**BIODIVERSITAS**
Volume 23, Number 1, January 2022
Pages: 273-285

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230133

# Growth and reproductive biology of white-spotted rabbitfish (*Siganus canaliculatus*) on different seagrass habitats in Inner Ambon Bay, Indonesia

**HUSAIN LATUCONSINA[1,♥], M. MUKHLIS KAMAL[2], RIDWAN AFFANDI[2], NURLISA A. BUTET[2]**
[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Islam Malang. Jl. MT Haryono No. 193, Dinoyo, Malang 65144, East Java, Indonesia. Tel.: +62-341-575461, Fax.: +62-341-552249, ♥email: husain.latuconsina@unisma.ac.id
[2]Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Institut Pertanian Bogor. Jl. Dramaga Raya, Bogor 16680, West Java, Indonesia

Manuscript received: 1 September 2021. Revision accepted: 25 December 2021.

**Abstract.** *Latuconsina H, Kamal MM, Affandi R, Butet NA. 2021. Growth and reproductive biology of White-spotted rabbitfish (*Siganus canaliculatus*) on different seagrass habitats in Inner Ambon Bay, Indonesia. Biodiversitas 23: 273-285.* Seagrass meadows are one of the important habitats for *Siganus canaliculatus*. This study aimed to compare the growth and reproductive biology of *S. canaliculatus* in different seagrass habitats on the Inner Ambon Bay. A fish sampling was observed once a month for a year (15 August 2018-20 July 2019) using a beach seine. The data analysis included growth patterns, condition factors, sex ratio, gonadal maturity, gonado somatic index, size at first maturity, and fecundity. The study results obtained body Length and weight varied between seagrass habitats, with an isometric growth pattern. The equation W: $0.0105\ L^{3,1007}$ male and W: $0.0165L^{2,9444}$ female in mixed vegetation, while for monospecific vegetation, male W: $0.0109L^{3,0891}$ and female W: $0.0143L^{3,0067}$. The value of condition factors, sex ratio, size at first maturity, and fecundity differed between seagrass habitats. The range of fecundity is 198,000-783,750 eggs, and there is a positive relationship between body length and weight with fecundity. A technical approach to fisheries management is needed, namely: (i) the size at first maturity is used as a reference for the size of fish that can be caught, and (ii) determination of mixed vegetation seagrass as a conservation area; and monospecific vegetation as fishing grounds.

**Keywords:** Condition factor, fecundity, gonado somatic index, growth pattern, sex ratio, *Siganus canaliculatus*

## INTRODUCTION

Seagrass is a flowering plant with rhizomes, leaves, and roots that live immersed in coastal waters and form a vast seagrass meadow. The fish community is one of the aquatic biotas associated with seagrass meadows as a habitat for feeding ground, nursery, protecting, and spawning ground (Nakamura et al. 2012; Ambo-Rappe et al. 2013; Espadero et al. 2020; Latuconsina 2020). So, seagrass meadows support fishery stocks and food security for coastal communities (Unsworth et al. 2010; De la Torre-Castro et al. 2014; Nordlund et al. 2017). One fish species with a strong relationship with seagrass meadows is a White-spotted rabbitfish (*Siganus canaliculatus*) (Latuconsina et al. 2013; Kwak et al. 2015; Suardi et al. 2016).

*Siganus canaliculatus* is widely distributed in three coastal ecosystems: mangrove forests, seagrass meadows, and coral reefs (Latuconsina et al. 2015; Suardi et al. 2016) has fast growth (Al-Qishawe et al. 2014; Annand and Reddy 2014). The length-weight relationships (LWRs) of males and females were significantly different (Al-Marzouqi et al. 2009; Annand and Reddy 2012), even different in the pre-spawning, spawning, and post-spawning phases (Al-Ghais 1993). Al-Marzouqi (2013) and Latuconsina et al. (2020[b]) obtained a length range of 26-28 cm in the first year. The size at first maturity of the male and female of *S. canaliculatus* tended to be different (13.2 cm-22.6 cm TL for males, and 13.9-25.7 cm for males) (Wassef and Hady 1997; Tharwat 2004; Al-Marzouqi et al. 2011; Annand and Reddy 2017). *S. canaliculatus* has great reproductive potential with fecundity values ranging from 5400-2,500,000 eggs (Al-Ghais 1993; Paraboles and Campos 2018; Suwarni et al. 2019; Latuconsina et al. 2020[c]).

In the Inner Ambon Bay, *S. canaliculatus* has a strong relationship with various types of seagrass meadows (Latuconsina et al. 2013; Latuconsina et al. 2020[a]). It can reach maturity at six months of age, with higher fishing mortality and exploitation rates (Manik 1998; Latuconsina et al. 2020[b]), high sedimentation pressure on seagrass habitats (Irawan and Nganro 2016; Noya et al. 2016). Besides, it will also affect seagrass vegetation, which can impact the growth and reproductive biology of *S. canaliculatus*. Madduppa et al. (2019) report that the vulnerability of *S. canaliculatus* in Jakarta Bay is strongly influenced by environmental factors and anthropogenic activities.

Research on the growth and reproductive biology of *S. canaliculatus* is common (Al-Marzouqi et al. 2011; Annand and Reddy 2017; Suwarni et al. 2019; Latuconsina et al. 2020[c]; Suwarni et al. 2020). Especially in the waters of Inner Ambon Bay, Manik (1998) and Latuconsina et al. (2020[b]) have researched the population dynamics of *S. canaliculatus*. Latuconsina et al. (2013) and Latuconsina et al. (2020[a]) have studied the ecological aspects of *S. canaliculatus*. However, scientific information on the growth and reproduction biology of *S. canaliculatus* in various seagrass meadows is still minimal. A length-weight relationship is an important tool in fisheries resource management because it can provide basic information for estimating fish stock growth patterns and conservation strategies (Habib et al. 2021). Growth and reproduction biology are important as the scientific information supports successful recruitment and survival in response to habitat changes (Annand and Reddy 2014). Scientific information of fish reproductive biology such as, i) size at first maturity; ii) spawning frequency; and iii) fecundity is essential in predicting the presence of a fish population and assists in the formulation of management strategies (Annand and Reddy 2017). Therefore, this study aimed to compare the growth (size composition, growth pattern, condition factors) and reproductive biology (sex ratio, gonad maturity stage, gonado somatic index, and fecundity) of *S. canaliculatus* in different seagrass meadows. It is hoped that it can become a technical reference for seagrass habitat-based fisheries management in the water of Inner Ambon Bay.

## MATERIALS AND METHODS

### Study area

This research was conducted on different seagrass habitats in the waters of Inner Ambon Bay, mixed vegetation seagrass meadows which include five species of seagrass (*Enhalus acoroides, Thalassia hemprichii, Halophila ovalis, Cymodocea rotundata*, and *Halodule pinifolia*) at Stations 1. Tanjung Tiram (3°39'16.5"S and 128°12'0.43 "E) and Station 2. Halong (3°39'32.9"S and 128°12'31.2"E) and a monospecific seagrass meadow where only one species of seagrass was found, namely *Enhalus acoroides* at stations 3. Poka (3°38'36.48"S and 128°11'42.54"E) and stations 4. Nania (03°37'58.7" S and 128°13'45.1" E (Figure 1).

### Data collection

Fishing was carried out at intervals of once a month for a year using beach seine with a total length of 30 m, and each wing measuring 14 m length and 2 m high, with a mesh size of 1.88 cm, has pockets with opening 3 m and a mesh size of 1.63 cm. The beach seine operation takes about one hour at each observation station. The total length of the fish samples was measured using a ruler with an accuracy of 0.1 cm and weighed with an electronic balance with an accuracy of 0.01 g. Fish sizes are grouped based on the length and classified as a juvenile (2.5-6.5 cm), sub-adult (6.6-12.5 cm), and adult (> 12.5 cm), referring to Lam (1974), Duray (1998), and Kwak et al. (2015). The sex of the fish was determined after being dissected, and the ovaries were observed. The gonad maturity stage was then observed based on its morphological (macroscopic) structure (Al-Ghais 1993; Annand and Reddy 2017) (Table 1). Ten samples of gonads in maturity stage IV were separated from the fish organs to be weighed. Some of the gonads were taken and weighed again and put into a sample bottle containing Gilson's solution to count the number of eggs. The observation parameters of growth and reproduction were carried out at the Biology Laboratory, Deep-Sea Research Center, Indonesian Institute of Sciences, Ambon.

### Data analysis

The growth pattern is known through the equation of the length-weight relationship (Le Cren 1951):

$$W = aL^b$$

Where, W: body weight (g); L: total length (cm); a: Intercept of the length-weight relationship curve with the y-axis); b: Slope.

