High catch of *Sardinella lemuru* (Bleeker, 1853) and plankton abundance in Prigi Waters: Case study in 2017 and 2019

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**Abstract.** Prigi Waters, East Java, is known as a fishing ground for mackerel tuna and other tunas. However, at the end of 2019, it was found that Bali Sardine (*Sardinella lemuru*) was a dominant caught that reach more than 56% of the total catch. The reason for the high fish abundance in 2019 is still unknown. Therefore, this study aims to understand the relationship between *S. lemuru* catch and plankton abundance in Prigi Waters during the high catch event and comparing a similar study in 2017. Plankton abundance was analyzed using the APHA method. Pearson correlation analysis was used to express the relationship between *S. lemuru* catch and plankton abundance. The result showed that the composition of zooplankton and phytoplankton in waters was 52.8:47.2. Class Bacillariophyceae dominated the phytoplankton group in Prigi waters (47%), where *Actinocyclus* is the most common genus found (28,762 cell/m\(^3\)). While in the zooplankton group, the class Maxillopoda dominated (75%), where *Nauplius* is the most common genus found (34,876 ind./m\(^3\)). The Pearson correlation analysis showed that *S. lemuru* catch in November 2019 was greatly influenced by phytoplankton (61.32%) than zooplankton (21.38%) abundances, and the rest was influenced by other factors. High and low plankton abundance in 2019 and 2017 has implications to high and low catch of *S.lemuru*, respectively. It is suggested that routine and continuous monitoring of plankton may provide good information for fisheries prediction and management in Prigi Waters.

**Keywords:** catch; correlation; plankton; Prigi Waters; *Sardinella lemuru*

1. **Introduction**

*Sardinella lemuru* (Bleeker, 1853) is a fish that often dominates the catch of fishermen in Indonesia. It is an important fishery commodity because it contains 17.8-20% of protein [1] and high Omega-3 [2]. *S. lemuru* is also dominant as a raw material in the fish canning industry [3]. *S. lemuru* catches in Indonesia fluctuates seasonally and even annually. It has occurred in Prigi waters as well. Based on Prigi Fishing Port statistic data [4], the catch of *S. lemuru* in 2015 was 2,277,493 kg then decreased in 2016, 2017, 2018 as 30,286; 15,018; 110,148 kg, respectively. However, *S. lemuru* catches increased sharply with the highest catch peaks in October-November reached 4,840,247 kg (17.15%) of the total production only in single 2019 (figure 1).
S. lemuru is a filter feeder organism that feeds on phytoplankton and zooplankton, especially copepods (zooplankton) [4]. The availability of S. lemuru in nature can be influenced by several factors, e.g. food availability [5]. A Previous study revealed that the catch of S. lemuru in the Bali Strait was closely related to the abundance of phytoplankton and zooplankton [3, 6]. However, there is very limited similar information for Prigi Waters. From this study, the question arises whether it is possible that the high catch of S. lemuru landed at the Prigi fishing port at the end of 2019 is also related to the abundance of food. This relationship is what makes this research important to do in the Prigi Waters. Therefore, this study aims to understand the relationship between the high catch of S. lemuru at the end of 2019 and the possible relationship to the abundance of plankton in 2019 and comparing it to a similar study in 2017. This study may provide basic information for the government in fisheries prediction and management in the Prigi waters.

![Figure 1](image1.png)

**Figure 1.** Time series of monthly mean Sardinella lemuru catch in the last 5 years landed at Prigi Fishing Port. The high peak of S. lemuru catch occurs in October, then November 2019.

2. Research methods

A sampling of plankton and fish were conducted at the same time using two boat system purse seiner. It was carried out at five fishing grounds during the peak of the S. lemuru catch event on 4-8 November 2019. It was one-day fishing where a trip was done within a day. Fishing grounds were determined by the captain based on his feeling and experiences. In this case, the fishing grounds (FG 1, 2, 3, 4, and 5) were in the southeast of Prigi Bay and landed in Prigi Fishing Port (figure 2). Plankton sampling was carried out soon after the hauling time of purse seiner [3]. A hundred ml surface seawater was filtered using 20 µm plankton net with three times repetitions. The filtered water was preserved with a 1% Lugol solution of 4-5 drops [7]. All fish caught from five fishing grounds were weighed and recorded. To understand the catch fluctuation in Prigi waters, then the 2019 dataset was compared to the previous data collecting in 2017 under the Marine Resource Exploration and Management (MEXMA) project.
Figure 2. Prigi waters where Prigi Bay and Prigi fishing port located. The five fishing grounds (FG 1, 2, 3, 4, and 5) in the current study located at the southeast of Prigi Bay.

