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CORAL REEF FISH COMMUNITY AT PULAU BIDONG, TERENGGANU, SOUTH CHINA SEA

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Abstract: Reef fishes are among the main constituents of coral reef ecosystems and an indicator of ecosystem health. The aim of this study is to determine the species occurrences of coral reef fish at Pulau Bidong, which is in the South China Sea off the east coast state of Terengganu, Peninsular Malaysia. Fish surveys were conducted from May to July 2018 using the visual census technique during SCUBA dives around the island. A total of 30 families, 61 genera and 101 species of coral reef fishes were identified. This indicates considerably high fish diversity and reflects the good condition of the reefs. Of the species identified, 65 % were reef-associated, 12 % were pelagic-oceanic and the rest (23 %) appeared to be found in both zones. The fish species were classified according to social behaviour (territorial, gregarious and nocturnal), feeding habits (carnivorous, herbivorous, omnivorous, planktivores, corallivores and invertebrate consumers) and IUCN Red List status (endangered, near threatened, vulnerable and data deficient). Of all the fish identified, 67±2 % were recorded either at Karang Tengah, Batu Payung or Dinding Laut — reef sites with considerable benthic structural complexity. Such reefs, with complex underwater features that attract a variety of fish species, are particularly important areas of Pulau Bidong and may provide an ecological baseline data that is useful for research and conservation management.

Keywords: Biodiversity, coral reef fishes, Pulau Bidong, South China Sea.

Introduction

The South China Sea is one of the most productive, large marine ecosystems with diverse plants and animals (Matsunuma *et al.*, 2011), where more than 710 marine fish species have been listed (Mohsin & Ambak, 1996). Coral reef fishes contribute to a significant constituent of reef ecosystems, which represent the most diverse vertebrate communities (Jones *et al.*, 2002). They come in a variety of shapes, sizes, colours and behaviours that blend well in their habitats' environment (Kingsford & Battershill, 1998; Anderson & Millar, 2004). However, published information regarding the abundance of reef indicator fishes in Peninsular Malaysia, Sabah and Sarawak is still limited since 2007. In addition, most surveyed sites, particularly in Peninsular Malaysia, are focused on marine protected areas (Hyde *et al.*, 2018).

Pulau Bidong is a small island off the coast of Terengganu in the South China Sea, with an area of approximately 1 km^2 . The island has been uninhabited since the Vietnamese refugees in the camp there were repatriated in the late 1980s (Grismer *et al.*, 2014). It is not gazetted as a marine park and tourism development is limited. The waters around the island contain a variety of benthic reef life forms, ranging from branching corals to massive rocky reef habitats, each hosting distinct fish communities (Matsunuma *et al.*, 2011). Previously, Rumeaida *et al.* (2014) assessed the diversity and abundance of fishes in Pulau Bidong that were caught using traps, gill nets and also sighted in

SCUBA dives, whereas Arai *et al.* (2015) and Amalina *et al.* (2016) studied the trophic levels of coral reef fish. However, assessments of coral reef fish occurrence in Pulau Bidong are still inadequate. The present status on the reef fish community structure in relation to underwater reef structural features of Pulau Bidong remains unclear.

Coral fish composition and distribution in certain reef ecosystems are controlled by biotic and abiotic factors, such as recruitment, food availability, coastal processes, local topography and physicochemical properties of the water (Harris, 1995). They are also affected by long-term changes in hydrological and meteorological parameters (Hossain *et al.*, 2012). This study recorded spatial occurrence of coral reef fishes in Pulau Bidong and classified them by their respective taxonomic groups to assess species richness, besides conservation status, rearing behaviour and feeding habits, to understand the functionality and vulnerability of the fish communities.

Materials and Methods

Study location

Coral reef fish surveys were conducted around Pulau Bidong (Lat. 5.62°N, Long. 103.06°E), Terengganu, in the east coast of Peninsular Malaysia (Figure 1). A preliminary manta tow survey was conducted around the island before the selection of 10 sampling sites: Pantai Pasir Cina, Batu Menangis, Batu Payung, Teluk Air, Dinding Laut, Christmas Garden, Karang Tengah, Pantai Tenggara, Vietnamese Jetty and Bidong Underwater Gallery (Figure 1). The sites represented various reef structures chosen to maximise fish diversity at the coral reefs (Table 1).

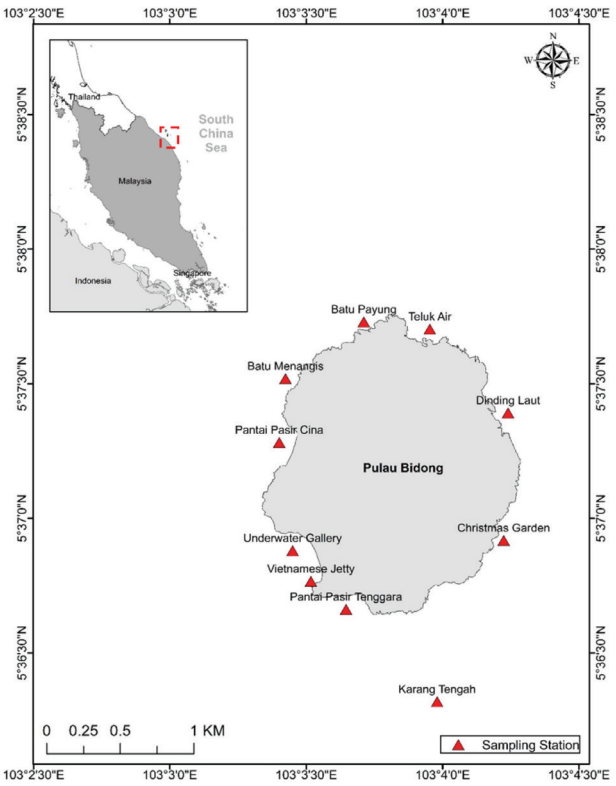

Figure 1: Map showing the location of Pulau Bidong in Peninsular Malaysia and sites around the 1km^2 island where coral reef fish surveys were conducted

Table 1: List of sampling date and underwater reef structural features at each survey station at Pulau Bidong, Terengganu

