

DIVERSITY AND ABUNDANCE OF CORAL REEF FISHES, GIVING EMPHASIS ON THE LARGE PREDATORS AT CHAGAR HUTANG BAY, REDANG ISLAND

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<https://doi.org/10.46754/umtjur.v6i3.493>

Received: 3 April 2024

Accepted: 23 April 2024

Published: 15 July 2024

Abstract: The Chagar Hutang Bay located on Pulau Redang, Terengganu, serves as a critical nesting site for green sea turtles (*Chelonia mydas*). Despite its ecological significance, there remains a lack of information regarding the diversity and abundance of coral reef fishes, particularly large predatory species, within the sanctuary site. To address this knowledge gap, the present study employed Baited Remote Underwater Video (BRUV) surveys to assess the fish assemblages across different reef zones, namely the shoreline, mid-reef, and forereef areas. A comprehensive analysis of nine one-hour BRUV surveys revealed a remarkable diversity of coral reef fishes, identifying 55 distinct species from 43 genera and 18 families. The forereef zone exhibited significantly higher fish density compared to other surveyed areas, underscoring its importance as a key habitat within the bay. Notably, large predatory fish species comprised 4.7% of the total fish abundance with four predatory groups, including trevallies, groupers, blacktip reef sharks (*Carcharhinus melanopterus*), and barracudas, documented in Chagar Hutang Bay. Among these predators, the blacktip reef shark and the groupers emerged as the dominant species. This study provides valuable insights into the coral reef fish diversity and abundance in Chagar Hutang Bay, highlighting the presence of key predatory species and emphasising the need for targeted conservation efforts to protect this ecologically significant marine habitat.

Keywords: Underwater predator, diversity index, Baited Remote Underwater Video (BRUV), prey-predator, Chagar Hutang Turtle Sanctuary (CHTS), South China Sea.

Introduction

Large predatory fish play a key role in coral reef ecosystems as apex or mesopredators, exerting substantial influence on the overall structure and dynamics of these diverse marine habitats (Heithaus *et al.*, 2013). The ecological role of these large predators is pivotal in maintaining the health, resilience, and biodiversity of coral reef ecosystems. One of the fundamental contributions of large predatory fish to coral reef ecosystems lies in their ability to regulate the population dynamics of smaller fishes (Ruppert *et al.*, 2013). Through predation, large predators impose top-down pressure on lower trophic levels, thereby preventing them from over-

exploiting smaller prey species. This regulatory function helps maintain a balanced trophic structure, reducing competition for resources and ensuring the stability of ecological interactions within the reef community (Christensen *et al.*, 2003; Mitcheson & Collin, 2011).

Furthermore, the presence of large predatory fish can significantly influence the behaviour, spatial distribution, and abundance of their prey. For example, the mere presence of reef sharks or barracudas can induce behavioural modifications in smaller fish species, leading to altered foraging patterns or habitat use to

minimise the risk of predation (Heupel *et al.*, 2014). These indirect effects of predation can have cascading impacts on ecosystem dynamics, influencing nutrient cycling, energy flow, and the overall resilience of coral reef ecosystems (Feeney *et al.*, 2012; Ferretti *et al.*, 2018). Additionally, large predatory fish contribute to the ecological resilience of coral reef ecosystems by selectively targeting weak, diseased, or less-fit individuals within prey populations. This selective predation can enhance the genetic diversity and adaptive capacity of species, making them more resilient to environmental stressors such as climate change, disease outbreaks, and habitat degradation (Nash *et al.*, 2016; Sala *et al.*, 2021), and thus, play a crucial role in sustaining the long-term viability and adaptive potential of coral reef communities.

Chagar Hutang Bay situated on Redang Island, serves as a critical nesting ground for green sea turtles (*Chelonia mydas*) and hawksbill sea turtles (*Eretmochelys imbricata*) and has been under the continuous monitoring of the Sea Turtle Research Unit (SEATRU) since 1993 (Chan, 2013; Poti *et al.*, 2021). Designated as a turtle sanctuary in 1995, Chagar Hutang remains a focal point for sea turtle conservation efforts in Malaysia (Ghazali *et al.*, 2019). Sea turtle hatchlings typically emerge from their underground nests during night-time, making

their way swiftly towards the sea. Upon entering the water, these hatchlings often face elevated predation risks.

