

Original Article

Stock assessment of the marine ornamental Vagabond Butterflyfish *Chaetodon vagabundus* Linnaeus, 1758 (Pisces, Chaetodontidae) and the Indo-Pacific sergeant *Abudefduf vaigiensis* (Quoy & Gaimard, 1825) from Iligan Bay, Southern Philippines

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Abstract: The success of fisheries depends critically on the state of the fish stocks. In this study, a total of 1,188 fish individuals belonging to two species of *Abudefduf vaigiensis* (711), *Chaetodon vagabundus* (477) were investigated based on the samples collected from the waters of Iligan Bay, Southern Philippines. Population parameters were assessed using length-frequency data with FiSAT II software. The results showed positive correlations between length and weight. The values of b significantly ($P < 0.000$) increased from 2.55 in *C. vagabundus* to 2.82 in *A. vaigiensis*. The growth and mortality parameters asymptotic length (L_{∞}), annual growth rate (K), annual total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) were 15.75 cm, 0.430, 1.60, 1.24, 0.28 and 0.18 for *A. vaigiensis* and 14.70 cm, 0.700, 2.60, 1.73, 1.09 and 0.39 for *C. vagabundus*, respectively. A bimodal recruitment pattern of unequal strength was observed for both species. The result of the virtual population analysis (VPA) routine showed that most of the small and young fish were prone to natural losses, while bigger fish were mostly caught by the fisherman. Finally, the maximum sustainable yield (E_{max}) for the two species was higher than the exploitation level, indicating that these two ornamental reef fishes were in good condition in Iligan Bay.

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Introduction

Ornamental fishkeeping is the second-largest hobby in the world, with the demand for ornamental fish steadily increasing annually (Muyot et al., 2019). Due to the considerable growth and diversification of the international ornamental fish trade, there is concern about its potential effects on the conservation of wild populations (Andrews, 1990; Domínguez and Botella, 2014), including its overall impact on the ecological balance of aquatic ecosystems. However, very little is known about the number or diversity of fish in commerce, and traded species are typically not traceable to their originating source because there has never been a proper monitoring system (Biondo and Burki, 2020). Available figures are based primarily on (often historical) estimates or are inferred using limited information from various formal and trade organizations. The data are also mostly based on the

declared value of the ornamental fish trade and often fail to distinguish between freshwater and marine fishes (Monticini, 2010), sometimes including invertebrates (Dee et al., 2014). It is, therefore, challenging to find evidence to support the industry's claims that the ornamental fish trade is sustainable (Monticini, 2010; OATA, 2014). This market scenario may result in a sudden decrease in the marine ornamental fish stock. Thus, stock assessment is needed to provide important scientific information necessary for the conservation and management of fish stocks (Hoggarth et al., 2006; Gebremedhin et al., 2021). The assessment of a fish stock must consider all the relevant factors, especially the direct impact of a fishery on a single species (Halpern et al., 2015).

Growth, mortality, and recruitment parameters are essential for assessing and managing fish stocks (Kalhor et al., 2017), as they determine catch and the

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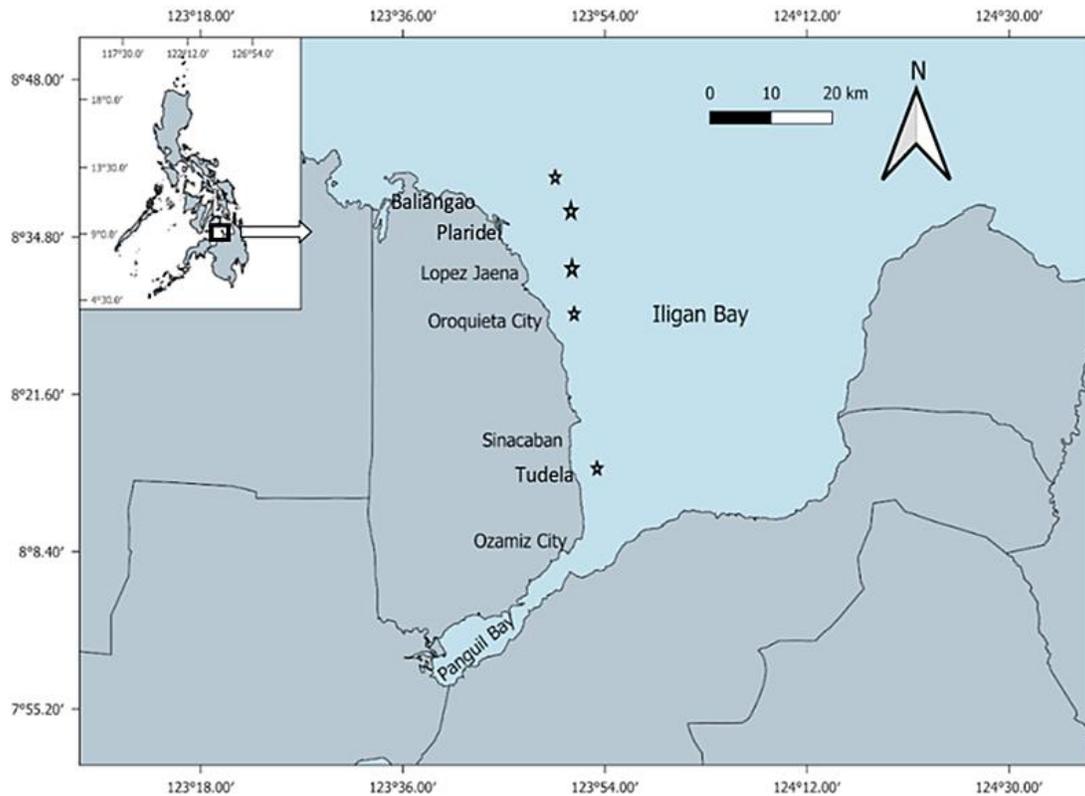


