Surface gill net catch composition and growth parameters of fringescale sardine (*Sardinella fimbriata*) in Prigi waters, Trenggalek, East Java

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Abstract. The surface gill net is one of the common fishing gears operated by fishermen in Prigi waters, with fringescale sardine (*Sardinella fimbriata*) as the dominant catch. The purposes of this research were to determine the catch composition of surface gill net with 1.25 and 2 inches in mesh size, diversity and similarity indexes, and several growth parameters of fringescale sardine. The research was conducted in Prigi waters, Trenggalek, from December 2019 to April 2020, by using a quantitative descriptive method with a random sampling technique to obtain primary data. Results informed that catch of 1.25 inches mesh surface gill net consisted of fringescale sardine and Bali sardine (*S. lemuru*), 53.21% and 46.79%, respectively. The catches of 2 inches mesh surface gill net consisted of fringescale sardine (25.82%), Bali sardine (29.23%), pony fish (*Leiognathus equulus*) (18.18%), and bullet tuna (*Auxis rochei*) (26.77%). The diversity index of the mesh size of 1.25 and 2 inches was low and moderate, respectively. Other assessments indicated that the length-weight relationship of fringescale sardine was negative allometric, $W=0.087L^{2.266}$, and the sex ratio between males and females was 1:2.4. In addition, the catch was dominated by immature fish, with an average value of gonadosomatic index (GSI) of 1.15%. In conclusion, the catch composition of the surface gill net with 1.25 and 2 inches in mesh size have high similarity, but low selectivity. The fringescale sardine can reproduce more than once a year.
Key Words: allometric, diversity index, fish assessment, immature, mesh size, sex ratio.

Introduction. A surface gill net is a type of fishing gear with rectangular shape, having the same mesh size, and is equipped with floats and sinkers to draw the net perfectly in a vertical direction. Most fishermen operate surface gill nets with a uniform mesh size in the entire net, so that the surface gill net becomes a selective fishing gear ensuring the sustainability of fisheries resources (Irpan et al 2018).

Prigi waters, Trenggalek, East Java Province is part of the National Fisheries Management Areas of the Republic of Indonesia (NFMARI) number 573, located in the northern part of the Indian Ocean. Formerly, according to the decision of Marine and Fisheries Minister (KEPMEN) No. 45/2011, fisheries resource in NFMARI 573 was estimated to be at a moderate level of exploitation (Setiyawan 2016). In contrast, a more recent assessment indicated that the fisheries resource exploitation in this area was at overexploited level (KEPMEN-KP No. 50/2017). This means that biological data assessment is needed to obtain a comprehensive image for sustainable fisheries management purposes (Wijayanto et al 2021).

Fringescale sardine (*Sardinella fimbriata*) is one of the dominant catches of the surface gill net and is abundant in Prigi waters (Bintoro 2020b). Information about fishing gear effectiveness and biological assessment such as length-weight relationship, gonad maturity level (GML), and gonadosomatic index (GSI) of the resources are needed as comprehensive knowledge to manage fisheries resource sustainability. Assessment of catch composition and fish growth parameters was applied in this research to obtain information about fishing gear and the biological aspect of the fish. Thus, this research aimed to determine catch composition, diversity and similarity indexes of the surface gill net with 1.25 and 2 inches in mesh size, and to identify several growth parameters such as length-weight relationship, sex ratio, gonad maturity level (GML), and gonadosomatic

index (GSI) of fringescale sardine in Prigi waters, Trenggalek. The data and information gathered can be used to analyze the status of fisheries resources in the Prigi water, Trenggalek, East Java Province.

Material and Method. This study used a descriptive quantitative method with data from random sampling from December 2019 to April 2020. The primary data set consisted of fringescale sardine catches using a surface gill net in Prigi, Trenggalek, East Java, with the fishing ground located at 111°43'50"-111°47'38" E and 8°21'03"-8°25'16" S (Figure 1). Secondary data sources included fish identification books and research-related publications. The catch composition was analyzed for the total weight of the catch and the number of catches per species. The analysis evaluates both diversity and similarity, including the number of individuals per species, the total number of individuals, and the maximum species diversity. In addition, several growth parameters such as length-weight relationship, sex ratio, gonad maturity level (GML), and gonadosomatic index (GSI) of fringescale sardine were identified.

