A Survey Report on the Coral Reef Ecology of Huangyan Dao

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Contents

Abstract

Huangyan Dao has always been China's inherent territory. China possesses indisputable sovereignty over Zhongsha Qundao and the adjacent waters including Huangyan Dao, and has sovereign rights and jurisdiction over the relevant waters. China's sovereignty and relevant rights over Huangyan Dao are supported by historical and solid legal evidence. In November 2024, China officially announced the territorial sea baselines of Huangyan Dao. In September 2025, China established Huangyan Dao National Nature Reserve.

From May to October 2025, South China Sea Ecological Center of Ministry of Natural Resources, along with South China Sea Development Research Institute, South China Sea Survey Center, South China Sea Marine Forcast and Hazard Mitigation Center, Beihai Marine Center, South China Sea Sea Area and Island Center, as well as Nansha Islands Coral Reef Ecosystem National Observation and Research Station and Technology Innovation Center for South China Sea Remote Sensing, Surveying and Mapping Collaborative Application, conducted a survey and assessment of the coral reef ecosystem of Huangyan Dao. The assessment method integrated historical data analysis and investigations including vessel navigation survey, diving investigation, satellite and aerial remote sensing, and in-situ observation.

The report indicates the following results. (1) The coral reef ecosystem of Huangyan Dao is in an overall healthy condition. A total of 135 species of reef-building corals belonging to 36 genera and 13 families are recorded. The hard coral cover of Huangyan Dao is relatively high, but with regional variations. Coral reef fishes and benthic macro-invertebrates are in large varieties. Furthermore, extensive and lush seagrass is distributed in the northern part of the lagoon of Huangyan Dao, covering an area of approximately 1.85 square kilometers. (2) The average hard coral cover of Huangyan Dao National Nature Reserve reaches as high as 38.8%, being an important breeding and habitat area for many endangered wildlife species, including 94 species listed as national first class and second class protected wildlife such as *Chelonia*

mydas, *Eretmochelys imbricata*, *Tridacna crocea*, *Tridacna maxima*, *Charonia tritonis*, and *Cypraea tigris.*

Analysis shows that in the 1960s and 1970s, the illegal military activities—such as bomb-dropping exercises—by the Philippines and other relevant countries caused severe damages to the coral reef of Huangyan Dao. Recently, illegal fishing and frequent intrusions by the Philippines have caused a great stress on the ecosystem. The abnormal increase in sea surface temperature caused by global climate change and the attacks by tropical cyclones, have also imposed adverse effects on the ecosystem. In addition, Huangyan Dao faces the potential risk of further degradation caused by outbreaks of *Acanthaster solaris*.

After the establishment of Huangyan Dao National Nature Reserve, strict protection measures and necessary ecological restoration efforts will be implemented to help maintain and enhance the diversity, stability, and sustainability of the coral reef ecosystem of Huangyan Dao.

Located in the central South China Sea, Huangyan Dao is an important part of Zhongsha Qundao (Figure 1-1), within the jurisdiction of Sansha City, Hainan Province, China. Huangyan Dao's unique geographical location, complex climatic characteristics, and favorable ecological environment have nurtured rich biodiversity, serving as an important distribution area for coral reef ecosystem in South China Sea and a treasure house of marine biological resources.

1. Overview of natural environment

Huangyan Dao is a large atoll that outcrops at low tide, with a shape resembling an isosceles triangle measuring about 14.5 km long from south to north and about 13.6 km wide from east to west. The lagoon features a complex geomorphology, with densely distributed patch reefs and a greater water depth in the central area, reaching down 22.4 m at the deepest. There is an about 400 m wide inlet at the southeast end connecting to the open sea, with a maximum water depth of 11.5 m. Numerous reefs on the reef flat outcrop during low tide (Figure 1-2), with one reef rock on each of the northern and southern side—known as Beiyan (Figure 1-3) and Nanyan respectively (Figure 1-4)—remaining exposed even at high tide.

The sea area of Huangyan Dao features a tropical oceanic monsoon climate. The prevailing wind directions vary seasonally: northeast wind prevails from October to the following April and southwest wind prevails from May to September, with the annual average wind speed of 5.3 m/s. Influenced by the monsoon (Figure 1-5), waves in the area predominantly come from the northeast in winter and from the southwest in summer, with the annual average significant wave height of 1.4 m. The annual average sea surface temperature is 28.6 ℃.

