Shell morphology and size distribution of Turbo spp in Sepanjang Beach by shell collecting: An Initial Survey

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Abstract. *Turbo* spp. in Sepanjang Beach, Gunung Kidul, Indonesia, are at risk of depletion due to their popularity for consumption and decoration. Protecting this species demands sustainable management practices. This initial survey aimed to examine the shell morphology, size distribution, and shell growth patterns of *Turbo* spp. at Sepanjang Beach, Indonesia, to establish baseline data for future research. A total of 233 shells were collected randomly and analyzed for morphological parameters. Shell dimensions exhibited variations in size, shape, color, and whorl features. Shells ranged from 7.59 to 60.96 mm in length and 7.47 to 52.43 mm in width. Operculum dimensions varied from 3.14 to 29.75 mm in length and 3 to 22 mm in width. Size frequency distributions highlighted a peak at 30-35 mm shell length. The right-skewed size distribution indicated a prevalence of smaller individuals, possibly influenced by the environmental and genetic factors. Positive correlations between shell and operculum dimensions suggested an isometric growth pattern, implying symmetrical shell development. These insights are crucial for developing effective conservation strategies for Sepanjang Beach. Further research, including species genetics, size at first gonadal maturity, and environmental influences, is recommended for a comprehensive understanding of *Turbo* spp. sustainability in the region.

1 Introduction

Turbo spp., also known as turban shells, are a diverse group of marine gastropods found in coastal ecosystems worldwide [1]. These herbivorous gastropods graze on algae attached to rocks or corals in the intertidal zone [2]. They are characterized by their thick operculum, which varies in color and serves as a defense mechanism against predators [1].

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In Indonesia, several Turbo species have been identified, including *Turbo crysostomus, Turbo crassus, Turbo sparverius, Turbo setosus, Turbo smaragdus, Turbo argyrostamus, Turbo bruneus,* and *Turbo marmoratus* [3-8]. Local communities have long harvested and consumed *Turbo* spp. as a traditional food source due to their high protein content and robust flavor [9]. These gastropods play a significant role in traditional cuisine, providing sustenance and cultural significance to coastal communities.

At Sepanjang Beach, several Turbo species have been discovered [5,10]. They are abundant, especially during the rainy season [5]. Locally known as "Usal," these gastropods are consumed by the local community and have become a culinary specialty of the Gunung Kidul region, attracting the interest of tourists [11,12]. Additionally, both locals and tourists collect the shells for their beautiful shapes and colors [5]. This activity has resulted in heightened exploitation, raising apprehensions regarding potential declines in wild populations. Therefore, knowledge about the eco-biology of *Turbo* spp. at Sepanjang Beach is required as a foundation for sustainable management.

This study aims to examine the shell morphology and shell size distribution of *Turbo* spp. at Sepanjang beach to gain important insights into their biology, population dynamics, and ecological interactions in marine ecosystems. Furthermore, the findings will contribute to ensuring the sustainable management of this valuable food resource, preserving the cultural traditions of the local people, and sustaining the livelihoods of coastal communities.

This study will adopt a practical and cost-effective method by collecting shells [13]. This method will allow researchers to learn about the presence and size variation of *Turbo* spp. on Sepanjang Beach in non-destructing way. It will also provide a valuable opportunity to conduct an initial survey to establish baseline data and lay the groundwork for more in-depth investigations.

2 Methods

2.1 Study Area

This study was located at Sepanjang Beach, Gunung Kidul, Yogyakarta, Indonesia (Figure 1). It extends for 550 meters and consists of sand beaches, rocky outcrops, and intertidal zones. Due to its unrestricted exposure to the Indonesian Ocean, the beach's topography is characterized by undulating waves and steep slopes [14].