Figure 1. Map of Iligan Bay in Northern Mindanao showing the different fish landing sites (stars) monitored in the present study. This map was generated using QGIS v3.10 software (QGIS Development Team, 2016).

annual amount of fish exploited from fisheries. Recently, several studies have examined the number of fish species and proposed management steps to maintain fish stocks using the FiSAT package (Kalhor et al., 2013; Memon et al., 2015; Majeed et al., 2022). Thus, this study focuses on the annual stock, population structure, and dynamics, growth, mortality, and production of the two ornamental coral reef fish species, Vagabond Butterflyfish (*Chaetodon vagabundus*) and Indo-Pacific sergeant (*Abudefduf vaigiensis*), in the waters of Iligan Bay. Length-frequency distribution data are used to determine stock status and regulate fishing effort to maintain the fish stock. The output of population dynamics indicates the level of exploitation of declining stocks. Hence, the generated information can be used as input to ecosystem-based fisheries management models for Iligan waters, which was previously unavailable. Additionally, it provides information to support the future implementation of captive breeding and management practices to reduce the ongoing depletion of natural stocks.

Materials and Methods

Study area: This study was conducted in Iligan Bay, Southern Philippines. The Bay is located in the southern part of Mindanao Sea, connected in the southwest with the narrow Panguil Bay (Fig. 1). It lies approximately between $123^{\circ}43'15''$ east longitude and $8^{\circ}30'31''$ north latitude. It has an estimated coastline of 170 km with an area of around 2,390 km² (Quiñones et al., 2020). The Philippine Bureau of Fisheries and Aquatic Resources (BFAR) has identified Iligan Bay as a main fishing ground for its fishery resources and as a habitat for wildlife assemblages, and it serves as a vital food producer (Lacuna and Alviro, 2014). The sampling stations were established at known coastal landing areas for coral reef fishes in Iligan Bay, namely the municipalities of Tudela, Oroquieta, Lopez Jaena, Plaridel, and Baliangao, Misamis Occidental (Fig. 1).

Data collection: Samples of at least 30 individuals of *A. vaigiensis* and *C. vagabundus* of varying sizes were collected monthly for 14 months (July 2021 to August 2022). The current stock assessment method for

ornamental coral reef fish species was based on the work of Jumawan et al. (2021). Data were gathered by trained fisherfolk enumerators using a standard survey form on catch and effort. The survey forms also include information on the landing site, fishing grounds, catch volume per species, the types and numbers of gear and boats used, and the number of fishing hours. All survey forms were collated and processed monthly. The survey was conducted over two-day intervals, once every 20 days in a month. The total length of each fish (in cm) was measured from the tip of the snout (with the mouth closed) to the extended tip of the caudal fin using a ruler. Body weight was measured to the nearest 0.1 g using a top-loading Mettler balance SB12001.

Data analyses

Length-weight relationship: The length-weight relationship (LWR) was expressed by the equation of $W = aL^b$, where W and L represent the weight and length of the fish, a is the initial growth index, and b is the equilibrium constant, which measures the growth pattern of the fish. The b value remains constant at 3 for ideal fish growth (Wootton, 1990; Ontomwa et al., 2018); lesser or greater values indicate either positive allometric growth ($b > 3$) or negative allometric growth ($b < 3$) (Ricker, 1975; Froese, 2006). LWR of the species that had sufficient samples was determined by linearly regressing the log-transformed data in scatter plots to obtain the a and b values following the procedure described by Le Cren (1951): $\log W = \log a + b \log L$.

Condition factor: The condition factor (c.f.) was calculated using the formula of $c.f. = 100W/L^3$ (Pauly, 1983), where W = weight in grams, and L = total length (cm). A t-test was used to determine the significance of the effect of weight on length ($P < 0.05$).

Growth parameters: To estimate the L_∞ and K parameters of the von Bertalanffy equation, the ELEFAN I (Electronic Length Frequency Analysis) (Gayanilo et al., 1997) software tool included in FiSAT II (FAO ICLARM Stock Assessment Tools) was employed. The initial seed value of L_∞ was further analyzed, where the constant (K) was

estimated from the k-scan routine, finding the best appropriate growth curve. Estimated L_∞ and K values were visually assessed for the progression of modes in the growth curve using the von Bertalanffy Growth Function (VBGF) (Pauly, 1983).

Mortality and exploitation rate: Using the FISAT II program, the natural mortality rate (M) was calculated using Pauly's (1980) mortality empirical equation at a mean temperature (T) of 28.2°C (Froese and Pauly, 2022): $\log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.4634 \log(T)$. Fishing mortality (F) was the difference between M and Z , and exploitation rate (E) was calculated using Beverton and Holt's equation (Guiland, 1971) of $E = F / Z = F / (F + M)$. An E near 0.5 is thought to indicate an appropriate amount of exploitation, whereas $E > 0.5$ denotes over-exploitation (Tesfaye and Wolff, 2015). The mortality parameters (Z , M , and F) and the exploitation rate (E) were estimated using the length-converted catch curve method (Pauly, 1984) and the mean annual habitat temperature of 28.2°C. Z is the total instantaneous mortality, M is natural mortality, and F is mortality caused by fishing.