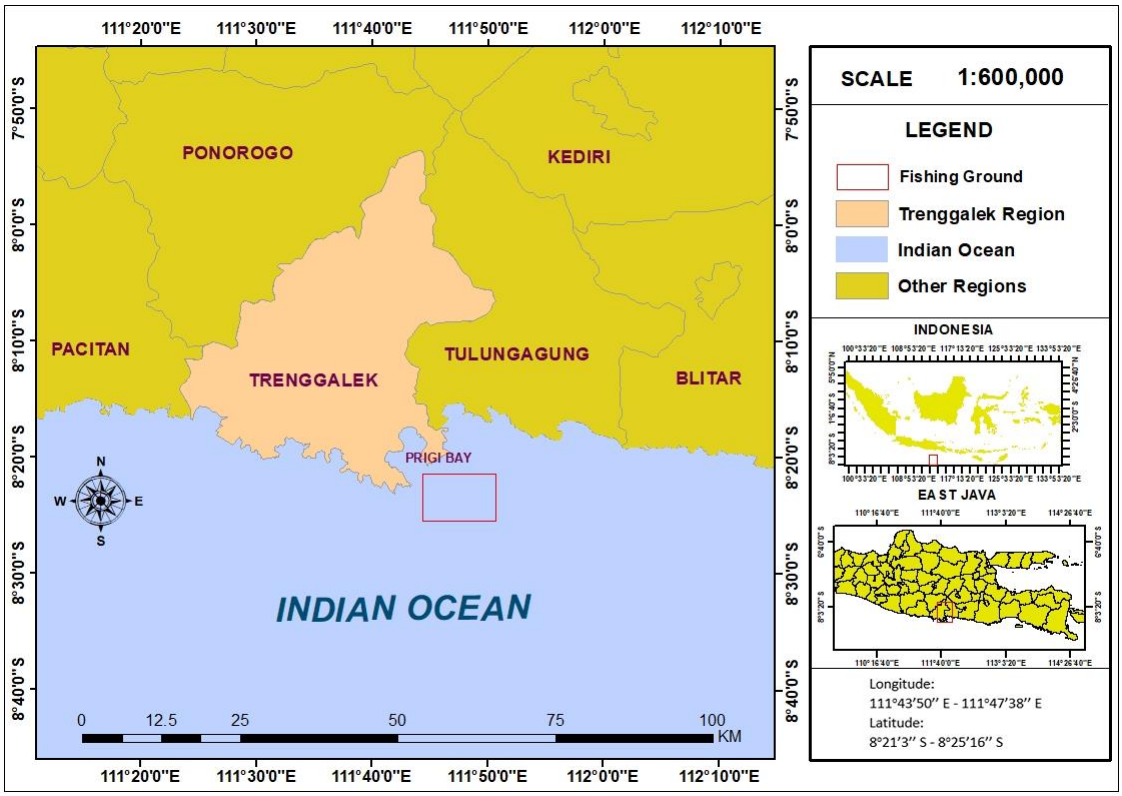

Figure 1. The study location.

Total catch composition. The total catch composition analysis is determined by the following equation (Susaniati et al 2013):

$$pi=ni/N \times 100$$

Where: pi - weight proportion of total catch (%); ni - the weight of species i (kg); N - total catch (kg).

Diversity index. The analysis of diversity was determined by the following equation (Wahyudewantoro 2009):

$$H' = \sum |Pi \; Ln \; Pi|$$
$$Pi = ni/N \times 100$$

Where: H' - diversity index; Pi - proportion of species i; ni - number of individual species i; N - total number of individuals.

Determination of criteria is as follows: H'<1 - low diversity; 1<H'<3 - moderate diversity; H'>3 - high diversity.

Similarity index. The similarity was determined by the following equation (Hoek et al 2014):

$$E=H'/Hmax$$
$$Hmax=lnS$$

Where: E - similarity index; Hmax - species diversity in maximum balance; S - the number of species.

Determination of criteria is as follows: E>0.6 - high similarity; 0.4<E<0.6 - moderate similarity; E<0.4 - low similarity.

Length-weight relationship. The length-weight relationship can be determined by using the formula below (Fuadi et al 2016; Bintoro et al 2019a, 2020a; Firdaus et al 2020):

$$LnW=Lna + b\ LnL$$

Where: W - fish weight (g); L - fish length (cm); a - intercept; b - slope.

To determine the growth pattern of fish, the t-test was applied. If the value of the t count is smaller than the t table, then b=3, and the growth pattern is isometric. In contrast, if the value of the t count is greater than the t table, then b≠3, and the growth pattern is allometric.