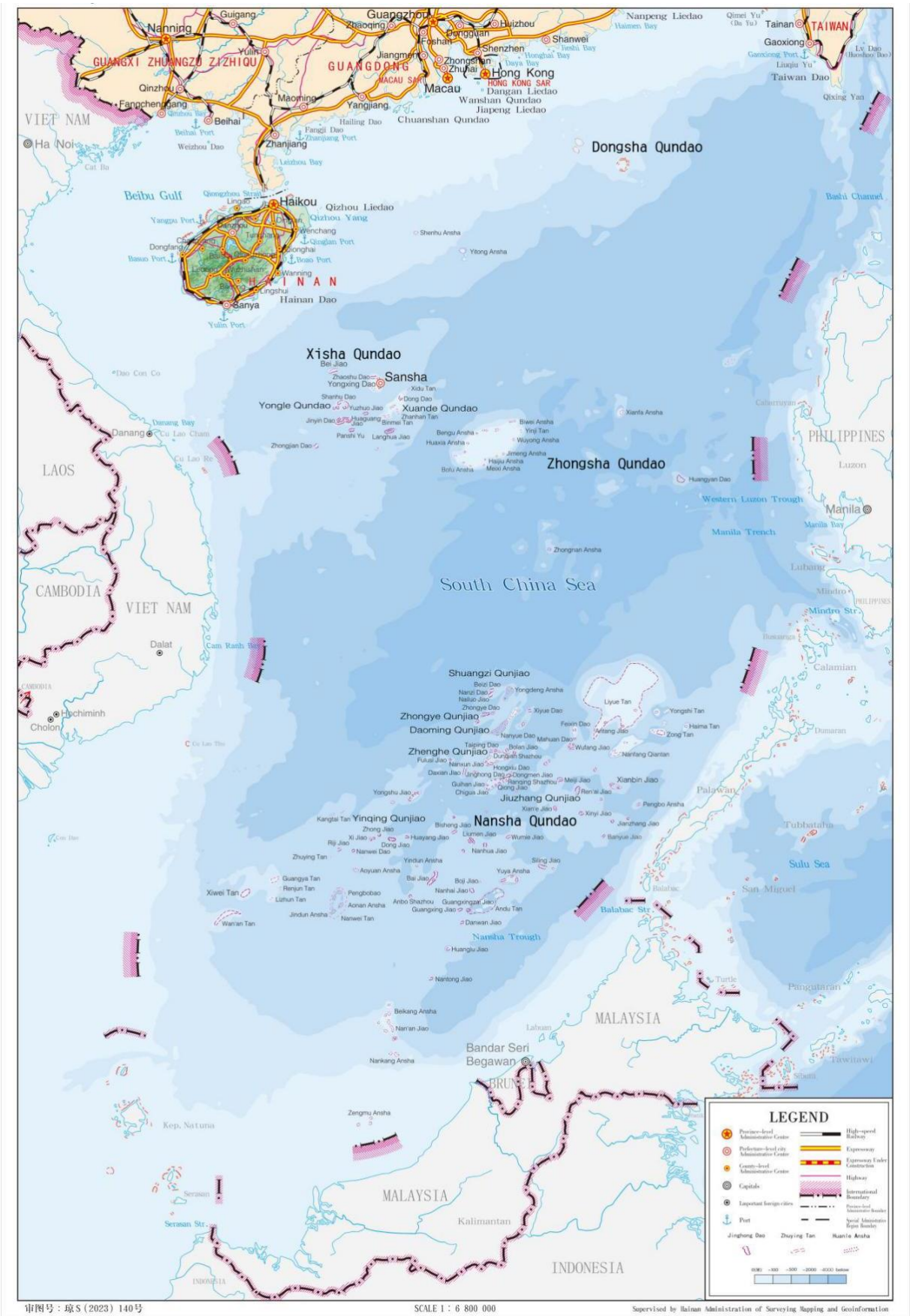


Figure 1-1 Location of Huangyan Dao

Figure 1-2 Numerous reefs outcrop on the reef flat during low tide

Figure 1-3 Beiyan

Figure 1-4 Nanyan

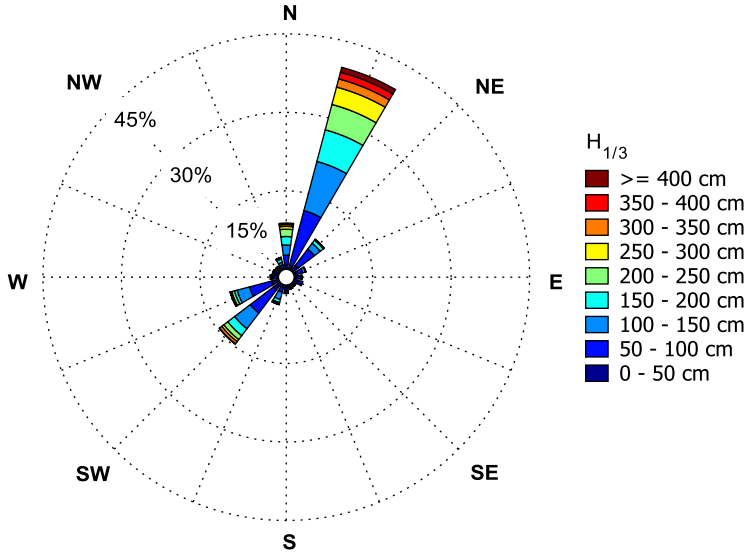


Figure 1-5 Wave rose diagram

2. Summary of the survey

In 2025, South China Sea Ecological Center of Ministry of Natural Resources along with other relevant institutes combined methods such as vessel navigation survey,

diving investigation, satellite and aerial remote sensing, in-situ observation to conduct a multi-disciplinary survey covering marine biology and ecology, hydrometeorology, marine chemistry, and marine geology on coral reef ecosystem of Huangyan Dao. The status of coral reef ecosystem of Huangyan Dao was comprehensively assessed by integrating historical data and achievements of scientific surveys in 1985 and 2012 as well as literature of Huangyan Dao.

From May 28 to June 28, 2025, a total of 14 quantitative survey stations and 47 qualitative patrol stations around the reef platform and lagoon were conducted for coral reef ecosystem (Figure 2-1), covering 96 parameters of 4 categories: coral communities, reef-dwelling organisms, habitat environment, and threatening factors. 9 quadrats were set up in the seagrass-intensive area in the northern part of the lagoon for seagrass ecosystem survey covering 26 parameters of 4 categories: seagrass communities, dwelling organisms, habitat environment, and carbon storage. In-situ observation facilities such as buoys, seabed-based observation platform were deployed in the lagoon and the northern side of reef platform to continuously obtain observational data on the ocean currents, waves, water quality, etc.

In addition, high-resolution satellite remote sensing images collected from 2015 to 2025 were used to invert the reef platform substrate types (Figure 2-2), and to calculate the reef platform area within a depth of 20 m as well as the coverage of different types of substrate and further analyze the changes in the coverage of reef-building corals. The change of the seagrass area in the northern lagoon was assessed using high-resolution satellite remote sensing images collected from 2010 to 2025.

