Plankton's abundance and its implications for *Sardinella lemuru* catch in Prigi waters

Aida Sartimbul¹,², Egha Trishnayana¹, Erfan Rohadi³, Nurul Muslihah⁴, Oktiyas M Lutfi¹, Feni Iranawati¹,², Ledhyane Ika Harlyan¹,², Erawati Wulandari⁵, and AB Sambah¹,²

¹Faculty of Fisheries and Marine Science, Brawijaya University, Malang 65145, East Java, Indonesia  
²Marine Resources Exploration and Management (MEXMA) Research Group, Brawijaya University, Malang 65145, East Java, Indonesia  
³Information Technology, State Polytechnic of Malang, Malang 65141, East Java, Indonesia  
⁴Department of Nutrition Science, Faculty of Medicine, Brawijaya University, Malang 65145, East Java, Indonesia  
⁵Prigi Fishing Port, Jalan Raya Prigi, Watulimo, Prigi, Trenggalek 66382, East Java, Indonesia

Email: aida@ub.ac.id

Abstract. *Sardinella lemuru* is well known as a dominant fish in Bali Strait. However, since 2010 the stocks have collapsed. Surprisingly, at the end of 2019 it was caught very abundantly in Prigi waters, Trenggalek, reaching 56.42% of the production by volume and 39.44% in value. The reason for this abundance is thought to be the abundant availability of food in nature. This study aimed to analyse the abundance of plankton in relation to the abundance of *S. lemuru* in Prigi waters at the end of November 2019. A total of 100 *S. lemuru* samples were caught using a purse seiner, while marine plankton were collected using a 20µm plankton net with a vertical method at 5 sampling sites in *S. lemuru* fishing grounds in Prigi waters. The morphology, morphometric and meristic characters of the *S. lemuru* specimens were analysed, as well as the gut contents. Plankton samples collected from the sea and *S. lemuru* guts were identified and their abundance analysed. The *S. lemuru* samples had a mean total length (TL) of 16.47 ± 0.19 cm. The plankton from the seawater consists of 52.8% zooplankton and 47.2% phytoplankton, consisting of 21 genera of phytoplankton and 12 genera of zooplankton. Actinocyclus dominated the phytoplankton group with an abundance of 14,098 ind/m³, while the zooplankton group was dominated by Acartia with an abundance of 15,592 ind/m³. Correlation analysis shows the value of the correlation coefficient between phytoplankton in the waters and the *S. lemuru* was r = 0.920 with a determination coefficient of 84.9%. The abundance of *S. lemuru* in November 2019 was due to the abundant availability of food in the fishing area when phytoplankton is the main food choice for *S. lemuru*.

1. Introduction

*Sardinella lemuru* is a dominant fish and is the main source of livelihood for Bali Strait fishermen. *S. lemuru* contains Omega-3 which is good for increasing the development of height and weight of children.
during the growth process [1]. This content increases the potential economic value of the S. lemuru commodity for local fishermen and the raw fisheries industry.

Apart from the waters of the Bali Strait, S. lemuru fish are also found in several waters in Indonesia, one of which is Prigi waters. However, the number of S. lemuru fish catches obtained in Prigi waters tends to be very small compared to the Bali Strait. Based on data from the Prigi Fishing Port, the catch of S. lemuru Fish in 2018 was only 110 tons or <1% of the total production volume. However, at the end of 2019, S. lemuru was abundantly caught in Prigi waters. Based on data from Prigi Fishing Port in 2019, the catch of S. lemuru is very dominant, reaching 56.24% of the total production volume with a production value of 39.44% [2] (Figure 1.).

![Figure 1](image1.jpg)

**Figure 1.** Abundant *Sardinella lemuru* were landed at Prigi Fishing Port, Trenggalek, Indonesia on 28 October 2019. (Source: Prigi Fishing Port/PPN Prigi).

The abundance of *S. lemuru* population can be caused by several factors, but the two most influencing factors are food availability and feeding behavior [3]. Food abundance tends to be followed by an increase in *S. lemuru* growth, with an effect of ± 50% [4]. *S. lemuru* is a filter feeder fish that feeds on phytoplankton and zooplankton, especially copepods (zooplankton) [5]. In the digestive tract of *S. lemuru*, 43% of phytoplankton were found and 27% copepods were found [6]. Different results show that the zooplankton found to dominate the stomach of *S. lemuru* ranged from 90.52 - 95.45% and the percentage of phytoplankton only ranged from 4.46-9.48% [7]. The difference in the dominance of plankton found in the stomach of *S. lemuru* makes this research important to do.

