

Observations on Coral Reefs of Hainan Island, South China Sea

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Two recent expeditions to Hainan Island provided the opportunity to survey coral reefs at various locations, including some which had been studied during earlier investigations. Since 1987 the reefs have apparently recently suffered from additional human impact. Dynamite fishing poses the major threat and large sections of the reefs are severely damaged. Increasing tourism with hotels built directly on the beach is also putting the coastal marine fauna at risk. Conservation measures and especially the enforcement of existing laws are urgently required.

Hainan Island situated in the tropical Gulf of Tongking is the largest island of the PR China. During recent years it has become China's largest special economic zone ('coastal economic free zone') with rapidly growing industry and tourism ('China's Hawaii'). Its coral reefs have been the subject of only a few investigations to date (Gurianova, 1959; Naumov *et al.*, 1960; Zou *et al.*, 1975; Hutchings & Wu, 1987). Information on the state of the reefs is, therefore, relatively poor. However, Hutchings & Wu (1987) reported extensive damage to the reefs in the south of the island probably as a result of over fishing the reefs and of silting by terrestrial run-off.

Two joint Chinese-German expeditions to Hainan were carried out in autumn 1990 and spring 1992. They investigated the coastal marine fauna and provided the opportunity to survey reefs at various locations, including those visited by Gurianova and Naumov *et al.* in 1957 and Hutchings & Wu in 1984. The following qualitative descriptions show that the reefs are suffering from human impact. A detailed survey and the implementation of conservation measures are urgently needed.

Material and Methods

Dives were carried out at the coral reefs of Shalao, at three different islets of Yalong Bay (Yezhu Islet, Dongzhou Islet, and Xizhou Islet) (Yalong Bay = Lunya Bay of Hutchings & Wu, 1987), at Xiaodonghai Bay (= Hsiao Tun Hai in Hutchings & Wu, 1987) and in Xincun lagoon (Fig. 1). Altogether 22 (28) dives were undertaken in 1990 (1992) with a total of 68 h spent under water. Most parts

of Xincun lagoon are very shallow, so after a short dive in 1992 we decided to use snorkeling gear instead of SCUBA.

During the dives corals and other animals observed were recorded and photographs were taken of the reefs and the most abundant species (Tables 1-5). Collections of various animal taxa were made with special emphasis on Polychaeta and Crustacea associated with living and dead corals. The results of these collections will be published separately.

Results

Shalao is situated on the east coast of Hainan Island. Dives were undertaken on the platform of a shallow fringing reef about 2000 m from the beach (up to 6 m depth) and on the reef edge (up to 17 m depth). Wide areas of the reef platform were covered with pieces of broken coral mainly from branching species. Together with calcareous algae they formed a loosely packed substrate. This layer of coral debris seemed to be rather thick as our manual attempt to remove the coral to reach the

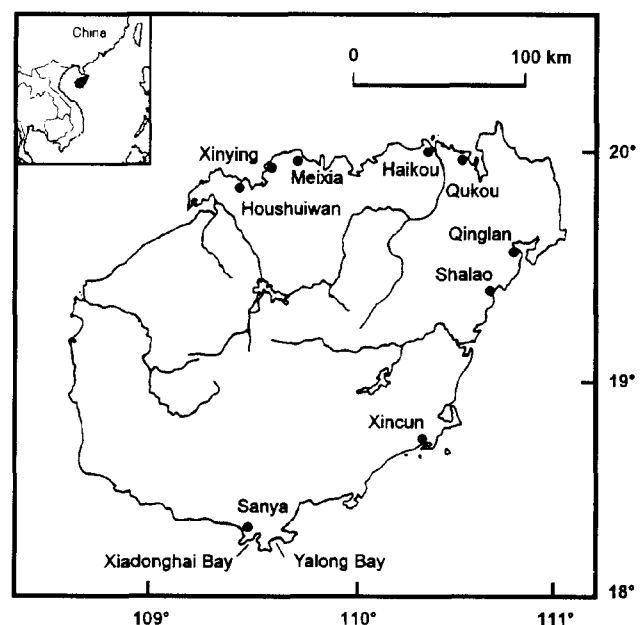


Fig. 1 Map of Hainan showing diving locations.

