Sex Changes and Gonad Maturity of Rivulated Parrotfish *Scarus rivulatus* (Valenciennes, 1840) from Seribu Islands, Indonesia

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Abstract

Parrotfish (Scarus rivulatus) is a species that can undergo sex change at a certain age and size (hermaphrodite protogynous). This study aims to analyze the process of sex change based on body color and gonadal tissue changes, as well as the gonadal development of the fish. Sampling was conducted monthly from January to September 2022. Fish samples were collected from fishermen in Seribu Islands. The parameters observed were sex, gonad maturity stage, body color changes, and anatomy and histology of the gonad. The samples were 1605 individuals, consisted of 831 females, 309 primary males (initial phase of males), and 465 secondary males (terminal phase of males). The total length of these fish ranged 8.8- 22.4 cm (females), 10.5-22.6 cm (primary males of males), and 15.1-28.1 cm (secondary males). Morphological differences between female fish, primary males, and secondary males are generally showed in body size, fin size, and body coloration. The histological analysis results of the gonads of primary male fish was indicated by the presence of residual perinucleolar oocytes in the layer of the gonads that coexist with sperm tissue. The body size of first mature gonads was 13.0 cm (female), 16.6 cm (primary male), and 17.6 cm (secondary male). Gonadal maturity stage (GMS) III and IV dominated each observation time. Hence, it was suspected that the fish spawned throughout the year. However, based on the distribution of the GMS, there was an increase in reproductive activity in January-March and July-September, with peak spawning in March and September.

Keywords: *Parrotfish, sex change, gonad maturity*

Introduction

Parrotfish *Scarus rivulatus* (Valenciennes, 1840) is a species from the Scaridae family, which is strongly associated with coral reef ecosystems, categorized as an herbivore, and plays an important functional role in the coral reef ecosystems by limiting the growth of alga communities that can inhibit coral recruitment and become a conduit for higher trophic level energy flows (Rotjan and Lewis, 2005; Green and Bellowed, 2009; Taylor and Cruz 2017; Freitas *et al*., 2019; Tuwo *et al.,* 2021). Like most Scaridae, the *S. rivulatus* exhibits sequential hermaphroditism (protogynous), capable of sex changes from female to male (Shao *et al.,* 2003; Tuwo *et al.,* 2021).

Several studies on sex reversal were carried out previously (Robertson and Warner, 1978; Shao *et al.,* 2003; Nakamura *et al.,* 2005; Munday *et al.,* 2006). Sequential hermaphroditism is a condition where individuals are born of one sex and change sex as they mature. Sex change occurs when individuals more efficiently reproduce as one sex when they are small and as the other sex when they are larger (Munday *et al.,* 2006). This condition allows individuals to maximize their reproductive lifespan by functioning as one sex as a juvenile and different sex as an adult.

Fish species that change sex tend to be very sensitive to fishing pressure. Sex changes in fish species present unique challenges for stock assessment and management. Fishing is known to cause size at sex change to decrease and sex ratios to increasingly skew because of sex-selective fishing patterns (Provost and Jensen, 2005). Rotjan and Lewis (2005) reported that of the 179 parrotfish and surgeonfish species observed, most parrotfish were listed as least concern species, including *Chlorurus bleekeri*, *C. japanensis, Scarus. flavipectoralis, S. ghoban, S. niger, S. quoyi,* and *S. rivulatus*. Meanwhile, *S. trispinosus* was in almost threatened category, and *Bolbometopon muricatum* was in the threatened category.

Parrotfish have been overfished on several coral reef ecosystems in Indonesia (Fatihah *et al.,*

https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.28.2.203-216
Received : 12-03-2023
Accepted : 27-05-2023

2021). In the last 10-20 years, increased fishing activity has led to declines in the parrotfish populations (*B. muricatum and Scarus guacamaia*). The threat of overfishing is compounded by the increasing risks coral reefs face due to anthropogenic pressures. Habitat degradation coupled with fisheries exploitation can negatively impact coral reef fish populations (Graham *et al.,* 2011). Freitas *et al.* (2019) added that *S. trispinosus* has declined in population by >50% and is considered one of the most endangered parrotfish in the world, which can lead to extinction (Ambariyanto, 2017).

Some studies on parrotfish were conducted in the Seribu Islands i.e. the characteristics of parrotfish fishing areas (Rifaldi, 2018), species composition and population structure of parrotfish (Khalifa, 2011), and analysis of factors affecting the price of parrotfish in Panggang Island (Lestari *et al.*, 2017). However, there is none existing study that examines aspects of sex changes and gonadal maturity of the parrotfish from the Seribu Islands.

Studies on the gonadal maturity aspect of the parrotfish are necessary as they have received little attention even though significant threats from fishing and habitat losses due to anthropogenic activities have contributed significantly to the decline of local populations. The parrotfish family should be prioritized for more studies and monitoring, despite its IUCN Red List Category. With better information on habitat and fisheries biology of the respective fish, many parrotfish species, currently listed as data deficient, may be qualify for the threatened category soon.

This study aims to analyze the process of sex reversal based on changes in fish body color and gonad maturity *of S. rivulatus* from the Seribu Islands. The results of the gonad maturity observations obtained from the study are important parameters indispensable in the sustainable management of the *S. rivulatus* parrotfish resources from Seribu Islands.

Materials and Methods

A sampling of parrotfish (*S. rivulatus*) was conducted each month from January to September 2022. The fishes were caught in sea waters of the Seribu Islands and landed on Panggang Island (Figure 1.). Sample identification was conducted at the Biomacro Laboratory, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University.

