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Eco-Biology of the Orbiculate Cardinalfish, *Sphaeramia orbicularis* in Seagrass Habitats of Pari Island, Indonesia

Siti Khasanah, Charles Parningotan Haratua Simanjuntak* & Gatot Yulianto
Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor Regency, West Java, Indonesia.
*Corresponding author, email: charles_phs@apps.ipb.ac.id
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ABSTRACT The seagrass ecosystem of Pari Island, Kepulauan Seribu National Park, provides essential habitat for various fish resources, such as *Sphaeramia orbicularis*. Little information has been reported on the biology and ecology of this species in Indonesia. This study describes the growth pattern, feeding ecology, and reproductive biology of *S. orbicularis* in the seagrass beds of Pari Island. Fish samples were collected monthly from November 2023 to April 2024 using a beach seine net. A total of 542 fish were obtained with a range of 17-85 mm and weights of 0.16-24.28 g. Fish growth patterns were isometric and positive allometric with condition factor values >1. Based on feeding ecology, *S. orbicularis* is categorized as a specialist and has a low niche breadth (B_A=0.2), with the primary diet being Gammaridae, Tanaidacea, and Brachyura. The fish population has a balanced sex ratio and spawns in January. This is indicated by the highest GMS mature gonad and GSI values found in that month. Egg fecundity ranged from 7,239-12,240 eggs with an average diameter of 0.0048-0.0052 mm, indicating a total spawner spawning pattern. The length of the first gonad maturity of male fish was 63.12 mm, while that of female fish was 65.27 mm.

Keywords: Allometric growth; gammarids; gonadosomatic index; opportunistic carnivore; total spawner

INTRODUCTION

Pari Island boasts a complex coastal ecosystem located in the South Seribu District of the Kepulauan Seribu Administrative Regency, DKI Jakarta Province. The dominant ecosystem on Pari Island is the seagrass ecosystem (Kusumaatmaja *et al*., 2016). Seagrass ecosystems are crucial as they provide essential habitats for many early-life fish species. These seagrass beds serve as nursery, spawning, foraging, and refuge areas from predators (Park & Kwak, 2018; Gilby *et al*., 2018). Fish species that utilize all three ecosystems in their life cycle provide compelling ecological evidence of inter-ecosystem connectivity in the marine environment (Unsworth *et al*., 2008).

One of the key inhabitants of the seagrass waters in Pari Island is the orbiculate cardinalfish, *Sphaeramia orbicularis*. This species, belonging to the Apogonidae family, is distinguished by its wide terminal mouth and a vertical black stripe between the dorsal and ventral fins, which is approximately half the diameter of the eye (Allen, 1975; Smith and Heemstra, 1986). *S. orbicularis* is widely distributed in tropical and subtropical regions, particularly the Indo-Pacific Ocean. It typically forms small schools in shallow waters (0.1-1 m) among mangrove roots, rocks, coral crevices, or along shorelines (Kuiter, 1992).

Fish growth and reproduction are closely related to feeding ecology. Several studies have demonstrated that a fish species' dietary habits can impact its growth rate and the maturation of its gonads (Abdul Samad *et al*., 2022; Simanjuntak & Sulistiono, 2022). Nutrition is a critical factor influencing fish species' reproductive performance and overall health (Effendie, 1979; Izquierdo *et al*., 2001; Gonzales Jr & Law, 2013).

Research on the dietary habits of *Sphaeramia orbicularis* has been conducted by Allen (1975) and Mess *et al.* (1998) in the mangrove forests of Kenya, Africa, while its reproductive aspects have been studied by Shao & Chen (1986) and Choi *et al.* (2012) in Chuuk Lagoon, Micronesia. However, information on the ecological and biological aspects of *S. orbicularis* in Indonesia is very limited. Therefore, this study aims to examine several eco-biological aspects of *S. orbicularis*, including length-weight relationships, condition factors, diet preference, niche breadth, sex ratio, levels and indices of gonadal maturity, fecundity, egg diameter, and size at first gonadal maturity.

MATERIALS AND METHODS

Data Collection

Study area

The research was conducted from November 2023 to April 2024, encompassing the various seasons in Indonesia: the first transitional season (November 2023), the rainy season (December 2023 to February 2024), and the second transitional season (March to April 2024). The study occurred along Pari Island's coast, Kepulauan Seribu, at four designated station points, as shown in Figure 1. The purposive sampling method guided the selection of station locations, which considered each site's distinct characteristics (Table 1).

Sampling & preservation method

Before conducting fish sampling, we measured water environment parameters-such as temperature and dissolved oxygen by DO meter, salinity by refractometer, and pH by pH meter-three times at each sampling station. A one-way ANOVA test was performed to check

Table 1. Research location characteristics.

