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Anomuran and brachyuran crab symbionts of Singapore hard corals of the families Acroporidae, Agariciidae and Pocilloporidae

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ABSTRACT: Anomuran and brachyuran crab symbionts from 51 colonies of corals belonging to the families Acroporidae, Agariciidae and Pocilloporidae were investigated. A total of seven species of anomurans and 27 species of brachyurans were collected, of which the majority were corallophilous symbionts. Comparisons with studies made at four oceanic reefs revealed a paucity of brachyuran corallicolous symbionts, with only four species of Anomura and four species of Brachyura observed in Singapore. However, there was a high abundance of corallophilous and casual symbionts in Singapore.

1 INTRODUCTION

The brachyuran and anomuran symbionts of hermatypic scleractinian corals around the world have been well documented (e.g. Garth 1964, 1973, 1984; Patton 1966, 1974, 1976; Castro 1976, 1978; Peyrot-Clausade 1977, 1979, 1983; von Prahl *et al.* 1978; Odinetz 1983; Grajal & Laughlin 1984; Nakasone *et al.* 1986; Chang *et al.* 1987; etc.). Most of these studies however, have been conducted in America, Australia, Seychelles and Pacific Islands, and much less is known for Singapore and other parts of Southeast Asia.

With regards to the Singapore fauna, Johnson (1962) was the first to document the obligate symbiont Crustacea from this area. He recorded a total of six anomurans (*Galathea elegans*, *G. spinosorostris*, *G.* n. sp., *Petrolisthes* cf. *militaris*, *P. lamarcki*, *Pachycheles sculptum*) and six brachyurans (*Hapalocarcinus marsupialis*, *Cymo andreossyi*, *C. melanodactylus*, *Tetralia glaberrima*, '*Domoecia hispida*', and '*Trapezius* sp.' (= *Trapezia*, spelling erroneous)) associated with hard corals. Serène (1966) subsequently added another obligate hapalocarcinid crab (*Neotroglocarcinus monodi*) to this obligate symbiont brachyuran fauna. No related studies have been conducted since, and except for some broader taxonomic studies conducted by Lanchester (1900, 1901), Nobili (1903), Johnson (1958, 1961, 1970), Ng & Tan (1984, 1988) and Ng (1987) which dealt with the obligate and non obligate anomuran and brachyuran fauna

