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Size distribution of *Haliotis asinina* and abundance of periphyton in tapulaga waters

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ABSTRACT

The Tapulaga waters, located in Soropia, Southeast Sulawesi, are among the coastal waters with significant potential for the seven-eyed abalone (*Haliotis asinina*). This species is a herbivorous gastropod that primarily consumes natural food sources such as periphyton and macroalgae. This study aims to determine the size distribution of *H. asinina* and analyze the presence of periphyton on seagrass leaves and macroalgal thalli. Sampling was conducted over six months in the Tapulaga waters of Soropia, Konawe Regency, Southeast Sulawesi, using a simple random sampling technique. The collected data were analyzed using descriptive statistical methods. The results indicate that the highest percentage of size distribution was observed in the range of 37.5–44.5 mm, comprising 34% of the total population. The population was categorized into two size groups: juveniles (≤ 49 mm) and adults (≥ 50 mm). Juveniles accounted for 75% of the total *H. asinina* population, while adults comprised 25%. A total of 11 periphyton species from three taxonomic classes Bacillariophyceae, Cyanophyceae, and Trebouxiophyceae—were identified on the seagrass species *Enhalus acoroides* and the macroalgae *Gracilaria salicornia*, *Padina* sp., *Halimeda* sp., *Galaxaura* sp., and *Gelidium* sp. The identified periphyton species included *Aulacoseira* sp., *Nitzschia* sp., *Synedra* sp., *Diatoma* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Melosira* sp., *Lyngbya* sp., *Planctonema* sp., and *Cocconeis* sp. Six of these periphyton species were present on both seagrass and macroalgal thalli. *Synedra* sp. was the most dominant species, exhibiting the highest abundance at 88,876 individuals/cm². The presence of periphyton as a natural food source attached to seagrass leaves and macroalgal thalli plays a crucial role in supporting the juvenile *H. asinina* population.

Introduction

Haliotis asinina, commonly known as the "mata tujuh" (seven-eyed) abalone (Dharma, 2005; Setyono, 2004; Ishak *et al*., 2020), is a gastropod species of high economic value, particularly in the fishing and aquaculture industries (Setyono, 2009a). This species is widely distributed across the eastern waters of Indonesia (Gallardo & Salayo, 2003; Setyono, 2009b), including the Tapulaga waters in Soropia, Southeast Sulawesi (Ishak *et al*., 2020).

The waters of Tapulaga Village serve as one of the habitats for *H. asinina*, alongside other locations in the Soropia District, Konawe Regency. This area is characterized by a seagrass ecosystem, which is exposed during low tide and submerged during high tide, making it part of the intertidal zone (Yulianda *et al*., 2013). Various species of macroalgae also inhabit this environment (Handayani, 2021), creating an ideal habitat for *H. asinina.*

Understanding the size distribution of populations is crucial for ecological studies and conservation efforts, as it provides insights into demographic structure, population dynamics, and overall ecosystem health. Population size distribution is influenced by multiple environmental factors, including food availability, predation, and habitat conditions (Ardiyansyah, 2018). Periphyton, or benthic diatoms, serve as a primary natural food source for abalones and play a significant role in their ecology (Nasrullah *et al*., 2016). Periphyton consists of a community of organisms that attach to various submerged surfaces in aquatic environments, such as rocks, bamboo substrates (Sibarani *et al*., 2020), cement plates, nets, plastics (Nasrullah *et al*., 2016; Zain *et al*., 2023), and seagrass leaves (Pabesak, 2004).

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The abundance and composition of periphyton directly influence the survival rates of *H. asinina* larvae (Jarayabrand & Paphavasit, 1996; Xing *et al.*, 2008; Nasrullah *et al.*, 2016).

This study focuses on analyzing the size distribution of *H. asinina* and the abundance of periphyton to better understand the relationship between population structure and habitat conditions. Examining size distribution provides valuable insights into individual size variation, growth patterns, and overall population dynamics, which are essential for assessing reproductive rates, maturity levels, and ecological pressures. Additionally, investigating periphyton abundance helps assess aquatic ecosystem health, as periphyton is sensitive to environmental changes and can serve as a biological indicator of water quality, nutrient levels, pollution, and marine productivity.