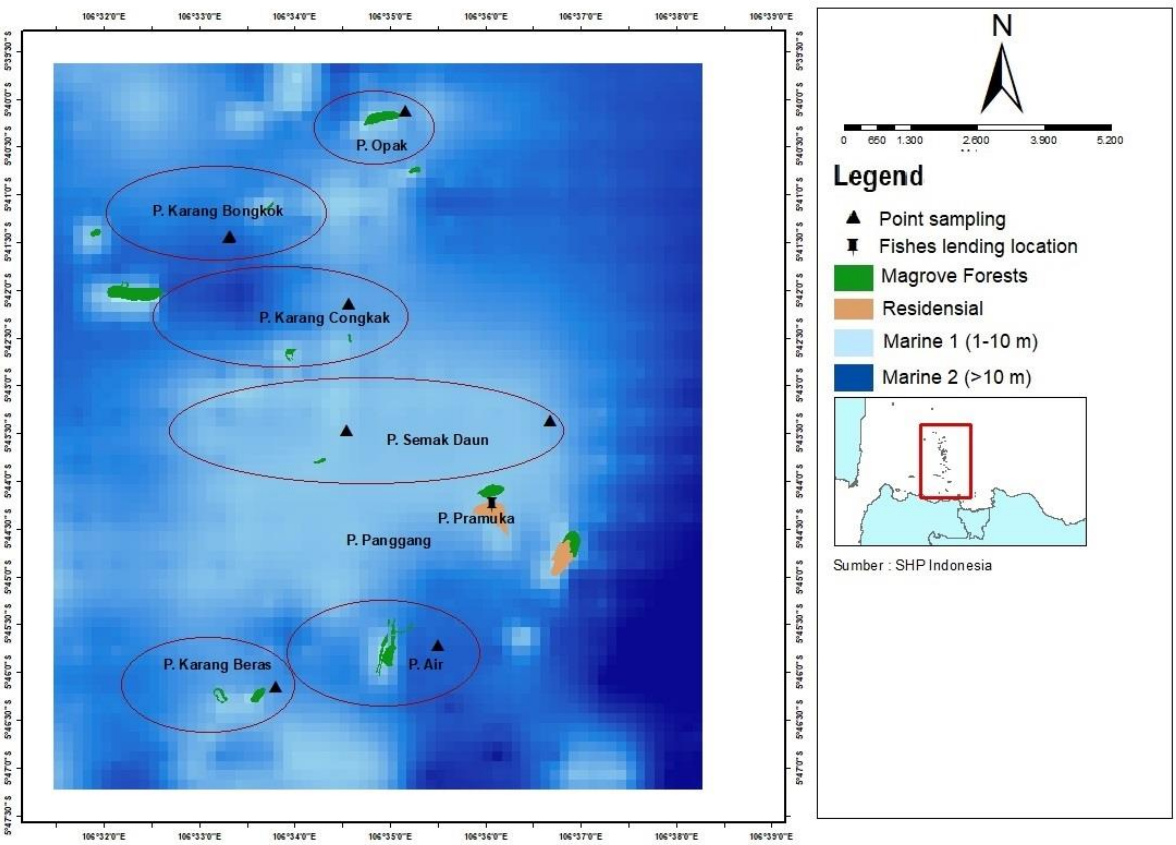

Figure 1. Sampling location of parrotfish *S. rivulatus* in Panggang Island, the Seribu Islands, of Jakarta

Parameters observed included gonadal maturity stage (GMS), size at first gonadal maturity (FM), and observations of color on fish morphology. Parameters measured were total length, weight, and gonad weight. The total length was measured from the mouth tip to the tip of the caudal fin with a ruler (1 mm accuracy). Fish body weight was measured using an analytical scale (accuracy 0.01 g) and gonad weight with a scale of accuracy 0.0001 g.

Fish species were identified following Allen *et al.* (2013). The sex of the fish sample was pre-distinguished by body coloration (morphology) because the fish was characterized by sexual dimorphism and specimen dissection was done afterwards to reconfirm its reproductive organs. Male fish were divided into two categories: primary males (initial phase males where the morphology was like female fish, but the reproductive organs were male) and secondary males (terminal phase males, after sex and morphological changes were complete).

Estimation of gonadal maturity was conducted visually and histologically. The visual observation was carried out by dissecting the abdominal part of the fish and making direct observations based on the color, shape, texture, and weight of the gonads (Tuwo *et al.,* 2020). Histological analysis was carried out from GMS I-V gonad samples, and the histological stages were classified following Shao *et al.* (2003). Primary male gonads were divided into three sections (anterior, median, and posterior), and histology was performed using standard procedures to characterize the gonads. The size of the fish's first maturing gonads was determined using the total length of the fish's gonadal maturity (GMS III and IV).

Data analysis

This study estimated the size at first gonadal maturity of the fish (FM) based on the total length of 50% of the samples that matured using the equation: FM= Lm50; the minimum size at sexual maturity was determined by drawing cumulative percent curves for each sex. The Lm50, at which 50% of the population showed gonadal maturity, was then used to present the minimum size at sexual maturity (Sparre and Venema, 1992).

Results and Discussion

Sex changes based on body coloration (morphology)

Morphological differences between female and male fish are generally seen in body size, fin size, and body coloration (Figure 2.). Color changes in female individual (Figure 2a.) started in the areas of the chest, dorsal fins, caudal fin, and pectoral fins. The caudal fin and dorsal fin changed from grey to yellowish orange, the pelvic fins began to appear orange, and the operculum slowly changed from grey to yellowish orange. The primary male phase (Figure 2b.) is generally grayish brown with the exact morphology of females, but the gonads are male. Most primary males are similar in color to females, while most secondary males are bright green.

In some cases, female gonads differentiate into secondary testes before changing color to secondary males. Secondary males (Figure 2c.) at this stage began to form irregular lines around the eyes, followed by a change in the color of the entire body scales to green, with brighter and more conspicuous orange spots, and the pelvic fins turned green and orange. On the head and operculum, there were irregular wavy line motifs. The more vivid green and orange colors are characteristic of this fish.

The results of this study follow the statement of Randall *et al.* (1983), stating that the change of females to males in *Scarus* are usually accompanied by changes in color patterns dominated by green throughout the fish body. Males resulting from sex change usually have more striking colors than female fish. For many reef fish, sex change from male to female is not only a transformation of gonadal tissue but is followed by changes in body color and behavioral patterns. This phenomenon is often seen in significant reef fish species such as Labridae and Scaridae (Paxton and Eschmeyer, 1998).

Parrotfish are protogynous hermaphrodites, that means these species start life as females and change to males. Sex change in hermaphroditic fishes is adaptive when individuals reproduce more efficiently as one sex when young and change sex when older or larger (Munday *et al.,* 2006). Sex change in female fish is influenced by genetic traits, population size, and the proportion of males and females in the water (Hasting and Petersen, 1986).

Most parrotfish are brightly colored and complex, with many species identical in their general morphology. *S. rivulatus* has a distinctive and striking color change pattern. This color change pattern can be observed in three crucial phases of its life cycle: the female, primary male, and secondary male phases. The last two phases are included in the life cycle as protogynous hermaphrodites. These three phases display different colors and contrast with the females. Changes in color patterns throughout the life history of sex-reversed fish cause difficulties in distinguishing between species within the parrotfish genera (Bellwood and Choat, 1989). Descriptions of the color change patterns of initial phase females and terminal phase males, including during sex change, help recognize and differentiate *S. rivulatus* from other occurring species.

The results of this study also show that the gonads in protogynous hermaphroditic fish are faster to undergo reversal than the color patterns in fish morphology. This condition is thought to be because reproductive organs require less energy to change sex than changes in the color of the fish body and will be more beneficial to the reproductive process of sex change occurring first. This study corroborates the statement of Shao *et al*. (2003), which assumes that changes in gonadal tissue are likely to precede changes in the body coloration of *S. rivulatus* during the sex change process.

Sex change based on the gonads (macroscopic and microscopic)

The structure of gonads from female to male macroscopical and microscopical primary and secondary phases were also observed in this study. There were distinct macroscopically and microscopically differences in the gonads of female and male fish (primary and secondary) (Figure 3.). *S. rivulatus* females in the mature phase had reddish yellow gonads (Figure 3a.), filled with ootid and ovum in the vitellogenin phase, and no spermatogenic tissue was found (Figure 3d.).

