

# A Cleaning Station Composed of Cleaner Shrimp and High Fish Diversity in a Coral Reef in Kenting, Southern Taiwan

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**Abstract.** A cleaning station hosted by more than 30 cleaner shrimp *Lysmata amboinensis* is described from a coral reef of Kenting National Park, southern Taiwan. At the station, two moray eels lived in holes, along with two groups of shrimp (*L. amboinensis* and *Rhynchocinetes durbanensis*) and a mixed school of more than 100 sweepers and cardinalfishes. The moray eels seemed to guard the station from intruding predators, and *L. amboinensis* provided a door-to-door cleaning service. Many fishes were found to be clients during the survey, and the area revealed a highly diverse fish fauna. This moray eel-guarded cleaning station appeared to have a mutualistic assemblage, resulting in the proliferation of cleaning shrimp. With adequate cleaners, fish clients tended to visit the station, which resulted in a rich community.

**Key words:** cleaning symbiosis, cleaner shrimp, fish diversity, coral reef, Kenting National Park.

## INTRODUCTION

Cleaning symbioses involve cleaner organisms (usually fish or shrimp) that remove ectoparasites, mucus, scales, or diseased tissue of larger fish “clients” (Feder, 1966). Such interactions have long been considered mutualistic (Trivers, 1971; Cushman and Beattie, 1991), but only recently was the hypothesis supported by quantitative studies (reviewed in Grutter, 2002).

Cleaners occur at specific sites known as cleaning stations. Fish cleaners are usually located on a sponge or coral head (Cheney and Côté, 2001), while shrimp cleaners prefer small holes and crevices (Becker et al., 2005). Cleaners perform attractive behaviors; for example, the shrimp *Stenopus hispidus* and *Periclimenes* spp. vigorously wave long antennae, while cleaning fish and shrimp signal by performing “dances” (Limbaugh, 1961; Potts, 1973) to advertise their cleaning services. When a client visits a station,

it adopts a characteristic inciting pose such as landing on the bottom or holding still in the water, and then a cleaner swims out from its hide at the station to inspect and clean it (Limbaugh *et al.*, 1961). Most documented cleaning stations, due to limits of local circumstances, are hosted by fewer than five cleaners, except stations of cleaner shrimp *Periclimenes anthophilus* associated with anemones which may be composed of up of ten cleaners (Sargent and Wagenbach, 1975).

This study reports on an unusual cleaning station containing dozens of cleaner shrimp which formed a mutualistic assemblage with local residents of a reef in southern Taiwan. In this study, we describe the species and interactions of cleaners and clients at the station; local fish diversity is also discussed.

## METHODS

The cleaning station is located 32 m in depth at the southeastern corner of the diving site at Dulijiao (the Lone Reef, 120°45:32E,

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21°56:33N). Embraced by three reefs, a south-facing concave area forms the center of the station which harbors a diverse benthic community including groups of cleaner shrimps. Distances among the three reefs are <7 m, and they shelter the station from the north-south tidal current.

Surveys of fish and cleaners were conducted by nine scuba dives covering different seasons in 2009~2011. Species and behaviors of cleaners and clients occurring within a 5-m range from

the concave area were recorded with underwater cameras and camcorders. The fish community in a 50 x 10-m zone outside the station was surveyed by a scuba-diving visual strip-transect method (McCormick and Choat, 1987).

