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CORAL REEF FISH COMMUNITIES IN A SEDIMENT STRESSED ENVIRONMENT

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ABSTRACT

The coral reefs of Singapore continue to support a diverse community of fish, scleractinian corals, sponges and other invertebrates, inspite of nearly three decades of reclamation projects which have contributed to the degradation of the reefs. Sedimentation rates ranging from 5 - 45 mg cm^{-2} day^{-1} have resulted in poor coral growth at the lower reef slope, due to decreased light levels, and retardation of juvenile coral settlement. Extensive visual assessment of the coral reef fish community have indicated 198 species, 20% from the family Pomacentridae. Labrids formed the next most diverse and abundant family. Analysis of the data revealed no correlation between reef fish abundance and live coral cover percentage. There was a correlation between fish abundance and distance from the mainland.

INTRODUCTION

Rapid urbanisation of landscarce Singapore over the last 30 years has placed intense pressure on the marine and coastal environments. Reclamation of the mainland coastline has increased the land area by 10%, from 581 km^2 in 1966 to 641 km^2 (LAW *et al.*, 1993; LIM *et al.*, in press). Many of the offshore islands have also been reclaimed. The Pulau Ayer Chawan group of islands, Pulau Bukom and Pulau Sebarok (Fig. 1) have been extensively developed for the petroleum industry, while the islands of Sentosa, St. John's, Kusu, The Sisters' and Pulau Hantu have undergone reclamation for the development of recreational facilities. These reclamation projects have had an adverse effect on the coral reefs. CHOU (in press) showed that the reefs with reclaimed reef flats had lower coral cover at the crest and upper reef slope compared to reefs with intact reef flats.

Despite the stresses imposed on the marine environment by these development projects, the coral reef ecosystem in Singapore still exhibits a high diversity of organisms. Research conducted under the ASEAN-Australia Marine Science Project: Living Coastal Resources (LCR) and the ASEAN-US Coastal Resources Management Project, have recorded the occurrence of 197 species of scleractinian corals (CHOU, 1993). Fish diversity had been previously studied by TAY and KHOO (1984), LIM and CHOU (1991a, 1991b), LOW and CHOU (1992), CHOU (1990), CHUA and CHOU (1994). This paper presents an overall view of the reef fish population in Singapore's sediment-stressed waters.

METHODOLOGY

Much of the data on sedimentation rates and coral reef fish population was collected using the methods developed under the LCR project, initially described by DARTNALL and JONES (1986). An updated account of the methods can be found in ENGLISH *et al.* (1994)

Sedimentation rates were measured using traps constructed from polyvinylchloride (PVC) pipes. Three sediment traps (1 set) were attached to a stainless steel rod with electrical wire (Fig. 2). Four sets were secured to the reef substratum at each of the twelve reef sites monitored. Traps were collected monthly and replaced with new sets. The dry weight (in mg) of sediment