All plankton samples were identified at Exploration of Fisheries and Marine Resources Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Brawijaya from 25 November–12 December 2019. Plankton observations were carried out by the sweeping method. Plankton count using a 1 ml Sedgwick Rafter Counting Cell volume and observed under a microscope with a magnification of $10\times10=100x$ [8]. Then the plankton abundance analysis was carried out by calculating the number of individual units observed using the equation (1) by APHA [7, 9].

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

where, $N$ = Plankton abundance, $n$ = Number of plankton in the entire field of view, $p$ = Number of a field of view observed, $O_i$ = Area of the Sedgwick Rafter Counting Cell (mm$^2$), $O_p$ = Area of view (mm$^2$), $V_r$ = Volume of filtered water (L), $V_o$ = Volume of water observed in SRCC (ml), $V_s$ = Volume of filtered water (ml).

3. Results and discussion

3.1. Catch of Sardinella lemuru in Prigi Waters

The number of catches of $S. lemuru$ from five fishing grounds in southeast Prigi Bay which landed at Prigi Fishing Port was shown in figure 3. The $S. lemuru$ catch had fluctuated during 4–8 November 2019. The lowest catch found at fishing ground 2 of 200 kg. While the highest catch was recorded at fishing ground 3 and 5 of 1700 kg each (figure 3).
During November, the *S. lemuru* catch was still high compared to the previous months. This is also experienced by water areas located in south Java and Bali Strait [10, 11]. The catch fluctuation of *S. lemuru* is thought to be influenced by the upwelling cycle that occurs in south Java [2], this fish enter the spawning period in the eastern season (Jun-Aug), then take time to develop until the transitional season 2. (September–November), many *S. lemuru* are caught by fishermen with the peak season in November [12].

### 3.2. Plankton abundance in Prigi Waters
Plankton abundance at five fishing grounds in Prigi waters shown in figure 4. The abundance ratio of phytoplankton and zooplankton was 48:52. The plankton found to have an average of 145,053 cell/m³ for phytoplankton with the highest abundance was found at fishing ground 3 of 222,788 cell/m³ and the lowest was at fishing ground 2 of 111,819 cell/m³. Whereas, zooplankton has an average of 155,924 ind./m³ with the highest abundance also at fishing ground 3 of 202,123 ind./m³ and the lowest is at fishing ground 2 as well of 119,745 ind./m³.

![Figure 3](image)

**Figure 3.** Catch of *Sardinella lemura* in five fishing grounds in Prigi waters fluctuated during 4-8 November 2019.

The results showed that class Bacillariophyceae dominated the phytoplankton group in Prigi waters by 47% (figure 5a) with Actinocyclus being the most common genus of 28,762 cells/m³ (table 1). The class Bacillariophyceae dominates the waters with 10 genera from a total of 21 phytoplankton genera found. The class Bacillariophyceae has a high abundance in waters because according to Odum [13], Bacillariophyceae has a fast growth rate, able to utilize nutrients properly, and able to adapt to environmental changes compared with other plankton classes.

![Figure 4](image)

**Figure 4.** (a) Plankton composition of Prigi waters and (b) Plankton distribution in five sampling sites of Prigi Waters.
Figure 5. The composition of plankton in Prigi waters according to their class, where (a) phytoplankton was dominated by Bacillariophyceae by 47% and (b) zooplankton was dominated by Maxillopoda by 75%.

Meanwhile, the zooplankton group, class Maxillopoda was dominated by 75% (figure 5b) with the most common genus found was Nauplius at 34,876 ind./m$^3$ (table 2). The class Maxillopoda dominates the waters with nine genera of twelve zooplankton genera found. The nine genera belong to the subclass Copepoda. The high abundance of copepods in the aquatic environment is due to the ability of Copepoda to live and adapt to various conditions of the aquatic environment [14, 15].

Table 1. Abundance and composition of phytoplankton in Prigi Waters.

| Class            | Genus         | Abundance (cells/m$^3$) |
|------------------|---------------|-------------------------|
| Bacillariophyceae| Actinocyclus  | 28762                   |
|                  | Ceratium      | 10021                   |
|                  | Chaetoceros   | 453                     |
|                  | Codonellopsis | 2038                    |
|                  | Coscinodiscus | 17778                   |
|                  | Cyclotella    | 12852                   |
|                  | Dinophysis    | 7587                    |
|                  | Euglena       | 8209                    |
|                  | Guinardia     | 113                     |
|                  | Navicula      | 453                     |
| Dinophyceae      | Noctiluca     | 4190                    |
|                  | Oocystis      | 7926                    |
|                  | Planktoniella | 170                     |
|                  | Protoperidinium| 10701                  |
|                  | Pseudosolenia | 962                     |
|                  | Pyrocystis    | 849                     |
| Chloropyceae     | Pyrophacus    | 5492                    |
| Euglenophyceidae | Rhabdonema    | 2774                    |
| Noctilucophyceae | Scenedesmus   | 9172                    |
| Oligotriceae     | Scrippsiella  | 2321                    |
| Trebouxiphycceae | Thalassiosira | 9908                    |
Table 2. Abundance and composition of zooplankton in Prigi waters.

