Abrenica et al. / The Philippine Journal of Fisheries 28(1): 97-118
DOI: 10.31398/tpjf/28.1.2020C0011

RESEARCH ARTICLE

Stock Assessment of Parrotfishes "Molmol" (Sub-Family Scarinae, Family Labridae) in the Major Fishing Grounds of Bohol, Central Visayas

Bruna T. Abrenica*, Johnson S. Paran, Analuz M. Bernales, Mario N. Ruinata, Allan L. Poquita

Bureau of Fisheries and Aquatic Resources Regional Office 7, Cebu City

ABSTRACT

The issue on the overfishing of parrotfishes, locally known as "molmol" (subfamily Scarinae under family Labridae), in the coastal waters of Bohol province in Central Visayas has been raised by the Provincial Agricultural and Fishery Council (PAFC) of Bohol through Resolution No. 1 series of 2018 that pushes for the implementation of "open and closed fishing season" of all parrotfishes in the entire province. In any management intervention, baseline assessment of the stocks in question should be done as a significant basis for appropriate measures to be taken, thus this study. In Bohol, apart from the economic value, they carry essential functions in maintaining the ecological balance in the reef ecosystem. Parrotfishes are considered economically important as preferred fish among locals and tourists.

The stock assessment of parrotfishes in Danajon Bank in the Bohol Sea and Cebu Strait was conducted by the National Stock Assessment Program (NSAP) Region 7 from 2015 to 2018 in 16 coastal municipalities of Bohol. It recorded 24 Scarine species across six genera. The green humphead parrotfish (*Bolbometopon muricatum*), categorized as vulnerable under the International Union for Conservation of Nature (IUCN) red list, was noted in Cebu Strait in 2015. *Scarus ghobban*, comprising 82.25%, dominated the catch in Danajon Bank; *Scarus forsteni* (30.07%) in Bohol Sea; and *Chlorurus sordidus* (58.45%) in Cebu Strait. Among the Scarines, *S. ghobban* dominated across fishing grounds from 2015 to 2018 with an aggregate of 10,267.69 kg (or 63.94%) monitored catch equivalent to 0.26% relative to all other species surveyed in the same period. The assessment also indicated that among the 22 fishing gear types being observed as used in catching parrotfishes, speargun is the most prevalent or frequently used.

Moreover, the same assessment showed that the catch seasonality of *S. ghobban* determined from spear gun appears to be abundant during the first quarter in a year; in June, August, and December when higher monthly mean Catch per Unit Effort (CPUE) were also noted. However, the annual mean CPUE of speargun has decreased from 11.93 kg/day in 2017 to 9.22 kg/day in 2018. Population parameters of *S. ghobban* as the top one species were estimated using the FAO-ICLARM Stock Assessment Tools (FISAT) software and Froese Indicator Tool. Biological indicators for *S. ghobban* show signs of overfishing as reflected on its high fishing mortality (F/M), decreasing average length below maturity length, decreasing catch per unit effort in the current year, low percentage of mature in the catch, and increasing exploitation ratio (E). All of which already breached the limit reference points. In 2017 and 2018, the mature size composition of the catch was only 1.9 percent and 0.3 percent, respectively, far off from the 90-100% target and below the 50% limit. The values indicate that majority of the samples were small sizes; however, it cannot be determined if they were juveniles since this study excludes reproductive sampling. Optimum length (Lopt) was estimated at 29 cm (Total Length); lengths within ± 10% Lopt range at 26.1 to 31.9 cm and megaspawner at 31.9 cm up. Based on the results, suggested recommendations are indicated herein for possible consideration of the policymakers.

*Corresponding Author: *rona_abrenica@yahoo.com*
Received: *February 17, 2020*
Accepted: *March 1, 2021*

Keywords: *stock assessment, parrotfishes, Scarus ghobban, speargun, Bohol*

1. INTRODUCTION

Parrotfishes, which consist of about 95 fish species, have traditionally been considered under the family-level taxon, Scaridae. Recent studies reported that they are now accepted as a clade in the tribe Cheilini and are now commonly referred to as scarine labrids (subfamily Scarinae, family Labridae), although their phylogenetic and evolutionary analyses are ongoing (Westneat and Alfaro 2005; Froese and Pauly 2020).

Locally named as "molmol" in Central Visayas, parrotfishes are a group of marine species found in relatively shallow tropical and subtropical coral reefs recognized distinctly with their brilliant coloration and fused beak-like jaws that make them look attractive (Adey and Loveland 2007). They are characterized by having a unique feeding mechanism that is why they can grind ingested carbonates into sand particles. The sand will eventually replace the sand particles being washed off along the beaches. This behavior will enable parrotfish to access nutritional resources and make them one of the most important groups of fishes with a critical role within coral reef ecosystems.

Parrotfishes are considered both commercially and ecologically vital for they possess the ability to modify the benthic biota, and they influence the restructuring of some reef fish assemblages (Bellwood et al. 2003; Elumba et al. 2019). A new study has discovered that parrotfish are extremely important for the health of the Great Barrier Reef as they regularly perform the task of scraping and cleaning inshore coral reefs. Parrotfishes are more important as coral sand producers, cleaners, and reef builders than having them fished as reefs are already lacking many important fishes (Horn 2018).

Parrotfishes can also be an indicator of fishing pressure in a particular coral reef ecosystem. In the study of Vallès and Oxenford (2014), they found that average parrotfish size on assemblage level might be a useful alternative indicator of fishing effects over the typical conditions of most Caribbean shallow reefs. Lavides et al. (2016) pointed out that the huge decline of disappearing finfish species such as bumphead parrotfish or "taungan," the humphead wrasse or "mameng," and the giant grouper or "kugtong" may have caused significant ecological impacts in the marine ecosystem considering their importance in coral reefs. Each of the species contributes to maintaining the ecological balance of the reef ecosystem. The humphead parrotfish helps control algal overgrowth and allows the healthy growth of corals as it scrapes and feeds on algae and bacteria. It also contributes to building sand beaches as it can remove as much as five tonnes of carbonate annually from the reef, half of which is living coral (Bellwood et al. 2003). The humphead wrasse feeds on crown-of-thorns starfish, which is a poisonous animal that eats living hard coral. It helps regulate the population size of the coral predator. In addition to their ecological importance, parrotfishes have high aesthetic *value as an attraction* in *diving* destinations because of their charismatic behavior and attractive and striking colorful appearance, making them highly potential for ecotourism.

Despite their ecological importance to reef ecosystems, parrotfishes are subject to numerous threats like global effects on ocean warming and acidification, overfishing, pollution, and habitat degradation (Hoey and Bonaldo 2018). A study by the International Union for Conservation of Nature (IUCN 2012) showed that corals in the Caribbean have declined by more than 50 percent since the 1970s at the same time as the decline of the parrotfish population in the region.

The Bohol province in Central Visayas, where major fishing grounds abound, such as the Camotes Sea, Danajon Bank, Cebu Strait, and the Bohol Sea, is rich in fishery resources. These seas are home to threatened residents and migratory species of cetaceans and famous for whale sharks and manta rays that are equally important to the ecological balance of the ecosystem. Apart from these resources, parrotfishes or "molmol" are considered as one of the essential fishery commodities in Bohol mainly because of their high economic values as preferred food fish among locals and tourists. Considering their high value, the market price of "molmol" ranges from PHp 120 to PHP 150 per kilogram for small-sized, PHP 180-200 for medium-sized; and PHP 250 to as high as PHP 500 per kilogram for large-sized species depending on the season (BFAR VII 2018) Also, the aesthetic value of Scarines benefits the developing tourism industry in Bohol islands, which is marked as one of the country's well-known diving and tourist spots.

At present, there is a fuming issue on the overfishing of parrotfishes in Bohol. In July 2018, the Provincial Agricultural and Fishery Council of Bohol lodged Resolution No. 1 series of 2018 pushing for the declaration of "open and closed fishing season for parrotfishes or 'molmol' in all coastal municipalities of Bohol" based on the premise that they are overfished (Provincial Agricultural and Fishery Council 2018).

However, there is a dearth of information or scientific studies to support the claim of overfishing as there is no report on stock assessment of parrotfishes in the area. Little information can be gleaned from the study of Green et al. (2004), indicating that parrotfishes as a group comprise 2.63% of the overall catch of Danajon Bank.

With these circumstances, this paper aims to provide science-based information on the stock status of parrotfishes in three major fishing grounds of Bohol, namely: Danajon Bank, Cebu Strait, and the Bohol Sea using the data of National Stock Assessment Program Region 7 gathered from 2015 to 2018. The data included specific information such as species composition, relative abundance, primary fishing gears used, catch per unit effort (CPUE), seasonality of catch, and the growth and mortality parameter of the dominant Scarine. The dominant species was evaluated based on three biological indicators: Lbar or Fishing Mortality, Froese Indicators (i.e., percentage of mature, megaspawner, and optimum length of the catch), and CPUE. The performance indicators generated will provide initial guidance to policymakers on the proper management and conservation of parrotfishes in Bohol.

2. MATERIALS AND METHODS

2.1 Study site

A total of 26 monitoring sites in 16 coastal municipalities and three fishing grounds of Bohol were monitored (Figure 1). At least 13 landing sites were established in coastal barangays of Danajon Bank, particularly Tungod in Inabanga; Corte Baud in Jetafe; Cataban and Tanghaligue in Talibon); Pinamgo Island, Puerto San Pedro, and Poblacion in Bien Unido; San Isidro and Tapon in Ubay; Popoo in Carlos P. Garcia; and Panaytayon, Macaas, and Pandan in Tubigon. Six sites were monitored in Cebu Strait and these were Mantatao Island in Calape; Lintuan in Loon; Poblacion and Punta Cruz in Maribojoc; and Manga and Poblacion 1 in Tagbilaran City. The other seven sites were located in Bohol Sea, namely: Alegria Sur in Loay; Baybayon in Mabini; Panas and Cogtong in Candijay; Canhaway in Guindulman; Can-opao in Jagna, and Poblacion Ubos in Loay.

