RESEARCH ARTICLE

Coral Reef Habitat and Associated Reef Fishes in the Kalayaan Island Group, West Philippine Sea

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ABSTRACT

The West Philippine Sea (WPS) is one of the identified biogeographic regions of the Philippines based on the biophysical attributes of its coral reef communities and has the highest biomass of reef fishes and species richness. From April to May 2022, coral reef assessment and fish visual census (FVC) through underwater surveys were conducted in nine sampling areas in the Kalayaan Island Group. A total of 19 dives in shallow water areas (SWR) and mesophotic coral ecosystems (MCE) were conducted. Sabina shoal has the highest percentage of coral cover in SWR, with an average of 35.66% and 30.62% in MCE. Moreover, the FVC results recorded 155 species from 28 families of reef fishes associated with live corals. The most dominant fish families are surgeonfishes (Acanthuridae), which shared 37%, followed by triggerfishes (Balistidae, 22%) and damselfishes (Pomacentridae, 10%). Among these, 76 species were found in Sabina Shoal. Species diversity of fishes revealed moderate to high diversity based on species richness, while the abundance was categorized as moderate to very high.

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1. INTRODUCTION

The Philippines has one of the most extensive coral reef areas (Aliño et al. 2004), estimated at 26,000 km^2 (Wilkinson 2008) hat holds an extraordinary species diversity, including more than 400 species of hard corals, 12 of which are unique to the area, and more than 900 species of reef fishes (Burke and Selig 2002). Reef fisheries constitute about 20% of the total marine production (1.64 million MT), and as of the late 1990s, only 30% of the country's coral reefs remain in good condition (Alcala and Russ 2002). Reefs in excellent condition were down to only 4.3% (at least 75% live coral cover), with an overall average of 32.3% hard coral cover (Licuanan and Gomez 2000). Initial findings on the nationwide assessment of coral reefs in the country reported a further decline since none of the sampled areas were in excellent condition in terms of live coral cover (Licuanan et al. 2017).

The Philippines is also one of the countries bordering the northwestern parts of the South China Sea, which is referred to as the West Philippine Sea (WPS). This area is home to a diverse range of fish and invertebrate species, including corals, gastropods, and bivalves, and is thought to have the highest species richness and biomass of reef-associated fauna of any marine biogeographic region in the Philippines. Along the western Philippines, coral reef areas are most extensive in Palawan, with an estimated cover of 9,800 km^2 or about 1/3 of the country's total reef area (Barut 2007), where high fish biomass and high species diversity were observed (Asian Development Bank 2014).

Coral reef fisheries are an important sub-sector of marine capture fisheries in the Philippines, where half the country's population depends on food and livelihood (e.g., fishing and tourism) (Verdadero et al. 2017). The Kalayaan Island Group (KIG) is a reef area within the WPS that has a huge fisheries potential of roughly 61,557-90,850 mt/yr, or 3-5% of the entire marine capture fisheries output (Arceo et al. 2020). Dominant reef fish families reported include Acanthuridae, Balistidae, Lethrinidae, and Scombridae. This is comparable with the findings of (Nañola et al. 1997; Phung et al. 1997; Long et al. 2008) on the Spratly Islands. Small pelagics such as round scads (*Decapterus* spp.), big-eyed scads (*Selar* spp.), and Indian mackerels (*Rastrelliger* spp.) were dominantly present in areas near northwestern Palawan based on purse seine explorations, the most important fishing gear in SCS-Western Philippines or WPS (Pastoral et al. 2000).

While KIG is hypothesized to serve as a potential source of pelagic propagules that can support other reef systems bordering the SCS, studies in this area were still limited especially the biodiversity surveys in shallow water reef (SWR) typically characterized as existing in a 0-30 meters depth range with light penetration (Menza et al. 2007) and mesophotic coral ecosystems (MCE) which are tropical and sub-tropical reefs between 30 m and potentially >150 m depth. In this study, we surveyed the coral reef habitat and fish species assemblages in SWR and MCE areas in nine locations of Kalayaan Island Group. Specifically, we looked at the current condition of reefs, coral genera, and fish species including the species richness, abundance, and biomass. The results of this study will provide baseline information and updated status of coral reef habitats in KIG and the associated reef fishes, contributing to our understanding of biodiversity in the area.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted in the Kalayaan Island Group, an offshore area comprising over 50 features located at the north-eastern section of Spratly Islands and is estimated to have a total sea area exclusive of Scarborough Shoal of 281,000 km^2 (Alcala and Encomienda 2015). We surveyed nine (9) areas in KIG namely: Patag Island, Lawak Island, Likas Island, Pagasa Island, Parola Island, Nares Bank, Recto Bank, Sabina Shoal, and Rizal Reef (Figure 1). Pagasa is the largest island occupied by the Philippines. Along with it, Likas and Parola islands are the only KIG areas with inhabitants. Regarding anthropogenic disturbances and governance, most of these locations are subject to medium to very high levels of integrated threats on a localized scale (Burke et al. 2011).

2.2 Underwater survey

Considering most islands were part of an atoll, at least 2 stations were randomly selected on every area representing outer and inner reefs. Underwater surveys were conducted between April and May 2022. All areas were surveyed twice for SWR and MCE except for Nares and Recto Banks, which were surveyed once for MCE due to relatively short survey time and sea conditions, as we only employed the utility boat during underwater surveys. Each dive per site lasted for 90 minutes. The locations of every station were marked with a Global Positioning System (GPS). The hard-coral cover was assessed using a modified photo-transect method described by Van Woesik et al. (2009). A SCUBA diver swims along the shallow side of the 150-m transect line, taking photographs of the substrate at marked 1-m intervals. Due to logistical constraints, a length of 30 m was considered as one transect, and with an interval of another 30 m, a total of 3 replicate transects were surveyed. Hence, three equally spaced 30-m transects within the 150-m transect line were photographed (Transect 1 = 0–30 m, 2 = 60–90 m, and 3 = 120–150 m).

To assess the associated fish assemblage, the same transects laid for the HCC survey were used for the Fish Visual Census (FVC) described by English et al. (1997). A SCUBA diver swims along the 30-m transect length, pausing at 5-m intervals to record counts per estimated length of identified fish species within an imaginary width of 5 m (2.5 m to both the left and right side of the transect) and height of 5 m. All fishes encountered were counted and identified to the lowest possible taxa using identification guides available (Allen et al. 1999; Allen 2010).

2.3 Data analysis

Captured images of benthos were processed for Coral Point Count (CPCe) analysis (Kohler and Gill 2006). Calculated hard coral cover (HCC) was classified within the "22-33-44" HCC scale, while the coral diversity was categorized based on taxonomic amalgamation units (TAUs) as described by (Licuanan et al. (2017) (Table 1).

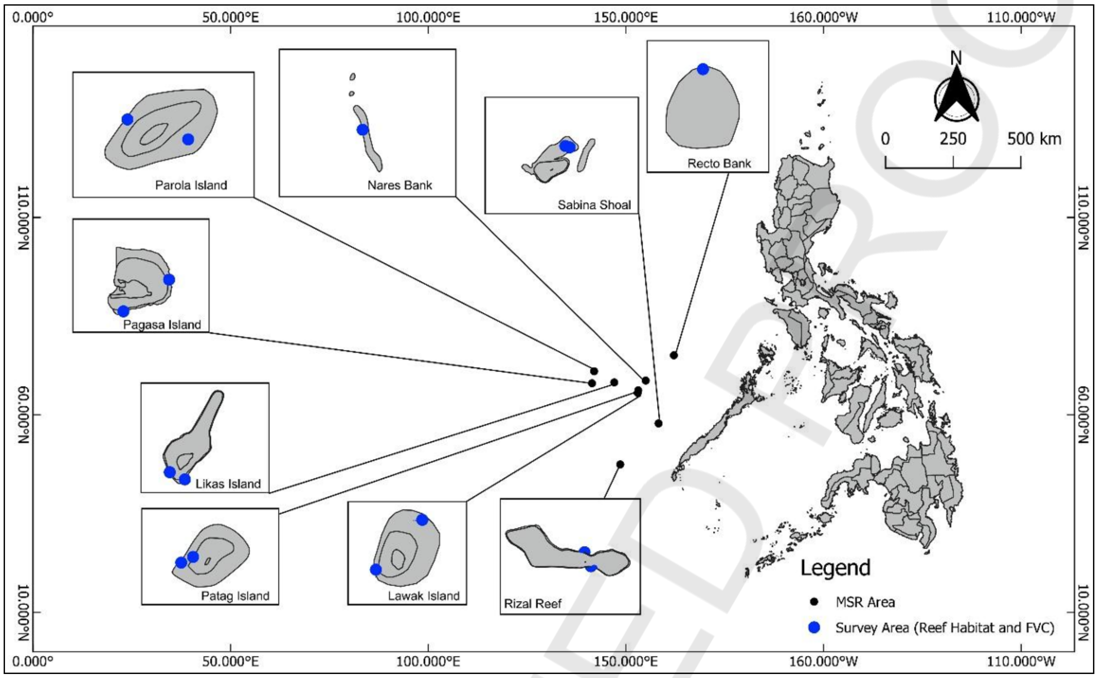

Figure 1. Survey sites for the coral reef habitat assessment and fish visual census in Kalayaan Island Group.