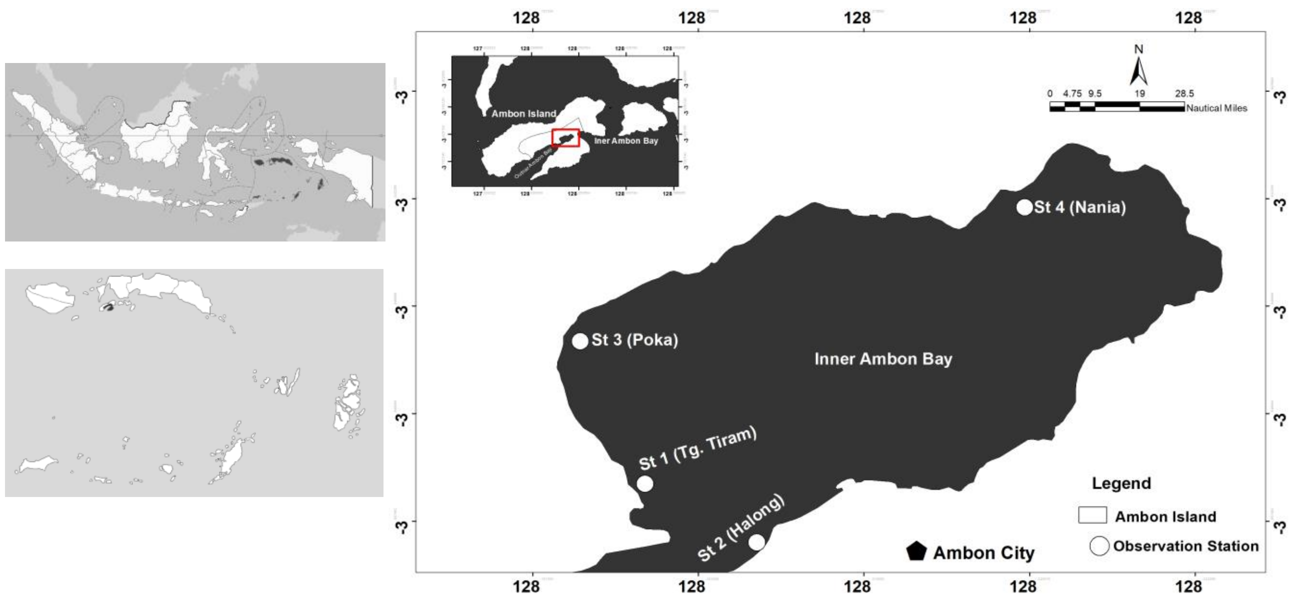



**Figure 1.** Map of research locations with sampling stations of *Siganus canaliculatus* on different seagrass habitats in Inner Ambon Bay, Ambon, Maluku Province, Indonesia

**Table 1.** Criteria for the classification of stages of gonad maturity of *Siganus canaliculatus*

| Stage | Male (testis) | Female (ovary) | Generally |
|---|---|---|---|
| I (Immature) | Testes are small, transparent, pale, filling a small part up to 1/3 of the body cavity | Ovaries are small, transparent, reddish, filling 1/3 of the body cavity | Sexual organs are not easily visible in body cavities |
| II (early maturing) | Testes whitish color, transparent, fill 1/2 part of the body cavity | Ovary pale yellow fills 1/2 part of the body cavity | Gonads like threads, transparent, the more clear the color can be distinguished between the testes or ovaries |
| III (late maturing) | The testes are creamy white, filling about 3/4 of the body cavity | Ovaries are pale yellowish, fill about part of the body cavity, blood vessels are visible on the dorsal side | The testes are white, and the sperm is visible when the testes are cut. Ovaries are yellowish. Eggs are yellow opaque |
| IV (Ripe) | The testes are creamy white, filling about 3/4 of the body cavity | Ovaries are yellowish pink, and more than the body cavity is filled with gonads, the blood vessels are more conspicuous | Gonads fill most of the body cavity |
| V (spawned) | The testes are reddish-cream, very soft, and fill more than 1/2 of the body cavity | Ovary yellowish pink fills half of the body cavity, saggy surface | Soft gonads, reddish ovary color, dull-white testes |

The t-test ($p < 0,05$) was used to test whether the value of b = 3 or not. If the value of b = 3 means that the fish has an isometric growth pattern, otherwise, if $b \neq 3$ means that the growth pattern is allometric. The strength of the relationship between length and weight of fish is indicated by the correlation coefficient (r) value. If the value of 'r' is close to 1, it indicates a strong relationship, but if the value of 'r' is close to 0, the relationship is very weak.

The condition factor was calculated based on the growth pattern equation (Effendie 1979)

If Isometric:

$$K = \frac{10^5 x\, W}{L^3}$$

If Allometric:

$$K = \frac{W}{aL^b}$$

Where, K: Condition factor; W: Fish weight (g); L: Total length of fish (cm), a and b: Constants obtained from regression.

The sex ratio is calculated as the proportion of male to female fish. Then the balance of these proportions was tested by Chi-square (Zar 2010):

$$X^2 = \sum_{i=1}^{k} \frac{O_i - E_i}{E_i}$$

Where, Oi: Frequency of observed male and female; Ei: Expected frequency, which is the frequency of male + female divided by two; $X^2$: The value of the random variable $X^2$ whose sample distribution is close to the chi-square distribution.

Gonad Maturity Stage (GM) was carried out by grouping the data based on the proportion of fish that had not and had matured gonads based on Gonad Maturity Stage during observations. Estimating the average size at first maturity using the Spearman-Karber equation (Udupa 1986):

$$m = x_k + \frac{X}{2} - \{X\Sigma p_i\},$$

with a 95% confidence interval,

$$\text{Antilog m} = \left[ m + 1{,}96 \sqrt{X^2 \Sigma \frac{p_i - q_i}{n_i - 1}} \right]$$

Where, m: logarithm of fish length at first maturity; Xk: logarithm of mean value at first maturity 100%; $X_k$: The log of the last length of the middle class at first maturity; X: logarithm of length increment at mean value; Pi: Proportion of gonadal mature in the length class with the number of fish in the length interval; the number of fish that are matured gonads in the long class; qi: 1 - pi; M: Antilog m of the length at first maturity.

Gonado Somatic Index (GSI) calculated by the equation (Johnson 1971):

$$GSI = \frac{G}{W} x\ 100$$

Where, GSI: Gonado Somatic Index (%); G: Gonad weight (g); W: Body weight (g).

Fecundity was calculated using the Gravimetric calculation method (Effendie 1979; Annand and Reddy 2017):

$$F = \frac{G\, x\, f}{g}$$

Where, F: Fecundity; G: total Weight of paired ovaries (g); f: No. of ova in a sample, g: weight of the sample (g).

The results of the analysis of growth and reproduction data are displayed in graphs and tables with the help of Excel 2010 software.

## RESULTS AND DISCUSSION

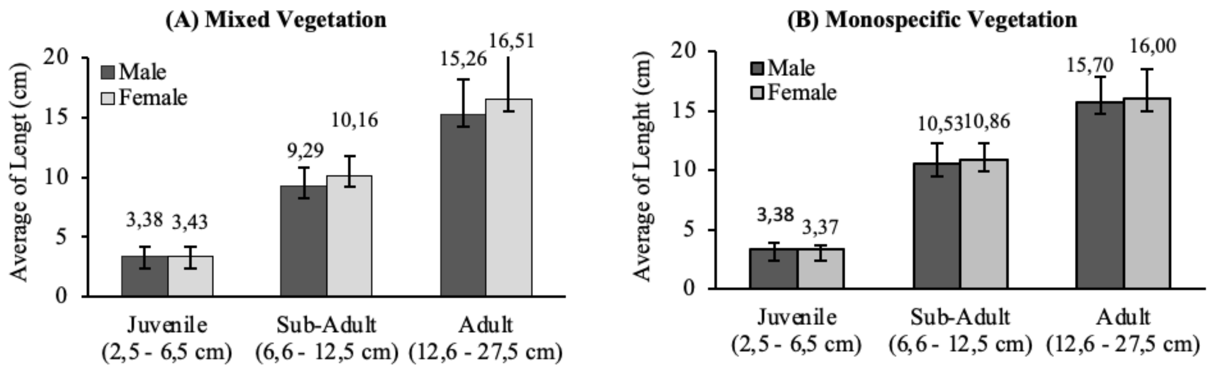
### The composition of fish size

The study results collected as many as 1050 individuals, including 598 males and 452 females (Figures 2). In the mixed vegetation seagrass habitat, which includes station 1, Tanjung Tiram, 290 individuals were collected (including 202 males and 88 females), and station 2, Halong, as many as 53 individuals (34 males and 19 females). As for the seagrass habitat, monospecific vegetation covers station 3 Poka collected as many as 308 individuals (162 males and 146 females) at station 4, Nania, as many as 399 individuals (200 males and 199 females).

The population of *S. canaliculatus* in seagrass habitat in the waters of Inner Ambon Bay has various lengths. It can be grouped into three age groups: juvenile, sub-adult, and adult (Figure 2). Variations in the length of *S. canaliculatus* indicate the role of seagrass meadows as an important habitat to support various biological activities of *S. canaliculatus* as Ambo-Rappe (2010), Munira et al. (2010[a]), and Latuconsina et al. (2013) found a positive relationship between diversity and density of seagrass vegetation and abundance of *S. canaliculatus*.

The length composition of *S. canaliculatus* varies between seagrass habitats in the waters of Inner Ambon Bay (Figure 2). However, the average life phase based on fish length groups was relatively evenly distributed between males and females in both types of seagrass habitats. Munira et al. (2010[a]) reported that male and female *S. canaliculatus* had the same spatial distribution in the seagrass habitat of Lonthoir strait, Banda Archipelago-Maluku. Although the monospecific seagrass habitat in Inner Ambon Bay has a low density, as reported by Irawan and Nganro (2016) and Latuconsina et al. (2020[a]), the number of *S. canaliculatus* individuals found in various age groups is relatively high. This phenomenon indicates that *S. canaliculatus* is strongly associated with the seagrass species *Enhalus acoroides*. According to Lam (1974) and Kuriandewa et al. (2003), *S. canaliculatus* is generally strongly associated with seagrass vegetation, especially *E. acoroides*. Munira et al. (2010[a]) also reported that juvenile size of *S. canaliculatus* tends to be associated with seagrass with large leaf morphology such as *E. acoroides* in the Lonthoir strait, Banda Archipelago-Maluku.

