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Gonadosomatic Index (GSI) of Sardinella lemuru from Pantukan, Davao de Oro

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Abstract

This study investigates the gonadosomatic index of *Sardinella lemuru*, a commercially important species inhabiting highly productive marine environments. Despite its economic and ecological value, there is limited information on the reproductive biology of this species, particularly concerning the gonadosomatic index, which is essential for understanding reproductive cycles, population dynamics, and effective fishery management. Samples of *Sardinella lemuru* were collected across two time points, and the index was measured to evaluate temporal patterns in reproductive development. Several individuals displayed values consistent with previous estimates for fecundity, suggesting advancing reproductive maturity during the observed period. The observed increase in gonadosomatic index values between sampling points may indicate progression toward a spawning phase. Linear regression analysis revealed a statistically significant positive relationship between body weight and gonad weight, suggesting that somatic growth influences reproductive investment. These findings highlight the reproductive potential of *Sardinella lemuru* and its relevance for aquaculture and fisheries sustainability. Future research should expand the sample size and extend the observation period to improve accuracy and consider additional factors influencing reproductive traits, including fecundity.

Keywords: Body weight; gonadal development; reproductive biology; sardine species; spawning potential

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1. INTRODUCTION

The Bali sardinella, scientifically known as *Sardinella lemuru*, is a significant and valuable species in the highly productive waters located between Bali Island and Java Island, Indonesia. However, the *S. lemuru* population has experienced a collapse since 2007 and has dramatically disappeared in 2010-2011, with production never recovering to previous levels. The decline in productivity is believed to be influenced by factors such as environmental conditions, fishing efforts, and food availability, according to Syah et al. (2019) and Hunnam (2021). Recent studies have linked these population collapses to climatic phenomena like the Indian Ocean Dipole (IOD) and El Niño–Southern Oscillation (ENSO), which significantly affect fish abundance in the Bali Strait (Jatisworo et al., 2021).

In the Philippines, *Sardinella lemuru* is one of the top ten most important species commercially fished. Since the 1950s, sardines have accounted for the majority of fish caught and are a vital source of protein for millions of Filipinos. In addition to being eaten fresh, *Sardinella lemuru* also has significant commercial uses in the production of fishmeal, canning, and food that is dried for consumption. High-quality lager-sized fish are the ones utilized for canning, whereas smaller fish and larger, damaged fish are processed for fishmeal (Khoufi et al., 2024). The top three species taken in Davao de Oro's maritime municipal waters in 2022 were Bali Sardinella, Squid, and Big-eyed Scad. 52.98 metric tons of Bali Sardinella were taken, followed by 52.92 metric tons of squid and 44.51 metric tons of big-eyed scad. When compared to the 73.61 metric tons of catch from the previous year, Bali Sardinella experienced a negative growth rate of -28.0 percent (PSA, 2023).

Sardines play a crucial role in the food web, serving as a base for pelagic predators like tuna and mackerel, as well as supporting many marine mammals and sea birds (Bennemann et al., 2025). However, recent assessments have shown that sardine stocks are being overfished (Sakamoto et al., 2024). At the national level in the Philippines, sardine stocks seem to be in good health, but certain areas, particularly in the western and central Visayas, are showing signs of depletion. This is supported by data from the National Stock Assessment Program (NSAP), which shows that sardines such as *S. gibbosa, S. fimbriata*, and *S. lemuru* are being overexploited. The evidence of overexploitation is based on the fact that captured fish are smaller than the standard length at first maturity for these species (Luceño et al., 2014). Further studies have indicated that in Tayabas Bay, Quezon, the spawning potential ratio (SPR) of *S. lemuru* is approximately 24%, nearing the limit reference point, suggesting that the stock is under significant reproductive stress (Ramos & Roque, 2023).

In Indonesia, similar concerns have been raised. A study analyzing the population condition of *S. lemuru* in Awang Bay, Lombok, found that the fishery activities were less sustainable, with a high proportion of young fish dominating the catch, indicating overfishing of immature individuals (Kalih et al., 2024). Additionally, research utilizing digital image analysis for length-weight data in Kedonganan revealed a declining growth pattern in *S. lemuru*, with fishing mortality rates lower than natural mortality, suggesting that smaller-sized fish have higher survival rates, potentially due to selective fishing pressures (Pertiwi et al., 2023).

1.1. Purpose of study

This study aims to examine the gonadosomatic index (GSI) of *Sardinella lemuru* and the relationship between gonad weight and body weight. This is one of the crucial measurements in assessing the fish's commercial potential, life history, culture, and management of the fishery. Despite the fish's ecological and economic significance, only a few studies on Philippine sardines have focused on their gonadosomatic index, and even fewer have been published. The available stock information is insufficient, and the data are outdated, except for the fish catch statistics.

