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MORPHOREGRESSION AND FIRST SIZE AT MATURITY OF GOLDSTRIPE SARDINELLA (*Sardinella gibbosa*) FROM BALI STRAIT WATERS

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ABSTRACT

Bali Strait was one of the highest density areas for small pelagic fish in Indonesian Fisheries Management Area (FMA)-573 with goldstripe sardinella (*Sardinella gibbosa*) as was one of the abundant species in the catch. The aims of this study were to reveal the morphoregression characteristics and the first size of maturity for *Sardinella gibbosa* in Bali Strait waters. A total of 1.282 goldstripe sardinella were measured in total length (TL), fork length (FL), and standard length (SL) and weighed during the study. All of the length measurement methods were highly related to the weight, which were $W = 4 \times 10^{-6} TL^{3.1686}$ ($R^2 = 0.9817$); $W = 4 \times 10^{-6} FL^{3.2334}$ ($R^2 = 0.9732$); and $W = 1 \times 10^{-5} SL^{3.0239}$ ($R^2 = 0.9656$), respectively. Among all the measurement methods, total length estimated the weight more accurately than the others. The growth pattern of goldstripe sardinella in this study were various based on the measurement method, sex, and the maturity level of the fish. A total of 800 individuals were dissected and their gonads examined. The sex was identified by visual characteristics. The size at 50% maturity for goldstripe sardinella in Bali Strait was 148 mm TL for male and 155 mm TL for female. Most of the caught fish were under the size at 50% maturity.

Keywords: Length; weight; regression; sardine; Pengambengan

INTRODUCTION

Bali Strait is one of the fishing areas in Indonesian Fisheries Management Area (FMA)-573. This strait separates Java and Bali and is an area of high primary productivity as shown by high concentrations of chlorophyll-a (Arianto *et al*., 2014), during upwelling phenomenon in the southeast monsoon season (June to October) (Ningsih *et al*., 2013). This nutrient leads to high productivity and biomass of small pelagic fish in these waters (Hendiarti *et al*., 2005; Susanto & Marra, 2005). Bali Strait at depths of 200 to 300 m was one of the highest density areas for small pelagic fish in Indonesia Fisheries Management Area (FMA)-573 (Ma'mun *et al*., 2017). Small pelagic fish resources in Bali Strait consist of several species with lemuru or Bali sardinella, *Sardinella lemuru,* as the dominant catch (Himelda *et al*., 2011; Puspasari *et al*., 2016; Sartimbul *et al*., 2018). Another abundant *Sardinella* that contributes to fisheries in this strait is the goldstripe sardinella (*Sardinella gibbosa*) (Pertami *et al*., 2017).

Bali sardinella has been overexploited in Bali Strait waters (Wujdi *et al*., 2012a; Wujdi & Wudianto, 2015) and has been scarcer since 2016. This has led to the goldstripe sardinella, which has a similar appearance to Bali sardinella, becoming a substitute for domestic fish processing in that period. Goldstripe sardinella is economically important and is sold fresh or after being processed as canned fish (Mu'nisa & Nurham, 2010). These fish are also ecologically important, as prey to large pelagic fish (Kasim *et al.,* 2014).

Typically, fish are measured using standard length (SL), fork length (FL), and total length (TL) (Rahardjo *et al*., 2011). Fish morpho regression is a study that estimates the relationships between different length measurements to enable conversions between measurements to be made, e.g. if the tail is damaged and total length cannot be measured and comparisons to be made between studies that use different length measurements (Moutopoulos & Stergiou, 2002). The similar research had been held in freshwater (Hossain, 2010; Radkhah & Eagderi, 2015), estuarine (Ferraz & Giarrizzo, 2015; Simon & Mazlan, 2008), and marine (Kara & Bayhan, 2008; Moutopoulos & Stergiou, 2002) fish species.