The Comparison of the number of *S. canaliculatus* individuals on life phases in different seagrass habitats in Inner Ambon Bay is shown in Figure 3.




**Figures 2.** Comparison of the average length of *Siganus canaliculatus* on life phases in different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

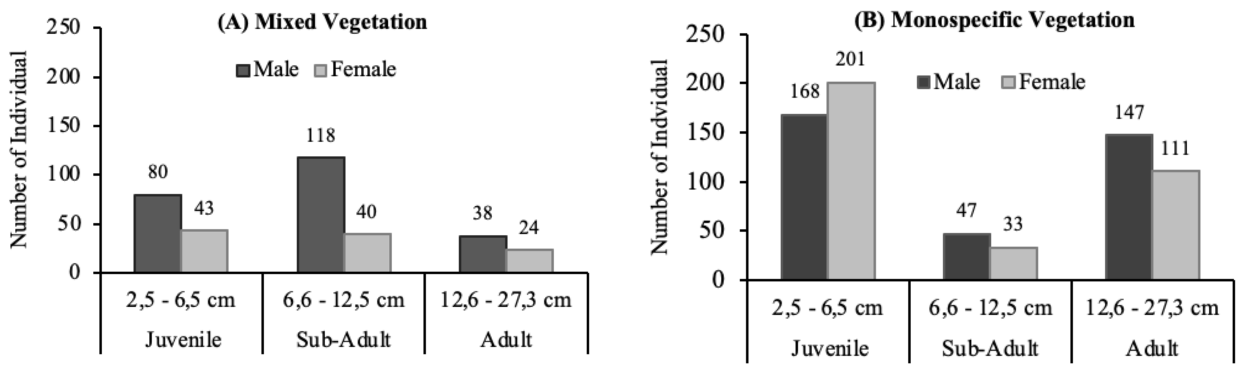



**Figure 3.** Comparison of the number of individuals of *Siganus canaliculatus* based on their life phase in different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

The percentage of fish collected based on juvenile size composition was 123 individuals (35.86%), 158 individuals (46.06%) sub-adult, and 62 individuals (18.08%) adult, while in monospecific vegetation seagrass habitats, the size was collected. juveniles as many as 369 individuals (52.19%), 80 sub-adults (11.32%), and 258 adults (36.49%). Juvenile size dominates all types of seagrass habitat; sub-adult size is more common in mixed vegetation seagrass habitat, while the adult size is more found in monospecific seagrass habitat. According to Hyndes et al. (2003), differences in diversity and size of fish based on variations in canopy characteristics of seagrass vegetation, differences in fish species composition between seagrass habitats partially reflect the composition of fish sizes in their respective habitats. This phenomenon indicates that the mixed vegetation seagrass habitat in Inner Ambon Bay is ideal for nursery and rearing grounds because it is dominated by juvenile and adult sizes. It has the potential to be used as a conservation area. While the monospecific seagrass vegetation is estimated to be suitable as a habitat for adult populations, it has more potential to be allocated as a fishing area for *S. canaliculatus*.

The dominance of juvenile *S. canaliculatus* in seagrass habitat was reported by Munira et al. (2010[b]) in the Lonthoir Strait, Banda Archipelago-Maluku, with sizes ranging from 4.4-30.0 cm (31.9% juvenile), and Suardi et al. (2016) in Luwu, South Sulawesi with a range of 2.2-14.1 cm (86.46% juvenile). This fact shows the role of seagrass beds as a nursery and rearing habitat for *S. canaliculatus*. This size variation in different seagrass habitats in Inner Ambon Bay waters (Figure 3) is influenced by fishing activity. This assumption is supported by Manik (1998) report, which previously found that fishing mortality was much lower than natural mortality ($F = 0.45 < M = 1.96$), with an exploitation rate of only 0,19 in Inner Ambon Bay. However, Latuconsina et al (2020[b]) reported a higher fishing mortality two decades later that approached natural mortality ($F = 2.18 < M = 2.37$) with an exploitation rate (E) = 0.48 at the same study site. The facts of this study in the Inner Ambon Bay indicate that seagrass habitats with different densities, diversity, and canopy structures of vegetation tend to be favoured by *S. canaliculatus* according to their life phase. The implication is that ecosystem-based to fisheries management must be based on the physical characteristics of seagrass habitats to support sustainable utilization.

Another factor is thought to be due to environmental conditions, including the carrying capacity of the seagrass habitat. According to Larkum et al. (2006), juvenile fish density in seagrass habitats depends on larval recruitment. It is supported by the reproductive intensity of adult fish and passive immigration from other areas. Juvenile and adult fish are self-distributed in the preferred habitat, and physical disturbances affect post-recruitment and biotic interactions influenced by the characteristics of the seagrass canopy. Latuconsina et al. (2012); Latuconsina and Ambo-Rappe (2013) found that turbidity was negatively correlated with the abundance of fish communities in seagrass habitats dominated by *S. canaliculatus* during the day and night as well as at different moon periods in the Inner Ambon Bay.

Latuconsina et al. (2020[a]) found higher turbidity levels in monospecific vegetation seagrass habitats than mixed vegetation. It is due to the location of the monospecific seagrass habitat, which is attached to the river flow. The high sedimentation in the Inner Ambon Bay due to land activities has threatened the existence of seagrass habitats (Irawan and Nganro 2016), with sediment transport rates reaching the range of 1.75-10.01 cm or about 39.9 mm/day (Noya et al. 2016). According to Quiros et al. (2017), Agricultural land activities and other anthropogenic activities on land harm seagrass conditions that affect the ecological integrity of seagrasses near watersheds. This phenomenon can potentially affect fish associations based on size structure and growth in seagrass habitats. The implication is that the management of fisheries of *S. canaliculatus* in Inner Ambon Bay considers the physical characteristics of seagrass habitats and the support of nearby habitats such as mangrove ecosystems and coral reefs. In addition, the management controls anthropogenic activities which threaten the habitat of seagrass beds and populations of *S. canaliculatus*.

**The growth patterns and condition factors**

Based on male and female individuals, the growth pattern was obtained by $\log W = -1.9788 + 3.1007 \log L$ and $\log W = -1.9626 + 3.0891 \log L$ (mixed vegetation) and $\log W = -1.7825 + 2.9444 \log L$ and $\log W = -1.8447 + 3.0067 \log L$ (monospecific vegetation). All equations show the coefficient of determination $R^2 = 0.99$, which means that 98-99% of the variation in length can explain body weight (Table 2).

The growth pattern of *S. canaliculatus* in all types of seagrass habitats in the waters of Inner Ambon Bay is isometric, which shows a balance between the rate of increase in length and body weight. However, there are variations in the b (slope) value between sexes and different seagrass habitats (Figure 4).

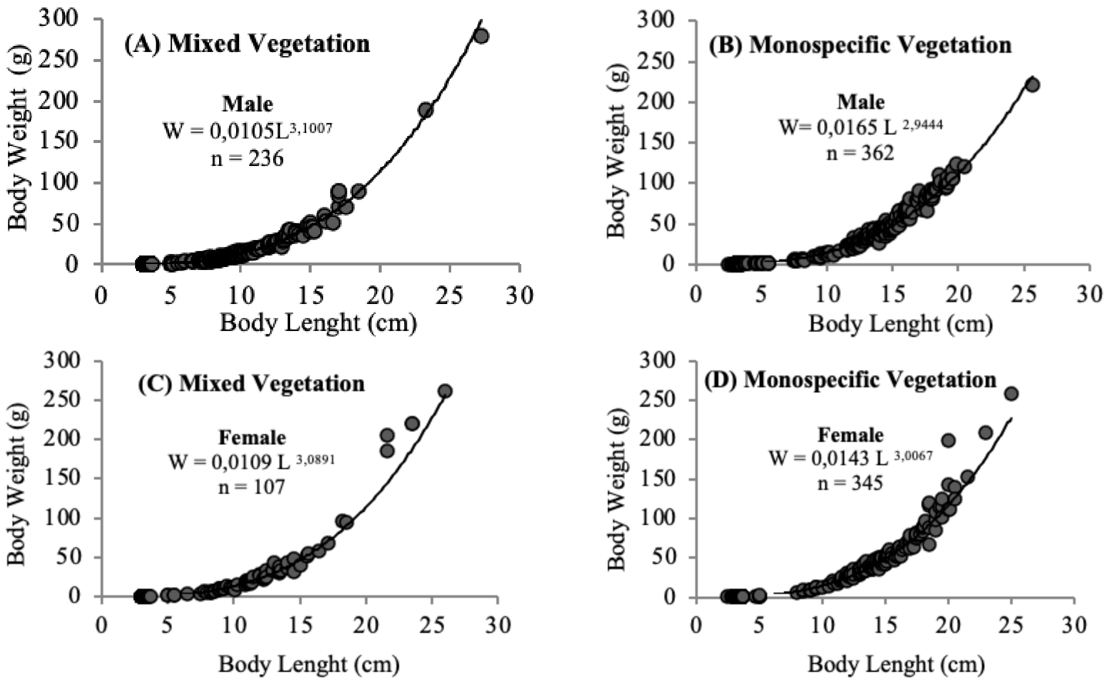
According to Froese et al. (2011), the value of b (slope) in the length-weight relationship determines the growth pattern. Isometric ($b = 3$) if the length and weight gain are equal, hypoallometric ($b < 3$), if the weight gain is slower than length, and hyperallometric ($b > 3$) if the opposite is true. Isometric growth patterns in *S. canaliculatus* were also found by Wassef and Hady (2001) in Saudi Arabia, Al-Marzouqi et al. (2009) in Oman-Saudi Arabia, Annand and Reddy (2012 ) in the Gulf of Mannar-India, and the Selayar Islands, South Sulawesi-Indonesia (Andy-Omar et al. 2015). Parameter b (slope) can vary seasonally and even daily and between habitats because it is very dependent on environmental parameters (Andreu-Soler et al. 2006). In this study, we found the coefficient of determination ($R^2$) ranged from 0.989-0.994 (Table 2) and tended to be higher in mixed vegetation habitats. It means that body length significantly affects body weight, with a high coefficient correlation (r) with a range of 0.995-0.997, which indicates a robust relationship between length and body weight. This indicates the ideal growth of *S. canaliculatus* in the Inner Ambon Bay, allegedly supported by seagrass habitat as a food source and feeding ground. According to Hanif et al.

