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An Appraisal on The Ecological Controversy and Conservation Strategy Resulting from The 2021 Referendum for Taoyuan Algal Reefs in Northwestern Taiwan

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ABSTRACT

The year 2021 witnessed the ecological controversy of algal reefs due to the proposed referendum for the removal of liquefied natural gas (LNG) terminals from algal reefs at Datan (大潭). Even though in the end the referendum failed to win the required voting threshold, the public still fails to comprehend the core issues involved with the referendum. In this review, seven scientific criteria listed by the Global Ocean Initiative (GOBI) were applied to assess whether Datan algal reefs could qualify as a marine protected area (MPA). The results showed that the majority of the highlights of the biodiversity of Datan algal reefs as claimed by the environmental organization "Action Alliance of Saving Data Algal Reef" were derived by incorrect methods, conjectures or exaggerations, which were evidently different from the facts. In order to effectively conserve and restore Datan algal reefs, it is suggested: (1) to implement the environmental commitments on Datan algal reefs; (2) to continuously input more efforts in the existing MPA (Guanxin [觀新] Algal Reefs Ecosystem Wildlife Refuge) so that it can provide the positive spill-over effect on nearby Datan algal reefs; (3) to mitigate, remove, and avoid sedimentation on the algae reefs; (4) to better understand the biology of the reef-building crustose coralline algae; (5) to study the biology of the protected coral *Polycyathus chaishanensis*; (6) to conduct the overall strategy to protect the Taoyuan coast and prevent and mitigate pollution; (7) to conduct ecological monitoring of Taoyuan algal reef ecosystems. In this way, existing algal reefs can provide ecological functions such as benefiting the recruitment of invertebrates and providing shelters for small benthos that would subsequently become prey for macrofauna and shorebirds. Eventually, the algal reef ecosystems should be able to provide its ecosystem services.

Keywords: crustose coralline algae, liquefied natural gas terminal, marine protected area, *Polycyathus chaishanensis*, sedimentation.

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1 INTRODUCTION

On December 18, 2021, voters in Taiwan voted on a nationwide referendum which asked, "Do you agree CPC's Third LNG Terminal should be relocated from the coastal area of Datan, Taoyuan City?" The result was a total of 3,901,171 voting in favor and 4,163,464 against. Therefore, the referendum failed to pass. Events leading to the proposition of this referendum are rather complicated and convoluted. The tactics used by environmental groups in formulating the referendum and the drive to promote public awareness of the issue deviated from the norm of scientific approaches, including smear campaigns used to attack those who were against the referendum. The purpose of this review is to chronicle the historical events leading to the proposal of the referendum and to offer the critiques on misleading information and data presented by the environmental groups and to offer a comprehensive plan on how to preserve the algal reefs involved in the referendum.

2 AN OVERVIEW ON THE ORIGIN OF THE REFERENDUM FOR DATAN ALGAL REEFS

In 1982, Coin Chemical Industrial Corporation drained cadmium-polluted water to the Datan area of Guanyin (觀音) Township, Taoyuan (桃園) County (now Taoyuan City), which resulted in cadmium-polluted rice. Environmental evaluation concluded that the whole Datan area was suspected of being contaminated with industrial wastes, and the government-initiated land expropriation and created Datan Industrial Park in 1992, which included the aforementioned polluted areas (Table 1).

In 1996, Tuntex Incorporation established Tungting Gas Corporation in Datan and proposed the project "Development of Guantang (觀塘) Industrial Park in Taoyuan" to construct liquefied natural gas (LNG) terminals on the coast. In 1999, reviews of the environmental impact assessment (EIA) of this project were passed by the Environmental Protection Agency, and Guantang Industrial Park was then set up. Reviews of the EIA of the project Guantang Industrial Port were passed as well in 2000. In this project, 232 acres of the coastal area were proposed to be filled with sediment for the construction of the Third LNG Terminal, which was the origin of the ecological controversy in ensuring years.

In 2001, Taiwan Power Company (TPC) constructed Datan Power Plant, and the construction of groins for the inlet (between Guanyin algal reefs and the G3 area of Datan algal reefs) and outlet (between the G3 and G2 area of Datan algal reefs) of the power plant was completed in 2003 (Figure 1). Simultaneously, Tungting Gas Corporation started reef excavation and 5 acres of reef reclamation in the G2 area and constructed a coastal groin (between G2 and G1 area of Datan algal reefs) (Figure 2). However, Tungting Gas Corporation failed to sign the LNG contract with TPC in 2003 and stopped the coastal development completely in 2004. The Taiwan government stopped the reclamation of Guantang Industrial Park in 2005 and terminated the agreement for "Investment, Development and Construction in Guantang Industrial Park" with Tungting Gas Corporation in 2007.

Due to the nuclear disaster that occurred in Fukushima, Japan in 2011, the Taiwan government announced a new policy in 2014 to ensure nuclear safety, reduce dependence on nuclear energy, create a green-energy and low-carbon-emission environment, and gradually to build a nuclear-free home. This policy was directed toward

renewable resources and gas-generated power. Hence in 2016, to prevent power shortages and alleviate air pollution, the Taiwan government planned to expand the scale of Datan Power Plant to replace old power plants that had higher pollution outputs.

In 2016, Chinese Petroleum Corporation (CPC) of Taiwan acquired Tunting Gas Corporation and took over the project of "Development of Guantang Industrial Park (Port)". In 2017, CPC released the reports "Environmental Impact Assessment and Differential Analysis of Environmental Conditions and Strategy Reviews for Guantang Industrial Park/Port, Taoyuan City" and "Environmental Impact Assessment for the Development of Guantang Industrial Park: Coping Strategies for Algal Reef Ecosystems". Simultaneously, concerns initiated by several civic advocacy groups over the possible impact caused by Guantang Industrial Park/Port on the algal reefs gradually drew the attention of the public.

The EIA reports and coping strategies proposed by CPC faced challenges by some environmental organizations that advocated preserving the algal reefs. These organizations considered the site inappropriate for the Third LNG Terminal and advocated removal of the Third LNG Terminal away from Datan coastal area. In January 2018, CPC proposed the project of "Avoidance and Replacement," in which the area for the development of Guantang Industrial Park was reduced from 232 to 37 acres to avoid the algal reefs and to safeguard the habitats of the protected coral *Polycyathus chaishanensis*. In addition, the project replaced the original industrial port by offshore open layout to maintain longshore current flows in the coastal zone.

In August 2018, CPC further proposed the revised project of "Avoidance and Replacement," in which the development area was further reduced to 23 acres and no additional land would be filled to maintain the existing algal reefs and coastline. On October 8th 2018, the reports "Environmental Impact Assessment and Differential Analysis of Environmental Conditions and Strategy Reviews for Guantang Industrial Park/Port, Taoyuan City" and "Environmental Impact Assessment Report for the Development of Guantang Industrial Park: Coping Strategies for Algal Reef Ecosystems" were approved by the Environmental Protection Agency. However, the environmental organizations strongly criticized this approval. In April 2019, the Ministry of the Interior issued the development permit of Guantang Industrial Park (Port included) to CPC. In June 2020, concerned that Datan algal reefs would be destroyed by the development of the Third LNG Terminal, the environmental organization "Action Alliance of Saving Data Algal Reef" launched the petition for the referendum "Treasuring Taoyuan Algal Reefs" and posed the question "Do you agree CPC's Third LNG Terminal should be evacuated from the coastal area of Datan, Taoyuan City?" in the referendum.

After the referendum was registered in May 2021, the government announced the project "Additional Seaward Movement of the Third LNG Terminal," in which the Third LNG Terminal was to be moved further seaward away from the coastline to maximize the protection of the algal reefs and to minimize the impacts on power supply, and thereby achieve the win-win goals of maintaining power supply and protecting algal reefs. Because of this newly proposed project, the period of construction was prolonged by 2.5 years, and the additional expenses increased to 15 billion NTD (New Taiwan Dollars). On December 18th 2021, the referendum failed to gain the approval of the public (Yes votes: 3,901,171 vs. No votes: 4,163,464), so CPC continued to carry out the development project of Guantang Industrial Park/Port. On March 2nd 2022, the revised project "Additional Seaward Movement of the Third LNG Terminal" was approved by the EPA. The construction of the Third LNG Terminal is expected to be completed by June 2025.