Fig. 1. Study area in Sepanjang Beach, Gunungkidul, Yogyakarta

2.2 Shell Collection

A random sampling technique was utilized to collect shells along the littoral of Sepanjang Beach. 233 shells were collected between May 28 and May 31, 2023. During the sampling, researchers strolled down the beach, collecting *Turbo* spp. shells wherever they came upon them. Shells (Fig. ***2***) were thoroughly examined to verify that they were complete and representative of *Turbo* spp. The shell morphology was evaluated using morphological parameters, including shell dimensions. The size distributions of the collected shells were examined to discover any noticeable trends or differences.

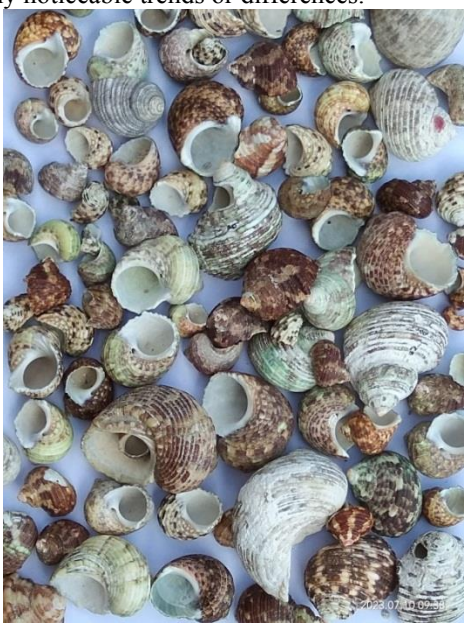

Fig. 2. *Turbo* spp shells collected from Sepanjang Beach showcasing variations in size and species

2.3 Morphological Measurement

The morphological parameters of each *Turbo* spp. shell were measured using digital calipers following collection. Shell length (the maximum dimension from the base to the apex, SL); shell width (the broadest dimension across the shell, SW); operculum length (the length of the operculum, OL); and operculum width (the width of the operculum, OW) were measured for each shell. These measurements provide valuable information about the size and shape variations of *Turbo* spp. shells. Fig. ***3*** illustrates a representative sample of measured shells in order to visualize shell dimensions. The figure illustrates the numerous morphological characteristics and measurements of each shell.

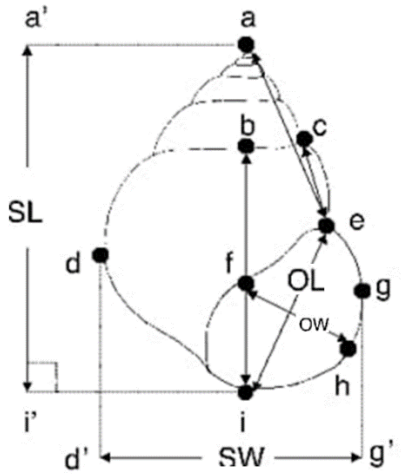

Fig. 3. *Turbo* spp dimension measurement. SL : shell length, SW : shell width, OL : operculum length, OW : operculum width

2.4 Data Analysis

For the shell dimensions, descriptive statistics including the mean, standard deviation, and range were computed. The variation in *Turbo* spp. diameters within the collected samples was visualized by plotting size frequency distributions. These distributions provided a graphical representation of the frequency of shells falling within various size ranges in order to determine the overall pattern of size distribution. Additionally, using linear regression, allometric relationships between shell length and width, as well as operculum length and width, were investigated. The R-squared (R^2) value, which represents the regression model's fit, was assessed to determine the strength of the relationships. This enabled the identification of any distinctive patterns or morphological changes in shells as their size increased.

2.5 Ethical Considerations

All activities involving the collection of shells were conducted in accordance with local regulations and ethical principles. During the study, no living organisms were injured or collected; only empty *Turbo* spp. shells were utilized for analysis.

3 Result And Discussion

3.1 Shell Morphology

The shells exhibited a range of morphological variations in terms of size and shape. Measurements of shell length, shell width, operculum length, and operculum width were recorded for each shell (Figure 1). Most of the shells found were damaged or not in perfect condition, and the operculum was also detached, making identification difficult. However, in general, the shells found have the following characteristics: a solid, imperforate shell with an ovate or ovate-conic shape. The shell color varies between dirty white, greenish, and patches of brown or black (Figure 5). All of them have six whorls that are convex, with differences in details such as the presence of spiral ribs, lirae, or scales on some whorls. The

aperture is generally oval or ovate. The columella is typically thickened and sometimes dilated at its base (Figure 4).