The Danajon Bank or Double Barrier Reef sits off between the northern part of Bohol Island and the southern part of the Camotes Sea. It is the sole double barrier reef in the Philippines and is one of the only three sites in the Indo-Pacific. It covers a broad area of 272 square kilometers, with an aggregate coastline of 699 kilometers comprising Cebu, Bohol, and Leyte provinces. It includes 40 islands and makes up over one percent of the total coral reef area in the Philippines, estimated at 27,000 square kilometers (Green et al. 2004). The outer reef runs 11 kilometers offshore; it comprises several units up to 23 kilometers long each. The inner barrier is two kilometers wide, separated from the littoral by an inshore channel that is 26 meters deep at most (Green et al. 2004). Cebu Strait, also known as Bohol Strait, is the body of water separating the islands of Bohol and Cebu. The strait is relatively deep, with a maximum depth of about 306 meters. It has a coastline length of 342.4 kilometers and has a total area of 3,933 square kilometers (Green et al. 2004).

2.2 Data collection

The collection of data follows the standard method used by NSAP (Santos et al. 2017). The field enumerators were trained technically by the National Fisheries Research and Development Institute (NFRDI) team before their deployment in their respective monitoring areas. The hired enumerators were tasked to monitor catch landings from all fishing gears (i.e., traps, nets, gill nets, and hook and line, among others) in the designated landing area from 2015 to 2018. The sampling scheme involved monitoring the landed catch for two successive days followed by a one-day interval for an average of 21 sampling days a month. Data were recorded in prepared forms that included the following information: name of the fishing ground; landing center; date of sampling; name of boats; number of fishing days of the actual operation (time); total catch by boat; catch sample weight (kilograms); catch composition (scientific names of the marine species); and name and signature of samplers or recorders. Fish and invertebrate samples were identified using NSAP training modules developed by NFRDI, published textbooks (i.e., Masuda et al. 1984; Randall et al. 1997; Rau and Rau 1980), journals, and online databases–FishBase and Sealife.

Data on the fishing boat, its propulsion, tonnage, and other relevant information were obtained through actual interviews with the fisherfolk. Fish samples were sorted by species, and their sample weights were recorded. Total lengths (TL) were measured in centimeters to the lower centimeter limit, while weight measurements were in kilograms.

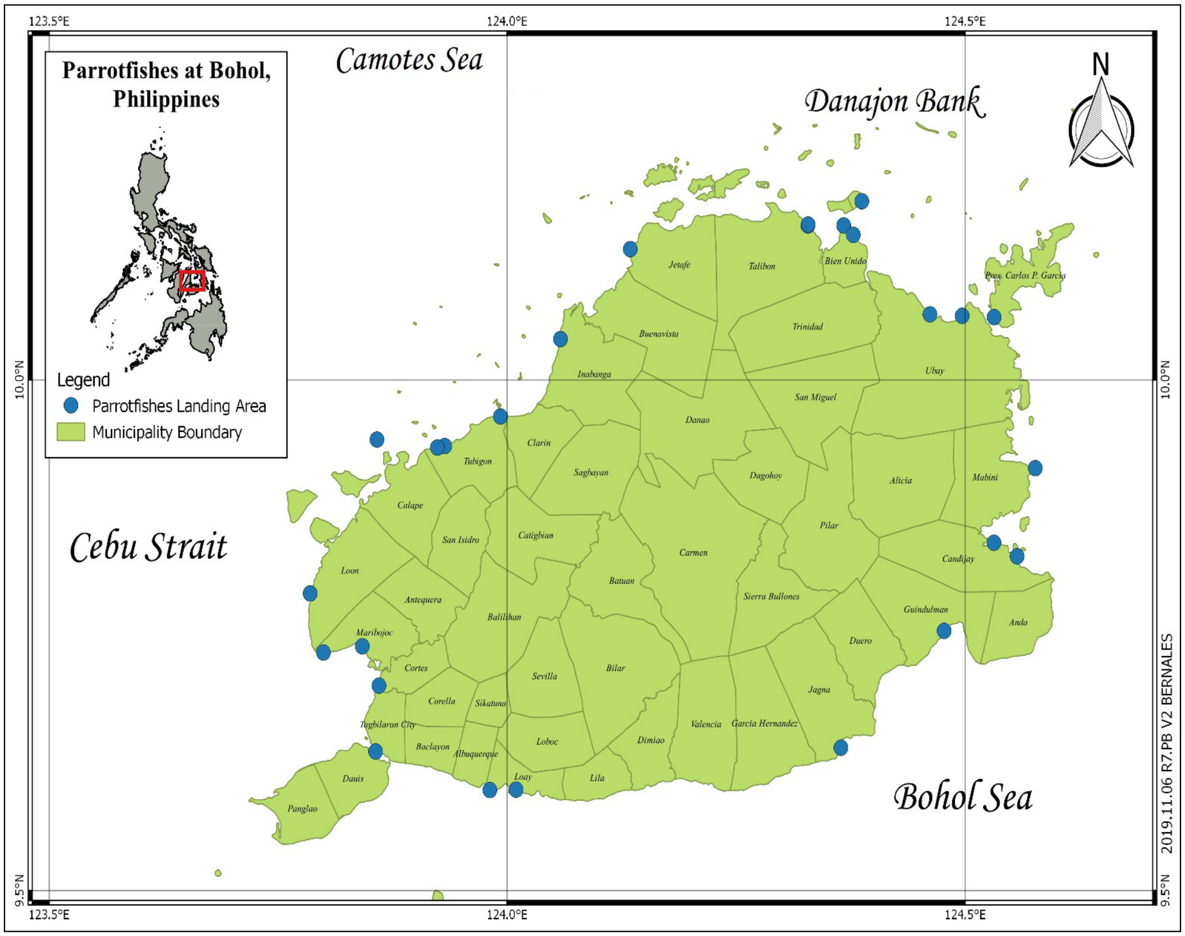

Figure 1. NSAP monitoring sites of parrotfishes in the major fishing grounds of Bohol.

2.3 Data processing and analysis

All data were submitted to the NSAP office in Cebu City for encoding and processing. Catch and effort, species composition, and length-frequency data of subfamily Scarinae from the monitored landings caught by various gear types were consolidated by month from 2015 to 2018. Annual fish data were processed and analyzed using the FISAT program developed by FAO and ICLARM and the Froese Indicator Tool (Froese 2004).

2.3.1 Catch per unit of effort (CPUE)

The different fishing gears used to catch parrotfish were identified. Catch is expressed in kilogram, while Effort used is the number of fishing days of operation for each gear type. All fishing gears and boats catching parrotfishes were observed to be under the municipal sector having less than three gross tonnages (GT) and operating once a day only. In this study, the CPUE of speargun as the primary gear targeting parrotfish was determined and considered in the analysis. The rest of the gears had a very minimal and variable representation of parrotfish landing. The mean CPUE per month was computed by dividing the total monthly catch over the total monthly fishing days per gear type. The annual mean CPUE was obtained by summating monthly fish catch divided by the total number of fishing days for the whole year. The computed CPUE for each gear is expressed in kilogram per day (kg/day).

2.3.2 Catch composition and dominant species in the catch

The dominant parrotfishes caught were determined based on the fishes' contribution by weight to the total monitored landings from 2015 to 2018. The dominant species were ranked to the highest percentage contribution to the catch.

2.3.3 Estimating growth and mortality of major Scarid species using L-F data

Analysis on growth and mortality parameters was done on the blue-barred parrotfish, *Scarus ghobban* "molmol" in Danajon Bank as the only major Scarine species that had sufficient length data required for the analysis. A total of 9,360 length frequencies, of which 4,406 were collected in 2017 and 4,954 in 2018, were used in the analysis.

Monthly length frequencies of *S. ghobban* were processed using the computer program FISAT version 1.2.2 (Gayanilo et al. 2005).

The von Bertalanffy growth parameters L_∞ and K were estimated first using the Powell-Wetherall method (Wetherall 1986) to approximate the asymptotic length (L_∞) and the ratio of the coefficients of mortality and growth (Z/K). Verification and final selection of growth parameters were carried out with the ELEFAN I (Electronic Length Frequency Analysis) routine.

The final values of L_∞ and K were used to calculate the length converted catch curve (Pauly 1984) to derive estimates of the instantaneous total mortality (Z). Further, estimates of natural mortality (M) were derived with the empirical equation given by Pauly (1980):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where L_∞ and K are the VBGF growth parameters, and T is the annual mean habitat temperature (°C) of the water in which the stock in question lives. For this study, the temperature value used was 28.3°C, which is the mean surface water temperature for the Philippines as a whole (Dalzell and Ganaden 1987). Furthermore, the fishing mortality (F=Z–M) and exploitation (E=F/Z) rates were obtained.

LBAR, length-based method, was used to evaluate the robustness of the average length of the species "*Scarus ghobban*" to estimate fishing mortality expressed as Fishing Mortality over Natural Mortality (F/M). Lbar is the average of fish above length at first capture (Lc), which is the fully exploited phase of the fishery. Decreasing length, especially when the majority of the catch is under length at maturity, will drive down the abundance and distribution of reproducing individuals, leading to growth and recruit overfishing of the stocks (Froese 2004; FISHE 2015). According to Soliman et al. (2009), overfishing happened due to excessive harvesting of juveniles and high exploitation of older individuals. However, the limitation of this study is the absence of reproductive biological information on the species to determine exactly the onset of its maturity. It also lacks information on the size at which it will exhibit sex change (from female to male) as an essential biological characteristic of parrotfish being protogynous hermaphrodite species.

Froese Indicator Tool (Froese 2004), which requires length-frequency data as the primary input for the analysis, was used to evaluate the condition of the stock based on simple biological indicators categorized as, one, a percentage of mature fish in the catch with 90-100% as a target. This follows the "let them spawn" principle wherein the immature sizes should be given a chance to grow in the fishery. The second indicator is the percent share of catch with optimum length (Lopt) with 100% as a target or the "let them grow" principle, that is, giving the fish sufficient time to grow to reach the size at first maturity (Lm). This is based on the premise that if the fish are given a chance to complete their spawning period and every spawner must produce at least one replacement spawner before they are harvested, the stock will sustain. The third and last indicator is the percent share of megaspawner in the catch, with 0%-10% as a target or the "let them live" principle. Megaspawner is the individual that has reached a size of at least 10% larger than the optimum length for a population. A large-sized spawner will contribute more productivity as a bigger female produces more and larger eggs and is more fecund than smaller ones (Froese 2004; FISHE 2015).