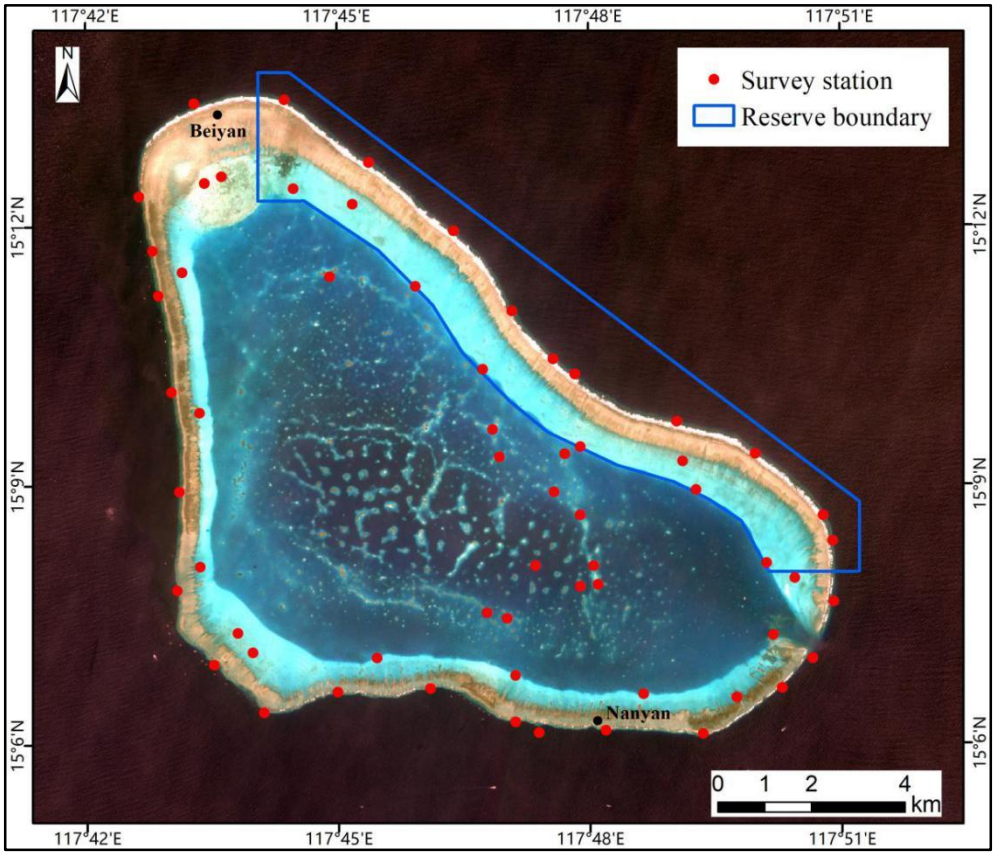


Figure 2-1 Diagram of survey stations in 2025

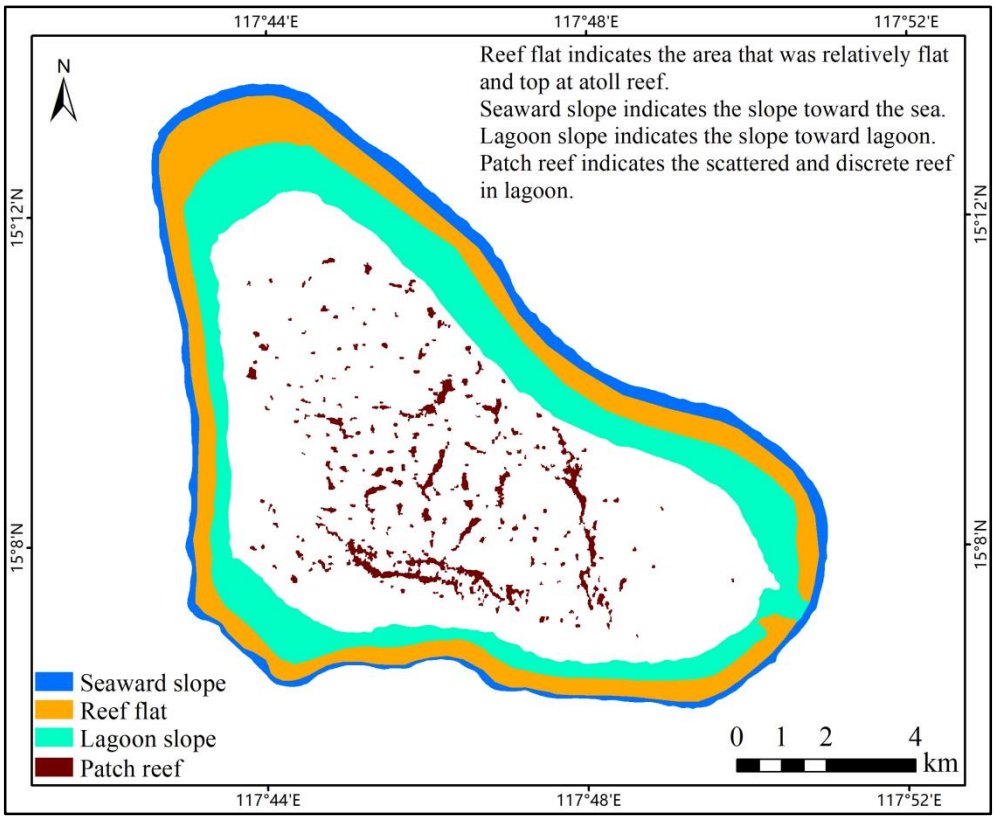


Figure 2-2 Geomorphology of Huangyan Dao reef platform in April 2025

3. The coral reef ecosystem status of Huangyan Dao

3.1 The reef-building coral coverage area on Huangyan Dao reef platform staying stable

High-resolution satellite remote sensing images collected from 2015 to 2025 show that the reef-building coral coverage area on Huangyan Dao reef platform is approximately 6.37 km^2 and has remained generally stable since 2015 (Figure 3-1).

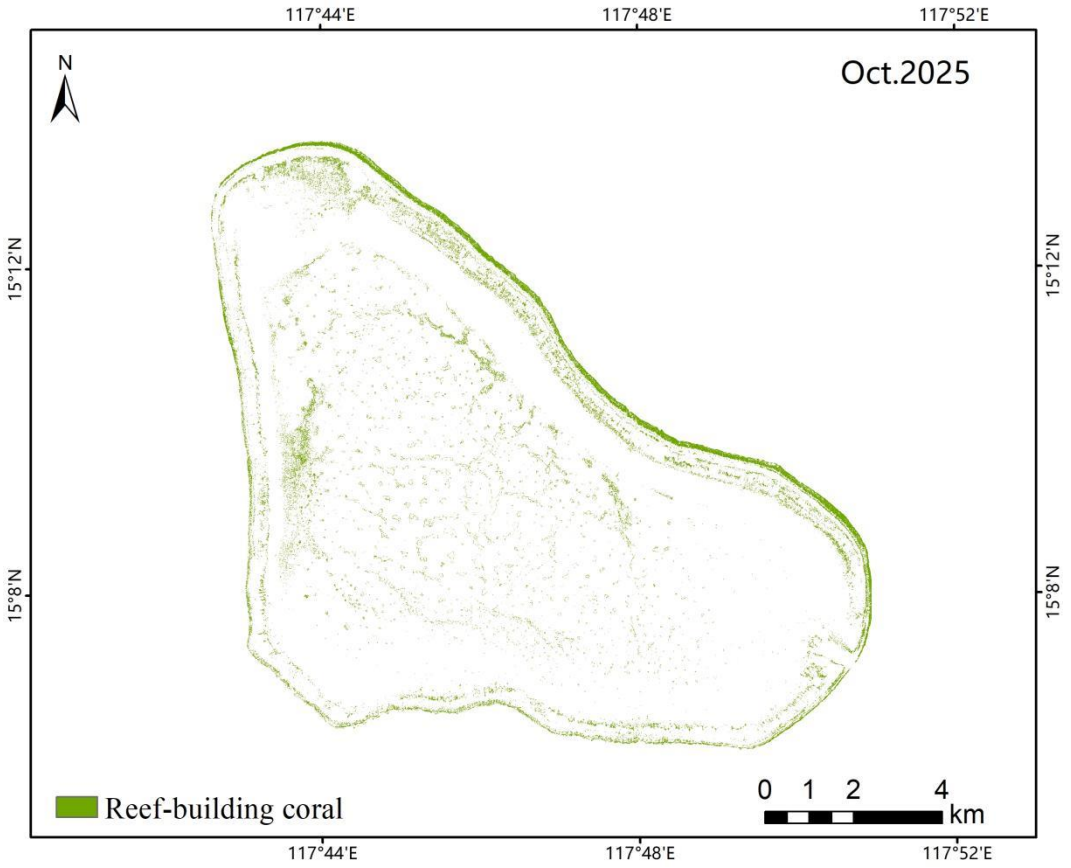


Figure 3-1 Distribution of reef-building corals on Huangyan Dao reef platform in October 2025

3.2 Coral reef ecosystem of Huangyan Dao maintaining healthy

Reef-building coral species are abundant. A total of 135 species of reef-building corals belonging to 36 genera and 13 families are found on Huangyan Dao—all listed as national second class protected wildlife in China, with the most species found in the northeast region. Among the reef-building corals, the family Acroporidae has the largest number of species, with 51 species found, accounting for 37.8%. The following is Merulinidae with 42 species, accounting for 31.1%. The dominant coral

species are *Porites lutea*, *Porites rus*, *Goniopora minor*, *Isopora palifera*, *Pocillopora eydouxi*, and *Goniastrea edwardsi*, mostly massive and branching corals.

The hard coral cover of Huangyan Dao is relatively high, but with regional variations. The result of quantitative survey indicates the regional disparities of the hard coral cover on Huangyan Dao is significant. The highest hard coral cover is found in the northeast (Figure 3-2), averaging 38.8%, which is higher than the most major coral reef regions worldwide. The average coral cover of lagoon where the sandy substrate is predominant and unsuitable for coral growth is the lowest with the average value of 7.8%. The reef-building corals there are mainly distributed on patch reefs. The coral cover in the west and south are relatively low, with the average value of 10.1%.

Base on a comprehensive analysis including geomorphology characteristics, satellite remote sensing inversion, historical outbreak records of *Acanthaster solaris*, on-site footage, and relevant literature, there are several reasons for the low reef-building coral cover in the west and south. Firstly, western and southern seaward slope of Huangyan Dao exhibits well-developed grooves which demonstrate the hydrodynamic condition are relatively strong. Combined with the steep slope, western and southern seaward slope are relatively unsuitable for the growth of branching corals, which are in consistent with the result recorded in historical documents （Van den hoek et al.，1978）and field observations that the region is dominated by massive corals. Secondly, extensive mortality of massive corals was documented in the west and south region in this survey, with the time of mortality assessed to be over 3 years. These dead corals may be associated with the successive outbreaks of *A. solaris* disasters happened at Xisha Qundao and Zhongsha Qundao since 2018, which may spread to this area and thus caused coral damage in this region.