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Along with the increasing utilization of goldstripe sardinella as a substitution for local consumption, little information is available for the length-length and length-weight relationships for *S. gibbosa* in Indonesian waters. The information would be useful as prerequisite for determining whether fishing activities could impact on the biological characteristics of species and is essential information for stock assessment models such as those that estimate spawning potential ratio (Prince *et al*., 2015; (Wujdi & Wudianto, 2015) and biomass level (Froese *et al*., 2011). The first size of maturity (the size at 50% maturity) is fundamental to establishment the size of fish that avoid exploitation of juvenile fish to ensure its sustainability (Vicentin *et al*., 2012). The aims of this study were to reveal the morphoregression correlation, such as length-length relationship and the length-weight relationship, and to estimate the first size of maturity for goldstripe sardinella in Bali Straits waters as essential requirement to predict the sustainability of the species in the future. This research is expected to be useful for the management of this fish in Bali Strait.

MATERIALS AND METHODS

Sample collection

Samples were monthly collected from June 2017 to April 2018 in Pengambengan, Bali, as one of the main fish landing bases around Bali Strait waters. Samples were caught by artisanal fishery using gillnet (mesh size 2 inch) and purse seine (mesh size 1 inch) operated on a one-day trip basis (Figure 1).

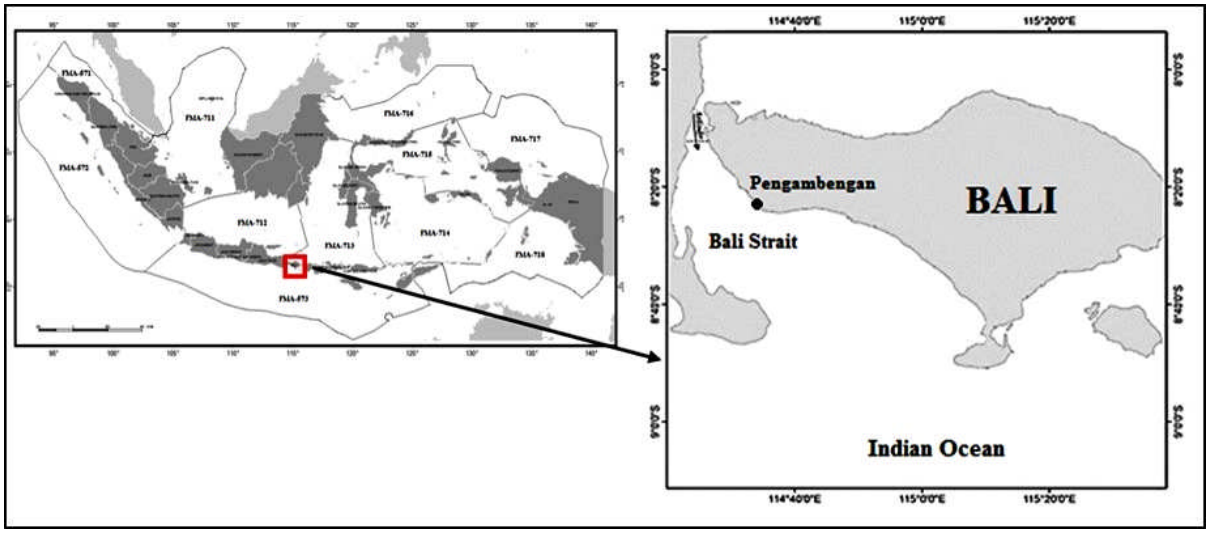

Figure 1. Location of the study area for goldstripe sardinella, *Sardinella gibbosa*, in the Bali Strait, Indonesia.

The fish was randomly sampled from the fishermen and was measured to obtain biological characteristics, including standard length (SL), fork length (FL) and total length (TL) to the nearest 1 mm, and body weight (BW) to the nearest 1 gram using a digital balance (Figure 2).