3. RESULTS

3.1 Species Composition and Relative Abundance

Tables 1A-1C present the parrotfish "molmol" species composition, monitored landed catch, and relative abundance by fishing ground recorded from 2015 to 2018. A total of 24 species of "molmol," three of which were undetermined Scarus belonging to six genera, were recorded from 26 landing centers in three fishing grounds covering 16 coastal municipalities of Bohol province. It accounted for 53% of the total 45 species of parrotfish reported in the Philippines (Froese and Pauly 2021). The highest count was obtained in Danajon Bank with 20 species, including three *Scarus* spp., the highest count was recorded in 2016 with 17 species. The Bohol Sea followed with 15 species and lowest in Cebu Strait with 14 species. On a yearly account, a low species count was noted in 2018 with three species in Danajon Bank, four in the Bohol Sea, and two in Cebu Strait. Overall, the species identified belong to six genera: *Bolbometopon, Calotomus, Chlorurus, Hipposcarus, Leptoscarus,* and well-represented *Scarus* group with 15 species, including three undetermined.

Table 1A. Total monitored landed catch (kg) and relative abundance (%) of parrotfish species in Danajon Bank from 2015 to 2018.

Species	2015		2016		2017		2018		Total	Overall
	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	RA (%)
Scarus ghobban	214.84	20.87	947.85	49.98	5,631.01	94.47	3,239.39	97.82	10,033.09	82.25
Scarus dimidiatus	343.46	33.37	122.78	6.47	53.42	0.90		-	519.65	4.26
Leptoscarus vaigiensis	125.24	12.17	220.59	11.63	88.04	1.48	47.74	1.44	481.61	3.95
Scarus schlegeli	75.54	7.34	196.41	10.36	69.28	1.16	21.45	0.65	362.69	2.97
Scarus tricolor	172.75	16.78	114.71	6.05	51.68	0.87		-	339.14	2.78
Scarus spp. (3)	27.68	2.69	79.89	4.21	16.55	0.28		-	124.12	1.02
Chlorurus sordidus	57.81	5.62	49.96	2.63		-		-	107.77	0.88
Scarus quoyi		-	20.17	1.06	39.68	0.67		-	59.85	0.49
Calotomus spinidens		-	49.67	2.62	9.00	0.15		-	58.67	0.48
Hipposcarus longiceps	0.24	0.02	35.01	1.85	0.57	0.01	2.91	0.09	38.72	0.32
Chlorurus bowersi		-	21.80	1.15		-		-	21.80	0.18
Scarus forsteni		-	17.95	0.95	1.25	0.02		-	19.20	0.16
Scarus flavipectoralis	3.33	0.32	10.17	0.54		-		-	13.50	0.11
Calotomus carolinus		-	6.00	0.32		-		-	6.00	0.05
Scarus niger	5.11	0.50	0.72	0.04		-		-	5.82	0.05
Scarus hypselopterus	0.65	0.06	1.70	0.09		-		-	2.35	0.02
Scarus globiceps	1.10	0.11	0.90	0.05		-		-	2.00	0.02
Chlorurus bleekeri	1.50	0.15		-		-		-	1.50	0.01
Scarus prasiognathos		-	0.18	0.01		-		-	0.18	0.00
Grand Total	**1,029.25**	**100**	**1,896.45**	**100**	**5,960.48**	**100**	**3,311.49**	**100**	**12,197.66**	**100**

Table 1B. Total monitored landed catch (kg) and relative abundance (%) of parrotfish species in the Bohol Sea from 2015 to 2018.

Species	2015		2016		2017		2018		Total	Overall
	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	RA (%)
Scarus forsteni	73.15	51.34			18.00	17.93	50.84	35.91	141.99	30.07
Scarus sp.	5.48	3.85	17.96	20.45	42.47	42.32	31.20	22.04	97.11	20.56
Leptoscarus vaigiensis	20.64	14.49	25.84	29.42	16.89	16.83	20.33	14.36	83.71	17.72
Scarus ghobban	8.26	5.80	32.69	37.21	10.01	9.97	4.68	3.31	55.64	11.78
Scarus dimidiatus	11.00	7.72	0.85	0.97	9.00	8.97	16.00	11.30	36.85	7.80
Scarus schlegeli	7.63	5.35	1.80	2.05		-	14.50	10.24	23.93	5.07
Calotomus spinidens	2.19	1.54	6.10	6.95		-		-	8.29	1.76
Scarus flavipectoralis	1.30	0.91	1.40	1.59		-	3.22	2.28	5.92	1.25
Scarus quoyi	1.10	0.77		-	4.00	3.99		-	5.10	1.08
Scarus niger	4.28	3.01		-		-		-	4.28	0.91
Chlorurus bleekeri	4.09	2.87		-		-		-	4.09	0.87
Chlorurus bowersi	0.20	0.14	1.01	1.15		-		-	1.21	0.26
Chlorurus sordidus	1.20	0.84		-		-		-	1.20	0.25
Hipposcarus longiceps	0.75	0.53		-		-		-	0.75	0.16
Scarus globiceps	0.55	0.39		-		-		-	0.55	0.12
Chlorurus capistra-toides		-		-		-	0.45	0.32	0.45	0.10

Continuation of Table 1B. Total monitored landed catch (kg) and relative abundance (%) of parrotfish species in the Bohol Sea from 2015 to 2018.

Species	2015		2016		2017		2018		Total	Overall
	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	RA (%)
Scarus rivulatus	0.40	0.28		-		-		-	0.40	0.08
Scarus prasiognathos		-	0.18	0.20		-	0.35	0.25	0.53	0.11
Scarus psittacus	0.25	0.18		-		-		-	0.25	0.05
Grand Total	**142.48**	**100**	**87.83**	**100**	**100.37**	**100**	**141.57**	**100**	**472.25**	**100**

Table 1C. Total monitored landed catch (kg) and relative abundance (%) of parrotfish species in Cebu Strait from 2015 to 2018.

Species	2015		2016		2017		2018		Total Monitored Catch	Overall RA (%)
	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA	Monitored Catch	% RA		
Chlorurus sordidus	1,878.58	61.92	100.00	31.33	1.12	3.37		-	1,979.70	58.45
Scarus quoyi	671.62	22.14	43.11	13.51		-		-	714.73	21.10
Scarus ghobban	158.51	5.22	9.00	2.82	11.45	34.55		-	178.96	5.28
Chlorurus japanensis	98.93	3.26	70.00	21.93		-		-	168.93	4.99
Chlorurus bowersi	123.84	4.08		-		-		-	123.84	3.66
Scarus tricolor		-	69.67	21.83	7.54	22.74	0.36	32.16	77.57	2.29
Calotomus spinidens	63.42	2.09	4.00	1.25		-		-	67.42	1.99
Scarus flavipectoralis	25.18	0.83	10.87	3.41		-		-	36.05	1.06
Leptoscarus vaigiensis	4.75	0.16	4.48	1.40	1.49	4.50		-	10.72	0.32
Scarus psittacus		-	5.17	1.62	3.80	11.47		-	8.97	0.26
Hipposcarus longiceps		-	0.72	0.23	7.74	23.37		-	8.46	0.25
Bolbometopon muricatum	5.60	0.18		-		-		-	5.60	0.17
Chlorurus bleekeri	2.33	0.08	2.18	0.68		-	0.77	67.84	5.28	0.16
Scarus sp. 1	1.00	0.03		-		-		-	1.00	0.03
Grand Total	**3,033.76**	**100**	**319.20**	**100**	**33.14**	**100**	**1.13**	**100**	**3,387.23**	**100**

The blue-barred parrotfish *Scarus ghobban* dominated in Danajon Bank, comprising the most significant share at 82.25%, *Scarus dimidiatus* at 4.26%, *Leptoscarus vaigiensis* at 3.95%, *Scarus schlegeli* at 2.97%, *Scarus tricolor* at 2.78%, and three *Scarus* spp. at 1.02%, which were present in lesser volume while the rest of the species contributed below 1%. Dominating the minimal volume of parrotfish landings in the Bohol Sea were *Scarus forsteni* (30.07%), *Scarus* sp. (20.56%), *Leptoscarus vaigiensis* (17.72%), *Scarus ghobban* (11.78%), *Scarus dimidiatus* (7.80%), and *Scarus schlegeli* (5.07%). In Cebu Strait, *Chlorurus sordidus* ranked first with a combined percentage share of 58.45%, followed by *Scarus quoyi* (21.10%), *Scarus ghobban* (5.28%), *Chlorurus japanensis* (4.99%), and *Chlorurus browersi* (3.66%).

Among all species of parrotfishes monitored from the three fishing grounds, *Scarus ghobban* emerged dominant, comprising the biggest aggregated share of 63.94% or 10,267.69 kg. However, *S. ghobban* comprised only 0.26% relative to the overall volume, including all species, parrotfishes and non-parrotfishes monitored in Central Visayas' three principal fishing grounds.

Relative abundance of parrotfishes from the monitored landed catch varies with fishing ground and landing site. The highest share was obtained in Danajon Bank at 75.96% contributed by Cataban and Tanghaligue, Talibon at 48.96% & 15.50% respectively, followed by Cebu Strait with a total of 21.09% of which Poblacion 1, Tagbilaran City (14.15%) was the major contributor and minor quantity in the Bohol Sea with 2.94% of which only Panas, Candijay had over 1% share (Table 2). As a group, the collective percentage of parrotfishes relative to the overall catch, including all fish families in Danajon Bank, is 2.18% or rank 16

(Table 3A). In comparison, Cebu Strait has a 0.17% share at rank 8 (Table 3B) and almost negligible in the Bohol Sea at 0.02% only at rank 97.

Table 2. Monitored catch of parrotfishes by landing site by fishing ground from 2015 to 2018.