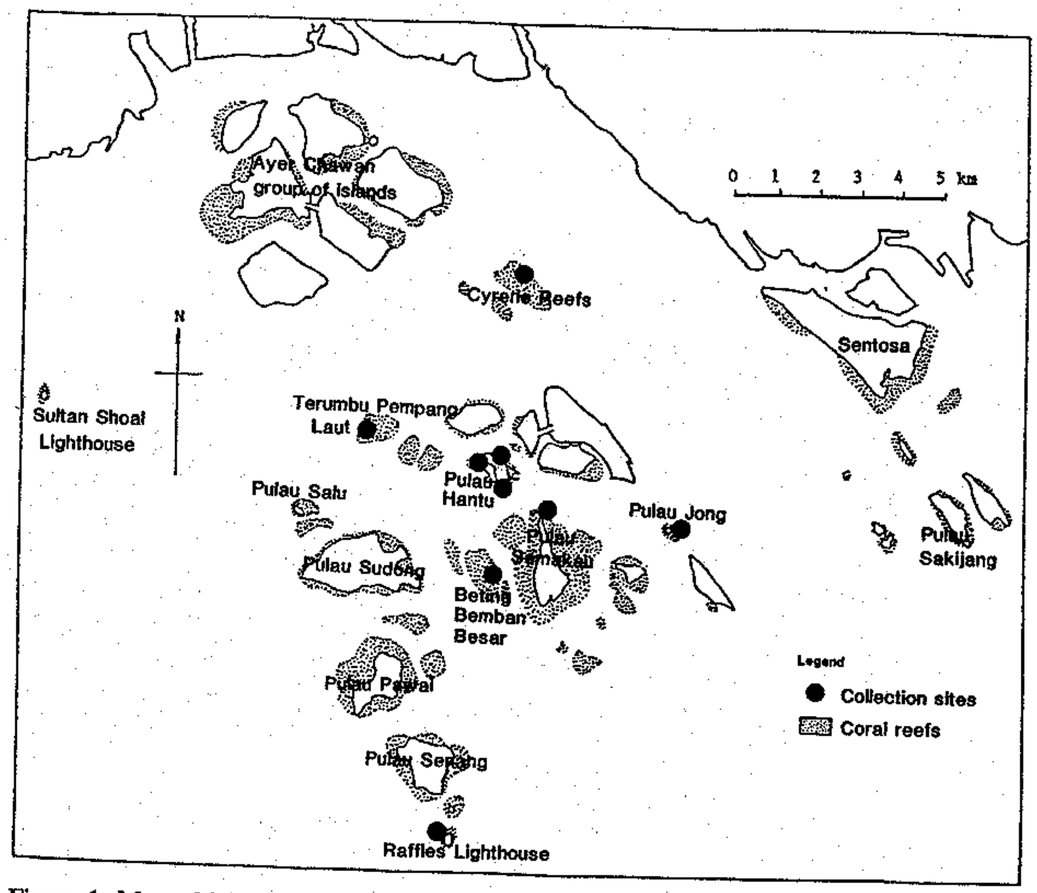

Figure 1. Map of islands and reefs located south and southwest of Singapore with the nine collection sites.

of Singapore, almost nothing else is known about this important component of the coral ecosystem.

The present study is intended to fill this gap. This paper documents the anomuran and brachyuran crab symbionts found on three families of hard corals, Acroporidae, Agariciidae and Pocilloporidae, from Singapore reefs. A comparison of these symbionts is also made with those observed in other reefs of the Indo-West Pacific region.

For convenience, the anomuran and brachyuran fauna would be referred to as crab symbionts. The thalassinid and pagurid components of the Anomura have been excluded. All specimens are deposited in the Zoological Reference Collection (ZRC), Department of Zoology, National University of Singapore.

2 MATERIALS AND METHOD

Whole colonies of corals were sampled randomly from the reefs of selected islands south of Singapore, using SCUBA. The colonies sampled were branching corals of the families Pocilloporidae and Acroporidae, and also several species belonging to the genus *Pavona* (family Agariciidae). The method of collection was modified from Abele & Patton (1976). Following the suggestion by Garth (1984), each colony was completely wrapped in a tagged polythene bag before being removed from its substrate with a hammer and chisel. As far as possible, only the living portions of the corals were collected. The bags were then tightly sealed to prevent any free-living organisms within the colony from escaping, and transported with aeration to the laboratory.

All sponges and tunicates were first removed from the corals in the laboratory before sampling because they have been known to house symbionts (Johnson 1962, 1970), after which each colony was broken up separately using a hammer and chisel. Crab symbionts were carefully separated according to their host-corals to avoid ambiguities. Fragments of the corals from which the symbionts were obtained were also preserved for later identification.

Collections were made from seven reefs south of Singapore between August and October, 1986 (Fig. 1). These were:

1. North, south and west of the fringing reefs of Pulau Hantu (ca. 1°13'36"N, 103°45'30"E).
2. Northeast of Cyrene, a patch reef (ca. 1°15'24"N, 103°44'36"E).
3. Northern tip of the fringing reef of Pulau Semakau (ca. 1°13'N, 103°45'36"E).
4. East of the fringing reef of Pulau Jong (ca. 1°12'48"N, 103°47'18"E).
5. Eastern edge of Beting Bemban Besar, a patch reef (ca. 1°12'30"N, 103°45'E).
6. Northwest of the fringing reef at Raffles Lighthouse (ca. 1°9'36"N, 103°44'30"E).
7. Western edge of Terumbu Pempang Laut, a patch reef (ca. 1°14'N, 103°43'18"E).

3 RESULTS

A total of 51 coral heads were sampled, viz., 25 Acroporidae, 12 Agariciidae and 14 Pocilloporidae. Nineteen species were recognized and are listed below. Numbers in brackets indicate the number of heads obtained of each species.

Acroporidae
Acropora aculeus (Dana, 1846) (4)
Acropora cytherea (Dana, 1846) (1)
Acropora dendrum (Bassett-Smith, 1890) (2)
Acropora donei Veron & Wallace, 1984 (3)
Acropora hyacinthus (Dana, 1846) (2)
Acropora latistella (Brook, 1892) (1)
Acropora nasuta (Dana, 1846) (2)
Acropora secale (Studer, 1878) (3)
Acropora selago (Studer, 1878) (1)
Acropora subulata (Dana, 1846) (1)
Acropora tenuis (Dana, 1846) (1)
Acropora valida (Dana, 1846) (1)
Acropora willisae Veron & Wallace, 1984 (2)
Montipora digitata (Dana, 1846) (1)

Agariciidae
Pavona cactus (Förskal, 1775) (1)
Pavona decussata (Dana, 1846) (4)
Pavona frondifera Lamarck, 1816 (7)