A study conducted by Oñate-Casado *et al.* (2021) revealed that 19.4% of hatchlings were predated, with the majority of predation events occurring within 50 m of the shoreline. This suggests that predators are more prevalent in the shallower regions of the bay, characterised by a coralline-rocky substrate. While previous gut content analysis studies have provided evidence indicating that blacktip reef sharks (*Carcharhinus melanopterus*) may prey on sea turtle hatchlings (Bashir *et al.*, 2020), there is limited specific data regarding the predation of hatchlings by other large predatory fish species in the area. These findings underscore the importance of understanding predator-prey interactions in Chagar Hutang Bay to develop effective conservation strategies for safeguarding vulnerable sea turtle populations.

Materials and Methods

Study Site

This study was conducted at Chagar Hutang Bay located at the northernmost part of Redang Island, approximately 25 km off the eastern coast of Terengganu State in Peninsular Malaysia (5°48.778' N and 103°0.502' E), in the South China Sea (Figure 1).

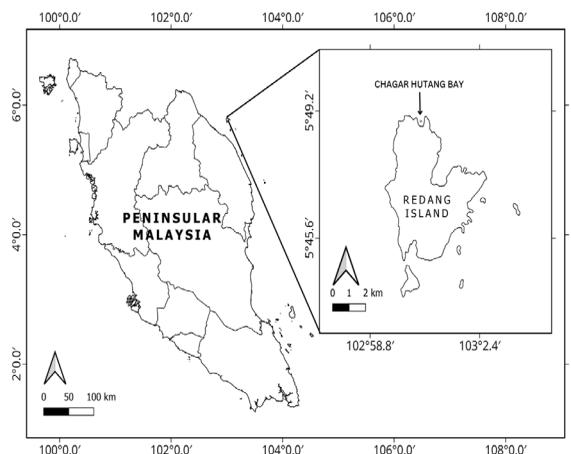


Figure 1: Chagar Hutang Bay, Redang Island

Baited Remote Underwater Video (BRUV) Surveys

BRUV surveys were deployed at Chagar Hutang from July to October of 2022. The BRUV structure followed a standard trapezoid design (Shea *et al.*, 2020), constructed from plastic PVC pipe, strengthened, and weighted concrete to ensure the structure would easily sink to the sea floor and sit stably in high currents (Figure 2). A single GoPro Hero 3 action camera programmed to record video at 1080p, 30fps, and in the

wide-angle mode setting was secured inside a waterproof dive housing and mounted to the BRUV structure to ensure the camera would record a wide horizontal view of the underwater environment. A plastic PVC bait arm held a bait bag constructed from plastic mesh and filled with approximately 500 g of sardine fish, 1.5 m away from the mounted GoPro camera, ensuring the bait bag was centred within the camera’s field of view.

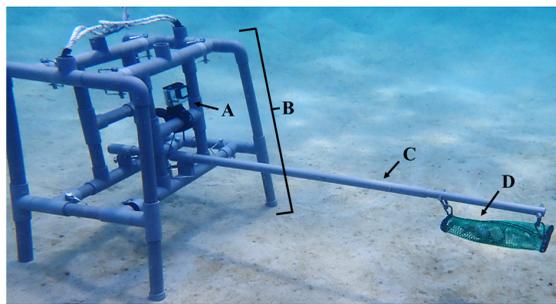


Figure 2: Baited Remote Underwater Video (BRUV) survey equipment, including (A) GoPro Hero 3 action camera inside protective dive housing, (B) concrete-filled PVC plastic frame, (C) PVC plastic bait arm, and (D) mesh bait bag containing 500 g fish bait

The BRUV structure was transported to selected sampling sites using a kayak and then, deployed underwater by a free diver. The placement of each BRUV on the sea floor was carefully adjusted to ensure an open and level horizontal field of view. BRUVs were left to

film for at least one hour, as this is a standard time for remote video surveys. GPS coordinates and depth were recorded for each survey site. Individual survey sites were deployed across three different reef zones, including forereef (8-12 m), mid-reef (3-7 m), and along the shoreline (1-2 m) within Chagar Hutang Bay (Figure 3).

