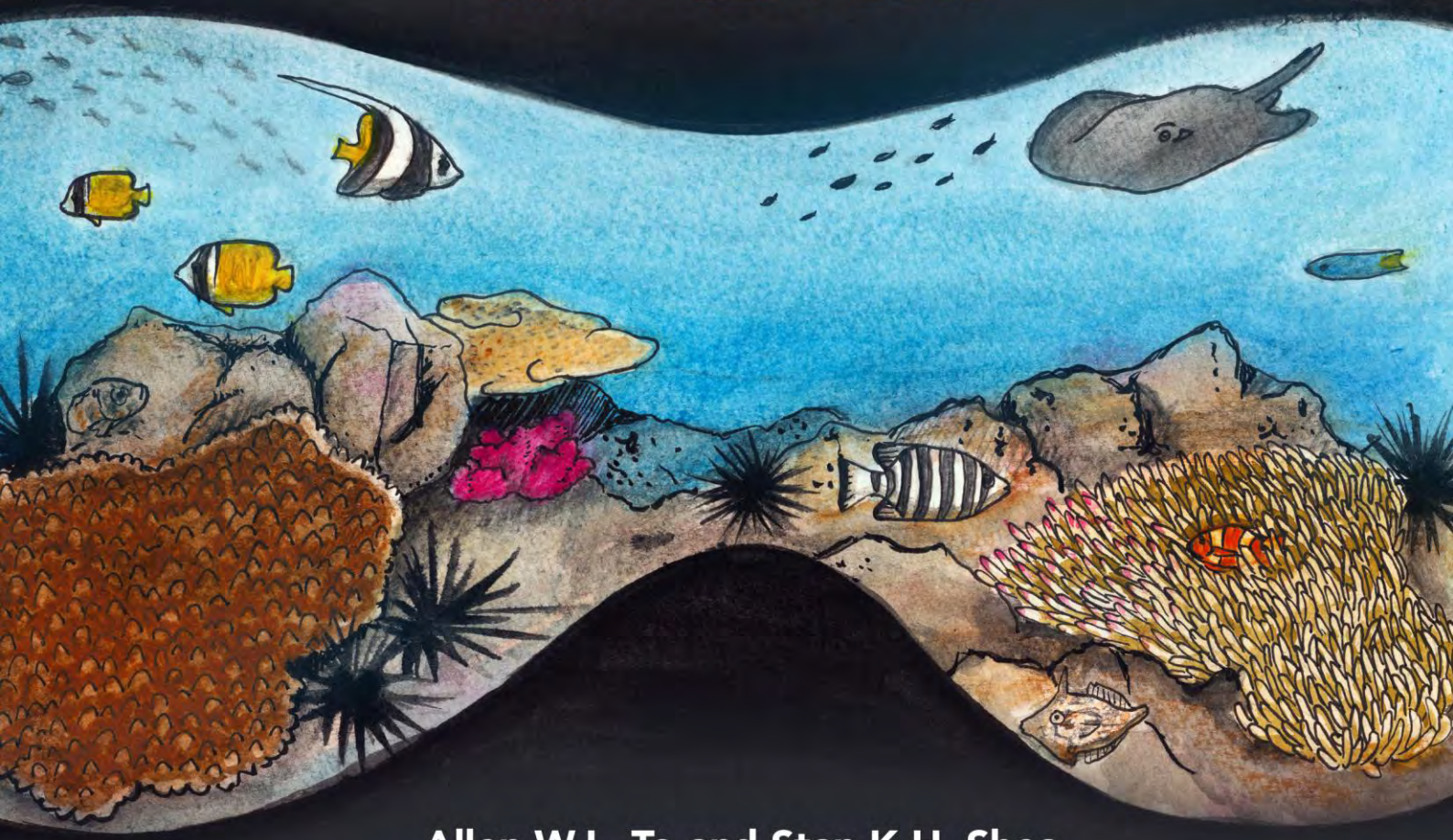
RAPID REEF FISH SURVEY AT DAYA BAY, GUANGDONG PROVINCE, CHINA

MAY – SEPT 2015



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Submitted to
State Key Laboratory in Marine Pollution,
City University of Hong Kong

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HONG KONG 114°E
REEF FISH
SURVEY

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Introduction

There have been a number of studies about Hong Kong marine fish diversity in the past, and in particular reef fish diversity in more recent years (Sadovy and Cornish 2000; To *et al*. 2013), however studies to give reef fish diversity and anecdotal data from Shenzhen's Daya Bay is found lacking. To offer a comparison, about 1,000 marine fish species, within which about 340 of them are reef fishes, have been recorded in Hong Kong through various studies (hk-fish.et 2016). For Daya Bay, located just next to Hong Kong's Mirs Bay, there is no such information.

While surveys to monitor the diversity and status of marine fish, in particular reef fish, in Daya Bay is limited, fishing pressures and coastal development and pollution in the area have gone unabated, without any measure of how the activities may directly or indirectly be impacting the marine life. Macrobenthic faunal diversity has shown a marked decline over the last few decades, due to habitat degradation in the area (Du *et al*. 2008). Intense fishing activities have also taken a heavy toll on fish stocks (Chen *et al*. 2003; Wang *et al*. 2010). A review on the fish species caught in bottom trawling in Daya Bay revealed dramatic changes in the total number of species and composition over the last few decades. The number of species, many of which are commercially valuable, dropped from 157 species in the 1980s to 110 species in the 1990s, and subsequently to 107 species in 2004 – 2005 (Wang *et al*. 2010). The dominant species also changed from the relatively high-value species such as hairtail and pomfret in the 1980s to relatively low-value species such as sardine, anchovy and juvenile porgy in more recent years (Wang *et al*. 2010). Fish stock in Daya Bay is declining. The current study, through a series of rapid reef fish survey in Daya Bay, aims to

- Updating the reef fish species occurring in the area
- Document the qualitative abundance of reef fish species
- Describe the characterization of reef fish diversity
- Identify reef fish hot spot

These data are updated baseline information about the reef fish status in Daya Bay, and will be essential for any subsequent analysis regarding fish stock assessment, environmental impact on coastal habitat, and be useful input into strategic coastal development.