For the level of exploitation of stocks, the following categories were used: (a) E below -10% of $E_{0.1}$ suggests underexploited; (b) $E = -10\%$ of $E_{0.1}$ to $E = +10\%$ of $E_{0.1}$, optimally exploited; (c) E above +10% of $E_{0.1}$ to below $E = E_{0.1}$, overexploited; and (d) E equal to or above $E_{0.5}$, highly overexploited. E values were also compared with the predicted E_{\max} (exploitation rate, which produces maximum yield) to determine if the stock's exploitation level is beyond the maximum sustainable yield level.

Probability of capture: Backward extrapolation of the descending limb was used to estimate the probability of capture. A selectivity curve was generated by fitting a logistic function to the probability of capture and size data, and it was used to derive sizes at capture probabilities of 25% (L_{25}), 50% (L_{50}), and 75% (L_{75}). L_{50} was also referred to as length at first capture (L_c). The length at first sexual maturity (L_{m50}) was computed using the equation proposed by Hoggarth et al. (2006): $L_{m50} = 2 \times L_\infty / 3$.

Recruitment pattern: Recruitment patterns for the

Table 1. Length-weight relationship parameters of two species collected from Iligan Bay. (a, intercept of the relationship; b, the slope of the relationship; r^2 , coefficient of determination; A+, allometric positive; A-, allometric negative; I, isometric). * significant differences from 3 ($P < 0.05$).

Family/ Species	<i>a</i>	<i>b</i>	r^2	c.f	<i>p</i> value	Growth behavior
	Regression coefficient					
Chaetodontidae <i>C. vagabundus</i>	0.08	2.55	0.79	1.01±0.12	0.000	A-
Pomacentridae <i>A. vaigiensis</i>	0.03	2.82	0.77	1.02±0.19	0.000	A-

Table 2. Summary of the population parameters of the two coral reef fish species in Iligan Bay, 2021-2022.

Species	L_{∞} (cm)	K (yr ⁻¹)	\emptyset	t_0	t_{max}
<i>A. vaigiensis</i>	15.75	0.430	2.831	-0.090	6.886
<i>C. vagabundus</i>	14.70	0.700	3.012	-0.693	3.593

two fish species were analyzed from September 2021 to August 2022. Recruitment was estimated from restructured time-series length-frequency data. The recruitment model was obtained by projecting the length-frequency data back on the time axis using the VBGF growth parameters L_{∞} , K , and t_0 (Moreau and Cuende, 1991).

Virtual population analysis: Length-structured virtual population analysis (VPA) and cohort analysis were conducted using the methods of Thomson and Bell (1984) and Gulland (1965). The estimates of L_{∞} , K , M , F , a (a constant in the length-weight relation), and b (the exponent) for the species were used as inputs to the VPA analysis for that species. The t_0 value was taken as zero.

Relative yield per recruit and relative biomass per recruit: The predicted growth parameters and the probability of capture by length were used to produce relative yield per recruit (Y/R) and relative biomass per recruit (B/R) values as a function of E (Pauly and Soriano, 1986). As a result, the maximum allowable limit of exploitation (E_{max}) corresponding to the maximum relative yield-per-recruit (MSY = Maximum Sustainable Yield), the exploitation rate at which the marginal increase in relative yield-per-recruit is $E_{0.1}$ or 10% of its virgin stock, and $E_{0.5}$ (TRP = target reference point), the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B/R) were calculated using Beverton and Holt Y/R analysis routine in FISAT II software.

Statistical analysis: The regression equation was fitted separately for each group, and the slopes (b -values) were tested for significant variation among groups using analysis of Variance. Statistical analysis was conducted using SPSS version 16.

Results

Length-weight relationships: Each species has specific length-weight parameters. The values of b significantly ($P < 0.000$) rose from 2.55 in *C. vagabundus* to 2.82 in *A. vaigiensis*. It is also clear that both species exhibit b -values less than 3, indicating negative allometric growth (A-). The condition factors for the species differed significantly, ranging from 1.01±0.12 in *C. vagabundus* to 1.02±0.19 in *A. vaigiensis* (Table 1). The present study showed positive correlations between length and weight. Although there was individual variation, weight significantly increased ($P = 0.00$) with body length, respectively (Fig. 2).

Growth Parameters: Figure 3 shows the restructured length-frequency distributions of the two ornamental coral reef fish species at the study site. The respective K -values for the two species, *C. vagabundus* and *A. vaigiensis*, were less than 1.0 (0.700 and 0.570, respectively). The growth performance index (\emptyset'), the age at zero length (t_0), and the t_{max} of the two coral reef fish are presented in Table 2. The VBGF plot showed that the maximum length frequency of *A. vaigiensis* was 10-11 cm, and for *C. vagabundus*, 20 cm.