## RESULTS AND DISCUSSION

### Cleaners at the station

Three species of cleaner shrimp were

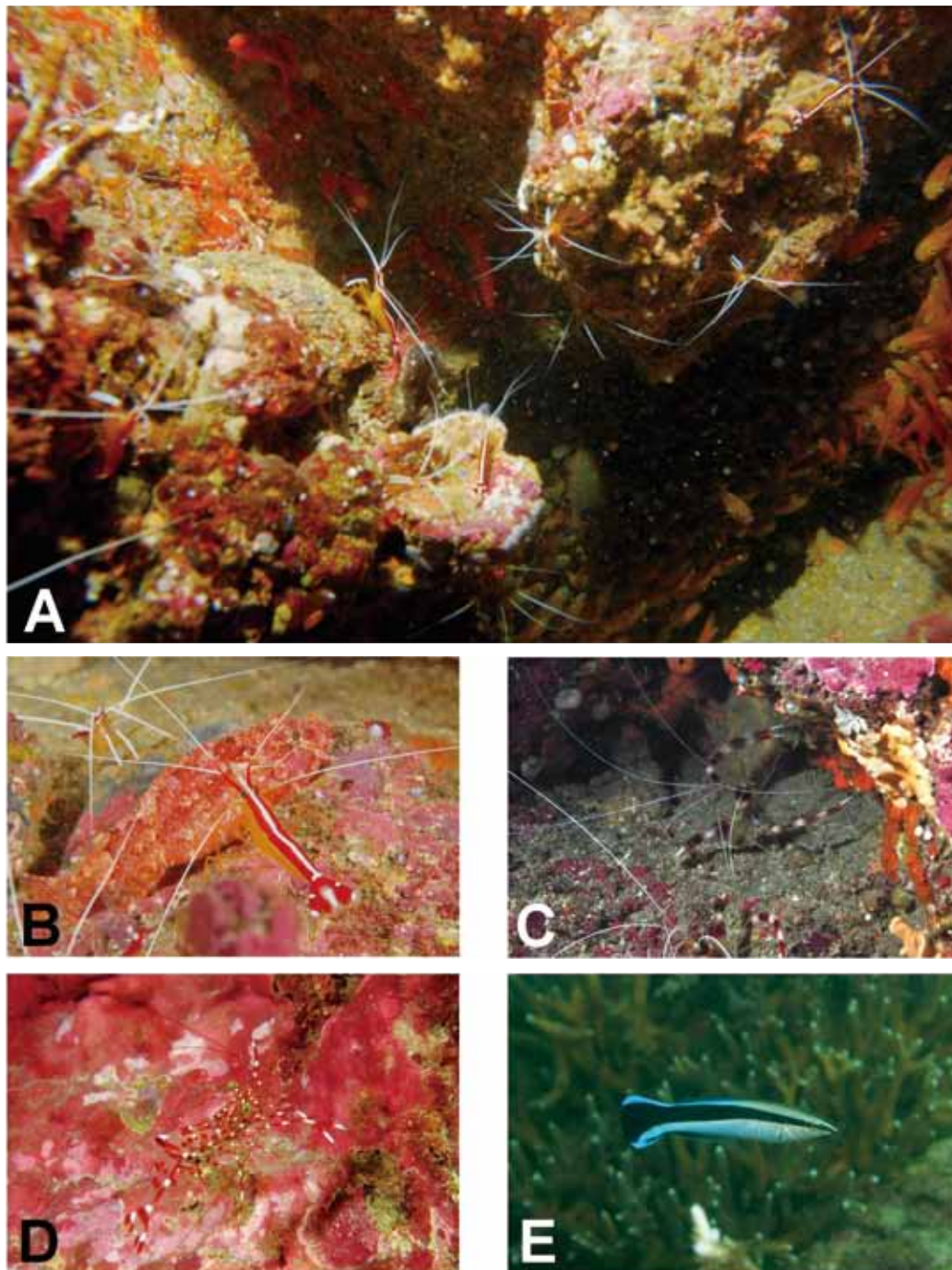


Fig. 1. Cleaners at the cleaning station. (A) A group of the humpback cleaner shrimp *Lysmata amboinensis*. (B) Close-up of *L. amboinensis*. (C) The banded coral shrimp *Stenopus hispidus*. (D) *Urocaridella antonbruunii*. (E) The bluestreak cleaner wrasse *Labroides dimidiatus*. Photo credits of (C) and (D): J-C. Chen.



recorded. The humpback cleaner shrimp *Lysmata amboinensis* was the most common species at the station (Fig. 1A, B). There were usually more than 30 individuals during the surveys. There were fewer than five banded coral shrimp *Stenopus hispidus* (Fig. 1C) and *Urocaridella antonbruunii* (Fig. 1D) individuals in each survey. Groups of *L. amboinensis* usually stayed on the exposed surface of the reef waiting for client fish. Waving their long white antennae to attract fish, *S. hispidus* waited in crevices or at the exit of their shelter. Cryptic *U. antonbruunii* hid in the reef, or blended into the *L. amboinensis* aggregation. Shrimp cleaners usually served their clients on the bottom or <1 m from their reef caves, consistent with observations reported by Wichsten (1995). As for cleaner fish, fewer than

five individuals of the bluestreak cleaner wrasse *Labroides dimidiatus* were seen within the 5-m range of the station for cleaning fish clients (Fig. 1E).

#### Non-cleaner shrimp residents at the station

Other than the three cleaner species, two non-cleaner shrimp were found around the station (Fig. 2). Occurring in a large aggregation, the Durban hinge-beak shrimp *Rhynchocinetes durbanensis* was dominant at the site. More than 200 individuals were usually found sharing the surface of the station reef with *L. amboinensis*, yet they maintained a distance of approximately 5~10 cm (Fig. 2A, B) between individuals. Underneath the station reef, a rare lobster species *Enoplometopus occidentalis* was found