Figure 3-2 Reef-building corals inhabited in the northeast of Huangyan Dao

Coral reef fishes and benthic macro-invertebrates are abundant. A total of 182 species of coral reef fish belonging to 27 families are recorded at Huangyan Dao (Figure 3-3). Most species listed under the families Labridae and Pomacentridae, with dominant species including *Ctenochaetus striatus*, *Chromis margaritifer*, *Acanthurus japonicus*, *Thalassoma amblycephalum*, and *Gnathodentex aureolineatus*. The average fish density is 80 ind./100m^2, with the highest density observed in the northeast. 16 species of parrotfish and 17 species of butterflyfish—both important indicator taxa for coral reef health—are found. Many economically valuable fish species are also found, including *Epinephelus merra*, *Cephalopholis argus*, *Caranx melampygus*, and *Lutjanus gibbus*. There is a large variety of benthic macro-invertebrates, mainly including sponges, sea squirts, soft corals, and gastropods. Economically important species such as *Panulirus versicolor*, *Thelenota anax*, *Spondylus squamosus*, *Lambis lamb*is, and *Rochia nilotica* are also observed (Figure 3-4; Figure 3-5). The diversity and distribution density of giant clams are high. There are 4 giant clam species belonging to 2 genera found at Huangyan Dao, namely *Tridacna crocea*, *Tridacna maxima*, *Hippopus hippopus*, and *Hippopus porcellanus* accounting for 50% of all giant clams species recorded in China. The average density of giant clams is 1.2 ind./100m ², with the highest density which reaches up to 75 ind./100m ²on some patch reefs inside the lagoon (Figure 3-6).

Figure 3-3 Coral reef fishes on Huangyan Dao

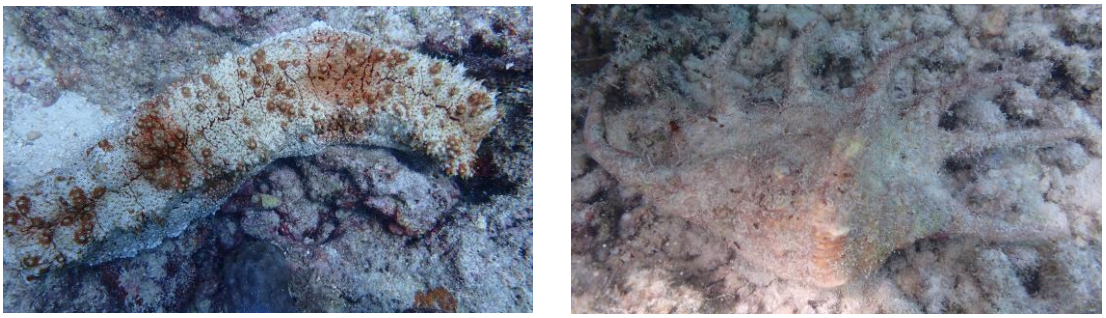


Figure 3-4 *Thelenota anax* (left) and *Lambis lambis* (right) on Huangyan Dao

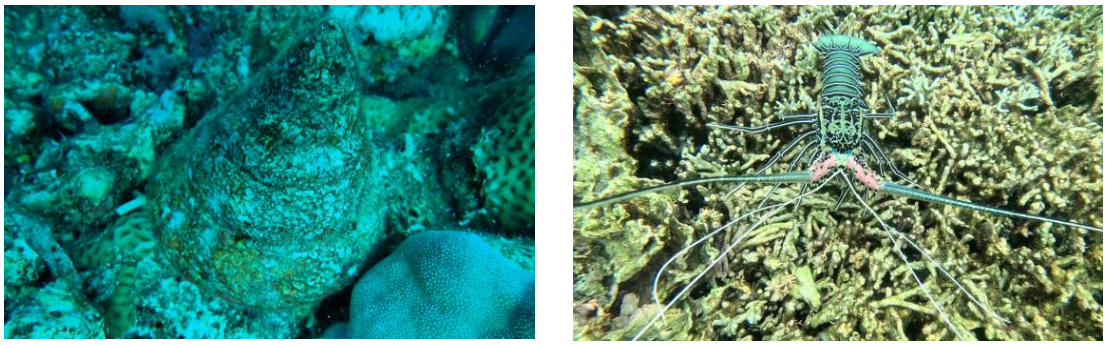


Figure 3-5 *Rochia nilotica* (left) and *Panulirus versicolor* (right) on Huangyan Dao

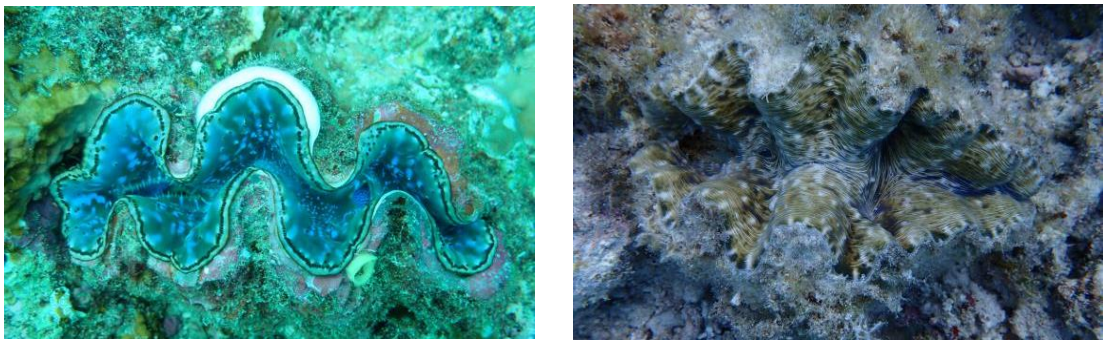


Figure 3-6 Giant clam species on Huangyan Dao (Up: *Tridacna crocea*; lower left: *Tridacna maxima*; lower right: *Hippopus hippopus*)

The coral reef habitat is of favorable quality. The seawater temperature, salinity, and pH value on Huangyan Dao are all suitable for coral growth. Average content of active phosphate, inorganic nitrogen, dissolved oxygen (DO), and oil in seawater is 1.9μg/L, 42.0μg/L, 6.4mg/L, and 16.0μg/L, respectively. Average content of heavy metals, such as mercury, arsenic, and chromium, in surface sediments is 0.0021μg/g,

0.78μg/g, and 2.3μg/g, respectively, while copper, lead, cadmium, and zinc are not detected. The content of these elements is all at a rather low level, far better than the standards for level-1 seawater quality and marine sediment quality. Fishes, bivalves, and gastropods feature a low content of mercury, copper, lead, cadmium, zinc, total chromium, and petroleum hydrocarbon, indicating good biological quality.

3.3 Extensive and lush seagrass distributed in the northern part of the lagoon of Huangyan Dao

Seagrass beds can purify seawater, sequester carbon to increase carbon sinks, stabilize seabed substrates, reduce the resuspension of seabed gravels that may damage corals, and provide habitats for breeding and sheltering of coral reef fishes. Extensive seagrass is distributed within the lagoon of Huangyan Dao, with continuous and lush seagrass in the northern part of the lagoon forming an approximately 1.85km ^{2} seagrass bed. The average coverage of seagrass in this region is 19.2%. The seagrass bed mainly consists of *Cymodocea rotundata* (Figure 3-7) and *Halophila ovalis* (Figure 3-8), with the former being the dominant species. *Cymodocea rotundata* grows vigorously, with an average shoot density of 1,118.7 shoots/m ^{2}, an average height of 10.6 cm, and a carbon density of 58.0 megagrams of carbon/km ^{2}. *Chelonia mydas* is found foraging on the seagrass bed (Figure 3-9). Various benthic macro-invertebrates are also recorded, including *Gibberulus gibberulus*, *Conus betulinus*, and *Tripneustes gratilla*. *G. gibberulus* is the dominant species, with an average density of 9.3 ind./m ^{2}.

Remote sensing survey results show that since 2010, the seagrass bed area in the northern part of the lagoon of Huangyan Dao has continuously expanded from 0.64 km ^{2}to 1.85 km ^{2}in 2025, with the scattered patches now connected into a continuous expanse (Figure 3-10).