TABLE 1
Corals from Hainan Island (diving observations on coral reefs).

Species/Location	Shalao	Xiaodonghai	Xizhou Islet	Dongzhou Islet	Yezhu Island
Hexacorallia					
<i>Acropora</i> spp.	+	+	r	r	++
<i>Actinodendron</i> sp.				+	++
<i>Cerianthus</i> sp.			+		+
<i>Diploastrea</i> sp.		+		+	++
<i>Euphyllia</i> sp.					+
<i>Favia</i> spp.	r	+		+	++
<i>Favites</i> spp.		+	++		
<i>Fungia</i> spp.	r	+		++	++
<i>Galaxea</i> sp.	+	+	++	+	++
<i>Goniastrea</i> sp.	+	+			++
<i>Goniopora</i> sp.		+	++		++
<i>Lobophyllia</i> sp.	r	+	+	+	+
<i>Millepora</i> sp.			r	+	++
<i>Montipora</i> spp.		+		+	++
<i>Oxypora</i> sp.	r		++		++
<i>Pavona</i> sp.				+	+
<i>Pectinia</i> sp.					++
<i>Platygyra</i> sp.		r		+	+
<i>Plerogyra</i> sp.		r		+	+
<i>Pocillopora</i> spp.	r	+		+	++
<i>Porites</i> spp.	+	++		+	++
<i>Radianthus</i> spp.	r	++	+	+	++
<i>Symphyllia</i> sp.	r				+
<i>Turbinaria</i> sp.		r	++		++
Octocorallia					
<i>Dendronephthya</i> spp.	r		++	+	++
<i>Junceella</i> sp.			++	++	+
<i>Sarcophyton</i> spp.			+	++	r
<i>Sinularia</i> spp.			++	++	r
Gorgonaria			++		

++ : common; + : present; r: rare.

TABLE 2
Fish from Hainan Island (diving observations on coral reefs).

Species/Location	Shalao	Xiaodonghai	Xizhou Islet	Dongzhou Islet	Yezhu Island
<i>Amphiprion clarki</i>					+
<i>Amphiprion frenatus</i>	+	+	r	r	++
<i>Amphiprion perideraion</i>		+			++
<i>Apogon aureus</i>		++			+
<i>Chaetodon octofasciatus</i>					+
<i>Chaetodon trifasciatus</i>		+		+	++
<i>Chromis</i> sp.	++			r	+
<i>Cirrhitichthys</i> sp.	+	+	++	+	+
<i>Dascyllus aruanus</i>	r	+			++
<i>Dascyllus reticulatus</i>		+		+	++
<i>Dascyllus trimaculatus</i>	r	+		+	++
<i>Dendrochirus brachypterus</i>				+	+
<i>Dendrochirus zebra</i>	r		+	+	+
<i>Diademichthys</i> sp.					++
<i>Diploprion bifasciatus</i>		r	r		+
<i>Heniochus acuminatus</i>	+	+		+	+
<i>Labracinus</i> spp.	++	r			
<i>Mypristis</i> sp.	r	++		+	+
<i>Pempheris</i> spp.	r	++		+	+
<i>Pterois antennata</i>					++
<i>Pterois radiata</i>	r	r			+
<i>Pterois volitans</i>			+	+	++
<i>Scorpaenopsis</i> sp.	r	r	+	+	+
<i>Zanclus cornutus</i>	r	r		r	+
Diodontidae		r			+
Gobiidae	+	++	++	++	++
Mullidae	r	+		+	++
Siganidae	r		+		++
Synodidae	+	r		+	++
Tetraodontidae	r	r			+

++ : common; + : present; r: rare.

TABLE 3
Echinodermata from Hainan Island (diving observations on coral reefs).