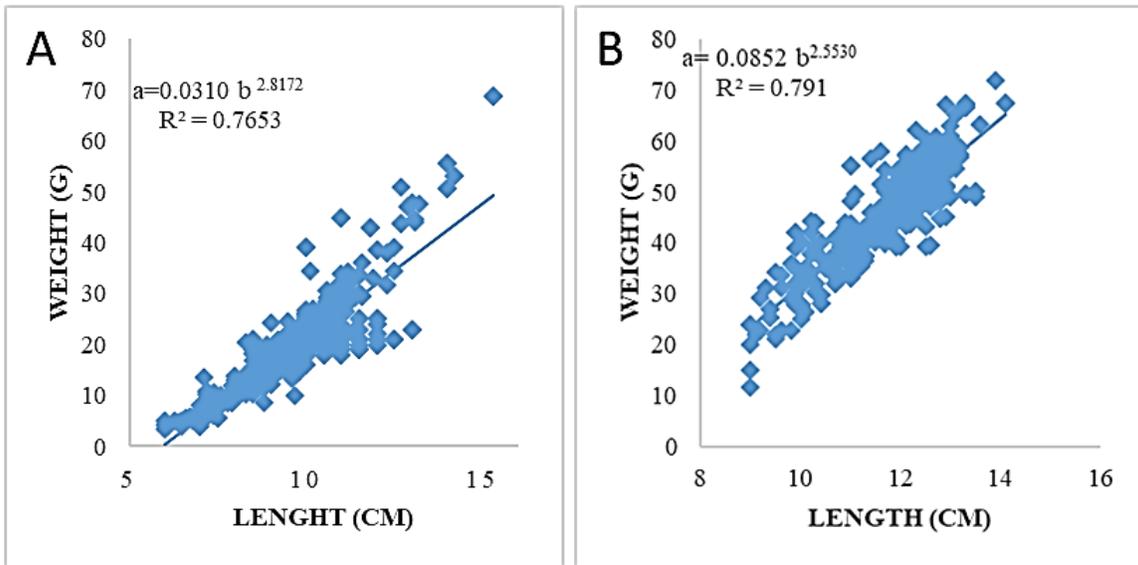


Figure 2. Length-weight relationship of ornamental fish species (A) *Abudedefduf vaigiensis* and (B) *Chaetodon vagabundus*.

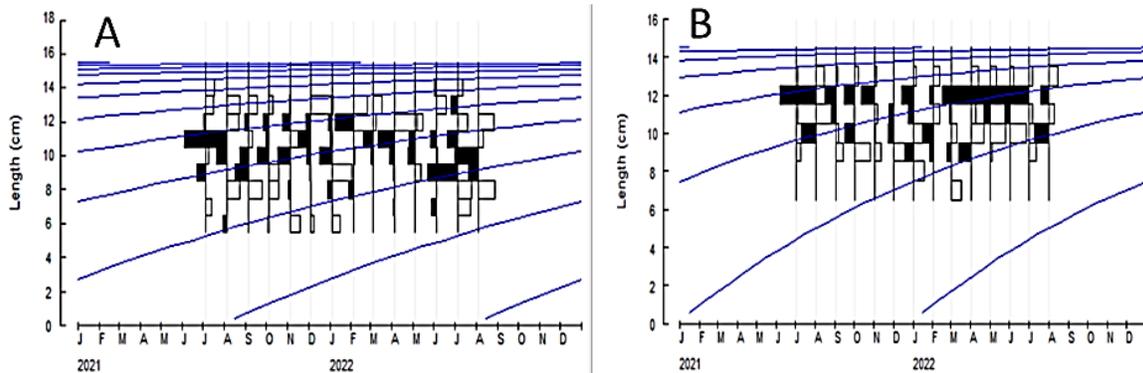


Figure 3. Length-frequency distribution output from FISAT II with superimposed growth curve for each ornamental fish species of (A) *Abudedefduf vaigiensis* and (B) *Chaetodon vagabundus*.

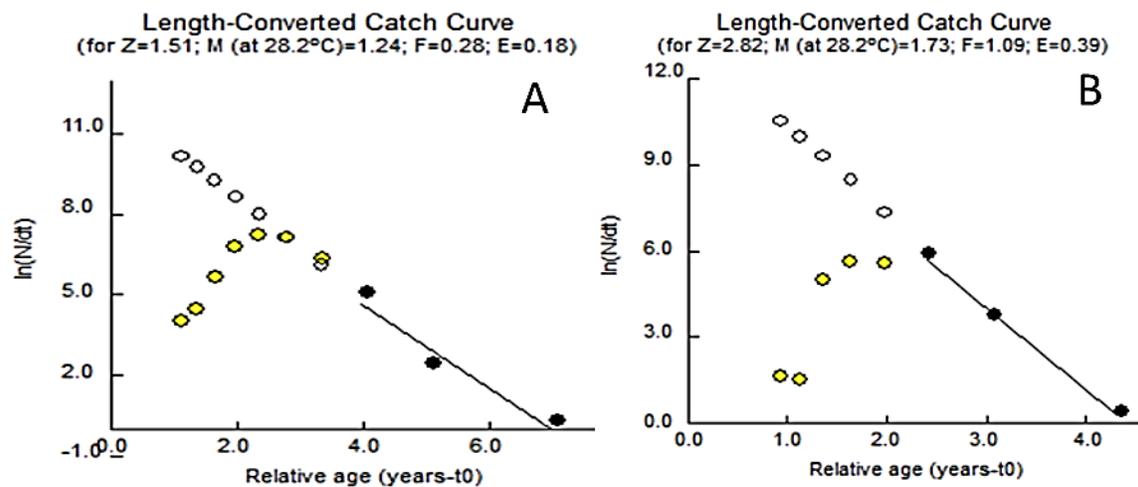


Figure 4. Catch curve analysis of ornamental fish species of (A) *Abudedefduf vaigiensis* and (B) *Chaetodon vagabundus*.