Table 1. Assessment scales to guide the interpretation of hard coral cover and coral diversity (as taxonomic amalgamation units or TaAUs) in the Philippines (Licuanan et al. 2017).

Hard Coral Cover			Hard Coral Diversity	
HCC Category A	>44%		Diversity Category A	>26 TAUs
HCC Category B	>33% - 44%		Diversity Category B	>22 - 26 TAUs
HCC Category C	>22% - 33%		Diversity Category C	>18-22 TAUs
HCC Category D	0-22%		Diversity Category D	0- 18 TAUs

For FVC, estimated fish biomass was calculated using the length *(L)* and weight *(W)* relationship with the equation of $W = aL^b$. The species' specific a and b values were determined and gathered from the website of fishbase.se *(http://www.fishbase.se/search.php)* and are presented in Table 3. For additional information, we also included the International Union for Conservation of Nature (IUCN) Red List Status of the species identified during FVC. Species identified to the genus level were assigned average *a* and *b* values. Species density was estimated by determining the sum of the visually obvious species observed along the laid transect. Further, fish diversity was determined by counting the number of fishes observed and identified at the species level during the conduct of the FVC. Reef fish status within the surveyed areas was determined based on the aforementioned parameters and were categorized into categories as described by Hilomen et al.(2000) and Nañola et al. (2006)(Table 4).

3. RESULTS AND DISCUSSION

3.1 Coral reef habitat

A total of 48 transects were surveyed, producing 1,440 captured images that were analyzed using the Coral Point Count (CPC) with Excel extension. Table 2 presents the summary of HCC and diversity categories of each sampling site. Most of the surveyed areas have HCC category D condition (up to 22% HCC). The lowest mean HCC was recorded in Lawak Island, with 0.86% in MCE and 6% in SWR. At Patag Island, the mean HCC in MCE was 1.75% and 5.76% in SWR. HCC in Likas was slightly lower than in Patag, with mean HCC in MCE at 1.65% and 3.35% in SWR. Pagasa, the largest island occupied by the Philippines, has a mean HCC of 2.41% in MCE and 4.37% in SWR. The mean HCC in Parola Island is slightly higher than Pagasa's, with 2.41% in MCE and

Table 2. Summary of Hard Coral Cover and Diversity in the Kalayaan Island Group.

Location	Site	Mean (%)	SE±	HCC Category	Diversity Category (TAU)
Lawak Island	SWR	6	0.73	D	D
	MCE	0.86	0.5	D	D
Patag Island	SWR	5.76	0.91	D	D
	MCE	1.75	0.23	D	D
Likas Island	SWR	3.35	0.61	D	D
	MCE	1.65	1.3	D	D
Pag-asa Island	SWR	4.37	0.32	D	D
	MCE	2.41	0.8	D	D
Parola Island	SWR	9.29	1.9	D	D
	MCE	2.41	0.8	D	D
Nares Bank	MCE	8.09	5.59	D	D
Recto Bank	MCE	3.62	1.06	D	D
Sabina Shoal	SWR	35.66	6.9	B	D
	MCE	30.52	5.22	C	D
Rizal Reef	SWR	13.38	3.43	D	D
	MCE	3.91	1.95	D	D

Table 3. List of fishes that were found and identified in KIG with the length-weight constants (a and b) obtained from FishBase and the IUCN Red List Status.

Family	Common Name	Scientific Name	a	b	IUCN Red List Status
Acanthuridae	Orange-socket surgeonfish	*Acanthurus auranticavus*	0.02344	2.95	LC
	Japan surgeonfish	*Acanthurus japonicus*	0.02344	2.95	LC
	Lined surgeonfish	*Acanthurus lineatus*	0.02239	2.95	LC
	Orangespot surgeonfish	*Acanthurus olivaceus*	0.02630	3.00	LC
	Chocolate surgeonfish	*Acanthurus pyroferus*	0.01995	3.01	LC
	Short-tail bristle-tooth	*Ctenochaetus cyanocheilus*	0.02344	2.96	LC
	Striated surgeonfish	*Ctenochaetus striatus*	0.02399	2.96	LC
	Whitemargin unicornfish	*Naso annulatus*	0.02399	2.94	LC
	Spotted unicornfish	*Naso brevirostris*	0.02089	2.99	LC
	Blue unicorn	*Naso caeruleacauda*	0.02089	2.95	LC
	Orangespine unicornfish	*Naso lituratus*	0.02818	2.96	LC
	Bluespine unicornfish	*Naso unicornis*	0.02399	2.94	LC
	Bignose unicornfish	*Naso vlamingii*	0.03162	2.96	LC
	Twotone tang	*Zebrasoma scopas*	0.02512	2.97	LC
	Sailfin tang	*Zebrasoma velifer*	0.02570	2.92	LC
Aulostomidae	Chinese trumpetfish	*Aulostomus chinensis*	0.00059	3.25	LC
Balistidae	Orange-lined triggerfish	*Balistapus undulatus*	0.02884	2.93	LC
	Clown triggerfish	*Balistoides conspicillum*	0.02692	2.92	LC
	Pinktail triggerfish	*Melichthys vidua*	0.02692	3.03	LC
	Red-toothed triggerfish	*Odonus niger*	0.03311	2.94	LC
Belonidae	Hound needlefish	*Tylosurus crocodilus*	0.00112	3.10	LC
Caesionidae	Yellow and blueback fusilier	*Caesio teres*	0.01202	3.10	LC
	Dark-banded fusilier	*Pterocaesio tile*	0.01288	3.15	LC

LC – least concerned; VU – vulnerable; NT – near-threatened

Continuation of Table 3. List of fishes that were found and identified in KIG with the length-weight constants (a and b) obtained from FishBase and the IUCN Red List Status.