Pocilloporidae
Pocillopora damicornis (Linnaeus, 1758) (11)
Pocillopora verrucosa (Ellis & Solander, 1786) (3)

The specimens of anomuran and brachyuran crabs collected during this study belong to the families Galatheidae, Porcellanidae, Majidae, Leucosiidae, Xanthidae, Trapeziidae, Pilumnidae and Portunidae. The classification of brachyurans follows Guinot (1978). The Xanthidae, Pilumnidae and Trapeziidae were originally recognized as subfamilies in one family, the Xanthidae s. lato, but under the present classification, they are distinct families in the superfamily Xanthoidea. The Xanthidae of earlier authors is thus equivalent to the present Xanthoidea. A complete list of symbiotic species obtained, and the number of individuals collected is given in a series of tables each representing a single collection site (Table 1 - Table 7).

Three categories of symbionts were recognized based on the nature of the relationship between the symbionts and their respective host corals. This was in accordance with the criteria put forth by Garth (1973, 1984) in distinguishing obligate from facultative symbionts.

The first category contains the corallicolous (= obligate of other authors) symbionts including species which live exclusively on live coral, and are often also specific to particular families or genera of corals. This is because the living coral environment is necessary to the symbiont, often occuring in mated pairs, for reproduction (Garth 1973).

Table 1. Species of symbiotic anomuran and brachyuran crabs collected from corals at Pulau Hantu (12 and 19 August; 19 September 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae								Agariciidae		Pocilloporidae
	CORAL *Acropora aculeus*	*A. aculeus*	*A. aculeus*	*A. hyacinthus*	*A. tenuis*	*A. subulata*	*A. valida*	*Montipora* sp.	*Pavona decussata*	*P. frondifera*	*Pocillopora damicornis*
Galathea spinosorostris					1			1		2	4
Pachycheles sculptus					1						
Porcellana (*Enosteoides*) *corallicola*	7				6			1	1		1
Porcellana (*Pisidia*) *latifrons*	8				19				2	1	44
Pilumnus barbatus								3			
Pilumnus spinifrons										1	
Thalamita sp.	1										
Tetralia nigrolineata			2	1	2	1	1				
Trapezia cymodoce								1			
Actaeodes mutatus	2							1			1
Liomera (*Liomera*) *margaritata*										1	
Medaeops granulosus	1										
Pilodius sp.								1			

Within the second category are the corallophilous symbionts, found on living corals in this study, but are also known to live in other habitats, such as dead coral, sponges or coral rubble. They are able to survive just as well in any of the habitats but seem to prefer the coral environment, although they are not as dependent on the live corals as the corallicolous symbionts.

The third category are the casual associates. Their habitats are not usually corals, but may have strayed into the colony by chance (see Castro, 1986, for an overview of symbiosis in coral reef communities). Most of the collections from other Indo-West Pacific reefs do not make a distinction between casual associates and corallophilous symbionts, but place them under a general facultative symbiont group.

Table 2. Species of symbiotic anomuran and brachyuran crabs collected from corals at Cyrene (15 August 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae	Agariciidae	
	CORAL *Acropora hyacinthus*	*Pavona decussata*	*P. decussata*
Galathea spinosorostris			2
Pachycheles sculptus			10
*Polyonyx biunguiculatus**			2
Porcellana (Enosteoides) corallicola		1	18
Porcellana (Pisidia) latifrons		20	4
Nucia sp.			1
Hyastenus subinermis			2
Pilumnus barbatus			5
Pilumnus labryrinthicus			2
Pilumnus spinifrons		2	1
Tetralia nigrolineata	2		
Actaeodes mutatus			1

*Found within sponges growing on the corals

All the symbionts found and the categories under which they are placed are listed in Table 8. In addition, a master list of all the corallicolous symbionts collected from host corals at all collection sites was also drawn up after the exclusion of the corallophilous symbionts and casual associates (Table 9).

The corallicolous acroporid symbiont community

Sixteen species of symbionts were collected from 25 acroporid heads (Table 8). The brachyuran *Tetralia nigrolineata* consistently occurred within the Acroporidae (Table 9). Most of the *Acropora* colonies collected housed at least one specimen of this crab which has been observed to feed on coral mucus and trapped particulate material.