Station	Sampling Date	Description
Pantai Pasir Cina (PC)	10 May 2018	Branching coral-dominated
Batu Menangis (BM)	13 May 2018	Branching coral, patchy massive coral-bedrock
Batu Payung (BP)	5 July 2018	Massive coral, rock with attached coral (encrusting, branching, tabulate), ravines, crevices and holes
Teluk Air (TA)	16 May 2018	Massive coral, rock with attached coral (encrusting, branching, tabulate), ravines, crevices and holes
Dinding Laut (DL)	28 June 2018	Massive coral, encrusting coral, facerock-bedrock with ravines, crevices and holes
Christmas Garden (CG)	16 May 2018	Mixed branching, foliose, submassive, and encrusting coral
Karang Tengah (KT)	28 June 2018	Submerged reef: mixed branching, foliose, and massive coral, rock with attached coral, ravines, crevices and holes
Pantai Tenggara (PT)	16 May 2018	Mixed branching, foliose, massive coral
Vietnamese Jetty (VJ)	10 May 2018	Mixed branching, tabulate, foliose and massive coral
Underwater Gallery (UG)	10 May 2018	Artificial reef on sandy bottom

Field Sampling

Fish survey was conducted using underwater visual census (UVC) technique during SCUBA dives (English *et al.,* 1997). Fish occurrence was recorded at water depths of around six to 10 metres for all sampling sites, and a distance of around 200 to 250 m by drift with parallel movement. Fish species were identified to the lowest taxonomic level (common species) using a standard identification procedure according to the *Field Guide to Fishes and Crustaceans of the Southeast Asian Region* (Lim *et al.*, 2018) and *Reef Fish Identification - Tropical Pacific* (Allen *et al.*, 2003), as well as details from the Global Information System of Fishes (FishBase) (Froese & Pauly, 2018). Photos were taken to help in the species identification. Fish species were also recorded during snorkelling or SCUBA diving around Pulau Bidong outside the sampling period.

Data Analyses

In this present study, we grouped reef fish into the three categories, namely the typical habitat zone, social behaviour and feeding habits. Reef fish that resided within the reef area were categorised as reef-associated, while those that moved in the water column were classified as pelagic-oceanic (Sale, 2006). The social behaviour of reef fish was categorised as territorial, gregarious or nocturnal. The feeding habits of fish associated to certain trophic levels were categorised as carnivorous, herbivorous, planktivorous, corallivorous, omnivorous and invertebrate consumers as stated in the FishBase website (Froese & Pauly, 2018). Conservation status was evaluated according to the IUCN Red List Categories and Criteria, which divided the species into nine categories: Not Evaluated, Data Deficient, Least Concern, Near Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in the Wild, and Extinct (IUCN, 2018). Fish species occurrence was compared between survey sites. The occurrence of fish species depended on their percentage of presence from

the total number of sampling stations (Hamza *et al.* 2013) as stated in Equation 1.

$$Percentage\ of\ fish\ occurence = \frac{x}{y} \times 100\% \quad \text{(Eq. 1)}$$

Where,

x = Occurrences of fish species at each station

y = Total occurrences of fish species at all stations

A multi-dimensional scaling (MDS) analysis was used to illustrate the differences between coral reef fish communities in the survey sites using Bray-Curtis similarities calculated based on species occurrence data as described by Clarke *et al.* (2008)to guard against interpretation of sample patterns that could have been obtained by chance, and two new tests of this type are described. In the multivariate analyses that arise in community ecology and many other environmental contexts, e.g. in linking assemblage patterns to forcing environmental variables (gradient analysis. All statistical analyses were performed using PRIMER 6 version 6.1.12.

Results and Discussion

Coral reef fish diversity

In this study, 30 families, 61 genera and 101 species of coral reef fish were identified (Table 2). This result indicated considerably high fish diversity in Pulau Bidong, despite not being gazetted as a "marine park" by the authorities, which consequently resulted in a lack of conservation measures on the island and its surrounding waters compared with other locations off Terengganu. During the Marine Biodiversity Expedition in 2012, where surveys were conducted in the state's marine parks, 88 fish species were recorded at Pulau Perhentian, 66 at Pulau Yu Besar/Yu Kecil, 112 at Pulau Kapas and 121 at Pulau Tenggol (Bachok *et al.*, 2013).

Table 2: List of fishes observed in Pulau Bidong, Terengganu, and grouped according to their typical habitat zone,, IUCN status, social behaviour and feeding type

Family / Species	Common Name	Habitat Zone	Social Behaviour	Feeding Habit	IUCN Status
UNDERWATER VISUAL CENSUS					
Acanthuridae (Surgeonfishes)					
Naso lituratus (Forster, 1801)	Orangespine Unicornfish	RA	T	HV	LC
Balistidae (Triggerfish)					
Pseudobalistes flavimarginatus (Rüppell, 1829)	Yellowmargin Triggerfish	RA	T	IC	NE
Belonidae (Needlefishes)					
Strongylura incisa (Valenciennes, 1846)	Reef Needlefish	PO	G	IC	NE
Caesionidae (Fusiliers)					
Caesio cuning (Bloch, 1791)	Redbelly Yellowtail Fusilier	PO	G	PV	NE
Pterocaesio chrysozona (Cuvier, 1830)	Goldband Fusilier	PO	G	PV	NE
Caesio teres (Seale, 1906)	Blue and Yellow Fusilier	PO	G	PV	LC
Caesio lunaris (Cuvier, 1830)	Lunar Fusilier	PO	G	PV	LC
Caesio xanthonota (*Bleeker, 1853*)	Yellowback Fusilier	PO	G	PV	LC
Dipterygonotus balteatus (Valenciennes, 1830)	Mottled Fusilier	PO	G	PV	LC