Carangidae	Bluefin trevally	*Caranx melampygus*	0.01738	2.96	LC
	Rainbow runner	*Elagatis bipinnulata*	0.01023	2.85	LC
Chaetodontidae	Lined butterflyfish	*Chaetodon lineolatus*	0.02344	2.94	LC
	Oval butterflyfish	*Chaetodon lunula*	0.01995	3.01	LC
	Ornate butterflyfish	*Chaetodon ornatissimus*	0.02630	3.02	LC
	Latticed butterflyfish	*Chaetodon rafflesii*	0.02291	3.00	LC
		Chaetodon sp.			
	Chevron butterflyfish	*Chaetodon trifascialis*	0.02138	2.95	NT
	Pacific double-saddle butterflyfish	*Chaetodon ulietensis*	0.02239	2.98	LC
	Vagabond butterflyfish	*Chaetodon vagabundus*	0.02042	2.98	LC
	Highfin coralfish	*Coradion altivelis*	0.02239	3.01	LC
	Longnose butterfly fish	*Forcipiger flavissimus*	0.01995	3.01	LC
	Longnose butterflyfish	*Forcipiger longirostris*	0.02291	3.02	LC
	Pyramid butterflyfish	*Hemitaurichthys polylepis*	0.19950	3.01	LC
	Pennant coralfish	*Heniochus acuminatus*	0.02291	3.04	LC
	Threeband pennantfish	*Heniochus chrysostomus*	0.01995	3.09	LC
	Horned bannerfish	*Heniochus varius*	0.01955	3.01	LC
Cirrhitidae	Arc-eye hawkfish	*Paracirrhites arcatus*	0.00995	3.09	LC
Epinephelidae	Redmouth grouper	*Aethaloperca rogaa*	0.01288	3.06	LC
	Slender grouper	*Anyperodon leucogrammicus*	0.01096	3.04	LC
	Peacock hind	*Cephalopholis argus*	0.01230	3.04	LC
	Chocolate hind	*Cephalopholis boenak*	0.01288	3.10	LC
	Freckled hind	*Cephalopholis microprion*	0.01698	3.04	LC
	Darkfin hind	*Cephalopholis urodeta*	0.01230	3.04	LC
	Orange-spotted grouper	*Epinephelus coioides*	0.01175	3.03	LC
	Blacktip grouper	*Epinephelus fasciatus*	0.01148	3.03	LC
	Brown-marbled grouper	*Epinephelus fuscoguttatus*	0.01047	3.04	VU
	Honeycomb grouper	*Epinephelus merra*	0.01202	3.05	LC
	Camouflage grouper	*Epinephelus polyphekadion*	0.01202	3.04	VU
	Sixbar grouper	*Epinephelus sexfasciatus*	0.01318	3.05	LC
		Epinephelus sp.			
	Masked grouper	*Gracila albomarginata*	0.01148	3.04	LC
		Pseudanthias sp.			
	Yellowstriped fairy basslet	*Pseudanthias tuka*	0.01349	3.00	LC
	Yellow-edged lyretail	*Variola louti*	0.01096	3.03	LC
Haemulidae	Oriental sweetlips	*Plectorhinchus vittatus*	0.01413	3.00	LC
Holocentridae	Shoulderbar soldierfish	*Myripristis kuntee*	0.02188	3.12	LC
	Myripristis murdjan	*Myripristis murdjan*	0.01778	3.06	LC
	Clearfin squirrelfish	*Neoniphon argenteus*	0.01950	2.94	LC
	Blackfin squirrelfish	*Neoniphon opercularis*	0.15850	2.97	LC
	Sammara squirrelfish	*Neoniphon sammara*	0.01622	2.96	LC
	Silverspot squirrelfish	*Sargocentron caudimaculatum*	0.02239	3.01	LC
	Sabre squirrelfish	*Sargocentron spiniferum*	0.01698	2.98	LC
Kyphosidae	Brassy chub	*Kyphosus vaigiensis*	0.01820	3.00	LC

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Continuation of Table 3. List of fishes that were found and identified in KIG with the length-weight constants (a and b) obtained from FishBase and the IUCN Red List Status.

Labridae	Lined wrasse	*Anampses lineatus*	0.00977	3.07	LC
	Lyretail hogfish	*Bodianus anthioides*	0.01230	3.05	LC
	Axilspot hogfish	*Bodianus axillaris*	0.01230	3.05	LC
	Splitlevel hogfish	*Bodianus mesothorax*	0.01230	3.05	LC
	Redbreasted wrasse	*Cheilinus fasciatus*	0.01585	2.95	LC
		Cheilinus sp.			
		Choerodon sp.			
	Orange-dotted tuskfish	*Choerodon anchorago*	0.01905	3.08	LC
	African coris	*Coris gaimard*	0.00977	3.07	LC
	Sling-jaw wrasse	*Epibulus insidiator*	0.02239	2.95	LC
	Bird wrasse	*Gomphosus varius*	0.00631	2.97	LC
	Checkerboard wrasse	*Halichoeres hortulanus*	0.00955	3.08	LC
	Axil spot wrasse	*Halichoeres podostigma*	0.00977	3.09	LC
		Halichoeres sp.			
	Barred thicklip	*Hemigymnus fasciatus*	0.00977	3.07	LC
	Pastel ringwrasse	*Hologymnosus doliatus*	0.00447	3.11	LC
	Bluestreak cleaner wrasse	*Labroides dimidiatus*	0.00589	3.17	LC
		Labroides sp.			
	Cheeklined wrasse	*Oxycheilinus digramma*	0.01905	2.95	LC
	Ringtail maori wrasse	*Oxycheilinus unifasciatus*	0.01585	2.95	LC
	Chiseltooth wrasse	*Pseudodax moluccanus*	0.01122	3.04	LC
	Cutribbon wrasse	*Stethojulis interrupta*	0.00977	3.06	LC
	Bluntheaded wrasse	*Thalassoma amblycephalum*	0.00933	3.06	LC
	Sixbar wrasse	*Thalassoma hardwicke*	0.00977	3.05	LC
	Fivestripe wrasse	*Thalassoma quinquevittatum*	0.00977	3.05	LC
		Thalassoma sp.			
Lethrinidae	Striped large-eye bream	*Gnathodentex aureolineatus*	0.01549	3.02	LC
		Gymnocranius sp.			
	Smalltooth emperor	*Lethrinus microdon*	0.01175	2.97	LC
	Humpnose big-eye bream	*Monotaxis grandoculis*	0.01950	2.98	LC
Lutjanidae	Small toothed jobfish	*Aphareus furca*	0.01738	2.95	LC
	Green jobfish	*Aprion virescens*	0.01413	2.94	LC
	Two-spot banded snapper	*Lutjanus biguttatus*	0.01479	2.97	LC
	Two-spot red snapper	*Lutjanus bohar*	0.01349	2.99	LC
	Common bluestripe snapper	*Lutjanus kasmira*	0.01479	2.97	LC
	Midnight snapper	*Macolor macularis*	0.01585	2.99	LC
	Black and white snapper	*Macolor niger*	0.01585	3.00	LC
Malacanthidae	Quakerfish	*Malacanthus brevirostris*	0.00537	3.03	LC
Microdesmidae	Blackfin dartfish	*Ptereleotris evides*	0.00389	3.12	LC
Monacanthidae	Harlequin filefish	*Oxymonacanthus longirostris*	0.01995	2.93	VU
Mullidae	Yellowfin goatfish	*Mulloidichthys vanicolensis*	0.01023	3.09	LC
	Bicolor goatfish	*Parupeneus barberinoides*	0.01380	3.13	LC
	Doublebar goatfish	*Parupeneus trifasciatus*	0.00813	3.18	LC
	Gold-saddle goatfish	*Parupeneus cyclostomus*	0.01259	3.09	LC

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Continuation of Table 3. List of fishes that were found and identified in KIG with the length-weight constants (a and b) obtained from FishBase and the IUCN Red List Status.