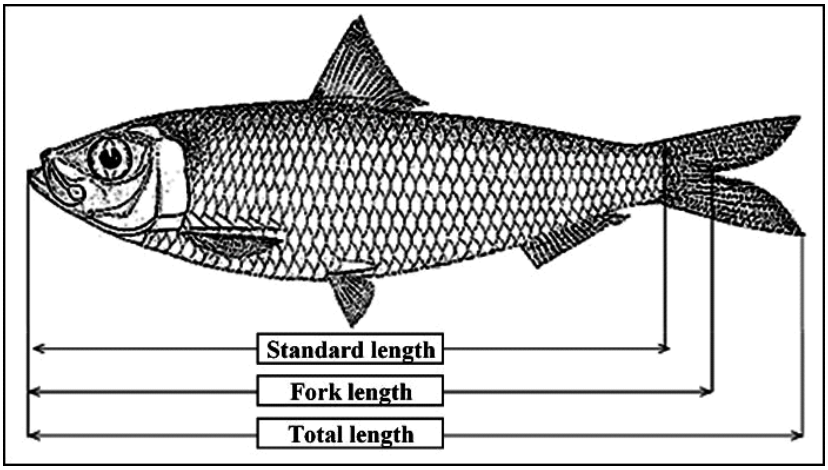

Figure 2. Three types of length measurements recorded for goldstripe sardinella, *Sardinella gibbosa*, caught in the Bali Strait, Indonesia.

A sub-sample of the measured fish were dissected to identify the sex and the maturity. Goldstripe sardinella have no secondary sexual characteristic so the sex and the maturity were determined visually based on the colour, form, and the size of the gonad (Tampubolon *et al*., 2019).

Data Analyses

The length-length relationships were calculated by comparing each type of length measurement (SL vs FL, SL vs TL, and FL vs TL) using linear regression, $y = a + bx$, where x and y are the different length measurements. The length-weight relationship was calculated using the formula $W = aL^b$ regression, where W is body weight (gram), L is body length (mm), b is the power of the relationship and a is the intercept.

To test whether the value of b from the regression equation of the length-weight relationship was significantly different from 3 or not, the Student t-test was applied. The hypothesis was used such as H_0 where the value of b is equal to 3 ($b = 3$) indicates the growth pattern is isometric and H_1 where $b \neq 3$ indicates the allometric pattern of growth. In this study, all statistical analyses were evaluated at $P < 0.05$ significance level, using Microsoft Excel.

Size at maturity is defined as the size at which 50% of the individuals in the sample size are in the mature stage. This was determined by using a logistic model by fitting the fraction of mature fish against length intervals using the nonlinear least square regression method of King (2007). In addition to the 50% of maturity, the 95% of maturity was also determined.

RESULTS AND DISCUSSION
Results

A total of 1.282 *S. gibbosa* were measured and weighed during the study. Of these, 800 individuals, consisting of 369 males, 328 females, and 103 sex unidentified fish, were dissected. The total length ranged from 70 – 208 mm; fork length from 62 – 175 mm; and standard length from 58 – 181 mm (Figure 3). The corresponding mean lengths were 136.21 ± 25.55 mm TL, 120.83 ± 22.96 mm FL, and 113.10 ± 22,93 mm SL (Figure 3).The smallest fish weighed 3.0 g, while the largest one was 83.02 g.