Chaetodontidae (Butterflyfish)					
Chaetodon octofasciatus (Bloch, 1787)	Eightbanded Butterflyfish	RA	G	CLV	LC
Coradion chrysozonus (Cuvier, 1831)	Goldengirdled Coralfish	RA	G	CLV	LC
Chelmon rostratus (Linnaeus, 1758)	Copperband Butterflyfish	RA	G	CLV	LC
Heniochus acuminatus (Linnaeus, 1758)	Longfin Bannerfish	RA	G	CLV	LC
Heniochus varius (Cuvier, 1829)	Humphead Bannerfish	RA	G	CLV	LC
Cirrhitidae (Hawkfish)					
Cirrhitichthys aprinus (Cuvier, 1829)	Threadfin Hawkfish	RA	T	CV	LC
Ephippidae (Batfish)					
Platax orbicularis (Forsskål, 1775)	Copper Batfish	PO	G	HV	NE
Grammatidae (Basslet)					
Gramma loreto (Poey, 1868)	Fairy Basslet	RA	T	HV	LC
Haemulidae (Sweetlips-Grunts)					
Diagramma picta picta (Thunberg, 1792)	Yellow-spotted Slatey	PO,RA	G	CV	NE
Plectorhinchus lineatus (Linnaeus, 1758)	Yellow-banded Sweetlips	PO,RA	G	CV	LC
Holocentridae (Squirrelfish or Soldierfish)					
Sargocentron rubrum (Forsskål, 1775)	Redcoat Squirrelfish	PO,RA	G/N	HV	LC
Myripristis hexagona (Lacepède, 1802)	Double-tooth Soldierfish	PO,RA	G/N	HV	LC
Labridae (Wrasse)					
Cheilinus fasciatus (Bloch, 1791)	Redbreasted Wrasse	RA	G	IC	LC
Cheilinus trilobatus (Lacepède, 1801)	Tripletail Wrasse	RA	G	IC	LC
Thalassoma lunare (Linnaeus, 1758)	Moon/Crescent Wrasse	RA	G	CLV	LC
Halichoeres argus (Bloch & Schneider, 1801)	Argus Wrasse	RA	G	CLV	LC
Epibulus insidiator (Pallas, 1770)	Slingjaw wrasse	RA	G	CLV	LC
Labroides dimidiatus (Valenciennes, 1839)	Bluestreak Cleaner Wrasse	RA	G	CLV	LC
Lutjanidae (Snapper)					
Lutjanus lutjanus (Bloch, 1790)	Bigeye Snapper	PO,RA	G	CV	LC
Lutjanus quinquelineatus (Bloch, 1790)	Five-lined Snapper	PO,RA	G	CV	LC
Lutjanus russelli (Bleeker, 1849)	Russel's Snapper	PO,RA	G	CV	NE
Lutjanus vitta (Quoy & Gaimard, 1824)	Brownstripe snapper	PO,RA	G	CV	LC
Lutjanus kasmira (Forsskål, 1775)	Bluestripe Snapper	PO,RA	G	CV	LC
Lutjanus rufolineatus (Valenciennes, 1830)	Golden-lined Snapper	PO,RA	G	CV	LC
Lutjanus decussatus (Cuvier, 1828)	Checkered Snapper	PO,RA	G	CV	LC
Monodactylidae (Moonfish)					
Monodactylus argenteus (Linnaeus, 1758)	Silver Moonfish	RA	G	PV	LC
Mugilidae (Mullets)					
Crenimugil crenilabis (Forsskål, 1775)	Fringelip Mullet	RA	G	HV	LC

Nemipteridae (Coral Bream)					
Scolopsis bilineata (Bloch, 1793)	Bridle Monocle Bream	RA	G	CV	LC
Pempheridae (Sweepers)					
Pempheris adusta (Bleeker, 1877)	Dusky Sweeper	RA	T	HV	NE
Pomancenthidae (Angelfish)					
Pomacanthus annularis (Bloch, 1787)	Blueringed Angelfish	PO,RA	T/G	HV	LC
Chaetodontoplus mesoleucus (Bloch, 1787)	Vermiculated Angelfish	RA	T/G	HV	LC
Pomacanthus sexstriatus (*Cuvier, 1831*)	Six-banded Angelfish	RA	T/G	HV	LC
Pomancentridae (Damselfishes and Anemonefishes)					
Abudefduf bengalensis (Bloch, 1787)	Bengal Sergeant	RA	T	OV	LC
Abudefduf sexfasciatus (*Lacepède, 1801*)	Scissortail Sergeant	RA	T	OV	LC
Abudefduf sordidus (Forsskål, 1775)	Black-spot Sergeant	RA	T	OV	LC
Amblypomacentrus breviceps (Schlegel & Müller, 1839)	Black-banded Demoiselle	RA	T	OV	LC
Amphiprion ocellaris (Cuvier, 1830)	False Brown Anemonefish	RA	T	OV	NE
Amphiprion perideraion (Bleeker, 1855)	Pink Anemonefish	RA	T	OV	LC
Amphiprion sebae (Bleeker, 1853)	Sebae Anemonefish	RA	T	OV	NE
Chromis atripectoralis (Welander & Schultz, 1951)	Black-axil Chromis	RA	T	PV	NE
Chromis analis (Cuvier, 1830)	Yellow Chromis	RA	T	PV	LC
Chrysiptera unimaculata (Cuvier, 1830)	Onespot Demoiselle	RA	T	PV	LC
Dascyllus reticulatus (Richardson, 1846)	Reticulate Dascyllus	RA	T	PV	NE
Dascyllus trimaculatus (Rüppell, 1829)	Three-spot Dascyllus	RA	T	PV	NE
Dischistodus fasciatus (Cuvier, 1830)	Banded Damsel	RA	T	PV	NE
Neoglyphidodon melas (Cuvier, 1830)	Bowtie Damselfish	RA	T	PV	NE
Neopomacentrus anabatoides (Bleeker, 1847)	Silver Demoiselle	RA	T	PV	NE
Neopomacentrus cyanomos (Bleeker, 1856)	Regal Damoiselle	RA	T	PV	NE
Pomacentrus coelestis (Jordan & Starks, 1901)	Neon Damselfish	RA	T	OV	NE
Pomacentrus moluccensis (Bleeker, 1853)	Lemon Damsel	RA	T	OV	NE
Pomacentrus tripunctatus (Cuvier, 1830)	Threespot Damsel	RA	T	OV	NE
Pseudochromidae (Dottybacks)					
Pseudochromis fuscus (Müller & Troschel, 1849)	Dusky Dottyback	RA	T	HV	LC
Pseudochromis ransonneti (Steindachner, 1870)	Yellowbelly Dottyback	RA	T	HV	NE
Scaridae (Parrotfish)					
Hipposcarus longiceps (Valenciennes, 1840)	Pacific Longnose Parrotfish	RA	G	HV	LC
Scarus ghobban (Forsskål, 1775)	Yellowscale Parrotfish	RA	G	HV	LC
Scarus psittacus (Forsskål, 1775)	Common Parrotfish	RA	G	HV	LC