The macroscopic appearance of gonad female *S. rivulatus* transitioning to primary males was still like females. However, their reproductive organs had changed to males with milky white gonads, exactly like the reproductive organs of secondary male fish (Figure 3b.). Histologically, gonads showed the presence of perinuclear stage oocytes (po) and spermatogenic tissue (sg) in one gonad (Figure 3e.). The gonads of secondary males that had undergone complete morphological changes were milky white (Figure 3c.), and there were degenerated atretic oocytes (ao) located between mature sperm cells or spermatid (st). Secondary males consisted entirely of spermatogenic tissue; no residual developed female germ cells were found (Figure 3f.). Both males (primary and secondary) contained spermatocytes at different development stages. Some gonads contained mature spermatozoa characterized by round heads and elongated caudals.

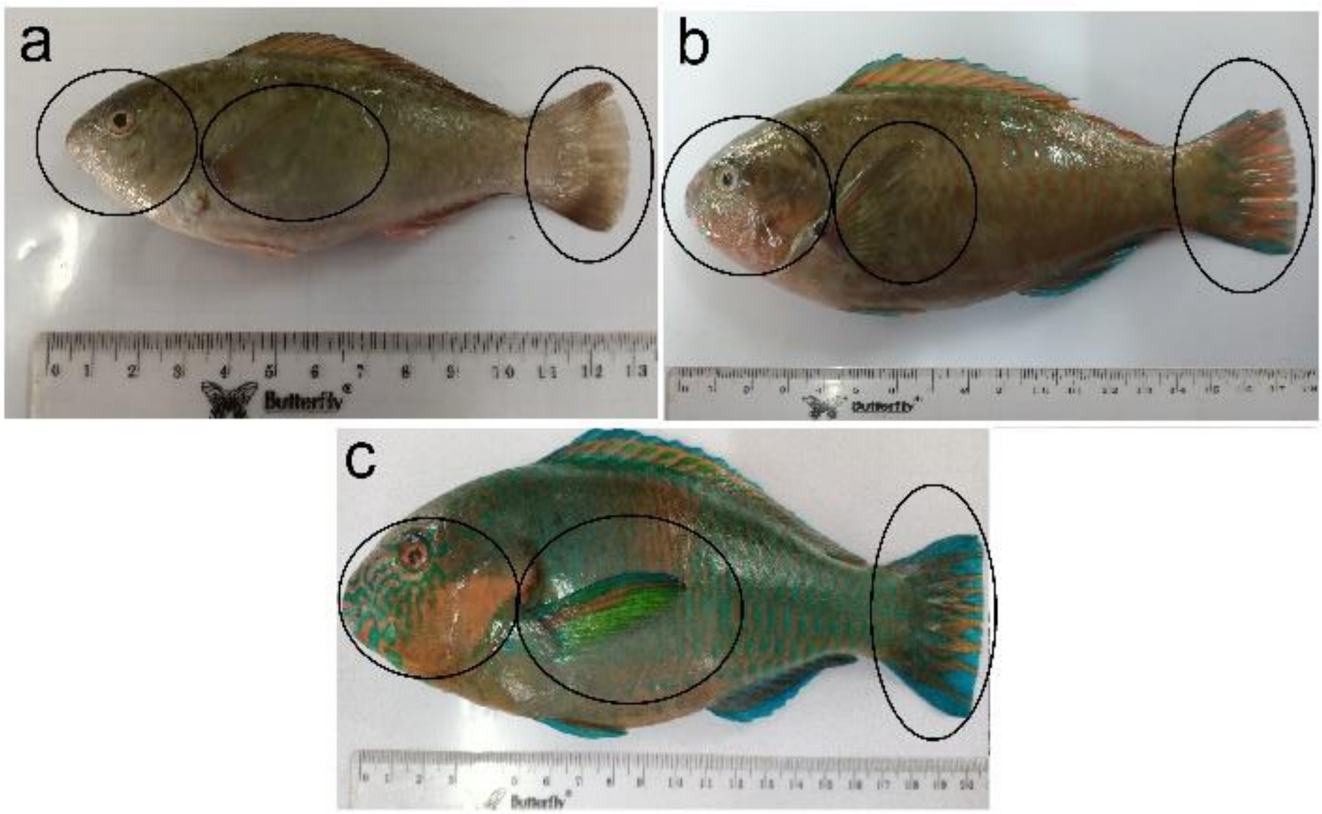

Figure 2. Color change process of female *S. rivulatus* (a = 12.9 cm), primary male (b = 18 cm) and secondary male (c = 20 cm).

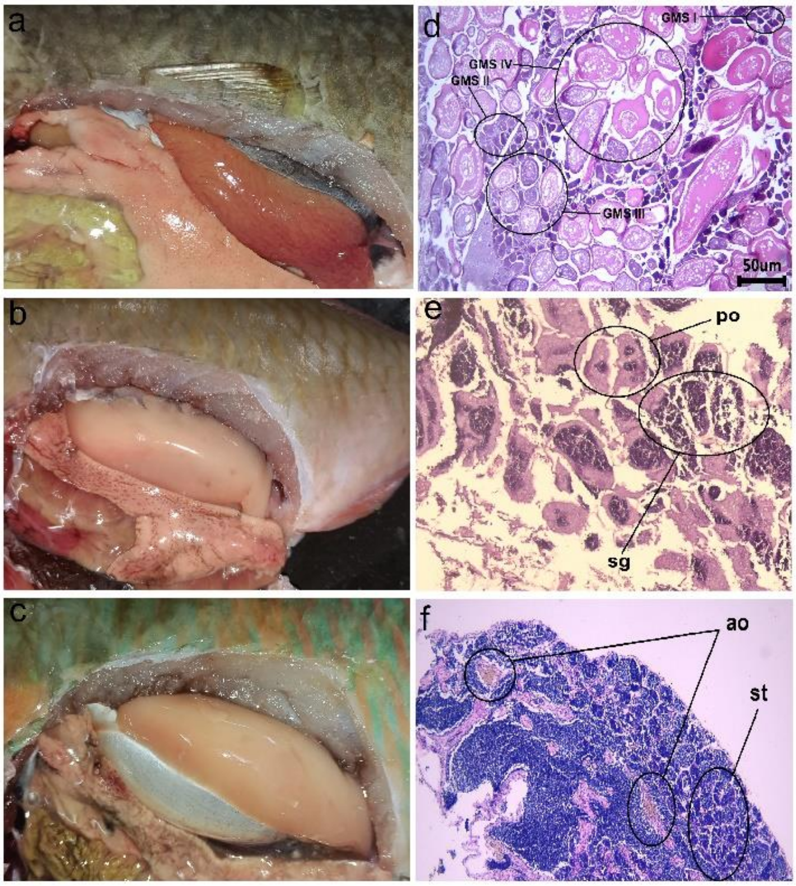

Figure 3. Macroscopic and microscopic characteristics histological of *S. rivulatus* gonads (a, d) female, (b, e) primary male, and (c, f) secondary male. Description: ao : atretic oocyte, GMS : gonadal maturity stage, po: perinucleolar oocyte, sg: spermatogenic tissue, st: Spermatid, with 40x magnification in 50 µm scale.