Methodology

Site selection

There is relatively little publicly accessible information regarding the distribution of coral communities and rocky reefs in and around Daya Bay, except for the annual reef check conducted in this area. To select the most relevant habitats for reef fish survey, information regarding the habitat distribution within Daya Bay was collected base on the information from past reef check in this area, and knowledge shared by experienced dive operators based in this region. Some of these selected areas have relatively high coral coverage such as Guiwan, where coral coverage is the highest within Guangdong province, having 65.6% hard coral coverage as reported in 2015 (Nanfang Daily, 2015). Other sites have varying degrees of rocky reef and coral communities. Sites are selected base on the availability of these habitats; other factors including the level of fishing pressure, proximity to human settlement and distance to travel are not included within the scope of consideration for site selection.

In total, 12 sites were selected for this reef fish survey in and around Daya Bay (Figure 1). These sites are scattered around the entrance to Daya Bay, and some are located within the central area of Daya Bay. Detailed descriptions of each of these survey sites are included in Appendix 1.

Figure 1. Map showing the locations of the 12 sites (red dive flags), in and around Daya Bay, selected for reef fish survey in this study.

Reef fish survey

Underwater observations are often used to record fish that occur in relatively clear, calm shallow marine water or freshwater areas (Côté and Perrow 2006), such as is often done in Hong Kong (Sadovy and Cornish 2000; To et al. 2013). Both snorkeling and SCUBA diving are widely used methods to conduct fish surveys (Côté and Perrow 2006), and this is particularly relevant to Hong Kong and adjacent areas, where coral communities are restricted to within 10 m below water surfaces (Sadovy and Cornish 2000). Survey techniques including the fixed transect count, point count and roving transects, are all possible options for the purpose of underwater reef fish surveys (Côté and Perrow 2006).

Each of these visual fish counting methods has specific pros and cons. In general, fixed transects and point counts give good measures of abundance and density; whilst a roving transect yields greater information on species diversity (Côté and Perrow 2006). One additional and distinctive advantage of the roving transect is that

it allows divers to do the survey without carrying the transect instruments (versus that of fixed transects), and allows divers to dive freely (versus staying at one particular point for fixed time for point count). Such features of the roving transect is much more appealing to recreational divers. This method is also adopted in a similar volunteer fish survey program by REEF, and is actually specifically designed for volunteer surveys (REEF 2012). For the objectives of this study, a roving transect is hence justifiably more appropriate.

In conducting the roving transects, or the roving diver technique (RDT), divers / snorkellers swim freely throughout a dive site and record every observed fish species that can be identified. Species and the approximate abundance ranking will be recorded during the survey. Each recorded species is assigned one of the four abundance categories based on the approximate number encountered during a single survey: single = 1, few = 2 – 10, many = 11 – 100 and abundant = >100. The search for reef fishes commences once the surveyors are in the water. As the survey aims to record as many fish species as possible, surveyors will also pay special attention to crevices and benthics, and includes all levels of the water column.

In this study, to ensure a consistent effort in surveying at each site, two surveyors formed a single survey team, and each underwater reef fish survey lasted for around 50 – 60 minutes, unless underwater visibility is too low to ensure safe diving. During the survey, surveyors swam slowly and parallel to the shore, and used underwater writing boards to record species as needed. Once back on-board the dive boat after each survey, surveyors went through a full list of reef fishes in a photo catalogue to aid re-calling each fish species sighted during the survey. The records of reef fish species for each site were then noted on reef fish survey sheets before the commencement of survey at another site. GPS locations of the sites were collected using Garmin GPSMAP 62s. All data were subsequently computerized and processed in Microsoft EXCEL for analysis. Underwater visibility was estimated by the surveyors.

Summary of key findings

Overview of survey

Reef fish surveys were conducted on 12th – 13th May, 8th – 9th Jun and 22nd – 23d Sep, 2015. One-off reef fish surveys were undertaken at every selected site in this rapid survey. The first eight reef fish surveys were conducted by both authors of this report, Allen To (AT) and Stanley Shea (SS), forming a single survey team; while the last four reef fish surveys were undertaken by AT and another dive buddy to form the survey team. In total, 1,272 man-minutes (equivalent to 21.2 man-hours) in total were spent underwater in the reef fish survey.

Reef fish surveys were conducted at an average depth of 3 – 5 m at each site, and the maximum depth of 4.6 – 11.8 m. The underwater visibility was between 1.5 – 5 m. It is notable that at several surveys, the underwater visibility was less than ideal – less than 3 m underwater visibility (Cornish 1999), and in two particular surveys it was as low as 1.5 m. However, due to complications in postponing and rescheduling survey visits, those surveys continued and were completed. The potential effect of less than ideal underwater visibility on reef fish survey result is discussed in later sections.

Characterization of reef fish species and familial diversity

A total of 92 reef fish species were identified and recorded from the survey at 12 sites. The full list of reef fish records is presented in Appendix 2. The cumulative reef fish species records against number of surveys started to level off gradually when approaching the end of the whole survey series. However new records were made throughout the survey, and new reef fish species was recorded in every survey except one of them which was conducted at the lowest underwater visibility recorded (Figure 2). This suggests that the reef fish survey could probably provide an updated snapshot on the reef fish diversity at the sites surveyed, but more surveys will need to be conducted (until the cumulative reef fish species record reaches plateau) before the results may be taken as a comprehensive record of reef fish inhabiting the coral and rocky reef habitats in these areas.

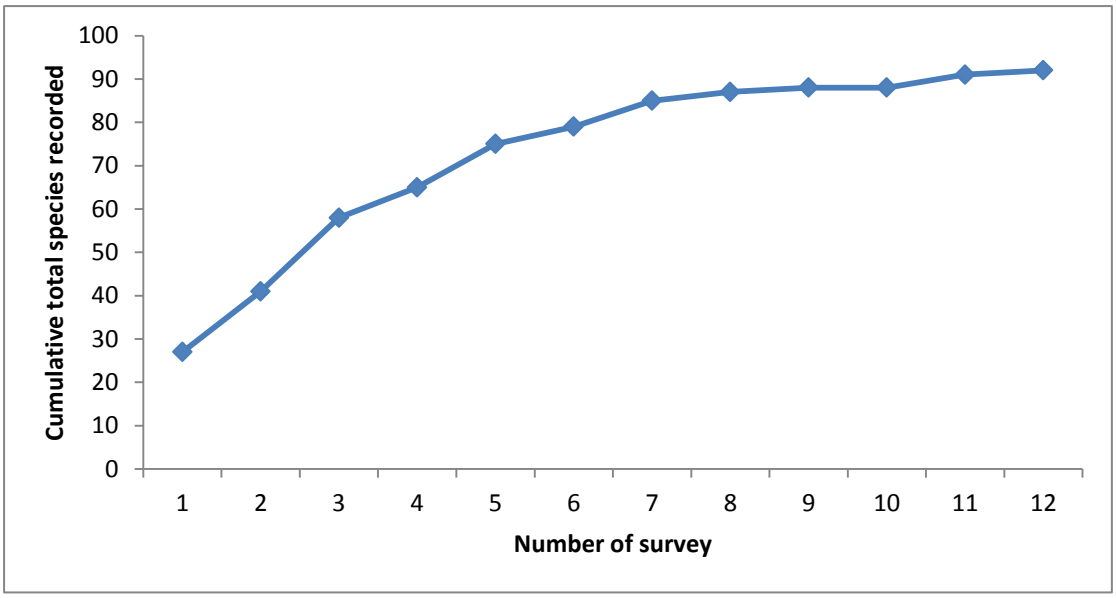

Figure 2. Cumulative reef fish records against number of surveys, showing the commencement of the levelling off near the end of the survey series.