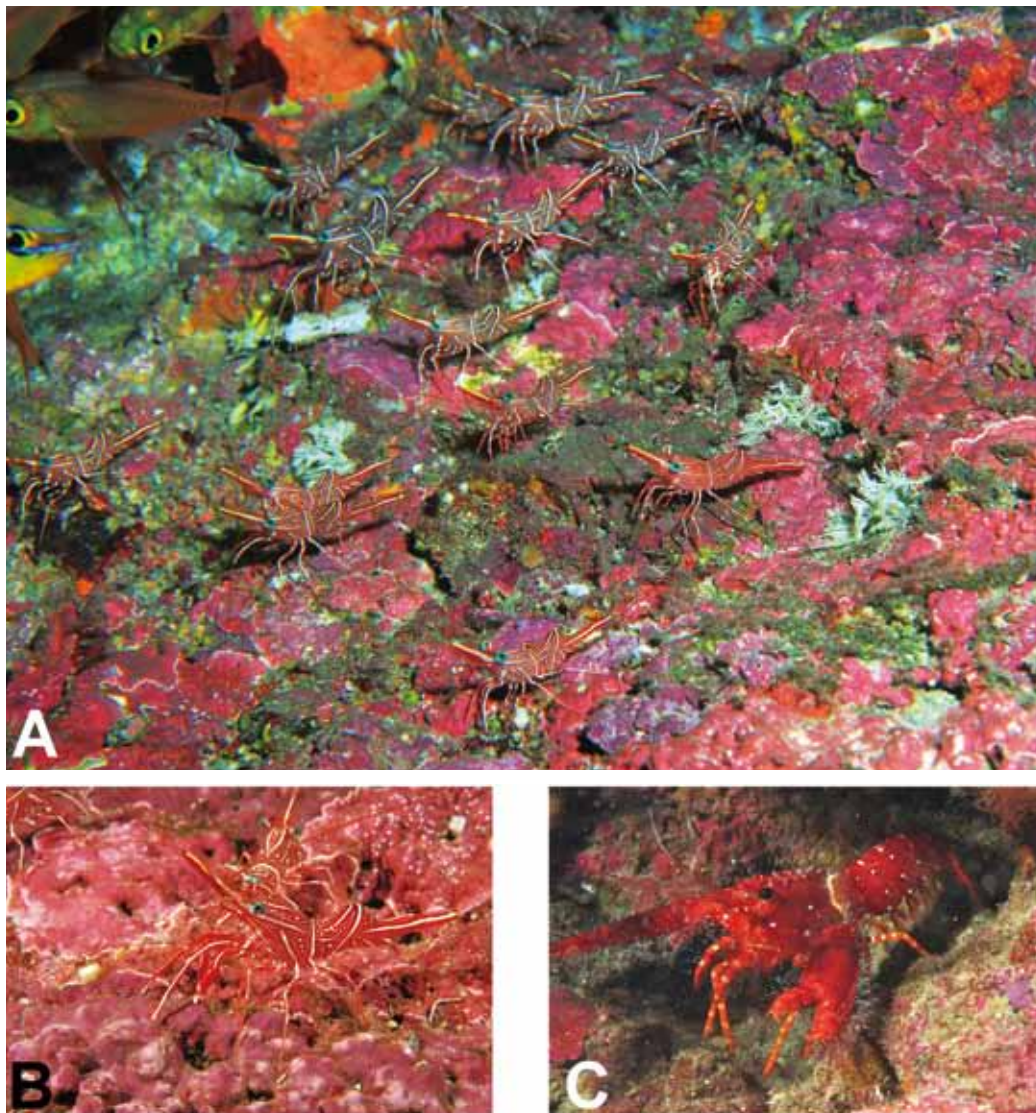


Fig. 2. Non-cleaner shrimp at the station. (A) A group of the Durban hinge-beak shrimp *Rhynchocinetes durbanensis*. (B) Close-up of *R. durbanensis*. (C) The lobster *Enoplometopus occidentalis*. Photo credits of (B) and (C): J.-C. Chen.

Table 1. Shrimp species list and their abundances at the cleaning station. Abundance indices: +, fewer than ten individuals; +++, between 30 and 100 individuals; +++++, more than 100 individuals.

Family	Species	Abundance
Enoplometopidae	<i>Enoplometopus occidentalis</i> Randall, 1840	+
Hippolytidae	<i>Lysmata amboinensis</i> de Man, 1888	+++
Palaemonidae	<i>Urocaridella antonbruunii</i> Bruce, 1967	+
Rhynchocinetidae	<i>Rhynchocinetes durbanensis</i> (Gordon, 1936)	++++
Stenopodidae	<i>Stenopus hispidus</i> (Oliver, 1811)	+
Total: 5 families and 5 species		

inhabiting the concaves (Fig. 2C). Shrimp species occurring at the station and their abundances are summarized in Table 1.