2. METHOD AND MATERIALS

The study was conducted in Pantukan, Davao de Oro, which is located 7° 7' 0" North, 125° 24' 0" East. A total number of 15 female *Sardinella lemuru* were bought from the fishermen from May 1 to June 1, 2023, for the determination of fecundity and GSI. The study used external physical characteristics to differentiate matured female fish, where a distended abdomen indicated maturity. The fish were cleaned with tap water, and their total length (TL) was measured using a scale with a precision of one millimeter, and their body weight (BW) was measured using an electronic balance after removing excess water with blotting paper.

The gonads were removed and weighed with an accuracy of 0.01 g. The gonadosomatic index (GSI% %) was calculated by dividing the weight of the gonads by the total weight of the fish and then multiplying by 100. The ovaries were preserved in 5% formalin for fecundity enumeration. Regression coefficients were calculated using the JASP application to establish the relationships between gonad weight (GW) and body weight (BW) were established (Akter et al., 2012).

3. RESULTS

3.1. Gonadosomatic index

The gonadosomatic index (GSI) is a commonly used metric in fish biology to assess the reproductive status and maturation of individuals. It provides valuable insights into the timing and intensity of the reproductive cycle. This study examined the GSI of *Sardinella lemuru,* a commercially important fish species, comparing the average GSI values observed in May and June. Figure 1 shows (a) the measurement of length, (b) the lateral view of Sardinella lemuru, and (c) the gonad.

Figure 1

(a) measuring the length (b) lateral view of Sardinella lemuru; (c) gonad

(a) (b) (c)

Table 1 shows the body weight, total length, gonad weight, and gonadosomatic index of *Sardinella lemuru* for May 2023. There were 15 female samples obtained commercially from Pantukan, Davao de Oro. It revealed that fish samples had an average body weight of 43.2 g, ranging from 38 g to 50 g. It also had an average length of 168 mm with an individual body length of around 150 – 180 mm. In terms of their gonad weight, it had an average of 1.5 g.

Table 1

Gonadosomatic Index of Sardinella lemuru last May 2023

Samples	Body Weight (g)	Total Length (mm)	Gonad Weight (g)	GSI (%)
1	40	175	1.0	2.500
2	43	170	2.0	4.651
3	41	165	1.0	2.439
4	48	180	3.0	6.250
5	38	160	0.5	1.316
6	43	150	0.2	0.465
7	46	175	2.0	4.348
8	40	160	1.0	2.500
9	43	180	1.0	2.326
10	50	180	3.0	6.000
11	46	165	2.0	4.348
12	43	170	2.0	4.651
13	40	160	1.0	2.500
14	39	155	0.5	1.282
15	48	175	2.0	4.167
Average	**43.2**	**168**	**1.5**	**3.316**

The gonadosomatic index of the fish samples was 3.316%. It can be noticed that the highest GSI was 6.250% while the lowest was 0.465%. A total of 7 individuals can be considered to belong under fecundity estimates as it reached the 4% index according to Joson-Pagulayan et al., (2019).

For June 2023, the body weight, total length, gonad weight, and gonadosomatic index of *Sardinella lemuru* are shown in Table 2. A total of 15 female samples were obtained commercially from the same location. It was discovered that fish samples ranged in body weight from 36 g to 68 g, with an average of 49.1 g. Its body lengths ranged from 155 to 200 mm, and its average length was 173 mm. It had an average weight of 1.7 g for its gonads.

Table 2

Gonadosomatic Index of Sardinella lemuru last June 2023

Samples	Body Weight (g)	Total Length (mm)	Gonad Weight (g)	GSI (%)
1	45	180	2.0	4.444
2	44	165	0.7	1.591
3	50	170	3.0	6.000
4	55	180	4.0	7.273
5	46	170	3.0	6.522
6	43	165	0.2	0.465
7	46	170	0.1	0.217
8	68	200	2.0	2.941
9	66	190	3.0	4.545
10	52	180	0.6	1.154
11	49	175	2.0	4.082
12	48	170	2.0	4.167
13	40	155	0.5	1.25
14	36	155	2.0	5.556
15	48	175	0.6	1.250
Average	**49.067**	**173.333**	**1.7**	**3.430**

The fish samples had a gonadosomatic index of 3.430%. The maximum GSI was 7.273%, and the lowest was 0.217%, as can be shown. About the publication of Joson-Pagulayan et al. (2019), 8 fishes from the sample can be categorized as belonging under fecundity estimations because they surpassed the 4% index.