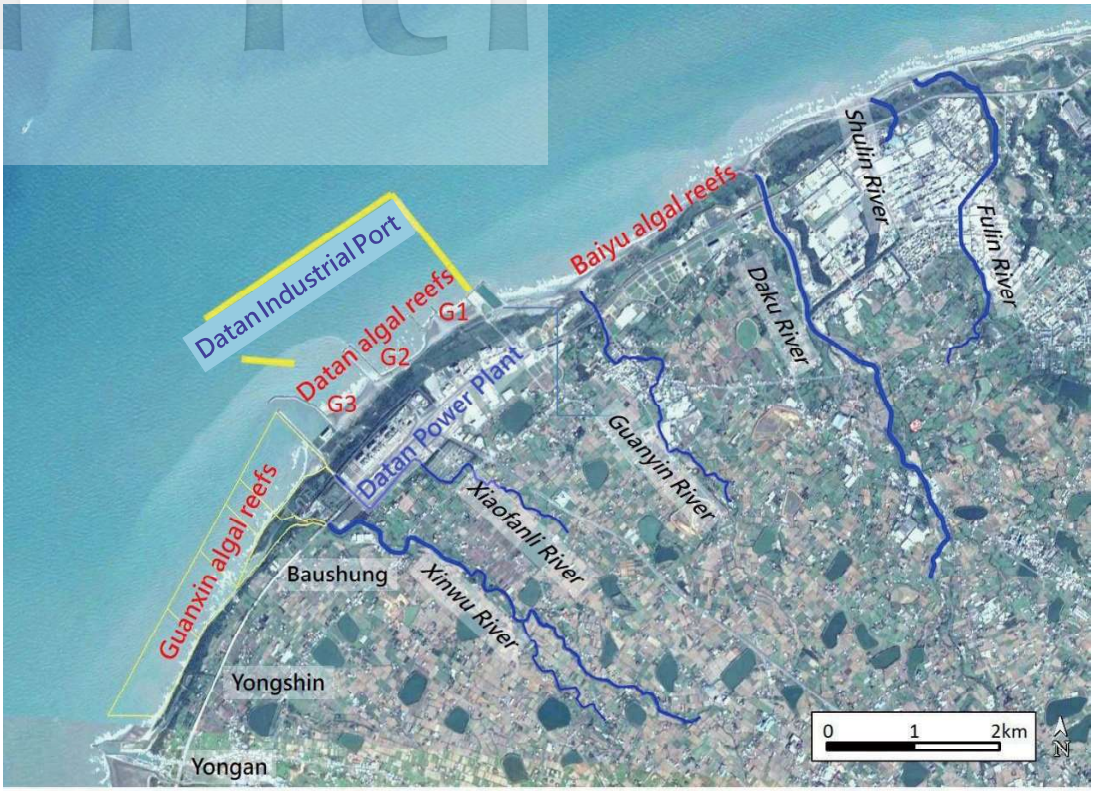

Figure 1. The relative locations of Guanxin algal reefs (Yongshin and Baushung), Datan algal reefs (G1, G2, and G3), Datan Power Plant and the Industrial Port, and Baiyu algal reefs.

Table 1. Chronology of the development in Datan algal reefs.

Year	Event
1982	Coin Chemical Industrial Corporation drained cadmium-contaminated water to the Datan area, which led to the cadmium-polluted rice produced in Datan.
1992	Datan Industrial Park was established because of the contaminated land.
1996	Tuntex Incorporation established Tungting Gas Corporation (TGC) and proposed the project of "Development of Guantang Industrial Park in Taoyuan County" to construct liquefied natural gas (LNG) terminals.
1999	"The Environmental Impact Assessment (EIA) of Guantang Industrial Park" was passed.
2000	The EIA of Guantang Industrial Port was passed.
2001	Taiwan Power Company (TPC) started to construct Datan Power Plant.
2003	TPC completed the construction of groins for the inlet and outlet of Datan Power Plant. TGC started reef excavation, reclaimed 5 acres of the G2 area, and constructed the coastal groin.
2004	TGC failed to sign the LNG contract with Chinese Petroleum Corporation (CPC) of Taiwan so that the coastal construction was aborted completely.
2005	Taiwan government stopped the reclamation of Guantang Industrial Park.
2007	Taiwan government terminated the agreement of "Investment, Development and Construction in Guantang Industrial Park" with TGC.

Year	Event
2014	To respond to the nuclear disaster in Fukushima, Japan in 2011, Taiwan government announced a new policy toward building a nuclear-free home by promoting renewable resources and gas-generated power.
2016	To prevent power shortage and reduce air pollution, Taiwan government proposed to expand the scale of Datan Power Plant. CPC acquired TGC and took over the project of "Development of Guantang Industrial Park (Port)".
2017	CPC issued the reports of "Environmental Impact Assessment and Differential Analysis of Environmental Conditions and Strategy Reviews for Guantang Industrial Park/Port, Taoyuan City" and "Environmental Impact Assessment for the Development of Guantang Industrial Park: Coping Strategies for Algal Reef Ecosystems". The concern on the possible impacts of the Third LNG terminal on the algal reefs has increasingly drawn attention of the public. The project of the LNG terminal was challenged by some environmental organizations that strongly advocated removal of the LNG terminal away from Datan coastal area.
2018	In January, CPC proposed the project of "Avoidance and Replacement", in which the development area of Guantang Industrial Park was reduced from 232 to 37 acres to avoid algal reefs and the habitats of the protected coral Polycyathus chaishanensis. In addition, the project replaced the original industrial port by offshore open layout to maintain longshore current flows in the coastal zone. In August, CPC further proposed to reduce the development area to 23 acres and no additional land was filled to maintain the existing algal reefs and coastline. On October 8th, "Environmental Impact Assessment and Differential Analysis of Environmental Conditions and Strategy Reviews for Guantang Industrial Park/Port, Taoyuan City" and "Environmental Impact Assessment Report for the Development of Guantang Industrial Park: Coping Strategies for Algal Reef Ecosystems" were approved by the Environmental Protection Agency.
2019	Ministry of the Interior issued the development permit of Guantang Industrial Park (Port included) to CPC.
2020	The environmental organization "Action Alliance of Saving Data Algal Reef" launched the petition for the referendum of "Treasuring Taoyuan Algal Reefs" and posed the question "Do you agree CPC's Third LNG Terminal should be evacuated from the coastal area of Datan, Taoyuan?" to the referendum.
2021	After the referendum was registered in May, the government announced the project of "Additional Seaward Movement of the Third LNG Terminal", in which the Third LNG Terminal will be moved further seaward away from the coastline to maximize the protection of the algal reefs and to minimize the impacts on power supply for achieving the win-win goals of maintaining power supply and protecting algal reefs. On December 18th, the referendum failed to win approval by the public (Yes vote: 3,901,171 vs. No vote: 4,163,464) so that CPC continually carried out the development project of Guantang Industrial Park/Port.
2022	On March 2nd, the revised project of "Additional Seaward Movement of the Third LNG Terminal" was approved by the EPA.
2025	The construction of the Third LNG Terminal is expected to be completed in June.

Figure 2. Ruined coastal areas caused by the excavation in the G2 area of Datan algal reefs by Tungting Gas Corporation in 2003.