The 92 recorded reef fish species fall into 38 families (Figure 3). Bases on the results from the reef fish survey, the top two most species-rich families are Labridae and Pomacentridae (with 10 species recorded for each), followed closely by Chaetodontidae and then Serranidae. Notably, these families are often some of the most speciose families in the South China Sea area, including Hong Kong, the Pratas Reef, Hainan Island and the Pescadores Islands (Sadovy and Cornish 2000).

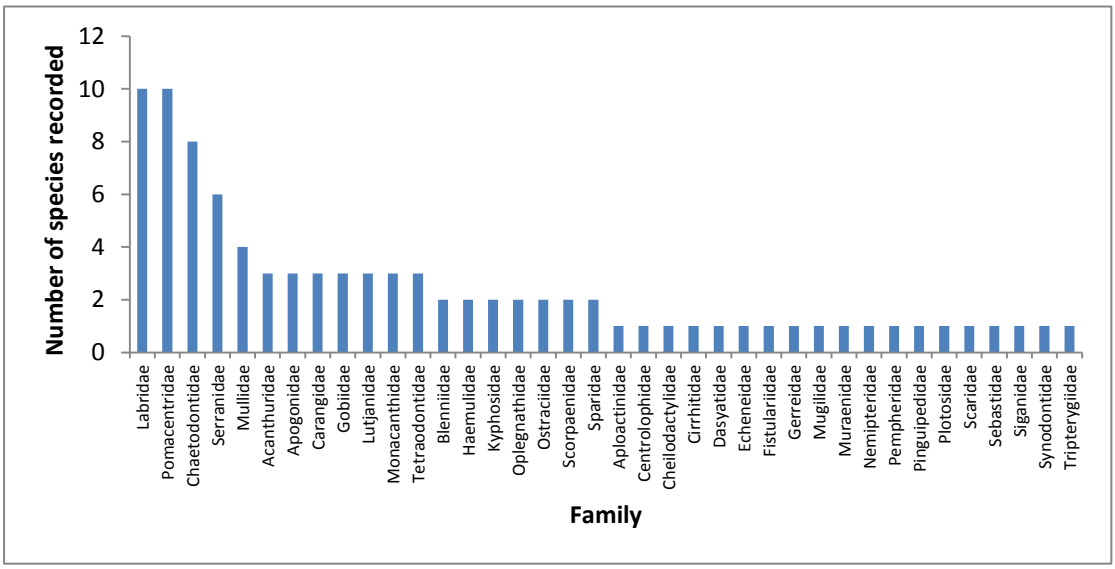

Figure 3. Number of species recorded in this survey for each family.

Among the 92 recorded reef fish species, there are nine species which were consistently spotted in the majority of the surveys. These include one cardinalfish, *Apogon doederleini*; three wrasses, *Halichoeres nigrescens*, *Stethojulis interrupta*, and *Thalassoma lunare*; two damselfishes, *Abudefduf bengalensis* and *Chromis notata*; one rockfish, *Sebastiscus marmoratus*; one grouper, *Diploprion bifasciatum*; and the rabbitfish, *Siganus canaliculatus*. The last species, *Siganus canaliculatus*, is the only species that was present and recorded in all surveys. All the other species listed above were recorded in at least 80% of all surveys. These nine species have also been recorded in reef fish surveys conducted in Hong Kong in the past two decades, with abundance varying from common to uncommon (Sadovy and Cornish 2000; To *et al*. 2013).

Notably, a number of species which are found to be much more common or even abundant in reef fish surveys in Hong Kong (To *et al.*, 2013), such as the cardinalfish, *Apogonichthyoides pseudotaeniatus*; blenny, *Petroscirtes breviceps*; damselfishes, *Neopomacentrus bankieri* and *Amphiprion clarkii*; sandperch, *Parapercis snyderi*; and grouper, *Cephalopholis boenak*, have yet to show a correspondingly strong presence in this survey, as shown in Appendix 2.

The reef fish survey records include nine species that are considered 'rare', according to reef fish surveys conducted in Hong Kong in the last two decades (Sadovy and Cornish 2000; To *et al*. 2013). These include the tang, *Zebrasoma velifer*; veletfish, *Paraploactis kagoshimensis*; butterflyfish, *Chaetodon plebeius*; goatfish, *Parupeneus heptacanthus*; two knifejaws, *Oplegnathus fasciatus* and *Oplegnathus punctatus*; boxfish, *Ostracion cubicus*; damselfish, *Pomacentrus coelestis*; and the sea bream, *Evynnis cardinalis*. Notably, this last species, *Evynnis cardinalis*, is listed as an 'Endangered' species by the IUCN (Iwatsuki and Carpenter 2014). These nine species were recorded in about 8 – 16% of all surveys.

Notable species records

The records of the two knifejaws, *Oplegnathus fasciatus* and *Oplegnathus punctatus*, are of particular importance. A small group of three individuals of *Oplegnathus fasciatus* of about 15 cm TL was sighted at Xiaosanmen, Northeast, while a single individual of *Oplegnathus punctatus* of a similar size was spotted hiding within rock crevices at Sanmen Island East. These two species are becoming rare in Hong Kong (Sadovy and Cornish 2000; To *et al*. 2013). The records of these two species in Hong Kong in recent years, according to the Hong Kong reef fish survey conducted by SS and AT, comprise of only a handful of sightings. The rarity of these species are

unsurprising, due to the generally high fishing pressure (both commercial and recreational) and overfished state of marine fishery resources in Hong Kong, and the high price paid for these species in the market (Lau and Li, 2000; Sadovy and Cornish, 2000; To *et al*., 2013).