Scarus quoyi (Valenciennes, 1840)	Quoy's Parrotfish	RA	G	HV	LC
Bolbometopon muricatum (Valenciennes, 1840)	Green Humphead Parrotfish	RA	G	HV	VU
Serranidae (Grouper)					
Cephalopholis boenak (Bloch, 1790)	Chocolate Grouper	RA	T	CV	LC
Cephalopholis formosa (Shaw, 1812)	Blueline Grouper	RA	T	CV	LC
Cephalopholis cyanostigma (Valenciennes, 1828)	Blue Spotted Grouper	RA	T	CV	LC
Diploprion bifasciatum (Cuvier, 1828)	Barred Soapfish	RA	T	CV	LC
Epinephelus fasciatus (Forsskål, 1775)	Blacktip Grouper	RA	T	CV	LC
Epinephelus corallicola (Valenciennes, 1828)	Duskyfin Grouper	RA	T	CV	DD
Epinephelus bontoides (Bleeker, 1855)	Palemargin Grouper	PO,RA	T	CV	DD
Siganidae (Rabbitfish)					
Siganus unimaculatus (Evermann & Seale, 1907)	One-spot foxface	PO	G	HV	NE
Siganus guttatus (Bloch, 1787)	Yellow blotch rabbitfish	PO	G	HV	LC
Siganus corallinus (Valenciennes, 1835)	Blue spotted spinefoot	PO	G	HV	LC
Siganus doliatus (Guérin-Méneville, 1829-38)	Barred Rabbitfish	PO	G	HV	LC
Siganus virgatus (Valenciennes, 1835)	Virgate Rabbitfish	PO	G	HV	NE
Siganus vulpinus (Schlegel & Müller, 1845)	Foxface Rabbitfish	PO	G	HV	LC
Tetraodontidae (Pufferfish)					
Arothron mappa (Lesson, 1831)	Map Puffer	RA	G	OV	LC
Arothron nigropunctatus (Bloch & Schneider, 1801)	Blackspotted Puffer	RA	G	OV	LC
Zanclidae (Moorish Idol)					
Zanclus cornutus (Linnaeus, 1758)	Moorish Idol	RA	G	CLV	LC
FISH OBSERVATION OUTSIDE STUDY PERIOD					
Balistidae (Triggerfishes)					
Balistoides viridescens (Bloch & Schneider, 1801)	Titan Triggerfish	PO	G	IC	NE
Carcharhinidae (Requiem Shark)					
Carcharhinus melanopterus (Quoy & Gaimard, 1824)	Blacktip Reef Shark	PO,RA	G	CV	NT
Carcharhinus limbatus (Müller & Henle, 1839)	Blacktip Shark	PO,RA	G	CV	NT
Carcharhinus leucas (Müller & Henle, 1839)	Bull Shark	PO,RA	G	CV	NT
Dasyatidae (Stingrays)					
Himantura fai (Jordan & Seale, 1906)	Pink Whipray/Tahitian Stingray	PO	G	OV	NE
Himantura granulata (Macleay, 1883)	Whitetail Stingray	PO	G	OV	NE

Taeniura lymma (Forsskål, 1775)	Blue-Spotted Stingray Ribbontail Ray	PO	G	OV	NT
Gobiidae (Gobies)					
Amblyeleotris steinitzi (Klausewitz, 1974)	Steinitz' Shrimpgoby	RA	T/G	OV	NE
Amblygobius phalaena (Valenciennes, 1837)	Banded Goby	RA	T/G	OV	NE
Cryptocentrus cinctus (Herre, 1936)	Yellow prawn-goby	RA	T/G	OV	NE
Istigobius decoratus (Herre, 1927)	Decorated Goby	RA	T/G	OV	NE
Valenciennea muralis (Valenciennes, 1837)	Mural Goby	RA	T/G	OV	NE
Muraenidae (Morays)					
Gymnothorax flavimarginatus (Rüppell, 1830)	Yellowmargin Moray	RA	T	OV	NE
Gymnothorax favagineus (Bloch & Schneider, 1801)	Blackspotted Moray/Laced Moray	RA	T	OV	NE
Gymnothorax isingteena (Richardson, 1845)	Spotted Moray	RA	T	OV	NE
Gymnothorax javanicus (Bleeker, 1859)	Giant Moray	RA	T	OV	NE
Rhincodontidae (Whale Shark)					
Rhincodon typus (Smith, 1828)	Whale Shark	PO	G	OV	EN
Scorpaenidae (Lionfishes)					
Pterois volitans (Linnaeus, 1758)	Red Lionfish/Common Lionfish	RA	G	CV	LC

RA-Reef Associated; PO-Pelagic Oceanic; EN-Endangered; NT-Near Threatened; VU-Vulnerable; LC-Least Concern; DD-Data Deficient; NE-Not Evaluated; T-Territorial; G-Gregarious; N-Nocturnal; CV-Carnivore; HV-Herbivore; PV-Planktivore; CLV-Corallivore; OV-Omnivore; and, IC-Invertebrate Consumer

A well-developed coral ecosystem in Pulau Bidong could attract a variety of reef fishes (Matsunama *et al.*, 2011). Pomancentridaes (damselfish) were found to be the most diverse family, which comprised a total of 19 species. As supported by Williams (1982), this family was often among the most abundant and diverse found within coral reef ecosystems. Less-diverse fish families with five to seven species were Serranidae (grouper), Lutjanidae (snapper), Caesionidae (fusiliers), Labridae (wrasse), Siganidae (rabbitfish), Chaetodontidae (butterflyfish) and Scaridae (parrotfish) (Table 2). On the other hand, the least-diverse fish families (one species each) recorded during UVC were Mugilidae, Monodactylidae, Nemipteridae, Ephippidae, Grammatidae, Cirrhitidae, Pempheridae, Acanthuridae, Ballistidae, Belonidae and Zanclidae (Table 2). Fish diversity might serve as a health indicator of many coral reef ecosystems (Díaz-Pérez *et al.*, 2016). Jones *et al.* (2004) demonstrated that degraded reefs supported less diverse fish assemblages, and were often dominated by a significant subset of species associated with dead coral, with algae or coral rubbles as substratum.

Habitat Zone and Social Behaviour

The coral reef fish behaviour in Pulau Bidong is still poorly understood, and evidence is lacking on the typical habitats used by reef fish. In this study, while we categorised two major fish habitat zones (pelagic-oceanic and reef-associated), the majority of fishes recorded were reef-associated. In general, Ogden and Quinn (1984) had shown that coral reef fishes were highly developed for adaptation to territoriality and home range behaviour patterns. In addition, precise spawning time aggregations also influenced the reef fish's habitat to be focused

on certain locations from the wider reef (Ogden and Quinn, 1984). The Caesionidae family were the only pelagic-oceanic fishes (Table 2), while Lutjanidae, Haemulidae and the Palemargin grouper (*Epinephelus bontoides*) were found to be both reef-associated and pelagic-oceanic.