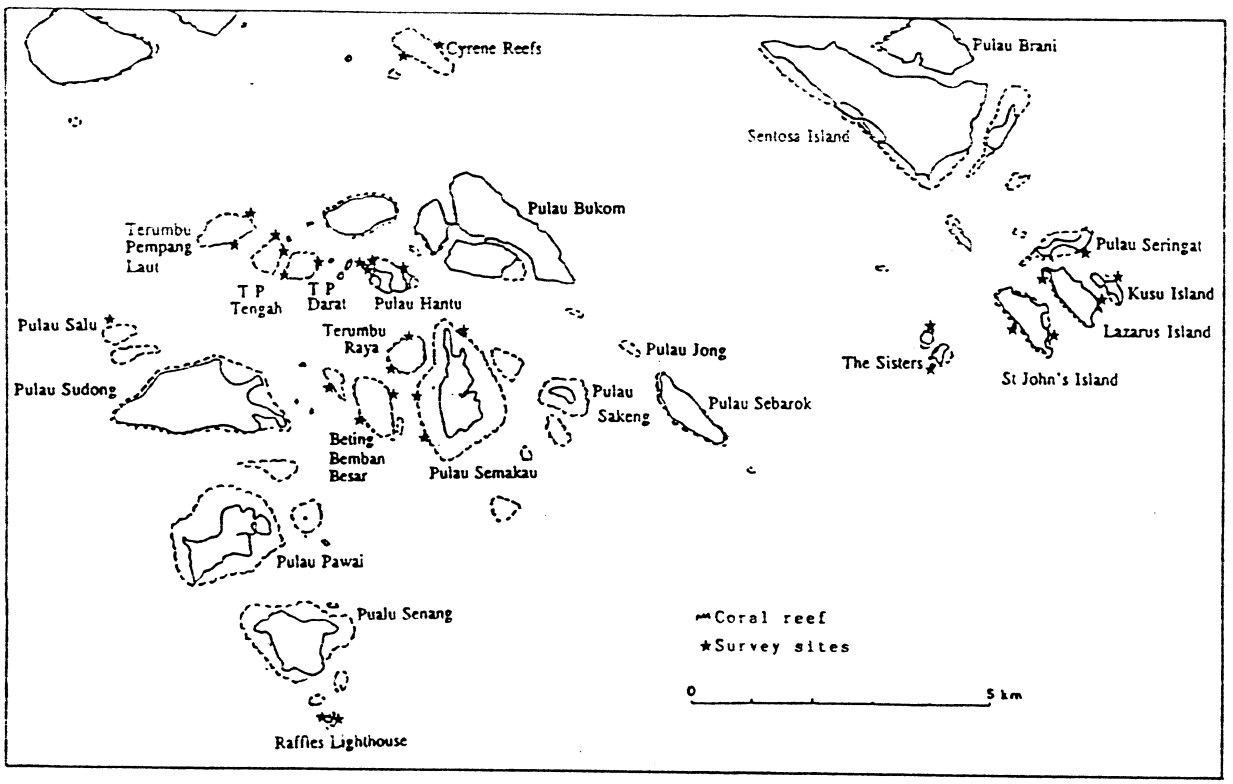

Fig. 1. Map of the southern islands of Singapore, showing fish visual census sites.

collected in each trap was determined, and the sedimentation rates (in mg $cm^{-2}day^{-1}$), calculated. Monitoring was conducted in 1989/90 and 1992/93.

Fish populations were surveyed along a 150 m transect tape by SCUBA divers, who recorded the number of fishes observed within 3 m to the left, right and above the tape, equivalent to a volume of 2700 m^3. The sites (as shown in Fig. 1) were surveyed along the 3 m and 10 m depths of the reef slope between 1987 and 1993. In addition, 12 sites at Cyrene Reefs, Pulau Hantu, Hantu West patch reef, Pulau Semakau, Lazarus Island and Raffles Lighthouse were monitored regularly between 1988 and 1993. The data was stored in dBase IV™ files (ENGLISH *et al.* 1994). In addition, data from TAY and KHOO (1984) was also included.

RESULTS AND DISCUSSION

The results of the sedimentation studies showed rates ranging from 5 to 45 mg cm^{-2} day^{-1} (LANE, 1991; LOW and CHOU, in press), an increase of 67 to 650 % from 1979, when CHAN (1980) recorded sedimentation rates to be between 3 to 6 mg cm^{-2} day^{-1}. Sedimentation is likely to remain the biggest threat to the coral reef community in Singapore, as several dumping projects of of dredged materials have been initiated at Pulau Semakau and at Kusu Island (J. NELSON, pers. comm.). Reclamation work to consolidate the Ayer Chawan group of islands into a large petrochemical complex has also begun (ANON., 1991). Plans for developing the St. John's/Kusu group of islands are also being studied (DHALIWAL, 1994).

The effects of sedimentation include decreasing the amount of light reaching the corals resulting in depressed growth and cover of hard corals at the lower reef slope (CHOU 1988). The energy for growth that would be derived from the activity of the coral zooxanthellae (a symbiotic alga embedded in the tissues of the coral) is reduced by the lowered light levels (ROGERS, 1979). Settlement of scleractinian coral juveniles on a substratum may also be inhibited, as coral juveniles may remain free-swimming to find more

suitable habitats, or once settled, may *bailout* (reverse metamorphosis) if sediment levels are too high (TE, 1992). Growth of settled colonies is also slowed (LANE, 1991), as energy has to be diverted to keep the colony sediment-free (DALLMEYER *et al.*, 1982 ABDEL-SALAM, 1988). Corals are also killed by direct smothering of colonies by sediment. The coral community structure reflect the sediment-stressed environment they occur in. Most of the species that occur in Singapore are tolerant of high sediment levels and possess the ability to shed sediment that settles on them (VERON, 1986). The most common growth forms encountered are foliose (to efficiently capture light for zooxanthallae activity) and massive (which are better able to dispose of settled sediment).