Mortality and exploitation rates: Using the annual average sea surface temperature (SST) of 28.2°C, the total (Z), natural (M), and fishing (F) mortality

estimates, and biological target (F_{opt}) points, as well as the exploitation rate of the two species, were calculated as shown in Figure 4 and Table 3. The

Table 3. Mortality and exploitation parameters of the two coral reef fish species in Iligan Bay.

Species	L_{∞} (cm)	K (yr ⁻¹)	Z (M+F)	M (Z-F)	F (Z-M)	F_{opt}	E (F/Z)
<i>C. vagabundus</i>	14.70	0.700	2.82	1.73	1.09	0.87	0.39
<i>A. vaigiensis</i>	15.75	0.430	1.60	1.24	0.28	0.62	0.18

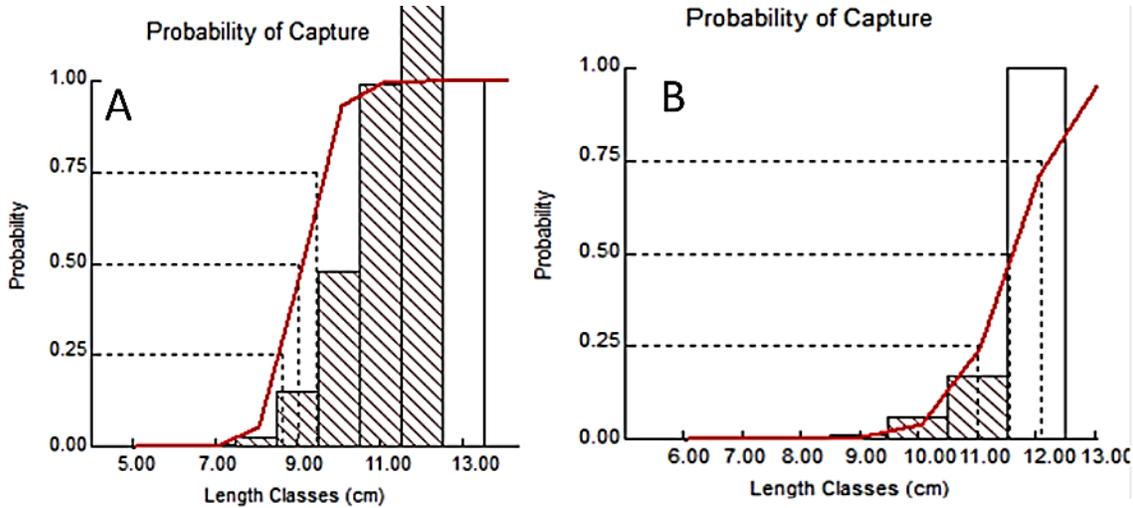


Figure 5. The selection curve for the probability of capture of ornamental fishes of (A) *Abudefduf vaigiensis* and (B) *Chaetodon vagabundus*.

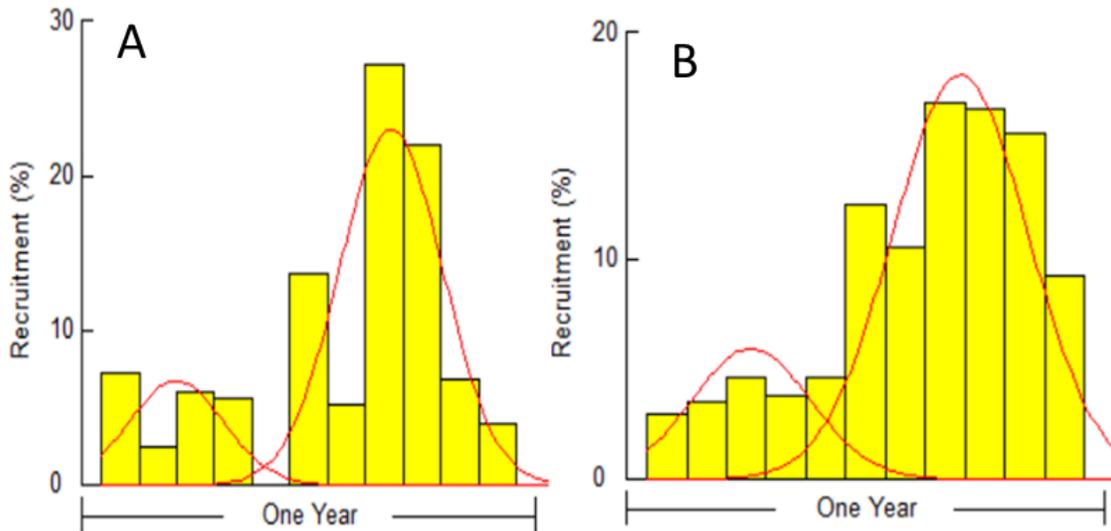


Figure 6. Recruitment patterns of ornamental fish species of (A) *Abudefduf vaigiensis* and (B) *Chaetodon vagabundus*.

results showed that the annual instantaneous total mortality coefficient (Z) was higher in *C. vagabundus* (2.82) than in *A. vaigiensis* (1.60). For instantaneous natural mortality (M) and fishing mortality estimates (F), the results showed that *C. vagabundus* had a higher value than *A. vaigiensis*. The F_{opt} values of *A. vaigiensis* and *C. vagabundus* were 0.62 and 0.87 year⁻¹, respectively (Table 3).