The morwong, *Cheilodactylus zonatus*, was considered as 'moderately abundant' in the late 1990s (Sadovy and Cornish 2000), but is more recently regarded as 'rare' in Hong Kong (To *et al*. 2013). Notably, individuals of this species were recorded at four sites of this study, rendering this species relatively more commonly encountered among those surveyed sites in this study than in Hong Kong. Nevertheless, further surveys can help establish a more robust and comprehensive comparison between the relative abundance of this species in and around Daya Bay, Shenzhen and Hong Kong.

The record of a single stingray, *Taeniura meyeni*, at Sanmen Island is worth mentioning. The site was composed of large boulders. While surveyors AT and SS were doing the surveys near the sea bottom, an individual of this species with an estimated wing span of about 1.5 m swam over. The tail of that individual was broken; suggesting that the individual was released by fishermen after the tail was cut. This is the largest individual of *Taeniura meyeni* observed in the wild by both authors in Hong Kong and adjacent waters in more than 700 dives.

Reef fish diversity among sites

Among the 12 sites surveyed, the two sites at Guiwan offered the highest reef fish species records, with at least 40 species records in a single survey. This is closely followed by Sanmen Island, East, where 38 species records were made (Figure 4). Based on the observation made on all surveyed sites, the two sites of Guiwan are hosts to a relatively diverse range of habitats, including rubble areas, hard coral communities, boulder reefs, soft coral communities and artificial rock structures. This diversity of habitats, and the complexity offered by these structures, might have contributed to the observed higher diversity of reef fish in these sites.

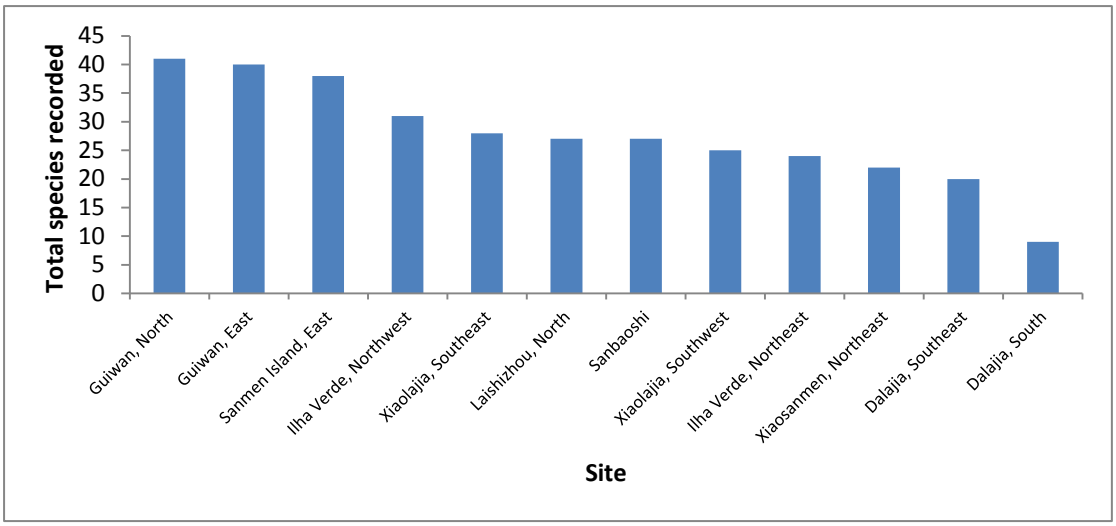

Figure 4. The total number of reef fish species recorded at each site.

Notably, the underwater visibility might also link to the relatively higher reef fish diversity recorded in the two surveys at Guiwan. A correlation analysis between the number of species recorded at each site and the underwater visibility showed a significant relationship between the two parameters ($p < 0.05$, $R^2 = 0.67$) (Figure 5). This suggests that the relatively higher underwater visibility during the survey at the two sites at Guiwan might have allowed for a higher diversity of reef fish to be recorded; likewise, the very low underwater visibility experienced at Dalajia, Southeast and Dalajia, South might have contributed to the relatively low number of species recorded, especially at the latter site, in which only nine reef fish species records were made.

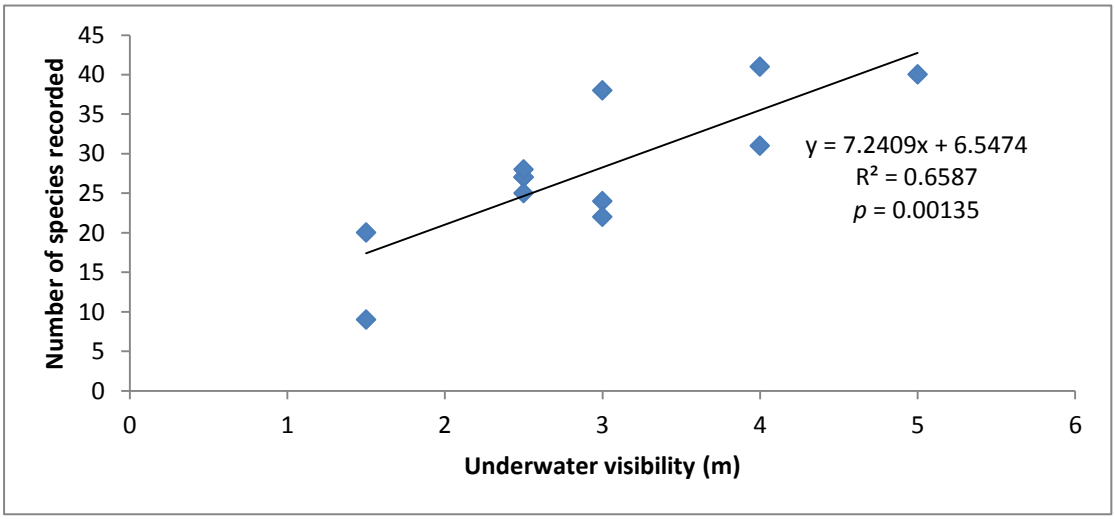

Figure 5. Relationship between the number of species recorded and the underwater visibility.

Conclusion

The rapid reef fish surveys made at 12 sites in and around the waters of Daya Bay documented 92 species, despite the very small number of surveys conducted at each site and the unexpectedly low underwater visibility during some of the surveys. The sightings of several commercially important and highly valuable reef fish species, and the exceptionally large size of one particular commercial species, strongly suggests the under-explored, under-documented and under-valued status of reef fish diversity in and around Daya Bay. Far more extensive surveillance is necessary before a dataset that is both representative of Daya Bay's reef fish biodiversity and comparable to that of other regions around mainland China can be obtained. Given our currently very limited understanding of the area's reef fish biodiversity, future and more in-depth research is highly warranted, and long-term monitoring, such as through regular underwater surveys, should be considered. This will provide essential information highly relevant to public education, fisheries management, and government conservation plans for reef fishes in and around Daya Bay.