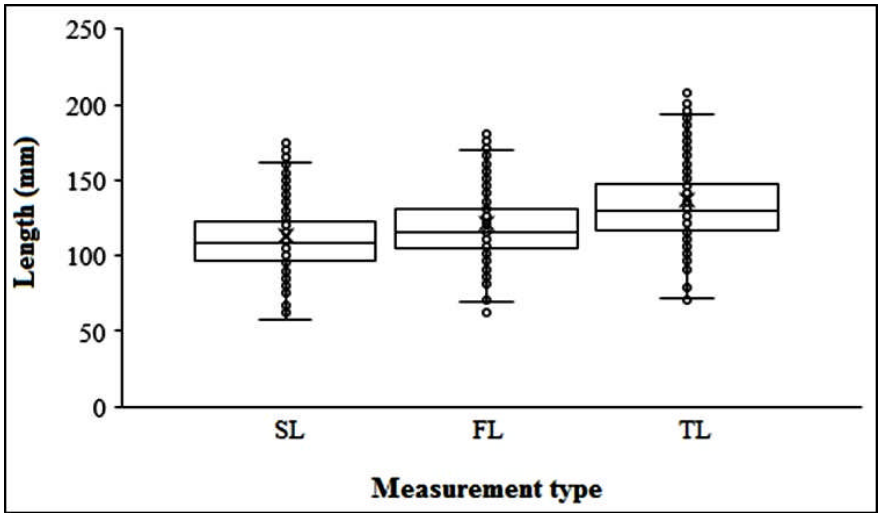

Figure 3. Box plots for the length composition of goldstripe sardinella, *Sardinella gibbosa*, collected in the Bali Strait, Indonesia between June 2017 and April 2018.

The analyses would give the length-length relationships first and then the length-weight relationships. The length-length relationship showed strong relationship between type of measurement with R^2 values > 0.98 for each relationship (Figure 4). The equations for the length-length relationship were $TL = 1.1506FL - 2.8248$, $TL = 1.1489SL + 6.2582$, and $FL = 0.9958TL + 8.2034$ (Figure 5).

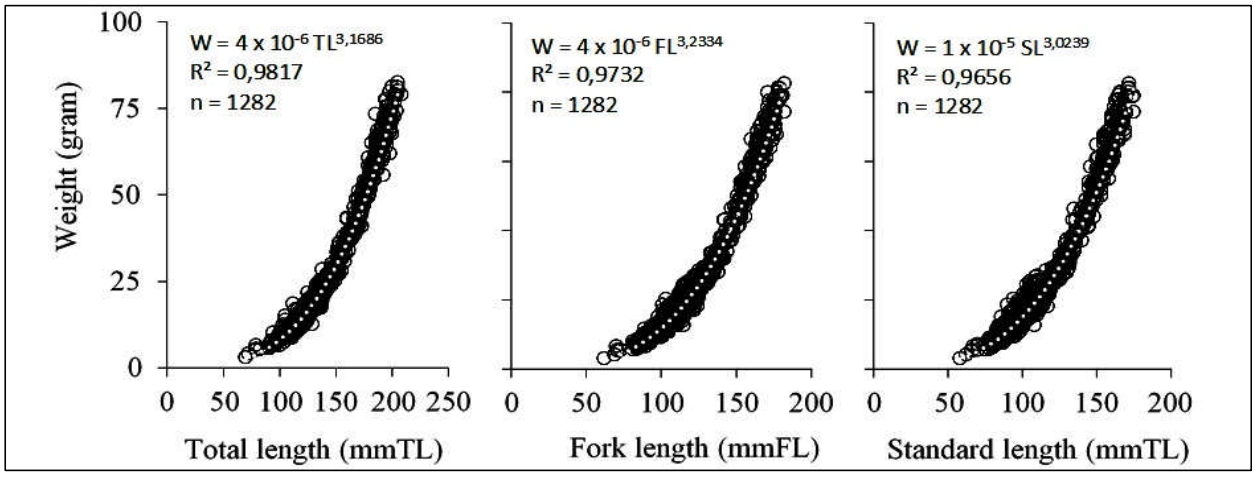

Figure 4. The length weight relationship of goldstripe sardinella, *Sardinella gibbosa*, in the Bali Strait waters of Indonesia.