3 CHRONOLOGICAL EVENTS OF ACTIONS RELEVANT TO CONSERVATION OF TAOYUAN ALGAL REEFS

The origin of conservation for Taoyuan algal reefs was earlier than the petition for the referendum which advocated for preserving the algal reefs (Table 2). In 2006, CPC constructed sea pipes for the transport of natural gases from the Second LNG Terminal in Taichung to Datan Power Plant, and the pipes landed across Guanyin algal reefs from the sea and ruined the seascape. This gained wide media coverage. Consequently, the government proposed establishment of a protected area for algal reefs. However, this issue was suspended due to the lack of fundamental scientific data. In 2012, the Taoyuan County Government contracted the Taiwan Wetland Society to survey and evaluate the possibility of establishing the protected area of Taoyuan algal reefs. The tasks included: (1) collection and subsequent analysis of scientific data for the algal reefs; (2) field surveys for the algal reefs; (3) cultivation of crustose coralline algae; (4) collection and subsequent analysis of the history of Taoyuan algal reefs; (5) analysis of topographical succession and modeling of coastal dynamics; (6) assessment of environmental economy; (7) collection and subsequent analysis of the contamination in Taoyuan algal reefs; (8) gathering and organizing local opinions; (9) drafting of laws and strategy for algal reef protection; (10) assessment of the causes for algal reef decline and searching for responsibility; (11) suggestions for further studies for conservation (Taiwan Wetland Society, 2013).

After finishing these tasks, the first scientific journal article regarding algal reef biodiversity was published, which was the first scientific publication to reveal the biodiversity of the algal reefs (Lin et al., 2013). This survey followed the standard operating procedures of monitoring in wetlands (Lin et al., 2009) and in algal reefs (Lin and Shao, 2020) and considered seasonal variations across supratidal, intertidal, and subtidal zones in the algal reefs extending from the estuary of Shulin River (樹林溪) to the estuary of Xinwu River (新屋溪).

A total of 10 species of macroalgae (13 species of crustose coralline algae were subsequently identified) and 129 species of macrofauna were recorded. The results showed that the highest abundance of species occurred in Guanyin algal reefs (labeled as Datan Power Plant), and the second highest abundance occurred in the estuary of the Xinwu River. In contrast, the algal reefs of Shulin River Estuary and Baiyu (白玉) had the lowest abundance of species. This study is the first article depicting that littoral sand drift and water pollution were the main factors influencing algal reef biodiversity. The low coverage of macroalgae and low abundance of species in the Guanyin River Estuary (labeled as Guanyin Watering Place) and Shulin River Estuary respectively resulted from the effects of sedimentation and serious water pollution. Lower abundance and sparse macroalgal coverage were observed in the Shulin River Estuary. Except in summer, benthic macrofauna were barely observed at this site, which was likely caused by industrial contamination. According to the species composition, only those that could tolerate pollution were able to survive, implying that the algal reefs had been noticeably polluted.

Compared with the relevant previous results (Dai et al., 2009; Liu, 2012), the scope of the study of Lin et al. (2013) was more comprehensive in surveying biodiversity of the algal reefs. In addition, regarding the pollution of the landscape and the algal reefs next to the south of the Shulin River Estuary, the crimson color of the reefs shown on the film taken from the sky by aerial film director Po-Lin Chi in 2011 was more likely the result of the dyeing and finishing plants near the Fulin River (富林溪) Estuary instead of the appearance of healthy algal reefs claimed by the environmental organization "Action Alliance of Saving Data Algal Reef". However, the crimson appearance shown on the film was used by the environmental organization to widely publicize the impression that the beautiful Datan algal reefs were about to be ruined by the LNG-terminal construction. The claim, unfortunately, was misleading and without solid scientific proof.

From a long-term perspective, the Taoyuan coast clearly showed the trend of being eroded (Taiwan Wetland Society, 2013). In particular, this occurred in the southern coastal areas of Datan Power Plant because the groin effect caused by the artificial structures nearby had led to significant coastal erosion and recession in the southern side of groin. However, the exposed algal reefs were beneficial to the survival of algal reef ecosystem because coastal sedimentation would have detrimental effects on the biodiversity of algal reefs. This study showed that the main streams flowing into Taoyuan algal reefs have been highly contaminated by organic loading from the watershed. According to the results of the pollution-diffusion simulations of biochemical oxygen demand (BOD), if there were detrimental pollutants drained into the estuary, the majority of the pollutants would concentrate in the estuary and cause rapid degradation of the environment of the algal reefs nearby and finally the decline of the algal reef ecosystem.

In addition, this study evaluated the human impact on Taoyuan algal reef ecosystems using contingent valuation; the results showed that the public was willing to pay between 505 and 709 NTD per person for algal reef conservation/restoration to maintain the current condition of the Guanyin algal reef ecosystem. Namely, the total value of this ecosystem would be between 5.3 and 7.5 billion NTD if paid by the entirely of the Taiwanese people.

Eventually, this study collected, analyzed, and discussed the laws with respect to each type of protected area in Taiwan. Considering the strength of conservation of algal reef ecosystems, the interactions among residents in the surrounding communities, and the execution of the competent authority or related institutes, eligible laws for management of algal reef ecosystem were proposed, including the Wildlife Conservation Act, Cultural Heritage Preservation Act, and Wetland Conservation Act. Amongst these acts, the Cultural Heritage Preservation Act was the direct approach to protect heritages such as algal reefs. However, its very strict restrictions may become obstacles for future ecosystem conservation efforts. In addition, the fishing activities originally adopted in the coastal area are no longer allowed for reasonable harvesting. The Wildlife Conservation Act will be mainly used to protect wildlife and their habitats, which could be applied to protect

the algal reef ecosystem as well. The wildlife refuges as coded in Wildlife Conservation Act can be classified into a core zone, buffer zone, and sustainable use zone, which can be respectively used for different levels of the conservation plan. Local people will be also allowed to conduct ecotourism and environmental education, which can benefit not only the algal reef ecosystem but also promote the proper use of the ecosystem. However, the conservation objective of Wildlife Conservation Act is not the seascape (i.e., algal reefs) per se. Were the EIA to be approved, the algal reefs may be jeopardized by coastal development. Hence, some environmental organizations consider that this law is unable to resist a large-scale development plan. The Wetland Conservation Act also classifies approved important wetlands into three classes and establishes the standard operation procedure from the avoidance, mitigation, and compensation for the loss resulting from development. It also requires a plan for the conservation and proper use of approved important wetlands for management. Hence, it appears that the Wetland Conservation Act is the most suitable act for algal reef conservation. However, at that time, the enforcement regulations of this act were not issued. Unfortunately, it was too late when the algal reefs were urgently needed to be protected.

The Taiwan Wetland Society (2013) indicated that the establishment of a protected area is not the optimal solution for destroyed habitats or endangered species. If a protected area is established, the supervising agencies would be required to invest more human resources, expenses, and time for effective management so as to keep or enhance the ecosystem function and service. Therefore, the overall strategy to protect the algal reefs was suggested: (1) To curb pollution from nearby industrial park, it is necessary to establish a platform for the environmental police, prosecutor, and the public. Informing the public about related penalties and ensuring the rights held by local communities will benefit local community's power of oversight; (2) Designated authority for coordination and information compilation is required for a protected area; (3) Promotion of environmental education; (4) Long-term environmental monitoring for the dynamics of coastal sediment transport. In 2012, the Taoyuan City Government considered that the establishment of a wildlife refuge based on the Wildlife Conservation Act will be a feasible way to protect the algal reef ecosystem. In April 2014, the Forestry Bureau of the Council of Agriculture announced the establishment of Taoyuan Guanxin (觀新) Algal Reefs Ecosystem Significant Wildlife Habitat. In July 2014, the Taoyuan City Government subsequently announced the establishment of Guanxin Algal Reefs Ecosystem Wildlife Refuge. In 2017, the Taoyuan City Government included the protection of algal reefs into coastal sustainable development and issued an official white paper for the protection of Taoyuan coastal ecosystems (Ju et al., 2017).

