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## Original article

# Abundance, Spatial Distribution Patterns, and Sex Ratio of Abalone (*Haliotis asinina*) in Salando Island, Tolitoli, Central Sulawesi

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**Abstract**

This study aimed to examine the ecological characteristics of the tropical abalone (Haliotis asinina) inhabiting the coastal waters of Salando Island, Tolitoli, Central Sulawesi, with a focus on its abundance, distribution pattern, and sex ratio. Sampling was conducted at five stations determined by substrate type, where abalone populations were present. At each station, three 25-m line transects were established, and five 5 × 5 m quadrats were positioned seaward for density estimation. Field observations and data analyses were performed at the Laboratory of Animal Biosystematics and Evolution, Faculty of Mathematics and Natural Sciences, Tadulako University. Environmental parameters, including pH, temperature, and salinity, were measured, while distribution mapping was conducted using GPS coordinates. The environmental conditions recorded ranged from pH 6.47–7.2, temperature 33.5–36 °C, and salinity 32.1–35.6 ppt, with coral reefs identified as the dominant substrate. The mean population density of H. asinina was 0.23 individuals/m². Morisita's index value is 2.25 indicated a clumped distribution pattern. The sex ratio analysis revealed a male-to-female ratio of 1.26:1, with males comprising 56% and females 44% of the sampled individuals. These findings suggest that H. asinina populations in Salando Island are primarily associated with coral reef habitats characterized by relatively high temperature and salinity levels. The species forms aggregated population structures and exhibits a male-biased sex ratio. The ecological data presented in this study provide essential baseline information to support sustainable management and conservation strategies for abalone populations in the coastal waters of Central Sulawesi, Indonesia.

## INTRODUCTION

Abalone (*Haliotis asinina*) is one of the most economically valuable marine molluscs and has become an important commodity in the international seafood market. In Indonesia, it is commonly known as the "seven-eyed shell" or "siput balik batu" and represents a promising fishery resource with significant development potential. Global demand


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for abalone reaches thousands of tons annually; however, its natural availability continues to decline due to overexploitation, habitat degradation, and coastal environmental changes (Peters *et al*., 2024; Cook, 2023).

The eastern coastal region of Indonesia, including Tolitoli Regency in Central Sulawesi Province, possesses marine ecosystems that provide ideal habitats for various marine biota, including abalone. One of the potential sites is Salando Island, characterized by extensive coral reefs and seagrass beds that serve as natural habitats for this species. Nevertheless, scientific data on the abundance, distribution patterns, and sex ratio of abalone populations in this region remain limited. Such information is essential to support sustainable management and conservation strategies, particularly given the increasing fishing pressure and the degradation of marine environments (Mingoa-Licuanan & Gomez, 2002).

The abundance of abalone populations is influenced by various environmental and biological factors. Parameters such as water quality, substrate type, and the intensity of human activities determine the survival and spatial distribution of abalone in the wild. Previous studies have shown that rocky and coral substrates provide optimal habitats for larval settlement and juvenile growth (Hadijah & Viky, 2015; Setyono *et al*., 2017). Moreover, salinity plays a crucial role in the growth and physiology of abalone, with optimal conditions typically ranging between 25–35 ppt (Creencia & Noro, 2018).

The sex ratio is a critical parameter in population dynamics, as it directly affects reproductive potential. In some abalone populations, the sex ratio may vary due to environmental factors or fishing pressure (Ishak *et al*., 2019; Kim *et al*., 2016). A study conducted in the coastal waters of Tapulaga, Southeast Sulawesi, reported that H. asinina exhibited a relatively balanced male-to-female ratio, indicating a healthy and natural population condition (Ishak *et al*., 2019).

Research on distribution and sex ratios has also been carried out on other mollusc species. For example, a study of the freshwater mussel (Anodonta woodiana) in Lake Rawapening, Central Java, demonstrated that environmental factors such as water quality, depth, and human activities strongly influence species abundance and distribution patterns (Setyobudi *et al*., 2018). Species distribution patterns may also reflect human intervention through conservation practices or resource management based on traditional ecological knowledge (Berkes *et al*., 2000). The sex ratio of a population can change due to uneven exploitation between sexes, which is commonly observed in species with high economic value (Campos *et al*., 2021).

The present study aims to provide baseline information on the abundance, distribution, and sex ratio of *Haliotis asinina* in the coastal waters of Salando Island. These findings are expected to serve as a scientific foundation for the sustainable management and conservation of this economically important species in the coastal ecosystems of Central Sulawesi.

## MATERIAL AND METHODS

The study was conducted from July 27 to August 03, 2025 at Salando Island, Tolitoli, Central Sulawesi, located at coordinates 1°20'08.8"N and 120°47'44.7"E.