A. Danajon Bank	**12,197.66 (kg)**	**75.96**
Cataban, Talibon	7,862.32	48.96
Tanghaligue, Talibon	2,489.30	15.50
Pinamgo Is.,Bien-Unido	545.05	3.39
San Isidro, Ubay, Bohol	275.22	1.71
Puerto San Pedro, Bien Unido	220.3	1.37
Popoo, Carlos P. Garcia	20.07	0.12
Poblacion, Bien Unido	11.29	0.07
Tapon, Ubay	5.22	0.03
Panaytayon, Tubigon	584.24	3.64
Tungod, Inabanga	159.14	0.99
Corte Baud, Getafe	6	0.04
Pandan, Tubigon	16.6	0.10
Kan-ikong Macaas, Tubigon	2.91	0.02
B. Bohol Sea	**472.25 (kg)**	**2.94**
Panas, Candijay	254.52	1.59
Cogtong, Candijay	97.16	0.61
Can-Opao, Jagna	86.98	0.54
Alegria Sur, Loay	13.92	0.09
Canhaway, Guindulman	11.35	0.07
Poblacion Ubos, Loay	7.12	0.04
Baybayon, Mabini	1.2	0.01
C. Cebu Strait	**3,387.23 (kg)**	**21.09**
Poblacion 1, Tagbilaran City	2,271.36	14.15
Mantatao Is., Calape	967.59	6.03
Poblacion, Maribojoc	124.87	0.78
Punta Cruz Maribojoc	18.28	0.11
Manga, Tagbilaran City	4	0.02
Lintuan, Loon	1.13	0.01
Grand Total	**16,057.14**	**100.00**

Table 3A. Relative abundance (%) of parrotfishes (Subfamily Scarinae, Family Labridae) from the monitored landed catch in Danajon Bank from 2015 to 2018.

Family	*Monitored Catch (kg)*	*% RA*
Scombridae	56,859.96	10.18
Belonidae	56,626.84	10.14
Carangidae	55,540.85	9.94
Leiognathidae	45,409.39	8.13
Siganidae	44,975.62	8.05
Lethrinidae	36,475.92	6.53
Nemipteridae	29,112.86	5.21

Continuation of Table 3A. Relative abundance (%) of parrotfishes (Subfamily Scarinae, Family Labridae) from the monitored landed catch in Danajon Bank from 2015 to 2018.

Family	*Monitored Catch (kg)*	*% RA*
Portunidae	25,529.90	4.57
Mullidae	22,664.13	4.06
Hemiramphidae	22,171.42	3.97
Loliginidae	19,610.77	3.51
Terapontidae	14,739.23	2.64
Gerreidae	14,362.58	2.57
Lutjanidae	13,417.50	2.40
Sphyraenidae	13,154.65	2.36
Sub-family Scarinae (Fam. Labridae)	**12,197.66**	**2.18**
Clupeidae	9,943.04	1.78
Serranidae	6,993.14	1.25
Mugilidae	6,714.09	1.20
Penaeidae	6,324.63	1.13
Others (80 families)	45,723.69	8.19
TOTAL	**558,547.85**	**100**

Table 3B. Relative abundance (%) of parrotfishes (Subfamily Scarinae, Family Labridae) from the monitored landed catch in Cebu Strait from 2015 to 2018.

Family	*Monitored Catch (kg)*	*% RA*
Carangidae	771,882.00	37.85
Scombridae	434,219.72	21.29
Clupeidae	303,706.57	14.89
Exocoetidae	68,146.72	3.34
Engraulidae	43,527.49	2.13
Menidae	41,147.26	2.02
Nomeidae	20,914.84	1.03
Sub-family Scarinae (Fam. Labridae)	**3,387.23**	**0.17**
Caesionidae	19,866.00	0.97
Siganidae	13,677.96	0.67
Myctophidae	10,829.39	0.53
Hemiramphidae	6,764.31	0.33
Lethrinidae	5,286.45	0.26
Lutjanidae	4,868.35	0.24
Leiognathidae	4,265.40	0.21
Sphyraenidae	3,540.10	0.17
Trichiuridae	3,501.06	0.17
Loliginidae	2,886.73	0.14
Nemipteridae	2,612.55	0.13
Bramidae	1,935.82	0.09
Others (51 Families)	272,454.23	13.36
TOTAL	2,039,420.17	100

3.2 Fishing Gears

Catch information revealed that 22 fishing gear types caught parrotfishes, all classified as municipal (Table 4). These gears were categorized into four groups, namely:
1. Hand instruments such as speargun and speargun with compressor;
2. Hook and line fishing to include troll line, bottom set long line, hook and line, multiple hook and line, and single handline.
3. Nets comprised *bagnet*, bottom set gillnet, drift gillnet, drive-in net, encircling gillnet, gillnet, ring net, scoop net, scoop net with light, surface set gill net, trammel net, and *lambaklad* or Otoshi-ami.
4. Barrier and traps such as fish corral and fish pot.

The most diverse gears were noted in Danajon Bank with 15 types, followed by Bohol Sea (13) and Cebu Strait (11). Among the gears, speargun was the primary fishing gear that targets parrotfishes. It is a highly selective gear with no record of by-catch. Fishers that are engaged in spearfishing have the opportunity to hand-pick and pursue high-valued, large-sized species like parrotfish.

Table 4. List and classification of fishing gear that caught parrotfishes in the three fishing grounds of Bohol, Central Visayas from 2015 to 2018.

GEARTYPE	**LOCAL NAME**	**Danajon Bank**	**Bohol Sea**	**Cebu Strait**
HAND INSTRUMENT				
Speargun*	Pana/Pamana	√	√	√
Speargun with Compressor	Pana/Compresor			√
HOOKS				
Bottom set long line	Palangre/Kitang	√	√	
Hook & Line	Undak	√		
Multiple hook and line	Undak	√	√	√
Single Handline	Pasol	√	√	√
Troll Line	Pamugit/Mesil	√		
NETS				
Bagnet	Tapay tapay		√	√
Bottom Set Gillnet	Pukot palugdang	√	√	√
Crab Net	Bintol/Pukot panglambay	√		
Drift gillnet	Pamo/Paanod	√	√	√
Drive-in-net	Pamo/Pambudlis		√	
Encircling gillnet	Likos	√		
Mid-Water Set Gillnet	Pukot	√		
Otoshi-Ami	Lambaklad		√	
Ring net	Likom/Lansa			√
Scoop net	Sibot/Sapyaw/Paapong		√	
Scoop Net with Light	Sibot/Sapyaw/Paapong		√	
Surface set Gillnet	Pukot	√		√
Trammel gillnet	Pukot/Triple	√	√	
TRAPS				
Fish corral	Bunsod	√	√	√
Fish pot	Bubo/Panggal	√	√	√
No. of Type		**15**	**14**	**11**

Legend: *major gear

The selectivity of speargun relative to parrotfish was reflected in the high percentage share of its catch (Table 5). In Danajon Bank, the highest monitored landings of parrotfish were caught by speargun contributing 70.89 % (8,646.81 kg) from 2015 to 2018. However, in the Bohol Sea, speargun ranked third at 9.58% (45.229 kg) and second in Cebu Strait at 26.36% (893.03 kg). Other gears that considerably caught parrotfish included bottom set gillnet at 20.68% (2,522.2 kg), drift gill net at 47.25% (1,600.48 kg), multiple hook and line at 5.60% (683.29 kg), and trammel net at 22.11% (104.39 kg).

Table 5. Relative Abundance (%) of parrotfishes per gear type per fishing ground.

Geartype	Monitored Catch (kg)	% RA
A. Danajon Bank		
Speargun	**8,646.81**	**70.89**
Bottom Set Gillnet	2,522.20	20.68
Multiple hook and line	683.29	5.6
Single Handline	152.23	1.25
Fish pot	90.08	0.74
Encircling gillnet	32.9	0.27
Crab Net	29.34	0.24
Bottom set long line	10.08	0.08
Surface set Gillnet	9.5	0.08
Trammel gillnet	8.91	0.07
Mid-Water Set Gillnet	6.7	0.05
Hook & Line	2.6	0.02
Drift gillnet	2.14	0.02
2 Boat Troll Line	0.89	0.01
Grand Total	12,197.66	100
B. Bohol Sea		
Bottom Set Gillnet	160.986	34.09
Trammel gillnet	104.396	22.11
Speargun	**45.229**	**9.58**
Otoshi-Ami (Lambaklad)	38.502	8.15
Drive-in-net	35.336	7.48
Bagnet	26.2	5.55
Multiple hook and line	19.921	4.22
Scoop net	12.4	2.63
Fish pot	11	2.33
Drift gillnet	6.744	1.43
Fish corral	4.391	0.93
Scoop Net with Light	3	0.64
Bottom set long line	2.345	0.5
Single Handline	1.8	0.38
Grand Total	472.25	100
C. Cebu Strait		
Drift gillnet	1,600.48	47.25
Speargun	**893.03**	**26.36**

Continuation of Table 5. Relative Abundance (%) of parrotfishes per gear type per fishing ground.

Geartype	Monitored Catch (kg)	% RA
Ring net	567.55	16.76
Bottom Set Gillnet	179.33	5.29
Speargun with Compressor	76.77	2.27
Fish pot	46.08	1.36
Fish corral	9.2	0.27
Surface set Gillnet	5.14	0.15
Single Handline	4.18	0.12
Multiple hook and line	3.23	0.1
Bagnet	2.25	0.07
Grand Total	3,387.23	100

3.3 Catch Per Unit Effort (CPUE)

The catch per unit effort (CPUE), which refers to the number of fish caught per unit of effort, was computed to obtain information on the catch rate. The CPUE was expressed in kilogram per fishing day (kg/day) of operation. In this particular study, the CPUE was computed only on speargun as the most frequently used main gear that targets parrotfish with landings well distributed throughout the monitoring period. The rest of the gears monitored had very patchy data, which may not represent the catch trend. Apart from being the main gear, speargun can gauge CPUE representation considering that its fishing efficiency is less variable than other gears like gillnet, which vary in length, width, and workforce operation, among others, influencing gear efficiency. The mean CPUE of speargun was computed monthly for each year and summarized annually to show the catch trend of parrotfishes in the three principal fishing grounds of Bohol. Figure 2A-2C summarized the CPUE rate and trend of speargun in the three fishing grounds.

The CPUE trend varies between months and years. In Danajon Bank, the average monthly CPUE was lower in 2015, ranging from 1.54 kg/day obtained in May to 3.51 kg/day in March. In 2016, the highest CPUE was noted in November at 10.29 kg/day, and the lowest was also observed in May at 2.45 kg/day. In 2017 higher CPUE was recorded in February and March at 19.6 kg/day and 19.5 kg/day, respectively. In 2018, CPUE ranged from 6.81 kg/day in January to 11.98 kg/day in July. The overall monthly mean in the four-year monitoring period was also computed to show pattern and variation in the catch trend. Results indicated that the highest catch rate was obtained in March at 8.84 kg/day, closely followed by August with 8.72 kg/day, February at 8.26 kg/day, and November at 8.08 kg/day. Higher values were noted in June and December at 7.55 kg/day and 7.42 kg/day, respectively. Lower catch rates were reported in September (4.03 kg/day), May (4.76kg/day), and January (5.74 kg/day). The annual trend revealed an increasing mean CPUE rate from 2.63 kg/day in 2015 to 3.91 kg/day in 2016 and 11.93 kg in 2017. However, it decreased to 9.22 kg/day in 2018 (Figure 2A).