Stations	Substrate type	Mangrove area category	Seagrass density category	Seagrass types
Ship Pier	Rocky sand	-	Slightly dense	*Thalassia hemprichii* *Cymodocea rotundata* *Enhalus acoroides*
Bintang Beach	Sand	Least wide	Rare	*E. acoroides* *T. hemprichi* *C. serrulata* *C. rotundata* *Halophila ovalis*
Fishing Pier	Sandy mud	Wide	Very dense	*E. acoroides*
Perawan Beach	Sand	Very wide	Dense	*E. acoroides* *T. hemprichi*

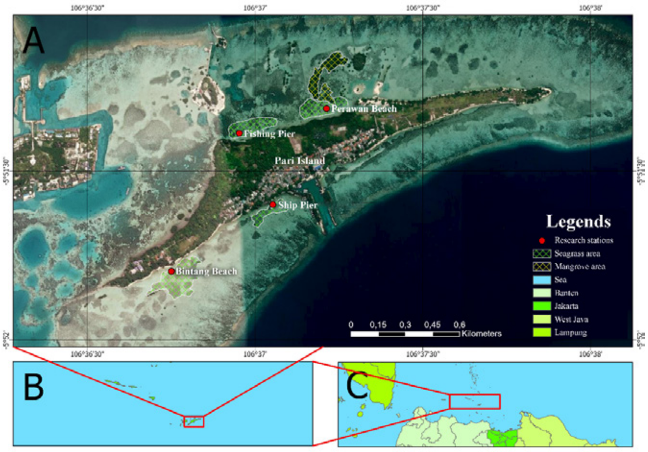

Figure 1. Fish sampling location in seagrass beds of Pari Island, Kepulauan Seribu National Park.

for differences in the aquatic environmental parameters across the months of observation. Fish sampling was conducted monthly using a seine net measuring 10 x 1 meters, with a mesh opening width of 5 mm and a bag size of 3 mm. After collection, the samples were soaked in 10% formalin for 2-3 hours, rinsed with clean water, and then preserved with 80% ethanol (Simanjuntak *et al.*, 2020). Subsequently, the fish samples were transported to the Macrobiology Laboratory at the Faculty of Fisheries and Marine Science, IPB University, for further analysis.

During the study period, a total of 542 individuals of *Sphaeramia orbicularis* were collected from the seagrass ecosystem of Pari Island. Each fish specimen was identified based on its morphology (Carpenter & Niem, 1999; Allen & Erdmann, 2012) and underwent a thorough analysis process. Each sample was measured for total length and body weight, and the length and weight of every individual fish were measured. Forty fish samples with varying body lengths were analyzed monthly for reproductive status and dietary composition. The samples were dissected, and the gonads and digestive tracts were separated. To maintain the integrity of their contents, the gonads and digestive tracts were preserved in 4% formalin for subsequent observation and analysis.

Sex determination and identification of fish gonad maturity stages (GMS) followed the criteria established by Kume *et al.* (2000). Female fish with gonad maturity stage (GMS) III and IV were analyzed for fecundity using the gravimetric method. The diameter of the eggs was measured using an ocular micrometer with 10x magnification. To study the fish diet, we extracted and examined the contents of the digestive tracts under a compound microscope. The types of fish diets were identified using the reference works of Yamaji (1979) and Conway *et al*. (2003).

Data analysis

Length-weight relationship

The length-weight relationship of *Sphaeramia orbicularis* was analyzed using the formula:

$$W = aL^b \quad \text{.......} \quad 1$$

Description:

W = Fish weight (g)
L = Fish length (mm)
a = constants
b = constants

The t-test tests the value of b=3 or b≠3 (Steel and Torrie, 1993). If the value of b=3, then the fish growth pattern is isometric. If the value of b≥3, then the fish growth pattern is positive allometric, while the value of b≤3, then the fish growth is negative allometric.

Condition factor

The calculation of the condition factor (K_n) was performed using the following formula:

$$K_n = \frac{W}{aL^b} \quad \text{.......} \quad 2$$

Description:

K_n = Condition factor
W = Fish weight (g)
L = Fish length (mm)
a = constants
b = constants

Composition of food organisms

The food composition of *Sphaeramia orbicularis* in Pari Island was determined using the index of preponderance (IP) analysis, as outlined by Natarajan & Jhingran (1961). This analysis categorizes food composition into main, secondary, and additional categories. The calculation of food type composition using IP analysis was performed with the following formula:

$$\mathrm{IP} = \frac{V_i \times O_i}{\sum_{i=1}^{n}(V_i \times O_i)} \times 100 \quad \text{......} \quad 3$$

Description:
- IP = Index of preponderance
- V_i = Percentage volume of i-th food item
- O_i = Percentage frequency of occurrence of i-th food item

Niche breadth

The niche breadth of fish describes the number of food resources breadth fish utilizes (Pianka, 1981). The calculation of niche area is used to determine the selectivity of a fish species to its food and its position in the food chain. The niche breadth was calculated based on Levins formula, which refers to Krebs (1989):

$$B = \frac{1}{\sum_j P_j^2} \quad \text{......} \quad 4$$

Description:
- B = Levins niche breadth
- P_j = Proportion of the j-th food found in the fish.