Recently, the abundance, diversity and distribution of fish had been extensively studied in the Setiu Wetlands of Terengganu (Kadir *et al.* (2018). The wetlands, with an area of 23,000 ha and located 33.5 km away from Pulau Bidong, comprised several coexisting ecosystems, such as a riparian forest, fresh water *Melaleuca*, peat swamp, mangrove and nipa palm forest, brackish lagoon with vegetated sandy island, seagrass bed and sandy beaches (Nakisah & Fauziah, 2003). At Pulau Bidong, we found three coral fishes [Russel's snapper (*Lutjanus ruselli*), silver moonfish (*Monodaetylus argenteus*) and yellow blotch (*Siganus guttatus*), Table 2] that were also observed in Setiu Wetlands (Kadir *et al.*, 2018). The snapper and blotch were in juvenile (19 and 25mm, respectively) and adult stage (238 and 182mm, respectively). Therefore, those three fish species had likely demonstrated habitat shifts from seagrass beds and/or mangrove areas to the coral reefs of Pulau Bidong as fish migration was often associated with their life history (Ogden and Quinn, 1984). For instance, Beck *et al.* (2011) and Parrish (1989) found that mangrove forest and seagrass beds to be selectively attractive to particular larvae of coral reef fishes, such as snappers (Lutjanidae) and grunts (Haemulidae), which then migrate to coral reef habitats during pre-adult stages (Brothers & McFarland, 1981). Therefore, further information on coral fish migrations could elucidate the connectivity between the fish in coral reefs at Pulau Bidong and coastal habitats, such as mangroves and estuaries.

Using underwater observations to understand the social behaviour and orientation of reef fish was critically important for our understanding of behavioural biology (Soares *et al.*, 2002; Sazima, 1986; Longhurst, 1981). As surveys were conducted during the day, most fish recorded (Table 2) were either territorial or gregarious. However, the Pomancentridae family displayed both territorial and gregarious behaviour. Fish species associated with live coral habitats co-exist in hierarchical groups (e.g. Gobiidae, Pomacentridae) and pairs (e.g. Chaetodontodae, Pomacanthidae) of conspecifics (Pratchett *et al.*, 2006; Wong *et al.*, 2008). Therefore, the territorial and/or gregarious behaviour relevant to most reef fish at Pulau Bidong might influence intra- and inter-specific competition for habitat resources, such as food and space.

Diel migration patterns usually occurred near dawn and dusk, relative to and from the feeding or resting areas (Currey *et al.*, 2015). The Holocentridae family were the only nocturnal reef fish recorded at Pulau Bidong (Table 2), reportedly leaving their reef shelters for about 30 minutes after sunset and aggregating in the water column above reefs (Hobson, 1972). As the surveys in this study were mainly conducted during the day, the fish species observed were predominantly diurnal. The difference between diurnal and nocturnal fish congregations was a critical aspect in coral reef ecology, and thus, should be investigated further to determine the daily shifts in fish assemblage.

Feeding Habits

Food webs consisted of various trophic levels and groups of organisms with similar feeding strategies. Considering broad trophic groups, reef fishes of Pulau Bidong were primarily omnivorous (25 %), followed by herbivorous (23 %) and carnivorous (22 %). Less common were the planktivorous (16 %), coralivorous (10 %) and invertebrate consumer (5 %) species. Secondary consumers, comprising carnivores, omnivores and invertebrate consumers, made up 51 % of the total species identified (Figure 2), a proportion broadly similar to other assessments of tropical reef communities (Hobson, 1982; Williams & Hatcher, 1983; Graham *et al.*, 2014).

Secondary consumers, which were primarily carnivorous, preyed on primary consumers (herbivores, corallivores and planktivores) but could also be omnivorous or herbivorous

(Kulbicki *et al.*, 2005). For example, the damselfish, wrasse (*Cheilinus fasciatus* and *C. trilobatus*) and needlefish (*Strongylura incisa*) all fed on small invertebrates and algae (Table 2), and were an important forage fish for larger predators in the reef (Hixon & Webster, 2002). Carnivorous fish found in this study belonged to the Cirrhitidae (hawkfish), Haemulidae (sweetlips-grunts), Serranidae (grouper), Lutjanidae (snapper) and Carcharhinidae (requiem shark) families. As predators, the carnivorous fish might also influence prey population dynamics and community structure (Boaden & Kingsford, 2015), and could eventually influence the equilibrium in reef fish assemblage structure in the highly-diverse coral reef ecosystems in Pulau Bidong.

In this study, a variety of feeding habits were identified (Table 2). Corallivorous fish comprised all species from the Chaetodontidae family, four species from the Labridae family (*Thalassoma lunare, Halichoeres argus, Epibulus insidiator,* and *Labroides dimidiatus*), and *Zanclus cornutus* from the Zaclidae family. Butterflyfishes (Chaetodontidae) were highly dependent on hard coral availability (Reese 1981; Soule & Kleppel 1988; Öhman *et al.*, 1998; Berumen *et al.*, 2005) as most were obligate corallivores utilising coral for more than 80 % of their total food intake (Cole *et al.*, 2008; Harmelin-Vivien, 1989; Harmelin-Vivien & Bouchon-Navaro 1983). Since Chaetodontidae fishes were particularly sensitive to coral loss from poor conservation efforts (Wilson *et al.*, 2014; 2006; Pratchett *et al.* 2008), they could become one of the best indicators to assess coral reef degradation and decline (Pratchett, 2005).

The Scaridae family comprised herbivore fishes and was well known as a main determinant of benthic community structure that significantly contributed to the resilience of coral reef ecosystems (Hughes *et al.*, 2007; Mumby, 2006; Paddack *et al.*, 2006; Bellwood *et al.,* 2003). The parrotfish, for example, would continuously nibble on corals, cleaning algae from its surface and removing dead coral, which is a substrate for competitive algae. It excrement of white carbonate sand could help to maintain the health of coral reefs (Hoey & Belwood, 2008; Choat, 1991). Parrotfish were abundant found in tropical reefs (Bellwood *et al.*, 2004), and this included Pulau Bidong. With such functional diversity, coral reef fishes must be protected from recreational activities like spearfishing, which had a tendency to damage the reef structures.