(2017) and Habib et al. (2021), that ideal fish growth always shows a coefficient of determination ($R^2$) between 0.9-1.0, indicating that environmental quality, including optimal food supply and/or suitable for fish growth.

Latuconsina et al. (2020[a]) obtained differences in the character of environmental parameters between seagrass habitats in the waters of Inner Ambon Bay. Seagrass habitats with monospecific vegetation have higher turbidity and chlorophyll-a values, presumably related to their proximity to river mouths. Bulmer et al. (2018) found higher inorganic nutrients and chlorophyll in seagrass habitats with high turbidity and low primary productivity, while lower nutrients were found in seagrass beds with high primary productivity and low turbidity. Furthermore, Latuconsina et al. (2020[a]) found higher salinity and pH values in mixed-vegetated seagrass habitats in the waters of Inner Ambon Bay, possibly due to the absence of river influences that could cause fluctuations in pH and salinity. Latuconsina et al. (2013) also found food variations in the stomach contents of *S. canaliculatus* associated with mixed vegetation seagrass habitats compared to monospecific vegetation seagrass habitats. This fact indicates that differences in aquatic environmental parameters between different seagrass habitats affect the variation in growth of *S. canaliculatus* associated with varying habitats of seagrass. According to Le Cren (1951), Effendie (2002), and Kara et al. (2017), the factors influencing the relationship between body length and weight in fish are maturity, sex, temperature, salinity, habitat, quality, and quantity of feed. According to Froese (2006), variations in the length-weight relationship of a fish species depend on the season, population, or differences in annual environmental conditions.

**Table 2.** Growth parameters of *Siganus canaliculatus* between different seagrass habitats in Inner Ambon Bay waters, Maluku, Indonesia

| Growth Parameters | Mixed vegetation | | Monospecific vegetation | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Length Range (L) | 3.0-27.3 | 3.0-26.0 | 2.5-25.6 | 2.5-25.0 |
| Average Lenght ±SE | 8.26 ± 0.29 | 8.88 ± 0.53 | 9.32 ± 0.31 | 8.15 ± 0.32 |
| Weight Range (W) | 0.3-278.9 | 0.2-260.8 | 0.2-220.5 | 0.2-258.0 |
| Average Weight ± SE | 15.08 ± 1.75 | 24.36 ± 4.58 | 27.07 ± 1.76 | 23.50 ± 2.00 |
| a | 0.010 | 0.011 | 0.017 | 0.014 |
| b | 3.101 | 3.089 | 2.944 | 3.006 |
| r | 0.995 | 0.995 | 0.997 | 0.996 |
| $R^2$ | 0.989 | 0.991 | 0.994 | 0.991 |
| Relationship of L - W | positive | positive | positive | positive |
| Growth Patern | Isometric | Isometric | Isometric | Isometric |
| t-count | 1.00 | 0.88 | 1.24 | 0.95 |
| t-table (α=0.01,db=2) | 2.60 | 2.62 | 2.59 | 2.59 |




**Figures 4.** Length and weight relationship of *Siganus canaliculatus* of between different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

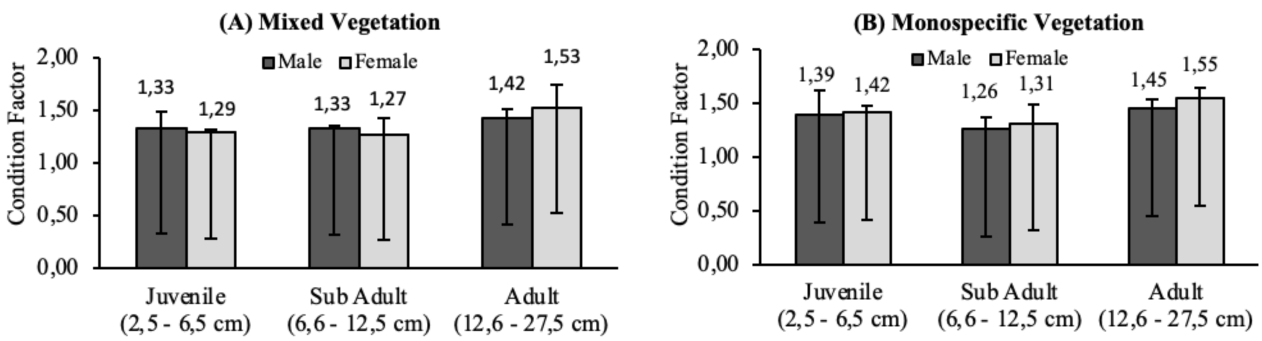
The results of the analysis of the condition factor (K) population of *S. canaliculatus* based on differences in seagrass habitat in Inner Ambon Bay waters are shown in Figure 5. Figure 5 shows the range of condition factor values for female fish 1.27-1.53 > males 1.33-1.42 in mixed vegetation seagrass habitats, as well as in monospecific seagrass vegetation, female fish condition factor values 1.31-1.55 > male 1.26-1.45. Tharwat (2005) also got the condition factor of female fish 1.34 > 1.29 males, and Suwarni et al. (2020) got a range of female fish condition factors of 0.96-1.93 > from males 0.81-1.93. The range of the condition factor of *S. canaliculatus* in seagrass habitat in Inner Ambon Bay waters is in a good category because the K value > 1. According to Jisr et al. (2018), the condition factor value is good if K > 1, and bad, if K < 1. The mean value of condition factor (K) varied considerably between seagrass habitats in all ages groups (Figure 5). Still, the results of the t-test (p>0,05) showed no difference in the average value of male and female condition factors between seagrass habitats. The relatively high value of the condition factor in the monospecific vegetation seagrass habitat is influenced by differences in the dominance of age groups. The adult group was more commonly found in monospecific seagrass habitats than mixed vegetation seagrass habitats dominated by sub-adult sizes. This assumption is supported by Wambiji et al. (2008), stating that the controlling factors for conditional factors are age, spawning season, sex, food availability, stomach fullness, and general fatness.

**The sex ratio, gonad maturity stage, and gonado somatic index**

The number of *S. canaliculatus* individuals obtained in Inner Ambon Bay was 1050, consisting of 598 males and 452 females. The sex ratio of male and female fish in each seagrass habitat is shown in Table 3.

The sex ratio of *S. canaliculatus* between different seagrass habitats in Inner Ambon Bay is 1.1: 1.0-2.2: 1.0 (Table 3). Differences in the sex ratio of *S. canaliculatus* were also found by Wassef and Hady (1997) in the Arabian Gulf (1.4: 1.0-2.3: 1.0) and Suwarni et al. (2019) in the waters of Jeneponto, South Sulawesi-Indonesia (1.7: 1.0-8.2: 1.0). The results of the Chi-square test showed that the sex ratio of *S. canaliculatus* in Inner Ambon Bay (Table 3) was significantly different in monospecific seagrass vegetation (P > 0.01), presumably due to the capture of fish of certain sex, which was more dominant. Annand and Reddy (2017) found that the difference in the sex ratio of the *S. canaliculatus* population was thought to be due to seasonal differences in mortality and other behavioural patterns between males and females. According to Soewardi (2007), differences in sex ratios can occur due to chance, selective mortality, and harvesting of certain sexes. The balance of the sex ratio will determine the effective population size and affect the circumstances of each fish to inherit genetic variations to the next generation through reproductive activities, which will determine the sustainability of its population in the wild.

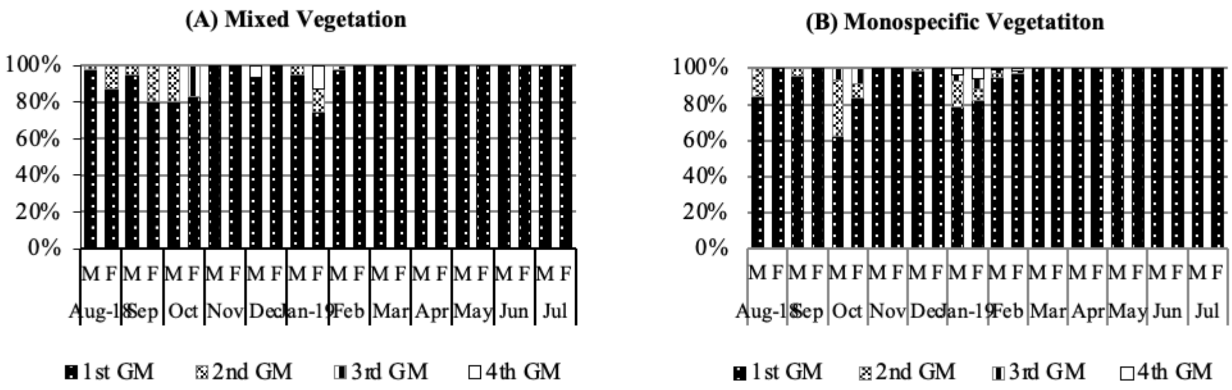
The gonad maturity stage (GM) of *S. canaliculatus* in both types of seagrass habitat in Inner Ambon Bay was more dominated by non-reproductive (Figures 6). *S. canaliculatus* was found at a minimum with gonad maturation III and IV levels during the study (Figure 6). This phenomenon supports the notion that *S. canaliculatus* does not make the seagrass habitat a spawning area but rather a feeding ground, nursery, and rearing. According to Johannes (1978), *S. canaliculatus* was found in seagrass meadows but spawned on coral reefs to avoid high predation in the pelagic larval phase.