Understanding the relationship between *H. asinina* size distribution and periphyton abundance is expected to provide valuable information for the effective management and conservation of this species. Furthermore, the findings of this study may contribute to the development of sustainable abalone aquaculture and enhance conservation efforts for the aquatic ecosystems that support *H. asinina*.

Materials and Methods

Study Location and Duration

Sampling was conducted monthly over a six-month period in the seagrass ecosystem of the Tapulaga waters, Soropia District, Southeast Sulawesi (Figure 1)

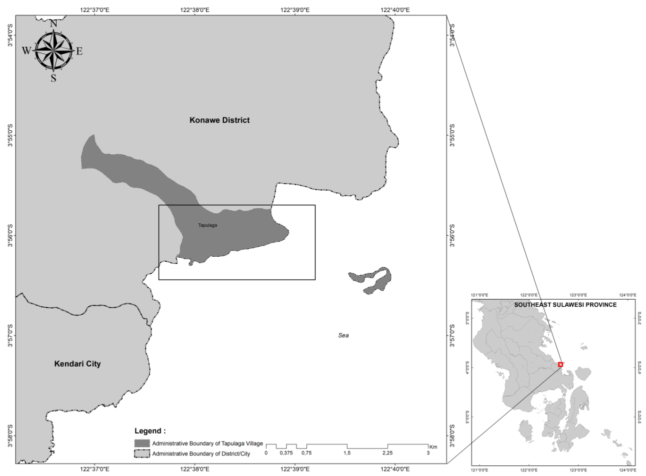

Figure 1. Map of the Research Site

Data Analysis

Research Tools and Materials

The equipment used in this study included digital calipers, rulers, microscopes, sample bottles, ethanol, brushes, trays, and periphyton identification guides (Prescott, 1970; Clark, 1981).

Data Collection Procedure

A simple random sampling technique was employed, and data were analyzed using descriptive statistics. The shell length of *H. asinina* was measured using a digital caliper with an accuracy of 0.1 mm. Periphyton samples were collected from the leaves of *Enhalus acoroides* seagrass and the thalli of various macroalgae species present at the sampling site. The leaves and thalli were standardized to the same length using a ruler and cut to approximately 10 cm² before being placed into sample bottles containing 4% formalin.

Periphyton (microalgae) observations were conducted using a light microscope at 40× magnification with a Sedgewick-Rafter Counting Cell (SRC) slide. Before observation, the periphyton was detached from the leaves and thalli by scraping them with a brush. The collected periphyton was then transferred into sample bottles containing 50 mL of water and preserved in 4% formalin. Periphyton identification was based on morphological characteristics following standard references (Yamaji, 1979; Biggs and Kilroy, 2000; Andrzej *et al.*, 2000).

Data analysis

The shell length data were analyzed using Sturges' formula (1926) as cited in Lempoy (2020) to determine the frequency distribution of the size classes.

$$k = 1 + 3{,}3 \log n$$

Where: k = number of classes, n = number of data points. The class interval was calculated using the following formula:

$$C = \frac{X_n - X_1}{k}$$

Where: C = class interval, Xn = highest data value; X1 = lowest data value, k = number of classes.

Periphyton abundance was calculated using the formula by Ameilda *et al.* (2016):

$$N = \frac{n \ x \ At \ x \ Vt}{AC \ x \ Vs \ x \ As}$$

Where: N = periphyton abundance (ind/cm²), n = number of observed periphyton individuals, At = cover glass area (22 x 22 mm²), Vt = total sample volume in the sample bottle (25 ml), Ac = microscope field area (1.036 mm²); Vs = volume of one drop of sample under the cover glass (0.5 ml); As = scraped substrate surface area (5 x 5 cm²).

Results

Size Distribution of *H. asinina*

Based on shell length measurements of *H. asinina*, the highest frequency (34%) was observed in the size class of 37.5–44.5 mm, which falls within the juvenile category (Figure 2).