This study aims to analyse the relationship between plankton abundance and the catch of *S. lemuru* in Prigi waters, so that it can provide an overview of plankton abundance and its effect on *S. lemuru* abundance in Prigi waters at the end of 2019 and provide information regarding *S. lemuru* fishing grounds in Prigi waters.

2. Methods
This research was conducted on 4-8 November 2019 in the *S. lemuru* fishing ground in Prigi waters, Trenggalek, East Java (Figure 2). The samples of *S. lemuru* were captured using purse seiner. Then plankton sampling in the waters is carried out simultaneously with *S. lemuru* fish collection. The vertical
method was collected using plankton net with a mesh size of 20 µm. Plankton samples were filtered vertically from 10 meters depth. The filtered water was put into the sample bottle and fixed with 1% lugol solution. Inverted microscope was applied for plankton cell enumeration and species identification under 200 or 400 magnification.

![Figure 2. Sampling location with five sampling sites is in accordance with the data collection day in Prigi waters: Red (Sampling 1); Gray (Sampling 2); Green (Sampling 3); Pink (Sampling 4); and Blue (Sampling 5).](image)

The samples of *S. lemuru* were measured for their morphometric and meristic characteristics and compared with the results in previous studies [9]. The results of these calculations were categorized into groups of *S. lemuru* sizes, namely (1) *Sempenti* (<11 cm); (2) *Protolan* (11-15 cm); (3) *Lemuru* (15-18 cm); and (4) *Lemuru Kucing* (> 18 cm) [6]. The fish that have been measured are then gastrointestinal tract from the upper oesophagus to the anus was removed by dissection to extract their stomach content and immediately preserved using alcohol with a concentration of 96%. The gastrointestinal tract is taken to the Fisheries and Marine Resources Exploration Laboratory to be analysed the food contained.

Plankton observations were carried out by the sweeping method over the Sedgewick Rafter Counting Cell. Observation of plankton in the stomach of the fish is carried out by removing the stomach contents and then diluting it with distilled water. Then the analysis of plankton in the waters is carried out by calculating the abundance of plankton species in the waters with individual units per litre. The abundance of plankton species is calculated based on the APHA method (1989) [8]:

$$N = \frac{n \times O_i \times V_r \times 1}{p \times O_p \times V_o \times V_s}$$

Where:

- $N$ = Plankton abundance (ind./m³)
- $n$ = The number of plankton in the entire field of view
- $p$ = The number of fields of view observed
- $O_i$ = Area Sedgewick Rafter Counting Cell (mm²)
- $O_p$ = Area of field of view (mm²)
- $V_r$ = Volume of filtered water (ml)
- $V_o$ = Volume of water observed in SRCC (ml)
- $V_s$ = Volume of filtered water (m³)
3. Result and Discussion

3.1. Catch of Sardinella lemuru in Prigi Waters
Total catch of *S. lemuru* in Prigi waters landed at Prigi Fishing Port in 2015-2019 are shown in Figure 3.

![Figure 3. Monthly catch of Sardinella lemuru landed at Prigi Fishing Port in 2015-2019. The highest catch for five years is in 2019 with peak catch in October-November.](image)

Based on the Figure 3, the number of *S. lemuru* catches landed at Prigi Fishing Port has decreased significantly from the total catch of 2277.50 tons in 2015 to 27.84 tons in 2016. In 2019 there was a very high increase in the catch of *S. lemuru*, reaching 4840.25 tons. Monthly mean catches data show that *S. lemuru* began to be seen in May-June and experienced a peak catching from October to November, especially in 2019. High *S. lemuru* catch often occurs in the transitional monsoon season (September to November) which is marked by peak catching of *S. lemuru* [4].

3.2. Morphometric and Meristic
Based on morphometric analysis, *S. lemuru* samples caught in Prigi waters in November 2019 had an average total length (TL) of about 16.47 cm and were categorized as the "lemuru" group. The "lemuru" category ranges from 15-18 cm in length [6]. The results of morphometric and meristic analysis are shown in Table 1.