Conservation Status

Overfishing and pollution were major threats faced by coral reef fishes (DeMartini *et al.*, 2008; Reynolds *et al.*, 2005; Dulvy *et al.*, 2003). Although there had been only one global extinction of marine fish species (McCauley *et al.*, 2015), numerous species had seen a significant decline, leading to local and regional extinctions (Dulvy *et al.*, 2003). Therefore, in this study, we gave particular attention to species that were vulnerable, threatened or endangered in the IUCN Red List. The whale shark (*Rhincodon typus*), a slow-moving planktivore, was not observed during sampling surveys, but had been frequently sighted by the survey team in the waters around Pulau Bidong, especially near Pulau Yu Besar, Yu Kecil and Pulau Tengkorak. The whale population worldwide had decreased by more than 50 % in the past 75 years, resulting in its listing as globally endangered in the IUCN Red List (IUCN, 2018).

Three near threatened requiem shark species [black tip reef shark (*Carcharhinus melanopterus*); black tip shark (*C. limbatus*) and bull shark (*C. leucas*)] and the near threatened blue-spotted stingrays (*Taeniura lymma*) were also observed in this study. Under the Elasmobranch resource utilisation, almost all shark and ray species in Malaysia were accepted as table food (Ali *et al.* 2004). Moreover, shark jaws and teeth were also allowed to be sold as rare souvenirs to enthusiasts, and discarded elasmobranch parts, such as the head, were used as bait for fish or crab traps. Small or inedible sharks that had no commercial value were sometimes sold to fish mill factories to produce fertiliser. In Malaysia, annual landings of shark and ray had increased significantly from 10,792 tonnes in 1982, to 27,948 tonnes in 2003, with

the Carcharhinidae family (requiem sharks) forming the bulk of these catches (Department of Fisheries Malaysia, 2006).

The Green Humphead Parrotfish (*Bolbometopon muricatum*) was also considered vulnerable by the IUCN (Table 2). Despite widespread population declines globally and being regarded as a prized catch (Dulvy & Polunin, 2004; Dulvy *et al.*, 2003), *B. muricatum* was observed to inhabit the coral reefs in Pulau Bidong. While, this study had identified two data deficient grouper species (*Epinephelus corallicola* and *E. bontoides*), data deficient groupers were believed to be less threatened than other data sufficient species (Luiz *et al.*, 2016). The IUCN status of most other coral reef fish recorded in this study was least concern or not evaluated.

Spatial Occurrence

Among survey locations, the highest fish diversity occurred at reefs with heterogeneous features, including rocky/bedrock with ravines, crevices and holes (Tables 1 and 3, Figures 3 and 4). Of all the fish species identified (n = 83), 67±2 % were recorded at Karang Tengah, Batu Payung and Dinding Laut, while 41 % were recorded at Teluk Air, and far fewer species were seen at other reefs (<31 %) (Figures 3 and 4). Based on the occurrence of reef fish, the MDS analysis showed that survey locations could be clustered into two distinct groups separated by non-overlapping confidence intervals (Figure 5). The group containing Karang Tengah, Batu Payung and Dinding Laut represented the highest reef fish species richness and high benthic structural complexity (Table 1).

In support of these results, other studies also showed that higher abundance and species richness of coral reef fish occurred at sites with more structural complexity (Bejarano *et al.*, 2011). Shelter availability had been a limiting resource for fishes at the fringe reefs of west Barbados in the West Indies (Ménard *et al.*, 2012), where specific topographic features also supported fish reproduction and provided feeding grounds, especially for predatory fish like groupers and sea bass (Anderson *et al.*, 2018). With complex underwater structures a likely major factor in attracting diverse fish assemblages, these three sites were important reefs in Pulau Bidong, and might provide an ecological baseline for further research and conservation management.

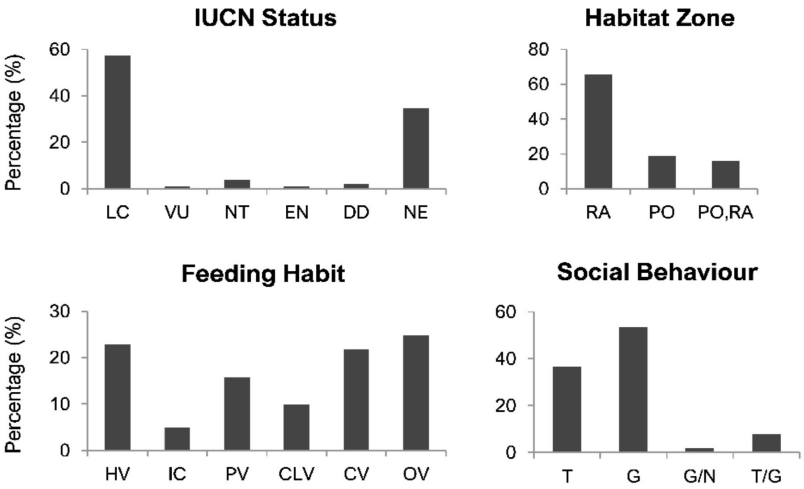

Figure 2: Total number of fish species (%) from Pulau Bidong according to IUCN status (LC, Least Concern; VU, Vulnerable; NT, Near Threatened; EN, Endangered; DD, Data Deficient; NE, Not Evaluated), habitat zone (RA, Reef Associated; PO, Pelagic Oceanic), feeding habit (HV, Herbivore; IC, Invertebrate Consumer; PV, Planktivore; CLV, Corallivore; CV, Carnivore; OV, Omnivore), and social behaviour (T, Territorial; G, Gregarious: N, Nocturnal)

Table 3: Occurrence of coral reef fishes at every sampling station of Pulau Bidong, Terengganu, South China Sea