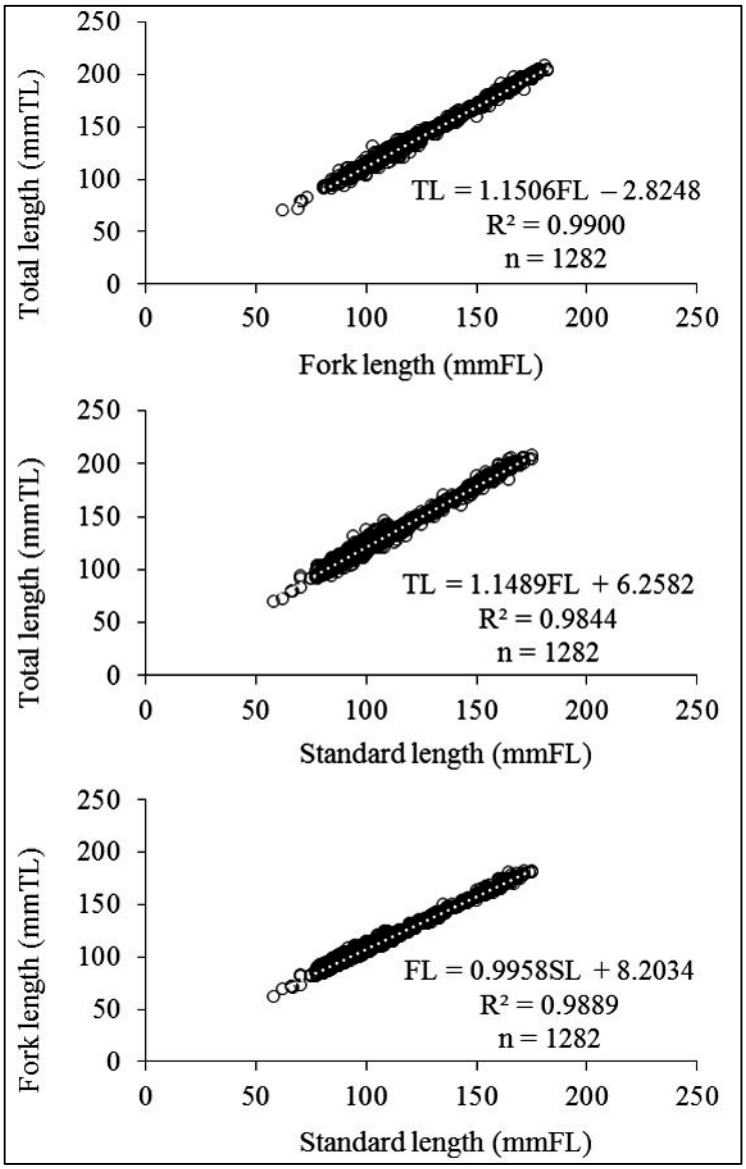

Figure 5. The length-length relationship of a) Fork length (FL) vs Total length (TL); b) Standard Length (SL) vs TL; and c) SL vs FL for goldstripe sardinella around Bali Waters.

The total length, fork length, and standard length all had a strong relationship with the weight, with R^2-values > 0.96 (Figure 4). The power coefficient ranged from 3.0 (*SL*) to 3.23 (*FL*) and are significantly different from 3 for the relationships between *TL* and *FL* and weight. The power coefficient between *SL*-weight did not significantly differ from 3 ($P > 0.05$). The growth patterns of the fish are various, depending on the maturity, sex, and the type of length (Table 1).

Table 1. Summary of the length weight relationships for the different sexes and estimated size at maturity for goldstripe Sardinella, *Sardinella gibbosa*, in the Bali Strait waters of Indonesia