Sex ratio. Analysis of the sex ratio was applied by using the following equation (Effendie 1997; Bintoro et al 2020a):

$$NK=\sum J/\sum B$$

Where: NK - sex ratio; ∑J - the number of male fish; ∑B - the number of female fish. Then the comparative analysis of the sex ratio observed and sex ratio expectation can can be determined by using the chi-square test formula as follows (Wujdi et al 2015):

$$X^2 = \frac{\sum(Oi - ei)^2}{ei}$$

Where: X^2 - Chi-square value; Oi - the frequency of male/female fish observed; Ei - the expected frequency.

Gonad maturity level (GML). Analysis of gonad maturity level (GML) was applied based on the dissection of the fish. A determination of GML was based on the modified guidelines and divided into the 5 phases presented in Table 1 (Effendie 1997; Bintoro et al 2021).

Gonadosomatic index (GSI). Gonadosomatic index analysis can be determined by applying the formula below (Sulistiono et al 2007; Bintoro et al 2019b, 2021):

$$GSI=Gw/Bw \times 100$$

Where: GSI - gonadosomatic index; GW - gonad weight; BW - body weight.

Table 1

Gonad maturity level (GML) classification by morphology

GML	*Status*	*Male*	*Female*
I	Immature	The shape of the testicles is thread like, with a shorter size and visible in the body cavity; the gonads are clear in color.	Ovary is thread like, long, to the forebody cavity, the gonads are clear in color, slippery surface.
II	Developing	Larger testicle size, milk white, shape clearer than GML I.	The size of the ovaries is bigger. The color is yellowish, and the eggs are not readily visible.
III	Ripening	The surface of the testicles is serrated; the color is getting white and the testicles are getting bigger.	Ovaries start to color, and gradually the morphology of the egg is visible to the naked eye. The oil grain is getting more visible.
IV	Ripe or fully mature	Like GML III, looks more clear, the testicles are getting solid.	The ovary size increases. The color of eggs is yellow, invisible oil grain, ovaries fill 1/2-2/3 of the abdominal cavity.
V	Spent	Part of the testis (anterior, posterior) is filled.	Ovaries have a wrinkled shape, their walls thicken, remaining eggs are located in the posterior section, many eggs have a shape like in GML IV.

Results. A catch composition analysis (in weight) of the surface gill net with mesh size of 1.25 inches indicated that the catch was1742 kg, consisting of 2 species only, namely fringescale sardine (*S. fimbriata*) (53.21%) and Bali sardine (*S. lemuru*) (46.79%). In contrast, the surface gill net with a mesh size of 2 inches caught 306.3 kg, consisting of 4 species. They were Bali sardine (*S. lemuru*) (29.23%), bullet tuna (*A. rochei*) (26.77%), fringescale sardine (*S. fimbriata*) (25.82%), and pony fish (*L. equulus*) (18.18%) (Figure 2).

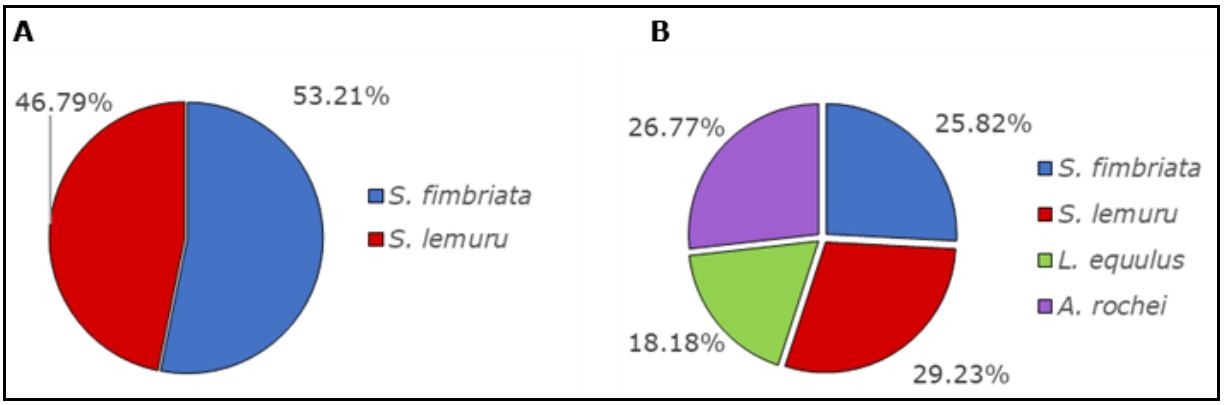

Figure 2. Composition of total catch on surface gill net with (A) 1.25 inches, and (B) 2 inches.