	Long-barbel goatfish	*Parupeneus macronemus*	0.00912	3.15	LC
	Manybar goatfish	*Parupeneus multifasciatus*	0.01288	3.10	LC
	Sidespot goatfish	*Parupeneus pleurostigma*	0.01175	3.10	LC
Nemipteridae	Two-lined monocle bream	*Scolopsis bilineata*	0.01380	3.06	LC
Pinguipedidae	Latticed sandperch	*Parapercis clathrata*	0.00692	3.06	LC
Pomacanthidae	Yellow angelfish	*Centropyge heraldi*	0.03090	2.88	LC
	Pearlscale angelfish	*Centropyge vrolikii*	0.03090	2.88	LC
	Emperor angelfish	*Pomacanthus imperator*	0.02512	2.87	LC
	Regal angelfish	*Pygoplites diacanthus*	0.03090	2.88	LC
Pomacentridae	Indo-Pacific sergeant	*Abudefduf vaigiensis*	0.02455	3.07	LC
	Yellowbelly damselfish	*Amblyglyphidodon leucogaster*	0.01995	2.95	LC
	Yellowtail clownfish	*Amphiprion clarkii*	0.02344	2.98	LC
	Tomato clownfish	*Amphiprion frenatus*	0.02344	2.98	LC
	Clown anemonefish	*Amphiprion ocellaris*	0.01479	3.00	LC
	Yellow clownfish	*Amphiprion sandaracinos*	0.01479	3.00	LC
	Ambon chromis	*Pycnochromis amboinensis*	0.02089	2.98	LC
	Bicolor chromis	*Pycnochromis margaritifer*	0.01660	2.97	LC
	Paletail chromis	*Chromis xanthura*	0.01413	2.94	LC
	Reticulate dascyllus	*Dascyllus reticulatus*	0.02951	2.99	LC
	Threespot dascyllus	*Dascyllus trimaculatus*	0.03467	2.93	LC
	Barhead damsel	*Neoglyphidodon thoracotaeniatus*	0.02344	2.94	LC
	Violet demoiselle	*Neopomacentrus violascens*	0.01479	2.99	LC
	Blackbar devil	*Plectroglyphidodon dickii*	0.02042	2.98	NT
	Whitespotted devil	*Stegastes lacrymatus*	0.02089	2.98	Not Evaluated
	Scaly damsel	*Pomacentrus lepidogenys*	0.02692	3.04	NT
	Philippine damsel	*Pomacentrus philippinus*	0.01778	2.98	LC
Scaridae	Bicolour parrotfish	*Cetoscarus bicolor*	0.01202	3.02	LC
	Bleeker's parrotfish	*Chlorurus bleekeri*	0.02754	3.01	LC
	Steephead parrots	*Chlorurus microrhinos*	0.01445	3.03	LC
	Daisy parrotfish	*Chlorurus sordidus*	0.01514	3.05	LC
	Chameleon parrotfish	*Scarus chameleon*	0.01445	3.03	LC
	Yellowbarred parrotfish	*Scarus dimidiatus*	0.01380	3.13	LC
	Yellowfin parrotfish	*Scarus flavipectoralis*	0.02399	3.03	LC
	Forsten's parrotfish	*Scarus forsteni*	0.02042	2.98	LC
	Blue-barred parrotfish	*Scarus ghobban*	0.01445	3.03	LC
	Ember parrotfish	*Scarus rubroviolaceus*	0.01288	3.10	LC
	Yellowband parrotfish	*Scarus schlegeli*	0.01660	3.03	LC
		Scarus sp.			
	Tricolour parrotfish	*Scarus tricolor*	0.01778	3.06	LC
Scombridae	Narrow-barred Spanish mackerel	*Scomberomorus commerson*	0.00661	3.00	LC
Siganidae	Foxface	*Siganus vulpinus*	0.01445	3.07	LC
Tetraodontidae	Blackspotted puffer	*Arothron nigropunctatus*	0.03715	2.87	LC
Zanclidae	Moorish idol	*Zanclus cornutus*	0.01738	3.00	LC

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Table 4. Categories for fish density and fish biomass used in this study (Hilomen et al. 2000) and Nañola et al. (2006).

Fish Density (species/1000m²)	**Very Poor**	**Poor**	**Moderate**	**High**	**Very High**
	0-201	202-676	677-2,267	2268-7,592	>7,592
Fish Biomass (MT/km²)	**Very Low**	**Low**	**Medium**	**High**	**Very High**
	<5	<6-10	<11-20	<21-40	>41

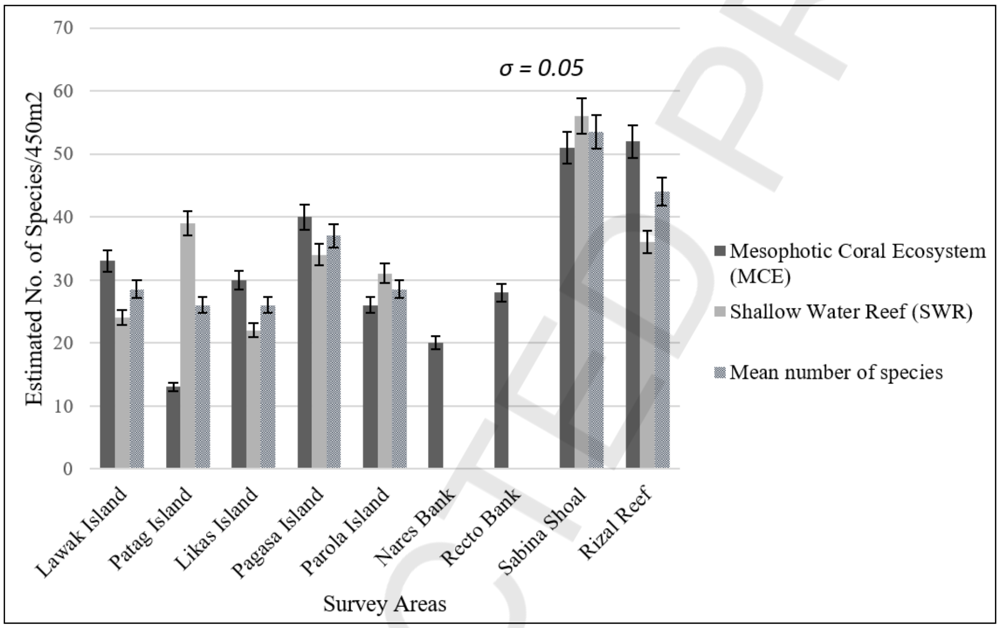

Figure 2. Estimated fish species richness of nine (9) surveyed areas in the West Philippine Sea.

9.29% in SWR. In Nares and Recto Banks, where the survey was conducted in MCE areas only, the HCC was 8.09% and 3.62%, respectively. Among the areas with HCC category D condition, the SWR areas of Rizal Reef have the highest mean percentage of 13.38. However, none of the areas exceeds the average coral cover of WPS, which is 25% (Licuanan et al. 2017). Sabina Shoal has the highest HCC with 30.52% in MCE and 35.66% in SWR with the corresponding HCC category C and B, respectively. This was slightly higher than the national average HCC of 22% (Licuanan et al. 2019). One possible explanation for this observation may be because Sabina Shoal is less explored than the other surveyed areas. Isolated reef regions in the SCS are said to have a remarkable potential for recovery from stresses (Mora et al. 2011). Furthermore, several offshore reefs where coral cover declined from 80% to 6% between 1998 and 2001 were documented to recover to up to 70% on most reefs from 2004 to 2008 (Hughes et al. 2012).

The classification of corals into groups provided by Licuanan et al. (2017) was based on a set of traits known as taxonomic amalgamation units or TAUs used to determine the coral diversity for all the study sites. Based on the TAUs listed by Licuanan et al. (2019), diversity is calculated by counting the number of TAUs observed per transect. The diversity of corals in all areas falls under category D (0-18 TAUs). The highest TAUs in SWR areas were recorded at Sabina Shoal (18), followed by Patag Island (13), Likas Island (11), and Parola Island (10), while Lawak and Pagasa islands have 9 and 6 TAUs, respectively. In MCE areas, the highest coral diversity was recorded at Sabina Shoal with 12 TAUs, while the rest have <10 TAUs. The observed coral diversities in all study sites were less than the reported diversity by Licuanan et al. (2019) in WPS, with an average of 19 TAUs.

The low coral cover documented in this study and the low threshold of coral diversity indicate that the reef areas of KIG are under pressure, which may be due to anthropogenic and climate-induced stressors (El-Naggar 2021). In the past decade, a decline from an average of > 60% to about 20% in the coral cover of offshore atolls and reefs in the SCS was documented (Hughes et al. 2012). This is attributed to several stressors, including pollution, sedimentation, overfishing, and habitat destruction due to coral mining and destructive fishing practices (Burke et al. 2011), Furthermore, due to their high susceptibility to warming and bleaching events, about 25% of tropical coral reefs have been destroyed (Lam et al. 2019). Signs of disturbances in KIG were also documented during the study, especially in the outer reef areas. Dead corals and rubbles were mainly observed. Locals and residents mentioned that fishermen from neighboring countries use explosives to fish. Blast fishing is one of the most important causes of reef destruction documented in Southeast Asia (Yap and Gomez 1994). Since the 1980s, reef surveys in areas facing the SCS revealed that 60% of recognizable scleractinians from the coral patches were dead. Many of these showed apparent signs of blasting, such as fractured branching corals in radiating patterns (McManus 1988). The presence of the coral-eating crown-of-thorns starfish (*Acanthaster planci*) also poses a significant threat to the regeneration of corals all over the reef communities. These organisms are the major natural enemy of reef-building corals that can cause mass mortalities, leading to an increase in benthic algae, loss of coral-feeding assemblages, and overall collapse of reef structural complexity (Kayal et al. 2012; Yang et al. 2015).