The histology of primary male fish gonad tissue was clarified by dividing the gonads into three parts (anterior, median, and posterior) to observe the important gonad characteristics (Figure 4.). All three parts of the gonad contained perinuclear stage oocytes. In the wall of the gonad tissue, there were still remnants of ovum tissue which later became a place for spermatogenic tissue to develop into spermatid groups. Spermatogenic tissue (sg) embedded in a typical gonad was mixed with perinuclear stage oocytes (po). The remaining oocytes attached to the lamella showed shrinkage, signifying the characteristic of atresia. The results of this study confirm the statement of Chan *et al.* (1967) that the remaining gonadal oocytes are likely to develop into spermatogenic cell groups. Shao *et al.* (2003) explained that the gonads of *S. rivulatus* in early-phase male individuals undergoing sex change from female to male have testicular tissue and ovarian tissue in one part of the gonads.

Characteristic features at sex change were made clear with higher magnification (Figure 6.). Interstitial (Leydig) cell extensions were developed in the gonadal lamellae. Atretic oocytes and some unreleased atretic follicles characterized the gonadal structure transformation from the ovary to the testis. At higher magnification, it shows a distinctive feature that fish experiencing sex change indicated spermatogenic cells enclosed in typical spermatocyte; spermatogonium emerged from connective tissue, developed and divided into spermatocytes.

Size distribution

The total sample of *S. rivulatus* parrotfish analyzed during the study was 1,605 individuals, consisting of 831 females, 309 primary males, and 465 secondary males. The total body length of these fish ranged from 8.8 to 22.4 cm for females, 10.5 to 22.6 cm for primary males, and 15.1 to 28.1 cm for secondary males, with an average of 15.0 cm for females, 14.7 cm for primary males, and 20.4 cm for secondary males (Figure 5.).

This study found female fish in small class intervals (8.8-10.4 cm to 22.5-24.1 cm) the larger of the class interval, the fewer female individuals. In addition, this study found primary male fish in the class interval of 10.5-12.1 cm to 22.5-24.1 cm and most were in 12.2-13.8 cm. On the other hand, the last-phase secondary male fish were only found in the large class interval of 13.9-15.5 cm to 17.6-29.2 cm, and most were found in the class interval of 19.1-20.7 cm.

The size distribution of *S. rivulatus* based on the class interval showed an overlap because the sex change time of an individual was not the same; some chose to change quickly, and some maintained their sex as a female. According to Nakamura *et al.* (2005), in some cases, sex change in fish is very diverse. Munday *et al.* (2006) added that some individuals change sex early, others change sex late, and some choose not to change sex. Sex change in female to male fish is influenced by genetic traits, population size and the proportion of males and females in the water (Hasting and Petersen, 1986).

Previous studies also showed an overlap between the female and male length ranges (primary and secondary). The female length range should be lower than the male one, but there is an overlap between these ranges (Robertson and Warner, 1978; Clavijo, 1982; Shao *et al.,* 2003). This area is the range of length where sexual change occurs within the group.

The size of primary male fish undergoing a transition in the Seribu Islands was smaller than previously reported. Shao *et al.* (2003) reported the length of early-phase *S. rivulatus* to be 10.0-47.5 cm, with late-phase males measuring approximately 27.5-52.5 cm. This finding was thought to be related to high fishing pressure. Sadovy and Shapiro (1988) stated that the relationship between body size and sex ratio in populations could be used to investigate reproductive and adaptation strategies in the face of environmental pressures in populations.

Gonadal maturity stage (GMS)

The stage of gonad maturity of *S. rivulatus* in this study was distinguished based on the macroscopic and microscopic characteristics of the gonads. The stage of gonad maturity was divided into five stages, namely immature gonads, the gonad development process (developing virgin), early gonad maturity (early developing), mature gonads (maturity), and post-spawning (spent). Macroscopic characteristics of male and female fish gonads can be seen in Figure 6. Macroscopically, male and female gonads were distinguished by their color and size. Male and female gonads had different variations in color and size at each maturity phase (Stage I-V). The gonads had two lobes separated at the anterior and united at the posterior parts.

In female fish, GMS I, had transparent and slightly reddish ovaries, like fine threads, small size, and blood vessels began to form. As the gonads developed into GMS II and III, the ovaries began to take on a reddish-yellow color. The ovary enlarges and occupies almost three-quarters of the body cavity. The surface was smooth, and oocytes began

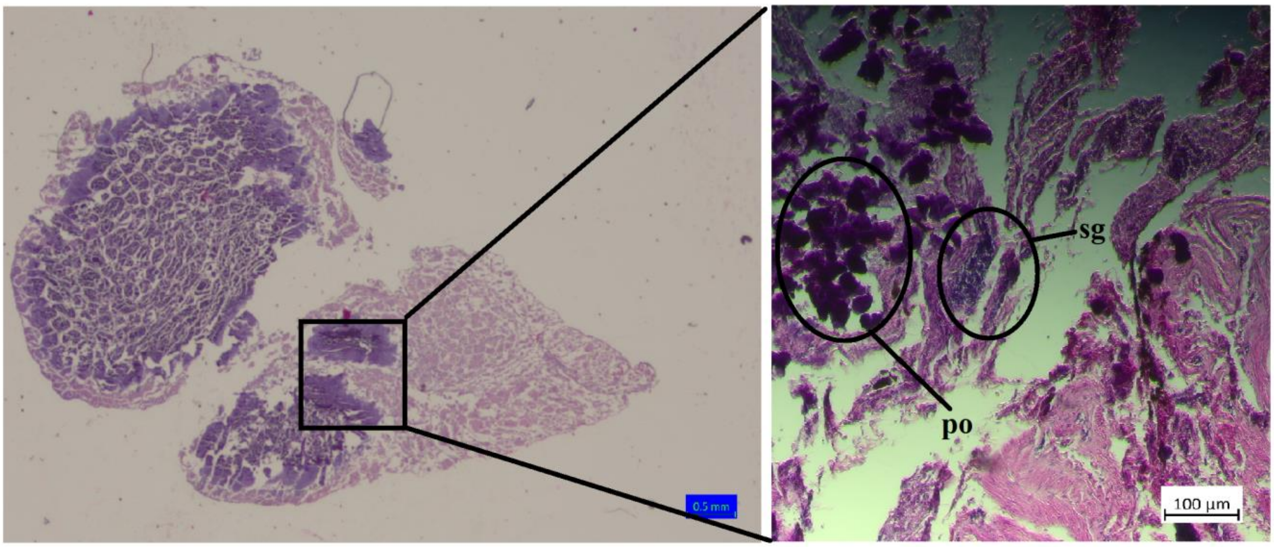

Figure 4. Extensive interstitial cell development accompanied the rapid proliferation of testicular lobules in primary male fish. Description: perinucleolar stage oocyte (po), spermatogenic cell (sg).

