' reproduction process is in vitro fertilization, and if sperm degrade the competence to move around in the water because of changes in the pH, the reproduction of Marine organisms will be suppressed [19]. Experimental data show that ocean acidification reduces the fertilization success rate of Marine invertebrates by 25%, and induces a reduction in species size and higher mortality [20].

5. Conclusion

In conclusion, there are three main stressors challenging the reef ecosystem in the GBR. The first is water pollution caused by agriculture, industry and tourism. Agricultural activities around the GBR have led to bring up the level of nutrients in the water, thereby increasing the number of coral predators and indirectly leading to a decrease in reef abundance. Herbicides and fertilizers used in agricultural activities flow into the GBR ecosystem with erosion. Herbicides flowing into seawater inhibit photosynthesis by coral reef symbiotic algae, reducing the energy supply to the reef's coral system. Fertilizers and soil flowing into the GBR ecosystem increase heavy metal levels, exposing Marine life in the GBR ecosystem to unsafe levels of high heavy metal concentrations. Oil spills caused by industrial activities can contain toxic substances that disrupt the normal growth activities of Marine life and threaten health. The augment in Marine litter in the coral ecosystem of the Great Barrier Reef is root in human activities due to the surge in tourism. The health and normal physiological activities of Marine organisem cannot be guaranteed under the prevalence of plastic waste. The incidence of disease has also aggrandized with the growing in Marine litter. Second, an essential role in maintaining ecosystem productivity is lost when commercial marine life is overfished. Third, ocean acidification caused by climate change has led to biological calcification and decreased reproductive success.

By having a better grasp of the stressors that impact the reef ecosystem in the GBR, we can more effectively mitigate the collapse of the reef ecosystem. It focuses on improving the water quality of the GBR ecosystem and reducing the impact of surrounding agricultural and industrial activities. Soil protection and soil erosion can be prevented in various ways. First, increase the vegetation cover of farmland and bare land, and plant windproof and soil-strengthening plants to reduce soil erosion. Second, through crop rotation and intercropping, soil structure can be maintained to the greatest extent, soil health can be improved, and the possibility of soil erosion can be reduced. Third, create wetlands or natural buffers along the edge of the GBR ecosystem and uutilize the natural buffers to absorb some of the agricultural pollutants.

Emphasize the sustainable development of fishery resources and crack down on overfishing. Scientific research is used to determine sustainable amounts of commercial fish to ensure that fisheries in the GBR ecosystem have sufficient time and opportunity to recover. Set fishing bans to allow fish in the breeding season to recover and expand existing conservation zones to ensure that larger areas of the reef ecosystem are effectively monitored.

Local departments are able to limit the environmental impact of petroleum spills by focusing on prevention, emergency response, technological improvement, policy regulation and corporate responsibility. Use more advanced technologies and facilities to prevent oil spills caused by aging equipment, and establish a rigorous facility inspection and maintenance program. Regular maintenance of cruise ships, storage tanks and other facilities can reduce petroleum leakage caused by equipment failure. Set up emergency devices to minimize petroleum leakage in the event of an accident.

Improving the rise in plastic waste caused by tourism can start with policy. Restricting the use of single-use plastics within the GBR ecosystem, switch to reusable or degradable alternatives such as bamboo, paper or degradable materials. Tourist are also encouraged to bring their eco-friendly items. In tourism campaigns, tourists are encouraged to bring reusable water bottles, cutlery and bags to reduce the need for single-use plastic. Support tour operators in providing reusable and environmentally friendly products.

Even though it is impossible to raise people's awareness about environmental protection in the short term, and the implementation cost would increase. If these measures are successfully implemented, the GBR ecosystem will benefit from reduced plastic pollution, improved Marine life, reduced coral bleaching and disruption of ecological chains, and the maintenance of biodiversity, enhancing its overall health and sustainability.

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