| Morphometric | 2019       | 2017       |
|--------------|------------|------------|
| TL           | 16.47 ± 0.19 | 16.51 ± 0.30 |
| FL           | 15.22 ± 0.52 | 14.84 ± 0.30 |
| SL           | 14.37 ± 0.12 | 14.14 ± 0.31 |
| PredL        | 6.30 ± 0.45  | 5.98 ± 0.15  |
| OrbL         | 1.06 ± 0.24  | 0.80 ± 0.00  |
| EyeL         | 1.12 ± 0.29  | 0.40 ± 0.00  |
| CpedL        | 1.05 ± 0.05  | 1.16 ± 0.07  |
| Hdl          | 3.75 ± 0.11  | 3.43 ± 0.07  |
| SntL         | 1.54 ± 0.09  | 1.14 ± 0.12  |
| POL          | 1.84 ± 0.15  | 1.50 ± 0.07  |
The results of the morphometric and meristic analysis of *S. lemuru* in 2019 were then carried out with the t-test with the morphometric and meristic *S. lemuru* caught in the same waters in 2017. Based on these results it is known that the morphometric and meristic characteristics of *S. lemuru* caught in Prigi waters in 2019 do not have the difference with the *S. lemuru* caught in 2017. Based on this comparison, it can be assumed that the *S. lemuru* caught in Prigi in November 2019 is the same as the *S. lemuru* characteristic caught in the same waters in 2017.

3.3. Plankton Abundance in Prigi Waters
Plankton in Prigi waters were found in 21 genera of phytoplankton (Table 2) and 12 genera of zooplankton (Table 3). The phytoplankton found were distributed into 9 classes, i.e. Bacillariophyceae (7 genus), Dinophyceae (6 genus), Mediophyceae (3 genus), Chlorophyceae (1 genus), Trebouxiophyceae (1 genus), Ciliatea (1 genus), Euglenophycidae (1 genus) and Noctilucophyceae (1 genus). Meanwhile, the zooplankton consist of Copepoda (8 genus), Gastropoda (2 genus) and Globothalamea (1 genus). Moreover, Figure 3 describes the composition of plankton.

| Genus       | Class              | Abundance (ind./m$^3$) |
|-------------|--------------------|------------------------|
| *Actinocyclus* | Bacillariophyceae | 14098                  |
| *Coscinodiscus* | Bacillariophyceae | 10667                  |
| *Navicula*    | Bacillariophyceae  | 272                    |
| *Planktoniella* | Bacillariophyceae | 102                    |
| *Pseudosolenia* | Bacillariophyceae | 1970                   |
| *Rhabdonema*  | Bacillariophyceae  | 577                    |
| *Guinardia*   | Ulvophyceae        | 68                     |
| *Ceratium*    | Dinophyceae        | 6013                   |
| *Dinophysis*  | Dinophyceae        | 4552                   |
| *Protoperidinium* | Dinophyceae       | 5096                   |
| *Pyrocystis*  | Dinophyceae        | 1631                   |
| *Pyrophacus*  | Dinophyceae        | 3193                   |
| *Scrippsiella* | Dinophyceae        | 1393                   |

Table 2. The abundance of phytoplankton (ind./m$^3$) in Prigi waters in November 2019 was 83,533 ind./m$^3$.  

| Genus       | Class            | Abundance (ind./m³) |
|------------|------------------|--------------------|
| Chaetoceros| Mediophyceae     | 272                |
| Cyclotella | Mediophyceae     | 7372               |
| Thalassiosira| Mediophyceae    | 7338               |
| Oocystis   | Trebouxiophyceae | 4756               |
| Scenedesmus| Clorophyceae     | 5503               |
| Codonellopsis| Ciliata         | 1223               |
| Euglena    | Euglenophycidae  | 4926               |
| Noctiluca  | Noctilucophyceae | 2514               |
| Total      |                  | 83533              |

Table 3. Zooplankton abundance (ind./m³) in Prigi Waters in November 2019 is 94,862 ind./m³.

| Genus     | Class            | Abundance (ind./m³) |
|-----------|------------------|--------------------|
| Acartia   | Copepoda         | 15592              |
| Balanus   | Copepoda         | 13180              |
| Bolivia   | Copepoda         | 255                |
| Canthocalanus| Copepoda      | 4688               |
| Cletocamptus| Copepoda      | 2446               |
| Cyclops   | Copepoda         | 12501              |
| Oithona   | Copepoda         | 5028               |
| Oncaea    | Copepoda         | 5333               |
| Paracalanus| Copepoda       | 12025              |
| Heliconoides| Gastropoda  | 340                |
| Nauplius  | Gastropoda       | 20926              |
| Discorbis | Globothalamia    | 2548               |
| Total     |                  | 94862              |

The result showed that the dominant phytoplankton class was Bacillariophyceae by 43% (Figure 4b) with Actinocyclus (8%) was the highest genus abundance (Figure 4a). The Bacillariophyceae class dominates in the waters with 7 genera of the total 21 phytoplankton genera found. The Bacillariophyceae class dominates in the waters with 7 genera of the total 21 phytoplankton genera found. Bacillariophyceae class is the dominant class found in several marine waters, one of which is South Malang waters which reaches 90% of the total abundance of other phytoplankton [10]. Phytoplankton class Bacillariophyceae have high abundance in waters because this class has good adaptability, is cosmopolitan, has strong resistance and has high production power [4].