The standardization of food niche breadth value of 0-1 is based on the calculation of Hulbert (1978) in Krebs (1989) with the formula:

$$B_A = \frac{B-1}{n-1} \quad \text{......} \quad 5$$

Description:
- B_A = Levins' standardized niche breadth (0-1)
- B = Levins niche breadth
- n = Number of food organisms utilized

Sex ratio

The sex ratio was analyzed by comparing the number of male fish to the number of female fish found each month. Male and female sex ratios were calculated using the formula (Effendie, 1979):

$$SR = \frac{M}{F} \quad \text{......} \quad 6$$

Description:
- SR = Sex ratio
- M = Number of male fish (ind)
- F = Number of female fish (ind)

The sex ratio was further analyzed using the Chi-square test. This further analysis aims to determine the balance of male and female fish. The chi-square test is calculated with the following formula (Steel and Torrie, 1993):

$$\chi^2 = \sum_{i=1}^{n} \frac{(o_i - oe_i)^2}{o_i} \quad \text{......} \quad 7$$

Description:
- χ^2 = Chi-square
- o_i = Observed value of males and females
- e_i = Expected value

Hypothesis testing for determining the sex ratio is based on the rejection or acceptance of H0 based on the value of χ^2 with the criteria: if χ^2 count > χ^2 table, then reject H0 means the sex ratio is not balanced, while if χ^2 count> χ^2 table, then accept H0 means the sex ratio is balanced.

Gonadosomatic index (GSI)

The quantitative development of fish gonads is observed by determining the gonadosomatic index (GSI) for each predetermined level of gonadal maturity for female and male fish. The higher GSI value, the more developed the gonads and the size of the eggs that will be released (Akhter *et al.*, 2020). The gonads were removed from the body cavity, weighed to an accuracy of 0.01 grams, and then used to calculate the gonadosomatic index (Effendie, 1979):

$$\mathrm{GSI} = \frac{W_g}{W_t} \times 100 \quad \text{......} \quad 8$$

Description:
- GSI = Gonadosomatic index
- W_g = Fish gonad weight (g)
- W_t = Fish body weight (g)

Fecundity

Fecundity is the number of female fish eggs released during spawning (Ngabito *et al.*, 2023). Fish fecundity was calculated using the formula (Effendie, 1979) as follows:

$$F = \frac{G \times N}{Q} \quad \text{......} \quad 9$$

Descriptions:
- F = Fecundity (eggs)
- G = Total gonad weight (g)
- N = Number of eggs in sub gonads (eggs)
- Q = Sub gonad weight (g)

Egg diameter

The formula used to measure egg diameter refers to Sharif *et al.* (2018), namely D = (Dh x Dv) x 0.5; with D = egg diameter (mm), Dh = horizontal egg diameter (mm), and Dv = vertical egg diameter (mm).

Length at first gonad maturation (Lm)

The Spearman-Karber method was used to determine the length of fish at first gonad maturity (Udupe, 1986), using the following formula:

$$m = \left[x_k + \left(\frac{x}{2}\right)\right] - \left(x \sum p_i\right) \quad \text{......} \quad 10$$

By using a 95% confidence interval, so:

$$\mathrm{antilog}\left[m \pm 1.96\sqrt{x^2 + \sum \frac{p_i - q_i}{n_i - 1}}\right]$$

Description:
- m = Log length of fish at first gonad maturity
- x_k = Log mean value of the last class interval of gonad-matured fish
- x = Increase in log length at the mean value
- p_i = Number of gonad-matured fish in the i-th class interval
- q_i = 1- p_i
- n_i = Number of fish in the i-th class interval.

RESULTS

Growth aspects

The fish ranged in length from 17 to 85 mm and in weight from 0.16 to 24.28 g. *S. orbicularis* was found most frequently at the fishing pier station, likely due to the species' preference for mangrove ecosystems, particularly *Rhizophora mucronata*, *Sonneratia alba,* and *Avicennia marina*, which are adjacent to seagrass ecosystems like *Enhalus acoroides* and *Thalassia hemprichii* (Mees *et al*., 1999). Due to its small size, *Sphaeramia orbicularis* benefits from the complex structure of the mangrove habitat near the seagrass ecosystem, which maximizes food availability and reduces the risk of predation. (Laegdsgaard & Johnson, 2001).

Shpaeramia orbicularis caught in November-December 2023 and March 2024 exhibited an isometric growth pattern, while those caught in January, February, and April 2024 displayed a positive allometric growth pattern (Table 2). Isometric growth patterns indicate that the growth of length and weight tends to be balanced. In contrast, positive allometric growth means that the weight of fish increases faster than their length. A one-way ANOVA analysis revealed significant differences in salinity ($p < 0.05$), dissolved oxygen ($p < 0.05$), and pH ($p < 0.05$) levels across different months, while temperature did not show significant variation ($p > 0.05$). Changes in aquatic environmental conditions can influence growth patterns, but the primary factor is the availability of food in the natural environment. Jennings *et al*. (2001), noted that the growth patterns are not solely determined by species characteristics; they are also intricately influenced by various environmental conditions such as pH and temperature, biological factors, and food availability. Furthermore, changes in fish weight, as noted by Meretsky *et al*. (2000), result from variations in nutrition and energy allocation for growth and reproduction. This complex interplay of factors underscores the dynamic nature of the seagrass ecosystem.