To further clarify the factors which contributed to the biodiversity of algal reefs, Yu et al. (2020) studied the algal reefs in Taoyuan by comparing the environmental and biological factors of different habitats, including algal reefs, gravel, and sand substrates. They found that the driving forces affecting Taoyuan algal reef ecosystems were water movement, sedimentation, and habitat surface rugosity. A conceptual model for the causes of algal reef biodiversity was proposed. This conceptual model illustrated that the habitats in Guanxin algal reefs had stronger water movement, lower concentration of drifting sand, and higher surface rugosity, which led to higher biodiversity. However, the lower biodiversity in the sandy flats was due to the lower water movement and higher concentration of drifting sand. This study shed new light on the conservation and restoration of Taoyuan algal reef ecosystems because water movement, sedimentation, and pollution were the main factors influencing the algal reef ecosystem and should be listed as the priority tasks to solve, which implies that listed factors have to be considered and that it did not matter which law was adopted for the protection of algal reef ecosystems.

Table 2. Conservation chronology of Taoyuan algal reef ecosystems.

Year	Event
2006	CPC constructed the sea pipes for the transport of natural gases to Datan Power Plant and damaged some algal reefs in Guanyin. This gained certain media coverage. Consequently, the government planned to establish a protected area for the algal reefs. However, this was suspended due to the lack of needed baseline scientific data.
2012	Taoyuan County Government contracted Taiwan Wetland Society to assess how to establish a protected area of Taoyuan algal reefs.
2014	Forestry Bureau of Council of Agriculture, announced the establishment of Taoyuan Guanxin Algal Reefs Ecosystem Significant Wildlife Habitat. Later, Taoyuan City Government announced the establishment of Guanxin Algal Reefs Ecosystem Wildlife Refuge.
2017	Taoyuan City Government issued a white paper to include the algal reefs for the protection of Taoyuan coastal ecosystems.

4 CONTROVERSY RESULTED FROM THE REFERENDUM FOR TAOYUAN ALGAL REEFS

The referendum "Do you agree CPC's Third LNG Terminal should be relocated from the coast area of Datan, Taoyuan City?" was registered in May 2021. Before a discussion of whether to vote in favor or not on the referendum, the Taiwanese people should realize the key question: Would voting "Yes" mean that Taoyuan algal reef ecosystem would be protected? In reality this issue was more complicated than we thought because it involved not only algal reef ecology per se but other issues, including air pollution, power supply, energy transition, economic development, and social justice in Taiwan. Algal reef ecology is a professional and scientific issue. However, the majority of the information delivered by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/), which appealed the public to vote in favor of the referendum was exaggerated, and they continually used incomplete information and incorrect descriptions to depict the Datan algal reefs as "Beautiful Algal Reefs" and "the LNG-terminal construction will definitely sabotage all the Taoyuan algal reef ecosystems," and thereby repeatedly misleading the public.

With regard to the protection of genetic resources in public seas, CBD-COP 10 in 2010 requested the members to evaluate and select the areas urgently needed to be protected, namely "Ecologically and Biologically Significant Marine Areas (EBSAs)," to proceed smoothly with the establishment of marine protected areas (MPAs) of "Biodiversity Beyond National Jurisdiction (BBNJ; or Areas Beyond National Jurisdiction, ABNJ)" in the future. Under the support of the Global Ocean Initiative (GOBI), seven scientific criteria were proposed for the evaluation of MPAs: (1) An unique or rare habitat; (2) A critical habitat for the life history of certain species; (3) A habitat for threatened, endangered or declining species; (4) A vulnerable, fragile, sensitive, or slow-recovery habitat; (5) A highly productive habitat; (6) A highly biodiverse habitat; (7) A habitat still retains its original nature. Henceforth, the 7 criteria have been used for the evaluation and establishment of MPAs in the exclusive economic zone (EEZ; within 200 nautical miles) of the coastal area of most countries. By following the aforementioned criteria, we evaluate the ecological conditions of Datan algal reefs to determine whether the algal reefs meet the seven criteria and could be qualified as MPAs as claimed by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/).

5 REFUTES ON CLAIMS MADE BY ENVIRONMENT GROUPS BASED ON THE SEVEN CRITERIA OF GLOBAL OCEAN INITIATIVE

5.1 An unique or rare habitat

5.1.1 "Taoyuan algal reefs are a national treasure and exclusive in the world"

This statement was made by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/). The designation of "National treasure" as claimed by the environmental organization "Action Alliance of Saving Data Algal Reef" was vague and never specified. Actually, algal reefs are not only distributed in Taoyuan, but they are also distributed in other coastal areas in Taiwan, including Xinfung, Danshui, Linshan Cape, and Kenting (Taiwan Wetland Society, 2013) and other coastal areas in the world, e.g., the intertidal algal reefs in the Mediterranean coast (Adey and Macintype, 1973; Chisholm, 2003). In reality, algal reefs are absolutely not a unique, rare, or exclusive habitat.

5.1.2 "Taoyuan algal reef ecosystems have existed for 7,600 Years"

This statement was claimed by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/). Algal reefs refer to the reefs built by crustose coralline algae (CCA). CCA are able to cement and stimulate the recruitment of the juveniles of marine invertebrates (e.g., corals) (Huggett et al., 2006). As a matter of fact, "algal reefs" contain two major types: (1) "Geological algal reefs" refer to the reef structures formed by CCA through hundreds or thousands of years; these are dead and static; (2) "Ecological algal reefs" refer to the fauna and flora (algae in fact) residing within the reef structures or pores and the trophic relationships among these organisms within the ecosystem; these reefs are alive and dynamical and provide "ecological function" within the system.

According to a geotechnical investigation (Asia Environmental Technical Cooperation, 2008), the Taoyuan coastline contains a 27-km-long stretch of algal reefs, and the widest reef was located on the northern coast of Chauyin (潮音), Dayuan (大園) Township (i.e., Guanyin algal reefs), extending seaward over 450 m. In earlier times, the majority of the reefs (approximately 6 m depth) were mainly comprised of scleractinian coral reefs, and CCA outgrew the corals at later times. The algal reefs composed of "Coralline-Coral Boundstone" were mainly situated on the south side of the Xiaofanli River (小飯壢溪) Estuary, namely the "Chauyin Karst Landscape". The highest thickness of the algal reefs in Taoyuan reaches about 6.4 m, and the thicker reef is located on the south side of the Puxin River (埔心溪) and the north side of the Guanyin River (Figure 1). On the south side of the Guanyin River, the thickness of algal reefs is reduced to approximately 1 m depth in Xingwu (新屋), near Yongan (永安) Fishing Port. The algal reefs on the north side of the Datan Power Plant are mainly composed of corals mixed with coralline algae. However, the algal reefs on the south side that has been protected in the Guanxin Algal Reefs Ecosystem Wildlife Refuge was composed of CCA mainly, partly mixed with corals. This indicates that the heritages of mostly pure algal reefs have been preserved in the MPA.

According to the result of radiocarbon dating, the Taoyuan algal reefs started to grow about 7,500 years ago, and the water at that time was transparent enough for the growth of corals. However, the water became turbid 4,500 years ago, which was unsuitable for the growth of corals and alternatively resulted in the formation of algal reefs composed mostly of CCA thereafter (Asia Environmental Technical Cooperation, 2008). The structure of algal reefs is dead and has been maintained over the past 7,000 years underground. Therefore, sediment burial is the best way to preserve the reef structure. On the contrary, sedimentation is harmful to the function of algal reef ecosystems, as the sand-covered CCA could be bleached within 3 days (Lu, 2018). Therefore, the protection strategy of algal reefs and algal reef ecosystems are mutually contradictory. However,

it is still unclear whether the environmental organization "Action Alliance of Saving Data Algal Reef" intends to preserve the ecosystem of Datan algal reefs or the structure of algal reefs per se? It is imperative for the environmental organization itself to clarify their desires and reach a consensus for the preservation of algal reefs.