Fish Species	Pantai Pasir Cina	Vietnam Jetty	Underwater Gallery	Panrai Tenggara	Batu Menangis	Christmas Garden	Teluk Air	Karang Tengah	Batu Payung	Dinding Laut	FREQUENCY OF OCCURRENCES
Abudefduf bengalensis	√	√	√	√	√	√	√	√	√	√	10
Abudefduf sexfasciatus	√	√	√	√	√	√	√	-	-	√	8
Abudefduf sordidus	√	√	√	√	√	√	√	-	-	√	8
Amblypomacentrus	√	√	√	√	√	√	√	-	-	-	7
Amphiprion ocellaris	√	-	-	√	-	-	-	√	√	√	5
Amphiprion perideraion	-	-	-	-	-	-	-	√	√	√	3
Amphiprion sebae	-	-	-	-	-	-	-	-	√	√	2
Arothron mappa	-	-	-	-	-	-	-	-	√	-	1
Arothron nigropunctatus	-	-	-	-	-	-	-	-	√	-	1
Bolbometopon muricatum	-	-	-	-	-	-	√	-	√	√	3
Caesio cunning	√	√	√	√	√	√	√	√	-	√	9
Caesio lunaris	-	-	-	-	-	-	-	√	-	√	2
Caesio teres	-	-	-	-	-	-	-	√	√	√	3
Caesio xanthonota	-	-	-	-	-	-	-	√	√	√	3
Cephalopholis boenak	√	√	√	-	√	√	√	√	√	√	9
Cephalopholis cyanostigma	-	-	-	-	√	√	-	√	√	√	5
Cephalopholis formosa	-	-	-	-	√	-	-	√	√	√	4
Chaetodon octofasciatus	√	√	√	√	√	√	√	√	√	√	10
Chaetodontoplus	-	-	-	-	√	-	-	√	√	√	4
Cheilinus fasciatus	-	√	√	-	-	√	√	√	-	√	6
Cheilinus trilobatus	-	-	-	-	-	√	√	-	-	-	2
Chelmon rostratus	-	√	-	-	-	√	√	√	√	√	6
Chromis analis	-	-	-	-	-	-	-	√	-	√	2
Chromis atripectoralis	-	-	-	-	-	-	-	-	√	-	1
Chrysiptera unimaculata	-	-	-	-	-	-	-	√	√	√	3
Cirrhitichthys aprinus	-	-	-	-	-	-	-	√	-	-	1
Coradion chrysozonus	-	-	-	-	-	√	√	√	√	√	5
Crenimugil crenilabis	-	-	-	-	-	-	-	√	-	-	1
Dascyllus reticulatus	√	√	√	√	√	√	√	-	-	-	7
Dascyllus trimaculatus	√	√	√	√	√	√	√	√	√	√	10
Diagramma picta picta	-	-	-	-	-	-	√	-	-	√	2
Diploprion bifasciatum	-	-	-	-	-	-	√	-	-	-	1
Dipterygonotus balteatus	-	-	-	-	-	-	√	-	-	-	1
Dischistodus fasciatus	√	√	√	√	√	√	√	-	-	-	7
Epibulus insidiator	-	-	-	-	-	-	-	√	√	√	3
Epinephelus bontoides	-	-	-	-	-	-	-	-	√	-	1
Epinephelus corallicola	-	-	-	-	-	-	√	√	-	√	3
Epinephelus fasciatus	-	-	-	-	-	-	-	√	√	√	3
Gramma loreto	-	-	√	-	-	-	-	√	√	√	4
Halichoeres argus	-	-	-	-	√	√	√	√	√	-	5
Heniochus acuminatus	-	-	-	-	-	-	-	√	√	√	3
Heniochus varius	-	-	-	-	-	-	-	-	√	-	1

Fish Species	Pantai Pasir Cina	Vietnam Jetty	Underwater Gallery	Panrai Tenggara	Batu Menangis	Christmas Garden	Teluk Air	Karang Tengah	Batu Payung	Dinding Laut	FREQUENCY OF OCCURRENCES
Hipposcarus longiceps	-	-	-	-	-	-	√	√	√	√	4
Labroides dimidiatus	-	-	-	-	-	-	-	-	√	√	2
Lutjanus decussatus	-	-	-	-	-	-	-	√	√	√	3
Lutjanus kasmira	-	-	-	-	-	-	-	√	-	√	2
Lutjanus lutjanus	-	-	-	-	-	-	-	√	-	√	2
Lutjanus quinquelineatus	-	-	-	-	-	-	-	√	-	√	2
Lutjanus rufolineatus	-	-	-	-	-	-	-	-	√	-	1
Lutjanus russelli	-	-	-	-	-	-	-	√	√	√	3
Lutjanus vitta	-	-	-	-	-	-	-	√	√	√	3
Monodactylus argenteus	-	-	-	-	-	-	-	√	-	√	2
Myripristis hexagona	-	-	-	-	-	-	-	-	√	-	1
Naso lituratus	-	-	-	-	-	-	-	√	√	-	2
Neoglyphidodon melas	√	√	√	√	√	√	√	√	√	√	10
Neopomacentrus	-	-	-	-	-	-	√	√	√	√	4
Neopomacentrus	-	-	-	-	-	-	√	√	√	√	4
Pempheris adusta	-	-	-	-	-	-	-	√	√	-	2
Platax orbicularis	-	-	-	-	√	-	-	-	-	-	1
Plectorhinchus lineatus	-	-	-	-	-	-	-	-	-	√	1
Pomacanthus annularis	-	√	√	√	√	-	-	√	√	√	7
Pomacanthus sexstriatus	-	-	-	-	-	-	-	-	√	-	1
Pomacentrus coelestis	√	√	√	√	√	√	√	√	√	-	9
Pomacentrus	√	√	√	√	√	√	√	√	√	√	10
Pomacentrus	-	-	-	-	-	-	-	√	√	√	3
Pseudobalistes	-	-	-	-	-	-	-	-	√	-	1
Pseudochromis fuscus	-	-	-	-	√	√	√	√	√	√	6
Pseudochromis	-	-	-	-	-	-	-	√	√	√	3
Pterocaesio chrysozona	-	-	-	-	-	-	√	-	√	-	2
Sargocentron rubrum	-	√	√	-	√	√	√	√	√	√	8
Scarus ghobban	-	√	√	√	√	√	√	√	√	√	9
Scarus psittacus	√	√	√	√	√	√	√	√	√	√	10
Scarus quoyi	√	√	√	√	√	√	√	√	√	√	10
Scolopsis bilineata	-	-	-	-	-	-	-	√	√	√	3
Siganus corallinus	√	√	√	√	√	√	√	√	-	√	9
Siganus doliatus	-	-	-	-	-	-	-	√	√	√	3
Siganus guttatus	√	√	-	-	-	-	-	√	-	√	4
Siganus unimaculatus	√	√	-	√	-	-	-	-	-	-	3
Siganus virgatus	-	-	-	-	-	-	-	√	√	√	3
Siganus vulpinus	-	-	-	-	-	-	-	-	√	-	1
Strongylura incisa	-	-	-	-	-	-	-	-	√	-	1
Thalassoma lunare	√	√	√	√	√	√	√	√	√	√	10
Zanclus cornutus	-	-	-	-	-	-	-	-	√	-	1
TOTAL NO. OF FISH SPECIES	20	22	22	20	26	25	38	55	58	55	