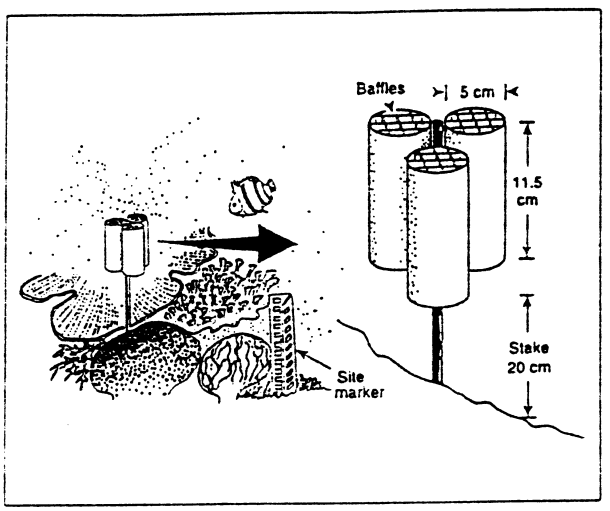

Fig. 2. Sediment traps used in the southern island of Singapore

Comprehensive surveys on the reef fish fauna of the southern islands have only been carried out in the last 10 years. To date, 198 reef fish species have been recorded (Table 1). This diversity was better than in the Gulf of Thailand, where only 90 species of reef fish were observed from 35 stations (SATUMANATPAN *et al.*, 1992). However, 135 species were recorded off just one reef in the Philippines (LUCHAVEZ and ALCALA, 1992), indicating a very high diversity of reef fish for the country as a whole. Compositionally, the fish populations in Singapore are quite similar to that of the other countries in the region, but some families were poorly represented. Only 5 species of butterfly fishes were observed in Singapore (Table 2), with *Chaetodon octofasciatus* and *Chelmon rostratus* being the most common. LUCHAVEZ and ALCALA (1992) reported a total of 18 species of chaetodontids from Campuyo reef in the Philippines, and ADRIM *et al.* (1991) reported 19 species from Indonesian waters. Thailand had the highest diversity with 20 species (SATUMANATPAN *et al.*, 1992). As many chaetodontids are exclusively coral feeders, they have been used as indicators of coral reef health (MANTHACHITRA *et al.* 1991) and their low diversity in Singapore may be an indication of the state of the reefs here.

The diversity of food fishes such as groupers (*Chepalapholis* spp. and *Plectropomus* spp.) and snappers (*Lutjanus* sp.) was also comparable, but intensive and selective fishing of these fishes has probably had a devastating impact on the populations of these two families in both Singapore and in the neighbouring countries. However, 14 species of snappers were reported by ADRIM (1992), from Indonesia. The pomacentrids formed the most diverse and abundant family on Singapore reefs, comprising 38 species. This is relatively low, despite Singapore's position in the center of pomacentrid diversity: 268 species are thought to occur in the Indo-West Pacific (ALLEN, 1991). The most common species occurring in Singapore are *Neopomacentrus azysron*, *Neopomacentrus filamentosus* and *Pomacentrus cuneatus*. Labrids are the next most diverse family, with 28 species, mostly from the genus *Halichoeres*. Other species that were prominent on Singapore reefs included *Caesio teres* (Caesionidae), *Selaroides leptolepis* (Carangidae), *Diploprion bifasciatus* (Grammistidae) and *Chaetodontoplus mesoleucus* (Pomacanthidae). Various species from the family Nemipteridae were also frequently sighted, especially *Scolopsis ciliaris* and *Pentopodius setosus*.