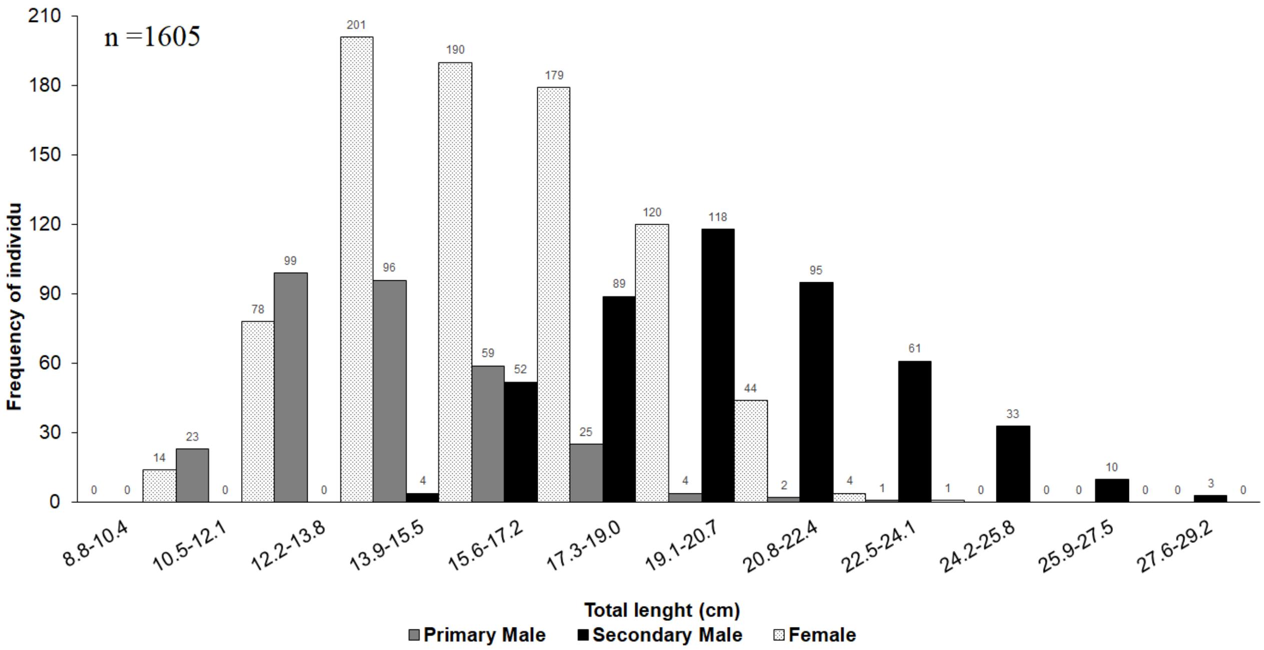

Figure 5. Frequency distribution of *S. rivulatus* by total length class interval

to show through the ovary wall and were solid but had not yet experienced egg release. In GMS IV, the ovaries filled almost the entire abdominal cavity, yellow from the enlarged oocytes, rough surface, and enlarged diameter, and blood vessels were increasingly clear on the outer surface of the ovarian wall. In this phase, egg release began. In GMS V, the size of the ovary decreased drastically, the ovary wall was soft, and the oocyte remains, were visible.

Macroscopic characteristics of gonads in male and female fish can be seen in Figure 6. GMS I have slender and threadlike testes, were transparent and colorless, and very small in size. In GMS II, the testes began to be white but more flattened and enlarged compared to the previous stage. The solid white testes became larger, flatter, and broader in GMS III. The texture occupied about three-fifths of the body cavity, and sperm ejection had not yet occurred. In GMS IV, the size of the testicles was large and dense, and blood vessels began to appear. The white testicle color was located length wise above the swim bladder and filled almost the entire abdominal cavity. In GMS V, the size of the testicle decreased dramatically, the testicular wall shrunk and weakened, and there were still remnants of sperm release. The study's result align with those macroscopic characteristics described by Sulistiono (2011) on *C. platygaster* in Ujung Pangkah Waters, Gresik, East Java and Tuwo *et al.* (2021) on *S. rivulatus* from the Seribu Islands.

Microscopic characteristics of female and male *S. rivulatus* gonads can be seen in Figure 7. Female GMS I gonads were filled with oogonium. GMS II was the chromatin nucleolar stage, and some nuclei looked concentrated in the center of the nucleus. Small-sized oocytes appeared round and oval, and inside was a large nucleus. At this stage, vitellogenesis had not occurred. In the perinucleolar stage in GMS III, the nucleolus was separated around the cytoplasm surface, and the size of the oocyte cells increased. The yolk vesicle stage showed yolk vesicles appearing in the peripheral region of the cytoplasm. This phase was also the early yolk stage, where yolk clumps began to appear and increase in number between the yolk vesicles, granulosa, and visible cell layers, the following yolk stage oocytes were large, and yolk clumps occupied the cytoplasm. The oocyte also appeared clearer and granular, the cytoplasm was thick, and the nucleus remained visible. In this phase, the cell size and the yolk granules in the cytoplasm increased.

GMS IV was where the nucleus migrated, the yolk globules and oil droplets began fusing, and the nucleus moved toward the membrane. After the germinal vesicles fused, the yolk globules formed one mass, and the oil droplets merged to form a larger one with well-formed cytoplasmic vacuoles. At this stage, the oocytes were mature and ready to be released. GMS V had many small-sized oocytes starting to develop oogonium (Og) and irregular septum, and some oocytes (Ov) remains appeared from the previous spawning.

Microscopic characteristics of male *S. rivulatus* gonads in histology were GMS I males found spermatogonia with many connective tissues, gonads began to develop into spermatocytes, and seminiferous tubule sacs began to enlarge. In GMS III, spermatocytes had developed into spermatids and began seeing the tail and spreading. GMS IV formed spermatozoa that were ready to be released.