5.2 A critical habitat for the life history of certain species

5.2.1 "Datan algal reefs are the nursing ground for *Sphyrna lewini*, an endangered shark species"

This statement was derived from the subproject II "Conservation of fishery resource in the hydrosphere of Taoyuan algal reefs and the community rebuild" of the project of "Reacquiring southern Taoyuan's satoyama and coast" supported by the Forestry Bureau (Chen et al., 2018). The endangered scalloped hammerhead (*Sphyrna lewini*) is a highly migratory fish species, ranging from the surface water, intertidal zone to waters 275 m deep. The catch of this species is commonly recorded in the coastal areas from northern to central Taiwan, including Danshui of New Taipei City, Zhuwei of Taoyuan City, Nanliau of Shinzhu County, Lungfeng of Miaoli County, and Wuchi of Taichung City. Hence, the catch of *S. lewini* in Datan algal reefs is quite normal. According the database regarding the catch of *S. lewini* from Taiwan Ocean Conservation and Fishery Sustainability Foundation (TOFF; https://www.toff.org.tw/), the number of *S. lewini* caught in other western coastal areas of Taiwan was higher than the number in Datan algal reefs. This indicates that there is little correlation between its distribution and algal reefs.

In 2020, National Taiwan Ocean University surveyed the coastal area of Taoyuan, including the coastal areas of Datan, Guanxin, and Yongan Fishing Port by use of the drift net fishing method (National Taiwan Ocean University, 2020). As a result, no matter the distance from the coast to ocean, *S. lewini* (including its embryos, newborn and juveniles ranging from 46 to 125 cm in length) was caught across all areas. The farther the distance to ocean was, the deeper the water was, and the more weight of the fish catch. According to the results of gut content analysis, *S. lewini* had higher tendency to feed on a variety of mobile prey (fish, shrimp, and squid) that commonly live in the whole coastal area, but not exclusively only in Datan algal reefs. A series of monthly surveys using the drift net fishing method was conducted (8 times in total) from July 2019 to October 2020, except for the restricted time for drift fishing between June and August. Within the coastal area of Datan algal reefs (i.e., the G1 and G2 areas), only 4 individuals of *S. lewini* were caught. However, 21 individuals were caught in the coastal area of Yongan Fishing Port. Accordingly, the juveniles were not exclusively distributed in Datan algal reefs as claimed (Chen et al., 2018).

When it comes to the issue of whether Datan algal reefs were the nursing ground for *S. lewini* or not, it requires the long-term tracking study for the life stage of the juveniles so as to clarify the relationship between algal reefs and the feeding, sheltering, and other activities of this species. However, the survey of Chen et al. (2018) was only executed in three seasons, without conducting any tracking study. As a matter of fact, there is no nursing ground, but there is a birthing ground for sharks. The conclusion that Datan algal reefs were the nursing ground for the growth of *S. lewini* juvenile was incorrect by simple conjecture.

5.2.2 "Algal reefs are the breeding ground of mullets"

This statement was derived from the website of the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/). Mullet is well known as a "messenger fish". It is a species of seasonally migratory fish, laying eggs in the sea with suitable temperature and salinity. Between the end of November and the following January, mullet schools migrate southbound alongside China's coastline, laying eggs during their traversing through the Taiwan Strait. Continually schooling southbound till the coastal area nearby Cape Eluanbi in the southernmost point of the island of Taiwan, schools then return northbound back to China's coastline. Mullet's fertilized eggs are buoyant and incubated in the water column rather than being attached on substrates, suggesting that the eggs are not deposited on algal reefs. The fingerlings range from 2

to 3 cm in length and live in the brackish estuary waters by feeding on benthic crustaceans and other invertebrates. The juveniles range between 3 and 5 cm in length and become omnivorous, feeding not only on crustaceans but also on phytoplankton and periphyton. As the juvenile grows up continuously and moves seaward, their length can reach over 5.5 cm. During this period, mullets turn herbivory in their feeding habits, and they prefer to feed on plant fragments, diatoms, and macroalgae. According to previous studies by the Council of Agriculture (www.coa.gov.tw/ws.php?id=2502215&print=Y), the breeding ground of mullets lies along the southwestern coastal area of Taiwan rather than Taoyuan algal reefs only. In addition, the results of Chen et al. (2018) show that there is not a large number of mullet juveniles in the coastal areas of Taoyuan algal reefs.

5.3 A habitat for threatened, endangered or declining species

5.3.1 "Datan algal reefs are the only habitat of the protected coral *Polycyathus chaishanensis*"

Kuo et al. (2020) surveyed the algal reefs of Baiyu, the G1 and G2 area of Datan, Xingwu, Yongshin (永興) and Yongan. Plenty of patches of *Polycyathus chaishanensis* were found in the G1 and G2 area, but there was no population found in Baiyu, Yongshin, and Yongan. Hence, they concluded that the G1 and G2 areas were the only habitats with healthy and stable populations of *P. chaishanensis*. However, some doubts have been found in the approaches used by Kuo et al. (2020) for the survey for *P. chaishanensis*:

A. On June 29th 2018, Chen (2018) published the article "Importance of maintaining Datan algal reefs in terms of the disappearing home to *Polycyathus chaishanensis*". The author mentioned that there were 3 patches of *P. chaishanensis* found in the Baushung (保生) reefs of Guanyin algal reefs and argued that it needed to be confirmed further. This indicates that the author had noticed that *P. chaishanensis* were found in Guanyin algal reefs. Yet there was no further update for this survey.

B. The Baushung area is within Taoyuan Guanxin Algal Reef Ecosystem Wildlife Refuge. The geomorphology of the algal reefs was similar to those in the G1 and G2 areas, suggesting that it is the habitat with highest potential of finding *P. chaishanensis*. Kuo et al. (2020) compared Guanxin's population of *P. chaishanensis* with Datan's population. However, it appears that Baushung's population was deliberately ignored by the authors without making comparison.

C. This survey did not provide detailed information about GPS location, quantitation methods (transects, grids, or others), and survey frequency for each site. It was said that the survey was conducted on foot, and this description regarding sampling design was incomplete and failed to offer useful information. Presuming that the survey frequency was different at each site, the more frequently a site was surveyed, the higher the possibility of finding *P. chaishanensis*. In addition, if this was caused by surveyors' intentions, even though the targets were observed, they might choose not to report the real population numbers. This would result in a serious bias in their conclusion.

D. Kuo et al. (2020) performed a prediction of occurrence of *P. chaishanensis* by using a regression model. If the regression model is significant, the distance from coral (*P. chaishanensis*) location to the coast (independent variable; X axis) seems to predict the patch size (dependent variable; Y axis). However, there were some doubts when applying this regression model.

   (a) In this study, the term "distance to coast" was undefined because the location of the coast was uncertain. However, the distance from coral location to coast was the only independent variable in the regression model.

   (b) The regression model showed the correlation coefficient (r) was 0.32 and the coefficient of determination (r^2) was merely 10%, indicating the explanation power or the confidence of this regression model was only 10%. The uncertainty was as high as 90%.

(c) The limitation of the regression model was that the model can only predict within the range of the observed distance from the coral location to coast (100-320 m). Hence, the prediction of the patch size of *P. chaishanensis* further than 320 m to the coast in the subtidal zone using this regression model is of high uncertainty. However, the authors claimed that the construction should be stopped because there are supposedly many big patch sizes of *P. chaishanensis* in the subtidal zone of the proposed Guantang Industrial Park. But such a speculation could not be substantiated without solid data being presented.

(d) Submersion time of tide pools and creeks, steepness, and frequency of sand burial may also play vital roles in the distribution and patch size of *P. chaishanensis*. Unfortunately, in this study, only a single independent variable was selected, and their conclusion appears hasty.

In 2012, a live rock from Indonesia was examined in Schiphol Airport, the Netherlands, and the attached corals were identified as *P. chaishanensis* by DNA barcoding (Hoeksema and Arrigoni, 2020). It is accordingly speculated that this coral species was not simply restricted in Kaohsiung of southern Taiwan (Lin et al., 2012) or Datan algal reefs of Taoyuan. It is more likely that this species is widely distributed more than thousands of kilometers from Taiwan to Indonesia. The aforementioned case highlights that this species could have been distributed in regions other than Taiwan, and the lack of surveying leads to the erroneous conclusion that this species is only endemic to Datan algal reefs, as claimed by the environmental organization.