The condition factors of male and female *Sphaeramia orbicularis*, as presented in Tables 3 and 4, showed varying average values. For males, the highest average condition factor was recorded in January, while the lowest was observed in February. Similarly, for females, the highest average condition factor also occurred in January, with the lowest recorded in December. Overall, the condition factor values were greater than 1, indicating that the fish are in good health and that their dietary needs are being adequately met (Kusmini *et al*., 2018).

The variation in condition factors observed each month may indicate the spawning season for fish. Both male and female fish exhibited an increase in condition factor from November to December as they entered the pre-spawning phase. The highest condition factor was recorded in January, followed by a decrease in February as the fish transitioned into the post-spawning phase. Moreover, the highest gonadosomatic index (GSI) for both male and female *Sphaeramia orbicularis*, indicating the peak spawning period, were also recorded in January (Fig. 4). Effendie (2002) noted that an increase in condition factors is observed when fish experience gonadal development that peaks just before spawning. In contrast, Lizama & Ambrosio (2002) found that condition factors typically decrease during spawning, as fish utilize their fat reserves for energy. Additionally, several factors can influence variations in condition factor values, including food availability, differences in fish size or age, and parasite pressure (Neff & Cargnelli, 2004).

Feeding ecology

All analyzed stomachs of *Sphaeramia orbicularis* ($n = 240$ individuals) contained food, and none were empty. This indicates that the captured fish were

Table 2. The growth pattern of *Sphaeramia orbicularis* in seagrass habitats of Pari Island.

Months	a	b	t_{hit}	t_{tab}	Growth types
November	0.00005	3.0101	0.0563	2.2945	Isometric
Desember	0.00004	3.0340	0.2631	2.2709	Isometric
January	0.00002	3.2763	3.0588	2.2606	Positive allometric
February	0.00002	3.1731	3.6975	2.2855	Positive allometric
March	0.00004	3.0354	0.1735	2.3289	Isometric
April	0.00002	3.2246	3.0582	2.3056	Positive allometric

Table 3. Condition factor of male *Sphaeramia orbicularis* in seagrass habitats of Pari Island.

Months	Condition Factor	
	Ranges	Mean ± SD
November	0.8866 - 1.2106	1.0036 ± 0.0876
December	0.9087 - 1.1855	1.0025 ± 0.0738
January	0.8808 - 1.1516	1.0210 ± 0.0794
February	0.9279 - 1.0965	1.0012 ± 0.0515
March	0.8672 - 1.1622	1.0027 ± 0.0760
April	0.8739 - 1.1611	1.0032 ± 0.0830

Table 4. Condition factor of female *Sphaeramia orbicularis* in seagrass habitats of Pari Island.

Months	Condition Factor	
	Ranges	Mean ± SD
November	0.8506 - 1.1464	1.0032 ± 0.0811
December	0.8696 - 1.1106	1.0023 ± 0.0694
January	0.8188 - 1.2304	1.0081 ± 0.1317
February	0.8345 - 1.1739	1.0029 ± 0.0776
March	0.7848 - 1.1982	1.0034 ± 0.0829
April	0.8412 - 1.2482	1.0052 ± 0.1069

Table 5. Group and food organism types of *Sphaeramia orbicularis* in seagrass habitats of Pari Island

Groups	**Food organism types**		
Copepods	*Corycaeus* sp.	*Microsetella* sp.	*Paracalanus* sp.
	Oncaea sp.	*Porcellidium* sp.	*Acartia* sp.
	Oithona sp.	*Peltidium* sp.	*Caligus* sp.
	Calanus sp.	*Oikopleura* sp.	
Malacostraca	*Gammarus* sp.	*Nebalia* sp.	*Leptochelia* sp.
	Mysis	Crab body part	Tanaidacea
	Odontodactylus sp.	Isopoda	
Branchiopods	Nauplius		
Ostracods	*Cypris* sp.	*Conchoecia* sp.	
Molluscs	Gastropods	Bivalve	
Annelida	Polychaeta		