Probability of capture: The length of catch

probability at 25% (L_{c25}), 50% (L_{c50} or length at first catch), 75% (L_{c75}), and length at first maturity (L_{m50}) of the two species is presented in Figure 5. The *A. vaigiensis* recorded $L_{c25} = 8.63$, $L_{c50} = 9.04$, $L_{c75} = 9.45$ and $L_{m50} = 10.50$ cm; and *C. vagabundus* $L_{c25} = 11.02$, $L_{c50} = 11.56$, $L_{c75} = 12.10$ and $L_{m50} = 9.80$ cm, respectively.

Recruitment pattern: Recruitment patterns were observed year-round (Fig. 6). The recruitment of

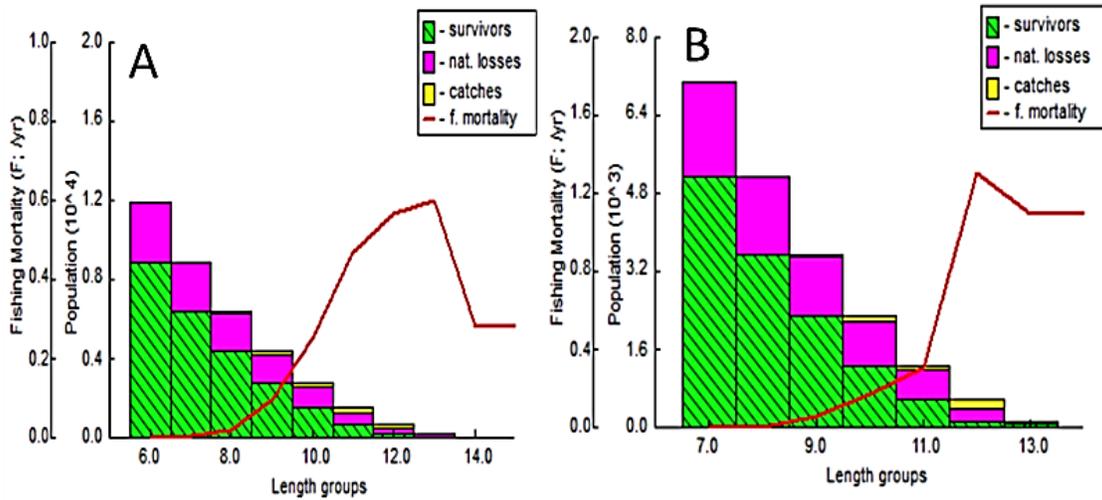


Figure 7. Virtual population analysis of ornamental fish species of (A) *Abudedefduf vaigiensis* and (B) *Chaetodon vagabundus*.

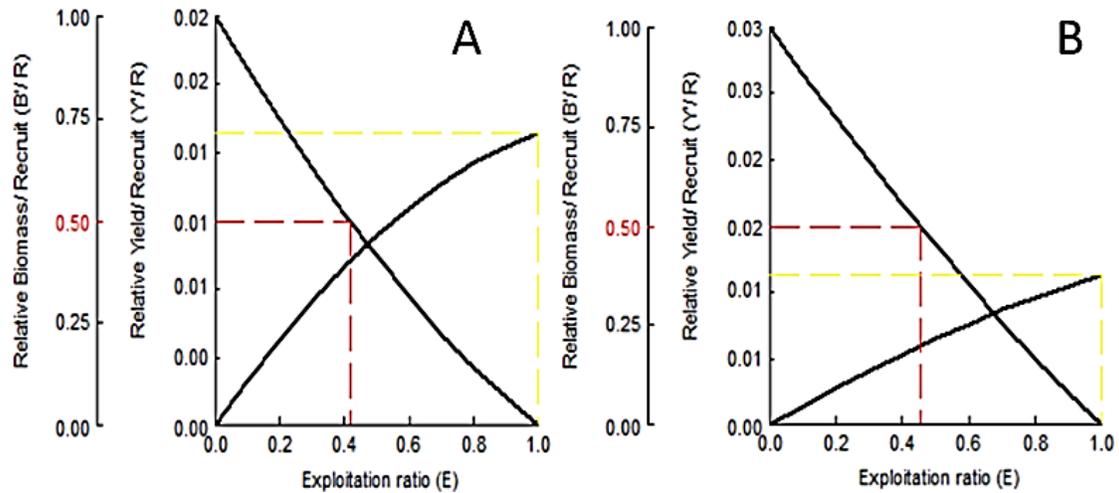


Figure 8. Relative yield/recruit and biomass/recruit of ornamental fish species of (A) *Abudedefduf vaigiensis* and (B) *Chaetodon vagabundus*.

A. vaigiensis appeared bimodal, although the modes were unequal in strength. The minor recruitment pulse occurred from September to December, peaking in September (7.06%), and the major recruitment pulse occurred from April to May, peaking in April (27.34%). A minor peak in *C. vagabundus* recruitment was observed from October to January, with a peak in November (4.53%), and the major peak was from April to June, with a peak in April at 16.87%.