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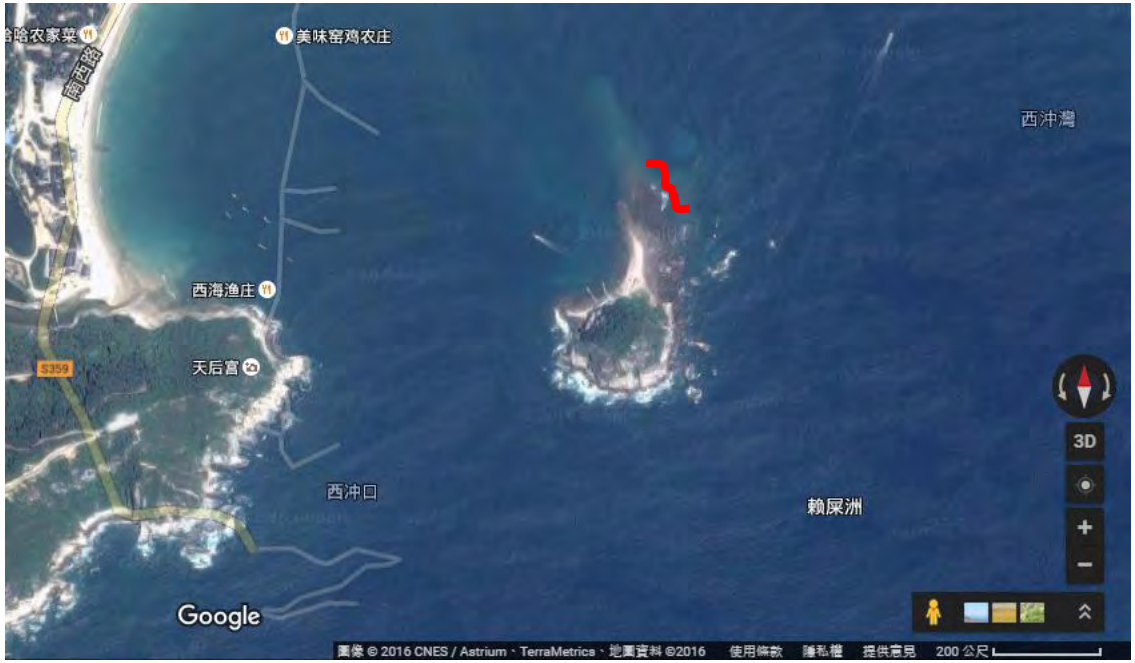
Appendix 1. Details of each survey sites.

Site (English)	Site (Chinese)	GPS readings	Site descriptions
Laishizhou, North	賴氏洲,北	Not collected	The site is located on the north side of an outlying island off the beach of Xichongwan (西沖灣). There is a resort with pier on the northwestern side of the island. The site is composed of rocky reefs, with some patches of coral communities, such as *Platygyra* species and occasional patches of macroalgae. 

Sanbaoshi	三寶石	N22°29.788’ E114°35.901’	The site is located nearshore, just opposite to a few large boulders rising from the sea surface. The habitat of the site is mainly sand and rubble, and interspersed with small boulders, with occasional patches of macroalgae. The site regularly receives wave action when vessels or speed-boats pass by this area. Abandoned fishing nets were observed at the site during the survey. 

Guiwan, East	鬼灣,東	N22°27.164’ E114°38.370’	The site is located in an outlying island situated between the Sanmen Island and the Xiaosanmen Island. A series of housing estates were being constructed on Sanmen Island nearshore, and this site is located on the southeast side of the construction site. The site is mainly a rocky reef, with one area at relatively deeper waters teemed with soft corals. A relatively higher concentration of coral communities is present at this site, including both encrusting and table corals. There is an area approximately half the size of a basketball court covered by anemone, where a considerable number of anemonefish (*Amphiprion clarkii*) can be found. The site is undoubtedly one of the best sites in terms of habitat diversity. Anglers using hook and line were observed during the survey. 

Guiwan, North	鬼灣,北	N22°27.164’ E114°38.370’	This site is a continuation of the previous site described. The habitat is mainly boulders and the nearshore side of this site is a typical rocky reef. Coral coverage is relatively lower than the previous site described. Near the end of the site is some artificial rocky structures. 
Ilha Verde, Northwest	青洲,西北	N22°24.376’ E114°39.733’	This site is situated in an outlying island. The site is a rocky reef, however, there is relatively less boulder than other rocky reefs surveyed in this study. Part of the site is almost a barren rocky reef which regularly receives wave action, and is teemed with barnacles. Patches of hard corals can be found. Cage traps were observed during the survey.

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Ilha Verde, Northeast	青洲,東北	N22°24.477’ E114°40.005’	This site is situated in the same island as the previously described site. It is a rocky reef, with large boulders. Coral communities are relatively scarce at this site. 

Sanmen Island, East	大三門,東	N22°28.160’ E114°39.037’	This site is located near the eastern-most tip of one of the largest outlying island in the Daya Bay. It is a rocky reef, and is composed of very large boulders interspersed with sandy and rubble substrate. Coral communities are very scarce. 

Xiaosanmen, Northeast	小三門,東北	N22°26.958’ E114°39.310’	The site is located in the northeastern tip of another relatively large outlying island in Daya Bay. It is a rocky reef, with large bounders. A part of the site is barren reef with occasional patches of hard corals. At least 10 cage traps were observed at this site during the survey. 

Dalajia, Southeast	大辣甲,東南	N22°34.013’ E114°39.326’	The site is located near the southeastern tip of one of the largest outlying islands in Daya Bay. When facing the site from the sea, the left hand side is borders by a rocky reef rising from the sea surface, and the front area is a beach along the shore. The site is a rocky reef; however much of the area is a barren reef with occasional patches of soft and hard corals, interspersed with sand and rubble in the substrate. 

Dalajia, South	大辣甲,南	N22°33.811’ E114°33.187’	This site is located on the southwestern side of the large outlying island as described in the previous site. It is a rocky reef, but a considerable area is composed of barren reef. The site regularly receives wave action. Soft corals and gorgonian are present at this site. 