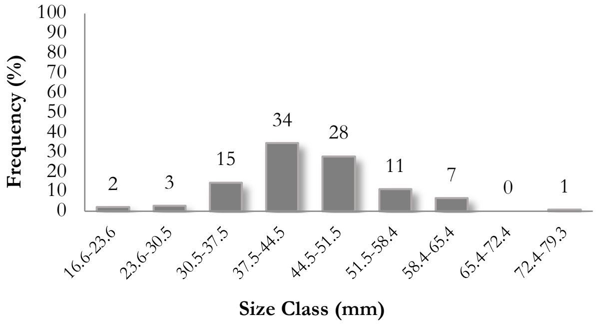

Figure 2. Distribution of frequenci of abalon shell's size in several size classes

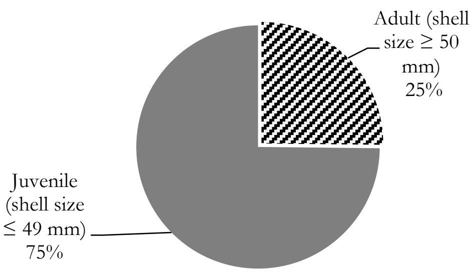

Figure 3. Percentage of Size Groups of Abalon *H. asinina* found in Tapulaga Waters

Analysis of shell length data from a total of 151 *H. asinina* individuals collected from the Tapulaga waters revealed that 25% of the population were adults (≥ 50 mm in shell length), while 75% were juveniles (≤ 49 mm in shell length). This indicates that the majority of the population consists of juveniles.

Periphyton Abundance

The types of periphyton and macroalgae identified in the Tapulaga waters are presented in Figure 3.

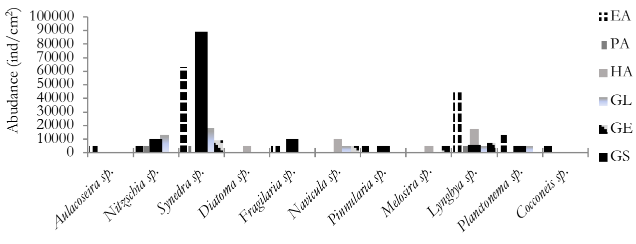

Figure 4. The types of periphyton and macroalgae identified in the Tapulaga waters

As shown in Figure 4, a total of 11 periphyton species were recorded in the Tapulaga waters, including *Aulacoseira* sp., *Nitzschia* sp., *Synedra* sp., *Diatoma* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Melosira* sp., *Lyngbya* sp., *Planctonema* sp., and *Cocconeis* sp. These species were identified on the leaves of the seagrass *Enhalus acoroides* and the thalli of several macroalgae species, including *Gracilaria salicornia*, *Padina* sp., *Halimeda* sp., *Galaxaura* sp., and *Gelidium* sp.

The same periphyton species were found on both seagrass leaves and macroalgal thalli. The abundance of periphyton on *E. acoroides* leaves and macroalgal thalli in the Tapulaga waters ranged from 5,000 to 88,876 individuals/cm². Among the recorded species, *Synedra* sp., from the class Bacillariophyceae, was the most dominant and exhibited the highest abundance across all observations on seagrass leaves and macroalgal thalli.

Discussion

The analysis indicates that the Tapulaga waters exhibit a high frequency of *Haliotis asinina* within the shell length size class of 37.5–44.5 mm, representing 34% of the population. Among the 151 *H. asinina* individuals sampled, 75% had shell sizes ≤ 49 mm, classifying them as juveniles, while 25% had shell sizes ≥ 50 mm, categorizing them as adults. The juvenile category is further subdivided into early juveniles and juveniles, whereas the adult category comprises subadults and adults. Early juveniles typically have a shell length between 5–10 mm (Franco *et al.*, 2022), while juveniles range from 24.3–25.3 mm (Jwa and Hong, 2023) or approximately 20.2 mm (Nivelais, 2023). Small abalone generally measure around 15.8 ± 1.6 mm (Rizzo *et al.*, 2024). Juvenile abalone exhibit shell lengths between 21 and 38 mm (Bullon et al., 2023). Abalone seeds range from 2.0–3.5 cm (WWF Indonesia and Rusdi, 2015). Small-sized abalone are classified as those measuring less than 40 mm (Ishak *et al.*, 2019). Ripe females typically have shell lengths between 58.1–69 mm (Capinpin *et al.*, 1998).