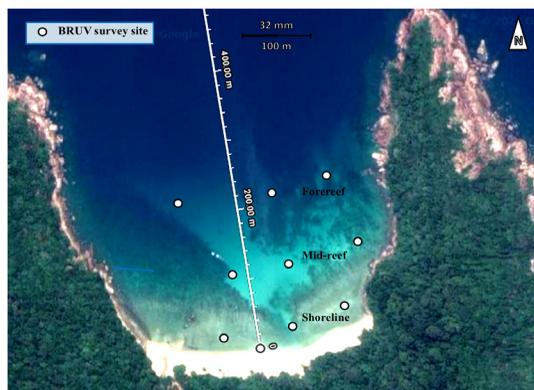


Figure 3: BRUV survey sites deployed between forereef, mid-reef, and shoreline zones in Chagar Hutang Bay

Video and Data Analysis

Fish species were discerned through visual assessments made from the recorded video footage. Where possible, all fish recorded were identified to the species level, but if the species could not be confidently recognised, individuals were recorded at the genus level. For example, this occurred for sightings of parrotfish (*Scarus* sp.), where the species did not approach the BRUVs units to enable an examination of morphological characteristics in detail.

The relative abundance of fish recorded using BRUVs was determined as the maximum number of individuals present of each species at a single point in time (Priede *et al.*, 1994). The identification procedure drew upon various references such as Matsunuma *et al.* (2011), Kimura *et al.* (2019), and Motomura *et al.* (2021) alongside the Fish Base database. Criteria for identification encompassed an analysis of body shape, colouration, and patterns exhibited by the fish captured in the video recordings (Omer, 2017). Each fish visible within the footage was identified and the MaxN values were duly recorded. Identification efforts were pursued down to the family and subordinate taxonomic ranks. Subsequently, the data gleaned from the video recordings were

collated and organised in tabular format for statistical analysis.

Fish interactions were classified based on engagement with baited BRUVs and their appearances within frames with careful notation of species arrival times. Diversity indices were calculated for species richness, Shannon Diversity Index, and Pielou’s Evenness Index. The resulting values for each survey were then, grouped and compared between different zones, namely forereef, mid-reef, and shoreline. The Kruskal-Wallis test, executed through Statistical Package for Social Sciences (SPSS) software was utilised to discern significant differences in fish abundance across different zones.

Results and Discussion

A total of 55 fish species belonging to 43 genera and 19 distinct families were identified during this study. This present study encountered more than 50% of the fish species and families documented in the list of fish found in Redang Island’s waters (Du *et al.*, 2019). The forereef area exhibited the highest relative abundances of fish species with a total of 75 individual fish, followed by the mid-reef and shoreline with total MaxN values of 40 and 31, respectively (Table 1).

Table 1: The abundance (MaxN), diversity, evenness, and richness indices of the coral reef fishes at Chagar Hutang Bay, Redang Island. Data are mean ± standard deviation (n = 3)

Zone	MaxN	Shannon Diversity Index	Pielou’s Evenness Index	Species Richness Index
Shoreline	31 ± 3	1.951 ± 0.164	0.878 ± 0.064	9 ± 2
Mid-reef	40 ± 7	2.524 ± 0.812	0.873 ± 0.131	19 ± 9
Forereef	75 ± 17	2.265 ± 0.550	0.810 ± 0.092	17 ± 6

Family Labridae was recorded to have the highest abundance (MaxN) among all species, followed by the Pomacentridae and the Scaridae (Table 2). Notably, *Thalassoma lunare* (Labridae), *Lethrinus ornatus* (Pomacentridae), and *Scarus* sp. (Scaridae) demonstrated the highest relative abundances of fish species with a total of 36, 20, and 14 individuals, respectively.

Regarding behaviour, none of the predator fish exhibited aggression towards the bait, indicating potential variations in dietary preferences and prey selection (Stallings, 2010). Notably, *Thalassoma lunare* and *Lethrinus ornatus* were the sole species observed to interact with the BRUV frequently. *Lethrinus ornatus*, commonly known as emperor fish is a carnivorous species primarily preying on small organisms and fish (Currey *et al.*, 2013).

The *Thalassoma lunare* or moon wrasse is a detritivore and occasionally feeds on juvenile fish (Holmes *et al.*, 2012). The *Scarus* species nonchalantly drifted past the BRUV camera without exhibiting any predatory behaviour. These fish do not pursue the bait as it does not align with their dietary proclivities, which consist mainly of consuming algae that thrive on coral formations (Hoey & Bonaldo, 2018).