Although there may have been signs of threats and disturbances due to natural and human-induced factors, coral recruits were observed and documented. Recruitment has a critical role in coral reef stability and recovery, as the status of reefs in KIG will also affect the abundance and diversity of fish and other marine organisms. Li et al. (2019) reported a good level of coral recruitment in some islands and atolls within the SCS, with a median of 6.67 individuals per m^2, which increases annually, indicating the relative health of corals in the area. The increased reef distance to the surrounding mainland within the SCS can also gradually decrease the nutrient levels, favoring the coral recruitment process. Consequently, it also increases temperature and light conditions thereby increasing the reef fish abundance (Liao et al. 2021; Xiao et al. 2022).

Regional efforts for better management and conservation of the area are significant, especially in areas like KIG. Attempts were made to establish international or multilateral regional fisheries management organizations to effectively manage the resources in SCS. However, little progress has been observed (Greer 2016). The Philippines has been actively engaging in a non-political effort (e.g., fora, workshops) with other key SCS fishing actors to provide critical information on its fisheries status and management efforts in WPS. Communication and mutual understanding are key to successful joint management of fisheries resources, including coral reef habitats in SCS (Chang et al. 2020).

3.2 Associated reef fishes

3.2.1 Fish diversity

Fish diversity was measured in terms of species richness and density of the fishes on a reef as described by Koh et al. (2002), The FVC results from the nine (9) surveyed areas showed 155 species from 28 families initially identified as reef fishes associated with live corals (Table 3). Considering the species richness of all sites, the top ten (10) fish Families recorded are the surgeonfishes (Acanthuridae), triggerfishes (Balistidae), damselfishes (Pomacentridae), fusiliers (Caesionidae), emperors (Lethrinidae), parrotfishes (Scaridae), butterflyfishes (Chaetodontidae), squirrelfishes (Holocentridae), wrasses (Labridae) and goatfishes (Mullidae). This was consistent with the most speciose families reported by Arceo et al. (2024), although a slight difference in the sequence of fish families was noted. The FVC also revealed that three species are considered vulnerable (VU), while three species are included in the near-threatened (NT) category based on the IUCN Red List Status (Table 3).

Sabina Shoal had the most diverse and visually obvious recorded species of 76, with a mean of 54 species within the surveyed area (MCE and SWR). The top five (5) species are Japan surgeonfish *(Acanthurus japonicus),* striated surgeonfish *(Ctenochaetus striatus),* striped large-eye bream *(Gnathodentex aureolineatus)*, ambon chromis *(Pycnochromis amboinensis)*, and five stripe wrasse *(Thalassoma quinquevittatum)*. Rizal Reef followed the Sabina Shoal regarding fish diversity, with 61 recorded species and a mean species composition 44 within the surveyed area. Within this reef, the top five (5) species observed were dark-banded fusilier *(Pterocaesio tile),* Japan surgeonfish *(Acanthurus japonicus),* striated surgeonfish *(Ctenochaetus striatus),* yellow-striped fairy basslet *(Pseudanthias tuka),* and bicolor chromis *(Pycnochromis margaritifer)*.

Variations in the number of fish species were observed in the two habitats *(MCE and SWR)*. Species richness in Patag, Parola, and Sabina's SWR areas is higher than their MCEs. Arceo et al. (2024) reported that there was an average decline of 7-9% in the diversity of fish species per decade, where the most substantial reductions of 32% and 38% were recorded in Palawan and KIG (Arceo et al. 2024). The high diversity of surgeonfishes (Acanthuridae) in KIG was notable. This group has significant roles in reef systems by influencing the rate of algal turf production, abundance, and dynamics, thereby maintaining coral colony growth (Green and Bellwood 2009; Burkepile and Hay 2010; Krimou et al. 2023). The dominance of surgeonfishes may be attributed to the small number of large predator species that may have experienced population declines due to intense fishing pressure and habitat degradation (Zhao et al. 2024). Similarly, a significant decrease in the number of large-sized fishes has been observed worldwide (Shellem et al. 2021; Ramírez et al. 2022), and a gradual shift towards smaller fishes are becoming more evident globally (Zhao et al. 2024).

Based on Hilomen's classification, the fish density results were observed as very poor to moderate for MCE and poor to moderate for the SWR survey (Table 5). The top ten (10) fish species recorded from highest to lowest individual per 1000 m^2 were surgeonfishes (Acanthuridae), triggerfishes (Balistidae), damselfishes (Pomacentridae), fusiliers (Caesionidae), emperors (Lethrinidae), parrotfishes (Scaridae), butterflyfishes (Chaetodontidae), squirrelfishes (Holocentridae), wrasses (Labridae) and goatfishes (Mullidae) (Figure 3). Reef fish density (based on the number of individuals per 500 m^2) in WPS is said to have declined by 20% in the 2000s, increasing to a 54% decline in 2010, with anthias, damselfishes, fusiliers, and wrasses showing the most significant decline (Arceo et al. 2024). Furthermore, a large school of *Odonus niger* (Family Balistidae) was also documented, which is presumably owing to the species' feature of inhabiting reef channels or slopes that are prone to strong currents as well as a high concentration of zooplankton in the area (Komyakova et al. 2018)

Table 5. Fish Species Density Category.

Survey Area	**Fish Density and Categorization (ind/1000m²)**		
	MCE	*SWR*	*Mean (MCE+SWR)*
Lawak Island	*247* *Low*	*611* *Low*	*429* *Low*
Patag Island	*1,903* *Moderate*	*1,433* *Moderate*	*1,668* *Moderate*
Likas Island	*863* *Moderate*	*708* *Moderate*	*786* *Moderate*
Pagasa Island	*1,099* *Moderate*	*1,085* *Moderate*	*1,092* *Moderate*
Parola Island	*638* *Low*	*417* *Low*	*528* *Low*
Nares Bank	*170* *Very low*	*No data*	*170* *Low*
Recto Bank	*883* *Moderate*	*No data*	*883* *Moderate*
Sabina Shoal	*558* *Low*	*920* *Moderate*	*739* *Moderate*
Rizal Reef	*1,083* *Moderate*	*1,042* *Moderate*	*1,063* *Moderate*

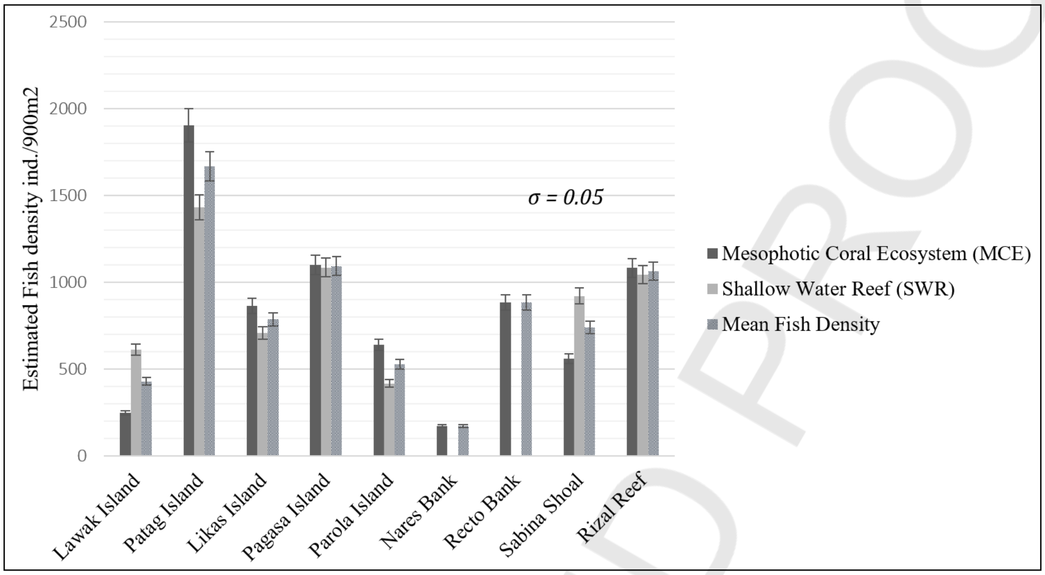

Figure 3. Mean Fish Density (ind/1000m^2) of nine (9) surveyed areas in the West Philippine Sea.