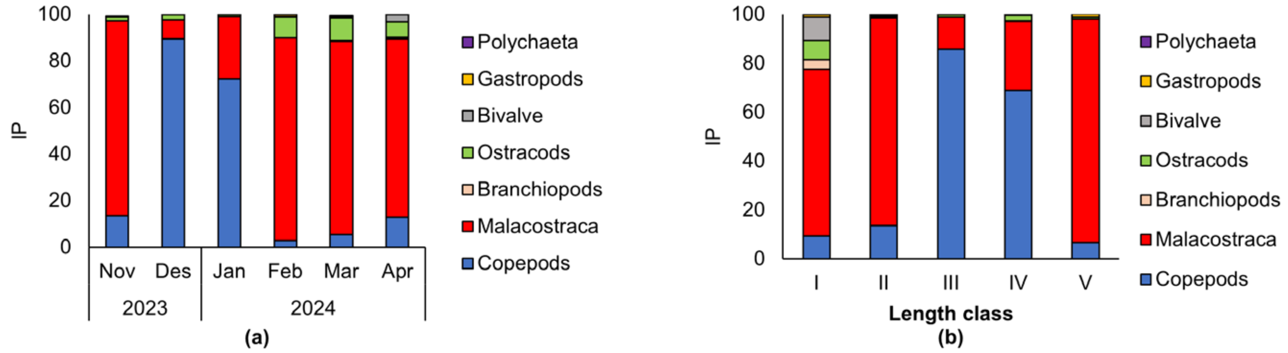

Figure 2. Composition of *Sphaeramia orbicularis* diet according to sampling time (a) and length class (b).
Note: Length class: I = 17-31; II = 32-46; III = 47-61; IV = 62-76; 77-91 mm.

actively feeding. The study identified six groups of fish-food organisms consumed by *S. orbicularis* during the research period: copepods, malacostraca, branchiopods, ostracods, molluscs, and annelida. Table 5 provides further details on these groups and the specific types of food organisms consumed by *S. orbicularis*.

The food composition of *Sphaeramia orbicularis* in the seagrass ecosystem of Pari Island varied monthly. Similarly, variations were observed in the food composition consumed across different size classes (Figure 2). During the study period, malacostraca served as the primary food source for fish in most months, with the exception of December and January. This suggests that fish mainly relied on malacostraca for their diet, while copepoda acted as a secondary food source. Since malacostraca are high in protein, their abundant availability enables fish to feed effectively, promoting growth, rapid maturation, and reproductive success (Gross *et al.*, 1988). Additionally, the diet composition by length group revealed that as the length of the fish increased, the diversity of consumed organisms decreased.

A study on the dietary aspects of *Sphaeramia orbicularis* in Kenyan mangroves by Mees *et al.* (1999) reported that the malacostraca group, particularly *Gammarus* sp., Tanaidacea, and brachyura (crabs), occupied the highest percentage compared to other organisms. The feeding activity of these fish typically occurs at dusk or in the evening. Smaller fish primarily fed on amphipods and harpacticoids, while larger fish targeted amphipods and gammarids as their primary food source. *S. orbicularis* is considered an opportunistic carnivore, exploiting a variety of small epibenthic, hyperbenthic, and planktonic prey (Mees *et al.*, 1999).

The niche breadth value (B_A) is categorized into three classifications: high (>0.6), medium (0.4-0.6), and low (<0.4) (Novakowski *et al.*, 2008). A lower niche area value indicates that the fish is more selective in food choices. The niche area for male *S. orbicularis* was calculated at 0.2498, while that for females was 0.2072 (Table 6). This suggests that male and female fish utilize smaller amounts of food and exhibit selectivity in their diets.

Table 6. Niche breadth of *Sphaeramia orbicularis* based on sex types.

	B_i	B_A
Male	6.1794	0.2072
Female	2.2959	0.0498

Sphaeramia orbicularis has a low niche breadth, indicating that it is a specialist fish. A lower niche breadth suggests reduced adaptability to new environments than fish with a higher niche breadth. This finding implies that *S. orbicularis* is highly dependent on seagrass ecosystems, especially those adjacent to mangrove ecosystems, which provides its primary food source, such

Table 7. Sex ratio of *Sphaeramia orbicularis* in seagrass habitats of Pari Island.

Months	Sex Ratio (M : F)	Chi Square Test		Description
		χ^2 hit	χ^2 tab	
November	1 : 0.7	5.4182	7.8147	Balanced
Desember	1 : 1.1	1.6429	7.8147	Balanced
January	1 : 0.7	5.8144	7.8147	Balanced
February	1 : 1.4	7.6420	7.8147	Balanced
March	1 : 1.2	3.4945	7.8147	Balanced
April	1 : 1.0	7.6883	7.8147	Balanced