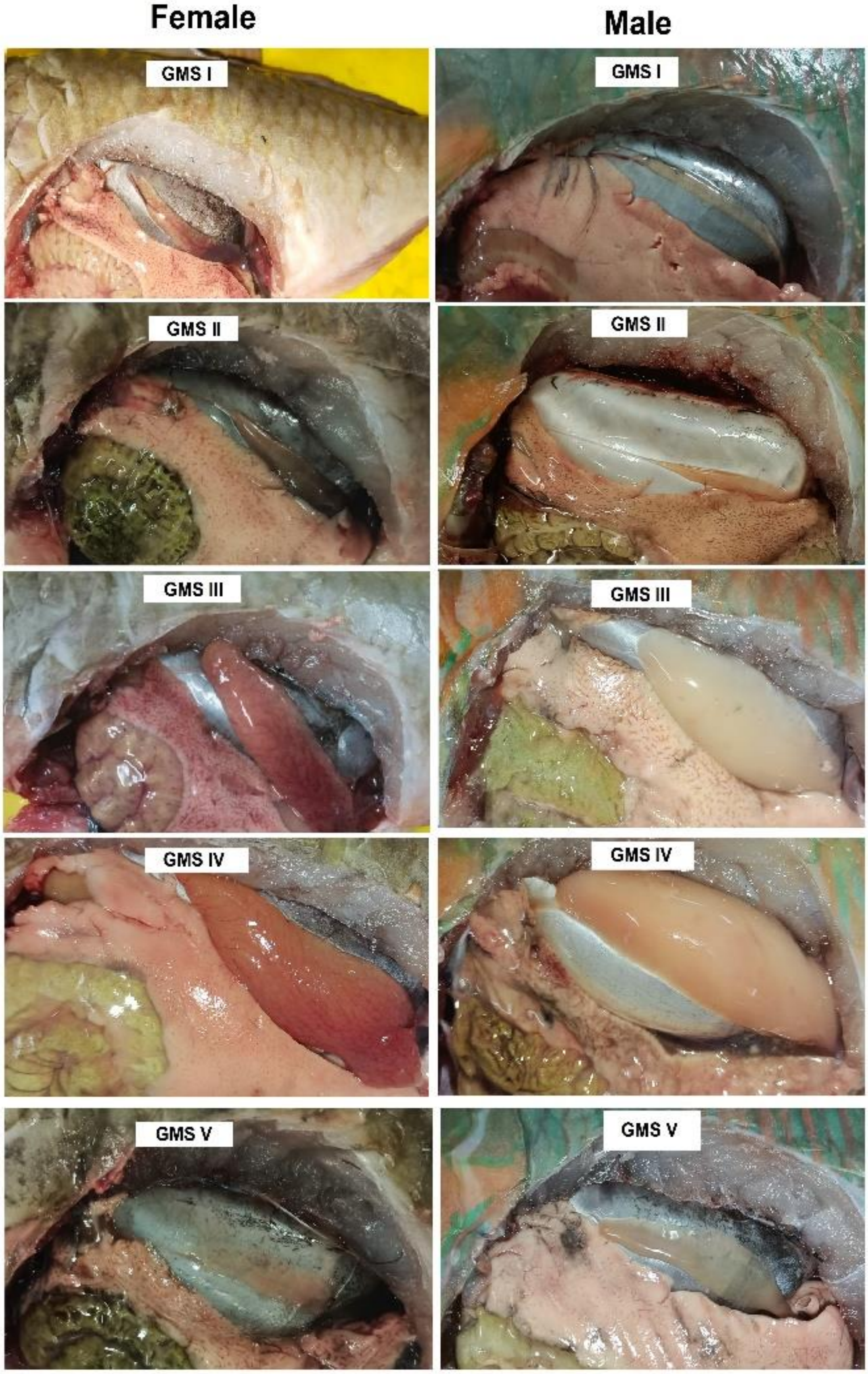

Figure 6. Macroscopic characteristics of *S. rivulatus* gonads in females and males. Description: GMS: gonadal maturity stage I – V.

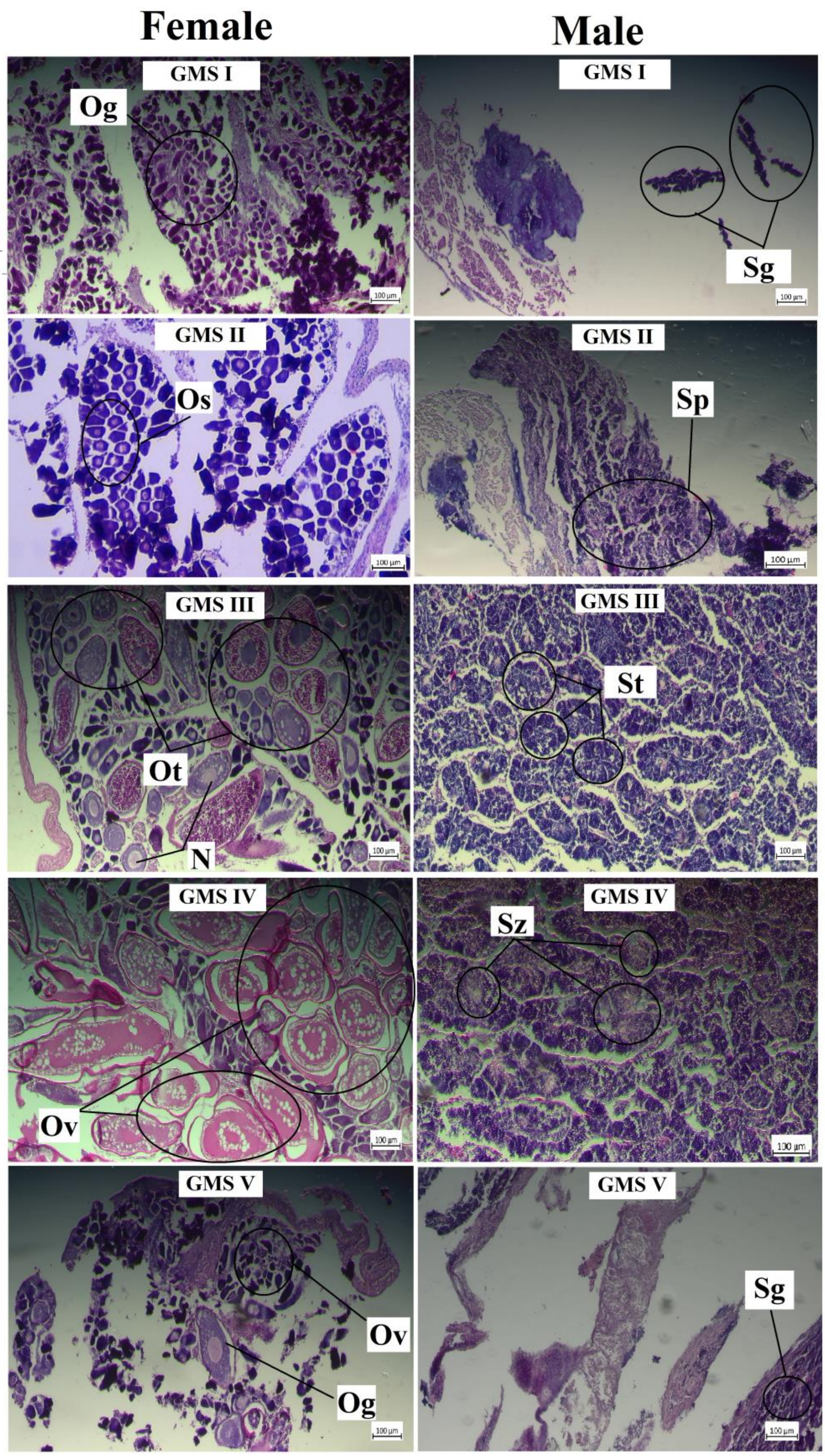

Figure 7. Characteristics of female and male *S. rivulatus* gonads. Description: N (Nucleus), Og (Oogonia), Os (Oocyte), Ot (Ootid) Ov (Ovum), Sg (Spermatogonium), Sp (Spermatocyte), St (Spermatid), and Sz (Spermatozoa).

In addition, GMS V was dominated by spermatogonium, although some spermatocytes were still present.