Table 3 presents the average GSI of *Sardinella lemuru* that was found to be 3.316 in May and 3.430 in June. This slight increase in the GSI between the two months suggests a potential progression in the reproductive activity of the fish species. Typically, an increase in GSI indicates the accumulation of reproductive tissues, such as gonads, as the fish prepare for spawning.

Table 3

Average GSI from May to June 2023

Month	GSI (%)
May	3.316
June	3.430
Average	**3.373**

The observed an increase in the average GSI from May to June may indicate that *Sardinella lemuru* experiences an advancing reproductive phase during this period. The rise in GSI suggests that the fish are undergoing gonadal development and maturation, potentially leading to an upcoming spawning event. Although GSI cannot offer information on successful spawning (e.g., mature eggs ejected), it can identify periods when the majority of fish contained mature ovaries (Brewer et al., 2008).

Several factors could contribute to the increase in GSI between May and June. Environmental cues such as water temperature, photoperiod, and food availability can influence the reproductive cycle of fish. These

factors may trigger hormonal changes and stimulate gonadal development in *Sardinella lemuru*, leading to an increase in GSI. This concurs with the findings of Echem (2016) that it can be related to several environmental effects, such as temperature, water velocity, amount and type of food consumed, or feeding method.

However, it is important to consider that individual variation, sampling bias, and other external factors can also affect GSI values. Additionally, GSI values can vary depending on the age, size, and overall health of the fish population. Therefore, it is crucial to interpret the GSI values in conjunction with other reproductive parameters and biological information to obtain a comprehensive understanding of the reproductive patterns of *Sardinella lemuru*.

Further studies, including histological examination of the gonads, hormonal analysis, and monitoring of reproductive behaviors, would be beneficial in confirming the reproductive phase and providing a more detailed understanding of the reproductive dynamics of *Sardinella lemuru* during the specific months of interest.

Overall, the observed increase in the average GSI from May to June suggests a potential progression in the reproductive activity of *Sardinella lemuru*. These findings contribute to our understanding of the species' reproductive biology and can have implications for fisheries management, conservation efforts, and the sustainable exploitation of this commercially important fish species. Conversely, a study conducted by Ginanjar (2006) showed that the spawning season of the fish is from September to October, which relates to the progression of its reproductive activity.

3.2. Relationship of gonad weight and body weight

Based on the linear regression analysis conducted using JASP it investigated the relationship between the gonad weight and the body weight of the *Sardinella lemuru.* The model summary in Table 4 reveals that the regression model explains a substantial amount of the variance in gonad weight, as indicated by the R-squared value of 0.729 (72.9%). This suggests that approximately 72.9% of the variability in gonad weight can be accounted for by changes in body weight.

Table 4

Linear Regression of Gonad Weight and Body Weight : Model Summary - Gonad Weight

Model	R	R^2	Adjusted R^2	RMSE
1	0.854	0.729	0.710	1.117

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Specifically, the coefficient for the independent variable (body weight) in Table 5 is estimated to be 0.036. This positive coefficient suggests a direct and positive relationship between body weight and gonad weight. For every one-unit increase in body weight, we can expect, on average, a 0.036-unit increase in gonad weight, assuming all other variables remain constant.

The coefficient is statistically significant, as evidenced by the t-value of 6.139. This implies strong evidence against the null hypothesis of no effect, indicating that the relationship between body weight and gonad weight is unlikely to be due to chance. Furthermore, the coefficient's standard error of 0.006 indicates the level of uncertainty associated with the coefficient estimate.

The 95% confidence interval for the coefficient ranges from 0.023 to 0.048. This means that we can be 95% confident that the true population coefficient lies within this interval. The narrow width of the confidence interval suggests a relatively precise estimate of the effect of body weight on gonad weight. The results of the study by Mahboob and Sheri (2002), which demonstrated the influence of gonadal growth on body weight or vice versa and the positive significance of the link between gonad weight and body weight in several fish species, can be credited for this.