The highest abundance of fish was observed at the upper reef slopes (Fig. 3). This could be attributed to sedimentation: the high sediment loads resulted in only a narrow belt of healthy coral growth along the upper slope and at the crest, resulting in the diversity and abundance of fish in this area. Analysis of data revealed

no correlation between reef fish abundance and live coral cover percentage. This is in contrast to other studies, where positive correlations were shown to exist between coral cover and fish abundance. There was, however, a correlation between fish abundance and distance from the mainland (LOW and CHOU, 1992). This may be related to sedimentation, which also showed a decrease moving away from the mainland (LOW and CHOU, in press). However, other factors such as proximity to the open ocean, the lack of topographical features on the reefs, wave action and the influence of divers and fishermen, must not be discounted.

Table 1. Coral reef fish species observed at the southern islands of Singapore. Data compiled from TAY and KHOO (1984), CHOU (1990), LIM & CHOU (1991a 1991b), LOW & CHOE (1992), CHUA & CHOU (1994)

Family	Species
Acanthuridae	*Acanthurus* sp.
Apogonidae	*Apogon bandanensis* *Apogon chrysotaenia* *Apogon compressus* *Apogon cyanosoma* *Apogon doederleini* *Apogon fucata* *Apogon seali (niger?)* *Apogon trimaculatus* *Cheilodipterus macrodon* *Cheilodipterus quinquelineatus* *Sphaeramia nematoptera*
Atherinidae	*Atherina* sp.
Balistidae	*Abalistes stellatus*
Batrachoidae	*Halophryne diemensis* *Halophryne trispinosus*
Blenniidae	*Entomacrodus stellifer lighti* *Meiacanthus grammistes* *Omobranchus* sp. *Petroscirtes temmincki* *Pseudochromidae ransonneti* Blenny sp. 1 (brown)
Brotulidae	*Dinematichthys iluocoeteoides*
Caesionidae	*Caesio caerulaureus* *Caesio erythrogaster* *Caesio teres*
Carangidae	*Alectis* cf. *ciliaris* *Carangoides ferdau* *Caranx* sp. 1 *Elegatis bipinnulata* *Scomberoides commersonianus* *Selaroides leptolepis*
Centriscidae	*Aeoliscus strigatus*
Centropomidae	*Psammoperca waigiensis*
Chaetodontidae	*Chaetodon octofasciatus* *Chelmon rostratus* *Coradion chrysozonus* *Heniochus acuminatus* *Parachaetodon ocellatus*
Congrogadidae	*Congrogadus subducens*
Dasyatididae	*Taeniura lymna*
Echeneidae	*Echeneis naucrates*
Ephippidae	*Platax batavianus* *Platax orbicularis* *Platax pinnatus* *Platax teira*
Gobiidae	*Acentrogobius* sp. *Amblygobius* sp. *Amblygobius sphynx* *Exyrias bellissimus* *Smilogobius singapurensis* *Valenciennea longipinnis*
Grammistidae	*Diploprion bifasciatus*
Pomadasyidae	*Plectorhynchus chaetodontoides* *Plectorhynchus lineatus* *Plectorhynchus pictus*
Hemirhamphidae	*Hemirhamphus far*
Syngnathidae	*Corythoichthys intestinalis* *Cosmocampus* sp.
Holocentridae	*Sargocentron rubrum* *Myripristis murdjan*