This study's results align with those described by Sulistiono *et al.* (2011). Histologically, the ovary in GMS I gonad was immature and dominated by oogonia, GMS II egg cells were getting bigger, and the nucleus was getting bigger, dominated by oocytes. GMS III oocytes were increasingly developing into ootids, and the nucleus appeared to be getting bigger, and the diameter was getting bigger.GMS IV, Ootids had developed into ovum, and oil granules had enlarged. In addition, the number of mature ovules decreased in GMS V, and there were mani oocytes and ootids.

The results of histological observations on the gonads of *S. rivulatus* fish also shown several levels of oocyte development. Many oogonium and primary oocytes still develop in the ovary for subsequent maturation. This condition illustrates that the type of gonad development of *S. rivulatus* fish is an asynchronous type that can spawn several times during the reproductive season. Thus, this type of fish spawning is a partial spawner that releases its eggs gradually.

According to Shao *et al.* (2003), the parrotfish genera can spawn several times, but only in certain seasons the eggs and fry have a higher chance of survival. The ovary of *S. rivulatus* is also reported as an asynchronous group type, where different stages of oocyte development can be observed in one gonad. Girolamo *et al.* (1999) revealed that *Sparisoma* sp parrotfish has asynchronous gonads that spawn multiple times. Freitas *et al. (*2018) added that *S. trispinosus* has different stages of oocyte development, indicating asynchronous oogenesis.

The distribution of GMS frequency based on the research time can be seen in Figure 8. The distribution of GMS frequency based on sex ratio shows that GM I, II, III, and IV presence is synchronous between male and female fish, with a reasonably varied percentage at each study time. This condition is suitable for the reproductive process of *S. rivulatus* (Tresnati *et al.,* 2020; Tuwo *et al.,* 2021)

During the sampling period, immature female fish gonads (GMS I and II) were found in each month of observation with varying amounts. The most female fish were found in September (GMS I) and April (GMS II), with a proportion of 21.05% and 15.22%, while the male fish were found in January (GMS I) and May (GMS II) with a proportion of 15.38% and 27.55%. GMS I and II indicated that spawning had occurred in these months. Aswady and Asriyana *(*2019) stated that a high percentage of immature GMS gonads indicated that in the previous month, spawning had occurred. A high percentage of parrotfish in the immature period indicated that population conditions experienced high recruitment.

GMS III and IV dominated each observation time for both females and males. Female fish were mainly found in March (GMS III) and July (GMS IV), with a proportion of 39.72% and 89.76%. On the other hand, male fish were mainly found in February (GMS III) and September (GMS IV), with a proportion of 46.15% and 71.01%. The average fish caught during the sampling period had GMS III and IV, indicating that *S. rivulatus* fish can spawn throughout the year with increased spawning activity in February-March and August-September. This study's results supported Freitas *et al. (*2019) research on *S. trispinosus*, which also indicated spawning throughout the year with increased activity in February-March and August-September*. S. iserti* had a reproductive season that reflected differences in light and dark cycles and food abundance (Clifton, 1984).

The assumption that *S. rivulatus* spawns throughout the year is also reinforced by the results of the research by Tuwo *et al.* (2021), who conducted a study on *S. rivulatus* in Spermonde waters showing the presence of GMS IV in each sampling period. This finding confirms the presence of gonadal mature *S. rivulatus* in every sampling period; hence, it can spawn at any time or throughout the year. Girolamo *et al. (*1999), observed the behavior and spawning activity of *S. sparisoma*, reported that spawning occurred daily in a short time and recorded the fish spawning several times. Female fish that finished spawning (GMS V) were only found in April with a proportion of 3.26%, whereas GMS V in males was found from April to September, with the highest numbers in April and July were, 12.99% and 30.53%, respectively.

The distribution of female fish gonad maturity stages based on the total length class interval can be seen in Figure 9. Fish with GMS IV was found in the class interval of 12.2 - 13.8 to 17.3 - 19.0 in both females and males. Venkataramani and Jayakumar (2006) reported that *S. russeli* fish matured at a size ranging from 25 to 27 cm.

Size at first gonad maturity

The size at first gonad maturity (FM) of fish can be seen in Figure 9. The figure shows that female fish reached the size at first gonadal maturity earlier than males. Female FM was 13.0 cm, primary

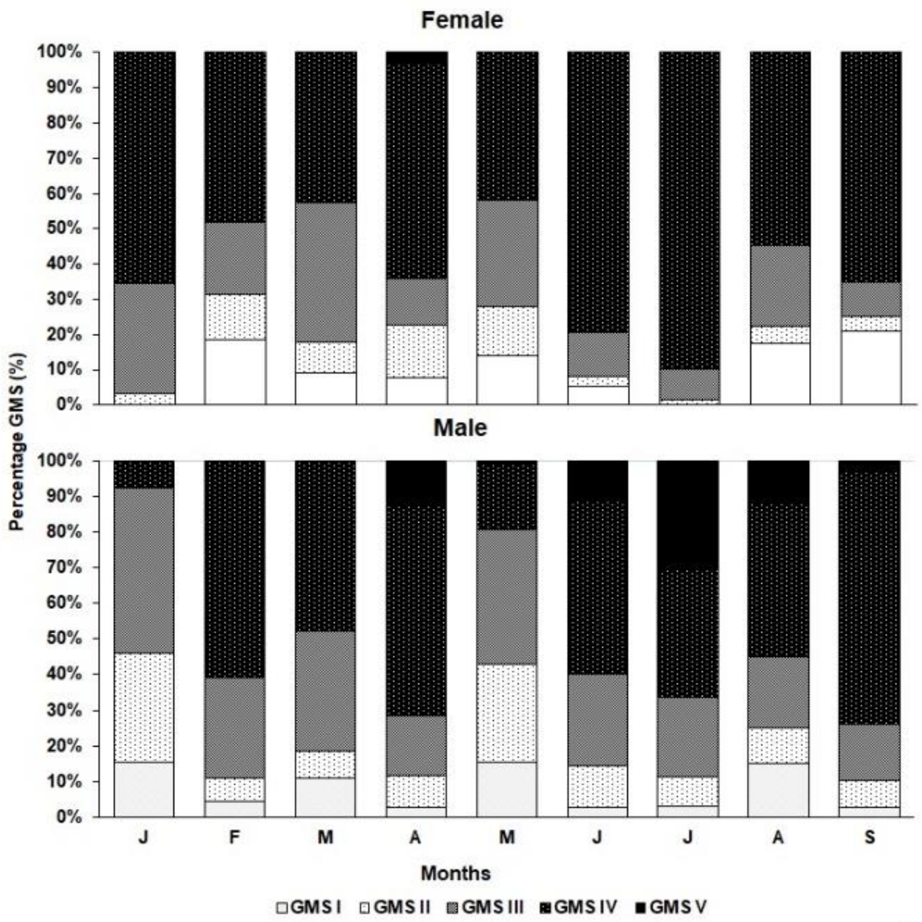

Figure 8. Distribution of gonad maturity stage of *S. rivulatus* based on time of research.

male FM was 16.6 cm, and secondary male FM was 17.6. FM indicates that an individual has reached maturity and is ready to spawn. The FM of male and female of rivulated parrotfish caught in Panggang Island was much smaller than that of female rivulated parrotfish in other waters in Indonesia. The FM of *S. rivulatus* in Tanjung Tiram waters ranged from 17.7 to 18.6 cm for males and 16.5 to 17.3 cm for females (Aswadi and Asriyana 2019). Tuwo *et al. (*2021) reported that the FM of *S. rivulatus* in the Spermonde Islands was 24.3 cm for males and 16.9 cm for females. The difference in FM values are related to the exploitation or fishing activity in a certain place.