Virtual population analysis: The length of the structured virtual population analysis of the two fish species is shown in Figure 7. The reduction of the abundance of *A. vaigiensis* at lengths 6-7 cm and *C. vagabundus* at 7-9 cm was mainly due to natural losses. The results also revealed that the majority of *A. vaigiensis* within the length group 8-10 cm was

more prone to being caught by fishermen, while the highest peak of fishing mortality ($F = 0.52 \text{ year}^{-1}$) occurred at length 10 cm. *Chaetodon vagabundus* within the length of 10-12 cm were the most vulnerable to fishing, with the highest peak of fishing mortality at a length of 12 cm corresponding to a 1.2 year^{-1} fishing mortality rate.

Relative yield-per-recruit and relative biomass-per-recruit: The Beverton and Holt *Y/R* analysis involving the knife-edge method routine was used to calculate the relative yield-per-recruit and biomass-per-recruit of the two ornamental coral reef fish species (Fig. 8). The input estimates used for L_{c50}/L_{∞} was 0.630, and M/K values was 2.88 for *A. vaigiensis*, and 0.78 and 2.47 for *C. vagabundus*, respectively. The 10% exploitation level ($E_{0.1}$) that corresponds to

the marginal increase in relative yield per recruit (Y/R) of its value and the maximum allowable limit of exploitation (E_{\max} or MSY) that gives the maximum relative yield per recruit (Y/R) was relatively similar for both *A. vaigiensis* and *C. vagabundus* (1.000).

Discussions

Length-weight relationship: The two ornamental fish species (*C. vagabundus* and *A. vaigiensis*) in the current study demonstrated a negative allometric growth. Rajesh et al. (2022) on the south-east coast of India, Sudhakar and Shameem (2009) from the Visakhapatnam coast, and Gumanao et al. (2016) from the Philippines reported the same results (negative allometric growth) in *A. vaigiensis*. The similarities in the somatic growth of fishes in this study with those in other regions might be attributed to environmental factors common in tropical oceans, such as temperature, oxygen concentration, salinity, and photoperiod (Dutta, 1994; Ong et al., 2018).

Even though the change of b -values depends primarily on the shape, various factors may be responsible for the differences in parameters of the length-weight relationships among seasons and years, such as salinity, food (quantity, quality, and size), sex and time of year, stage of maturity (Ricker, 1973; Pauly, 1984; Weatherley and Gill, 1987; Sparre, 1992; Alam et al., 2018). Additionally, the variation in b exponents may be related to differences in the sampling area, productivity, or sample lengths (Le Cren, 1951; Weatherley and Gill, 1987). According to Le Cren (1951) and Alam et al. (2018), the fish in which the value of b ranges between 2.5 and 4 is in good condition. Hence, the results of this study suggest that the degree of well-being, or the coefficient condition, for the growth of the two ornamental fish species in Iligan Bay is good. Variations in a fish's coefficient of condition primarily reflect the state of sexual maturity and the degree of nourishment (Ahmed et al., 2020).

The relationship between length and weight can be used to estimate the condition factor of fish species. In fisheries science, the condition factor is used to compare the condition or well-being of fish (Ahmed

et al., 2011). It is based on the hypothesis that heavier fish of a particular length are in a better physiological condition (Bagenal and Tesch, 1978). Both biotic and abiotic environmental conditions strongly influence it and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005). The condition factors of the two species in the present study were greater than 1, indicating that the fish species were in good condition in Iligan Bay. This may be due to the presence of a fish sanctuary in the area, which shelters fish life and habitats, allowing them to recover from human impacts such as pollution and overfishing.

Growth parameters: The results of the present study could provide baseline information on the population dynamics of fish species in tropical settings. The growth rate (K) and growth performance indices for asymptotic length (Φ') of the *C. vagabundus* in this study recorded higher values of asymptotic length (Φ') and t_{\max} (3.01 and 3.59) and lower growth rate (0.70) as compared to *C. larvatus* and *H. acuminatus* (Zekeria et al., 2006; Mahadevan et al., 2021). The variation in growth estimates (L_{∞} , K , Φ' , and t_{\max}) among the ornamental coral reef fish species in the Philippines and abroad can be attributed to the sampling procedure, gear selectivity, variety of data, differences in their lifestyle, ecological characteristics of fish and different environmental conditions like adjusting to the standing stock in the wild or its response to the exploitation rate and fishing pressure by commercial and artisanal fishers (Adams, 1980; Panda et al., 2016). Another factor that could influence differences in growth parameters was the type of fishing gear used. For instance, nets with a smaller mesh size tend to catch smaller fish, while larger mesh-size nets only catch fish that are big enough to be trapped inside the net. On the other hand, line fishing catches fewer fish than net fishing (Fadzly et al., 2017). Recent data suggest that the individual's genotypes, hormones, and physiological conditions are equally important endogenous regulators of growth (Ahmed et al., 2020).