3.2.2 Fish Biomass

Based on the classification described by Hilomen et al.(2000) and Nañola et al. (2006) the estimated fish biomass within the surveyed area was categorized from moderate to very high fish biomass level (Table 6). Both habitat types (MCE and SWR sites) consistently had very high fish biomass. The majority of the species that contributed to these were surgeonfishes (Acanthuridae), triggerfishes (Balistidae), and fusiliers (Caesionidae). Other target fish species, such as emperors (Lethrinidae), parrotfishes (Scaridae), goatfishes (Mullidae), snappers (Lutjanidae), and trevallies (Carangidae), contributed to the high biomass because of their large size (Figure 4). Despite these findings, fish biomass in WPS has declined by an average of 23% per decade, resulting in an estimated reduction of 14 metric tons per square kilometer (mt/km^2). This decrease is due to a large drop in damselfish density and lower biomass in targeted fish groups, particularly fusiliers and parrotfishes (Arceo et al. 2024).

4. CONCLUSION

This study assessed the coral reef habitats and associated reef fish communities within the Kalayaan Island Group (KIG) and surrounding areas in the WPS. The overall results indicate that most surveyed sites exhibit low hard coral cover (HCC), with the majority classified under category D conditions (< 22% HCC). The highest coral cover was recorded at Sabina Shoal (30.52% in MCE and 35.66% in SWR, exceeding the national average HCC of 22%. In contrast, other sites such as Lawak, Patag, Likas, and Pagasa islands showed markedly lower coral cover, suggesting significant anthropogenic and environmental pressures. The coral diversity, measured using taxonomic amalgamation units (TAUs), was also generally low, with all surveyed areas falling within category D (0–18 TAUs), further indicating the degraded state of these reefs.

The primary factors contributing to the observed decline in coral cover and diversity appear to be a combination of natural and human-induced stressors. The presence of dead corals, rubble, and the reported occurrence of blast fishing suggests ongoing destructive practices that threaten reef resilience. Additionally, outbreaks of the coral-eating crown-of-thorns starfish (*Acanthaster planci*) pose further risks to coral regeneration. Despite these threats, coral recruits were documented, indicating that some level of natural recovery is occurring, though prevailing environmental conditions may constrain the rate and success of recruitment.

Fish community assessments revealed a total of 155 species from 28 families associated with live corals, with the highest species richness recorded at Sabina Shoal and Rizal Reef. Species composition was dominated by surgeonfishes (Acanthuridae), triggerfishes (Balistidae), damselfishes (Pomacentridae), and fusiliers (Caesionidae), among others. Notably, six species were classified as either vulnerable or near-threatened according to the IUCN Red List. Fish density ranged from very poor to moderate, with a declining trend in reef fish populations, consistent with regional reports of

Table 6. Fish Species Biomass.

Survey Area	Fish Biomass and Categorization (kg/1000m²)		
	MCE	SWR	Mean (MCE+SWR)
Lawak Island	52 Very high	*33* High	*43* *Very High*
Patag Island	31 High	73 *Very High*	*52* *Very High*
Likas Island	*77* *Very High*	*62* *Very High*	*70* *Very High*
Pagasa Island	*54* *Very High*	*44* *Very High*	*49* *Very High*
Parola Island	*47* *Very High*	*34* *High*	*31* *High*
Nares Bank	*12* *Moderate*	*No data*	*12* *Moderate*
Recto Bank	*42* *Very High*	*No data*	*42* *Very High*
Sabina Shoal	*70* *Very High*	*44* *Very High*	*57* *Very High*
Rizal Reef	*103* *Very high*	*65* *Very High*	*1,063* *Moderate*

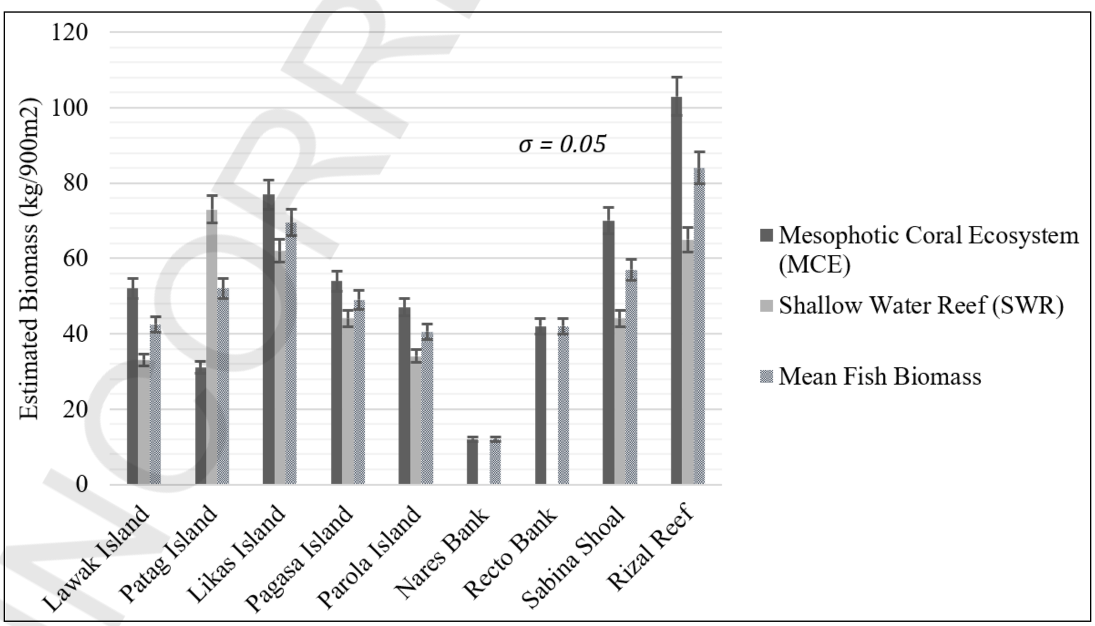

Figure 4. Level of fish biomass within surveyed areas.