#### Fish residents around the station

At the site, fish residents formed a highly connected, diverse community (Fig. 3). A school of more than 100 sweepers and cardinalfishes was found at the exit of the concave, which probably served as shelter from predators. The school mostly consisted of residential *Parapriacanthus ransonneti* (Fig. 3A), *Apogon aureus* (Fig. 3B), *A. apogonides* (Fig. 3C), *A. fraenatus* (Fig. 3D), *A. notatus* (Fig. 3E), and *Rhabdamia gracilis* (Fig. 3F). *Archamia fucata* was occasionally observed in a lower abundance. Inside the reef, two moray eels, *Gymnothorax melatremus* and *G. favagineus*, inhabited the concaves adjacent to the cleaner residents. As divers approached, *G. melatremus*

would stretch its heads out of its hide while the sweepers and cardinalfish aggregated near the hole (Fig. 3G). As door-to-door cleaners, the cleaner shrimp *L. amboinensis* tended to climb onto *G. favagineus* for cleaning (Fig. 3H).

At the station, fish clients included *Cephalopholis miniata* (Fig. 4A), *Diodon liturosus* (Fig. 4B), and *Pseudanthias pleurotaenia* (Fig. 4C). Other fishes found near the station included *Centropyge bicolor* (Fig. 4D), *Cephalopholis spiloparaea* (Fig. 4E), *Cirrhilabrus rubrimarginatus* (Fig. 4F), *Diagramma pictus* (Fig. 4G), and *Genicanthus melanospilos* (Fig. 4H); a complete list of fish recorded in the surveys is provided in Table 2.

#### Interactions between cleaners and fish clients

This shrimp-dominated cleaning station attracted many fishes, not only clients for the cleaning service but also species such as sweepers

Table 2. Fish species list and their abundances around the cleaning station. Abundance indices: +, fewer than ten individuals; ++, between ten and 30 individuals; +++, between 30 and 100 individuals; +++++, more than 100 individuals.

Family	Species	Abundance
Acanthuridae	<i>Acanthurus dussumieri</i> Valenciennes, 1835	+
	<i>Acanthurus olivaceus</i> Bloch et Schneider, 1801	+
	<i>Ctenochaetus binotatus</i> Randall, 1955	+
	<i>Naso hexacanthus</i> (Bleeker, 1855)	+
	<i>Zebrasoma veliferum</i> (Bloch, 1795)	+
Apogonidae	<i>Apogon apogonides</i> (Bleeker, 1856)	++
	<i>Apogon aureus</i> (Lacepède, 1802)	+
	<i>Rhabdamia gracilis</i> (Bleeker, 1856)	++++

Family	Species	Abundance	
Balistidae	<i>Balistapus undulates</i> (Park, 1797)	+	
	<i>Balistoides conspicillum</i> (Bloch et Schneider, 1801)	+	
	<i>Sufflamen bursa</i> (Bloch et Schneider, 1801)	+	
Caesionidae	<i>Caesio caerulaurea</i> Lacepède, 1801	+++	
	<i>Caesio teres</i> Seale, 1906	+	
	<i>Pterocaesio digramma</i> (Bleeker, 1865)	+++	
Chaetodontidae	<i>Chaetodon argentatus</i> Smith et Radcliffe, 1911	+	
	<i>Chaetodon auripes</i> Jordan et Snyder, 1901	+	
	<i>Chaetodon citrinellus</i> Cuvier, 1831	+	
	<i>Chaetodon kleinii</i> Bloch, 1790	++	
	<i>Chaetodon lineolatus</i> Cuvier, 1831	+	
	<i>Chaetodon lunula</i> (Lacepède, 1802)	+	
	<i>Chaetodon plebeius</i> Cuvier, 1831	+	
	<i>Chaetodon punctatofasciatus</i> Cuvier, 1831	+	
	<i>Chaetodon speculum</i> Cuvier, 1831	+	
	<i>Chaetodon unimaculatus</i> Bloch, 1787	+	
	<i>Chaetodon xanthurus</i> Bleeker, 1857	+	
	<i>Forcipiger longirostris</i> (Broussonet, 1782)	+	
	<i>Heniochus acuminatus</i> (Linnaeus, 1758)	+	
	Cirrhitidae	<i>Cirrhitichthys aprinus</i> (Cuvier, 1829)	+
		<i>Cirrhitichthys falco</i> Randall, 1963	+
<i>Oxycirrhites typus</i> Bleeker, 1857		+	
<i>Paracirrhites arcatus</i> (Cuvier, 1829)		+	
Diodontidae	<i>Diodon holocanthus</i> Linnaeus, 1758	+	
Gobiidae	<i>Amblyeleotris guttata</i> (Fowler, 1938)	++	
	<i>Amblyeleotris ogasawarensis</i> Yanagisawa, 1978	++	
	<i>Amblyeleotris periophthalma</i> (Bleeker, 1853)	++	
	<i>Amblyeleotris stenotaeniata</i> Randall, 2004	+	
	<i>Amblyeleotris wheeleri</i> (Polunin et Lubbock, 1977)	++	
	<i>Amblyeleotris yanoi</i> Aonuma et Yoshino, 1996	+	
	<i>Bryaninops yongei</i> (Davis et Cohen, 1969)	++	
	<i>Cryptocentrus albidorsus</i> (Yanagisawa, 1978)	+	
	<i>Ctenogobiops tangaroai</i> Lubbock et Polunin, 1977	+	
	<i>Flabelligobius</i> sp.	+	
<i>Fusigobius neophytus</i> (Günther, 1877)	+		