Diversity index (H'). The total sample (number of fish) obtained by the mesh size of 1.25 inches was 46331 fish, which consisted of 2 species only, namely fringescale sardine (25956 fish) and Bali sardine (20375 fish). The value of Pi for them was 0.56 and 0.44, respectively. On the mesh size of 2 inches, the total sample was 7114 fish, which

consisted of 4 species, namely Bali sardine (2238 fish), fringescale sardine (2215 fish), bullet tuna (2005 fish), and pony fish (656 fish). Additionally, the value of Pi of these four species was 0.315, 0.311, 0.282, and 0.92, respectively. Hence, the diversity index of mesh size 1.25 inches was 0.69. This is categorized as low diversity. While mesh size of 2 inches was classified as moderate diversity with the value of diversity index as much as 1.30 (Table 2).

Table 2

Value of catch diversity of surface gill net with a mesh size of 1.25 inches and 2 inches

Number	*Mesh size (inches)*	*Diversity*	*Category*
1	1.25	0.69	Low
2	2.00	1.30	Moderate

Similarity index (E). Analysis of the similarity index (E) illustrated that the value of the similarity of catches from the 2 mesh sizes (1.25 and 2 inches) was 0.99 and 0.94, respectively. This result informs that the catches of both surface gill nets (with a mesh size of 1.25 and 2 inches) had a high level of similarity (Table 2).

Table 1

Value of similarity of surface gill net with a mesh size of 1.25 inches and 2 inches

Number	*Mesh size (inches)*	*Similarity*	*Category*
1	1.25	0.99	High
2	2.00	0.94	High

Length-weight relationship. Analysis of the length-weight relationship was only applied on fringescale sardine as the dominant catch of the surface gill net with two different mesh sizes, 1.25 and 2 inches. The analysis was based on 1015 samples. The relationship equation was $W=0.087L^{2.266}$ with R^2 value of 0.731 (Figure 3). A t-test of b value was conducted as a complement to relationship analysis. The t-test results indicated that the t count (16.99) was higher than the t table (1.962). The b value of 2.266 was classified as negatively allometric, being lower than 3.

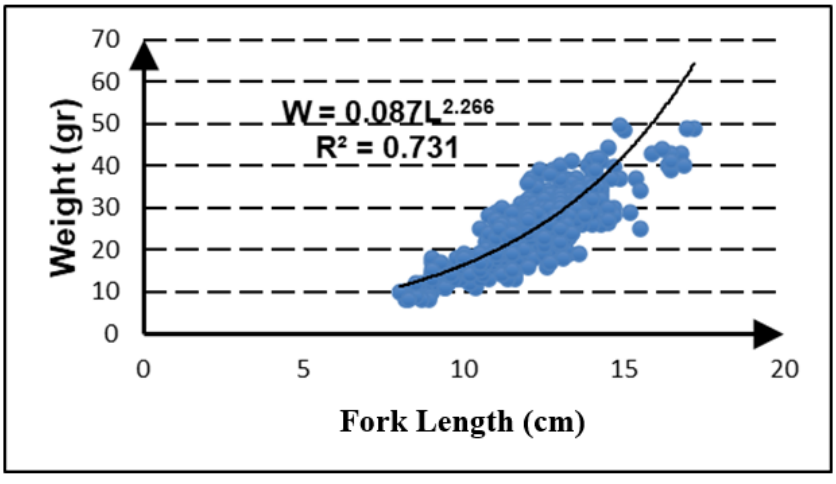

Figure 3. Length-weight relationship of fringescale sardine (*Sardinella fimbriata*).

Sex ratio. The analysis of the sex ratio on 252 fish samples illustrated that the number of males (74 samples) was much lower than that of females (178 samples), with 29% males and 71% females. According to the chi-square analysis, the comparison between males and females was 1:2.4, with a calculated X^2 value of 0.341 and X^2 table of 3.841.

The lower value of X^2 count than X^2 table means that there is no significant difference between the calculated sex ratio and expected sex ratio.

Gonad maturity level (GML) and gonadosomatic index (GSI). Most samples were dominated by immature fish (GML 1 and 2). Among the 252 fish samples, 10% (25 fish) were mature, and 90% (227 fish) were immature. Furthermore, only 4 fish were in GML 5 stage (Figure 4).