Adult abalone generally measure over 50 mm (Ishak *et al.*, 2020; WWF Indonesia and Rusdi, 2015; Xiaobing *et al.*, 2010). The minimum harvest size for green abalone (*Haliotis fulgens*) is 150 mm (Bauer *et al.*, 2024). The onset of gonadal maturity in *H. asinina* occurs at a shell length of 64 mm (Hadijah, 2017).

The high percentage of juveniles observed in this study (Figure 1) is closely related to the availability of natural food sources. Juvenile abalone primarily consume periphyton or benthic diatoms from the microalgae group, which are found attached to seagrass leaves and macroalgal thalli. Observations identified 11 types of periphyton on seagrass leaves and macroalgal thalli, including *Aulacoseira* sp., *Nitzschia* sp., *Synedra* sp., *Diatoma* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Melosira* sp., *Lyngbya* sp., *Planctonema* sp., and *Cocconeis* sp. Six periphyton species were found on both seagrass and macroalgae: *Nitzschia* sp., *Synedra* sp., *Fragilaria* sp., *Pinnularia* sp., *Lyngbya* sp., and *Planctonema* sp. Among these, *Nitzschia* sp. serves as a suitable natural food source for early juvenile *H. asinina*. Other important periphyton species for juvenile *H. asinina* include *Cocconeis* sp., *Nitzschia* sp., *Amphora* sp., and *Navicula ramosissima* (Villa-Franco *et al.*, 2022).

The periphyton species preferred by juvenile abalone include *Nitzschia* sp., *Navicula* sp., and *Cocconeis* sp. (Imai, 1982). Additionally, *Navicula mollis*, *Stauroneis* sp., *N. ramosissima*, *Pleurosigma* sp., and *Cocconeis* sp. are benthic diatoms that stimulate metamorphosis and growth, with cell lengths ranging from 13.64 ± 0.29 µm to 26.54 ± 0.45 µm (Capinpin, 2015). *Cocconeis* sp., *Nitzschia* sp., *Amphora* sp., and *Navicula ramosissima* are considered suitable live feeds for early juvenile *H. asinina* (Villa-Franco et al., 2022). The most essential natural food sources during the early juvenile stage are *Nitzschia* sp. and *Navicula* sp., as they provide key nutrients for early abalone growth (Setyono, 2009a). Abalone larvae primarily consume benthic diatoms, while adults feed on seaweed or macroalgae (Nurfajrie *et al.*, 2014).

The abundance of *Synedra* sp. ranged from 5,000 to 88,876 individuals/cm². The high abundance of *Synedra* sp. observed on all surfaces of seagrass leaves and macroalgal thalli suggests potential environmental pollution; however, further studies are required to determine the pollution category. The highest periphyton abundance of *Synedra* sp. was recorded on *Enhalus acoroides* leaves (63,333 individuals/cm²) and on the macroalgae *Gracilaria salicornia* thalli (88,876 individuals/cm²). *Synedra* sp., a periphyton species from the class Bacillariophyceae, exhibited the highest abundance among all identified periphyton species. This species is known for its ability to survive in unfavorable environmental conditions (Conradie, 2008) and can thrive in low-nitrogen and phosphate conditions (Venter, 2003). It is also recognized as a bioindicator for water quality assessment and is often associated with pollution in aquatic ecosystems (Rangpan, 2008; Isti'anah *et al.*, 2015).