Family	Species	Abundance
	<i>Gnatholepis anjerensis</i> (Bleeker, 1851)	+
	<i>Gnatholepis cauerensis cauerensis</i> (Bleeker, 1853)	+
	<i>Istigobius decoratus</i> (Herre, 1927)	+
	<i>Pleurosicya mossambica</i> Smith, 1959	+
	<i>Valenciennea helsdingenii</i> (Bleeker, 1858)	+
Haemulidae	<i>Diagramma pictus</i> (Tortonese, 1936)	++
	<i>Plectorhinchus picus</i> (Cuvier, 1828)	++
Holocentridae	<i>Neoniphon samara</i> (Forsskål, 1775)	+
	<i>Sargocentron diadema</i> (Lacepède, 1802)	+
Labridae	<i>Anampses caeruleopunctatus</i> Rüppell, 1829	+
	<i>Anampses twistii</i> Bleeker, 1856	+
	<i>Bodianus dictynna</i> Gomon, 2006	+
	<i>Bodianus mesothorax</i> (Bloch et Schneider, 1801)	+
	<i>Cheilinus chlorourus</i> (Bloch, 1791)	+
	<i>Cheilinus oxycephalus</i> Bleeker, 1853	+
	<i>Cheilinus trilobatus</i> Lacepède, 1801	+
	<i>Choerodon jordani</i> (Snyder, 1908)	+
	<i>Cirrhilabrus rubrimarginatus</i> Randall, 1992	+
	<i>Coris aygula</i> Lacepède, 1801	+
	<i>Coris dorsomacula</i> Fowler, 1908	+
	<i>Halichoeres chrysus</i> Randall, 1981	+
	<i>Halichoeres hartzfeldii</i> (Bleeker, 1852)	+
	<i>Hologymnosus doliatus</i> (Lacepède, 1801)	+
	<i>Labroides dimidiatus</i> (Valenciennes, 1839)	+
	<i>Macropharyngodon meleagris</i> (Valenciennes, 1839)	+
	<i>Macropharyngodon negrosensis</i> Herre, 1932	+
	<i>Paracheilinus carpenteri</i> Randall et Lubbock, 1981	+
	<i>Pseudocheilinus evanidus</i> Jordan et Evermann, 1903	+
	<i>Pseudocheilinus hexataenia</i> (Bleeker, 1857)	+
	<i>Pseudocheilinus octotaenia</i> Jenkins, 1901	+
	<i>Pseudodax moluccanus</i> (Valenciennes, 1840)	+
Lethrinidae	<i>Lethrinus harak</i> (Forsskål, 1775)	+
Lutjanidae	<i>Lutjanus quinquelineatus</i> (Bloch, 1790)	+
	<i>Macolor niger</i> (Forsskål, 1775)	+
Monacanthidae	<i>Paraluteres prionurus</i> (Bleeker, 1851)	+

Family	Species	Abundance
Mullidae	<i>Parupeneus ciliatus</i> (Lacepède, 1802)	+
	<i>Parupeneus heptacanthus</i> (Lacepède, 1802)	+
	<i>Parupeneus indicus</i> (Shaw, 1803)	+
	<i>Parupeneus multifasciatus</i> (Quoy et Gaimard, 1825)	+
	<i>Parupeneus pleurostigma</i> (Bennett, 1831)	+
	<i>Upeneus tragula</i> Richardson, 1846	+
Muraenidae	<i>Gymnothorax favagineus</i> Bloch et Schneider, 1801	+
	<i>Gymnothorax melatremus</i> Schultz, 1953	+
Nemipteridae	<i>Pentapodus aureofasciatus</i> Russell, 2001	+
	<i>Scolopsis affinis</i> Peters, 1877	+
	<i>Scolopsis monogramma</i> (Cuvier, 1830)	+
	<i>Scolopsis vosmeri</i> (Bloch, 1792)	+
	<i>Scolopsis xenochrous</i> Günther, 1872	+
Ostraciidae	<i>Ostracion cubicus</i> Linnaeus, 1758	+
	<i>Ostracion rhinorhynchus</i> Bleeker, 1852	+
Pempheridae	<i>Parapriacanthus ransonneti</i> Steindachner, 1870	+++
Pinguipedidae	<i>Parapercis multiplicata</i> Randall, 1984	++
	<i>Parapercis tetracantha</i> (Lacepède, 1801)	+
Plesiopidae	<i>Calloplesiops altivelis</i> (Steindachner, 1903)	+
Pomacanthidae	<i>Apolemichthys trimaculatus</i> (Cuvier, 1831)	+
	<i>Centropyge bicolor</i> (Bloch, 1787)	+
	<i>Centropyge bispinosa</i> (Günther, 1860)	+
	<i>Centropyge tibicen</i> (Cuvier, 1831)	+
	<i>Centropyge vrolikii</i> (Bleeker, 1853)	+
	<i>Genicanthus melanospilos</i> (Bleeker, 1857)	+
	<i>Genicanthus semifasciatus</i> (Kamohara, 1934)	+
	<i>Pomacanthus imperator</i> (Bloch, 1787)	+
	<i>Pomacanthus semicirculatus</i> (Cuvier, 1831)	+
	Pomacentridae	<i>Amblyglyphidodon aureus</i> (Cuvier, 1830)
<i>Amphiprion clarkia</i> (Bennett, 1830)		+
<i>Chromis delta</i> Randall, 1988		+
<i>Chromis flavomaculata</i> Kamohara, 1960		+
<i>Chromis margaritifer</i> Fowler, 1946		++
<i>Chrysiptera kuiteri</i> Allen et Rajasuriya, 1995		+
<i>Pomacentrus stigma</i> Fowler et Bean, 1928		+