There was one unexpected occurrence of *Trapezia cymodoce* in *Montipora*

Table 3. Species of symbiotic anomuran and brachyuran crabs collected from corals at Pulau Semakau (22 August 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae	Agariciidae	
	CORAL *Acropora aculeus*	*Pavona cactus*	*P. frondifera*
Galathea spinosorostris		1	4
Porcellana (Enosteoides) corallicola			5
Porcellana (Pisidia) latifrons		7	9
Pilumnus barbatus		1	2
Pilumnus spinifrons		1	
Planopilumnus orientalis		1	
Actaeodes mutatus	1	1	1
Gaillardiellus rueppelli		1	
Liomera (Liomera) pallida	1		
Pilodius nigrocrinitus			

sp. (an acroporid). This brachyuran is a known corallicolous symbiont of pocilloporid corals (see Garth 1964, 1984; Knudsen 1967; Castro 1976; Chang *et al.* 1987).

Other corallicolous symbionts observed on the Acroporidae were the anomurans *Galathea spinosorostris, Pachycheles sculptus* and *Porcellana* (*Enosteoides*) *corallicola*, and brachyurans *Cymo andreossyi* and *C. melanodactylus* (Table 9).

The corallicolous agariciid symbiont community

Twenty-one species of symbionts, the majority of which were corallophilous in nature, were obtained from 12 *Pavona* colonies (Table 8). The corallicolous symbionts found living within the agariciids were: *Galathea spinosorostris, Pachycheles sculptus, Petrolisthes* cf. *militaris* and *Porcellana* (*Enosteoides*) *corallicola*, all of them non-family specific (Table 9).

The corallicolous pocilloporid symbiont community

Eighteen species of symbionts were collected from 14 pocilloporid heads (Table

Table 4. Species of symbiotic anomuran and brachyuran crabs collected from corals at Pulau Jong (26 August; 24 October 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae			Agariciidae		Pocilloporidae		
CORAL	*Acropora nasuta*	*A. nasuta*	*A. willisae*	*Pavona frondifera*	*P. frondifera*	*Pocillopora damicornis*	*P. damicornis*	*P. damicornis*
Galathea spinosorostris				1			1	
Pachycheles sculptus							3	
Petrolisthes cf. *militaris*				1				
Porcellana (Enosteoides) corallicola				12			12	
Porcellana (Pisidia) latifrons				8			13	
Actumnus elegans							1	
Pilumnus barbatus				1				
Pilumnus edamensis				1				
Pilumnus spinifrons				1	3			
Tetralia nigrolineata	2	2	1					
Trapezia cymodoce						1	1	1
Actaeodes mutatus							2	
Novactaea pulchella				1				
Pilodius nigrocrinitus					1		1	
Pilodius sp.							1	

8), of which 11 were *Pocillopora damicornis* and three were *P. verrucosa*. The corallicolous crab *Trapezia cymodoce* appeared only in four of the 14 coral heads collected.

In addition, the anomurans *Galathea spinosorostris, Pachycheles sculptus, Petrolisthes* cf. *militaris, Porcellana* (*Enosteoides*) *corallicola,* and xanthid *Cymo andreossyi* were also observed (Table 9).

Summary of the corallicolous symbionts

Based on observations in this study as well as previously published data (e.g. Johnson 1958, 1962, 1970; Garth 1964, 1973, 1984; Odinetz 1983, 1984; etc), the corallicolous symbionts identified could be categorized into family specific and non-family specific symbionts.

Table 5. Species of symbiotic anomuran and brachyuran crabs collected from corals at Beting Bemban Besar (29 August 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae		Agariciidae
CORAL	*Acropora donei*	*A. latistella*	*Pavona frondifera*
Pachycheles sculptus			1
Porcellana (Pisidia) latifrons		2	
Pilumnus spinifrons			1
Tetralia nigrolineata	1	1	
Chlorodiella nigra		2	
Cymo andreossyi		1	
Gaillardiellus rueppelli	1		

The following have been defined as family specific: *Tetralia nigrolineata* and *Cymo melanodactylus* on the family Acroporidae; *Trapezia cymodoce* on the family Pocilloporidae.

Non-family specific corallicolous symbionts invariably found on live corals that were collected in this study are: *Cymo andreossyi*, the brachyuran from both pocilloporid and acroporid corals and the anomurans: *Galathea spinosorostris, Pachycheles sculptus, Petrolisthes* cf. *militaris* and *Porcellana* (*Enosteoides*) *corallicola.*

4 DISCUSSION

This paper presents an extensive study of the anomuran and brachyuran symbionts living within branching corals of the families Acroporidae and Pocilloporidae, and in leaf-like corals Agariciidae of reefs south of Singapore. Twenty species out of the total of 34 symbiont species collected were corallophiles whilst the corallicolous symbionts and casual associates totalled eight species and six species respectively (Table 8).