Sex	Maturity	n	Length range	Average	*a*	*b*	*r*	R^2	Growth pattern
Total Length									
Male	Juvenile	175	100-164	134.47	$1.8x10^{-5}$	2.84	0.98	0.95	Allometric (-)
	Adult	194	120-200	162.23	$0.6x10^{-5}$	3.10	0.99	0.98	Allometric (+)
Female	Juvenile	172	102-170	134.34	$1.4x10^{-5}$	2.91	0.97	0.94	Isometric
	Adult	156	118-208	176.55	$0.6x10^{-5}$	3.08	0.99	0.98	Allometric (+)
Fork Length									
Male	Juvenile	175	90-147	119.25	$2.8x10^{-5}$	2.83	0.96	0.92	Allometric (-)
	Adult	194	104-175	143.06	$1.1x10^{-5}$	3.04	0.98	0.97	Isometric
Female	Juvenile	172	92-156	119.17	$2.0x10^{-5}$	2.90	0.97	0.94	Isometric
	Adult	156	103-182	155.26	$1.5x10^{-5}$	2.98	0.98	0.96	Isometric
Standard Length									
Male	Juvenile	175	85-140	111.02	$17.0x10^{-5}$	2.48	0.95	0.89	Allometric (-)
	Adult	194	95-166	139.75	$14.3x10^{-5}$	2.56	0.99	0.98	Allometric (-)
Female	Juvenile	172	85-148	113.31	$17.6x10^{-5}$	2.48	0.95	0.91	Allometric (-)
	Adult	156	94-175	150.99	$16.1x10^{-5}$	2.54	0.98	0.97	Allometric (-)

The size at maturity is the size where it has 50% probability that an adult was matured when the fish picked up randomly from the population. Based on the logistic curve, the size at maturity for goldstripe sardinella in the Bali Strait was 148 mm TL for male and 155 mm TL for female (Figure 5). The majority of measured fish (>75%) were captured below this maturity size (Figure 6). Meanwhile, the size at 95% maturity was 176 mm TL for male and 179 mm TL for female.

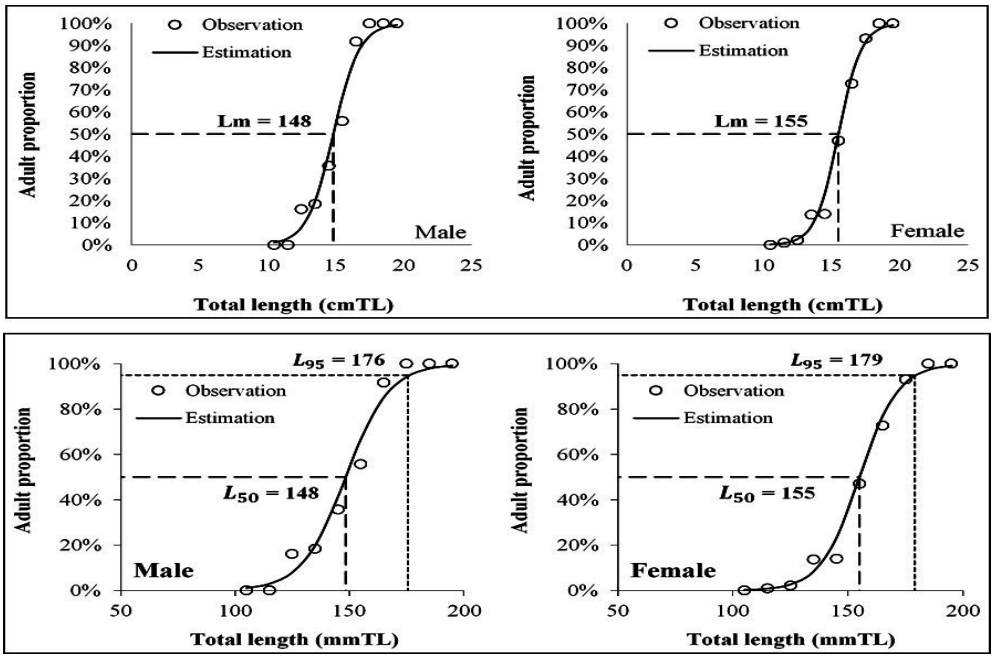

Figure 6. The relationship between the total length and the proportion of matured fish, showing the size at 50% and 95% maturity for male and female goldstripe sardinella in Bali Strait waters.