Family	Species	Abundance
Ptereleotridae	<i>Ptereleotris evides</i> (Jordan et Hubbs, 1925)	+
Scaridae	<i>Calotomus carolinus</i> (Valenciennes, 1840)	+
	<i>Chlorurus bowersi</i> (Snyder, 1909)	+
	<i>Scarus rubroviolaceus</i> Bleeker, 1847	+
	<i>Scarus schlegeli</i> (Bleeker, 1861)	+
	<i>Pterois radiate</i> Cuvier, 1829	+
Scorpaenidae	<i>Scorpaenopsis cirrhosa</i> (Thunberg, 1793)	+
	<i>Cephalopholis argus</i> Bloch et Schneider, 1801	+
Serranidae	<i>Cephalopholis miniata</i> (Forsskål, 1775)	+
	<i>Cephalopholis spiloparaea</i> (Valenciennes, 1828)	+
	<i>Cephalopholis urodeta</i> (Forster, 1801)	+
	<i>Diploprion bifasciatum</i> Cuvier, 1828	+
	<i>Epinephelus malabaricus</i> (Bloch et Schneider, 1801)	+
	<i>Grammistes sexlineatus</i> (Thunberg, 1792)	+
	<i>Pseudanthias hypselosoma</i> Bleeker, 1878	++
	<i>Pseudanthias pleurotaenia</i> (Bleeker, 1857)	+++
	<i>Variola louti</i> (Forsskål, 1775)	+
	Siganidae	<i>Siganus fuscescens</i> (Houttuyn, 1782)
<i>Canthigaster valentine</i> (Bleeker, 1853)		+
Tetraodontidae		
Total: 29 families and 132 species		

and cardinalfish that aggregated at the reef inhabited by the voracious moray eels. Since the station was sheltered by adjacent reefs, it was seldom affected by sweeping tidal currents. The crevices and holes of the reef provided shelter for cleaners and smaller residents. Moray eels at the site may function as guards from external predators for local residents, and shrimp cleaners offered door-to-door service in exchange. A similar moray eel-shrimp assemblage was documented in Mabul, Malaysia of an association of a moray eel *G. favageneus* with a group of *R. durbanensis* and a few cleaners (*S. hispidus* and *Urocaridella* sp.) that massed together in a reef hole (Kuitert and Debelius, 2009). Such an assemblage implies mutualism. In a guarded neighborhood, cleaner shrimp are apt to proliferate, and the potential to service fishes

therefore increases. When there are more cleaners available, more fish clients tend to visit. Such an active cleaning station may lead to a highly diverse reef community.

Although the cleaning station contributed to a high diversity of fish fauna, the shrimp cleaners and residents are vulnerable to poaching and illegal fishing. Thus we suggest that the administration of Kenting National Park conduct regular monitoring and surveys at these sites with rich biodiversity.