Xiaolajia, Southeast	小辣甲,東南	N22°36.853’ E114°38.052’	The site is located on the eastern side of a medium-sized outlying island in the Daya Bay. It is a rocky reef, composed of mainly barren reef, with occasional medium-sized boulders and patches of encrusting hard corals. 

Xiaolajia, Southwest	小辣甲,西南	N22°36.767’ E114°37.779’	The site is located on the western side of the island as described for the previous site. This site is a rocky reef and regularly receives wave action. The site composes of partly barren reef and partly medium-sized to large boulders. Patches of encrusting hard corals are present and there are occasional patches of branching coral such as *Acropora* species. A few table corals such as *Turbinaria* species can also be found. At least five cage traps were observed during the survey. 

Appendix 2. Detail records of reef fish at all survey sites; S = single (1), F = few (2 – 10), M = many (11 – 100), A = abundant (> 100).

		Laishizhou, North 賴氏洲,北	Sanbaoshi 三寶石	Guiwan, East 鬼灣,東	Guiwan, North 鬼灣,北	Ilha Verde, Northwest 青洲,西北	Ilha Verde, Northeast 青洲,東北	Sanmen Island, East 大三門,東	Xiaosanmen, Northeast 小三門,東北	Dalajia, Southeast 大辣甲,東南	Dalajia, South 大辣甲,南	Xiaolajia, Southeast 小辣甲,東南	Xiaolajia, Southwest 小辣甲,西南	Percentage presence among all survey sites	Remarks on rare or common species #
Acanthuridae	*Acanthurus dussumieri*		S		S	S		S	F					41.7	
Acanthuridae	*Prionurus scalprum*					F			S					16.7	
Acanthuridae	*Zebrasoma velifer*					S								8.3	rare
Aploactinidae	*Paraploactis kagoshimensis*			F										8.3	rare
Apogonidae	*Apogon doederleini*	S	F	F	F	M	M	M	M	F		F	F	91.7	common
Apogonidae	*Apogonichthyoides pseudotaeniatus*			M	F					F		F	S	41.7	
Apogonidae	*Ostorhinchus fleurieu*							M	M	F			F	33.3	
Blenniidae	*Entomacrodus stellifer lighti*		M				M	M	S					33.3	
Blenniidae	*Petroscirtes breviceps*		F	F	F				S					33.3	
Carangidae	*Carangoides praeustus*									F				8.3	
Carangidae	*Selaroides leptolepis*				F	F	M		M			M	M	50.0	
Carangidae	*Seriola dumerili*							F						8.3	
Centrolophidae	*Psenopsis anomala*						S	F						16.7	
Chaetodontidae	*Chaetodon auriga*	F		F	F	F	S	F				S		58.3	

Chaetodontidae	*Chaetodon auripes*			**S**	**F**	**F**	**F**	**M**	**S**					50.0	
Chaetodontidae	*Chaetodon lineolatus*			**S**	**F**							**S**		25.0	
Chaetodontidae	*Chaetodon octofasciatus*				**S**									8.3	
Chaetodontidae	*Chaetodon plebeius*				**S**									8.3	rare
Chaetodontidae	*Chaetodon speculum*			**F**	**F**								**S**	25.0	
Chaetodontidae	*Chaetodon wiebeli*		**S**	**F**	**F**	**S**						**F**	**S**	50.0	
Chaetodontidae	*Heniochus acuminatus*			**S**										8.3	
Cheilodactylidae	*Cheilodactylus zonatus*		**F**					**S**	**S**			**S**		33.3	
Cirrhitidae	*Cirrhitichthys aureus*	**F**			**S**			**S**						25.0	
Dasyatidae	*Taeniura meyeni*						**S**	**S**						16.7	
Echeneidae	*Echeneis naucrates*							**F**						8.3	
Fistulariidae	*Fistularia commersonii*					**F**	**F**							16.7	
Gerreidae	*Gerres oblongus*				**F**							**F**	**S**	25.0	
Gobiidae	*Amblyeleotris gymnocephala*							**S**	**S**					16.7	
Gobiidae	*Eviota sp.*	**S**												8.3	
Gobiidae	*Istigobius diadema*			**F**	**F**			**M**		**F**		**F**		41.7	
Haemulidae	*Diagramma pictum*			**F**		**F**	**S**	**F**		**F**				41.7	
Haemulidae	*Parapristipoma trilineatum*	**M**												8.3	
Kyphosidae	*Girella punctata*				**S**		**S**							16.7	
Kyphosidae	*Microcanthus strigatus*		**F**		**F**									16.7	
Labridae	*Anampses caeruleopunctatus*		**S**											8.3	
Labridae	*Halichoeres kneri*											**S**		8.3	

Labridae	*Halichoeres nebulosus*						F							8.3	
Labridae	*Halichoeres nigrescens*	M	M	M	M	M	F	F		F		F	F	83.3	common
Labridae	*Halichoeres tenuispinis*	F	F	M		M	M	M						50.0	
Labridae	*Labroides dimidiatus*	F		S				F						25.0	
Labridae	*Parajulis poecilepterus*					F								8.3	
Labridae	*Pseudolabrus eoethinus*		S											8.3	
Labridae	*Stethojulis interrupta*	M	F	M	F	M	M	M		F		F	M	83.3	common
Labridae	*Thalassoma lunare*	M	S	M	F	M	F	M		F	F	F		83.3	common
Lutjanidae	*Lutjanus argentimaculatus*											S		8.3	
Lutjanidae	*Lutjanus russellii*		F			S				S		F		33.3	
Lutjanidae	*Lutjanus stellatus*												S	8.3	
Monacanthidae	*Monacanthus chinensis*	S		F	F		S						S	41.7	
Monacanthidae	*Paramonacanthus sulcatus*	S								S				16.7	
Monacanthidae	*Stephanolepis cirrhifer*					F		F						16.7	
Mugilidae	*Mugil cephalus cephalus*					F								8.3	
Mullidae	*Parupeneus biaculeatus*	M	M	M	M				S					41.7	
Mullidae	*Parupeneus heptacanthus*			S										8.3	rare
Mullidae	*Parupeneus indicus*		S				S	S			S			33.3	
Mullidae	*Upeneus tragula*					S								8.3	
Muraenidae	*Gymnothorax reevesii*		S					S						16.7	
Nemipteridae	*Scolopsis vosmeri*			M	F									16.7	
Oplegnathidae	*Oplegnathus fasciatus*								F					8.3	rare