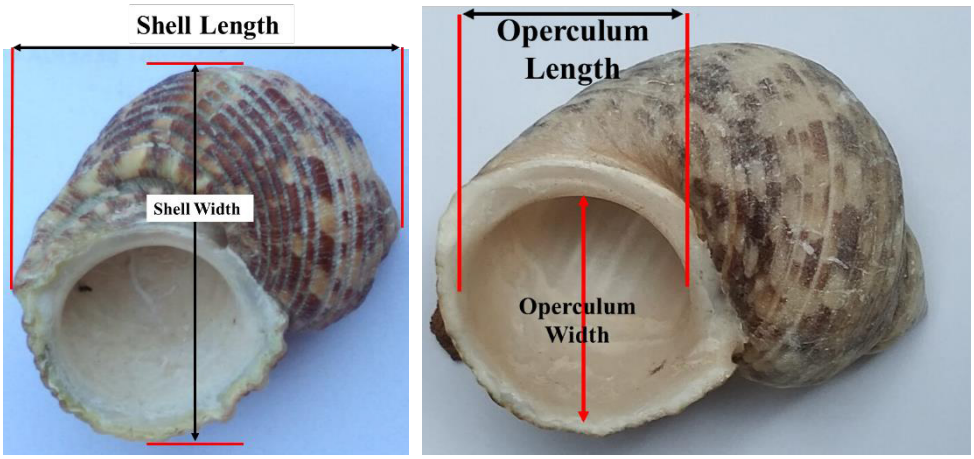

Fig. 4. *Turbo* spp dimension measurement in A) shell length and shell width, B) operculum length and operculum width

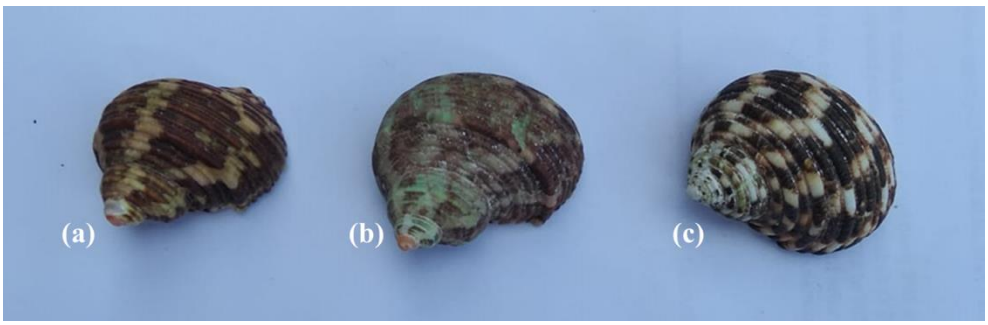

Fig 5. The variations in *Turbo* spp. shells that were found

The dimensions of *Turbo* spp. found in Sepanjang Beach were as follows: shell length ranged from 7.59 to 60.96 mm, shell width ranged from 7.47 to 52.43 mm, operculum length ranged from 3.14 to 29.75 mm, and operculum width ranged from 3 to 22 mm (Table 1).

Table 1. Descriptive statistics of shell dimensions for *Turbo* spp in Sepanjang Beach

Parameter	Shell Length (mm)	Shell Width (mm)	Operculum Length (mm)	Operculum width (mm)
Mean	28.79	26.33	12.26	10.89
Median	29.02	27.19	12.32	10.68
Mode	33.2	30.93	14.34	8.63
Standard Deviation	9.92	8.70	4.35	3.82
Range	53.37	44.96	26.61	19
Minimum	7.59	7.47	3.14	3
Maximum	60.96	52.43	29.75	22