The GSI value varied from zero to 11.83%. During the three months of assessments, the average value of GSI in January, February, and March was 1.15%, 0.58%, and 0.37%, respectively (Figure 5).

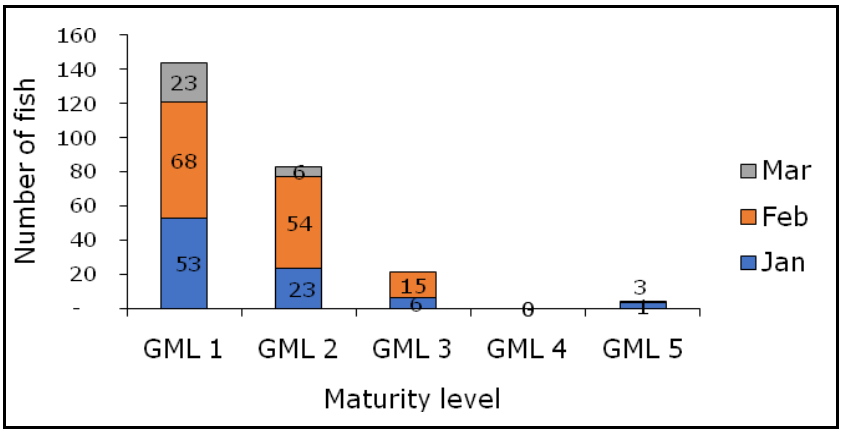

Figure 4. Gonad maturity level.

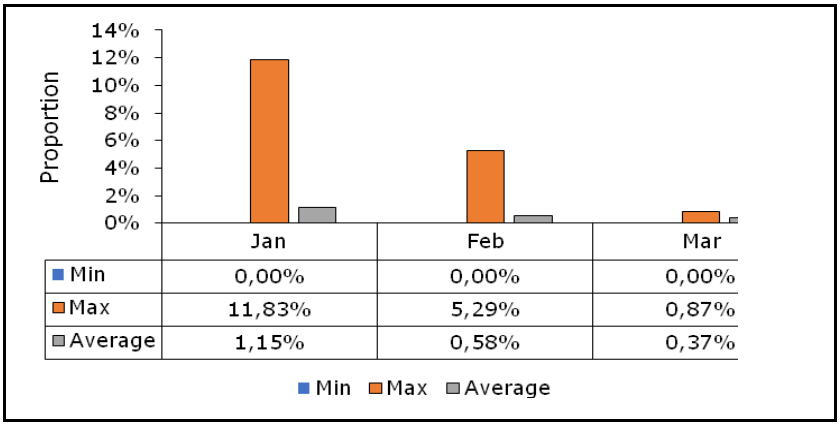

Figure 5. Gonadosomatic index (GSI).

Discussion. There were differences in catch composition between surface gill net mesh sizes of 1.25 and 2 inches. The catch of the former fishing gear only consisted of 2 species, fringescale sardine and Bali sardine. The latest fishing gear captured 4 species, namely fringescale sardine, Bali sardine, bullet tuna and pony fish. Fringescale sardine and Bali sardine are smaller than bullet tuna and pony fish in body size. The fishing gear featured a smaller mesh, to catch fish of a more manageable size. In addition, the fringescale sardine and Bali sardine were collected in great numbers in larger mesh sizes (2 inches), but they were not dominating the catch.

Pelagic fish were the primary targeted species of a surface gill net in Prigi waters. In addition to catching fringescale sardine, the fishing gears were able to catch other pelagic species like Bali sardine, pony fish, and bullet tuna. While mesh size played an important role in the diversity of the fish caught, other variables, including fishing ground and immersion duration, may have had an effect on catch diversity. Changes in the environment can potentially impact various fish food sources and alter consumer habits

when eating (Ulukyanan et al 2019). There were similarities between the two different mesh sizes of surface gill nets. The fishing period was the same (night fishing activity), and the fish were entangled in a large proportion in the head and the trunk region. Due to the use of two different mesh sizes of the surface gill net, there were two distinct undeniable conditions for the capture. Larger fish sizes are more likely to be caught by 2 inches mesh size of surface gill net, although only in a small number, while the amount of catch of 1.25 inches mesh size gill nets tended to be in a smaller, with a large number, but in a lower individual weight (Tawari 2013; Coheny et al 2018).