Figure 3-7 *Cymodocea rotundata* on Huangyan Dao

Figure 3-8 *Halophila ovalis* on Huangyan Dao

Figure 3-9 *Chelonia mydas* foraging on the seagrass bed

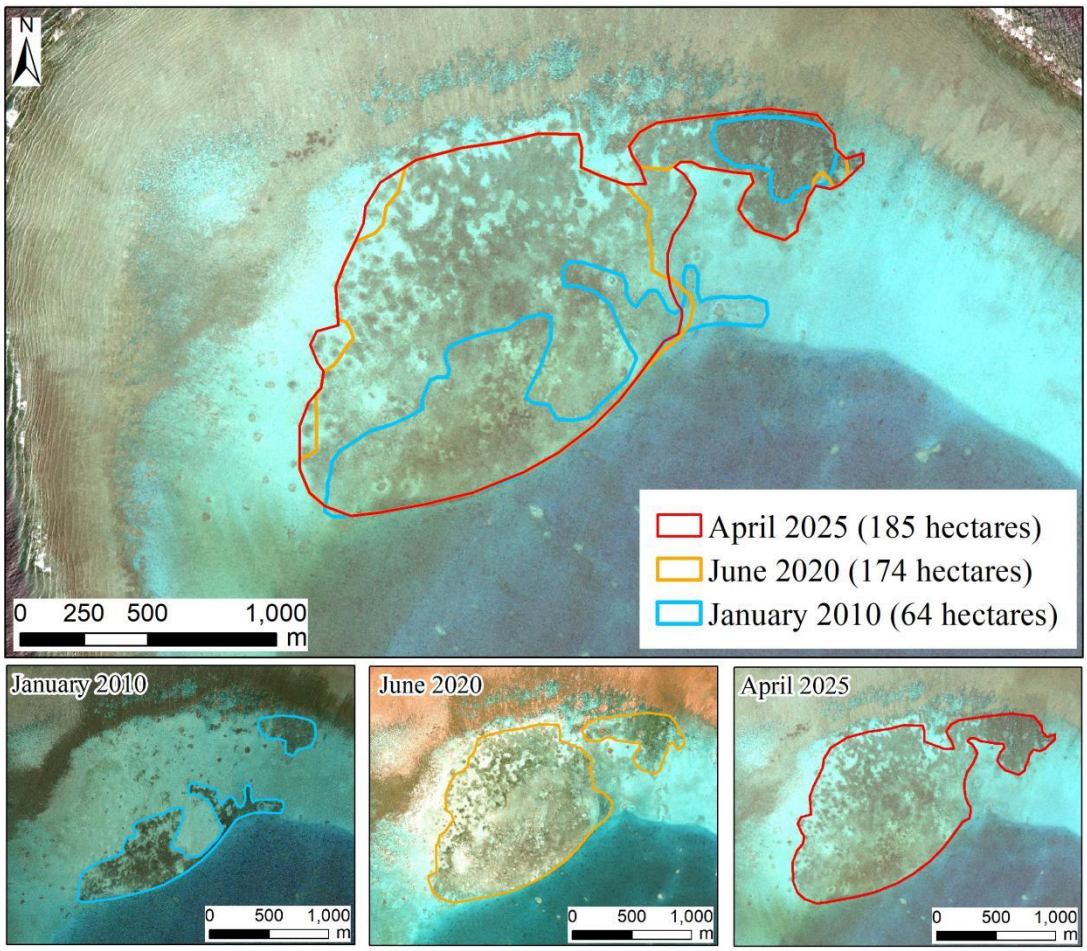


Figure 3-10 Expanding coverage of seagrass bed on Huangyan Dao

4. The coral reef ecosystem status of Huangyan Dao National Nature Reserve

4.1 Coral reef ecosystem maintaining in good condition

Huangyan Dao National Nature Reserve features well-preserved habitat. High-resolution satellite remote sensing images show that the reef-building coral coverage area of Huangyan Dao National Nature Reserve accounted for 43.0% of Huangyan Dao. A total of 85 species of reef-building corals belonging to 25 genera and 8 families are observed within Huangyan Dao National Nature Reserve, accounting for 63.0% of the total on Huangyan Dao. Dominant reef-building coral species were as following，*P. rus*，*P. lutea*, *I. palifera*, *Goniastrea pectinata*, *P. verrucosa*, *P. eydouxi*, *Favites abdita*, *Coelastrea aspera*, *Goniastrea favulus*, which are mostly massive and branching corals. A cluster of branching corals,

predominantly the species *Isopora brueggemanni*, were distributed in the central area of the reserve (Figure 4-1). The average hard coral cover of the reserve is 38.8% and the highest area reaches 55.1%.

A total of 88 species of coral reef fish are recorded within Huangyan Dao National Nature Reserve, accounting for 48.3% of total fish species of Huangyan Dao, with an average density of 134 ind./100m². Macro-invertebrates including crustaceans, bivalves, and gastropods are abundant both in species and quantity, with gastropods reaching a density of 18 ind./100m². This area has the largest number of reef-building coral species and highest hard coral cover, as well as the largest number of species and highest density of coral reef fish on Huangyan Dao.

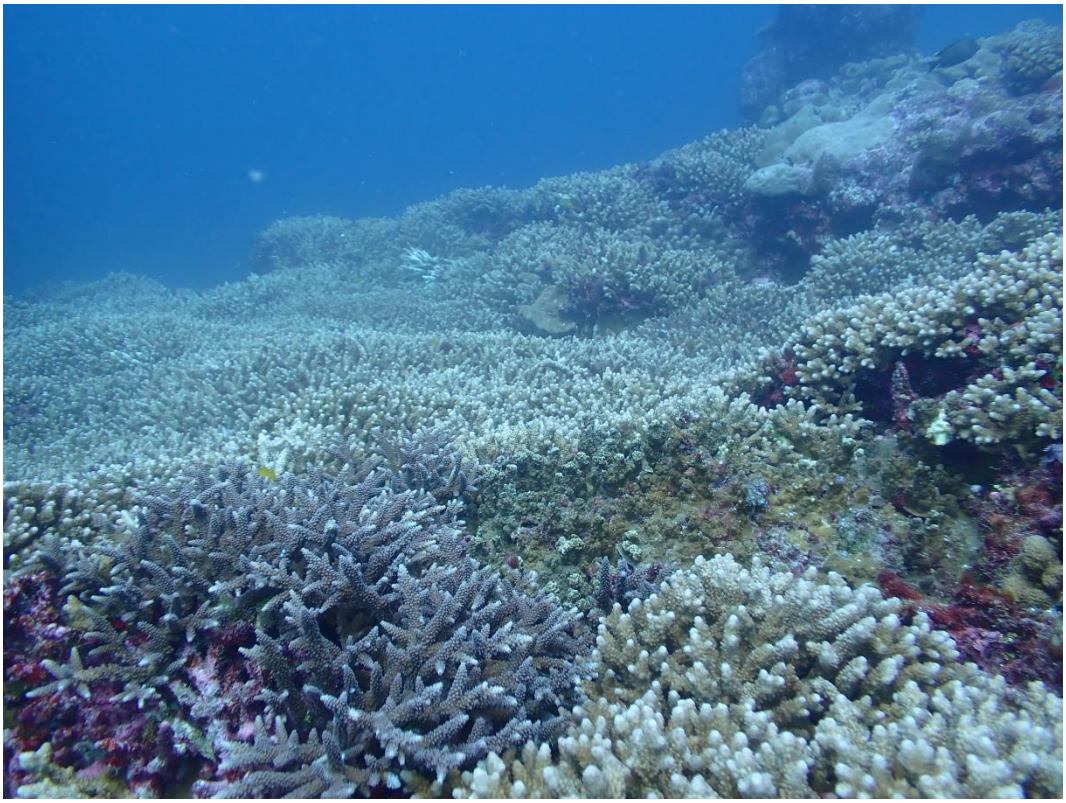


Figure 4-1 A cluster of branching corals in the central area of the reserve

4.2 A rich variety of endangered wildlife

Huangyan Dao National Nature Reserve is an important breeding and habitat area for many endangered wildlife species. Two species belonging to the national first class protected wildlife are documented during the survey, namely *Chelonia mydas*, *Eretmochelys imbricata* (Figure 4-2). A total of 92 species under national second

class protected wildlife are found, including 85 species of reef-building corals, species of *T. crocea*, *T. maxima*, *C. tritonis*, *C. tigris* (Figure 4-3), *Heliopora coerulea*, as well as *Millepora platyphylla*, and *Millepora tenera*. Additionally, *Aetobatus narinari* and *Bolbometopon muricatum*—respectively listed by the International Union for Conservation of Nature (IUCN) as endangered and threatened—are observed (Figure 4-4).