**Figures 5.** Comparison of the value of the condition factor (K) of *Siganus canaliculatus* in different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

**Table 3.** Comparison of sex ratios of *Siganus canaliculatus* between different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

| Reproductive parameters | Mixed vegetation | | Monospecific vegetation | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| n (%) | 236 (68.8%) | 107 (31.2%) | 362 (51.2%) | 345 (48.8%) |
| Sex Ratio | 2.2 : 1.0 | | 1.1 : 1.0 | |
| $X^2_{count}$:$X^2_{table}$ α=0.01,db =1 | 17.22 < 24.72 | | 36.69 > 24.72 | |

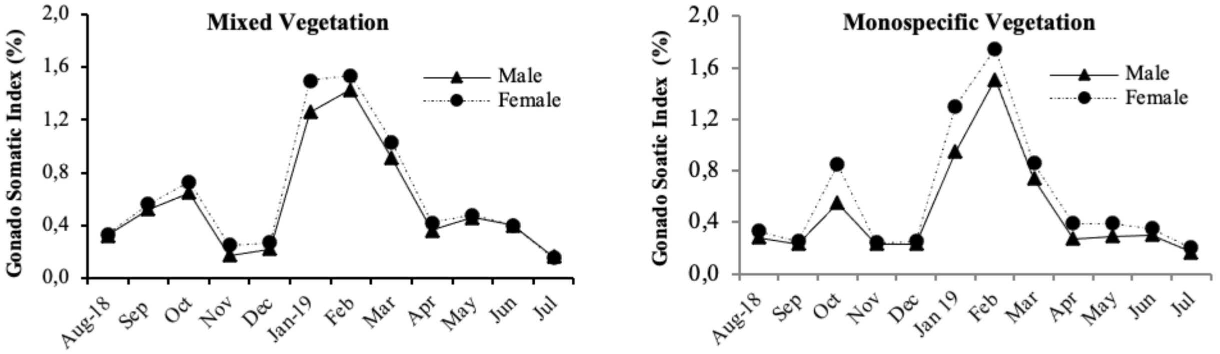



**Figures 6.** Monthly percentage distribution of the gonad maturity stage of *Siganus canaliculatus* in different seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

According to Fisher et al. (2005), rabbitfish (*Siganus* spp.) has a wide distribution potential supported by ocean currents, with a strong swimming ability at a speed of 34.2-87.1 cm/s (mean 67.1±8.9) during the pelagic larval phase (29.5 mm TL). Saputra and Lekalette (2016) found the surface current velocity during full moon tide in the range of 0.010-0.273 m/s in Inner Ambon Bay. Putra and Pratomo (2019) found that the current velocity at high tide tends to be small, namely, 0.01 m/s, while at low tide, the current velocity ranges from 0.015 m/s-0.030 m/s in Inner Ambon Bay. Based on this phenomenon, the role of tidal currents in Inner Ambon Bay will significantly support the spatial distribution of *S. canaliculatus* larvae from spawning areas to the nearest seagrass habitat by following the direction of tidal currents.

Determination of the spawning season of *S. canaliculatus* based on the average Gonado Somatic Index (GSI) values obtained each month of observation (Figures 7) indicates that the peak of the spawning season of *S. canaliculatus* is expected to occur from January to March. Al-Ghais (1993) found fluctuations in the GSI of *S. canaliculatus* in the southern Arabian Gulf adjusted to the spawning season, where there was an increase in Gonad Maturity Stage values during the spawning season (March-May), the peak in April with a range of GSI values of 0.5-10.0. Annand and Reddy (2017) also saw an increase in GSI values during November-March with a peak in January in the Gulf of Mannar-India, with GSI values of 2.5-5.0 for males and 7.0-9.0 for females. The Ganado Somatic Index value of the population of *S. canaliculatus* obtained in Inner Ambon Bay is very low (0.15 to 1.75) compared to other studies. This phenomenon is due to the lack of gonads mature fish collected during the month of observation. Further strengthens the notion that *S. canaliculatus* does not make seagrass meadows a spawning habitat.

In addition to GSI, the peak of the spawning season can also be predicted based on the abundance of juvenile *S. canaliculatus* (length 2.5-3.5 cm TL) during January to February in Inner Ambon Bay (Figure 8), which can be predicted > 30 days before the spawning season. According to May et al. (1974), the juvenile phase of *S. canaliculatus* at a size of 20-24 mm (SL) after 21 days of hatching, larvae with an initial length of 2.1 mm (SL) grew to 21.8 mm on day 33. According to Lavina and Alcala (1973), *S. canaliculatus* forms dense aggregations in seagrass habitats in a size range of 20-30 mm (SL), after 2-3 days of the dark moon phase, during January-April. Latuconsina et al. (2013) found an abundance juvenile of *S. canaliculatus* in March-May, and peaks in April in the mixed vegetation seagrass habitat in Inner Ambon Bay.




**Figures 7.** The mean value of *Siganus canaliculatus* gonado somatic index (GSI) on different seagrass habitats during observations in Inner Ambon Bay, Maluku, Indonesia

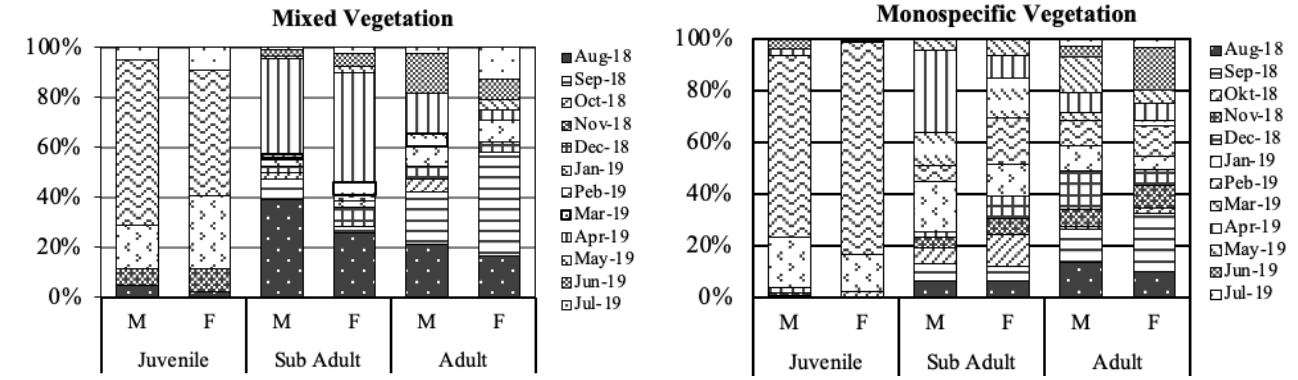



**Figure 8.** Distribution of size composition of fish collected during the study in different seagrass habitats In Inner Ambon Bay, Maluku, Indonesia

The estimation of the peak spawning season of *S. canaliculatus* is from January to March in the Inner Ambon Bay (Figure 7). However, the finding of a higher abundance of *S. canaliculatus* is from January to February (Figure 8), coinciding with the fishing season, as reported by Matakupan et al. (2018), who stated that the peak of the fishing season in the Inner Ambon Bay is from December to February, characterized by low rainfall and sea waves. The fishing gear operated in the waters of Inner Ambon Bay are handlines, gill nets, and beach seine. Therefore, regulatory support is needed regarding the use of fishing gear that is more selective for fish resources by considering the size at first maturity to support the sustainable utilization of fish biological resources in the Inner Ambon Bay, including *S. canaliculatus*.

**The size at first maturity and fecundity**

The results of estimating the average size at first maturity of the *S. canaliculatus* population using the Spearman-Karber equation are shown in Table 4. The population of female *S. canaliculatus* size at first maturity a smaller than the male in the waters of Inner Ambon Bay on mixed and single vegetation seagrass habitats.

The difference in size at the first maturity of *S. canaliculatus* between seagrass habitats may happen because each fish population applies a reproductive strategy based on its response to different environmental parameters and fishing pressures. For example, monospecific seagrass habitats in Inner Ambon Bay tend to experience fluctuations in environmental parameters because they are close to river mouths, with the main character being high turbidity values. In contrast, mixed vegetation seagrass habitats tend to have high salinity values and low turbidity (Latuconsina et al. 2020[a]). In addition, the monospecific seagrass habitat in the Inner Ambon Bay is the main fishing area. Therefore, it is suspected that fishing pressure also affects the reproductive strategy of *S. canaliculatus* to reach gonad maturity quickly.