The diversity analysis applied in this research can be used to justify whether or not the surface gill net is a selective fishing gear. The selectivity of fishing gear can predict the pattern of fisheries resources exploited by the surface gill net. As a result, if the diversity index is high, the level of fishing gear selectivity will be considered low due to the high variety both in fish species and sizes (Wiyono 2009). The diversity index value obtained in this study for a mesh size of 1.25 inches (0.69) is considered low. This indicated that the fishing gear had a high degree of selectivity. The diversity index value of the 2 inches mesh size (1.30) indicated a moderate level of diversity, implying a low level of selectivity. As a result, the surface gill net with the mesh size of 2 inches is less selective than the 1.25 inches mesh size gill net operated in Prigi waters. The similarity index value illustrated the similarity of individual distribution of fish population. If the similarity value is higher, then the uniform distribution of fish communities is low. According to the activity of the fishing gear, a higher the similarity value show a lower level of fishing gear selectivity. Fishing gear selectivity increases with decreasing similarity values (Darmawaty et al 2019). In this study, based on the value of the similarity index, the surface gill nets with mesh sizes of 1.25 inches (0.99) and 2 inches (0.94) were classified in the high similarity category in terms of catch. In other words, these fishing gears were categorized as having a low degree of selectivity.

Length-weight relationship analysis on fringescale sardine in this research was determined to be b=2.266, classified as negatively allometric, since the value of b is lower than 3. It indicates that the fringescale sardine had a faster growth in length than in weight. This condition was in accordance with two previous studies, one in a different location (Bali Strait waters) and one in the same research site. They informed that the length-weight relationship of fringescale sardine both in Bali strait and Prigi waters was negatively allometric (Bintoro et al 2019c, 2020b). The b value obtained can be influenced by several factors such as physiological conditions, environmental factors including temperature, pH, salinity, geographic location and sampling techniques, number of fish samples, and biological factors, including fish gonad development and food availability. The R^2 value of 0.731 suggests that the length of the fish had a significant effect on the fish's body weight. The growth pattern generated by negative allometric growth can be affected by various factors, including internal factors of fish, such as sex and maturity level, and external factors, such as access to food, water quality, and seasonal changes (Tampubolon et al 2019).

The sex ratio can determine the stability of the fish population in waters. Sex ratio analysis showed that the ratio of male and female fish was 1:2.4. This ratio can be an imbalanced condition between male and female fish, where the number of females is much higher than that of males. However, this imbalance is still considered normal, because if the female fish is more dominant than the male fish, the fish may change their sex before spawning occurs (Provost et al 2016). The occurrence of an imbalanced sex ratio can be influenced by various factors, including distribution patterns, food availability, population circumstances, and the food chain balance. The imbalance in fringescale sardine populations in Prigi waters may be caused by water conditions and differences in behavior (Suryati et al 2014).

The GML analysis can identify fish spawning activity. In this study, samples were dominated by immature fish. However, some mature fish were discovered, although in a small number. Capturing immature fish must be avoided, because it will jeopardize the fisheries' resource sustainability. Appropriate environmental factors such as food availability, and suitable temperature and salinity will lead to successful fish spawning activity. Another factor affecting spawning success is seasonal variation induced by

fluctuations in the annual rainy season and different geographical locations (Sulistiono et al 2011). This research showed that the average GSI was around 0.37-1.15%. It means that fringescale sardine in Prigi waters can spawn more than once a year due to its GSI value of less than 20%. Two previous studies had similar results. They informed that fringescale sardine in Bali strait (Bintoro et al 2019c) and Prigi waters (Bintoro et al 2020b) had a GSI value of less than 20%. The GSI value can also determine gonad activity. Changes in the GSI value each month can be seen based on fish spawning time. When gonad development is ongoing, the gonads will reach their maximum size and deflate soon by themselves when spawning is completed (Sulistiono et al 2011).

Conclusions. The surface gill net in Prigi waters caught 4 species, namely fringescale sardine (*S. fimbriata*), Bali sardine (*S. lemuru*), bullet tuna (*A. rochei*), and pony fish (*L. equulus*). The gill nets with a mesh size of 1.25 inches and 2 inches had a low and moderate diversity of catch, respectively. The similarity index of both was categorized as high, but the selectivity was low. Fringescale sardine had a negatively allometric length-weight relationship and was dominated by immature fish. At the same time, the sex ratio between males and females was 1:2.4. The fringescale sardine could reproduce more than once a year. Hence, the potential future prospects of stock sustainability are bright due to the good performance of reproduction ability in one year.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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