Although three categories were established for the symbionts encountered,

Table 6. Species of symbiotic anomuran and brachyuran crabs collected from corals at Raffles Lighthouse (2 September; 16 October 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae					Agari-ciidae	Pocilloporidae						
	CORAL	*Acropora secale*	*A. secale*	*A. donei*	*A. willisae*	*Pavona decussata*	*P. frondifera*	*Pocillopora damicornis*	*P. damicornis*	*P. damicornis*	*P. damicornis*	*P. verrucosa*	*P. verrucosa*	*P. verrucosa*
Galathea spinosorostris					1	3	4			5			2
Pachycheles sculptus						1	4		1				2
Petrolisthes lamarckii											1		4
Petrolisthes cf. *militaris*								2	2				15
Porcellana (Enosteoides) corallicola						5	5	2	4	1	7		16
Porcellana (Pisidia) latifrons						2		19	2	4	19	4	1 25
Cryptonemus sp.							1						
Achaeus lacertosus													1
Hyastenus subinermis												1	
Tylocarcinus styx									1				
Actumnus elegans						4	5		1	2	3	1	3 5
Pilumnus edamensis							1						
Pilumnus spinifrons						2					4		
Tetralia nigrolineata	1	1	1	1	2								
Trapezia cymodoce								1					
Actaeodes mutatus						2	2				1		1
Chlorodiella nigra											2		
Cymo andreossyi									1	1		2	
Cymo melanodactylus	2			1									
Liomera (Liomera) venosa							1						
Pilodius nigrocrinitus													1

the boundaries of each of the categories are by no means always distinct since some symbionts cannot confidently be classified into either of the groups due to a dearth of knowledge of their habits. This is in addition to the unstable systematics of some of the symbiont groups (e.g. the Pilumnidae, *fide* Ng & Tan 1984; Ng 1987). In short, much more work has to be done on these groups before they can be correctly categorized.

Table 7. Species of symbiotic anomuran and brachyuran crabs collected from corals at Terumbu Pempang Laut (9 September; 16 October 1986). Numbers indicate the number of individuals recovered from each coral head.

Symbionts	Acroporidae					Agari-ciidae	Pocillo-poridae		
	CORAL	*Acropora cytherea*	*A. donei*	*A. selago*	*A. dendrum*	*A. dendrum*	*Pavona frondifera*	*Pocillopora damicornis*	*P. damicornis*	*P. damicornis*
Galathea spinosorostris								5	6	1
Pachycheles sculptus										4
Petrolisthes lamarkii										2
Petrolisthes cf.*militaris*										1
Porcellana (Enosteoides) corallicola								8	8	
Porcellana (Pisidia) latifrons							2	18	9	35
Actumnus elegans								1		12
*Actumnus elegans**										1
Actumnus sp.										1
Hyastenus ? hilgendorfi									1	
Pilumnus spinifrons							1			4
Tetralia nigrolineata	1	2	1	2	2					
Actaeodes mutatus								1		
Cymo andreossyi										5
Liomera (Liomera) venosa										1

*Found within sponge at coral base.

In the present study, the xanthid *Cymo andreossyi* was found in both acroporid and pocilloporid corals. It has also been reported to be found living in the oculinid, *Galaxea fasicularis* (see Garth 1984) as well as dead and overgrown coral (Garth 1964). The latter records are not likely to be representative of their habitats, and *Cymo andreossyi* is probably a corallicolous coral symbionts (see Patton 1966, Garth 1984), and is here regarded as such.

Tetralia nigrolineata was found on all *Acropora* colonies collected, except in three colonies of *A. aculeus*. The consistency of *Tetralia nigrolineata's* occurrence on the Acroporidae and its absence in the other coral families collected in this study leaves little doubt as to its host specificity at the family level (see Castro 1976).

Table 8. Species list of symbionts found on the three families of corals studied.