Latuconsina et al. (2020[c]) found that the size at first maturity of female *S. canaliculatus* was smaller (14.9 cm) than the male (18.9 cm) in seagrass habitat in the waters of Buntal Island - Kotania Bay, Maluku, presumably due to high fishing pressure. Therefore, it is suspected that *S. canaliculatus* applied a reproductive strategy to reach gonadal maturity before being exploited quickly. According to Lappalainena et al. (2016), increased fishing pressure can change life history characteristics, such as growth and size or age at maturity.

The female group reached maturity at a smaller body length than the male group in Inner Ambon Bay was thought to be related to the different growth and reproduction strategies between male and female groups. According to Freiters et al. (2016), during the juvenile period until before gonadal maturity, male fish will invest energy for long growth to increase their competitive advantage when competing for female partners for spawning. After males reach the minimum size for reproduction, energy is invested in growth heavy. The opposite pattern occurs in female fish before the start of the reproduction will invest energy to increase body weight used after reproduction is achieved. However, this is not a standard pattern generally accepted for every fish species. According to Affandi and Tang (2017), the size at first maturity is related to growth and environmental influences. According to Lagler et al. (1977), age, size, and physiological conditions, external environmental factors such as temperature, currents, tides, moon phases, and spawning support.

*S. canaliculatus* caught in Inner Ambon Bay waters reached maturity size (24-26 cm) for males and females (Table 4). Latuconsina et al. (2020[b]) estimated that the age of *S. canaliculatus* in Inner Ambon Bay waters can reach a size of 25.9 cm at a year old and is generally exploited in the relative age range between <1 year until < 2 years. Tharwat (2004) obtained the size at first maturity of male *S. canaliculatus* of 18 cm and female 19 cm and recommended capturing them at >20 cm to support long-term spawning. Latuconsina et al. (2020[c]) reported that the size at first maturity for females was 14.9 cm (14.5-15.5 cm) smaller than the male 18.9 cm (18.8-19.1 cm) in the waters of Buntal Island - Kotania Bay, Maluku-Indonesia, and recommends being caught is at body length >15 cm TL. This fact shows that each area has different sizes at first maturity according to the environment and fishing pressure. Thus, using *S. canaliculatus* in the Inner Ambon

Bay is recommended at a minimum size range of 24-26 cm through selectivity of fishing gear to provide spawning opportunities. According to Muhammad (2011), the biotechnical approach in fisheries management is through selectivity of fishing gear adjusted to the age class and type of target fish caught.

Comparison of the fecundity values of *S. canaliculatus* between seagrass habitats (Table 5) shows variations in the fecundity values between seagrass habitats, with very varied range values and higher in monospecific seagrass habitats.

The potential reproductive biology of *S. canaliculatus* in the Inner Ambon Bay is quite significant based on its fecundity value (Table 5). According to Murua et al. (2003), in addition to sex ratio and proportion of adult individuals, fecundity is also an important factor that supports the reproductive potential of fish stocks in the wild. The fecundity of the female *S. canaliculatus* population in Inner Ambon Bay is relatively high, ranging from 198,400 to 783,750 eggs. Higher than the report of Suwarni et al. (2019), who obtained 5,416-130,760 eggs (range of body length (8.5-24.5 cm TL), Tharwat (2004) 58,925-838,652 eggs (17.0-35.0 cm TL), but still below Al-Marzouqi et al. (2011) which obtained 242,042-607,615 eggs (26.5-37.5 cm TL). According to Effendie (2002), fecundity variations in fish are related to age composition, feed availability, population density, temperature, and dissolved oxygen. Fish in infertile waters have lower fecundity values. According to Al-Ghais (1993), the magnitude of *S. canaliculatus* fecundity is to overcome the high natural mortality during the pelagic larval phase.

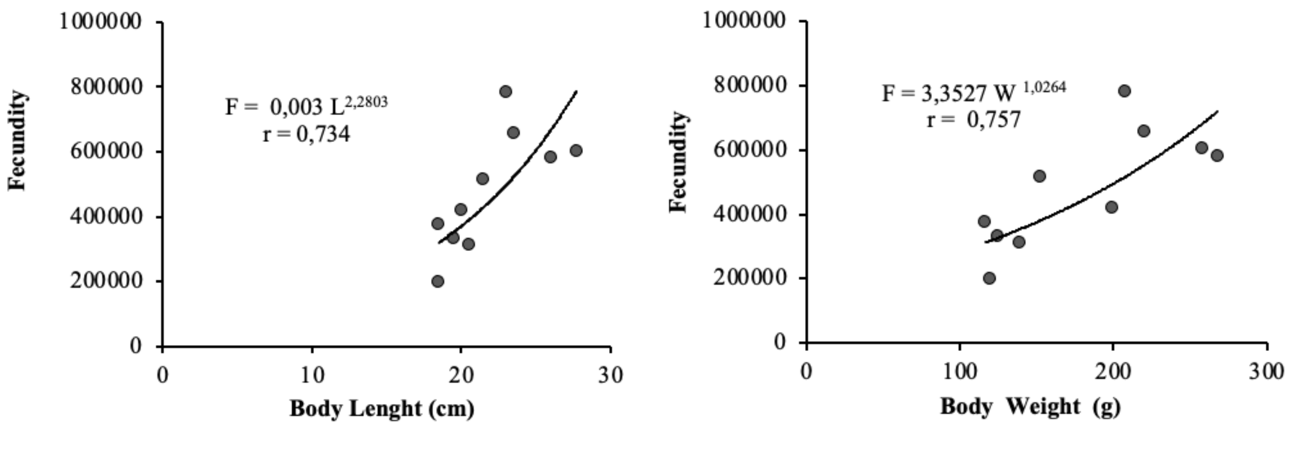
Figure 9 shows a relatively strong relationship between length and weight with fecundity. It means that length and weight determine the value of fecundity. As found by Tharwat (2004), Al-Marzouqi et al. (2011), Paraboles and Campos (2018), and Suwarni et al. (2019). Paraboles and Campos (2018) recommend that the population of *S. canaliculatus* be allowed to grow at an optimal size to produce a large fecundity that has the potential to support the sustainability of its stock in the wild through a continuous recruitment process. Thus, selectivity of fishing gear needs to be applied to support the sustainable utilization of *S. canaliculatus* in the waters of Inner Ambon Bay, taking into account the size of the size at first maturity.

**Table 4.** The size at first maturity of *Siganus canaliculatus* on different seagrass habitats during observations in Inner Ambon Bay, Maluku, Indonesia

| Type of seagrass habitat | Size at first maturity (cm) | | Length range (cm) | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Mixed vegetation | 26.7 | 24.3 | 26.2-27,2 | 17.0-30.6 |
| Monospecific vegetation | 24.4 | 23.5 | 24.0-24.8 | 21.0-26.4 |

**Table 5.** Comparison of *Siganus canaliculatus* fecundity between seagrass habitats in Inner Ambon Bay, Maluku, Indonesia

| Type of seagrass habitat | Fecundity (eggs) | Average ± Std | Body length range (cm) |
|---|---|---|---|
| Mixed vegetation | 582,00-658,966 | 620,483 ± 54,423 | 23.5-26.0 |
| Monospecific vegetation | 198,400-783,750 | 442,818 ± 185,671 | 18.5-25.0 |




**Figures 9.** Relationship between body length and weight with the fecundity of *Siganus canaliculatus* females in Inner Ambon Bay, Maluku, Indonesia

According to Widodo and Suadi (2006), if the selectivity of fishing gear is not enforced, it will cause growth overfishing and potentially lead to recruitment overfishing. Furthermore, the high mortality and exploitation rate of *S. canaliculatus* in the Inner Ambon Bay (Latuconsina et al. 2020[b]) and the peak fishing season from December to February (Matakupan et al. 2018) is estimated to coincide with the peak of the spawning season. Therefore, it may threaten the presence of *S. canaliculatus* directly in Inner Ambon Bay. In addition, the high rate of sedimentation in the Inner Ambon Bay (Irawan and Nganro 2016; Noya et al. 2016) threatens the existence of seagrass beds as a habitat for *S. canaliculatus*, thus indirectly potentially reducing. Therefore, it is necessary to develop in situ conservation areas. According to Latuconsina (2020), in situ conservation area development is a manifestation of ecosystem-based fisheries management to ensure growth, reproduction, and recruitment processes fish population realize sustainable fisheries utilization.

In conclusion, the composition of the body length of *Siganus canaliculatus* varies between seagrass habitats. The growth pattern is isometric, with good condition factors in all types of seagrass habitats. The sex ratio and size at first maturity differed between males and females and between types of seagrass habitat. The resulting fecundity was relatively high and differed between the type of seagrass habitat, and there was a positive relationship between fecundity and body length and weight. Therefore, consideration of fisheries management for sustainable utilization of *S. canaliculatus* in Inner Ambon Bay is needed, including two technical considerations. The first is the selectivity of fishing gear concerning the size at first maturity as a reference for the appropriate or allowed size to be caught. The second is the determination of mixed vegetation seagrass habitat as a conservation area; and monospecific vegetation as fishing grounds.

## ACKNOWLEDGEMENTS

The author thanks the Educational Fund Management Institute - Ministry of Finance of the Republic of Indonesia (LPDP) for the assistance of 2019 Fiscal Year Research Dissertation Research Scholarship No. PRJ-32 / LPDP.4 / 2019.