Mortality rate parameters and exploitation rate: Total mortality (Z) and fishing mortality (F) indicate

the level of exploitation of the species. An exploitation rate (E) near or equal to 0.5 is thought to indicate an appropriate ideal amount of exploitation, whereas $E > 0.5$ denotes over-exploitation and $E < 0.5$ under-exploitation (Dalzell and Peñaflor, 1989; Tesfaye and Wolff, 2015). However, Beddington and Cooke (1983) suggest that the conservative optimum for fishing mortality was $E = 0.3$. In this study, the F -values for *C. vagabundus* and *A. vaigiensis* were lower than natural mortality (M) ($E < 0.5$), indicating no overexploitation of these species in the study area. A fishing mortality rate (F) above F_{opt} denoted overfishing, or fisheries declined (Niamaimandi et al., 2015).

The variation in mortality and exploitation rates observed in different studies were driven by ecological differences, physiological conditions of fish, feeding habits, fishing pressure, and data resources in each sampling location (Zan-bi et al., 2022). In general, exploited fish have higher fishing mortality than natural mortality; however, in the fish species studied, most fish die before being caught from natural causes. High natural mortality was influenced by factors such as predation, especially for small fish, which serve as prey for larger pelagic and demersal fish, marine mammals, and seabirds (Lederoun et al., 2015; Sekadende et al., 2020). Small fish play a vital role in the marine ecosystem, as they connect higher-trophic-level animals to those in lower trophic levels through biomass exchange (Palomera et al., 2007). In areas where fishing mortality was high, it was mainly due to overexploitation of fishery resources or fishers' non-compliance with the region's fisheries conservation laws and regulations (Panda et al., 2016; Rahman et al., 2018).

Probability of capture: One common cause of bias in length-frequency data is the selectivity of the gear(s) used to obtain the samples. This bias can be overcome by correcting size-frequency samples using capture probabilities. Comparing the two values of length at first capture (L_{c50}) and length at first maturity (L_{m50}) would allow us to know if the species is already mature once they are captured. The L_{c50} and the L_m of *A. vaigiensis* and *C. vagabundus*, were 9.04 and 10.50

cm; 11.56 and 9.80 cm, respectively. These results revealed that *A. vaigiensis* has a lower L_{c50} than L_{m50} , indicating that these species were caught at much smaller, younger sizes. This occurred due to the mesh size of the nets used by the fishers in the area. These fishes belong to the top 5 most abundant catch composition of the bottom set gill net; and most of the mesh size of the bottom set gillnet used by the fishers in the area was 83 mm, which is somewhat smaller. In the study conducted by the USAID (2013) on the catch comparison of two mesh sizes (84 and 92 mm) in the bottom gillnet used in the Gambian sole fishery, the increased mesh size had the potential to be a meaningful management tool for the sole and catfish fisheries while also improving the status of grunt and butterfish.

Although the F -values for these species were lower than natural mortality, the fishing gear used must be monitored to ensure sustainability. The “spawn-at-least-once” principle suggests that sustainability is secured if fish become vulnerable to commercial gear only after they have spawned (Vasilakopoulos et al., 2011). These data imply that a specific management strategy is needed, and the estimated length at first capture (L_c) can be used as a criterion for determining fisheries resource management initiatives (Rehatta et al., 2021).

Recruitment pattern: The recruitment patterns of the two studied species were bimodal - a common characteristic among Philippine species (Dalzell and Peñaflor, 1989). However, variability in recruitment patterns across all species was influenced by under-representation of juveniles due to the type of gear or mesh size used (Panda et al., 2016). Other factors that could affect recruitment variability include fish biological characteristics, the seasonality of monsoons, physical water parameters such as salinity and temperature, and the availability of food, which can affect gonad development prior to spawning (Azim et al., 2017; Uba, 2020).

Virtual population analysis: The results of the virtual population analysis routine showed that most small and young fish were prone to natural mortality. This might happen because small fish are more

vulnerable to predation, while mature fish dominate the fishers' catch. The estimates of VPA routines in the area varied widely across the fish life span: smaller fish were commonly preyed upon by natural predators, while larger fish were usually targeted by fishers (Zanbi et al., 2022). The findings of the current study, however, were opposite to those in the Mediterranean Sea and Bangladesh. That was overexploited ($E > 5$), with fishing mortality exceeding natural mortality, as the majority of their catch consisted of juveniles, according to VPA estimates. As a result, fish stock recruitment and renewal in those studies were decreased (Parvez and Nabi, 2015; Amin et al., 2019). These differences in VPA results might be due to limitations of the tool, such as the assumption that the cohort's natural mortality at age 't' (M) is constant. VPA also deals with the population dynamics of single species, whereas natural fish populations almost always interact with one another and with other species (Bharti, 2019).

Relative yield-per-recruit and relative biomass-per-recruit: Based on the result of the relative yield per recruit and relative biomass per recruit estimated using values from L_{50}/L_{∞} and M/K showed exploitation ratios for *A. vaigiensis* ($E_{0.1} = 1.00$, $E_{0.5} = 0.42$, $E_{\max} = 1.00$), and *C. vagabundus* ($E_{0.1} = 1.00$, $E_{0.5} = 0.45$, $E_{\max} = 1.00$), where E_{\max} values were above the exploitation rate for the two ornamental coral reef fish species. This indicates that the fishery for these species in Iligan Bay was at an appropriate level, as several references indicate that fish populations are overfished when E_{\max} is below the exploitation level (Azim et al., 2017; Sajan et al., 2015; Amina et al., 2019). Moreover, the presence of MPA or fish sanctuaries at the sampling sites that supply recruits to the fishery might be a contributing factor to the higher E_{\max} value than the E level.

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