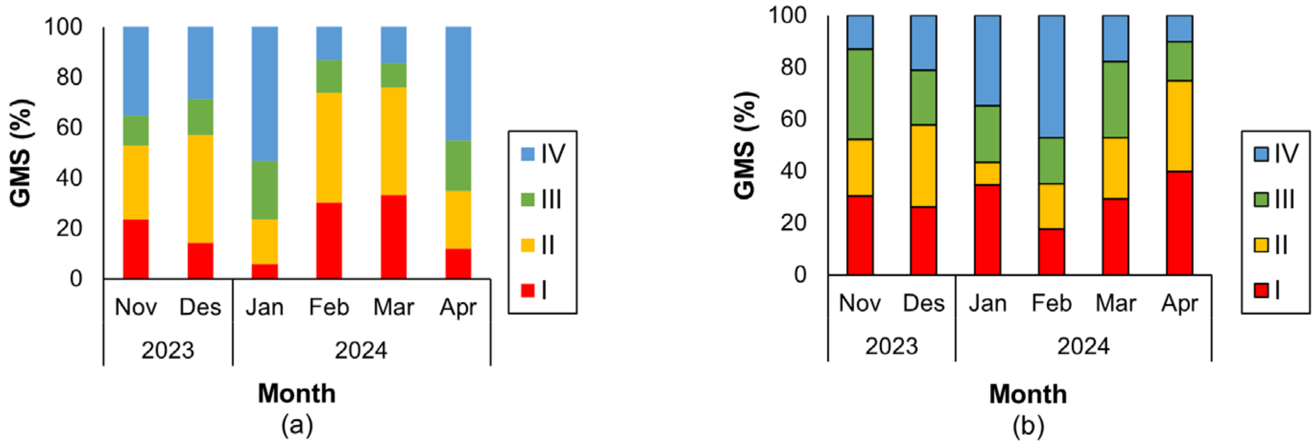

Figure 3. Gonad maturity stage (GMS) percentages of *Sphaeramia orbicularis* (a) male (n = 120) and (b) female (n = 120) in each month from November 2023 to April 2024 in seagrass habitats of Pari Island.

as malacostraca. Generally, smaller fish are specialists and exhibit greater selectivity in their food choices (Effendie, 2002). The lower niche size is believed to be attributable to the female fish's selection of available food resources in the waters (Hedianto *et al*., 2010).

Reproductive biology

The results of this study are comparable to those of *S. orbicularis* in Chuuk Lagoon, Micronesia, where the overall sex ratio was nearly balanced (Table 7). However, females tended to dominate, particularly at lengths of 45-50 mm and 70-75 mm (Choi *et al*., 2012). Deviations from a 1:1 sex ratio may arise due to differences in fish distribution, activity, and behavior (Türkmen *et al*., 2002); variations in male and female reproductive strategies, mortality rates, and life spans (Sadovy, 1996); as well as parental care behaviors (Mazzoni & Caramaschi, 1997; Liang *et al*., 2005). The dominance of female fish in an ecosystem suggests abundant food availability, whereas male dominance may indicate reduced food resources (Nikolsky, 1963).

Results from the reproductive analysis of 240 samples of *Sphaeramia orbicularis* show the percentage of various levels of gonadal maturity (GMS) presented in Figure 3. In February, male fish exhibited the highest percentage of mature gonads (GMS III and IV) at 68%, whereas the lowest rate of mature gonads, at 25%, was observed in April.

It was observed that GMS IV was present every month, indicating that *S. orbicularis* has the potential to spawn year-round. Mating and spawning of *S. orbicularis* have been reported to occur every two weeks around the new and full moons (Allen, 1975). This observation is supported by Choi *et al*. (2012), who noted that the reproductive activity of *S. orbicularis* occurs continuously throughout the year. Natural factors such as tidal variations and seasonal temperature changes can influence the increased reproductive activity of reef fishes, including *S. orbicularis*, particularly in tropical environments (Takemura *et al*., 2004).

Based on the overall average index of gonadosomatic index (GSI) values for *S. orbicularis* (Figure 4), the lowest GSI value for male fish (0.26) was recorded in March, while the highest value (0.70) was observed in April. For female fish, the highest GSI (2.05) was noted in January, while the lowest (1.09) was recorded in February. This indicates that the peak spawning period for *S. orbicularis* in the seagrass ecosystem of Pari Island occurs in January, consistent with the finding that the highest percentage of mature female gonads was also observed in that month (Figure 3).

The GSI of female *S. orbicularis* based on the results of Choi *et al*., (2012) showed the highest value in January and then dropped dramatically in the following month, February. In contrast, the The GMS value for male fish tends to remain stable. Following spawning, the GSI value decreases significantly, as nearly all the eggs have been released (Caballes *et al*., 2021). A higher GSI value indicates more developed gonads and larger eggs to be released (Akhter *et al*., 2020).

The sustainability of fish resources is closely linked to their reproductive success (Jatiswara *et al.*, 2020). Fecundity analysis can estimate the number of eggs released during spawning, which in turn helps assess the reproductive potential of the fish. The relative fecundity values of *S. orbicularis* varied from 7,239 to 12,240 eggs among 57 individual fish collected in GMS III and IV, with the highest fecundity recorded in December 2023 and the lowest in February 2024 (Figure 5).