## REFERENCES

Affandi R, Tang UM. 2017. Aquatic Animal Physiology. Intimedia, Malang. [Indonesian]

Al-Ghais SM. 1993. Some aspects of the biology of *Siganus canaliculatus* in the Southern Arabian Gulf. Bull Mar Sci 52 (3): 886-897.

Al-Marzouqi A, Al-Nahdi A, Jayabalan N, Al-Habsi S. 2009. Stomach contents and length-weight relationship of the white-spotted rabbitfish *Siganus canaliculatus* (Park 1797) from the Arabian Sea coast of Oman. J Mar Biol Assoc India 51 (2): 211-216.

Al-Marzouqi A, Jayabalan N, Al-Nahdi A, Al-Anbory. 2011. Reproductive biology of the White-spotted Rabbitfish, *Siganus canaliculatus* (Park, 1797) in the Arabian Sea coast of Oman. West Indian Ocean J Mar Sci 10 (1): 73-82.

Al-Marzouqi A. 2013. Length-based stock assessment of the white-spotted rabbitfish, *Siganus canaliculatus* (Park, 1797) from the Arabia Sea of Oman. Thalassas Intl J Mar Sci 29 (2): 67-76.

Al-Qishawe MMS, Ali TS, Abahussain AA. 2014. Stock assessment of white-spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Jubail marine wildlife sanctuary, Saudi Arabia. Intl J Fish Aquat Stud 1 (6): 48-54.

Ambo-Rappe, R. 2010. Fish community structure in different seagrass beds of Barrang Lompo island. J Trop Mar Sci Technol 2 (2): 62-73. DOI: 10.29244/jitkt.v2i2.7853. [Indonesian]

Ambo-Rappe R, Nessa MN, Latuconsina H, Lajus DL. 2013. Relationship between the tropical seagrass bed characteristics and the structure of the associated fish community. Open J Ecol 3 (5): 331-342. DOI: 10.4236/oje.2013.35038.

Annand M, Reddy PSR. 2012. Length-weight relationship of the whitespotted rabbitfish *Siganus canaliculatus* (Park, 1797) from Gulf of Mannar, South India. J Mar Biol Ass India 54 (1): 91-94. DOI: 10.6024/jmbai.2012.54.1.01731-11.

Annand M, Reddy PSR. 2014. Age and growth white-spotted rabbitfish *Siganus canaliculatus* from the Gulf of Mannar-South India. Indian J Geo-Mar Sci 43 (3): 427-433.

Annand M, Reddy PSR. 2017. Reproductive biology of the rabbitfish *Siganus canaliculatus* in the Gulf of Mannar Region India. Indian J Geo-Mar Sci 46 (1): 131-140.

Andreu-Soler A, Oliva-Patern FJ, Torralva M. 2006. A review of length-weight relationships of fish from the Segura River basin (SE Iberian Peninsula). J Appl Ichthyol 22: 295-296. DOI: 10.1111/j.1439-0426.2006.00719.x.

Andy OSB, Fitrawati R, Sitepu FG, Umar MT, Nur M. 2015. Growth pattern of white-Spotted Spinefoot, *Siganus Canalicullatus* (Park, 1797) populations in the waters of the Northern Coast of Selayar Islands District, South Sulawesi. Torani 25 (2): 169-177. DOI: 10.35911/torani.v25i3.2609. [Indonesian]

Bulmer RH, Townsend, Drylie MT, Lohrer AM. 2018. Elevated turbidity and the nutrient removal capacity of seagrass. J Front Mar Sci 5 (462): 1-9. DOI: 10.3389/fmars.2018.00462.

de la Torre-Castro M, Carlo GD, Jiddawi NS. 2014. Seagrass importance for a small-scale fishery in the tropics: The need for seascape management. Mar Pollut Bull 83: 398-407. DOI: 10.1016/j.marpolbul.2014.03.034.

Duray MD. 1998. Biology and Culture of Siganids. Aquaculture Department Southeast Asian Fisheries Development Center (SEAFDEC), Tigbauan, Iloilo, Philippines.

Effendie MI. 1979. Fisheries Biology Method. Dewi Sri Foundation, Bogor. [Indonesian]

Effendie MI. 2002. Fisheries Biology. Pustaka Nusantara Foundation, Yogyakarta. [Indonesian]

Espadero ADA, Nakamura Y, Uy WH, Tongnunu P, Horinouch M. 2020. Tropical intertidal seagrass beds: An overlooked foraging habitat for fishes revealed by underwater videos. J Exp Mar Biol Ecol 526: 151353. DOI: 10.1016/j.jembe.2020.151353.

Fisher R, Leis JM, Clark DL, Wilson SK. 2005. Critical swimming speeds of latestage coral reef fish larvae: variation within species, among species and between location. Mar Biol 147: 1201-1212. DOI: 10.1007.s00227-005-0001-x.

Freiters TMS, Vitor HCAVHC, Montag LFA, Fontoura NF. 2016. Predicting size at first sexual maturity from length/weight relationship: A case study with an Amazonian catfish. Neotrop Ichthyol 14 (4): e150152. DOI: 10.1590/1982-0224-20150152.

Froese R. 2006. Cube law, condition factor, and weight-length relationships: History, meta-analysis, and recommendations. J Appl Ichthyol 22: 241-253. DOI: 10.1111/j.1439-0426.2006.00805.x.

Froese R, Tsikliras AC, Stergiou KI. 2011. Editorial note on weight-length relations of fishes. J Acta Ichthyol Piscatoria 41 (4): 261-263. DOI: 10.3750/AIP2011.41.4.01.

Habib A, Hanizar MIA, Kamal MS, Azmi MAS, Seah YG. 2021. Length-weight relationships of four demersal fish species from Chendering, Terengganu, Malaysia. Thalassas Intl J Mar Sci 37: 205-207. DOI: 10.1007/s41208-021-00285-5.

Hanif MA, Siddik MAB, Chaklader MR, Pham HD, Kleindienst R. 2017. Length-weight relationships of three catfish species from a tributary of the Dhaleshwari River, Bangladesh. J Appl Ichthyol 00: 1-2. DOI: 10.1111/jai.13448.

Hyndes GA, Kendrick AJ, MacArthur LD, Stewart E. 2003. Differences in the species and size composition of fish assemblages in three distinct seagrass habitats with differing plant and meadow structure. Mar Biol 142: 1195-1206. DOI: 10.1007/s00227-003-1010-2.

Irawan A, Nganro MN. 2016. Distribution of seagrass in Inner Ambon Bay. J Trop Mar Sci Technol 8 (1): 99-114. DOI: 10.29244/jitkt.v8i1.12499. [Indonesian]

Jisr N, Younes G, Sukhn C, El-Dakdouki MH. 2018. Length-weight relationships and relative condition factor of fish inhabiting the marine area of the Eastern Mediterranean city, Tripoli-Lebanon. Egypt J Aquat Res 44 (5): 299-305. DOI: 10.1016/j.ejar.2018.11.004.

Johannes RE. 1978. Reproductive strategies of coastal marine fishes in the tropics. J Environ Biol Fish 3 (1): 65-84. DOI: 10.1007/BF00006309.

Johnson JE. 1971. Maturity and fecundity of threadfin shad, *Dorosoma petenense* (Gunther) in Central Arizona reservoirs. Transactions Am Fish Soc 100 (1): 74-85.

Kara A, Saglam C, Acarli D, Cengiz O. 2017. Length-weight relationships for 48 fish species of the Gediz estuary, in I˙zmir Bay (Central Aegean Sea, Turkey). J Mar Biol Assoc U K 98 (4): 879-884. DOI: 10.1017/S0025315416001879.

Kuriandewa TE, Kiswara W, Hutomo M, Soemodihardjo S. 2003. The seagrass of Indonesia. In: Green EP, Short FT (eds). World Atlas of Seagrasses. Prepared by the UIMEP World Conservation Monitoring Centre. Berkeley and Los Angeles, California (US).

Kwak SN, Klumpp DW, Park JM. 2015. Feeding relationships among juveniles of abundant fish species inhabiting tropical seagrass beds in Cockle Bay, North Queensland, Australia. N Z J Mar Freshw Res 49 (2): 205-223. DOI: 10.1080/00288330.2014.990467.

Lagler KF, Bardach RH, Miler, Passino DRM. 1977. Ichthyology. Second edition. John Wiley and Sons Inc, Toronto, Canada.

Lam TJ. 1974. Siganids: Their biology and mariculture potential. Aquaculture 3 (4): 325-354. DOI: 10.1016/0044-8486(74)90001-5.

Lappalainena A, Saks L, Sustarc M, Heikinheimo O, Jürgens K, Kokkonen E, Kurkilahti M, Verliin A, Vetema M. 2016. Length at maturity as a potential indicator of fishing pressure effects on coastal pikeperch (*Sander lucioperca*) stocks in the northern Baltic Sea. Fish Res 174: 47-57. DOI: 10.1016/j.fishres.2015.08.013.

Larkum AWD, Orth RJ, Duarte CM. 2006. Seagrasses: Biology, Ecology And Conservation. Springer, Netherlands.