Oplegnathidae	*Oplegnathus punctatus*							S						8.3	rare
Ostraciidae	*Ostracion cubicus*					S						S		16.7	rare
Ostraciidae	*Ostracion immaculatus*								S					8.3	
Pempheridae	*Pempheris ovalensis*			M	M	F							M	33.3	
Pinguipedidae	*Parapercis snyderi*			M	F									16.7	
Plotosidae	*Plotosus lineatus*	S												8.3	
Pomacentridae	*Abudefduf bengalensis*	M	F	F	F		F	F	M	F	F	F	F	91.7	common
Pomacentridae	*Abudefduf sexfasciatus*		F										F	16.7	
Pomacentridae	*Abudefduf sordidus*						S	F						16.7	
Pomacentridae	*Abudefduf vaigiensis*	M	F		F	M		F	M		F	F	F	75.0	
Pomacentridae	*Amphiprion clarkii*	F	F	M	M					F		F	F	58.3	
Pomacentridae	*Chromis notata*	A		M	M	A	M	A	A	M	F	A	A	91.7	common
Pomacentridae	*Dascyllus trimaculatus*			S										8.3	
Pomacentridae	*Neopomacentrus bankieri*	A		F	F			F		M	F	M	A	66.7	
Pomacentridae	*Neopomacentrus cyanomos*	M		F								A	A	33.3	
Pomacentridae	*Pomacentrus coelestis*	S				F								16.7	rare
Scaridae	*Scarus ghobban*			S	F				S				F	33.3	
Scorpaenidae	*Dendrochirus zebra*				F			S						16.7	
Scorpaenidae	*Scropaenopsis cf. cirrhosa*		S	S	S	S		M	S					50.0	
Sebastidae	*Sebastiscus marmoratus*	F	F	F	M	F		M	M	F	F	F		83.3	common
Serranidae	*Cephalopholis boenak*	F		F	M			S		F		M	M	58.3	
Serranidae	*Diploprion bifasciatum*			F	M	S	S	M	M	F	S	F	F	83.3	common

Serranidae	*Epinephelus awoara*					F								8.3	
Serranidae	*Epinephelus fasciatomaculosus*							S						8.3	
Serranidae	*Epinephelus quoyanus*			F									S	16.7	
Serranidae	*Epinephelus trimaculatus*	S		S										16.7	
Siganidae	*Siganus canaliculatus*	M	M	F	M	M	A	M	A	F	F	M	S	100.0	common
Sparidae	*Evynnis cardinalis*				F									8.3	rare ^
Sparidae	*Pagrus major*		F	F	A									25.0	
Synodontidae	*Synodus dermatogenys*			F	S									16.7	
Tetraodontidae	*Arothron hispidus*											S		8.3	
Tetraodontidae	*Chelonodon patoca*	F	M	F	M									33.3	
Tetraodontidae	*Takifugu alboplumbeus*					F	F	M	F	F		F	F	58.3	
Tripterygiidae	*Enneapterygius etheostomus*	S	F			F	F	S						41.7	
Total species count		27	27	40	41	31	24	38	22	20 ~	9 ~	28	25		

rare species are those that are considered as ‘rare’ by Sadovy and Cornish (2000) and To *et al*. (2013). Common species are considered as species whose percentage presence among all survey sites exceeds 80% in this study.

^ this species is considered as “Endangered” by the IUCN.

~ very low underwater visibility (1.5 m) experienced during the reef fish survey.

Appendix 3. Photos taken during the reef fish surveys.

Photo 1. Yellow hawkfish, *Cirrhitichthys aureus*, at Laishizhou.

Photo 2. Abandoned fish net, at Sanbaoshi.

Photo 3. Spottedtail morwong, *Cheilodactylus zonatus*, a commercially valuable species, observed at Sanboshi.

Photo 4. A juvenile bluespotted wrasse, *Anampses caeruleopunctatus*, at Sanboshi.

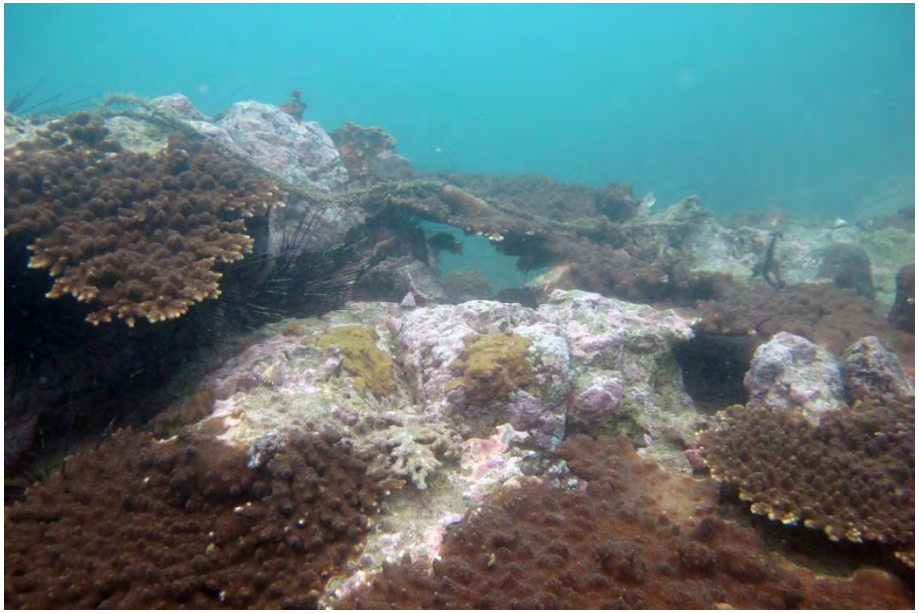

Photo 5. Coral communicates at Guiwan.

Photo 6. An individual of pennant coralfish, *Heniochus acuminatus*, was observed at Guiwan.