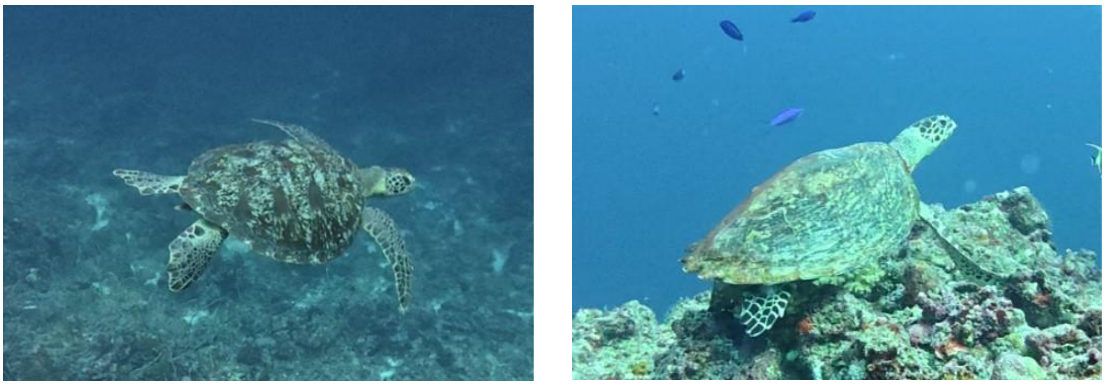


Figure 4-2 *Chelonia mydas* (left) and *Eretmochelys imbricata* (right) on Huangyan Dao

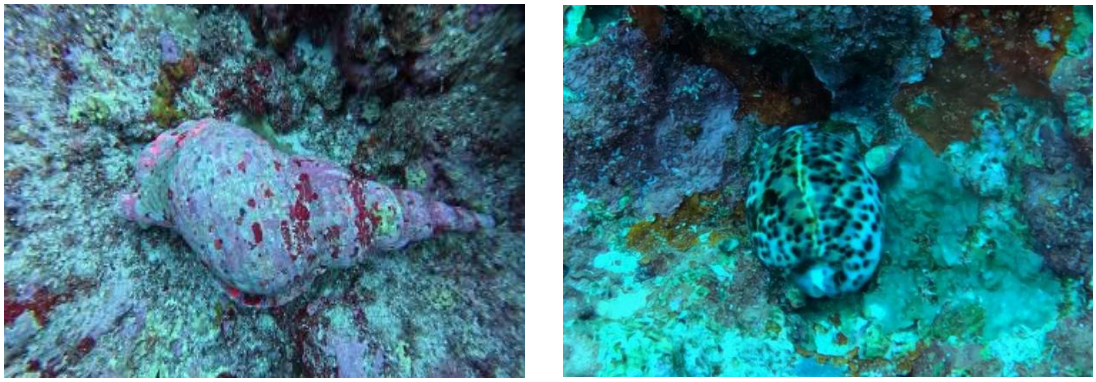


Figure 4-3 *Charonia tritonis* (left) and *Cypraea tigris* (right) on Huangyan Dao

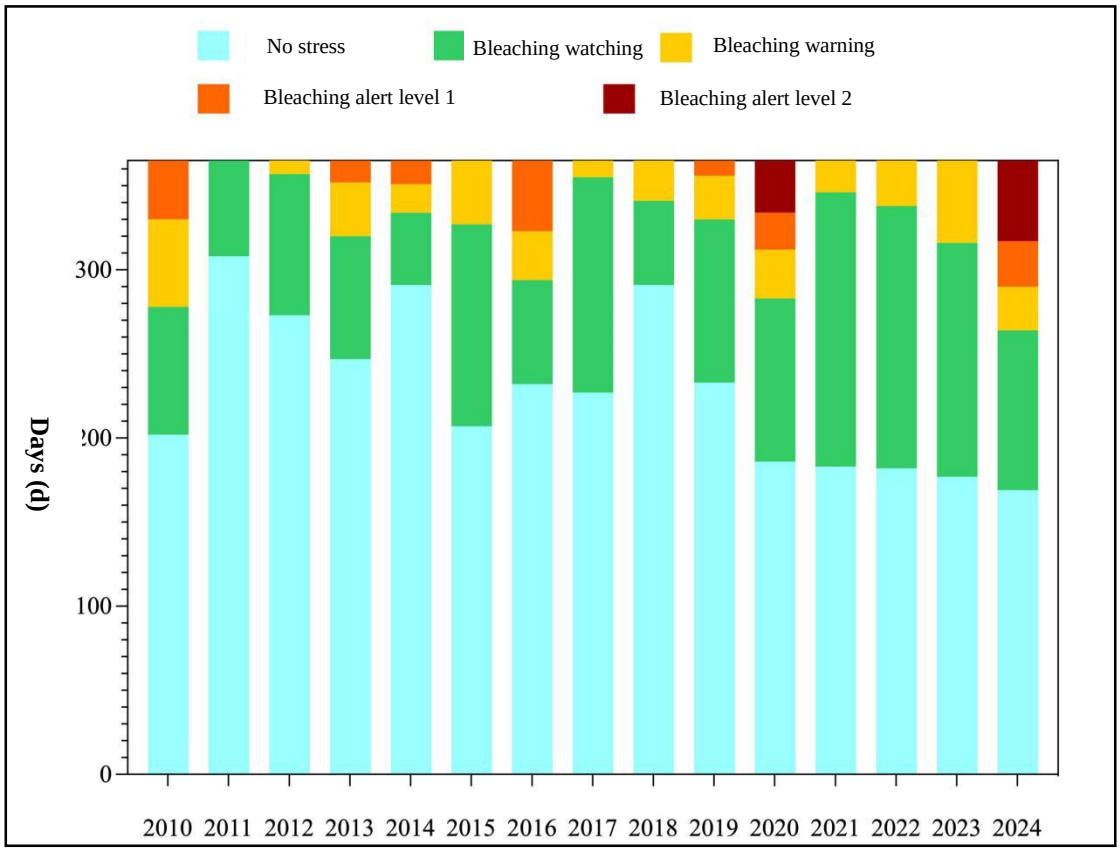
Figure 4-4 *Aetobatus narinari* (left) and *Bolbometopon muricatum* (right) on Huangyan Dao

5. Threats faced by coral reef ecosystem of Huangyan Dao

Despite its sound condition, the coral reef ecosystem of Huangyan Dao still faces a series of threats, such as abnormal increase in sea surface temperature, outbreaks of coral predators, tropical cyclones, and illegal and irresponsible activities by certain countries.