Latuconsina H. 2020. Fish Ecology Tropical Waters: Biodiversity, Adaptation, Threats, and Management. Gadjah Mada University Press, Yogyakarta. [Indonesian]

Latuconsina H, Nessa MN, Ambo-Rappe R. 2012. The composition on species and structure of seagrass fish community in Tanjung Tiram - Inner Ambon Bay. J Trop Mar Sci Technol 4 (1): 35-46. DOI: 10.29244/jitkt.v4i1.7804. [Indonesian]

Latuconsina H, Ambo-Rappe R. 2013. Daily variability of fish community in seagrass beds of Tanjung Tiram - Inner Ambon Bay. J Indones Ichthyol 13 (1): 35-53. DOI: 10.32491/jii.v13i1.110. [Indonesian]

Latuconsina H, Ambo-Rappe R, Nessa MN. 2013. Association of white-spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in seagrass ecosystems in the waters of Inner Ambon Bay. Proceedings of the 4th National Seminar on Fish, Fish Diversity: Conservation and Management for the Welfare of Coastal Communities. Indonesian Ichtiological Society, Makassar, 12 Juni 2012. [Indonesian]

Latuconsina H, Sangadji MH, Naudin. 2015. The daily variability of seagrass fish related to the presence of mangroves and coral reefs in the waters of Buntal Island-Kotania Bay, West Seram Regency. Proceedings of the Annual Scientific Meeting XI, Indonesian Association of Oceanologists. Balikpapan 17-18 November 2014. [Indonesian]

Latuconsina H, Affandi R, Kamal MM, Butet NA. 2020[a]. Spatial distribution of White-spotted Rabbitfish *Siganus canaliculatus* Parak, 1797 on different seagrass beds habitat of the Inner Ambon Bay. J Trop Mar Sci Technol 12 (1): 89-106. DOI: 10.29244/jitkt.v12i1.27908. [Indonesian]

Latuconsina H, Affandi R, Kamal MM, Butet NA. 2020[b]. On the assessment of white-spotted rabbitfish (*Siganus canaliculatus* Park, 1797) stock in the Inner Ambon Bay, Indonesia. AACL Bioflux 13 (4): 1827-1835.

Latuconsina H, Lestaluhu R, Rumasoreng R. 2020[c]. Reproduction of White-spotted Rabbitfish (*Siganus canaliculatus* Park, 1797) in water of Buntal Island, Kotania Bay, West Seram - Mollucas. J Fish Agribus 13: 470-478. DOI: 10.29239/j.agrikan.13.2. [Indonesian]

Lavina EM, Alcala AC. 1973. Ecological studies on Philippine siganid fishes in southern Negros, Philippines. J Sillima 12 (2): 191-210.

Le Cren ED. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (Perca fluviatilis). J Anim Ecol 20 (2): 201-219. DOI: 10.2307/1540.

Madduppa H, Margaretha MK, Bramandito A, Prartono T, Subhan B, Arafat D, Anggraini MP. 2019. Short communication: Intraspecific genetic diversity and population subdivision of rabbitfish (Siganidae: *Siganus canaliculatus*) in urbanized reefs of Jakarta Bay, Indonesia. Biodiversitas 20 (10): 2897-2902. DOI: 10.13057/biodiv/d200917.

Manik N. 1998 Estimation of growth parameters and mortality of rabbit fish (*Siganus canaliculatus*) in Inner Ambon Bay. Mollucas Surround Waters 12: 55-63. [Indonesian]

Matakupan H, Hiariey J, Tupamahu A, Baskoro MS. 2018. Dynamics of pelagic fish fishing ground in Ambon City. J Indones Aquat 3 (2): 136-143. DOI: 10.24198/jaki.v3i2.23401. [Indonesian]

May RC, Popper D, McVey JP. 1974. Rearing and larval development of *Siganus canaliculatus* (Park) (Pisces: Siganidae). Micronesica 10 (2): 285-298.

Muhammad S. 2011. Fisheries and Marine Development Policy: Systems Approach. Brawijaya University Press, Malang. [Indonesian]

Murua HG, Kraus Saborido-Rey F, Witthames PR, Thorsen A, Junquera S. 2003. Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. J Northw Atl Fish Sci 33: 33-54. DOI: 10.2960/J.v33.a3.

Munira, Sulistiono, Zairion. 2010[a]. Spatial distribution of rabbitfish *Siganus canaliculatus* in the seagrass beds of Lonthoir Strait, Banda Archipelago, Moluccas. J Indones Ichthyol 10 (1): 25-33. DOI: 10.32491/jii.v10i1.175. [Indonesian]

Munira, Sulistiono, Zairion. 2010[b]. Length-weight relationship and growth of rabbitfish, *Siganus canaliculatus* (Park, 1797) in the seagrass beds of Lonthoir Strait, Banda Archipelago, Maluku. J Ichthyol Indones 10 (2): 153-163. DOI: 10.32491/jii.v10i2.167. [Indonesian]

Nakamura Y, Hirota K, Shibuno T, Watanabe Y. 2012. Variability in nursery function of tropical seagrass beds during fish ontogeny: Timing of ontogenetic habitat shift. Mar Biol 159: 1305-1315. DOI: 10.1007/s00227-012-1911-z.

Nordlund LM, Unsworth RFK, Gullström M, Cullen-Unsworth LC. 2017. Global significance of seagrass fishery activity. Fish Fish 19: 399-412. DOI: 10.1111/faf.12259.

Noya YA, Purba M, Koropitas AF, Prartono T. 2016. Cohesive sediment transport modeling on Inner Ambon Bay. J Trop Mar Sci Technol 8 (2): 671-687. DOI: 10.29244/jitkt.v8i2.15834. [Indonesian]

Paraboles LC, Campos WL. 2018. Fecundity and oocyte development of the white-spotted rabbitfish *Siganus canaliculatus* (Park 1797) in Palompon, Leyte, Eastern Visayas, Philippines. J Asian Fish Sci 31: 245-251. DOI: 10.33997/j.afs.2018.31.3.006.

Putra HS, Pratomo DG. 2019. Analysis of sediment flow and transport using 3-dimensional hydrodynamic modeling (Case study: Ambon Bay, Ambon City, Maluku). J Eng ITS 8 (2): 124-129. [Indonesian]

Quiros TEAL, Croll C, Tershy B, Fortes MD, Raimondi P. 2017. Land use is a better predictor of tropical seagrass condition than marine protection. Biol Conserv 209: 454-463. DOI: 10.1016/j.biocon.2017.03.011.

Saputra FRT, Lekalette JD. 2016. Water mass dynamics in Ambon Bay. Widyariset 2 (2): 143-152. DOI: 10.14203/widyariset.2.2.2016.143-152. [Indonesian]

Soewardi K. 2007. Management of Genetic Diversity of Fisheries and Marine Resources. Department of Aquatic Resources Management, Institut Pertanian Bogor, Bogor. [Indonesian]

Suardi, Wiryawan B, Taurusman AA, Santoso J, Riyanto M. 2016. Variations in size and catch distribution of white-spotted rabbitfish *Siganus canaliculatus* on bio-FADs from spatially and temporary, at Luwu-South Sulawesi, Indonesia. AACL Bioflux 9 (6): 1220-1232.

Suwarni, Tresnti J, Andy OS, Tuwo A. 2019. Some reproductive biology studies of rabbitfish *Siganus canaliculatus* (Park,1797) from the Southern Coastal Waters of Jeneponto, South Sulawesi, Indonesia. J Biosci Biotechnol Res Asia 16 (3): 617-624. DOI: 10.13005/bbra/2777.

Suwarni, Tresnti J, Andy OSB, Tuwo A. 2020. Growth pattern and condition factor of the white-spotted rabbitfish, *Siganus canaliculatus* (Park, 1797) in marine coastal waters of luwu, Bone Bay, South Sulawesi, Indonesia. Plant Archives 20: 3476-3479.

Tharwat AA. 2004. Reproductive cycle and mariculture potential of the rabbitfish *Siganus canaliculatus* in Saudi Arabia. Egypt J Aquat Biol Fish 8 (4): 123-143. DOI: 10.21608/ejabf.2004.1812.

Tharwat AA. 2005. Fishery assessment of the rabbitfish *Siganus canaliculatus* from the Arabian Gulf Saudi Arabia. Egypt J Aquat Biol Fish 9 (1): 117-136.

Udupa KS. 1986. Statistical method of estimating the size at first maturity in fishes. ICLARM, Metro Manila. J Fishbyte 4 (2): 8-10.

Unsworth RKF, Cullen LC, Pretty JN, Smith DJ, Bell JJ. 2010. Economic and subsistence values of the standing stocks of seagrass fisheries: Potential benefits of no-fishing marine protected area management. Ocean Coast Manag 53: 218-224. DOI: 10.1016/j.ocecoaman.2010.04.002.

Wambiji N, Ohtomi J, Fulanda B, Kimani E, Kulundu N, Hossaind MY. 2008. Morphometric relationship and condition factor of *Siganus stellatus*, *S. canaliculatus* and *S. sutor* (Pisces: Siganidae) from the Western Indian Ocean Waters. South Pac Stud 29 (1): 1-15.

Wassef EA, Hady HAA. 1997. Breeding biology of rabbitfish *Siganus canaliculatus* (Siganidae) in mid Arabian Gulf. J Fish Res 33: 159-166. DOI: 10.1016/S0165-7836(97)00075-1.

Wassef EA, Hady HAA. 2001. Some biological studies and gonadal development of rabbitfish *Siganus canaliculatus* (Park) and *Siganus spinus* L. (F: Siganidae) from the Gulf Waters off Saudi Arabia. J King Abdulaziz Univ 12 (1): 189-208. DOI: 10.4197/mar.12-1.14.

Widodo J, Suwadi. 2006. Marine Fisheries Resources Management. Gadjah Mada University Press, Yogyakarta. [Indonesian]

Zar JH. 2010. Biostatistical Analysis. 5th Edition, Prentice-Hall/Pearson, Upper Saddle River, USA.