Labridae	*Bodianus mesothorax*
	Cheilinus diagrammus
	Cheilinus fasciatus
	Choerodon anchorago
	Choerodon schoenleinii
	Diproctocanthus xanthurus
	Duymaeria flagellifera
	Halichoeres bicolor
	Halichoeres chloropterus
	Halichoeres dussumieri
	Halichoeres hartzfeldii
	Halichoeres hoeveni
	Halichoeres margaritaceus
	Halichoeres melanochir
	Halichoeres melanurus
	Halichoeres melapterus
	Halichoeres nebulosus
	Halichoeres nigrescens
	Halichoeres poecilopterus
	Halichoeres scapularis
	Halichoeres vroliki
	Halichoeres zeylonicus
	Labroides dimidiatus
	Pteragogus flagellifer
	Stethojulis trilineata
	Stethojulis strigiventer
	Thalassoma lunare
Leiognathidae	*Leiognathus equulus*
	Leiognathus splendens
Lethrinidae	*Lethrinus lentjan*
	Lethrinus nebulosus
Lutjanidae	*Lutjanus argentimaculatus*
	Lutjanus carponotatus
	Lutjanus chrysotaenia
	Lutjanus decussatus
	Lutjanus johnii
	Lutjanus lutjanus
Monacanthidae	*Monacanthus chinensis*
	Monacanthus macrurus
	Monacanthus tormentosus.
Monodactylidae	*Monodactylus argenteus*
Mugilidae	*Mugil* sp.
Mugiloididae	*Parapercis clathrata*
	Parapercis xanthozona
Mullidae	*Upeneus tragula*
Muraenidae	*Gymnothorax* sp.
	Muraenichthys sp.
Nemipteridae	*Pentapodus bilineatus*
	Pentapodus nemurus
	Pentapodus paradiceus
	Pentapodus caninus
	Pentapodus setosus
	Pentapodus trilineatus
	Pentapodus trivittatus
	Scolopsis affinis
	Scolopsis bilineatus
	Scolopsis ciliatus
	Scolopsis dubiosus
	Scolopsis leucotaenia
	Scolopsis margaritifer
	Scolopsis monogramma
	Scolopsis phaeops
	Scolopsis trilineatus
	Scolopsis vosmeri
Ostraciidae	*Ostracion cubicus*
Pempheridae	*Pempheris* sp. 1
	Pempheris sp. 2
Pinguipidae	*Parapercis clathrata*
	Parapercis xanthozona
Platycephalidae	*Platycephalus nematophthalmus*
Plotosidae	*Paraplotosus albilabris*
Pomacanthidae	*Chaetodontoplus mesoleucus*
	Pomacanthus annularis
	Pomacanthus imperator
	Pomacanthus sexstriatus
Pomacentridae	*Abudefduf bengalensis*
	Abudefduf saxatilis
	Abudefduf septemfasciatus
	Abudefduf sexfasciatus
	Abudefduf notatus
	Abudefduf vaigiensis
	Amblyglyphidodon curacao
	Amblyglyphidodon leucogaster
	Amphiprion clarkii

	Amphiprion frenatus	Scaridae	*Scarus ghobban*
	Amphiprion melanopus		*Scarus (niger?)*
	Amphiprion ocellaris		
	Chromis cinerascens	Scorpaenidae	*Scorpaena picta*
	Chromis atripectoralis		*Scorpaenopsis cirrhosa*
	Chrysiptera sp.		*Synanceja horrida*
	Chrysiptera unimaculata		
	Dascyllus trimaculatus	Serranidae	*Cephalopholis argus*
	Dischistodus chrysopoecilus		*Cephalopholis boenack*
	Dischistodus fasciatus		*Cephalopholis miniatus*
	Dischistodus prosopotaenia		*Cromileptes altivelis*
	Eupomacentrus apicalis		*Epinephelus tauvina*
	Hemiglyphidodon plagiometopon		*Epinephelus malabaricus*
	Neoglyphydodon melas		*Plectropomus areolatus*
	Neoglyphidodon nigroris		*Plectropomus leopardus*
	Neoglyphidodon azysron		*Plectropomus maculatus*
	Neopomacentrus cyanomos		
	Neopomacentrus filamentosus	Siganidae	*Siganus canaliculatus*
	Pomacentrus alexanderae		*Siganus guttatus*
	Pomacentrus bankanensis		*Siganus javus*
	Pomacentrus brachialis		*Siganus virgatus*
	Pomacentrus cuneatus		
	Pomacentrus grammorhynchus	Sphyraenidae	*Sphyraena flavicauda*
	Pomacentrus littoralis		
	Pomacentrus moluccensis	Synodontidae	*Synodus* sp.
	Pomacentrus popei		
	Pomacentrus rhondonatus	Tetraodontidae	*Arothron hispidus*
	Pomacentrus tripuntatus		*Arothron mapa*
	Pomachromis richardsoni		*Arothron stellatus*
Pseudochromidae	*Pseudochromis ransonneti*	Trichonotidae	*Trichonotus setigerus*

Table 2. Diversity of snappers, groupers and chaetodontids in the ASEAN region. Data compiled from ADRIM *et al.* (1991), LUCHAVEZ and ALCALA (1992), SATUMANATPAN *et al.* (1992), ADRIM (1992).