Species/Location	Shalao	Xiaodonghai	Xizhou Islet	Dongzhou Islet	Yezhu Island
<i>Acanthaster planci</i>				r	+
<i>Bohadschia marmorata</i>				r	+
<i>Comanthus parvicirrus</i>			r	+	++
<i>Comanthina schlegeli</i>			r	+	++
<i>Comatella</i> spp.			r	+	++
<i>Culcita novaeguineae</i>	+			+	++
<i>Diadema savigny</i>				+	
<i>Diadema setosum</i>			r	+	++
<i>Echinothrix calamaris</i>	r		+	+	++
<i>Holothuria edulis</i>	r		+	++	++
<i>Linckia laevigata</i>	r			+	+
<i>Luidia maculata</i>			r		+
<i>Stichopus chloronotus</i>					+
<i>Synapta maculata</i>				+	++
<i>Toxopneustes pileolus</i>	r	+		++	++
<i>Tripneustes gratilla</i>	r	+	r	++	++

+ + : common; + : present; r: rare.

TABLE 4
Porifera from Hainan Island (diving observations on coral reefs).

Species/Location	Shalao	Xiaodonghai	Xincun	Yezhu Island
<i>Biemna fortis</i>			+	
<i>Callyspongia diffusa</i>			+	
<i>Callyspongia ridleyi</i>		+	+	
<i>Cynachyra</i> sp.			+	+
<i>Dysidea fragilis</i>		+	+	
<i>Gelliodes incrustans</i>			+	
<i>Haliclona</i> sp.			+	
<i>Iotrochostylia iota</i>			+	
<i>Pachychalina melior</i>			+	
<i>Pachychalina similis</i>			+	
<i>Pachychalina</i> spp.			+	
<i>Psammaplysilla purpurea</i>				+
<i>Reniera cinarea</i>			+	+
<i>Rhaphisia pallida</i>			+	
<i>Sigmatocia symbiotica</i>	+	+	+	+
<i>Spirastrella</i> sp.			+	
<i>Spongia officinalis</i>	+	+		+
<i>Spongia zimocca</i>				+
<i>Spongionella gracilis</i>			+	
<i>Stelletta tenui</i>			+	+
<i>Tethya aurantium</i>		+		
<i>Zygomycale parishii</i>			+	

+ + : common; + : present; r: rare.

underlying substrate was not successful. This coral rubble provided a good shelter for various invertebrates, such as crabs and ophiuroids. Only rarely single blocks of living corals rising up to 2 m above the ground and associated fishes were observed. Scattered over the surface of the coral debris we found pits, 2–4 m in diameter and 0.5–1.5 m deep. These were probably the results of explosions. The bottom of these pits was almost entirely covered with sea anemones (*Entacmaea quadricolor*).

The reef edge formed a wall of only 2 m height. The sandy bottom continued into the reef through narrow channels perpendicular to the reef edge. A number of different hermatypic corals (such as *Acropora*, *Porites*, *Galaxea*, *Goniopora*, *Favia*) together with some soft corals (*Dendronephthya*, *Sarcophyton* (Table 1)) and associated fish fauna were observed (Table 2). A dotted-back species, *Labracinus* sp. (Teleostei: Pseudochromidae) was particularly common. Although only low numbers and a poor diversity of coral-associated fish and invertebrates were found, the coral of the reef edge, however, showed no destructions and appeared to be in a good, healthy state.

The bay of Xincun—located on the southeast coast of Hainan Island—is almost completely separated from the sea; most of it is very shallow (3–6 m depth) and the water was extremely turbid (visibility < 2 m). The bottom was covered with broken coral and resembled closely the reef top at Shalao. Small craters (1–4 m in diameter) were common. Only relatively few species of living corals were found (Table 1) with *Pavona* being predominant. Among the coral rubble swimming crabs (Portunidae) were observed. Fish were very rare but sponges highly abundant. Fish and pearl oysters were cultured in the lagoon.