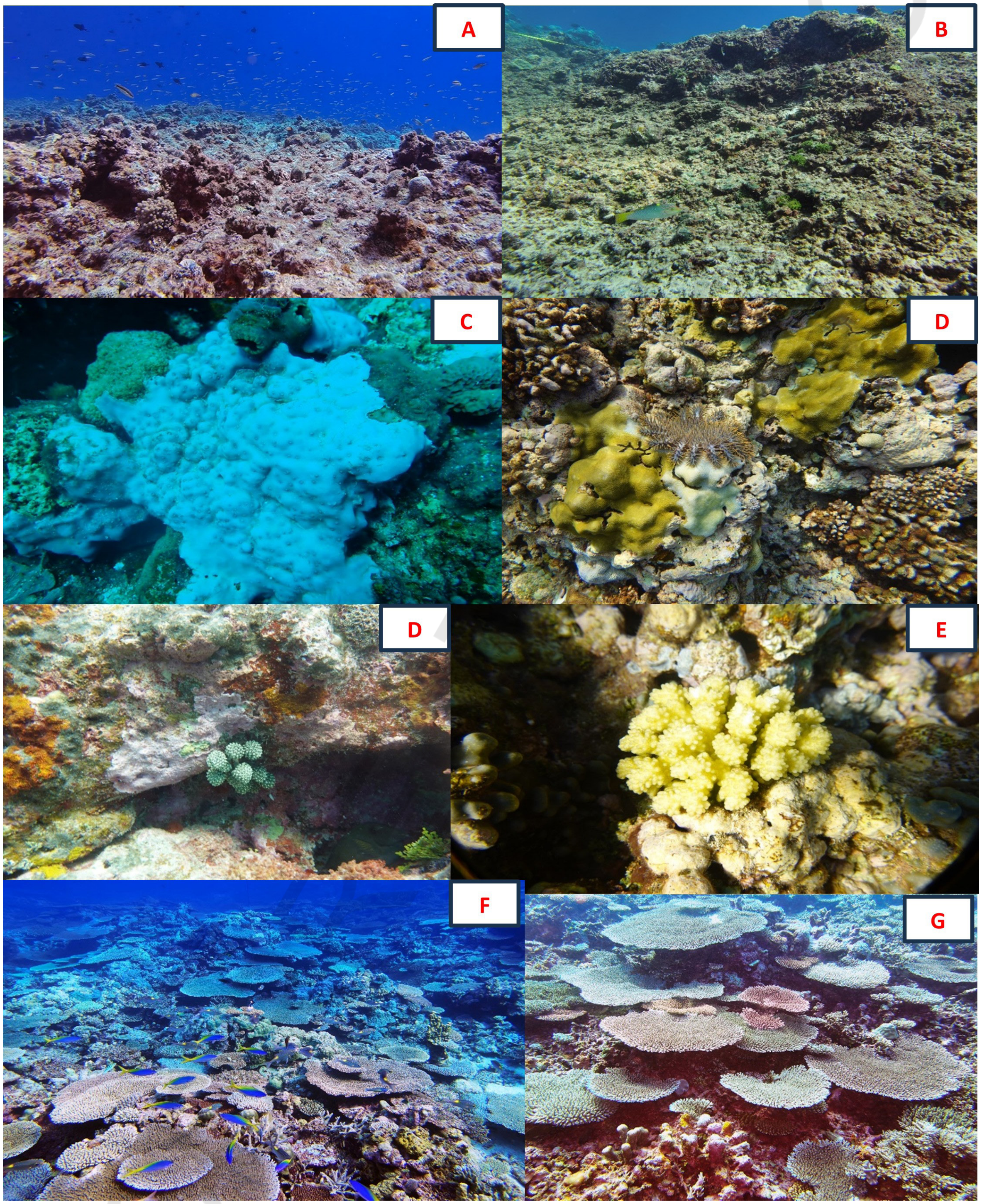

Figure 5. Photodocumentations observed in the coral reef of Kalayaan Island Group. Damage coral reefs taken at Parola (Figure A) and Patag (Figure B). Signs of threats such as coral bleaching in Lawak (Figure C) and a portion of dead coral caused by Crown -of-thorns seastar (CoTS) in Pagasa (Figure D). Coral recruits in Likas (Figure D) and Patag (Figure E). Figures F and G are the coral cover found in Sabina Shoal.

fishery resource depletion. Fish biomass remained relatively high across sites, mainly due to the presence of herbivorous and mid-trophic level species such as surgeonfishes, emperors, and parrotfishes. However, the continued decline in reef fish biomass, particularly among targeted fish groups, raises concerns over the region's long-term sustainability of reef-associated fisheries.

Given the ecological significance of the WPS and the vulnerability of its coral reef ecosystems, enhanced conservation and management measures are imperative. The decline in coral cover and fish biomass aligns with broader regional trends in the South China Sea, emphasizing the need for cooperative efforts in resource management. Strengthening policies to curb destructive fishing practices, promoting reef resilience through marine protected areas, and enhancing enforcement mechanisms will be critical to mitigating further reef degradation. Furthermore, as advocated in previous regional discussions, international collaboration and science-based management approaches may provide a pathway toward sustainable fisheries and reef conservation in the WPS.

This study highlights the urgent need for proactive conservation strategies to safeguard coral reef ecosystems and associated fish communities in the KIG. The findings underscore the necessity of continued monitoring, research, and policy interventions to enhance reef resilience and ensure the long-term sustainability of marine resources in this ecologically and geopolitically significant region.

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AUTHOR CONTRIBUTIONS

Acosta RP: Formal analysis, Writing - Original draft preparation. **Porlaje RZ:** Investigation. **de la Torre A**: Investigation. **Galang RB:** Investigation. **Borja VM**: Reviewing, Investigation. **Romena L:** Reviewing. **Furio FF:** Conceptualization, Supervision, Reviewing. **Tobias ML:** Writing - Original draft preparation. **Mutia MTM:** Supervision, Reviewing.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare. All co-authors have seen and agreed with the contents of the manuscript, and there is no financial interest to report. We certify that the submission is an original work and is not under review at any other publication.

ETHICS STATEMENT

No animal or human studies were carried out by the authors.

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DOI: 10.31398/tpjf/32.1.2023A005

Supplemental data

Table 1. List of fishes documented in the SWR and MCE regions per survey site in Kalayaan Island Group.

Family	Scientific Name	*Sabina* SWR	*Sabina* MCE	*Rizal* SWR	*Rizal* MCE	*Pagasa* SWR	*Pagasa* MCE	*Patag* SWR	*Patag* MCE	*Parola* SWR	*Parola* MCE	*Likas* SWR	*Likas* MCE	*Lawak* SWR	*Lawak* MCE	*Nares* MCE	*Recto* MCE
Acanthuridae	*Acanthurus auranticavus*														x		
	Acanthurus japonicus	x	x	x	x	x	x	x		x	x	x	x	x	x		x
	Acanthurus lineatus							x				x					
	Acanthurus olivaceus							x	x					x	x		x
	Acanthurus pyroferus				x				x						x		x
	Ctenochaetus cyanocheilus				x												
	Ctenochaetus striatus	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Naso annulatus			x	x												
	Naso brevirostris			x													
	Naso caeruleacauda											x					
	Naso lituratus	x	x	x		x	x			x	x	x					x
	Naso unicornis			x												x	
	Naso vlamingii														x		
	Zebrasoma scopas		x	x	x		x	x									
	Zebrasoma velifer	x	x	x	x												
Aulostomidae	*Aulostomus chinensis*			x													

Balistidae	*Balistapus undulatus*		x	x													
	Balistoides conspicillum	x										x					
	Melichthys vidua	x	x	x	x	x		x	x		x	x	x	x	x	x	x
	Odonus niger								x					x	x	x	x
Belonidae	*Tylosurus crocodilus*												x				
Caesionidae	*Caesio teres*	x					x										
	Pterocaesio tile			x	x			x				x	x			x	
Carangidae	*Caranx melampygus*			x									x				
	Elagatis bipinnulata					x		x				x	x				
Chaetodontidae	*Chaetodon lineolatus*	x	x														
	Chaetodon lunula									x							
	Chaetodon ornatissimus	x	x	x				x		x		x					
	Chaetodon rafflesii		x														
	Chaetodon sp.			x	x			x									
	Chaetodon trifascialis	x	x														
	Chaetodon ulietensis		x						x		x			x	x		
	Chaetodon vagabundus														x		
	Coradion altivelis		x														x
	Forcipiger flavissimus			x	x	x	x										
	Forcipiger longirostris	x									x				x		x
	Hemitaurichthys polylepis	x		x	x	x	x					x		x			x
	Heniochus acuminatus														x		

	Heniochus chrysostomus	x	x	x	x	x	x	x						x			x
	Heniochus varius						x										
Cirrhitidae	*Paracirrhites arcatus*	x	x														x
Epinephelidae	*Aethaloperca rogaa*		x														
	Anyperodon leucogrammicus	x		x													
	Cephalopholis argus	x	x	x			x	x			x	x	x				
	Cephalopholis boenak		x				x										
	Cephalopholis microprion												x		x		
	Cephalopholis urodeta	x	x	x	x		x	x		x	x		x	x			
	Epinephelus coioides					x	x	x									
	Epinephelus fasciatus														x		
	Epinephelus fuscoguttatus			x													
	Epinephelus merra	x	x			x	x				x		x				
	Epinephelus polyphekadion							x									
	Epinephelus sexfasciatus						x				x						
	Epinephelus sp.	x		x													
	Gracila albomarginata			x													
	Pseudanthias sp.				x												
	Pseudanthias tuka		x	x													
	Variola louti														x	x	
Haemulidae	*Plectorhinchus vittatus*														x		
	Myripristis kuntee			x			x	x								x	

Holocentridae	*Myripristis murdjan*				x		x	x									
	Neoniphon argenteus							x		x						x	
	Neoniphon opercularis			x	x												
	Neoniphon sammara							x									
	Sargocentron caudimaculatum			x	x			x						x	x		
	Sargocentron spiniferum	x		x	x	x	x										x
Kyphosidae	*Kyphosus vaigiensis*			x						x							
Labridae	*Anampses lineatus*										x						
	Bodianus anthioides	x		x	x												
	Bodianus axillaris									x							
	Bodianus mesothorax			x									x		x		
	Cheilinus fasciatus			x		x								x			
	Cheilinus sp.	x	x												x		
	Choerodon sp.						x							x			
	Choerodon anchorago												x				
	Coris gaimard					x							x				
	Epibulus insidiator			x	x												
	Gomphosus varius	x	x	x	x					x							
	Halichoeres hortulanus	x	x			x		x		x	x	x	x	x	x		x
	Halichoeres podostigma						x										
	Halichoeres sp.																x
	Hemigymnus fasciatus						x										