3.2 Shell Size Distribution

The shell size distribution of *Turbo* spp. in Sepanjang Beach was analyzed by examining the shell length, shell width, operculum length, and operculum width. The frequency distribution of each parameter was summarized using histograms in Figure 6-9

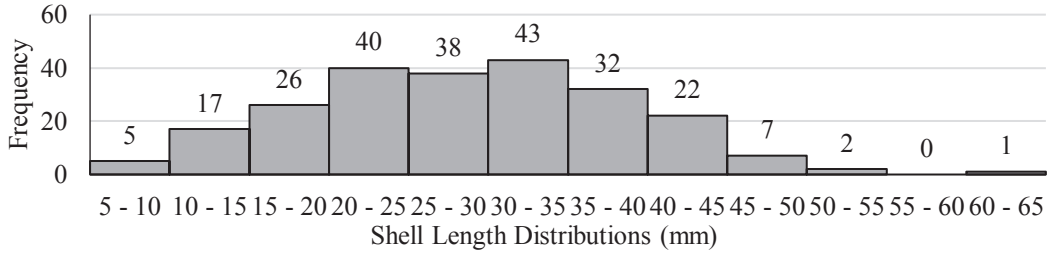

Fig. 6. Shell Length Distribution of *Turbo* spp in Sepanjang Beach

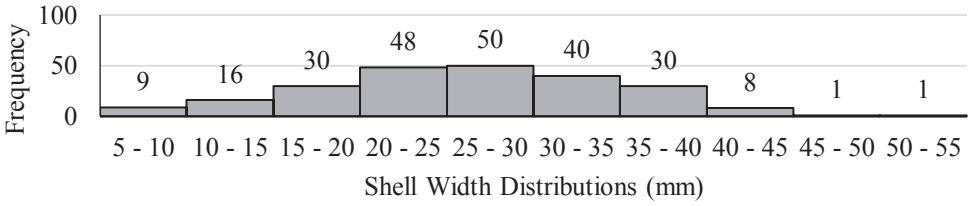

Fig.7. Shell Width Distribution of *Turbo* spp in Sepanjang Beach

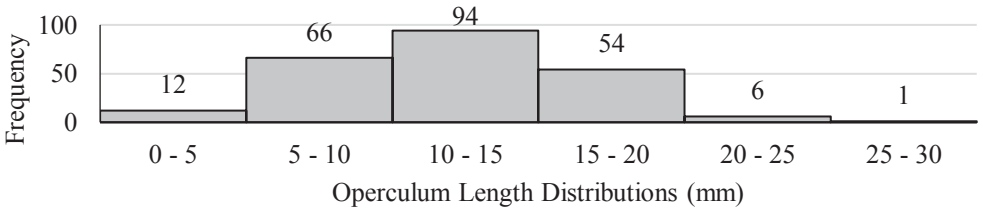

Fig.8. Operculum Length Distribution of *Turbo* spp in Sepanjang Beach

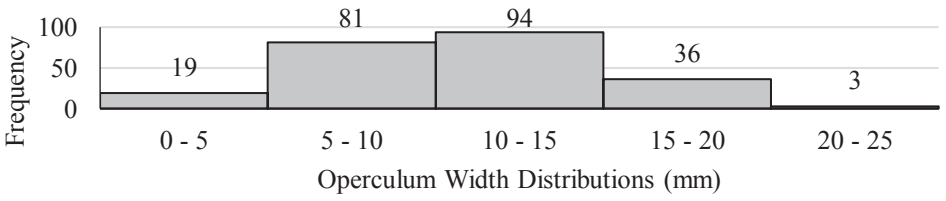

Fig.9. Operculum Width Distribution of *Turbo* spp in Sepanjang Beach

The figure shows the distribution of shell length (Figure 6), width (Figure 7), operculum length (Figure 8), and width (Figure 9) of *Turbo* spp. shells at Sepanjang Beach. The shell length distribution shows a frequency peak between 30 and 35 mm, indicating that the majority of shells are in this size range. The shell width distribution is highest in range 25-50 mm. The operculum length and width distributions show that the majority of opercula are in the 10-15 mm size range. All of the distributions all right-skewed.