	Singapore	Thailand	Indonesia	Philippines
Lutjanidae (snappers)	6	N.A.	14	4
Serranidae (groupers)	9	8	N.A	9
Chaetodontidae (butterflyfishes)	5	20	19	18

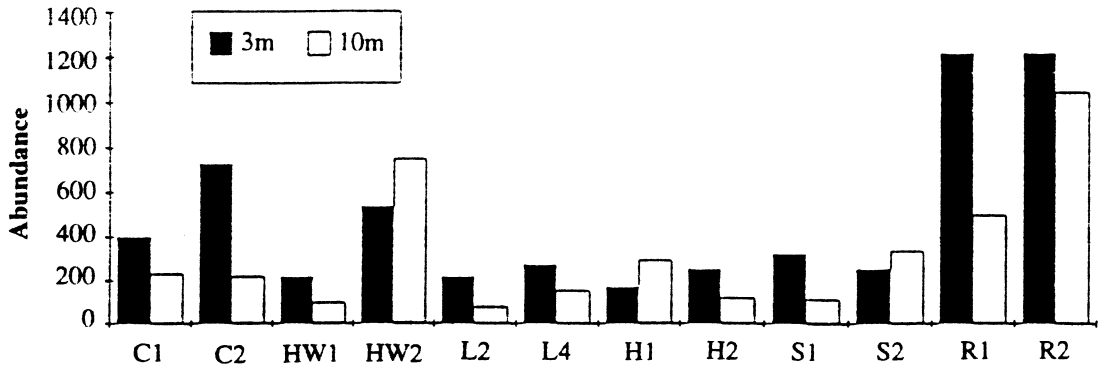

Fig. 3. Reef fish abundance at the 3 m and 10 m depths of the southern island of Singapore

The future of coral reefs in Singapore is uncertain. The demand for land for housing the growing population, for industrial development, and for recreational areas is increasing. Reclamation and development of the islands will continue well into the next century. However, the use of more responsible and "environmentally-friendly" reclamation and development techniques have been proposed. The development of the eastern half of Pulau Semakau into a dumping ground will begin with the construction of a multilayered rock bund surrounding the dumping site (NATHAN, 1993). The rock bund will prevent leaching of waste into the marine environment, and waste water will be treated to meet Singapore's discharge standards.

Public awareness of the status of the coral reefs is also increasing. This is due mainly to the efforts of several non-governmental organisations, such as the Nature Society of Singapore (NSS) and, in particular, the National Council on the Environment (NCE) and the Reef Survey and Conservation Project group (RSCP), comprising the Republic of Singapore Yacht Club, the Singapore Underwater Federation and the Singapore Institute of Biology. The creation of 4 managed areas at the southern islands was originally proposed by the RSCP group, and was later included in the Ministry of Environment's "Green Plan". The NCE and the RSCP group (with the sponsorship of Shell Petroleum) also recently set up mooring buoys at Pulau Hantu, a popular site for sport divers and leisure craft. This will help minimise anchour damage to the reefs there (ANON., 1994). In addition, several posters and a video have also been produced. The NSS has also initiated a "Reef Rescue" project. Phase I involved the translocation of coral colonies from Buran Darat (east of Sentosa) to a site south of Sentosa that had already been developed. A survival rate of 69% was reported, but the claim is based on biased sampling of a small, non-representative area. Phase II of the project involves the translocation of coral colonies from the soon to be reclaimed sites at the Pulau Ayer Chawan group of islands to a site at Sentosa (different from phase I). Careful monitoring of the transplanted colonies needs to be done to validate the reported high survival rates.

Singapore presents a unique case study in coastal area management. On one hand, the diversity of the coral reefs must be preserved. On the other, development is necessary to improve Singapore's economic status. The coral reefs are a natural heritage, and is a source of food, medicines and raw materials. Healthy reefs are also attractive to tourists. Singapore is also a signatory to the Convention on Biological Diversity. Thus, halting the destruction of the coral reefs through responsible management of the coastal and marine environments is of paramount importance

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