Symbionts	Acroporidae	Agariciidae	Pocilloporidae
Corallicolous Symbionts			
Anomura			
Family : Galatheidae			
Galathea spinosorostris Dana, 1852	*	*	*
Family : Porcellanidae			
Pachycheles sculptus (H. Milne Edwards, 1837)	*	*	*
Petrolisthes cf. *militaris* (Heller, 1862) *sensu* Johnson, 1970		*	*
Porcellana (Enosteoides) corallicola Haswell, 1881	*	*	*
Brachyura			
Family : Trapeziidae			
Tetralia nigrolineata Serène & Dat, 1957	*		
Trapezia cymodoce (Herbst, 1799)	*		*
Family : Xanthidae			
Cymo andreossyi (Audouin, 1826)	*		*
Cymo melanodactylus De Haan, 1833	*		
Corallophilous Symbionts			
Anomura			
Family : Porcellanidae			
Petrolisthes lamarckii (Leach, 1815) *sensu* Johnson, 1970			*
Porcellana (Pisidia) latifrons Stimpson, 1858	*	*	*
Brachyura			
Family : Majidae			
Achaeus lacertosus Stimpson, 1857			*
Hyastenus subinermnis (Zehntner, 1894)		*	*
Tylocarcinus styx (Herbst, 1803)			*
Family : Pilumnidae			
Actumnus elegans De Man, 1887		*	*
Pilumnus barbatus A. Milne Edwards, 1873	*	*	
Pilumnus edamensis (De Man, 1887)		*	
Pilumnus spinifrons Ng & Tan, 1984		*	*
Family : Portunidae			
Thalamita sp.	*		
Family : Xanthidae			
Actaeodes mutatus Guinot, 1976	*	*	*
Chlorodiella nigra (Förskal, 1775)	*		*
Gaillardiellus rueppelli (Krauss, 1843)	*	*	
Liomera (Liomera) margaritata (A. Milne Edwards, 1873)		*	
Liomera (Liomera) pallida (Borradaile, 1900)	*		
Liomera (Liomera) venosa (H. Milne Edwards, 1834)		*	*
Medaeops granulosus (Haswell, 1882)	*		
Novactaea pulchella (A. Milne Edwards, 1873)		*	
Pilodius nigrocrinitus Stimpson, 1858		*	*
Pilodius sp.	*		

Table 8 *(continued)*.

Symbionts	Acroporidae	Agariciidae	Pocilloporidae
Casual Associates			
Anomura			
Family : Porcellanidae			
Polyonyx biunguicaulatus Dana, 1852		*	
Brachyura			
Family : Leucosiidae			
? *Cryptonemus* sp.		*	
? *Nucia* sp.		*	
Family : Majidae			
Hyastenus ? *hilgendorfi* De Man, 1888			*
Family : Pilumnidae			
Pilumnus labyrinthicus Miers, 1884		*	
Planopilumnus orientalis Balss, 1933		*	

* presence of symbiont

Table 9. Master list of all corallicolous symbionts collected at the sites: Pulau Hantu, Cyrene, Pulau Semakau, Pualau Jong, Beting Bemban Besar, Raffles Lighthouse, Terumbu Pempang Laut (12 August - 16 October). Numbers indicate the total number of individuals of symbiont species recorded from each coral species. Numbers in brackets indicate the total number of coral heads sampled for each coral species.

Symbionts	Acroporidae															Agariciidae			Pocilloporidae	
CORAL	*Acropora aculues* (4)	*A. cytherea* (1)	*A. dendrum* (2)	*A. donei* (3)	*A. hyacinthus* (2)	*A. latistella* (1)	*A. nasuta* (2)	*A. secale* (3)	*A. selago* (1)	*A. subulata* (1)	*A. tenuis* (1)	*A. valida* (1)	*A. willisae* (2)	*Montipora* sp. (1)	*Pavona cactus* (1)	*P. decussata* (4)	*P. frondifera* (7)	*Pocillopora damicornis* (11)	*P. verrucosa* (3)
Galathea spinosorostris											1		1	1	1	5	11	22	2
Pachycheles sculptus											1					11	5	8	2
Petrolisthes cf. *militaris*																	1	5	15
Porcellana (Enosteoides) corallicola	7										6			1		25	22	43	16
Tetralia nigrolineata	2	1	4	4	3	1	4	3	1	1	2	1	3						
Trapezia cymodoce														1				4	
Cymo andreossyi						1												7	2
Cymo melanodactylus				1				2											

Many symbionts termed 'casual associates' are likely to be sponge dwellers. Sponges are invariably linked to corals, often being found between branches or at the coral bases, especially those of the genus, *Pavona*. *Pilumnus labyrinthicus* is such an example. This crab was reported by Johnson (1962) to be a commensal of sponges and has been substantiated by other collections (Ng, unpublished data). The five specimens presently collected from the agariciid *Pavona decussata* were probably from sponges found at the base of the coral colony. These symbionts could have emerged from the sponges present on the coral onto the coral branches in transit, before the sponges were removed in the laboratory.

Crabs symbiotic to coral have been well studied in several other localities. Four studies in particular, are detailed enough to be compared with our study. These are: Garth (1964) (Eniwetok Atoll and Marshall Islands); Patton (1966, 1974) (Heron Island and Queensland, Australia); Garth (1973) (Ceylon, Sri Lanka and the Maldive Islands) and Garth (1984) (Seychelles and Amirante Islands). It is unfortunate that all these reports do not discuss the anomurans in any detail. Some excluded them altogether. Thus, a complete analysis of all decapod crustaceans cannot be carried out.