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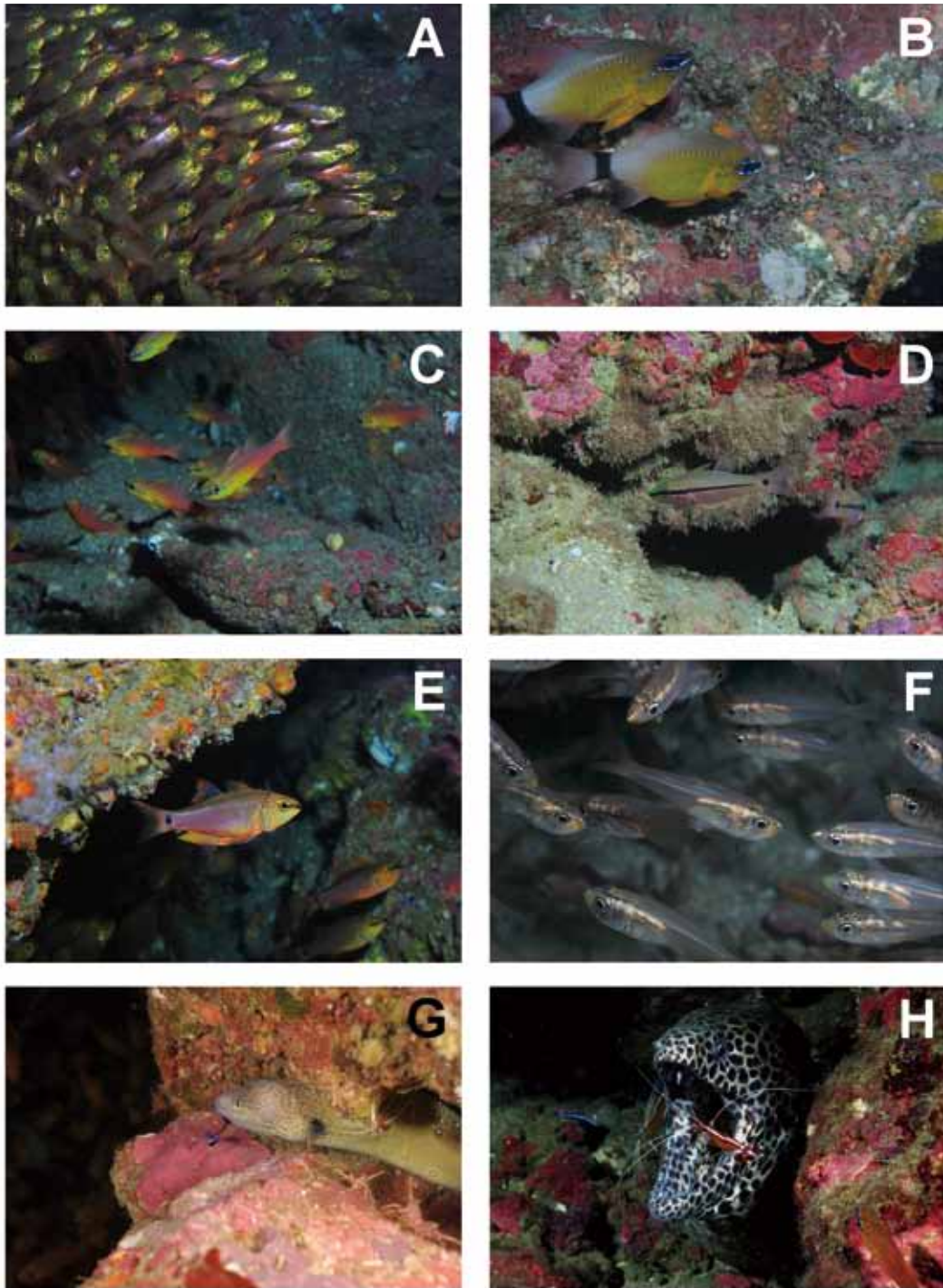


Fig. 3. Fish residents at the station. A mixed school of sweepers and cardinalfishes aggregated at the station: (A) *Parapriacanthus ransonneti*, (B) *Apogon aureus*, (C) *A. apogonides*, (D) *A. frenatus*, (E) *A. notatus*, and (F) *Rhabdamia gracilis*. Two moray eels inhabited holes at the station: (G) *Gymnothorax melatremus* and (H) *G. favagineus*. Cleaners usually provided door-to-door service to these vicious neighbors. Photo credits of (G) and (H): J.-C. Chen.