Table 2: Total cumulative fish abundance recorded from the BRUV survey at the different reef zones (MaxN)

Family	Scientific Name	Common Name	Forereef	Mid-reef	Shoreline
Acanthuridae	<i>Naso lituratus</i>	Naso Tang		2	
Balistidae	<i>Pseudobalistes flavimarginatus</i>	Yellowmargin Triggerfish		1	1
Caesionidae	<i>Caesio cuning</i>	Redbelly Yellowtail Fusilier	3	2	
	<i>Pterocaesio chrysozona</i>	Goldband Fusilier	1		
Carangidae	<i>Carangoides gymnothethus</i>	Bludger Trevally		1	2
	<i>Gnathanodon speciosus</i>	Golden Trevally		1	
	<i>Trachinotus bailloni</i>	Bluefin Trevally			3
Carcharhinidae	<i>Carcharhinus melanopterus</i>	Blacktip Reef Shark	3	1	1
Chaetodontidae	<i>Chaetodon adiergastos</i>	Crosshatch Butterflyfish		2	
	<i>Chaetodontoplus mesoleucus</i>	Vermiculated Angelfish	2	1	
	<i>Chelmon rostratus</i>	Copperband Butterflyfish		1	
	<i>Coradion chrysozonus</i>	Goldtail Demoiselle	1	1	
	<i>Heniochus acuminatus</i>	Pennant Coralfish		2	
Dorosomtidae	<i>Hilsa kelee</i>	Kelee Shad			7
Echeneidae	<i>Echeneis naucrates</i>	Live Sharksucker	4	1	
Ephippidae	<i>Platax boersii</i>	Brushtail Batfish		1	
	<i>Cheilinus fasciatus</i>	Titan Triggerfish	2	2	1
	<i>Epibulus insidiator</i>	Slingjaw Wrasse		2	
Labridae	<i>Halichoeres hortulanus</i>	Ornate Wrasse		1	
	<i>Hemigymnus melapterus</i>	Blackeye Thicklip	1	2	1

	<i>Labroides dimidiatus</i>	Bluestreak Cleaner Wrasse	3	2	
	<i>Oxycheilinus digramma</i>	Redbreasted Wrasse	2	2	
	<i>Thalassoma lunare</i>	Moon Wrasse	36	7	5
Lethrinidae	<i>Lethrinus ornatus</i>	Ornate Emperor	14	13	1
Lutjanidae	<i>Lutjanus decussatus</i>	Mangrove Red Snapper			2
Mugilidae	<i>Ellochelon vaigiensis</i>	Banded Sweetlips		12	5
Nemipteridae	<i>Scolopsis margaritifera</i>	Black Pearl Wrasse	6		
	<i>Scolopsis monogramma</i>	Monogrammed Monocle Bream		4	8
Pomacentridae	<i>Abudefduf bengalensis</i>	Bengal Sergeant			5
	<i>Abudefduf sexfasciatus</i>	Scissortail Sergeant			2
	<i>Amblyglyphidodon curacao</i>	Curacao Damsel	5		
	<i>Amblyglyphidodon leucogaster</i>	Whitetail Dascyllus	3		
	<i>Dascyllus reticulatus</i>	Reticulated Dascyllus		3	
	<i>Dascyllus trimaculatus</i>	Three-spot Dascyllus		3	
	<i>Dischistodus perspicillatus</i>	Spectacled Parrotfish		1	
	<i>Neopomacentrus anabatooides</i>	Lemon Damsel	1		
	<i>Neopomacentrus cyanomos</i>	Blue Damsel	10	1	
	<i>Plectroglyphidodon obreptus</i>	Masked Damsel	2		
	<i>Pomacanthus annularis</i>	Blue Ring Angelfish		1	
	<i>Pomacentrus coelestis</i>	Blue Demoiselle	4		7
	<i>Pomacentrus moluccensis</i>	Lemon Damsel	2		
	<i>Pomacentrus philippinus</i>	Filipino Damsel	1		
Scaridae	<i>Chlorurus spilurus</i>	Bullethead Parrotfish		1	
	<i>Scarus</i> sp.	Parrotfish	20	2	10