In the Tapulaga waters, adult *Haliotis asinina* were present, although in smaller numbers (25%). Adult *H. asinina* exhibit greater selectivity in their diet compared to juveniles, primarily consuming macroalgae (Permana *et al.*, 2017). Both adults and larvae have been reported to favor a combination of benthic algae (Hadijah *et al.*, 2017), and even juvenile *H. squamata* consume macroalgae (Damayanti *et al.*, 2018). Adults show a preference for brown macroalgae over green algae (Imai, 1982). Other studies indicate that red algae, particularly *Gracilaria* sp., promote growth and gonad maturation in *H. asinina* (Singhagraiwan and Doi, 1993; Capinpin and Corre, 1996; Priyambodo *et al.*, 2005; Setyono, 2006; Hadijah *et al.*, 2014). This type of algae has been shown to support optimal growth in abalone (Susanto *et al.*, 2008; Rusdi *et al.*, 2010) and is commonly used as the primary feed in floating cage aquaculture (WWF Indonesia and Rusdi, 2015). Other macroalgae species preferred by abalone include *Gracilaria verrucosa*, *Ulva* sp., and *Kappaphycus* sp. (Setyono, 2009a).

The low percentage of adult *H. asinina* in Tapulaga may be influenced by the types of macroalgae available, which may be less suitable for their dietary preferences. The macroalgae species found in Tapulaga include *Gracilaria salicornia*, *Padina minor*, *Halimeda* sp., *Galaxaura* sp., and *Gelidium* sp. Among these, *Gracilaria* sp. is particularly favored by abalone due to its relatively soft thallus texture (Chen, 1984; Rusdi *et al.*, 2010), smaller branches (Hadijah *et al.*, 2017), and slightly thinner cell walls with pseudophylls (Erniati *et al.*, 2022). Additionally, *Gracilaria* sp. serves as a natural food source that enhances both growth and survival in abalone (Reyes and Fermin, 2003; Naidoo *et al.*, 2006; Qi *et al.*, 2010). This macroalgae species also contains the probiotic Alg 3.1, which enhances nutrient availability in the digestive system of *H. asinina* (Faturrahman, 2013). In contrast, *G. salicornia* is characterized by a large and dense thallus (Tuiyo, 2014), while *Ulva* sp. has a soft texture that is easily digestible by juvenile abalone (Chen, 1984). *Halimeda* sp., in contrast, is green and has a stiff thallus (Erniati *et al.*, 2022).

Several factors influence the selection of macroalgae as a food source for abalone, including algal morphology, texture, hardness, metabolite composition, and nutritional content (Shepherd and Steinberg, 1992; Masita *et al.*, 2016; Akbar and Hasan, 2024). Abalone consumes algae in quantities ranging from 10% to 30% of their body weight daily (Chen, 1989). As herbivorous marine gastropods, abalone feed on both microalgae and macroalgae, including red, green, and brown algae (Faturrahman *et al.*, 2015). In their natural habitat, most adult abalone are sedentary, capturing floating macroalgae from the water column (Allen *et al.*, 2006). They also consume benthic microalgae when macroalgae resources are scarce, such as in tropical coral reef environments (Sawatpeera *et al*., 1998). In tropical regions, abalone consumes various macroalgae species, including *Gracilaria* sp., *Laurencia obtusa*, *Ulva* sp., *Hypnea asper*, and *Kappaphycus alvarezii* (Setyono, 2009a).

The texture of macroalgal thalli plays a crucial role in abalone food selection, along with its chemical composition and nutritional value. *Gracilaria verrucosa*, for example, is rich in protein and fiber and contains essential amino acids such as L-threonine, L-glycine, L-leucine, and L-alanine (Ma'ruf *et al*., 2013).

Conclusion

The size distribution of *Haliotis asinina* in Tapulaga indicates that juveniles constitute the majority of the population. This high abundance of juvenile abalone is likely supported by the availability of natural food sources, particularly microalgae, including periphyton and benthic diatoms, which thrive on seagrass leaves and macroalgae thalli. Among the periphyton species identified, *Synedra* sp. was the most dominant. The high prevalence of this species may indicate potential environmental pollution; however, further research is required to assess the extent and nature of the pollution.

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