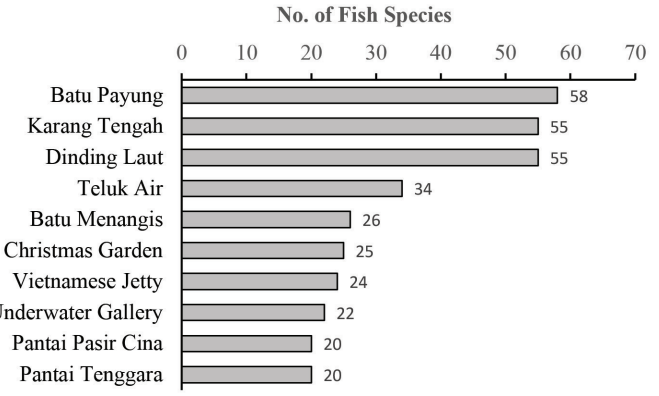

Figure 3: Total number of coral reef fish species recorded at each sampling station around Pulau Bidong, Terengganu

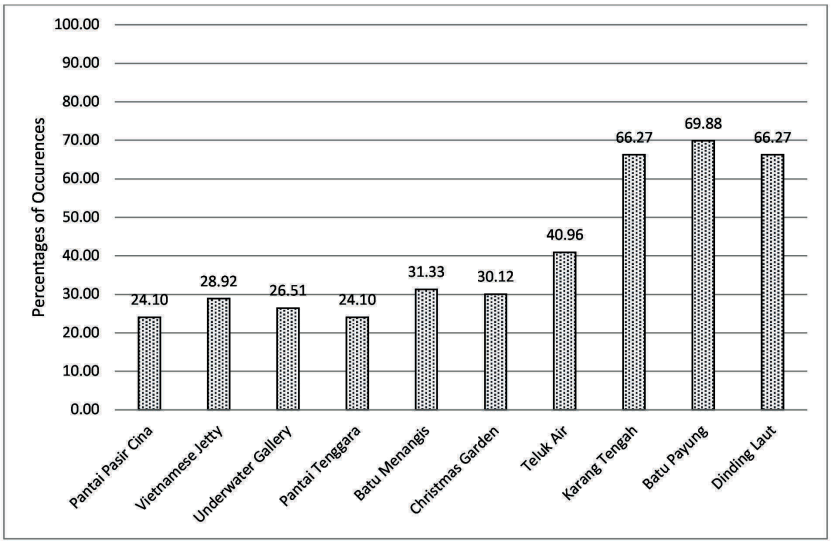

Figure 4: Percentages of coral reef fish occurrences between sampling stations around Pulau Bidong, Terengganu

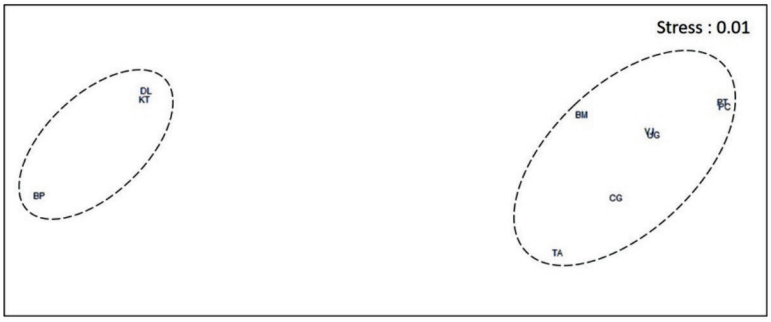

Figure 5: Multi-dimensional Scaling (MDS) plot showing the clustering of survey sites based on between-site Bray-Curtis similarities derived from coral reef fish species occurrence

All seven species of *Lutjanus* were recorded in at least one of the three complex benthic structure reefs (Karang Tengah, Batu Payung and Dinding Laut), as well as certain groupers (*Epinephelus bontoides*, *E. corallicola* and *E. fasciatus*), Pomacentridae (*Chromis analis, C. atripectoralis*, *Chrysiptera unimaculata*, *Cirrhitichthys aprinus, Neopomacentrus anabatoides, N. cyanomos*), rabbitfish (*Siganus virgatus, S. vulpinus, Strongylura incisa*), fusiliers (*Caesio lunaris*, *C. teres*, *C. xanthonota*, *Pterocaesio chrysozona*), parrotfish (*Bolbometopon muricatum*, *Hipposcarus longiceps*), wrasse (*Labroides dimidiatus*, *Epibulus insidiator*), moonfish (*Monodactylus argenteus*), squirrelfish (*Myripristis hexagona*), surgeonfish (*Naso lituratus*), grunts (*Plectorhinchus lineatus*), coral bream (*Scolopsis bilineata*), Moorish idol (*Zanclus cornutus*) and sweepers (*Pempheris adusta*).

The eight coral reef fish species that occurred in all 10 sampling sites were *Abudefduf bengalensis, Chaetodon octofasciatus, Dascyllus trimaculatus, Neoglyphidodon melas, Pomacentrus moluccensis, Scarus psittacus, Scarus quoyi* and *Thalassoma lunare*. Despite the large number of fish species recorded, daytime sampling surveys did not fully represent nocturnal and cryptic diurnal fish species that hide in shelters during the day, and predators that use shaded shelters to hunt.

Conclusion

This study revealed additional data on the coral reef fish communities in Pulau Bidong in the South China Sea. Although the island has not been gazetted as a marine park, fish diversity was considerably high due to the number of species occurrences, reflecting a good health status of the coral reef ecosystems around the island. Species richness was also most likely underestimated due to daytime surveys, which did not detect many nocturnal, cryptic diurnal and cryptic predatory fish. Most species recorded were reef-associated that utilised various feeding strategies throughout the trophic levels of the food web.

However, the presence of pelagic-oceanic species and fish species found in nearby estuaries suggested that various coral reef fish at Pulau Bidong might have undergone a considerable migration, revealing potential candidates to drive the connectivity between the mainland and offshore island reefs. The presence of threatened and endangered marine fish species underpinned the importance of coral reefs as fish habitats in Pulau Bidong. Hence, more surveys would be needed to understand the ecological significance of seasonal and long-term trends in coral reef fish diversity and abundance.

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