5.1 Stress induced by abnormal increase in sea surface temperature

The abnormal increase in sea surface temperature caused by global climate change can lead to large-scale coral bleaching and even mortality, resulting in the structural and functional degradation of coral reef ecosystem. According to international coral bleaching models and standards, corals in the waters of Huangyan Dao have experienced strong bleaching stress which mainly concentrated between June and September from 2020 to 2024. In 2024, Level-2 coral bleaching alert (indicating large-scale bleaching with a high likelihood of coral mortality) was recorded in more than 40 days (Figure 5-1), the longest record in this area since 2010. Result of the field survey in June 2025 indicates a 3% mortality rate of reef-building corals within one year on Huangyan Dao, with branching corals which are relatively less heat-resistant being the main victim. This shows that the abnormal increase in sea surface temperature driven by global climate change may have partially caused coral bleaching and mortality on Huangyan Dao, exerting a certain level of stress on the coral reef ecosystem.



5.2 Stress induced by outbreaks of coral predators

Outbreaks of *A. solaris* is one of the important reasons for disruption of coral reef ecosystem. In recent years, major distribution areas of coral reef have reported the massive outbreak incidents of *A. solaris* which lead to degradation of the coral reef ecosystem. Specifically within South China Sea, the outbreak disasters of *A. solaris* have been recorded in Xisha Qundao, Zhongsha Qundao since 2018.

During the field survey, the hard coral cover in the west and south is relatively low with some recruited *Pocillopora* species observed there. Meanwhile, 11 *A. solaris* are found on the seaward slope and lagoon slope in the southern area (Figure 5-2). Based on the records of *A. solaris* outbreaks in the South China Sea in recent years, combined with the traits that *Pocillopora* often emerged as pioneer species (Cunning et al., 2018) during the natural recovery of damaged coral reef communities, it is inferred that outbreak of *A. solaris* may have occurred in the west and south of Huangyan Dao and lead to coral degradation in these areas. Up until now, the

distribution of recruited *Pocillopora* suggests that the impaired coral reef ecosystem is undergoing the stage of restoration.

It should be noted that in spite of the distribution density of *A. solaris* in the south area of Huangyan Dao below the outbreak threshold, the high hard coral cover in the northeast provides abundant food for *A. solaris*, indicating a potential risk of outbreaks of *A. solaris* within the northeast region and further impairing the coral reef ecosystem of Huangyan Dao.

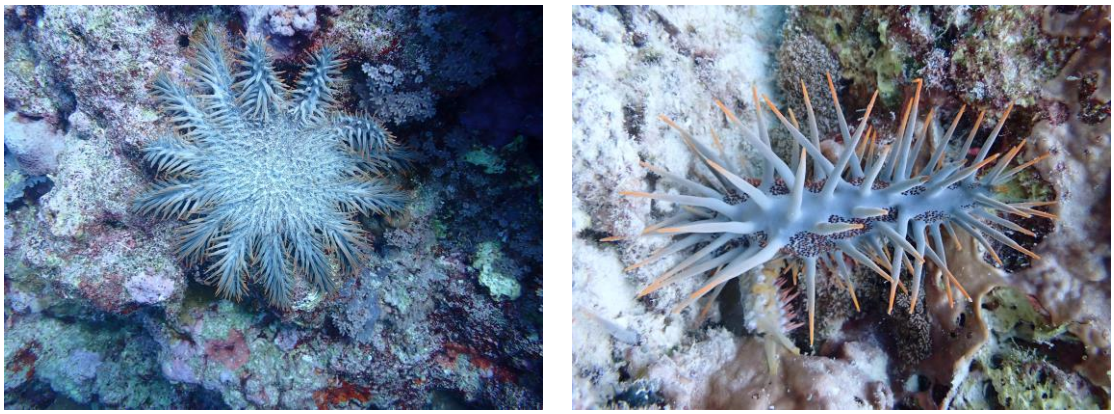


Figure 5-2 *Acanthaster solaris* on Huangyan Dao

5.3 Stress induced by tropical cyclones

Huangyan Dao is frequently affected by tropical cyclones. Statistics show that a total of 63 tropical cyclones passed within a minimal distance of 150 km of Huangyan Dao from January 1994 to October 2025, 7 of which were formed in these waters, 21 tropical cyclones passed within a minimal distance of 50 km, including 1 super typhoon and 4 strong typhoons.

Studies show that when tropical cyclones reach the wind speed of 17 m/s (Scale 8) and persist for more than 19.5 hours, or when they exceed the wind speed of 24.7 m/s (Scale 10), they can cause damage to coral reefs (Puotinen, 2007). Strong typhoon Vamco, the 22nd Typhoon of 2020, with its maximum wind speed reaching 33 m/s, met these conditions when it affected Huangyan Dao and might have caused damage to coral reefs there.

5.4 Stress and disruption induced by illegal and irresponsible activities by certain countries

Illegal military activities such as bomb-dropping exercises carried out by the Philippines and other relevant countries have caused severe damage to the coral reef of Huangyan Dao. Studies show that a single ordinary bomb can instantly fragment reef structures within a radius of 1 m - 1.5 m (Pet-soede et al., 1998), while the bomb craters and large-scale coral damage resulting from bomb explosion would take 50 years - 100 years to recover naturally (Raymundo et al., 2007).

In the 1960s and 1970s, the Philippines and other relevant countries illegally abandoned vessels and deployed concrete targets in the waters of Huangyan Dao for bomb training. In 1985, Chinese scientific researchers discovered abandoned vessels with numerous bomb craters and shot marks in the region (Figure 5-3). These abandoned vessels, concrete targets, and bomb-dropping activities would directly lead to the collapse of reef platforms, cause fatal damage to large numbers of corals and reef-dwelling organisms, and finally severely impair coral reef of Huangyan Dao.

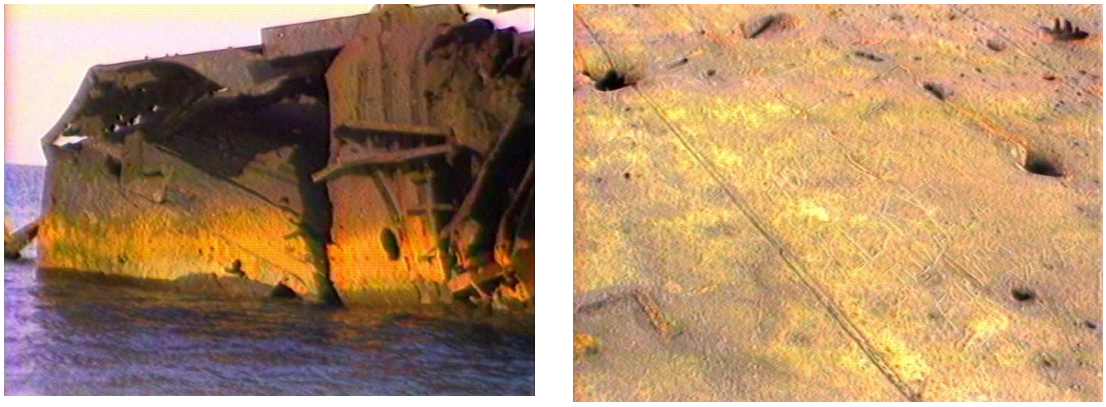


Figure 5-3 Foreign target vessel on the eastern side of Huangyan Dao in 1985 (left) and the bullet marks on the vessel (right)

The Philippines' illegal fishing activities and frequent intrusions have adversely affected the ecosystem of Huangyan Dao. China Coast Guard and the former China Marine Surveillance have repeatedly discovered large numbers of Philippine vessels illegally fishing in the waters around Huangyan Dao. From 2013 to 2018, they drove away more than 900 Philippine fishing boats (Figures 5-4) and removed over 30 Philippine floating tanks. Satellite remote-sensing imagery taken on May 18, 2016, showed more than 20 Philippine fishing boats operating in the waters around

Huangyan Dao (Figure 5-5)—during China's summer fishing moratorium in South China Sea. The Philippines have also frequently organized large groups of vessels to intrude into the waters of Huangyan Dao. According to incomplete statistics, there have been 14 such intrusions since 2024, on a larger scale and at a higher frequency after the establishment of Huangyan Dao National Nature Reserve in September 2025. The survey in 2025 found abandoned items bearing Philippine production marks (Figure 5–6), as well as a discarded floating tank left behind by Philippines. Under the influence of ocean currents, the ropes and iron blocks used beneath the floating tanks for anchoring caused direct damage to the corals at and around the anchoring points (Figure 5–7). The Philippines' unsustainable illegal fishing activities and frequent intrusions have brought about abandoned materials and pollutant discharge, adversely affecting the health of Huangyan Dao ecosystem. In particular, the frequent intrusions also increase the risks of vessel grounding and oil spills. These illegal and irresponsible activities posed a serious threat to the ecosystem in this region.