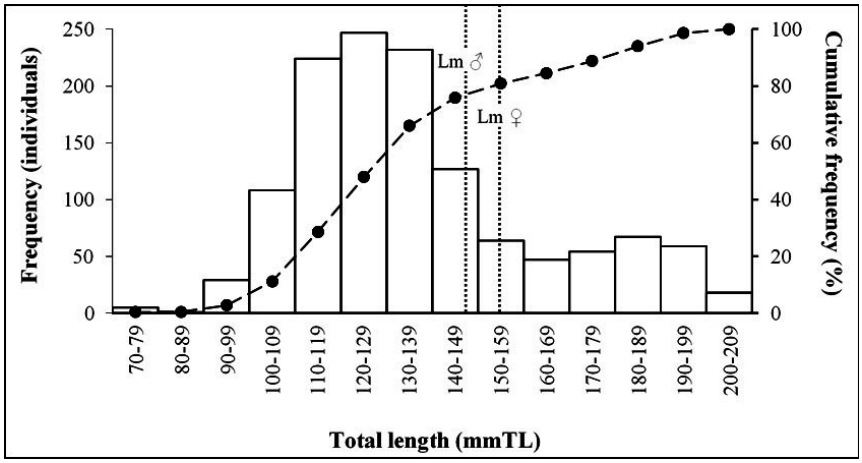

Figure 7. The total length distribution and cumulative frequency distribution of goldstripe sardinella expand. Size at 50% maturity of males and females (L_m) is also shown.

Discussion

Goldstripe sardinella, *S.gibbosa*, is one of the most captured fish in the Bali Strait (Pertami *et al*., 2017). This fish also could be found in some waters in Indonesia, such as around Bangka Belitung (Satriawan *et al*., 2017), West Java (Bukit *et al*., 2017; Ernawati & Kamal, 2010), East Java (Zakaria *et al*., 2017), South Sulawesi (Mu'nisa & Nurham, 2010), and East Lombok (Syukur *et al.* 2016).

The length of fish measured in this study covered the juvenile and adult fish, ranging in size from 70–208 mm total length (TL), which is smaller, particularly for the longer fish, than that for *S. gibbosa* in Bengal Bay Bangladesh, which were 94-296 mm TL (Mondol *et al*. 2017). The difference in size distribution is due to the size of the mesh in the fishing gear used that is related to the fishing selectivity. The mesh size of gillnet used in the Mondol's study ranged from 2.0 to 5.0 cm or larger than fishing gears used in this study (1-inch purse seine and 2-inch gillnet).

Total length, fork length, and standard length of *S. gibbosa* were highly related to the body weight. The correlation coefficients, which were formed from the length- weight relationship for all of the measurements, were almost worth one. But, based on the correlation value, the total length estimated the weight more accurately than fork length and standard length. Royce (1942), who studied the comparison of using standard length and total length for estimating weight, also reported that total length was better than standard length for predicting weight. In the absence of other more specific data, this equation could be applied for the same species within the range of the sampled fish. For this kind of study, extrapolation from bigger or smaller size than the sampled fish is not recommended (Pol *et al*., 2011).

The length-weight relationship of *S. gibbosa* in this study are various based on the measurement method, sex, and the maturity level of the fish. Nam *et al*. (2016) reported that the growth pattern of *S. gibbosa* in nearshore area of Ham Thuan Nam District, Taiwan, was reported by the sex; while Ghosh *et al.*, (2013) stated that one in the Bay of Bengal was reported by the maturity level. Beside the internal factors, the external ones like season (Elahi *et al*., 2015; Nahdi *et al*., 2016; Yilmaz *et al*., 2010), habitat and water quality (Bobori *et al*., 2010; Isa *et al*., 2010) and availability of food (Ferraz & Giarrizzo, 2015; Wujdi *et al*., 2012b) affected the length- weight relationship of fish.