Yalong Bay is a wide bay shaped like a crescent with a beach of clean, white sand. It is situated about 1 h drive east of Sanya in the very south of the island. In the northeast part of the bay the islets Yezhu, Dongzhou and Xizhou are situated 1–2 and 3–4 nautical miles, respectively, from the beach. The bottom of Yalong Bay seemed to be mainly sandy.

The reefs of Yezhu Island showed the highest diversity of all sites visited, with a high percentage of living coral. However, wide areas with dead corals were also observed.

TABLE 5

Mollusca, Crustacea Decapoda, and Polychaeta from Hainan Island (diving observations on coral reefs).

Species/Location	Shalao	Xiaodonghai	Xizhou Islet	Dongzhou Islet	Yezhu Island
Mollusca					
<i>Charonia tritonis</i>					r
<i>Chicoreus brunneus</i>			++		++
<i>Harpago chiragra</i>			+		+
<i>Lambis lambis</i>			++		++
<i>Lopha</i> spp.		+	++	+	++
<i>Ovula ovum</i>				++	
<i>Pinna</i> spp.			++		++
<i>Pinctada</i> spp.	+	+	++	+	++
<i>Pteria</i> spp.	++	+	++	+	++
<i>Spondylus</i> sp.	+	+	++	+	++
<i>Strombus luhuanus</i>			++		
<i>Tectus pyramis</i>	r	r	++	++	r
<i>Tridacna squamosa</i>	+	+	+	+	++
<i>Trochus maculatus</i>	r	r	++	++	r
<i>Vasum turbinellum</i>			++		++
Conidae		r			+
Cypraeidae	r	r			+
Polychaeta					
<i>Sabellastarte</i> sp.	r	r		r	+
<i>Spirobranchus giganteus</i>	+	++		+	++
Crustacea Decapoda					
<i>Alpheus</i> sp.	r	+		+	++
<i>Charybdis</i> sp.	++	r			+
<i>Panulirus stimpsoni</i>	+	r			r
<i>Percnon</i> sp.		++			
<i>Periclimenes brevicarpalis</i>					r
<i>Periclimenes imperator</i>					+
<i>Periclimenes soror</i>		r		+	++
<i>Rhynchocinetes</i> sp.	+	+		+	++
<i>Stenopus hispidus</i>		+			+
<i>Thalamita</i> sp.	r	++		+	+
<i>Thor amboinensis</i>		r		r	++
<i>Trapezia</i> spp.	+	+		+	++

++: common; +: present; r: rare.

Coral colonies built scattered reefs at 2–10 m depth; single specimens occurred down to 13 m. Below 10 m the bottom was sandy and from 13 m downwards muddy sediment was found. Visibility was generally very low, that is, between 1.5 and 3 m. The coral genera observed are listed in Table 1. Areas covered with coral colonies were separated by large patches of rubble and coarse coral sand. Knobby and foliaceous forms such as *Porites*, *Galaxea*, *Favia*, *Fungia*, *Goniopora*, *Montipora* and *Pectinia* were dominant, although staghorn and table corals of the genus *Acropora* as well as fire corals (*Millepora*) and brain corals (e.g. *Lobophyllia*, *Symphyllia*) also occurred. At a depth of 5–7 m remarkably large *Porites* boulders of up to several metres height and 2–3 m in diameter were observed. They were heavily interspersed with serpulid polychaetes (*Spirobranchus giganteus*) and bivalved molluscs (*Tridacna*, several oyster species). On the landward, that is northern, side of Yezhu Island a sheltered bay with shallow water was used as anchoring and fishing ground by local fishermen. Underwater many craters could be seen in the sand. Corals were almost completely destroyed above a depth of 3 m. Even bigger rocks or coral blocks (*Porites*) of up to 2 m in diameter were broken or turned upside down. Among the fish observed those without swimming bladder (scorpion fish etcetera) were dominant.