Figure 5-4 Philippine fishing boats illegally operating at Huangyan Dao

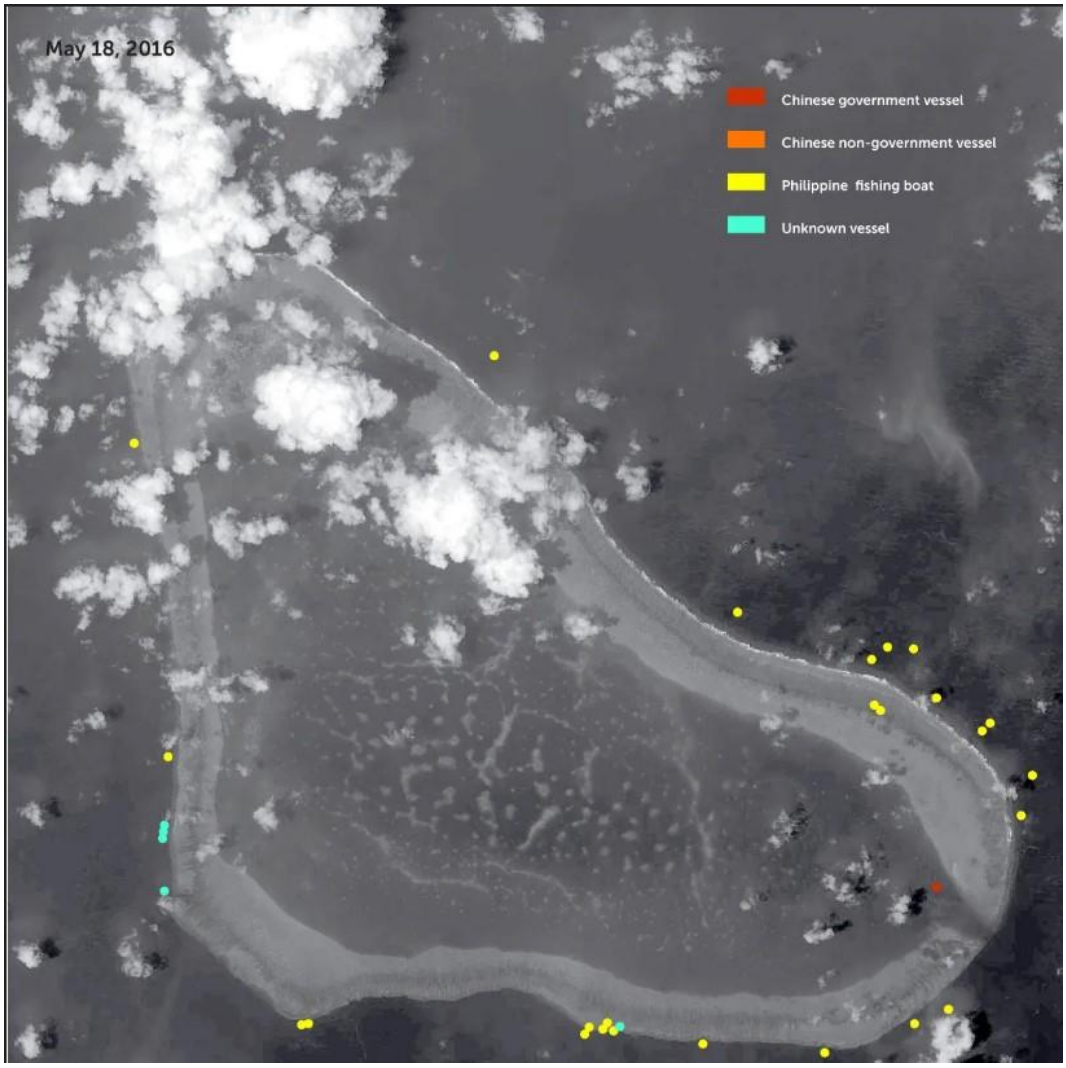


Figure 5-5 Large numbers of Philippine fishing boats on Huangyan Dao during China's fishing moratorium (quoted from America's Centre for Strategic and International Studies)

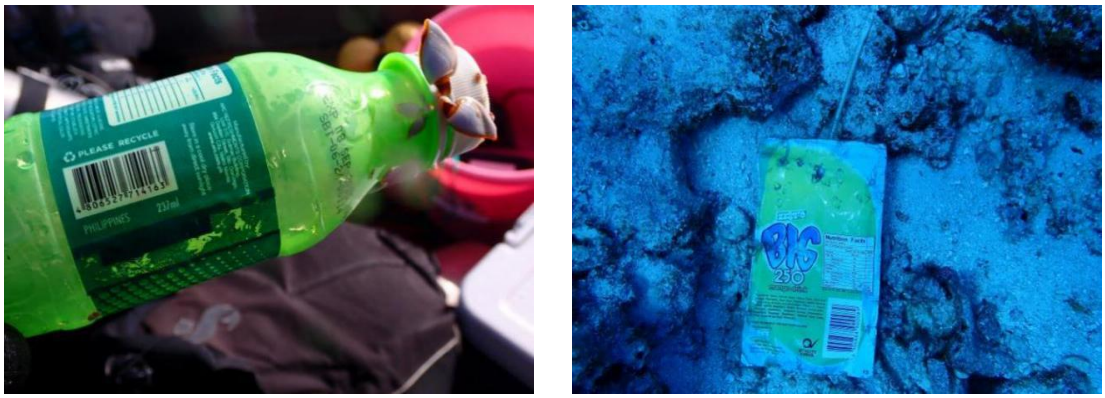


Figure 5-6 Abandoned items bearing Philippine production marks founded underwater on Huangyan Dao during the survey in 2025

Figure 5-7 A discarded floating tank by Philippines on Huangyan Dao during the survey in 2025

6. Conclusion

The coral reef ecosystem of Huangyan Dao is generally in a favorable state, with abundant endangered wildlife species as well as continuous and lush seagrass, giving it extremely high conservation value. However, it still faces threats such as coral thermal bleaching, outbreaks of coral predators, and tropical cyclones. In addition, illegal military activities, such as bomb-dropping exercises conducted by the Philippines and other relevant countries in the 1960s and 1970s, have already caused severe damage to the coral reef of Huangyan Dao, while illegal fishing activities and frequent intrusions by the Philippines have also induced a great stress on the ecosystem.

In September 2025, China has established Huangyan Dao National Nature Reserve, incorporating the northeastern area which features the largest number and highest coral cover of reef-building coral species as well as frequent endangered wildlife activities into the protected zone. Rigorous conservation management would be implemented to reduce the negative impacts generated by human activities and other external factors. At the same time, China will further improve the regular alerting and monitoring mechanism on Huangyan Dao, and consistently carry out surveys, studies, conservation and restoration to maintain and enhance the diversity, stability, and sustainability of the coral reef ecosystem.