In the parrotfish genera, females generally reach their first gonadal maturity earlier than males (Robertson and Warner*,* 1978; Tuwo *et al.,* 2021). Barba (2010) suggested that parrotfish (*S. rivulatus* Valenciennes, 1840) began to experience gonadal maturity at the age of 1.5 years with a body length of 18.5 cm in females and at the age of 3.3 years with a body length of 24.3 cm in males.

The smaller FM of *S. rivulatus* in females than in males confirms the assumption that rivulated parrotfish are protogynous hermaphrodites. The Scaridae family is protogynous, starting as a female and changing into a male fish at a certain period (Choat and Robertson, 1975). The results of previous research have also confirmed that *S. rivulatus* is a protogynous hermaphrodite that starts as a female and transforms into a male. Female *S. rivulatus* were reported to have a total length range of 12.6 to 27.0 cm, after which they transformed into males with a total length range of 24.6 to 35.0 cm (Shao *et al.,* 2003). When the size of these females was compared to the much smaller females caught in Panggang Island (90-228 mm), it can be strongly assumed that *S. rivulatus* in Panggang Island has been overexploited. The gonad size of fish at first maturity is correlated with the fish's growth and the environment's effects on growth and reproductive strategies (Nasution *et al.,* 2007). Trippel *et al. (*1997) and Tuwo *et al. (*2021) state that overfishing causes fish pressure to mature their gonads at a smaller size.

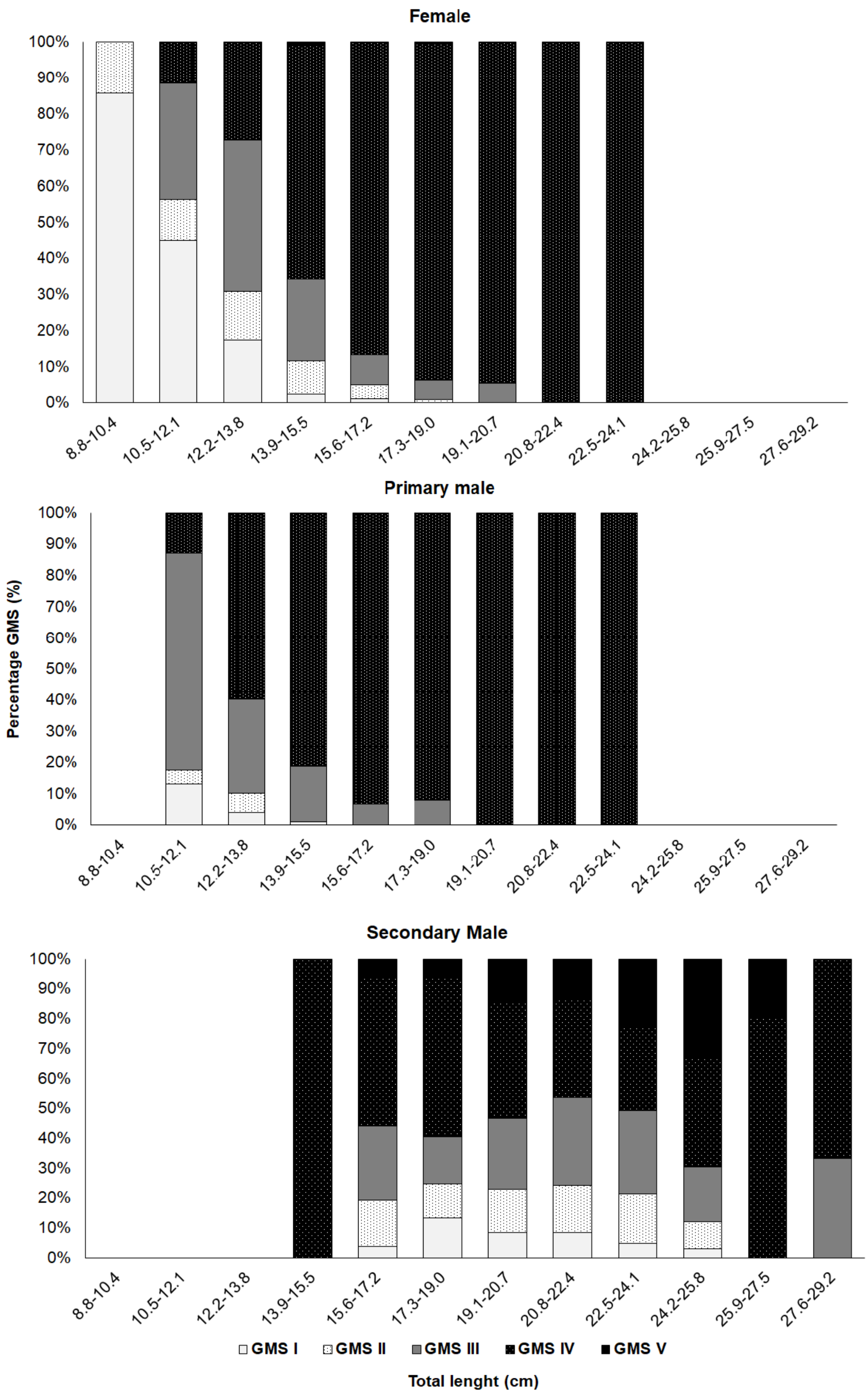

Figure 9. Distribution of gonadal maturity stage of *S. rivulatus* based on class intervals.

The duration of gonad maturity is closely related to the exploitation or capture level in a location that affects and changes female fish spawning behavior (Aswady and Asriyana 2019). Previous studies found that the parrotfish caught in Karang Congkak Waters were mostly small. The size ranged from 12.3 to 14.4 cm, and the length of adult parrotfish tended to decrease (Khalifa, 2011).

Conclusion

The morphology and gonadal tissue *S. rivulatus* can be used to characterize sex change. Morphological changes between female fish, primary males, and secondary males are generally expressed in body size, fin size, and body coloration. The results of performed gonad histology showed the presence of residual perinuclear stage oocytes that develop into spermatogenic sperm tissue. GMS III and IV dominated each observation time. Hence, it was suspected that the fish spawned throughout the year. Based on the histological analysis, the gonad development type was asynchronous which it can spawn many times in the reproductive season. The first mature gonad size of females was 13.0 cm, primary males 16.6 cm, and secondary males 17.6 cm. GMS III and IV dominated each observation time. Hence, it was suspected that the fish spawned throughout the year. Based on GMS distribution, there was an increase in reproductive activity in January - March and July - September, with peak spawning in March and September.

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