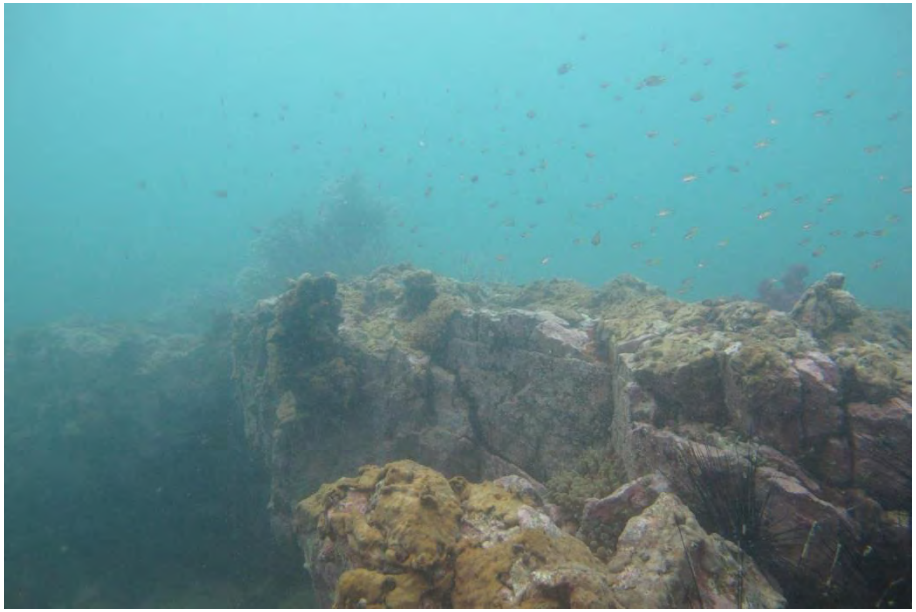

Photo 7. A section of barren rocky reef at Guiwan.

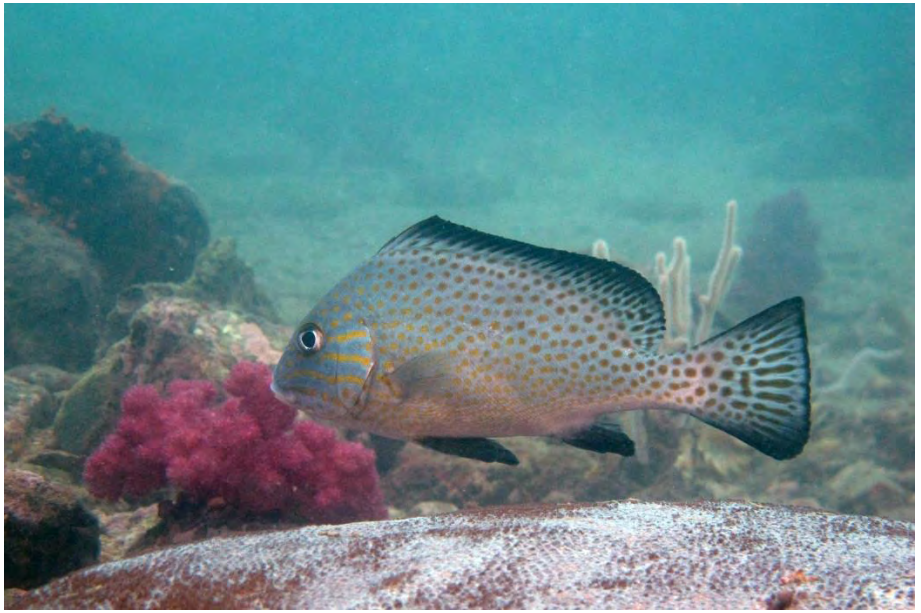

Photo 8. A few individuals of painted sweetlips, *Diagramma pictum*, were observed to form a small group, at Guiwan.

Photo 9. A big patch of rocky reef at Guiwan is covered with anemones.

Photo 10. A pair of velvetfish, *Paraploactis kagoshimensis*, was observed at Guiwan. These individuals were well camouflaged against the substrate.

Photo 11. U-mark sandperch, *Parapercis snyderi*, uses the pelvic fin to perch on boulders.

Photo 12. A juvenile longfin grouper, *Epinephelus quoyanus*, observed at Guiwan.

Photo 13. A group of barred soapfish, *Diploprion bifasciatum*, at Guiwan. This is one of the most common species found in this study.

Photo 14. False kelpfish, *Sebastiscus marmoratus*, another common species found in this study.

Photo 15. Zebra turkeyfish, *Dendrochirus zebra*, hiding among coral communities at Guiwan.

Photo 16. A group of oriental butterflyfish, *Chaetodon auripes*, and threadfin butterflyfish, *Chaetodon auriga*, at Guiwan.

	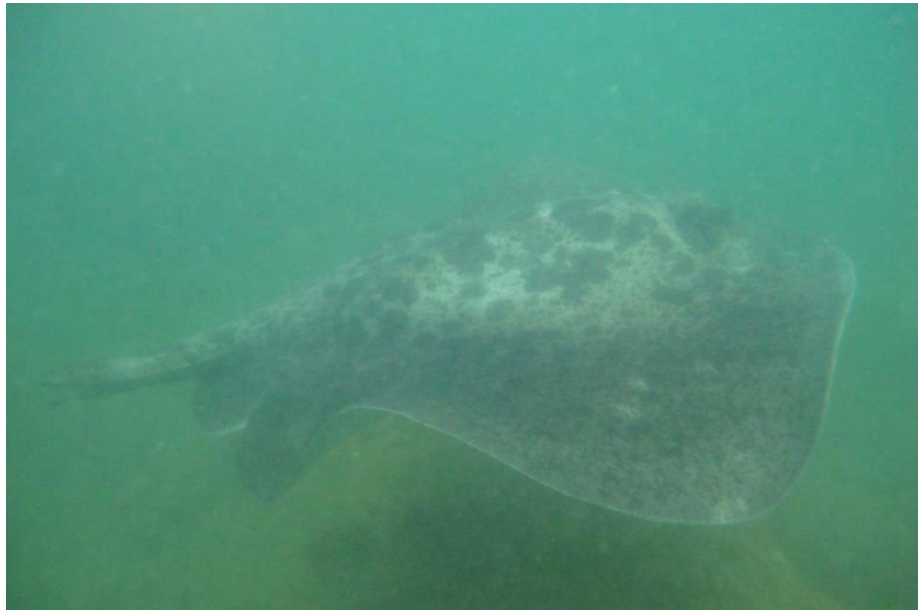
Photo 17. A series of cage traps was observed at Ilha Verde during the survey.	Photo 18. A round ribbontail ray, *Taeniura meyeni*, with estimated wing span of 1.5 m, was observed over rocky reef at Sanmen Island.

	
Photo 19. Spotted knifejaw, *Oplegnathus punctatus*, a commercially valuable species, was sighted at Sanmen Island.	Photo 20. A small group of barred knifejaw, *Oplegnathus fasciatus*, another commercially valuable species, was observed at Xiaosanmen.

	
Photo 21. Mudbank filefish, *Paramonacanthus sulcatus*, sighted at Dalajia.	Photo 22. White-spotted puffer, *Arothron hispidus*, observed at Xiaolajia.