Serranidae	<i>Cephalopholis boenak</i>	Chocolate Hind	1	1	
	<i>Cephalopholis cyanostigma</i>	Blue-spotted Grouper	3	2	1
	<i>Cephalopholis microprion</i>	Yellowfin Grouper	1		
	<i>Diploprion bifasciatum</i>	Barred Soapfish	1	2	
	<i>Epinephelus quoyanus</i>	Duskytail Grouper	2	2	
	<i>Plectropomus leopardus</i>	Leopard Coral Grouper	2	1	
Siganidae	<i>Siganus corallinus</i>	Coral Rabbitfish	2	2	
	<i>Siganus guttatus</i>	Blotched Foxface Rabbitfish	3	3	
	<i>Siganus virgatus</i>	Barred Spinefoot		1	
	<i>Siganus vulpinus</i>	Foxface Rabbitfish	2	2	
Sphyraenidae	<i>Sphyraena putnamae</i>	Mottled Barracuda		2	

Variations in fish abundance are influenced by many factors such as habitat preferences, coral complexity, and food availability, where fish species tend to exhibit increased abundance and diversity in deeper waters due to the broader range of available food resources (Henke, 2010; Komyakova *et al.*, 2013). Throughout observations, the mid-reef and forereef areas have exhibited a higher degree of coral coverage. Nevertheless, due to time constraints, no comprehensive coral survey was conducted. It is recommended that a future coral cover survey be undertaken during the BRUVs survey to acquire more detailed information on this matter (Hills & Wilkinson, 2004; Komyakova *et al.*, 2013).

This study also highlighted variations in the Shannon Diversity Index values calculated from surveys deployed at different depths, with the mid-reef boasting the highest diversity index (3.28), trailed by the forereef (2.79), and shoreline (2.54). The discrepancy in diversity might be attributed to the lower coral cover observed near the shoreline, as suggested by Komyakova *et al.* (2013). Moreover, the

shoreline rubble and sandy sea floor covering, as opposed to the mid and forereef's higher coral coverage, indicates lesser ecological diversity, although confirmation through coral surveys remains necessary in future surveys. While Pielou's Evenness Index is higher in the mid-reef and shoreline, signalling a more uniform distribution of fish species at these depths compared to the forereef (Ulfah *et al.*, 2019). Using bait in deeper waters with the BRUV method can impact the types and visibility of fish recorded, potentially introducing biases that require meticulous interpretation of relative abundance estimates (Caldwell *et al.*, 2016). Despite this limitation, the BRUV technique offers distinct advantages such as studying the composition of large predator fish without the diver effect, which can otherwise cause fish to flee. This allows for more accurate observations and understanding of predator behaviour in their natural habitat.

The study identified a total of four large predator groups: Trevallies, blacktip reef sharks, groupers, and barracuda. Among the large predators are the blacktip reef shark (*C.*

melanopterus) and the blue-spotted grouper (*C. cyanostigma*), which exhibited the highest abundance (n = 3), appearing in a single frame. Given their size and dietary preferences, these large predatory fish species may pose a significant predation risk to sea turtle hatchlings within the sanctuary. To elucidate the predator-prey dynamics between these fish species and sea turtle hatchlings, future research employing methodologies such as gut content analysis or stable isotope analysis is recommended (Bashir *et al.*, 2020). This study provides preliminary insights into the biodiversity and abundance of coral reef fish species in Chagar Hutang Bay, laying the foundation for further investigations aimed at identifying potential predators impacting sea turtle hatchling survival in this critical nesting area.

Conclusions

The study documented 55 fish species in Chagar Hutang Bay, highlighting Labridae, Pomacentridae, and Scaridae as the most abundant families. Large predators such as blacktip reef sharks and groupers were also observed, suggesting a potential risk to sea turtle hatchlings. The study offers initial insights into coral reef fish biodiversity in Chagar Hutang Bay, setting a basis for future research on predators affecting sea turtle hatchling survival.

Acknowledgements

We acknowledged the assistance and logistic support provided by the Chagar Hutang Marine Research Station and SEATRU team. This study was supported by the Ministry of Higher Education Malaysia under a research grant from the Higher Institution Centre of Excellence (HICoE, VOT no. 56059), Institute of Oceanography and Environment, Universiti Malaysia Terengganu.

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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