| Class           | Genus    | Abundance (ind/m³) |
|-----------------|----------|--------------------|
| Maxillopoda     | Acartia  | 25987              |
|                 | Balanus  | 21967              |
|                 | Canthocalanus | 7813              |
|                 | Cletocamptus | 4076             |
|                 | Cyclops  | 20835              |
|                 | Nauplius | 34876              |
|                 | Oitthona | 8379               |
|                 | Oncaea   | 8889               |
|                 | Paracalanus | 20042            |
| Globothalamea   | Bolivina | 170                |
|                 | Discorbis| 2548               |
| Gastropoda      | Heliconoides | 340              |

3.3. Relationship between plankton abundance and catch

The Pearson correlation analysis was used to explain the relationship between plankton abundance and catch [16]. The strength and weakness of a relationship between variables can be expressed in the magnitude of the correlation coefficient. The correlation value between plankton abundance and catch was shown in figure 6.

![Figure 6](image-url)  
**Figure 6.** Relationship between plankton abundance and *Sardinella lemuru* catch.

The Pearson correlation shows that the strong correlation between the abundance of phytoplankton and the catch of *S. lemuru* in each fishing ground. The high catch was found at fishing ground 3. It was suspected that this phenomenon was due to the high abundance of plankton at fishing ground 3, and vice versa at the lowest value at fishing ground 2.

Based on the results of the correlation analysis, the correlation coefficient between phytoplankton in the waters and the catch of *S. lemuru* was 0.783 with a coefficient of determination of 0.6132. Meanwhile, the correlation coefficient between zooplankton in the waters and the catch of *S. lemuru* was 0.462 with a determination coefficient of 0.2138 (figure 6). The result indicates that phytoplankton and zooplankton in the waters have a strong relationship and affect the catch of *S. lemuru* by 61.32% and 21.38%, respectively, and the rest is influenced by other factors like abiotic factors [17].

*S. lemuru* is a small pelagic fish known as phytoplankton feeder mainly Baccilariophyceae class, such as *Coscinodiscus* sp. often found in their diet [18]. Meanwhile, the abundance of zooplankton has a moderate relationship with the catch of *S. lemuru*. According to Adinugroho et al. [19], a zooplankton abundance peak often occurs after a high phytoplankton abundance because zooplankton grows slower than phytoplankton. The time lag between plankton abundance and fish predation [2, 20] also causes a
correlation value between zooplankton abundance and catches classified as moderate. Pertami et al. [21] also explained that the dietary composition of S. lemuru also changes depending on the season and the size of the fish.

To determine the effect of plankton abundance on the high catch of S. lemuru in Prigi waters, case studies of plankton abundance and S. lemuru catch in 2019 were compared to the previous dataset (2017) as based on data collected by the MEXMA research group. Based on Statistics data, 2017 was the year with the lowest catch of S. lemuru in the last 5 years (figure 1). 2017 was a poor year for S. lemuru, where the result of the research in 2017 the catch for S. lemuru was only 15,018 kg when plankton abundance only reached 6,794 cell/m³ (phytoplankton) and 10,757 ind./m³ (zooplankton), on contrary in 2019 it reached 4,840,247 kg was followed by the high abundance of phytoplankton (1,450,053 cell/m³) and zooplankton (155,924 ind./m³) (table 3).

| Year | Number of Phytoplankton (cell/m³) | Number of Zooplankton (ind./m³) | Temperature (°C) | Chl-a | Catch (kg) |
|------|---------------------------------|---------------------------------|----------------|-------|------------|
| 2017 | 6794                            | 10757                           | 28.94          | 0.27  | 15018      |
| 2019 | 145053                          | 155924                          | 25.83          | 3.49  | 4840247    |

4. Conclusion

The high catch of S. lemuru in November 2019 was indeed influenced by the abundance of plankton. The correlation analysis showed that phytoplankton had a greater influence on the catch of S. lemuru at the time of the study as 61.32% compared with zooplankton which was only 21.38% and the rest was influenced by other factors like abiotic factors. Class Bacillariophyceae (phytoplankton) was dominated in this study. It is suggested to conduct routine and continuous plankton and S. lemuru monitoring for fish prediction and management.

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