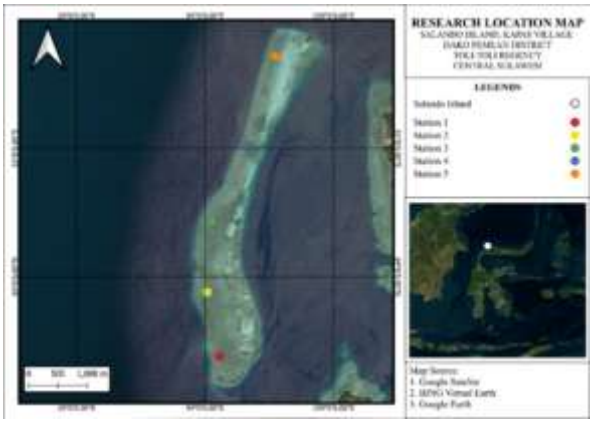


**Fig 1.** Map of the Research Location

Species identification was carried out directly at the study site, and further examinations were conducted at the Laboratory of Animal Biosystematics and Evolution, Department of Biology, Faculty of Mathematics and Natural Sciences, Tadulako University.

The research applied a descriptive-exploratory approach. Sampling locations were determined using purposive sampling, taking into account ecological conditions and site suitability. Samples were collected from five stations based on substrate types where the species was found. At each station, three line transects of 25 m were established, with five quadrat plots measuring 5 × 5 m laid toward the sea.

Some specimens were preserved in 70% alcohol and stored in a cool box for gonad identification. Each specimen was recorded and classified by sex, based on gonad coloration.

The equipment used included rulers, a camera (Nikon D100), knife or crowbar, buckets, measuring tapes, transect ropes, a thermometer, a pH meter, a salinometer, a GPS unit, plastic trays, plastic bags, zip-lock bags, sample bottles, writing tools, and labels. Alcohol (70%) was used as the primary

preservative. Sample preparation involved immersion in 70% alcohol, and photographic documentation was performed with a Nikon D100 camera.

Environmental parameters measured consisted of pH, temperature, salinity, and the type of substrate where samples were found. Data analysis included population abundance, expressed as the mean number of individuals per unit area and volume. The density of *Haliotis asinina* was calculated using Odum (1993) formula. Distribution patterns were analyzed using Morisita's index to determine whether the distribution was clumped, random, or uniform. The sex ratio was expressed as the proportion of males to females identified.

## RESULTS AND DISCUSSION

### Description of Abalone

Abalone is a marine mollusc belonging to the class Gastropods, family Haliotidae, and genus Haliotis. The shell of abalone is flat, broad, and oval-shaped, with a hard exterior surface that ranges in color from greenish-brown to grayish, decorated with small protuberances and a row of respiratory pores aligned along one side. The inner surface of the shell displays a lustrous nacreous layer (mother of pearl). Its soft body consists of a broad, muscular foot, which functions to firmly attach the animal to coral in shallow marine habitats. The mantle covers most of the body and is responsible for secreting the shell. Sensory organs in the form of small tentacles are located around the mouth.

**Fig 2.** Sample of Abalone (*Haliotis asinina*) (Scale bar = 1 cm).

Water quality parameters temperature, salinity, and pH are shown in **Table 1.** The data analysis of abalone abundance is presented in **Table 2.** The results of the Morisita index analysis from the five sampling stations showed Id > 1 with a value of 2.25, indicating a clumped distribution pattern. The analysis data of sex ratio observations are presented in **Table 3.**

**Table 3.** Analysis Results of Sex Ratio

| Station | Male | Female | Ratio |
|---|---|---|---|
| I | 15 | 9 | 1,66 : 1 |
| II | 7 | 8 | 1 : 1,14 |
| III | 3 | 4 | 1 : 1,33 |
| IV | 12 | 7 | 1,71 : 1 |
| V | 6 | 6 | 1 : 1 |
| Total | 43 | 34 | **1,26 : 1** |

**Table 1.** Environmental Parameters

| Parameters | Station | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| pH | 7 | 7 | 7 | 6,68-6,99 | 6,47-7,2 |
| Temperature (˚C) | 33,5 | 34-34,2 | 34-36 | 33,6-34,2 | 33,5-33,7 |
| Salinity (ppt) | 32 | 32,1-35,6 | 32,4-34,1 | 32,4-33,7 | 32,1-33 |
| Substrate | coral | coral | coral | coral | coral |

**Table 2.** Results of Abalone Abundance Observations

| | Total Individuals per Station | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| **Transect 1** | 9 | 2 | 1 | 5 | 3 |
| | 4 | 2 | 1 | 2 | 2 |
| | 3 | 0 | 0 | 2 | 0 |
| **Transect 2** | 3 | 1 | 2 | 4 | 2 |
| | 4 | 3 | 1 | 2 | 1 |
| | 0 | 0 | 1 | 1 | 0 |
| **Transect 3** | 3 | 5 | 1 | 3 | 1 |
| | 1 | 2 | 1 | 3 | 3 |
| | 0 | 0 | 0 | 0 | 0 |
| **Total** | 27 | 15 | 8 | 22 | 12 |
| **Abundance(Ind/m$^2$)** | 0,36 | 0,20 | 0,11 | 0,30 | 0,16 |
| **Mean** | | | **0,23** | | |