3.4 Shell Growth Pattern

An allometric relationship analysis was performed to further study the link between several morphological features of *Turbo* spp. at Sepanjang Beach. Allometry is the study of how relative proportions of various body regions vary with size. This study examined shell growth pattern through shell length and width. By comparing the length to the width of each individual shell, a scatter plot (Fig.) was generated. The scatter plot illustrates any discernible patterns or alterations in shell shape as its size increases.

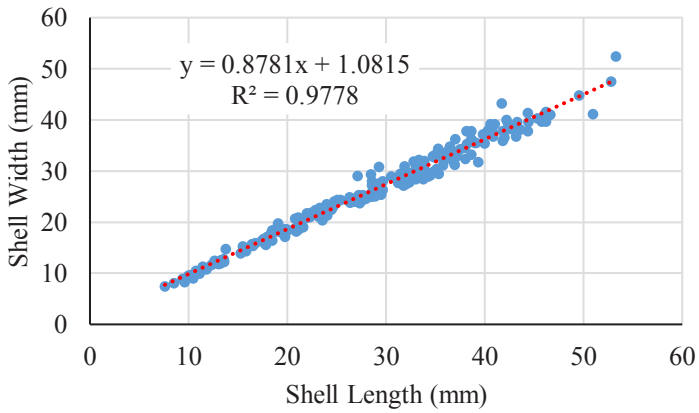

Fig.10. Relationship between shell length (mm) and shell width (mm)

The scatter plot shows a positive correlation (R^2=0,9778) between shell length and shell width (Figure 10), indicating that shell width tends to increase as shell length increases. This indicates that the growth of *Turbo* spp. shells on Sepanjang Beach is isometric, meaning that all dimensions increase proportionally. The scatter plot also reveals a positive correlation (R^2=9698) between the length and width of the operculum (Figure 11), indicating that as the length of the operculum increases, so does its width. This suggests that the development of *Turbo* spp. opercula in Sepanjang Beach is also isometric, meaning that the width changes at the same rate as the length.

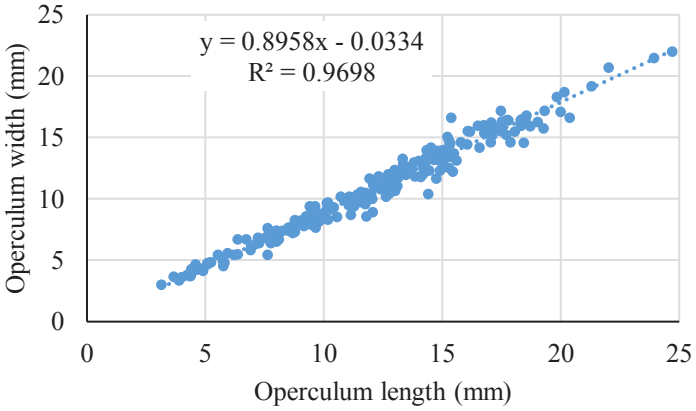

Fig.11. Relationship between operculum length (mm) and operculum width (mm)

3.5 Disscussion

Generally, Turbo snails prefer environments characterized by diverse topography with microalgae on coral rock, gently sloping beaches less than 20 meters deep, and strong water currents without river flow or pollution [15,16]. In the study area, similar conditions prevail, including sandy beaches with large rocks, strong waves, and the absence of river flow. The research area also had no presence of mangroves or seagrass. Living *Turbo* spp. in Sepanjang beach were found often concealed beneath rocks or within crevices. The variations in shell morphology observed in our research demonstrate the plasticity of *Turbo* spp. shells in response to environmental and genetic influences [6,17].

Based on the morphology and morphometrics of the shell, *Turbo* spp. in Sepanjang Beach had an average SL of 28.79 mm with a range of 7.59-60.96 mm and the most frequent size was 30-35 mm. *Turbo Setosus* and *Turbo stenogyrus* in Manokwari had SL ranged of 32.27 - 60.02 mm and 14.55–58.53 mm, respectively [18,19]. *Turbo brunneus* found in Singapore has an SL range of 24.00-38.00 mm [20].