The western side of the island is rocky and goes steeply down to a depth of 10–12 m where it continues to the sandy bottom. Dynamite fishing is practised here as we

could see and hear during several dives. The destruction, however, was not as severe as in shallow water. Diversity of corals was high in this area (Table 1). Large numbers of soft corals occurred (*Dendronephthya*) as well as various host anemones (*Radianthus*, *Actinodendron*) together with several species of clownfish (*Amphiprion clarkii*, *A. frenatus*, *A. perideraion*) (Table 2) or symbiotic shrimps (*Thor amboinensis*, *Periclimenes brevicarpalis*). Sea urchins (*Diadema setosum*, *D. savigny*) and crinoids (*Comanthus parvicirrus*, *Comanthina schlegeli*, *Comatella* sp.) were very abundant. Sea cucumbers (*Holothuria edulis*, *Bohadschia marmorata*) and starfish (*Linckia laevigata*, *Culcita novaeguineae*, *Acanthaster planci*) were common.

The seaward, that is southern, side of Yezhu Island is also rocky and steep. Big granite boulders of several metres in diameter were covered with scattered small coral colonies, mainly encrusting forms like *Turbinaria*, *Oxypora* and *Galaxea* and with serpulid tubeworms (*Spirobranchus giganteus*). In 1992 several assemblages of seaweed (*Sargassum* sp., 2–3 m long) were noted between the rocks. Sea whips (*Junceella* sp.) were found below 10 m. At a depth of ca 20 m the slope continued onto the flat muddy-sandy bottom. Several big cerianthid anemones were found in this location.

The reefs examined at Dongzhou Islet—situated on the sheltered, landward side of Yalong Bay—were similar to those of Yezhu, but showed a less diverse fauna of hermatypic corals as well as lower abundance of living

corals. Single, isolated coral patches were surrounded by extensive sandy areas. Large *Porites* blocks were present and between a depth of 6–10 m wide areas were covered with soft corals of the family Alcyonidae (*Sinularia*, *Sarcophyton*). The diversity and abundance of the coral associated fauna, particularly of the fish and the echinoderms, were much lower than those observed on the reefs at Yezhu Island. *Diadema* and Crinoidae occurred less frequently than in Yezhu, the fish observed mainly belonging to the families Gobiidae, Synodidae, Scorpaenidae and Pomacentridae. Dynamiting of fish was observed at Dongzhou Islet, although less frequently than at Yezhu Island.

Xizhou Islet is the most offshore-situated island of Yalong Bay. Its landward side drops slowly to a depth of 16 m. Between a depth of 1–4 m the bottom was completely covered with rubble and broken corals such as *Porites* and *Acropora*. No living corals were discovered. From 4–8 m depth single colonies of living corals occurred, mainly knob-like and encrusting forms such as *Galaxea*, *Turbinaria*, *Goniopora*. Between 6 and 10 m large assemblages of *Sinularia* were found. In depths exceeding 10 m only encrusting corals occurred. The ground between 4 and 10 m was covered with coarse sand, coral rubble, and single granite boulders. Below 10 m the sediment consisted of muddy sand.

The seaward (southern) shore is a steep slope formed of large granite rocks. Underwater the rocky drop-off continues to a depth of ca 26 m where it changes into coarse sand. A strong current was present on this site and the visibility was generally below 1 m. Only encrusting corals such as *Turbinaria* were observed. Below 10 m depth gorgonian sea fans, sea whips (*Junceella*), and soft corals (*Dendronephthya*) were abundant. Very few fish belonging mainly to the families Cirrhitidae, Scorpaenidae and Gobiidae were recognized.