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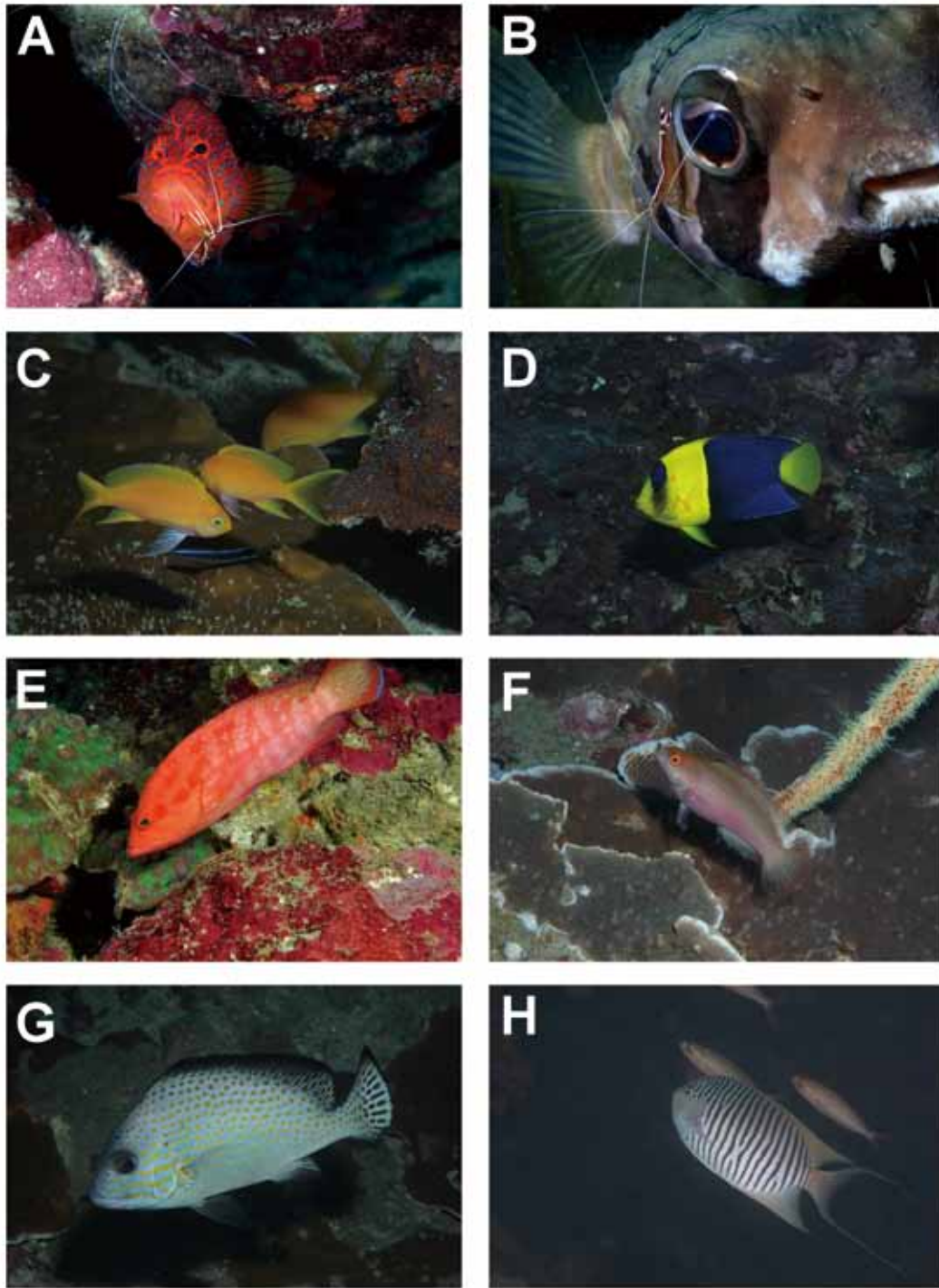


Fig. 4. Fishes observed around the station. Three fish clients: (A) *Cephalopholis miniata*, (B) *Diodon liturosus*, and (C) *Pseudanthias pleurotaenia*. Selected examples of other fish observed: (D) *Centropyge bicolor*, (E) *Cephalopholis spiloparaea*, (F) *Cirrhitilabrus rubrimarginatus*, (G) *Diagramma pictus*, and (H) *Genicanthus melanospilos*. A complete list of fishes observed in this study is given in Table 1. Photo credits of (A) and (B): Y.-C. Tsai; (E): J.-C. Chen.

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## 墾丁海域的清潔蝦清潔站與周圍的豐富魚類多樣性

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2. 國立自然科學博物館動物學組

本研究紀錄描述一個位於台灣南部墾丁海域，擁有超過30隻白背鞭藻蝦的清潔站與周圍的生物相。在這個清潔站的洞穴內，有兩隻裸胸鯙與兩個蝦群（白背鞭藻蝦與德班活額蝦）共棲；在洞穴外還有100隻以上的擬金眼鯛與天竺鯛混合群。裸胸鯙似乎在清潔站裡扮演守護者的角色，使站內其他生物免於外來的攻擊，而清潔蝦則為裸胸鯙提供到府清潔的服務作為回報。在清潔站的範圍內觀察到許多魚來此接受清潔服務，而周圍的魚類相也很豐富。我們推論這個清潔站因為有裸胸鯙的保護，站內的清潔蝦族群得以繁衍；清潔蝦的數目增加了，也吸引更多的魚前來接受清潔服務，連帶豐富了當地的魚類群聚。

關鍵詞：清潔共生、清潔蝦、魚類多樣性、珊瑚礁、墾丁國家公園。