Table 5

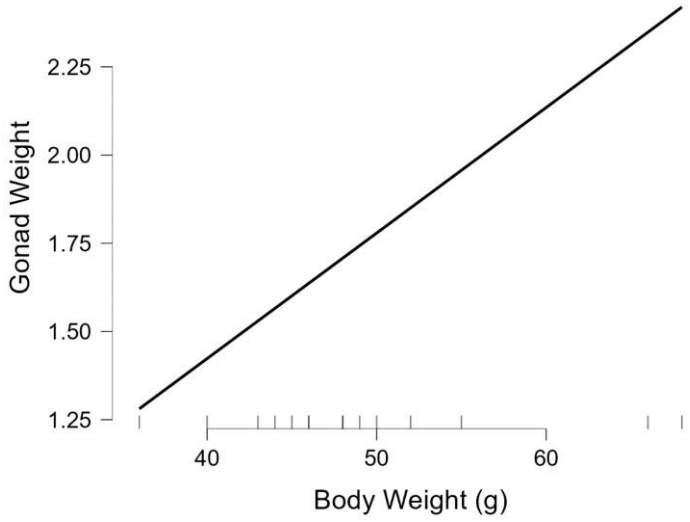
Coefficients of body weight

Model		Unstandardized	Standard Error	Standardized	t	p	95% CI Lower	95% CI Upper
1	H Body Weight (g)	0.036	0.006	0.254	6.139	< .001	0.023	0.048

In conclusion, the linear regression analysis using JASP reveals a statistically significant and positive relationship between body weight and gonad weight. This is congruent with the findings of Akter et al. (2012). In Figure 2, as body weight increases, there is a corresponding increase in gonad weight. Approximately 72.9% of the variability in gonad weight can be explained by variations in body weight. However, it's important to note that this analysis is limited to the variables included in the model, and there may be other factors influencing gonad weight that were not considered.

Figure 2

The marginal effect of Body Weight (g) on Gonad Weight



4. DISCUSSION

The results of the study indicate a slight but notable increase in the gonadosomatic index (GSI) of Sardinella lemuru from May (3.316%) to June (3.430%), suggesting that the reproductive cycle of the species may be advancing as it moves toward a potential spawning period. A higher number of individuals in June (8 out of 15) exceeded the 4% GSI threshold for fecundity estimates compared to May (7 out of 15), indicating a growing proportion of reproductively mature individuals. This finding is consistent with the reproductive pattern described by Joson-Pagulayan et al. (2019), where a GSI value above 4% suggests active reproductive development. Although the overall increase was modest, it may reflect biological progression driven by environmental factors.

Environmental conditions such as increasing water temperature, extended photoperiod, and improved food availability during the transition from May to June may have played a crucial role in stimulating gonadal development. This is in agreement with Echem (2016), who highlighted the role of ecological factors in triggering hormonal responses that regulate fish reproduction. However, some individual samples still had low GSI values despite being collected in June, which could be due to individual physiological variability, age differences, or health status. Moreover, a few samples in both months presented very low GSI values (<1%),

which might be indicative of immature or post-spawning individuals, underscoring the variability in reproductive timing among the population.

Furthermore, the strong and statistically significant positive correlation between body weight and gonad weight (R^2 = 0.729) suggests that larger individuals tend to allocate more energy to reproductive tissue development. This is congruent with findings by Mahboob and Sheri (2002) and Akter et al. (2012), who also reported a significant relationship between these parameters in fish. The regression coefficient of 0.036 indicates that for every gram increase in body weight, gonad weight increases by approximately 0.036 g. This relationship supports the use of body size as a predictive measure for reproductive investment in Sardinella lemuru, although further analysis involving age and histological gonad development would strengthen this interpretation.

5. CONCLUSION

In summary, the study provides valuable insights into the reproductive biology of Sardinella lemuru, revealing a gradual increase in GSI from May to June, which likely reflects advancing gonadal maturation in preparation for spawning. The findings also highlight the utility of GSI as a practical, non-invasive tool to assess reproductive readiness in fish populations, particularly when used in combination with metrics like body weight and gonad weight. The increase in GSI suggests that environmental conditions in June may be more favorable for reproductive activity than in May.

Moreover, the significant positive relationship between body weight and gonad weight implies that larger individuals have a higher reproductive potential, which is vital information for fishery management. These findings can help inform sustainable harvesting strategies by indicating optimal periods for fishing restrictions to protect spawning individuals. Future studies involving histological analyses, reproductive hormone profiling, and longer-term monitoring would enhance our understanding of the species' spawning cycles and improve conservation and management practices for this economically important fish.

The following recommendations and suggestions emerged from the findings of this study. First, the research established significant baseline data concerning the gonadosomatic index of Sardinella lemuru in Pantukan, Davao de Oro. However, extending the study duration to a period of six to twelve months is recommended to capture more pronounced variations, particularly in fecundity estimation. Second, increasing the sample size is advised to enhance the statistical reliability and robustness of the results. Lastly, to achieve a more comprehensive understanding of oocyte development and spawning characteristics, histological examination of the gonadal tissues is recommended.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

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