5.3.2 "Fish population declined in Data algal reefs due to the construction of the third LGN terminal"

This statement was derived from the results of the subproject II "Conservation and rebuilding the community of fishery resources in the hydrosphere of Taoyuan algal reefs" of the project "Reacquiring southern Taoyuan's satoyama and coast" supported by Forestry Bureau (Chen et al., 2018). However, the qualitative methods showed 80% of the fish species and 96% of the fish numbers were collected from the local fishermen and anglers. These data barely implied that the G2 area of Datan was a habitat for economic fishes. The published results (Heard et al., 2021) derived from the subproject II, which mentioned the sampling methods including clove oil, drift net fishing, and interviewing the local fishermen. Yet each of these methods was highly distinct and unique, and most of the data could not be standardized for comparison. Although species list can be made by different survey methods, it is doubtful that the abundance (the number of each fish species) derived from these distinct methods can be added up directly. As a matter of fact, only the abundance caught by the clove-oil method can be standardized by the area of tide pool. However, the number of tide pools rather than the area of tide pools was used as the sampling unit for this study. Each tidal pool differs from the others and hence the number of fish species residing in each could be different. The information regarding the area of each tide pool was lacking in their studies, so the abundance of data could not be transformed to density data standardized by the sampling area.

Other methods (drift net fishing and interviews with fishermen) failed to provide standardized data of fish abundance. In addition, fish catch data scarcely referred to fish abundance. Interviews with fishermen should be considered to be within the discipline of social science, since the sampling method could not be validated by the quantitative methods used in natural science research. In theory, the data collected by interviews with fishermen about fish species numbers cannot be directly added up with those determined by the methods of field collection methods. In particular, the time scales among field sampling with the clove-oil method, drift net fishing and fish catch data derived from interviews with fishermen were distinct and were not compatible. The conclusions would change greatly if the interview data were removed from their analyses.

As a matter of fact, the results of Heard et al. (2021) also showed that the local fishermen generally considered the decrease of fish catch over the past two decades could be attributed to the pollution from Baiyu

Industrial Park as well as overfishing rather than the construction of the Third LNG Terminal. The statement that the degeneration of the ecosystem in the G2 area of Datan was due to the pollution from the LNG-terminal construction nearby could then be considered as a hypothesis requiring future monitoring and validation. In this study, underwater soundscape and accumulated fish otoliths in tide pools were also applied to examine the biodiversity of the algal reefs. However, the soundscape survey was still in its preliminary stage, which was mainly collecting the sounds from crustaceans' crackling and waves. In addition, since only a small number of fish juveniles' otoliths were collected in this study, the method lacked rigorous sampling for precise quantification. These fragmentary data were unable to provide the evidence of negative impact caused by the LNG-terminal construction. Therefore, their conclusions that the LNG-terminal construction had destroyed the fish population of algal reefs was simply speculative.

5.4 A vulnerable, fragile, sensitive, or slow-recovery habitat

5.4.1 "Algal reefs are irreversible ecosystems"

This statement was derived from the promotional video of "Aerial view of algal reefs" of the series of "Guided reading along the coast" released by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/). The video mentions that sediments and reefs co-form the precious and irreversible seascape of algal reefs. However, the statement of the irreversibility of the algal reefs was inconsistent with fact.

The reason why the algal reefs became dominant on the Taoyuan coast 4,500 years ago was that the seawater turned turbid, and that the corals were unable to surpass the growth of coralline algae at that time, so CCA could thrive and form the reefs. Compared with the aerial photographs or satellite images taken in 1984 or earlier, the Taoyuan coast was mostly covered by sediments (Lin, 2020a). Hence, calcium-carbonate algal reefs formed by CCA about 7,600 years ago were buried at the depth of 6 m and still remains there until now. However, in 2003, a groin of the outlet was built for Datan Power Plant by TPC, and TGC also constructed the groin in Datan algal reefs. The consequences were that these coastal development projects had altered the seascape of Datan algal reefs. By examining the long-term change of satellite images since 2005, Datan algal reefs were exposed in 2005, while in 2010, they were buried again due to the passing of a typhoon. Subsequently in 2017, it was exposed again because of the passing of another typhoon. Accordingly, Datan algal reefs are repeatedly covered by sediments and exposed due to typhoons or seasonal northeastern monsoon events (Lin, 2020a). Consequently, the ecosystems are of continual succession due to the repeated burial and exposure processes, implying that the reef ecosystems are to some extent resilient to the disturbance of sediments because some macrofauna can be observed in Datan algal reefs after a short time of 5 years since its recent exposure in 2017 (Chen et al., 2018; Lin, 2020b). Therefore it is erroneous to conclude that algal reefs are irreversible ecosystems as claimed by the environmental organization.

5.5 A highly productive habitat

5.5.1 Algal reefs are blue carbon ecosystems

This statement was derived from the subproject V "Surveys on macroalgae and crustose coralline algae in the algal reefs from Baiyu to Xingwu to build the scientific database of the algae used by the community in the past" of the project "Reacquiring southern Taoyuan's satoyama and coast" supported by Forestry Bureau (Chen et al., 2018). As a matter of fact, the structure of algal reefs has no capacity to absorb carbon, only the living crustose coralline algae can absorb carbon. Compared with "Green Carbon," e.g., terrestrial forests, "Blue Carbon" refers to marine ecosystems, e.g., mangroves, seagrass beds, and salt marshes, that are able to absorb and store carbon dioxide and mitigate the global warming effect (Li et al., 2018; Zou et al., 2021). The Taiwan Wetland Society (2013) measured the rate of carbon fixation by CCA using the microelectrode method to determine the change of dissolved oxygen concentration via photosynthesis, and the results showed that the rate

of carbon fixation by CCA averaged 65 g C m^{-2} yr^{-1}, which was lower than that of the diatoms on the surface of tidal flats (101 g C m^{-2} yr^{-1}, Lin et al., 2020) and was approximately 10% of the rate of seagrass beds (523-1453 g C m^{-2} yr^{-1}, Zou et al., 2021) and 5% of the rate of mangroves (1086-2764 g C m^{-2} yr^{-1}, Li et al. 2018). In addition, there was no sediment pool for algal reefs to store the carbon. On the other hand, the calcification of CCA might emit 0.6 moles of carbon dioxide and become a carbon source during the formation of calcium carbonate (Saderne et al., 2019). Like coral reefs, algal reefs are hardly recognized as Blue Carbon ecosystems.

5.5.2 "Datan algal reefs harbor a high number of crabs and morays"

This speculation was derived from the results of the subproject III "Relationships amongst the ecology, environment, living industry and crab diversity near Guanyin-Xinwu coastal community" of the project of "Reacquiring southern Taoyuan's satoyama and coast" supported by Forestry Bureau (Chen et al., 2018). In Datan algal reefs, the estimated density of the crab *Eriphia ferox* was claimed to be 0.7±1.1 individuals m^{-2} (Mean±SD) and 164,000 individuals in total. The estimated abundance of the crab *Nanosesarma minutum* was 606.82±1117.65 individuals m^{-3} (Mean±SD) and 21,373,000 individuals in total. These surprisingly high numbers obtained by multiplying the crab abundance with the total area or volume of Datan algal reefs were based on the assumption that these two species were evenly distributed on the surface and below the underground of Datan algal reefs during ebb tide. However, the distribution of these two crab species was absolutely not evenly distributed in Datan algal reefs because both the standard deviations were larger than the mean values, suggesting that these two crab species prefer to stay together in certain tide pools. The total numbers of these two crab species in Datan algal reefs were obviously overestimated and exaggerated by the wrong assumption of the even distribution in the algal reefs.