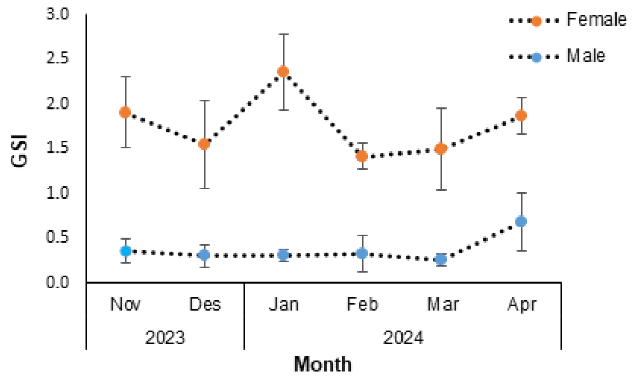

Figure 4. Gonadosomatic index (GSI) of male and female *Sphaeramia orbicularis.*

Egg counts exceeding one thousand indicate a high reproductive potential (Kasmi *et al.*, 2017). In Kenyan mangrove forests, the fecundity of *S. orbicularis* has been reported to range from 4,712 to 10,031 eggs (Mees *et al.*, 1999), while Shao & Chen (1986) found fecundity values between 6,100 and 11,700 eggs. The number of mature eggs is influenced by the volume of the abdominal cavity containing mature eggs and the size of the oocytes (Duarte & Araújo, 2002). High fecundity is

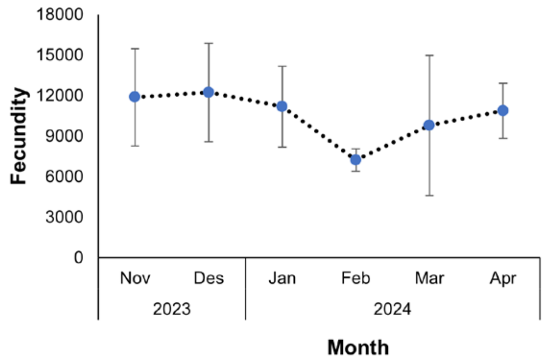

Figure 5. Relative fecundity of *Sphaeramia orbicularis* (n = 57 individuals, GMS III & IV).

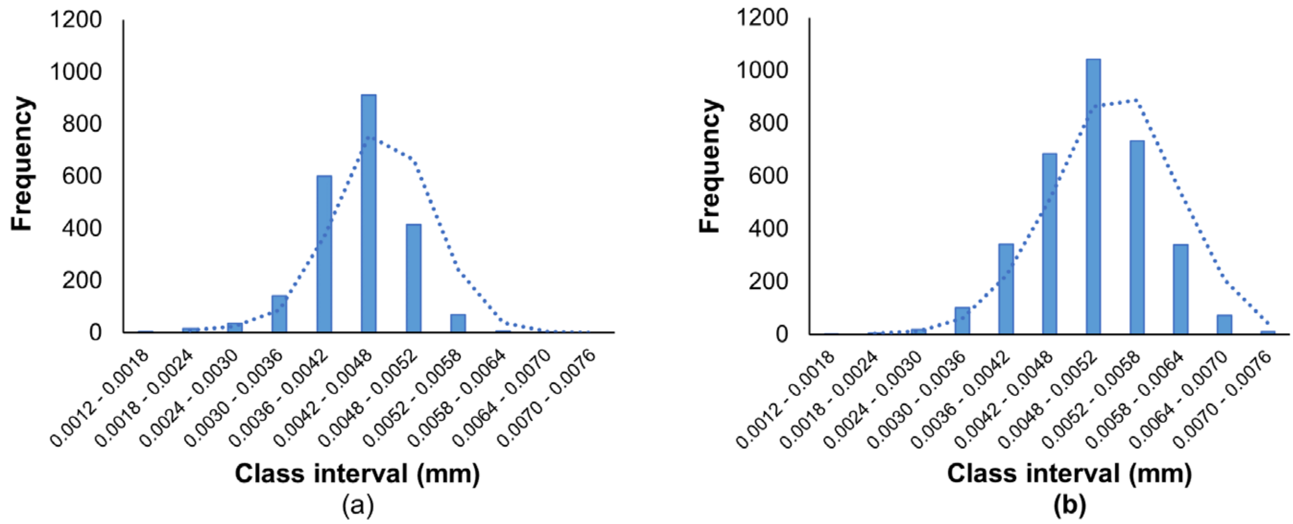

Figure 6. Egg diameter distribution of *Sphaeramia orbicularis* (a) GMS III (b) GMS IV.