Xiaodonghai Bay is a crescent-shaped, sheltered bay with coral sand in the centre and rocky shore at both ends. It is situated about 3 km southeast of Sanya. The reef is built of rocks and boulders which form a system of channels and crevices, overgrown by mainly knobby and encrusting corals, e.g. *Goniopora*, *Favia*, and *Galaxea*. These labyrinth-like structures were situated at a depth of 3–10 m and separated by large channels with coarse coral sand. Occasionally *Acropora* tables and large blocks of *Porites* up to 4 m height and several metres diameter occurred. The abundance of living corals in general was relatively low, and although dynamite-fishing was observed frequently, only a few destroyed corals were seen. Fish were not common at this site, mainly the families Gobiidae, Apogonidae (*Apogon aureus*), Pomacentridae (*Dascyllus* sp., *Amphiprion frenatus*, *Amphiprion perideraion*), and Pempheridae were present. We also found some Chaetodontidae (*Chaetodon trifasciatus*, *Heniochus acuminatus*) and Synodidae. Only two larger echinoderm species were recorded (*Tripneustes gratilla*, *Toxopneustes pileolus*). Crinoids and *Diadema* were not present at this location. Algae like *Sargassum* and *Turbinaria* were common.

Discussion

The coastal marine habitats of Hainan Island and

especially its coral reefs are threatened by many different human impacts. The vast majority of Hainans populations of 6.7 million, i.e. 192 people km⁻² (Anon., 1989), is living in the coastal region and uses the food resources of the sea very intensively. Algae are harvested in the intertidal regions. Crustaceans, molluscs and sipunculans are collected on the tidal flats. The fishermen often return with a small catch consisting of a considerable number of small and juvenile fish, which may be considered a sign of overfishing. In bays and at the edge of fringing reefs fish are caught using dynamite. The explosives are thrown from small boats or by people wading in the water. In shallow water the dead fish are collected from the surface by hand. In deeper water two fishing vessels pull a bottom trawl over the site where the dynamite has been dropped. The charges are sometimes very powerful with fountains rising to several metres in height. Besides killing fish regardless of their subsequent use as food these explosions destroy the reef structure and thus the natural nursery habitat for young indigenous fish.

The high abundance of *Diadema*, found at Yalong Bay, is regarded as an indication of the disturbance of the balance of the ecosystem, possibly induced by overfishing. Sea urchins are considered the most important bioerosive factor on a reef (Scoffin *et al.*, 1980). The grazing echinoids also remove coral larvae thus preventing recolonization (Sammarco, 1980; Hay, 1984). In 1984, Hutchings & Wu (1987) counted relatively low numbers of *Diadema*. They related this to the fact that fishing had been restricted. Fishing is still restricted today but there is obviously no enforcement of this law. Even fishing with dynamite, which is strictly forbidden, is not prosecuted.

In all our diving locations underwater visibility was very low, only 2–3 m or even less. It remained unclear to us what caused the high sediment load of the water, since the sea was calm and there were no rivers entering Yalong Bay. Only in Xincun lagoon might the high turbidity have been explained by two rivers entering the lagoon and numerous ships in the fishing harbour.

Another threat for the coastal marine life comes from increasing tourism. Sanya has been chosen to become an important international holiday resort. Improvements to the infrastructure, such as roads and hotels, are under construction in the city and at the main nearby natural attractions like Tian Ya Hai Jiao ('The Lands End'). Hotels have already been built directly on the beach, for example in Dadonghai Bay east of Sanya. At Yalong Bay the construction of a hotel was stopped for an unknown reason after the frame had been erected. At natural attractions like Tian Ya Hai Jiao and on Ximaozhou Island ('West Coral Island') local people sell shells, corals, and other natural products as souvenirs to tourists.

At Xiaodonghai Bay, on Ximaozhou Island, and other places corals are mined for construction. For this purpose corals are broken up by explosions or by towing a hook behind a boat. The massive layer of broken coral at Xincun and Shalao is probably the result of these activities.

The largest and most diverse coral reefs of Hainan are situated in the southern part of the island near the city of Sanya, where water is generally clearer and warmer than in the north. The deterioration of the reefs reported by

Hutchings & Wu (1987) still continues. Dynamite fishing has become a major problem since their investigations and the reefs surveyed during our expeditions showed severe damage. Hutchings & Wu reported the reefs of Yalong Bay in a good state owing to fishing restrictions. It is still restricted today and the use of dynamite is forbidden, but there is no enforcement of these regulations. Conservation measures are urgently required, especially if Hainan is to preserve its natural beauty and attraction to international tourists.

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