It appears that speargun was not commonly used in the Bohol Sea, as reflected in the patchy data. The highest mean CPUE was 3.65 kg/day, while the lowest was 0.45 kg/day observed in December and February 2017, respectively. The annual mean catch rate obtained from 2015 to 2018, which ranged from 1.01 kg/day to 1.6 kg/day, was comparable across years at a slightly fluctuating trend (Figure 2B).

A similar observation was noted in Cebu Strait, where speargun was not the main gear used in the area as reflected by sporadic data representation. From 2015 to 2018, only in 2015 that almost all months were represented except in November. Higher CPUE were observed in October (2.48 kg/day), July (2.19 kg/day), April (2.13 kg/day), June (2.06 kg/day), and May (2.04 kg/day). The CPUE values obtained in 2015 demonstrated a similar catch trend between months and were less variable. Minimal data was observed in the succeeding years, with only two months each recorded in 2016 and 2018 and no data obtained in 2017. However, the annual mean CPUE showed a decreasing trend, with the highest rate recorded in 2015 at 2 kg/day and lowest in 2018 at 0.57 kg/day (Figure 2C).

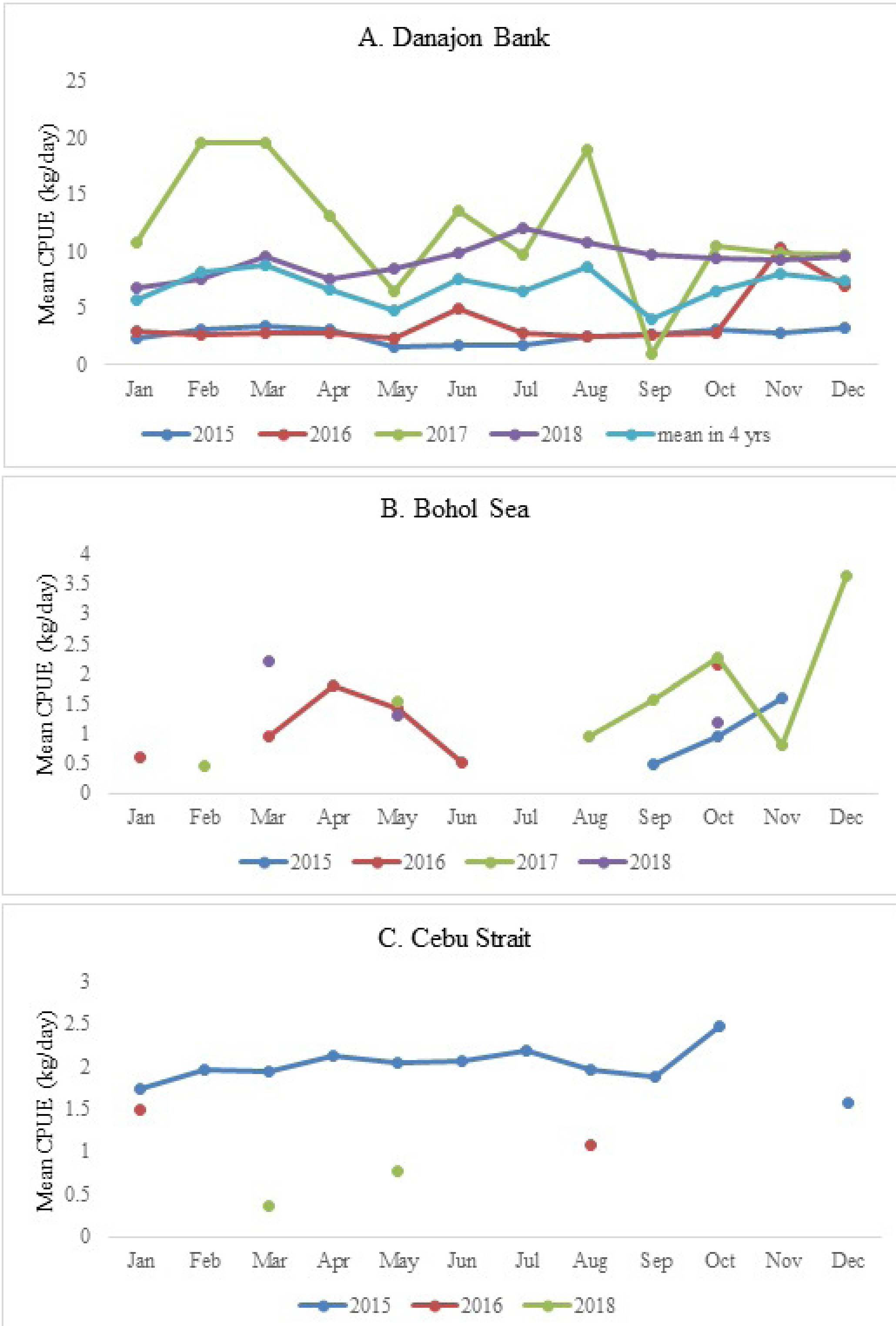

Figure 2A-C. Monthly mean catch per unit effort (CPUE kg/day) of speargun in the three major fishing grounds of Bohol monitored from 2015 to 2018.

3.4 Seasonality of *Scarus ghobban*

The seasonality of the catch of the blue-barred parrotfish, *Scarus ghobban*, as the dominant species reported in this study, was determined based on the monthly relative abundance from its overall monitored landings in Danajon Bank from 2015 to 2018. To avoid the influence of other gears on the seasonality pattern of *S. ghobban*, catch data from speargun alone as the main gear was used (Figure 3). It was observed that *S. ghobban* was present year-round except for January-April 2015 and September 2016, where there was no recorded catch of this species. Results show that it was abundant in the first quarter and in June, December, and August. The highest abundance was noted in June, ranging from 10.66%–63.81%, followed by December (05.97%–31.27%), March (5.44%–14.61%), February (1.59%–12.26%), and August (2.69%–11.76%). Low abundance was observed in September (0.02%–8.12%) and October (0.53%–8.31%).

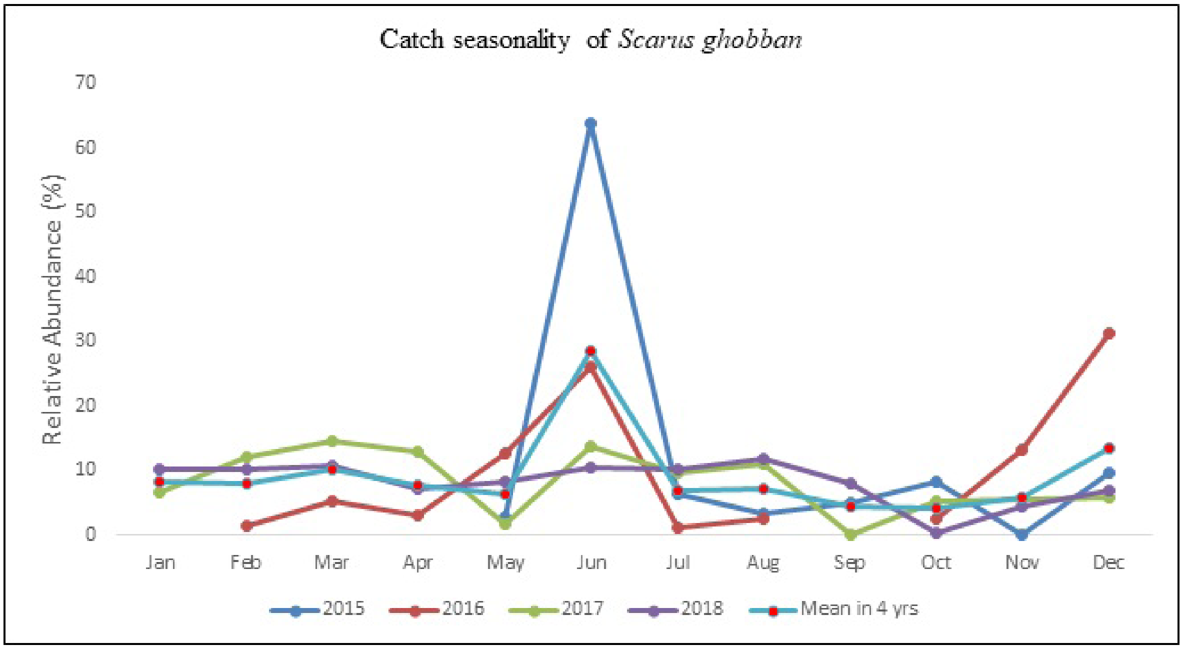

Figure 3. Seasonality of catch of blue-barred parrotfish Scraus ghobban caught by speargun in Danajon Bank from 2015 to 2018.

3.5 Population Parameters

Estimates on the population parameters of *Scarus ghobban* being the dominant parrotfish species recorded in this study were further performed. Among the parrotfishes, *S. ghobban* was the only species with sufficient length frequency (LF) data to generate growth and mortality information. A total of 4,406 and 4,954 individual length frequencies (Total Length in cm) collected in 2017 and 2018, respectively, solely from Danajon Bank were used to estimate Length infinity (L_∞), growth coefficient (K), and Natural mortality (M) and Total Mortality (Z) using FISAT II routine. The generated parameters (L_∞, K, and M) were used as inputs to Froese Indicators Tool (Froese 2004) to determine biological indicators such as percentage mature, optimum length or sizes, and megaspawner of the catch.

S. ghobban in Danajon Bank can grow to a maximum length (L_∞) of 47.8 cm (total length) at a quite slow growth rate (K) of 0.58 yr^{-1}, suggesting that it can live up to 13 years at the maximum (Grandcourt 2002). Demersal species such as parrotfish have slower growth rate at a longer life span compared to pelagic species. The maximum observed length (L_{max}) in the catch was 44 cm. Since we did not have reproductive data, which is supposedly the basis for length maturity (Lm) computation, the Lm here was estimated using the life history tools of FishBase with (L_∞) as the input (Froese and Pauly 2021). The resulting length at which *S. ghobban* started to mature (Lm) was about 26.9 cm (TL).