Garth's (1984) study of the coral reef of the Seychelles and Amirante Islands dealt only with brachyuran community. Amongst the corallicolous commensals present, he obtained seven species of the genus *Trapezia*, three of *Tetralia*, four of *Cymo*, and two of *Domecia*. Compared with his collection, the present study seems to be poor in corallicolous brachyuran taxa. Only *Cymo andreossyi, C. melanodactylus, Tetralia nigrolineata* and *Trapezia cymodoce* were collected in this study. *Trapezia septata* (Dana 1852), has been collected in littoral areas from Sentosa island, just off Singapore (Ng, unpublished data), but none were obtained in the course of this study. The species common to both regions are *Trapezia cymodoce, Cymo andreossyi* and *C. melanodactylus*.

In Ceylon and the Maldive Islands, decapod crustacea of the coral genera *Pocillopora* and *Acropora* were studied by Garth (1973). Again, the number of Singapore corallicolous symbiont taxa compares very poorly with that from the Maldives. The brachyuran fauna of the Maldives is richer in species, the Singaporean fauna being only 25% that of the Maldives. Only *Cymo melanodactylus* and *Trapezia cymodoce* are common to both areas.

The study made by Patton (1974) in Heron Island concentrated on the symbionts inhabiting *Pocillopora damicornis* heads. Previously, a study was carried out on six reefs in Queensland (Patton 1966), during which both coral families Pocilloporidae and Acroporidae were sampled. The Singaporean xanthoid corallicolous fauna is again poorer in comparison.

In Garth's (1964) collection carried out in Eniwetok Atoll, various crustacean decapods were studied, with emphasis on the brachyura. As in other regions, the number of corallicolous xanthoid species was greater than Singapore. Only *Cymo andreossyi, C. melanodactylus* and *Trapezia cymodoce* are common to both regions.

Most recently, Chang *et al.* (1987) studied the xanthoid symbionts of two species of *Pocillopora* from Taiwan. This study only examined the crabs of the families Pilumnidae, Xanthidae *sensu stricto*, and Trapeziidae, and excluded other taxa. Moreover, a great many of the taxa in the above mentioned families could not be identified and a direct comparison with the results of the present study is not possible. Nine species of *Trapezia*, however, were identified, similar to the findings of previous studies done in the Seychelles, Eniwetok, Ceylon (Sri Lanka), Maldives and Australia.

In a Ph.D. Thesis, Odinetz (1983) also conducted a detailed study of the symbionts found on 11 species of *Pocillopora* from French Polynesia and Guam. Since many of the ecological findings in this important work remain unpublished, its content has not been included in our comparisons. With regards to her general conclusions concerning habitat specificity, pairing ratios, etc., most aspects agree with results obtained by other workers from the Pacific and Indo-Pacific islands. Interestingly, Odinetz (1983, 1984) documented that non-corallicolous coral associates were dominant on fringing reef *Pocillopora* where organic matter is believed to be more abundant, while *Pocillopora* in barrier and outer reef slopes had more obligate symbionts.

In these comparisons, it is important to note the paucity of brachyuran corallicolous symbionts found in Singapore. Only one species of the genus *Tetralia* and two of *Trapezia* were collected whereas the other regions had at least two of *Tetralia* (Eniwetok and Maldives) and four of *Trapezia* (Heron Island, Australia). In addition to this, the genus *Domecia*, a corallicolous symbiont of the Acroporidae, and the gall crabs of the family Cryptochiridae (= Hapalocarcinidae, *fide* Kropp & Manning 1985), were not collected in this study. *Domecia* is unlikely to be found here and the ZRC has no local records of this genus. Johnson (1962) recorded "*Domoecia hispida*" (spelling erroneous) from hard corals in Singapore, but his specimen could not be located. Considering that no other records were made (the authors have yet to encounter this taxon in Malaysian or Singapore waters), and the ZRC has no specimens from these areas, the presence of *Domecia* in Singapore must be held suspect. As to the Cryptochiridae, Johnson (1962) recorded *Hapalocarcinus marsupialis* Stimpson, 1859, from Singapore corals, but it has not been encountered since. Serène (1966) recorded *Neotroglocarcinus monodi* (Fize & Serène, 1955)from the ahermatypic dendrophylliid coral genus *Turbinaria*, whilst Chuang (1961) merely mentioned that *Cryptochirus* was found in Singapore. We have examined a poorly preserved male specimen labelled *Cryptochirus* sp. collected by D.S. Johnson in 1952 from Pulau Pawai in southern Singapore. The specimen is almost certainly *C. coralliodytes* Heller, 1861 (see Takeda & Tamura 1980d). The label did not indicate the coral host, but the species is known to inhabit many genera of the Faviidae and Merulinidae (Takeda & Tamura 1980d). No other records are known. In the study at Eniwetok (Garth 1964), only a single species, *Hapalocarcinus marsupialis* was recorded. Gall crabs are usually small