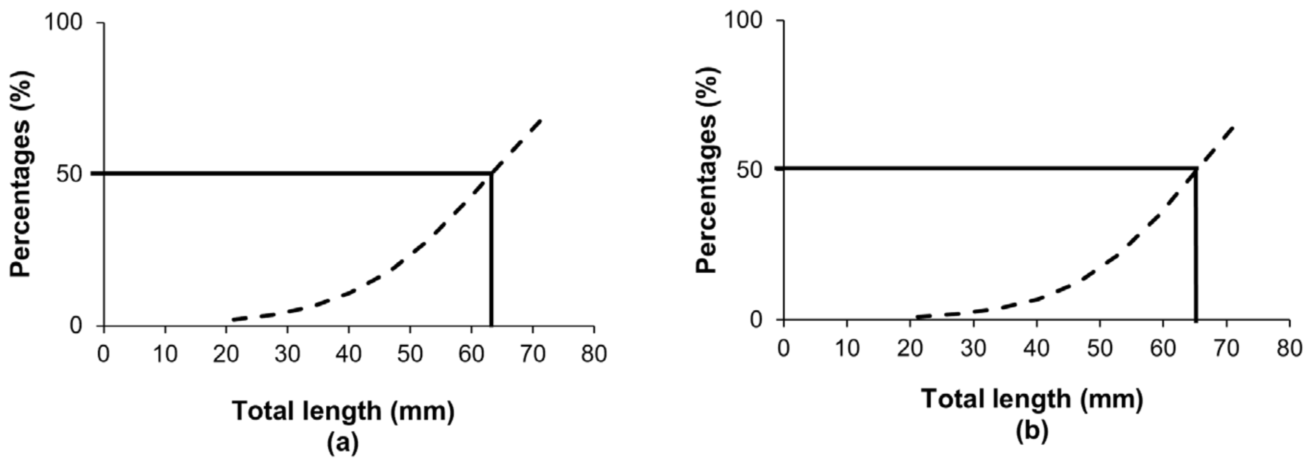

Figure 7. Length of first maturity (Lm) *Sphaeramia orbicularis* (a) male and (b) female.

considered a mechanism and strategy for fish to enhance the number of eggs and the growth rate of fish larvae (Bagenal, 1966, as cited in Duarte & Araújo, 2002).

The distribution of egg diameters for *Sphaeramia orbicularis* ranged from 0.0012 to 0.0076 mm (Figure 6). The egg diameter for GMS III female fish (n = 17 individuals), with the highest frequency of 911 eggs, was found to be between 0.0042 and 0.0048 mm. In contrast, for GMS IV female fish (n = 40 individuals), the peak frequency of egg diameter was 1,042 eggs, occurring at a size of 0.0048 to 0.0052 mm. Each GMS of gonadal maturity exhibits a peak, identifiable through the frequency values corresponding to the largest egg diameter sizes.

According to the study by Mees et al. (1999), the diameter of gonadally mature *S. orbicularis* eggs averaged around 0.004 mm. Female *S. orbicularis* are total spawners, releasing all their eggs during spawning. The egg diameter distribution with a single peak indicates that the fish spawn simultaneously (Rahardjo & Simanjuntak, 2007; Sjafei *et al*., 2008). This simultaneous spawning pattern allows the fish to align their next spawning season closely, resulting in greater availability of fish stocks in natural environments (Setiawan & Sulistiawan, 2014).

Figure 7 shows the length at which *S. orbicularis* first reaches gonadal maturity in the seagrass ecosystem of Pari Island. Male *S. orbicularis* reaches gonadal maturity at a length of 63.12 mm, while females reach maturity at 65.27 mm. In contrast, the lengths at maturity found in Chuuk Lagoon, Micronesia, were smaller, with males maturing at 44 mm and females at 46 mm (Choi *et al*., 2012). This difference in values is common for the same species across different geographical locations (Dahlan *et al*., 2015).

The length at first gonadal maturity can indicate fish populations' potential pressures (Sangadji *et al*. 2023; Romdoni *et al*., 2024). In cases of overfishing, the size of first-maturing gonads tends to decrease, a trend often characterized by catches dominated by smaller fish (Agustina *et al*., 2015; Munandar *et al*. 2024). This reduction in adult fish size is thought to be an adaptation aimed at restoring species balance in response to overfishing and environmental changes (Jatiswara *et al*., 2020).

CONCLUSION AND RECOMMENDATION

Conclusion

Sphaeramia orbicularis, found in the seagrass ecosystem of Pari Island within Kepulauan Seribu National Park, demonstrates both positive allometric and isometric growth patterns, with a condition factor value exceeding 1. Regarding dietary aspects, this species is a specialist with a narrow ecological niche, primarily feeding on Gammaridae, Tanaidacea, and Brachyura. The sex ratio of *S. orbicularis* is balanced, with male fish maturing faster than females. Spawning occurs in January, which is indicated by the highest recorded values of gonadal maturation stage (GMS) and gonadosomatic index (GSI) during this month. This fish species exhibits significant reproductive potential and follows a total spawner spawning pattern.

Recommendation

This study shows that seagrass ecosystems and nearby mangroves are crucial habitats for *Sphaeramia orbicularis*. Therefore, the seagrass and mangrove ecosystems on Pari Island, along with other islands in the Kepulauan Seribu, need protection.

AUTHORS' CONTRIBUTIONS

Conceptualization: CPHS; Investigation, Formal analysis, Data curation, Visualization, Writing-original draft preparation: SK and CPHS; Writing—review and editing: CPHS and GY; Funding acquisition: CPHS. All authors have read and agreed to the final version of the manuscript.

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