## Discussion

### Environmental Condition of Salando Island

Geographically, Salando Island is located at 01°20'28" N and 120°47'51" E, within Kapas Village, Dako Pemean District, Tolitoli Regency. Salando Island is surrounded by white sandy beaches and extensive coral reefs, with a seagrass along the reef flat that emerges during low tide (Dinas Perikanan Kabupaten Tolitoli, 2021).

The results from temperature in five observation stations ranged between 33.5–36°C, there was no notable difference in temperature, with variations of 1-2°C at the stations. This range is relatively high compared to the optimal temperature for *Haliotis asinina* survival, which is around 24°C (Basir *et al*., 2023). Results from observations at five stations indicated that the water temperature was no longer suitable for the growth of Abalone. Water temperature is closely related to the amount of dissolved oxygen present in water and how aquatic organisms use oxygen. Dissolved oxygen is inversely related to temperature; as water temperature increases, the oxygen levels decline. Rising temperatures lead to higher metabolic rates. As metabolism rises, additional energy is needed to adjust to the surroundings, leading to lower oxygen levels because of heightened energy metabolism (Hayati *et al*., 2018).

Salinity ranged between 32.1–35.6 ppt, which falls within the general tolerance range of abalone (28–34 ppt; Rusdi & Jompa, 2020). Salinity range affects the osmotic level and energy content of Abalone. Salinity increases can be affected by when the measurement is taken and the tidal conditions present during that time. The salinity of a water body is affected by the entry of freshwater into saltwater, precipitation, seasonal changes, geography, tidal actions, and evaporation (Sumarno, 2013).

pH values ranged between 6.68–7.20, which are lower than normal seawater pH (±8.1) (Rusdi dan Jompa, 2020). Such acidic conditions can negatively affect abalone, particularly in embryonic development, larval growth, and shell formation (Tahil & Danilo, 2016; Santander & Sayno, 2018).

Qualitative observations showed that *Haliotis asinina* were attached to coral reef substrates. Such substrates provide shelter, settlement surfaces for larvae, and food resources such as microalgae and biofilm (Creencia & Noro, 2018). Habitat degradation caused by sedimentation, destructive fishing, or climate change may reduce the carrying capacity for abalone populations (Philips and Shima, 2006; Mundy and McAllister, 2022; Sugiono, *et al*., 2022).

### Abundance and Distribution Pattern of Abalone

The number of individuals varied among stations. The highest abundance was observed at Station 1 (27 individuals), while the lowest abundance occurred at Station 3 (8 individuals). The average density across the study area was 0.23 individuals/m². High abundance in stations 1 and 4 was associated with complex substrates and high of algae, while low abundance in station 3 was likely influenced by sedimentation or fishing activities. This aligns with Creencia & Noro (2018), that habitat quality directly influences abalone populations. Morisita's Index analysis yielded an Id value > 1 at all stations, specifically 2.25, indicating a clumped distribution pattern. Such a pattern is typical of benthic organisms that depend on specific habitats such as reef crevices and areas with abundant food availability (Krebs, 1999; Ishak *et al*., 2020).

### Sex Ratio

Observation revealed that the sex ratio of *Haliotis asinina* in Salando Island waters was 56% males and 44% females, or approximately 1.26 : 1. Ecologically, this ratio is relatively balanced and supports reproductive success (Rochmady *et al*., 2012). The slight dominance of males may be influenced by environmental factors (temperature, substrate, and food availability) or fishing activities. Female abalone tend to be larger in size and have higher economic value, making them more susceptible to exploitation. If such conditions persist, natural reproduction potential in the habitat could decline.

## CONCLUSION

The ecological assessment of *Haliotis asinina* in Salando Island indicates that the population is experiencing environmental pressures that may affect its long term sustainability. Elevated water temperatures, suboptimal pH levels, and localized sedimentation suggest that the current habitat conditions are approaching the physiological tolerance limits of abalone, thereby potentially reducing growth, survival, and reproductive success. The distribution pattern and spatial differences in abundance reflect the species strong dependence on high quality coral substrates and adequate algal resources, highlighting the vulnerability of abalone to habitat degradation caused by sedimentation and destructive fishing activities. Although the sex ratio remains relatively balanced, continued environmental stress or selective harvesting especially of larger females may impair future recruitment. Overall, the findings

informed that *Haliotis asinina* is need a habitat protection and routine monitoring of water quality to ensure the ecological resilience of abalone populations in Salando Island.

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