	Hologymnosus doliatus	x	x														
	Labroides dimidiatus	x	x	x	x	x	x	x	x	x		x		x	x		
	Labroides sp.							x				x					
	Oxycheilinus digramma		x												x		
	Oxycheilinus unifasciatus		x														
	Pseudodax moluccanus	x						x							x		
	Stethojulis interrupta		x														
	Thalassoma amblycephalum		x			x		x	x								
	Thalassoma hardwicke	x	x			x	x			x							
	Thalassoma quinquevittatum	x	x			x				x	x	x					x
	Thalassoma sp.							x			x						
Lethrinidae	*Gnathodentex aureolineatus*	x	x	x	x	x	x	x		x	x		x	x	x	x	x
	Gymnocranius sp.									x							
	Lethrinus microdon	x		x													
	Monotaxis grandoculis	x	x	x	x				x	x	x	x			x		
Lutjanidae	*Aphareus furca*		x	x	x	x				x							x
	Aprion virescens	x	x					x	x		x		x	x	x	x	x
	Lutjanus biguttatus	x															
	Lutjanus bohar	x															
	Lutjanus kasmira	x			x			x								x	
	Macolor macularis									x			x				
	Macolor niger	x						x		x			x				

Malacanthidae	*Malacanthus brevirostris*															x	
Microdesmidae	*Ptereleotris evides*					x							x				
Monacanthidae	*Oxymonacanthus longirostris*		x														
Mullidae	*Mulloidichthys vanicolensis*	x	x	x			x	x		x			x				
	Parupeneus barberinoides									x							
	Parupeneus trifasciatus		x	x	x	x	x	x			x	x	x	x	x		
	Parupeneus cyclostomus			x						x							
	Parupeneus macronemus																x
	Parupeneus multifasciatus		x				x									x	
	Parupeneus pleurostigma									x							
Nemipteridae	*Scolopsis bilineata*							x									
Pinguipedidae	*Parapercis clathrata*														x	x	x
Pomacanthidae	*Centropyge heraldi*															x	x
	Centropyge vrolikii									x							
	Pomacanthus imperator	x													x		
	Pygoplites diacanthus	x	x	x		x	x				x	x	x		x		
Pomacentridae	*Abudefduf vaigiensis*			x		x	x										
	Amblyglyphidodon leucogaster						x										
	Amphiprion clarkii										x					x	

	Amphiprion frenatus		x														
	Amphiprion ocellaris		x														
	Amphiprion sandaracinos						x										
	Pycnochromis amboinensis	x	x		x												
	Pycnochromis margaritifer	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
	Chromis xanthura			x		x	x										
	Dascyllus reticulatus	x	x														
	Dascyllus trimaculatus					x					x					x	
	Neoglyphidodon thoracotaeniatus						x										
	Neopomacentrus violascens													x			
	Plectroglyphidodon dickii		x														
	Stegastes lacrymatus	x			x	x	x										
	Pomacentrus lepidogenys		x														
	Pomacentrus philippinus		x			x	x			x							
Scaridae	*Cetoscarus bicolor*		x										x	x			
	Chlorurus bleekeri	x															
	Chlorurus microrhinos	x		x		x		x									
	Chlorurus sordidus	x	x	x	x												
	Scarus chameleon									x			x				
	Scarus dimidiatus									x				x			

	Scarus flavipectoralis		x														
	Scarus forsteni	x	x	x	x	x	x	x			x		x	x	x	x	x
	Scarus ghobban																x
	Scarus rubroviolaceus		x														
	Scarus schlegeli																x
	Scarus sp.		x	x	x	x	x	x	x	x	x	x	x	x		x	x
	Scarus tricolor					x		x									
Scombridae	*Scomberomorus commerson*												x				
Siganidae	*Siganus vulpinus*	x		x													
Tetraodontidae	*Arothron nigropunctatus*										x						
Zanclidae	*Zanclus cornutus*	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x

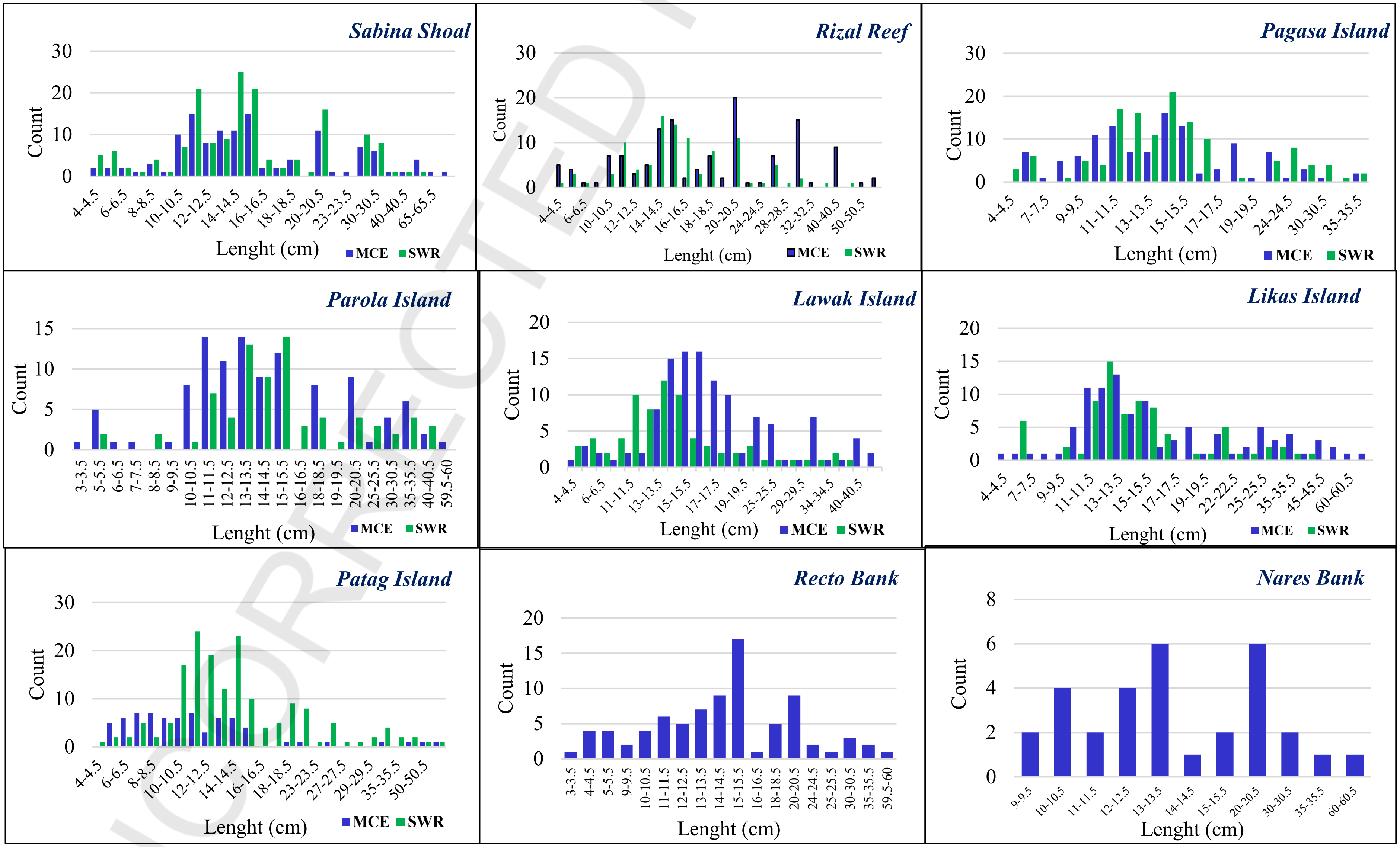

Figure 1. Size composition of fishes in the SWR and MCE of each survey site in KIG