Similarly, the total number of morays (*Gymnothorax* spp.) was overestimated by an incorrect assumption. By examining the methods used in Chen et al. (2018), the estimation was based on the number of morays caught by bait (with Pacific saury) traps in 2017 in the G1 and G2 areas of Datan. In total, 11 individual morays were caught during the period of 9 days from 25th July to 21st of September. In detail, none was caught in the G1 area; 8, 1, and 2 individuals were caught in Tide pool A, B and C in the G2 area, respectively. Again, the surveys showed that the distribution of morays in Datan algal reefs was not even and that the morays apparently preferred to gather in Tide pool A. However, the estimation of the total number of morays in Datan algal reefs failed to recognize that: (1) baiting was not a random sampling method; (2) tide pools are a porous 3-D structure rather than a simple 2-D surface; (3) no explanation why Tide pool A was chosen as a representative tide pool in Datan algal reefs; and (4) the unknown reason for using only the data of the highest number caught in Tide pool A in the G2 area but deleting the data of zero in the G1 area and the small numbers in other tide pools in the G2 area for calculation. Tide pool A with a water surface area of 803 m^2 was surveyed three times, and the mean catch number 2.67 individuals was multiplied with the pool area of 336,642 m^2 during ebb tide in Datan algal reefs, which led to an estimation of the total number of 1,200 individuals (actually 1,119 by calculation) in the whole Datan algal reefs (G1 and G2). The bias resulted from sampling and estimation that obviously overestimated the total number of morays in Datan algal reefs.

5.6 A highly biodiverse habitat

5.6.1 "The biodiversity of algal reefs is equivalent to that of coral reefs"

In November 2021, National Geographic Magazine interviewed staff members of the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/) and published the article "How algal reefs go in the future," which elaborates that algal reef ecosystems with high productivity, stable habitats and high biodiversity as equivalent coral reefs. In reality, this statement was far from the fact. From 2001 to 2005, more than 1,100 species were recorded during the 5 years of surveys in the coral reefs in Kenting (Shao et al., 2005). Taoyuan algal reefs have received much attention over the past 5 years (from 2017

to 2021) and huge sums of money have been used for intensive and extensive surveys. Yet, less than 160 species were recorded (Chen et al., 2018; Lin, 2020b). There is almost an order-of-magnitude less than the species number recorded in Kenting coral reefs, mainly because the two environments were evidently different (Lin et al., 2013). Coral reefs exist only in the subtidal zone with clear seawater and stable environments. However, CCA can tolerate turbid seawater and live in the habitats unsuitable for corals, like deeper waters with low light, intertidal zones frequently lapped by waves, tidal flats with high variation of salinity, and estuaries with high nutrient concentrations. Once corals are unable to grow, CCA can therefore thrive and form algal reefs. Primary producers in algal reefs are less than those in coral reefs due to the lack of light and instability of sandy substrate, which limits the food sources for consumers. In addition, there are other stresses for the organisms living in algal reefs, like continually scratching by silt and sand and low irradiance, which might be the reason for the relatively lower biodiversity in algal reefs than in coral reefs (Lin et al., 2013).

Compared with the fauna densities derived from surveys for a complete seasonal cycle in other coastal habitats in Taiwan, the fauna density in Guanxin algal reefs was several times higher than that in sandy mudflats, e.g., 5 times that of Gaomei Wetland (高美濕地) (Lin et al., 2007) and 8 times higher than that of Xianshan Weltand (香山濕地) (Hsieh, 2006). However, the species number of Guanxin algal reefs (152 species) was similar to that of rocky shore (145 species; Liao et al., 2011) and algal reefs (125 species; Liao et al., 2011) in the northern coast of Taiwan and of Gaomei Wetland (128 species, Lin et al., 2007), but was higher than that of gravel shore in the northern coast of Taiwan (Liao et al., 2011) and of Xianshan Wetland (Hsieh., 2006). According to this comparison, it is speculated that the biodiversity of algal reef was similar to that of rocky habitats in the western coast of Taiwan. The controversy and concerns of algal reefs over the recent 5 years have led to more investment of manpower, materials, and other resources for the surveys in Taoyuan algal reefs (Chen et al., 2018; Lin, 2020b). In addition, there have been other prior surveys (Dai et al., 2009; Liu, 2012; Lin et al., 2013). Yet, by combining the aforementioned studies, most of the species recorded in algal reefs were the common species distributed on the western coast of Taiwan, and none of the species that only resides in algal reefs or only in Datan algal reefs, which implies that these species are not endemic only to algal reefs.

In the referendum orientation event which was held on December 11th 2021, the leader of the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/) reported that among 27 recorded species of CCA, 21 species were new and 9 were endemic species, and the advocates claimed that they were the pride of Dantan algal reefs. However, this statement is disputable. Marine creatures like spores produced by CCA are frequently moved back and forth by waves and currents until suitable habitats are found for them to reside. Accordingly, it is uncertain whether endemic species exist only in a certain location. An example is that the claimed endemic coral *P. chaishanensi* which was also found in Kaohsiung (Lin et al., 2012) and Indonesia (Hoeksema and Arrigoni, 2020). As a matter of fact, the majority of species within an ecosystem is of low abundance and less dominant, while there is the higher possibility of finding these species as site number and survey frequency increase. In addition, prior surveys for CCA in Taiwan were focused on coral reefs, so that the species in other habitats were little known.

Other possibilities include: (1) algal reefs are scarcely the hotspots for international taxonomists and ecologists, so it is hard to find relevant literature; (2) due to the controversy regarding algal reefs over the past 5 years, researchers were given sufficient funds to conduct intensive and extensive surveys and therefore CCA were found. However, these findings do not necessarily mean that these species are exclusively distributed in Datan algal reefs only. The majority of CCA have also been found in the nearby protected area Guanxin algal reefs, and likely could be found in other places where no survey has been conducted yet. In reality, many ecosystems in Taiwan are worth paying more attention to, but there are still no funds to perform such surveys.

5.6.2 "Biodiversity of Datan algal reefs is better than of Guanxin algal reefs"

Many environments consider the coast of Taoyuan, Guanxin Protected Area and Xucuogang Wetlands to have higher biodiversity, both being two ecological hotspots on Taoyuan Coast (Ju et al., 2017). However, Li et al. (2021) claimed that the crab species and abundance (density) in the G2 area of Datan were higher than those in Guanxin algal reefs. Yet, the applied statistics were questionable and the results barely matched their conclusions. First of all, only qualitative comparison of crab density amongst the G1 and G2 areas and Yongshin was conducted by Li et al. (2021) rather than quantitative analyses. Li et al. (2021) performed surveys at 6 sites for crab abundance, and the results showed the highest species number (36 species) was found in Yongshin of Guanxin algal reefs, which was more than the G2 area of Datan. The density of small crabs within the reefs (1.91 individuals per sampler) of Baushung of Guanxin algal reefs was also higher than that in the G2 area of Datan (1.72 individuals per sampler). These results failed to support their conclusion.

Furthermore, the authors removed the crab species found in other habitats out of the species found in algal reefs and reached the conclusion that Yongshin had 8 crab species residing only in algal reefs, but the G2 area had 18 crab species. The authors did not clearly define what crab species was residing only in algal reefs, so this data processing appeared deliberate. The results in Figure 2 of the paper (Li et al., 2021) showed that the most diverse family in the G2 area of Datan was Portunidae, which was likely to be found in the tide pools of the intertidal zones, not directly residing on algal reefs, suggesting that there was no direct relationship between the Portunidae distribution and algal reefs. From the perspective of conservation biology, in addition to the conservation for species diversity, diverse habitats should also be protected. Instead, the results of Li et al. (2021) highlighted that there were 36 crab species in the different habitat types of Yongshin, which confirmed the decision of the establishment of "Guanxin Algal Reefs Ecosystem Wildlife Refuge" in 2014 as most crab species have been successfully protected in the protected area with different habitat types. The key issue is: do we need to set up one more nearby protection area with overlapping functions?