Consistent with previous research on gastropod morphology [21] which emphasized the significance of shell characteristics as key identifiers of species, these findings confirm the significance of shell characteristics as key identifiers. Based on the shells found and also based on prior studies of gastropods [5] at Sepanjang Beach, it is possible that the *Turbo* spp. in Sepanjang consists of several species, namely *Turbo setosus*, *Turbo crassus,* and *Turbo argyrostomus*, but for more certainty, it must be further identified using living biota.

The shell size frequency distribution of *Turbo* spp. in Sepanjang Beach was right-skewed, meaning that there are more small species than large species. There are possibly a few reasons for this, including: small species are easier to evolve and diversify, large species have more constraints on them, such as needing more food and energy to survive and being more vulnerable to predators, mall species are more likely to survive mass extinction [23]. At Sepanjang beach these gastropods are sessile, attached to coral rocks, so large sizes are easy for predators to take, including local communities who will take turbos when the tide is low. This causes more small-sized shells to be found.

The right-skewness of body size distributions has important implications for the diversity, stability, and resilience of ecosystems [23]. For example, it suggests that small species are more important to the overall diversity and stability of ecosystems, and that large species are at greater risk of extinction. This shell size could be part of the plasticity of *Turbo* spp. in

Sepanjang Beach. However, it is important to note that plasticity is not the only possible explanation for the right-skewed shell size distribution of *Turbo* spp. in Sepanjang Beach. It is also possible that the distribution is due to genetic factors. More research is needed to determine the relative contributions of genetic and environmental factors to the shell size distribution of *Turbo* spp. in Sepanjang Beach. It is also necessary to conduct a study on the size of the first mature gonads to determine the minimum size of turbos that can be taken by the community.

This study also revealed the shell growth pattern through the correlation between shell length and width, as well as the length and width of the operculum in *Turbo* spp. By measuring the size of Turbo snail shells and opercula from these deposits, we can estimate its biomass populations in the past in a non-destructive way [2]. The positive correlation between shell length and width of *Turbo* spp. indicates an isometric growth pattern, in which the shell's width increases proportionally as its length increases [23]. Similarly, the positive correlation between the length and width of the operculum indicates a consistent growth pattern of the operculum as its size increases [24]. This is similar to *Turbo brunneus* found in Labrador Beach Singapore, which has a strong correlation between SH and SW [20] and has isometric growth. This shows that the growth of both is symmetrical, not rounded or tapered. In contrast, *Turbo stenogyrus* and *T. setosus* in Papua have negative allometric growth, where the weight gain is slower than the length [18,19]. The relationship between the size of different body parts in gastropods is determined by both their genes and environmental factors [25].

Our findings contribute to the understanding of shell morphology, size distribution, and shell growth patterns of *Turbo* spp. at Sepanjang Beach. Comprehending the population characteristics and growth patterns of *Turbo* spp. is crucial for developing effective conservation and management strategies and evaluating the ecological health and biodiversity of Sepanjang Beach. Further research is highly recommended to explore aspects such as species genetics, the size at first gonadal maturity, and the influence of environmental factors on these gastropods.

5 Conclussions

This study provides valuable insights into the shell morphology, size distribution, and shell growth patterns of *Turbo* spp. at Sepanjang Beach. The findings highlight the diversity of shell forms and the range of sizes present in this population. The right-skewed shell size distribution suggests that smaller individuals are more abundant, possibly due to ecological and genetic factors. The positive correlation between shell length and width, as well as between operculum length and width, indicates an isometric growth pattern, where the proportions remain constant as the organism grows. Understanding the population characteristics and growth patterns of *Turbo* spp. is essential for developing effective conservation and management strategies and evaluating the ecological health and biodiversity of Sepanjang Beach. Further research is highly recommended to explore aspects such as species genetics, the size at first gonadal maturity, and the influence of environmental factors on these gastropods.

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