Meanwhile, in the zooplankton group, the Copepod class dominated by 78% with the highest genus abundance, namely Nauplia at 12%. The class/subclass Hexanauplia/ Copepoda dominates in the waters with 8 genera of 11 zooplankton genera found. Copepods were also found to dominate 88.3% of other zooplankton species found in the waters of the Bali Strait and in the waters of South Malang about 50% of other zooplankton species [4]. Zooplankton distribution is very broad from zero meters to the ocean floor because zooplankton does not really care about temperature, light, and food availability [11].
Figure 4. Composition of plankton based on class, where zooplankton (a) is dominated by Copepods by 75% and phytoplankton (b) is dominated by Bacillariophyceae by 33%.

3.3 Comparison of Plankton in The Waters and Guts
The composition of plankton in the waters is known to be 52.8% zooplankton and 47.2% phytoplankton. While in the stomach, the percentage of phytoplankton is greater than that of zooplankton, which is 51.5% (Figure 5). Scatterplot regression of plankton in the waters and guts as described in Figure 6.

Figure 5. Composition of plankton in the waters and guts.

Figure 6. Scatterplot regression of Plankton in the waters and guts.
Based on the results of the correlation statistical test (Figure 6), the correlation coefficient value between phytoplankton in the waters and the *S. lemuru* stomach is \( r = 0.920 \) with a determination coefficient of 84.69%. While the value of the correlation coefficient between zooplankton in the stomach of *S. lemuru* is \( r = -0.028 \) with a determination coefficient of 0.08%. The results of this comparison show that phytoplankton in the waters has a strong relationship and affects the abundance of phytoplankton in the fish stomach by 84.69% and the rest is influenced by other factors. The abundance of zooplankton in the waters has a weak relationship and affects the abundance of zooplankton in the fish stomach by 0.08% and the rest is influenced by other factors. Then it was discovered that phytoplankton also had a stronger relationship with *S. lemuru* in the waters of the Bali Strait rather than zooplankton [4]. Some of the factors that cause differences in plankton in waters with fish stomach are the uneven distribution of organisms as fish food, food availability, the choice of these fish, and changes in water conditions [12].

The very high *S. lemuru* abundance in November 2019 is thought to be closely related to the influence of upwelling in the Southern Java. During the Southeast monsoon, upwelling occurs in the southern waters of Central Java-East Java which increases natural productivity of the waters and applies the opposite in the Northwest monsoon [13]. *S. lemuru* is a seasonal fish because the appearance and end of the fish season depends on water conditions and the current season [14]. The spawning season of *S. lemuru* occurs in the Southeast monsoon which will then develop into adulthood until finally many are caught in the transitional monsoon season to the Northwest monsoon [15]. In the process, after an increase in marine productivity, a time lag of approximately 3 months is required due to grazing process until the *S. lemuru* population increases [16].

In addition, the high number of *S. lemuru* in 2019 is closely related to the occurrence of positive *El Niño* and IOD phenomena [16]. Based on the observations of Meteorological, Climatology, and Geophysics Agency in 2019, an *El Niño* phenomenon occurred in the Pacific Ocean and positive IOD in the Indian Ocean [17]. The existence of positive *El Niño* and IOD phenomena generally causes longer upwelling duration and increased upwelling intensity so that productivity is higher than normal years in Southern Java waters [18].

4. Conclusion
The abundance of *S. lemuru* in November 2019 was due to the abundance availability of food in the fishing area when phytoplankton is the main food choice for *S. lemuru*. The results of this comparison show that phytoplankton in the waters has a stronger relationship and affects the abundance of phytoplankton in the fish stomach by 84.69% and the rest is influenced by other factors. Then it is known that the abundance of *S. lemuru* is influenced by the abundance of phytoplankton in the waters, where the abundance of phytoplankton affects the number of *S. lemuru* catches more than zooplankton. This study may provide a good information in fish diet, fishing ground, and fishing season for government as one of considerations in the future sustainable fish management in Prigi Waters.

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