If the crab species counted or collected from fixed grids on the reefs or in the reefs were defined as the crab species residing the algal reefs (Li et al., 2021), their results showed only 5 and 6 species were respectively collected at Yongshin and Datan. However, 2 species were repeatedly recorded using the two methods, so that only 9 crab species residing in algal reefs were actually found. This is far fewer than the crustaceans recorded in the intertidal zone of Kenting coral reefs (18 families, 53 species) in the project "Long-term ecological monitoring for coral reefs in Kenting National Park" (Ho, 2011). This direct comparison suggests that crab diversity in algal reefs was far lower than that in coral reefs.

5.7 A habitat still remains its original nature

Datan algal reefs have been subjected to anthropogenic impacts since 1982, e.g., coastal pollution, reef excavation, reclamation, and groin construction for the power plant inlet and outlet (Table 1). The environments of Taoyuan coast have continually changed in terms of not only water quality but sedimentation for a long time. The aerial photographs showed the erosion and sedimentation occurred back and forth since 2005, and at least sedimentation over algal reefs occurred over the span of more than half of the time. Between 2005 and 2008, the algal reefs were impacted by some typhoons and exposed again as the sediments covering the reefs were blown away. However, the G1 area of Datan was covered by sediments again from 2009 to 2014, and exposed again in 2015 due to typhoons. The Guanxin Algal Reefs Ecosystem Wildlife Refuge today was once a sandy flat in 2001. After the groin of outlet for TPC's Datan Power Plant was established, the groin started to hinder the sand drifting from north to south and hence caused the sedimentation and erosion respectively occurring on its northern and southern coast. Due to the lack of sediment source, Guanxin algal reefs, situated on the south of the groin, were therefore re-exposed till now. The reason why some of the G2 area of Datan was exposed

might be from the effect of the two artificial headlands nearby. The long-term geomorphological change indicates that sedimentation has a significant effect on Taoyuan algal reefs so that living CCA can survive only in flowing tide pools or subtidal zones as the sediments accumulated less on a substrate due to the frequent disturbance by water movement. Lin (2020b) also found the coverage of living CCA in Guanxin algal reefs to be higher than that in Datan algal reefs. However, Chen et al. (2018) performed a survey on the sediment coverage in algal reefs intentionally by using a windshield wiper to brush away the sediments and hence to increase the coverage of living CCA in Datan algal reefs considerably. Such purposeful manipulation was seriously against the operation of natural ecosystems.

6 SUMMARY OF THE CLAIMED HIGHLIGHTS IN DATAN ALGAL REEFS

Almost all the highlights regarding the biodiversity in Datan algal reefs as claimed by the environmental organization "Action Alliance of Saving Data Algal Reef" (http://algalreef.weebly.com/) were based on purposeful manipulation, incorrect assumptions or methods and conjectures, and exaggerated conclusions (Table 3). The real seascape of Datan algal reefs was far away from what the environmental organization claimed, and the research methods and statements of their studies were not rigorous. Scientific research should be based on objectivity and evidence, and should not manipulate experiments ideologically, omit objective facts purposely, spread doubtful results, further mislead the public, and even spread innuendo or rumors against those with different opinions on conservation strategies. Such tactics are against the spirit of science which endeavors to seek truths through rigorous research.

Table 3. Critiques on the claimed highlights in Datan algal reefs made by the environmental organization "Action Alliance of Saving Data Algal Reef".

Issue	Unverified hypothesis	Misleading sampling methods	Misleading sampling designs	Incorrect statistical methods	Incorrect Interpretation
Millennium algal reef ecosystems					V (Confusion with the differences between geological and ecological algal reefs)
Blue-carbon algal reefs	V (Ability to absorb and store carbon)				V (Facts: Low capability to absorb and store carbon; possible carbon sources)
Coverage of crustose coralline algae		V (Brushing by using wind shield wiper)			
Polycyathus chaishanensis			V (Purposely misleading)	V (Fact: Model with low confidence)	V (Fact: Datan algal reefs are not the only habitat)

Issue	Unverified hypothesis	Misleading sampling methods	Misleading sampling designs	Incorrect statistical methods	Incorrect Interpretation
Crab abundance and diversity	V (Homogeneous distribution)	V (Observers' disturbance)	V (Grid is not representative; Limitation of habitat types)	V (Facts: Heterogeneous distribution but using homogeneous assumption; More habitat types, more species)	
Abundance of *Gymnothorax* spp.		V (Bias caused by baiting)	V (Grid is not representative; purposely overestimating)	V (Fact: Heterogeneous distribution but using homogeneous assumption)	
Sphyrna lewini	V (Nursing ground)				V (Fact: Not the hotspot being caught)

7 STRATEGIES FOR CONSERVATION AND RESTORATION FOR TAOYUAN ALGAL REEF ECOSYSTEMS

For future effective conservation and restoration of Taoyuan algal reef ecosystems of the "Guanxin Algal Reefs Ecosystem Wildlife Refuge", which has existed with high biodiversity and well-grown CCA, it is suggested that it should be given more input and effort. Concurrently, *P. chaishanensis* can also be protected because this species has been found in the Guanxin algal reefs. By doing so, the protected area should be able to perform its spill-over effect from Taoyuan algal reefs to the western coast of Taiwan or even the western Indo-Pacific region.

Listed in the followings are proposed strategies worth consideration:

1. With the understanding that living CCA only reside in flowing tide pools and subtidal zones and the main factors regulating the growth of CCA and algal reef ecosystems, therefore, the following suggestions should be given higher priority:

   (1) The sediments caused by coastal construction, pollution from inland and ocean nearby, human impact should be relieved, removed, or avoided in the existing algal reefs.

   (2) Strengthening the fundamental biological studies for CCA, having a further understanding of the timing of release and attachment of the tetraspores and the main effects on the breeding and growth of CCA.

2. Three major approaches on understanding the fundamental biology of CCA are suggested:

   (1) Species composition of CCA in the Guanxin algal reefs and field monitoring for the seasonal changes of algal coverage;

(2) Breeding period and life history of CCA;

(3) Relationship between the growth of CCA and environmental factors (e.g., sediment covering, nutrients, water temperature, light, and turbidity).

3. Acquiring detailed information of the life history and habitat requirement of *P. chaishanensis* which would benefit the conservation efforts. Four major research projects are suggested:

   (1) Life history, e.g., maturation size, how long to maturation, spatial distribution, potential of spatial spread, lifespan, recruitment, and patch size and structure;

   (2) Inhabiting environments, e.g., the characters of living habitat, feasibility of transplanting, the relationship between zooxanthellae and coralline algae;

   (3) Potential threats for its survival, e.g., factors leading to its mortality, tolerance for temperature, competition, tolerance of juveniles, predators, diseases;

   (4) Population size and its distribution.

4. Executing overall strategies for pollution control on Taoyuan coast including interception for the polluted water originally drained to Taoyuan coast and prevention for the sedimentation caused by the Third LNG Terminal or other construction. By doing so, the existing algal reefs on the 27 kilometers of Taoyuan coastline can best use its resilience and recovery by its self-organization and self-construction capacity. This would promote the recruitment of plenty of marine invertebrates, create shelters for meiofauna, further provide food for macrofauna and shorebirds, and would, eventually, restore the ecological function and ecosystem service of algal reefs, which would enrich the fishery in the northwestern coast of Taiwan, and promote the economic wellfare of local people.

5. Development of monitoring programs for the algal reefs of Guanxin, Datan and Baiyu following the guidelines proposed in "Standard Operating Procedure of Survey and Monitoring for Algal Reef Ecosystem" (Lin and Shao, 2020). Depending on research team's human resources and funding, the monitoring program can select from Class I (Observer's Program), Class II (Basic Program), to Class III (Advanced Program). No matter whichever program is selected, the first and most important task is to establish the conceptual model so as to analyze the effects of Before-After Control-Impact (BACI). It is essential that the monitoring program should concern what to explore, deepen planning for sampling methods and design, statistically analyze the collected data, interpret the possible cause-and-effect relationship amongst parameters, and finally provide the strategy regarding how to cope the impacts.

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