Summary results of the performance indicators from Lbar and Froese analysis for *S. ghobban* are presented in Table 6. The estimated optimum length (Lopt) was 29 cm. The optimum length refers to the length at which the fewest individuals of a population have to be harvested to reach the maximum biomass.

However, the range where the optimum harvest is achieved falls at optimum length Lopt (±10%) calculated as 10% lower than Lopt to 10% higher than Lopt. The resulting (±10%) Lopt fell at 26.1–31.9 cm (TL). Figure 4A-4B shows the percentage of samples within the length optimum range and megaspawner in 2017 and 2018. It shows that in 2017 about 11.8% of the samples were at the Lopt ±10% range compared to 7.9% in 2018. However, both values were far from the 100% target for optimum length and way below the 50% limit. Regarding the spawning population of the stock, the megaspawners comprised 1.1% in 2017, higher than 0.1% in 2018. Both values obtained for megaspawners of *S. ghobban* in this study were within the target reference points (0-10%) set for demersal stocks. On the other hand, the percentage of mature in the population seemed very low, only 1.9% in 2017 and even lower in 2018 at 0.3%. Combining the percentage of mature and megaspawner obtained for each year showed that it is beyond the 50% limit for mature individuals that should be in the catch. It could be inferred that the majority of the samples were of small sizes.

Table 6. Summary of biological performance indicators of *Scarus ghobban* in Danajon Bank from 2017 to 2018.

Performance Indicator	Target Reference Points (TRP)	Limit Reference Point (LRP)	Results		Assessment Method	Interpretation
			2017	2018		
Fishing Mortality/LBAR					Catch curve	
F/M	F = M or F/M = < 1	F = M or F/M = > 1 or 2	2.7	4.5	Length Frequency Data/ Mean Length	Breach LRP
FROESE % mature % with +10 Lopt % mega-spawners	90-100 % 100% 0-10%	50% and less 80 % -99% 20%	1.9 11.8 1.1	0.3 7.9 0.1	Froese Indicators	Breach LRP
Average length in Total Length (cm)	Above Lm and Increasing	Below Lm and Decreasing	22.32	21.84	Average length	Decreasing
Average CPUE of Speargun (kg/day)	Increasing/ Stable	Decreasing	11.93	9.22	Catch trends	Decreasing
Exploitation Ratio (E)	0.5	0.6	0.65	0.67	Length Frequency	Breach LRP

Note: Target Reference Points (TRPs) are desirable or optimum values to be achieved, while Limit Reference Points (LRPs) are values to be avoided. Lm refers to length at first maturity.

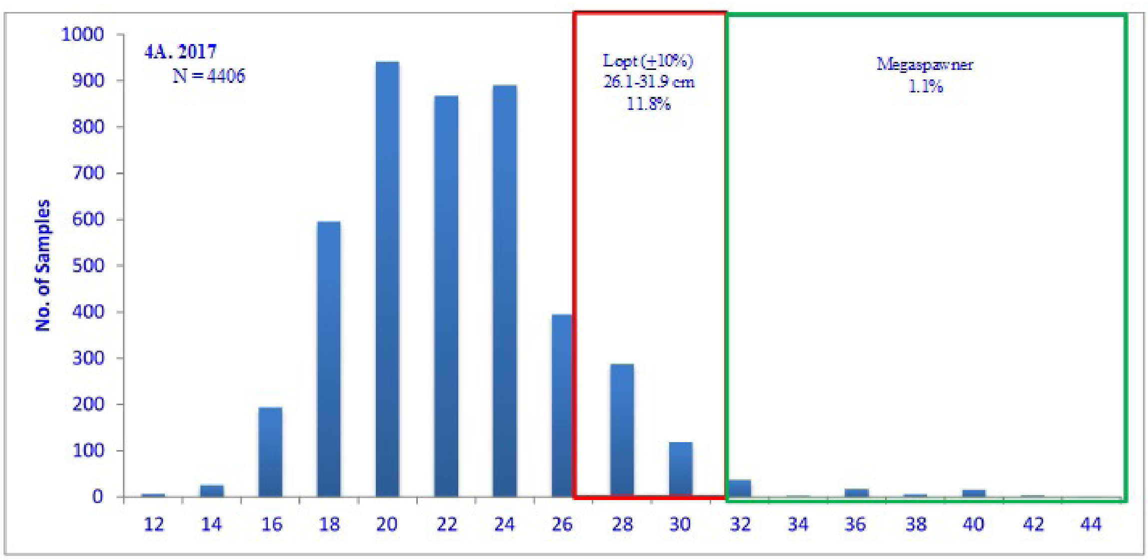

Figure 4A. Percent estimates of catch within +10% optimum length (Lopt+10%) and megaspawner of *Scarus ghobban* in Danajon Bank in 2017 and 2018.

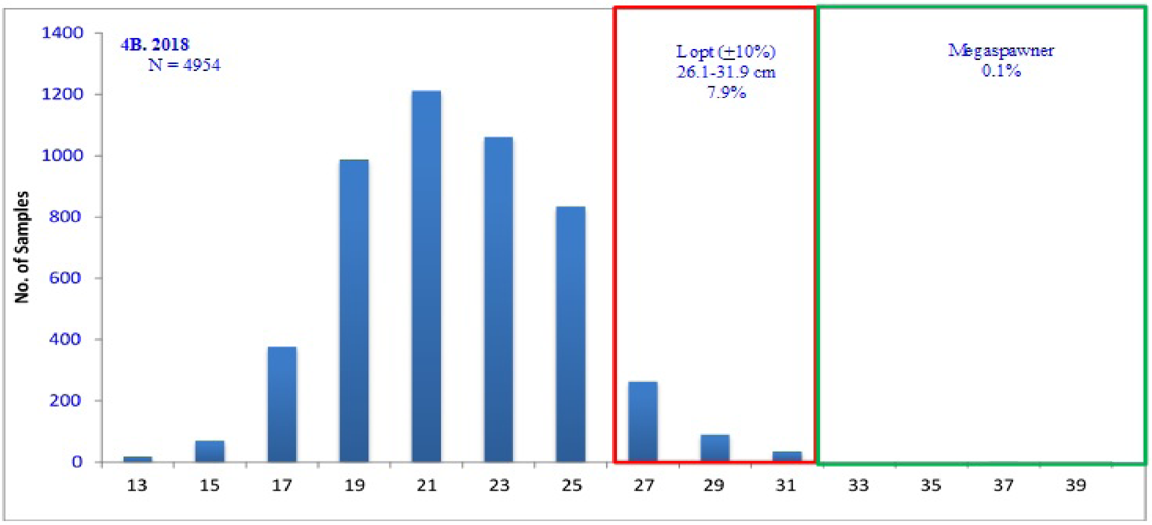

Figure 4B. Percent estimates of catch within +10% optimum length (Lopt+10%) and megaspawner of *Scarus ghobban* in Danajon Bank in 2017 and 2018.

The results from LBAR (F/M) analysis to determine the ratio of fishing mortality against natural mortality showed that fishing pressure on *S. ghobban* was high, as reflected in the high F/M ratio calculated at 2.7 in 2018 and 4.5 in 2018. These values already breached the 2.0 limit reference points or the values we avoid for the stock to be sustainable. Consequently, it was observed that the average length of *S. ghobban* has decreased from 22.32 cm in 2017 to 21.84 in 2018, lower than the 26.9 cm maturity length. Decreasing mean lengths exhibited by *S. ghobban* could be attributed to increasing fishing pressure on the stocks.

In this study, the estimated exploitation ratio (E) of fishing mortality to that of total mortality was high in 2017 (0.65) and 2018 (0.67), already beyond the 0.5 optimum level.

4. DISCUSSION

4.1 Species Composition, Relative Abundance, and Seasonality

Stock assessment of parrotfishes "molmol" conducted in Danajon Bank, the Bohol Sea, and Cebu Strait from 2015 to 2018 recorded 24 species in six genera: *Bolbometopon, Calotomus, Chlorurus, Hipposcarus, Leptoscarus,* and *Scarus*. The species composition was about 53% of the 45 total parrotfish species reported in the Philippines. Danajon Bank registered the highest species count, followed by the Bohol Sea and then Cebu Strait. Of the three fishing grounds assessed, it appears that Danajon Bank was more diverse, which could be attributed to its rare geologic formation, being one of the six double barrier reefs in the world, characterized by more nearshore fisheries compared to more deep-sea fisheries in the Bohol Sea and Cebu Strait. According to Carpenter and Springer (2005), a peak of marine biodiversity occurs in the central Philippine Islands, with special marine conservation efforts warranted within the Danajon Bank because of its importance as a global center of marine biodiversity. Even though Danajon Bank has a high degree of diversity in its marine flora and fauna, previous studies reported that while coral diversity in the area is high, actual living coral cover is low (Calumpong 2005; Armada et al. 2009; Lucas 2010). Their findings showed that the coral reef condition reflects the extent of habitat degradation in Danajon, as evidenced by the low living coral cover and very low fish biomass, suggesting that the general status of the area is degraded and overfished.

Further observation revealed that speargun, which targets parrotfish, was frequently used in Danajon Bank compared to the other two fishing grounds. The overall contribution of parrotfishes as a group relative to all other fish families in Danajon Bank was higher than in Cebu Strait and in the Bohol Sea. However, it was slightly lower than the value recorded in the previous study of Green et al. (2004) in Danajon Bank.

Among the 24 species of parrotfishes monitored from the three fishing grounds, the blue-barred parrotfish *Scarus ghobban* dominated relative to all other species, including non-parrotfishes. *S. ghobban* was present year-round and observed to be abundant in June, December, and March and less abundant during September and October. Tresnati et al. (2019), in their study conducted at Makassar, Indonesia, reported that the catch of parrotfish was randomly distributed, and there were no target species in the parrotfish catch. The fishermen caught whatever sizes of which large-sized parrotfish were captured using the spear, whereas the medium and small-sized parrotfish seem to be captured using the net.

On the other hand, it is significant to note the presence of green humphead parrotfish, *Bolbometopon muricatum*, in Cebu Strait reported in 2015. however, the species diversity of parrotfish seemed low in the area. Sightings of *B. muricatum* in the Philippines are recorded in Lanuza Bay, Surigao del Sur, and Bongo Island, Moro Gulf (Froese and Pauly 2021) Globally, *B. muricatum* is listed as Vulnerable under the IUCN red list (IUCN 2012). Furthermore, a joint study of Haribon Foundation and New Castle University reported that *B. muricatum* is among the 59 species in danger of extinction in the next 10 to 15 years if unsustainable fishing continues (Lavides et al. 2016).