The length-length relationship is important in fisheries management, especially for comparing the data among studies using different measurement types of length. For *S. gibbosa*, most of the researchers used total length (Ernawati & Kamal, 2010; Ghosh *et al*., 2013; Nam *et al*., 2016), but some used standard length (Sekharan, 1968; Thomas *et al*., 2014) and fork length (Krissunari & Hariati, 1994).

The estimated length at 50% maturity for the male *S. gibbosa* (148 mm TL) was smaller than that for females (155 mm TL), similar to the findings for this species reported by Ernawati & Kamal (2010) in the coastal waters of West Java and Krissunari & Hariati (1994) in the north waters of Rembang, with females have a larger size at 50% maturity than males in all studies. This is stipulated that the length at first maturity is influences by the sex of the fish. The length at 50% maturity is also influenced by the fishing location with different environmental conditions that can lead to variation in gonad development. The maturation process of sardine is strongly influenced

by the environment (Kripa *et al*., 2018). In the Bali Strait, *S. gibbosa* reach maturity for the first time at smaller size than those from Blanakan and Labuan and the north waters of Rembang; whereas it is bigger than from Palabuhanratu, Bay of Bengal, and Dar es Salaam coast (Table 2). The length at first maturity of *S. gibbosa* is smaller than *S. lemuru* in the Bali Strait (18.9 cmFL, Wujdi *et al*., 2013).

Table 2. Size of 50% maturity of *S. gibbosa* in various locations

No	Location	Lm_{50}	Reference
1	Dar es Salaam coast, Tanzania	105 mmSL (combined)	Okera, 1974
2	Rembang, Central Java, Indonesia	142 mmFL (male) 146 mmFL (female)	Krissunari & Hariati, 1994
3	Blanakan, West Java, Indonesia	157 mmTL (male) 165 mmTL (female)	Ernawati & Kamal, 2010
4	Labuan, West Java, Indonesia	140 mmTL (male) 142.5 mmTL (female)	Ernawati & Kamal, 2010
5	Palabuhanratu, West Java, Indonesia	153.5 mmTL (male) 163 mmTL (female)	Ernawati & Kamal, 2010
6	Bay of Bengal, India	130 mmTL (combined)	Ghosh *et al*., 2013

The first size of maturity is a capable and cost-efficient indicator of the effects of fisheries on the maturation of fish stocks (Lappalainen *et al*., 2016). Unfortunately, because the study has never been done before in the Bali Strait and adjacent waters in the past, the comparison of the length at first maturity by time could not be done, so it was with the $L_{95.}$ Ernawati & Kamal (2010) stated that the decrease of the fish's first size of maturity is a response that could be found in the waters with intense fishing activity.

The size structure of captured fish is one of the criteria for good environmental status of commercial fish (Brunel & Piet, 2013). Unfortunately, this study revealed that the exploited *S. gibbosa* from Bali Strait waters were dominated by the juvenile fish. The size of the most captured fish was under the first size of maturity. The *S. gibbosa* were harvested when they we re growing and did not reach the maturity yet. It means they never got a chance to spawn once in their lifetime. Wehye *et al.* (2017) stated that this condition will lead to growth overfishing and can possibly threaten the sustainability of the *S. gibbosa* along with the increasing fishing pressure. The amount of fish reproduction beca me lesser because the potential parent fish were captured when they were still growing. To ensure the continuity and sustainability usage of this fish, management by banning fishing and landing *S. gibbosa* below its first size of maturity is need to be considered and implemented soon.

CONCLUSIONS

Total length, fork length, and standard length of goldstripe sardinella were strongly related to body weight. Total length estimated the weight more accurately than the other length measurements. The relationship between length and weight and the estimated size at 50% maturity differed between the sexes. The size at 50% maturity for goldstripe sardinella in the Bali Strait was 148 mm TL for male and 155 mm TL for females, much longer than the mean size at capture from this study of 136.1 mm TL. These findings suggest that growth overfishing is occurring and that consideration should be given in introducing a minimum size at capture, possibly through increasing the permitted mesh sizes of gill nets and purse seines.

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