and inconspicuous and are relatively difficult to locate, hidden in tiny cavities within coral branches. This may explain their apparent rarity, but ecological factors cannot be ruled out. The family however, appears to be much more common in corals from southern Japan (Takeda & Tamura, 1979, 1980a, 1980b, 1980c, 1980d, 1981a, 1981b, 1981c,1983, 1986), and has also been collected from Pulau Tioman, off western Peninsular Malaysia (Ng, unpublished data).

A recent study of decapod crusaceans associated with corals *Pavona frondifera* and *Pocillopora damicornis* (Nakasone *el al.* 1986) in the Gulf of Thailand which lies on the Sunda Shelf, also revealed a low species richness of corallicolous symbionts, as is observed at present in Singapore. Only two species, *Cymo andreossyi* and *Trapezia cymodoce,* were recorded. The existing evidence thus seems to suggest that reefs located on the Sunda Shelf tend to support a poorer corallicolous brachyuran fauna when compared to oceanic reefs.

The coral reefs in Singapore are also characterized by the low frequency of occurrence of *Trapezia cymodoce* on pocilloporid corals. In the Thai study (Nakasone *et al.* 1986), 25 specimens of *T. cymodoce* were collected from 12 *Pocillopora* heads in Khang Khao Island and 19 from seven heads in Samui Island. Unfortunately, occurrence on individual corals was not documented. The data, however, seems to indicate that there were at least one pair of *Trapezia* within each coral head. The frequency of occurrence was a hundred percent from both localities, as was observed in the other studies (Garth 1964, 1973, 1984; Patton 1966, 1974). The situation in Singapore thus appears to be anomalous, with only four occurrences of *Trapezia* in the 14 head of *Pocillopora* sampled (frequency of occurrence = 36.4%)

On the other hand, the species richness of facultative symbionts (corallophilous symbionts and casual associates) occurring on Singapore corals are comparable to those in Eniwetok and Seychelles (Garth 1964, 1984). In addition, the species richness of these symbionts present on Singapore pocilloporid corals is higher than that of Heron Island (Patton 1974) and the Maldives (Garth 1973).

The oceanographic conditions of the coastal waters of Singapore must be taken into consideration. The low species richness in the corallicolous brachyuran community could be attributed to the high degree of sedimentation in Singapore waters. Secchi disc readings range between 1.3 m and 4.7 m, with the lower values being the norm, even on sunny days. This high turbidity of the waters, which drastically reduces sunlight penetration, is due primarily to three decades of land reclamation projects (Chou 1985). The reduction in light penetration, surprisingly does not seem to affect the growth of corals as much as the presence of organisms living within the reefs, the coral growth in Singapore being still relatively good (Chong 1985, Chou & Koh 1986, Wong 1982).

In addition, the salinity of the waters of the Sunda Shelf tend to fluctuate more than in oceanic reefs. Fresh water run-offs and heavy rain during the monsoons cause a distinct drop in salinity, the average salinity of this region ranging from 25% to 32% in the period between 1976 and 1978 (Lim 1984a, 1984b). This is

much lower than that of oceanic reefs, which have salinities approximating 34% to 37% (Ingmanson & Wallace 1973).

Abele (1976) attributed differences to proportions of corallicolous and non-corallicolous species present in reef habitats to environmental variability. He believed that variations in temperature, salinity and turbidity tend to have more adverse effects on corallicoles, but less so for facultatives. Kropp & Birkeland (1981) compared crustacean associates of *Pocillopora verrucosa* from a high island and an atoll. They found that in addition to environmental variability, high benthic productivity, or the ability to use benthic detritus which is present in great abundance, may also explain differences in proportions of associated fauna. These factors may explain the greater abundance of corallophilous brachyuran species found in Singapore corals, but further investigations are required.

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NOTE ADDED IN PRESS

The specimens identified in this paper as *Galathea spinosorostris* were identified using Johnson's (1970) paper. Dr. Keiji Baba has recently informed the last author (pers. comm.) that they should be referred to a new species instead. The description of this new species by K. Baba and S.C. Oh is currently in press.

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