4.2 Fishing Gears and CPUE

Among the fishing gears documented in this study, it shows that speargun was the primary gear that targets parrotfish observed to be widely used in Danajon Bank than in the Bohol Sea and Cebu Strait. Danajon Bank also recorded the highest diversity of parrotfishes and the most diverse kind of gears. The catch rate of speargun as the representative gear for CPUE estimate was computed in the three fishing grounds.

The monthly CPUE trend of speargun in Danajon Bank indicated the highest mean catch rate in March and lowest in September. The CPUEs generated from April, July, and October were most representative of the annual mean.

The highest CPUE values were consistently obtained in Danajon Bank compared to those obtained in the Bohol Sea and Cebu Strait. The high species diversity, multi-gear fishery, and high catch rate in Danajon Bank can be attributed to more nearshore fisheries than offshore fisheries in the Bohol Sea and Cebu Strait.

Generally, the annual CPUE of speargun in the three fishing grounds showed a fluctuating trend with a noticeable decline in the current year. In the Philippines in general, parrotfishes ranked 20 in the municipal marine production, with 4,182.12 MT in 2016, increased to 14,197.99 MT in 2017, and dropped to 13,228.14 MT in 2018, generating a contribution of only (0.02%) (PSA 2018).

To date, there is no published literature to compare if the current catch rate of parrotfishes in Bohol is declining, increasing, or stable. In the absence of baseline information, the assumption is that increasing CPUE for at least 5 to 10 years can represent an increased abundance of targeted stock in the water and can be used as a performance indicator of productivity (FISHE Manual). In addition, the increase in CPUE can also be influenced by the increased efficiency of the gear being used.

4.3 Growth and Mortality Parameters

The length infinity or asymptotic length (L_∞) estimated at 47.8 cm (TL) of *S. ghobban* in Danajon Bank was higher than the values reported in other countries like India (27.4 cm TL), Seychelles (27.5 cm FL), Micronesia (31 cm FL) (Grandcourt 2002) Taiwan (42.2 cm SL), and Solomon Islands (28.8 cm SL) in 15 years (Visconti et al. 2017). However, much lower than 75 cm (TL) maximum length was reported in the Asia Pacific region (www.fishbase.org). The growth constant (K) estimated at 0.58 yr-1 was higher than the values in Seychelles (0.473) and India (0.56) (Froese and Pauly 2021); however, lower than the rate in Taiwan (0.68 in 15 years) and Solomon Islands (1.51 in 15 years) (Visconti et al. 2017). The length at first maturity (Lm) of *S. ghobban* calculated from FishBase using the life history tool was 26.9 cm (TL). It is estimated that 50% of the individuals in a population have reached reproductive maturity at this particular length. At present, there is no published information on the population dynamics of *S. ghobban* specific in the Philippines.

Froese indicator analysis on the estimation of catches categorized as a percentage of mature, percent with optimum length (Lopt+10%), and percent megaspawner of *S. ghobban* generated results far-off from the 90-100% target for mature and 100% target for optimum length (Lopt+10%). The estimated percentage of mature in the catch was only 1.9% and 0.3%, while the catch within the (+10%) optimum length were 11.8% and 7.9% in 2017 and 2018, respectively. The megaspawner comprising 1.1% and 0.1% were also very low. The short composition of mature in the catch could indicate that there were more individuals with smaller sizes but does not necessarily imply that they were all juveniles since reproductive biology sampling was not conducted. The target reference points for megaspawner that should be in the catch are between 0-10% for demersal species (Froese 2004; FISHE 2015). The megaspawner has a size of at least 10% bigger than the optimum length. In this study, the computed optimum length of *S. ghobban* was 29 cm (TL); thus, the size of megaspawner starts at 31.9 cm (TL) and above. The megaspawnner in Danajon Bank was smaller than the terminal phase (TP) size of male *S. ghobban* reported in Taiwan, which has 39.73 cm (SL) but higher than in Solomon Islands (27.87 cm) (SL) (Visconti et al. 2017).

On the other hand, the optimum length range (Lopt+10%) generated for *S. ghobban* was between 26.1 to 31.9 cm (TL). Ideally, these are the length sizes where optimum harvest and economic benefit are achieved. However, it can be noted that within this range, *S. ghobban* may not have undergone a sex change, and there is a danger of harvesting females that have not yet transitioned to terminal males. Parrotfishes are protogynous hermaphrodites. In the course of their life history, they transition from a mostly female "initial phase" to an all-male "terminal- phase (Pavlowich et al. 2018). All megaspawners are expected to be all terminal-phase males. The protandric nature of parrotfish complicates management options as they transition from a female initial phase to an all-male terminal phase. Because of this complex nature, catching the optimum length (29 cm) may not be appropriate unless the size at which sex change occurs for *S. ghobban* in the Danajon Bank is determined. It is suggested, however, to catch only the terminal-phase male. For this case, the size selection starts at 31.9 cm onwards. According to Pavlowich et al. (2018), restricting catch to only terminal-phase (male) fish typically led to populations of greater abundance and biomass and less-disturbed life-phase ratio, compared to similar fishing mortality applied to the whole population of different phases. Limiting the catch to terminal-phase fish also contributes higher catch volume than harvesting any life phase under the same levels of fishing mortality and size selection. It can also be the key to protecting and improving protogynous hermaphrodite populations with a flexible sex-change pattern. By having a robust population of initial-phase fish, the reproductive potential maybe maximized when the size at life-phase transition compensates for changes in population structure. Moreover, catching only terminal-phase fish eliminates mortality on a large segment of the population, such as the initial-phase fish, limiting the number of fish caught, thereby contributing to the increase in total population size and biomass of female fish or initial-phase fish. The increase in biomass is equivalent to the increased income of fishers.

Previous studies have suggested maintaining the size at the selection above the average size at sex change, which is essentially the same as a terminal-only rule, to avoid sperm limitation (Alonzo and Mangel 2004).

The results from LBAR (F/M) analysis on fishing mortality ratio against natural mortality indicated a sign of overfishing on *S. ghobban*, having obtained a high F/M of 2.7 in 2017 and 4.5 in 2018. These values have already breached the 2.0 limit reference point for fishing mortality. Consequently, the average length of *S. ghobban* has decreased from 22.32 cm (TL) in 2017 to 21.84 cm (TL) 2018, lower than 26.9 cm maturity length. Decreasing mean lengths exhibited by *S. ghobban* could be attributed to increasing fishing pressure on the stocks.

Consistent with the fishing mortality result, the exploitation ratio (E) of *S. ghobban* in 2017 (E=0.65) and 2018 (E=0.67) were also high and beyond the optimum level, and the limit reference value of 0.6. The optimum fishing mortality in an exploited stock should be approximately equal to natural mortality, or exploitation ratio (E) is roughly equal to 0.5 (Ingles and Pauly 1984). The higher the E ratio, the higher the fishing effort has been exerted into the fishery. The exploitation values 0.3 to 0.5 are the E values of maximizing biological yield (Pauly 1984). According to Gulland 1971, for a stock to be optimally exploited, the fishing mortality should be about equal to natural mortality. This could also mean that half or more of the biomass per recruit seems to be exploited by the fishery. A high exploitation ratio (E) may indicate unsustainable fishing as the fish are not given a chance to grow bigger and replenish the stock in the wild. The high fishing mortality and exploitation ratio obtained for *S. ghobban* could indicate high fishing pressure, leading to unsustainable harvesting of the stock.

The high exploitation rate observed for *S. ghobban* in Danajon Bank could be associated with some factors such as indiscriminate and uncontrolled fishing, illegal fishing practices (i.e., alleged use of explosives), fish life-history traits, and socio-economic factors like access to market facilities, high demand of the resource, poverty, and overpopulation.

5. CONCLUSION AND RECOMMENDATIONS

Results revealed that 24 out of the 45 species of parrotfishes recorded in the Philippines are observed in this study, of which one species, *Bolbometopon muricatum* or humphead parrotfish, is categorized as vulnerable under the IUCN red list. Among the three fishing grounds surrounding Bohol Island, Danajon Bank is the most diverse with 20 species and contributed the most significant share (75.96%) of parrotfish catch with *Scarus ghobban* as a major contributor harvested by speargun. The highest diversity of parrotfishes noted in Danajon Bank could be attributed to a more productive nearshore fisheries characteristic of the area and the frequent use of speargun as target gear for parrotfish compared to offshore fisheries of the Bohol Sea and Cebu Strait. Catch seasonality of *S. ghobban* from speargun in Danajon Bank was noted to be abundant in the first quarter and in June, August, and December, which correlates with the higher catch rate of this gear during these months. The higher abundance and CPUE may be due to a more productive fishery during these months. However, the annual mean CPUE of speargun showed an increasing trend from 2015 to 2017 and somehow decreased in 2018.

Length-based analysis of performance indicators of *S. ghobban* as the most dominant parrotfish species show signs of overfishing as reflected in high fishing mortality (F), increasing exploitation ratio (E), decreasing average size under maturity length, and decreasing CPUE in the current year. This would mean that high fishing pressure is exerted on the stock. Froese indicators also show very low percentages of mature sizes, within +10% optimum length (Lopt) and megaspawner. This indicates that most of the length composition was of small sizes, possibly mixed juveniles and mature individuals. Indicators analyzed show decreasing trend while some have already breached the limit reference points.

The low percentage of mature and megaspawner in the catch, decreasing average length, which is already below maturity size, high fishing mortality, and high exploitation ratio of *S. ghobban* in Danajon Bank are some indications of high fishing pressure which will eventually lead to unsustainable harvesting of the stock if not properly manage.

Based on the results of the study, the following are hereby recommended:

- Strict implementation of existing fishery laws and regulations against destructive fishing (i.e., use of explosives and cyanide allegedly rampant in the island barangays of Bohol and the use of fine-meshed nets);
- Because of the protogynous nature of parrotfish, restricting catch to only terminal-phase male (>31 cm total length) is suggested to maintain the population's reproductive potential even if the optimum range fell at 26.1 to 31.9 cm. However, this recommendation can only be made with speargun or spearfishing being a selective gear as the fisher has the option to select which size to capture;
- Continuous (at least ten years) stock assessment or catch monitoring focusing on "molmol" fishery in the existing sites with parrotfish landings;
- Revive monitoring of previously monitored site (i.e., Mantatao Island, Calape) with significant parrotfish landings;
- Conduct reproductive biology study of *Scarus ghobban* and other commonly caught Scarine species (*Leptoscarus vaigiensis, Scarus quoyi, Scarus dimidiatus, Scarus tricolor*) to determine spawning pattern which will be the basis for seasonal closure if appropriate. Through reproductive biology study, other critical biological parameters such as Gonado-Somatic Index (GSI), fecundity, and Spawning Potential Ratio (SPR) of the stock can also be determined;
- Conduct underwater fish visual assessment, a fisheries-independent survey to estimate density, spawning stock biomass, and abundance of parrotfish in the specific fishing ground;
- Conduct total inventory of boat and fishing gears to examine gear selectivity and determine total production and Maximum Sustainable Yield (MSY);
- Include on-site price monitoring of "molmol" fishery, including fishing inputs and operational cost, to determine the income per unit of effort (IPUE) per fisher per gear type and determine the Maximum Economic Yield (MEY) as a whole.
- Spatial seasonal closure of parrotfishes shall be imposed if appropriate. This can be done only after the conduct of reproductive biology study;
- Holistic Information Education Campaign (IEC) on the ecological importance of parrotfishes relative to all other aquatic species in the coral reef ecosystem; and
- IEC on coral reef conservation as an essential habitat of parrotfishes and other aquatic organisms.

ACKNOWLEDGMENT

The authors would like to acknowledge with gratitude the contribution and support of the following: BFAR Central Office for the funding; NFRDI through Dr. Lilian Garcia for the technical support, mentoring, and encouragement; special thanks to Dr. Jose Ingles of EDF for the invaluable help in the analysis of data; to Ms. May Miasco-Cabucos for proofreading the manuscript; to the Local Government Unit of Bohol through their Municipal Agriculturists and Fishery Technicians for the support during the survey; to all NSAP field enumerators, encoders and analysts involved in the project; and to all the fisherfolk who willingly and voluntarily shared their daily catch information. To God almighty for the protection, strength, and guidance.

AUTHOR CONTRIBUTIONS

Abrenica BT: Conceptualization, Formal analysis, Writing–Original Draft, Writing–Review & Editing. **Paran JS:** Visualization. **Bernales AM:** Formal analysis, Visualization. **Ruinata MN:** Writing–Review & Editing. **Allan L. Poquita:** Supervision.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ETHICS STATEMENT

The researchers followed all institutional and national guidelines for the care and use of laboratory animals.

REFERENCES

Adey WH, Loveland K. 2007. Dynamic Aquaria. 3rd edition. Building Living Ecosystems. eBook ISBN: 9780080469102. p. 528

Alonzo SH, Mangel M. 2004. Sex-change rules, stock dynamics, and the performance of spawning per-recruit measures in protogynous stocks. Fish Bull. 103(2):229–245. http://aquaticcommons.org/id/eprint/9610

Armada N, White AT, Christie P. 2009. Managing Fisheries Resources in Danajon Bank, Bohol, Philippines: An Ecosystem-Based approach. Coast Manag. 37(3-4):308–330. https://doi.org/10.1080/08920750902851609

Bellwood DR, Hoey AS, Choat JH. 2003. Limited functional redundancy in high diversity systems: Resilience and ecosystem function on coral reefs. Ecol Lett. 6(4):281–285. https://doi.org/10.1046/j.1461-0248.2003.00432.x

[BFAR VII] Bureau of Fisheries and Aquatic Resources Region VII. 2018. Price Monitoring Report. Unpublished Report.

Calumpong HP. 2005. Baseline assessment of Danajon Bank, Bohol. Coast. Curr. Newsl. 7(1):9–10. Silliman University Marine Laboratory.

Carpenter KE, Springer VG. 2005. The center of the center of marine shore fish biodiversity: the Philippine islands. Environ Biol Fishes. 72:467–480. https://doi.org/10.1007/s10641-004-3154-4

Dalzell P, Ganaden R. 1987. A Review of the Fisheries for Small Pelagic Fishers in the Philippine Waters. BFAR Technical Paper series 10(1). Manila: BFAR and International Center for Living Aquatic Resources Management. p. 54

Elumba ME, Mata MAE, Abpi MM, Nañola CL. 2019. Age-based Growth Variation of Green-blotched Parrotfish *Scarus quoyi* in the Southern Philippine Seas. Phil J Sci. 148(2):411–417.

[FISHE] Framework for Integrated Stock and Habitat Evaluation Workbook. 2015. Assessing and Managing Data-Limited Fishery Using FISHE. Environment Defense Fund. fishe.edf.org

Froese R. 2004. Keep it simple: three indicators to deal with overfishing. Fish Fish. 5(1): 86–91. https://doi.org/10.1111/j.1467-2979.2004.00144.x

Froese R, Pauly D, editors [Internet]. 2020. FishBase. Scarinae Rafinesque, 1810. [cited 31 Oct 2020]. https://www.marinespecies.org/aphia.php?p=taxdetails&id=151787

Froese R, Pauly D, editors [Internet]. 2021. Fishbase. World Wide Web electronic publication. [cited 31 Oct 2020]. www.fishbase.org, version (02/2021)

Gayanilo FCJ, Sparre P, Pauly D. 2005. FiSAT II FAO ICLARM Fish Stock Assessment Tools User's Guide version 1.2.2. Food and Agriculture

Organization of the United Nations. http://www.fao.org/fishery/topic/16072/en

Grandcourt EM. 2002. Demographic characteristics of a selection of exploited reef fish from the Seychelles: Preliminary study. Mar Freshwat Res. 53(2):123–130. https://doi.org/10.1071/MF01123

Green SJ, Flores JO, Dizon-Corrales JQ, Martinez RT, Nuñal DRM, Armada NB, White AT. 2004. The Fishes of Central Visayas, Philippines: Status and Trends. Cebu City: Coastal Resources Management Project of the Environment and Natural Resources and the Bureau of Fisheries and Aquatic Resources. p. 159

Hoey AS, Bonaldo RM. 2018. Biology of Parrotfishes. 1st edition. CRC Press. ISBN 9781482224016. CAT# K22357. 420 pp

Horn HW. 2018. The Importance of Parrotfishes, also known as Mol-Mol. Alona Beach, Panglao Bohol, Philippines. www.facebook.com

Ingles J, Pauly D. 1984. Atlas of the Growth, Mortality and Recruitment of Philippine Fishes. Manila: International Center for Living Aquatic Resources Management (ICLARM). https://hdl.handle.net/20.500.12348/3468

[IUCN] International Union for Conservation of Nature. Red List. 2012.

Lavides MN, Molina EPV, de la Rosa GE, Jr, Mill A, Rushton SP, Stead SM, et al. (2016). Patterns of Coral-Reef Finfish Species Disappearances Inferred from Fishers' Knowledge in Global Epicentre of Marine Shorefish Diversity. PLoS ONE. 11(5):e0155752. https://doi.org/10.1371/journal.pone.0155752

Lucas EY. 2010. Outer Danajon Bank, Philippines: Biophysical State, Local Resource Use Patterns, and Feasible Governance Structures for a Large-Scale No-take Marine Protected Area. Thesis (M.M.A.)–University of Washington.

Masuda H, Amoaka K, Araga C, Uyeno T, Yoshino T, editors. 1984. The Fishes of the Japanese Archipelago. Tokyo: Tokai University Press. p 437.

Pauly D. 1980. On the interrelationships between natural mortality growth parameters and mean environmental temperature in 175 fish stocks. ICES J Mar Sci. 39(2):175–192. https://doi.org/10.1093/icesjms/39.2.175

Pauly D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Stud Rev. 8:325. https://hdl.handle.net/20.500.12348/3445

Pavlowich T, Webster DG, Kapuscinski AR. 2018. Leveraging sex change in parrotfish to manage fished populations. Elem Sci Anth. 6:63. https://doi.org/10.1525/elementa.318

[PAFC] Provincial Agricultural and Fishery Council. 2018. Resolution No. 1 series of 2018.

[PSA] Philippine Statistics Authority. 2018. Fisheries Situation Report. January-December 2018.

Randall JE, Allen GR, Steene RC. 1997. Fishes of the Great Barrier Reef and Coral Sea. Honolulu: University of Hawaii Press. p. 507

Rau N, Rau A. 1980. Commercial Marine Fishes of the Central Philippines. Eschborn: German Agency for Technical Cooperation. p. 623.

Santos MD, Barut NC, Bayate AD, editors. 2017. National Stock Assessment Program: The Philippine Capture Fisheries Atlas. Quezon City: Bureau of Fisheries and Aquatic Resources-National Fisheries Research and Development Institute.

Soliman VS, Bobiles RU, Yamaoka K. 2009. Overfishing of Three Siganid Species (Family: Siganidae) in Lagonoy Gulf, Philippines. Kuroship Science. 2:145-150. https://core.ac.uk/reader/70352247

Tresnati J, Yasir I, Yanti A, Rahmani PY, Aprianto R, Tuwo A. 2019. Multi years catch composition and abundance of Parrotfish landed at Makassar Fisheries Port. IOP Conf. Ser.: Earth Environ Sci. 473: 012059. https:/doi.org/10.1088/1755-1315/473/1/012059

Vallès H, Oxenford HA. 2014. Parrotfish Size: A Simple yet Useful Alternative Indicator of

Fishing Effects on Caribbean Reefs? PLoS ONE. 9(1):e86291. https://doi.org/10.1371/journal.pone.0086291

Visconti V, Sabetian A, Trip E, Jones M. 2017. Age, Growth and Reproductive Characteristics of the Blue-barred Parrotfish *Scarus ghobban* from Taiwan and Solomon Islands. 50th Anniversary Symposium of the Fisheries Society of the British Isles, University of Exeter, UK, 3–7 July 2017. Fisheries Society of the British Isles. http://hdl.handle.net/10292/12390

Westneat MW, Alfaro ME. 2005. Phylogenetic relationships and evolutionary history of the reef fish family Labridae. Mol Phylogenet Evol. 36(2):370-390. https://doi.org/10.1016/j.ympev.2005.02.001

Wetherall JA. 1986. A new method for estimating growth and mortality parameters from length frequency data. Fishbyte. 4(1):12–14. https://EconPapers.repec.org/RePEc:wfi:wfbyte:39528