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Population Density and Distribution Pattern of Golden Apple Snail (*Pomacea canaliculata* L.) in the Rice Field Ecosystem

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Abstract

The golden apple snail (*Pomacea canaliculata*) is a freshwater mollusc species commonly found in rice field ecosystems and is recognized as one of the major pests of rice crops. This species possesses a high adaptive capacity and a rapid reproductive rate, allowing its population to increase rapidly and cause significant damage to rice plants. Nevertheless, the golden apple snail also has ecological roles and potential benefits, including serving as an alternative feed source for livestock and fish, as well as contributing to the decomposition of organic matter in aquatic environments. This study aimed to analyze the population density and distribution pattern of the golden apple snail in the rice fields of Dolago Padang Village, South Parigi District. The research employed a quantitative descriptive approach using a field survey method. Data were collected using a quadrat sampling technique with plot sizes of 2 × 2 m established at three different observation stations. The number of golden apple snail individuals within each plot was counted directly and subsequently analyzed to determine population density and distribution patterns using the Morisita Index. In addition, environmental parameters, including water temperature and pH, were measured. The results showed that a total of 90 golden apple snail individuals were recorded during the study. Population density ranged from 1 to 2 individuals/m², which was categorized as moderate. The distribution pattern of the golden apple snail at all observation stations was classified as uniform, as indicated by Morisita Index values below 1 (Id < 1). Environmental conditions, with temperatures ranging from 27–30°C and pH values between 6.5 and 7.2, were within the optimal range supporting the presence and development of the golden apple snail.

Keywords: Golden Apple Snail; Population Density; Distribution Pattern; Morisita Index; Rice Field Ecosystem.

INTRODUCTION

Rice field ecosystems are flooded agricultural lands that support the survival of various aquatic organisms, including *Pomacea canaliculata*, one of the most commonly encountered aquatic species in these habitats (Safitri et al., 2021). In addition to serving as the primary source of rice production, rice field ecosystems provide a range of environmental services, such as habitats for biodiversity, natural water filtration, and the maintenance of ecological balance (Horgan et al., 2021). Environmental conditions in rice fields, characterized by standing water, muddy substrates, and high organic matter content, create favorable habitats for the growth and development of aquatic organisms. These ecological factors support the presence and proliferation of the golden apple snail, which is known for its high adaptability to shallow, nutrient-rich aquatic environments. Furthermore, the species exhibits a high reproductive rate and rapid dispersal ability, enabling populations to increase quickly under suitable environmental conditions. Large populations of this species can alter the structure of aquatic communities and cause significant damage to rice crops through their herbivorous feeding activities (Guan et al., 2024).

The golden apple snail, also known as the channeled apple snail, is a freshwater gastropod belonging to the family Ampullariidae. Native to South America, this species was introduced to Indonesia in the early 1980s and has since become a serious pest of rice cultivation throughout Indonesia and other Southeast Asian countries. Hundreds of hectares of rice fields and young rice plants have suffered severe damage due to infestations of the golden apple snail, which has been identified primarily as *Pomacea canaliculata* (Marwoto & Isnaningsih, 2011). According to specimens preserved in the Museum Zoologicum Bogoriense (MZB) collection, *P. canaliculata* is characterized by a rounded shell with coloration ranging from yellow to dark brown. The shell color is generally lighter around the suture region, and the shell wall is relatively thick, with some individuals displaying dark brown transverse bands extending toward the shell aperture. This species possesses a remarkable ability to adapt to a wide range of environmental conditions and exhibits rapid reproductive capacity, allowing its population to increase substantially within a short period of time (Savira et al., 2024).

Golden apple snails are among the most common agricultural pests and can cause severe damage to rice crops. *Pomacea canaliculata* has been reported to inflict damage ranging from 13.2% to 96.5% on rice plants. According to various studies, yield losses caused by this pest may reach 10–40% in rice cultivation areas (Horgan et al., 2021). In general, apple snails of the genus *Pomacea* possess a high capacity to adapt to a wide range of freshwater habitats, including rivers, rice fields, lakes, and wetlands (Guan et al., 2024). Despite their detrimental impacts on agriculture, these snails also have potential economic value, particularly as an alternative feed ingredient in aquaculture (Andriani et al., 2023). Golden apple snails contain protein, lipids, and carbohydrates that can serve as nutritional sources for cultured fish, thereby reducing dependence on more expensive feed ingredients such as fish meal. The utilization of alternative protein sources in aquaculture feed has been shown to improve feed efficiency, growth performance, and survival rates of farmed fish (Santos et al., 2020).

The occurrence of golden apple snails in rice field ecosystems is closely associated with environmental factors such as water availability, substrate characteristics, and food resources. These factors influence both population density and distribution patterns within a habitat (Dewi et al., 2022). The distribution of organisms in rice field ecosystems is strongly affected by relatively homogeneous environmental conditions, which often promote a more even distribution in areas with similar resource availability. Population density and distribution pattern are two important ecological parameters used to understand the dynamics of organisms within a habitat. The spatial distribution of organisms is influenced not only by physical environmental conditions but also by biotic interactions, such as competition and resource availability, which collectively shape patterns of individual dispersion (Morales & Barone, 2016). Population density refers to the number of individuals occupying a given area, whereas distribution pattern describes how those individuals are arranged spatially, whether randomly, clumped, or uniformly (Dewi et al., 2022). In rice field ecosystems, the density and distribution of golden apple snails are affected by various environmental factors, including water depth, substrate type, and the availability of organic matter as a food source (Mulyanti et al., 2022). Variations in these environmental conditions often cause organisms to concentrate in areas that provide the most favorable conditions for survival (Hendrival et al., 2022). Therefore, this study aimed to analyze the population density and distribution pattern of the golden apple snail as a basis for developing effective management and pest control strategies in rice field ecosystems.

MATERIALS AND METHODS

Study Area

This study was conducted in March 2026 in the rice fields of Dolago Padang Village, South Parigi District, Parigi Moutong Regency, Central Sulawesi, Indonesia (Figure 1). The study area consists of irrigated rice fields characterized by standing water, muddy substrates, and dense rice vegetation. These environmental conditions provide suitable habitats for a variety of aquatic organisms, including the golden apple snail (*Pomacea canaliculata*), which is commonly found in rice field ecosystems. The study site was selected using a purposive sampling approach based on the presence and abundance of golden apple snail populations.

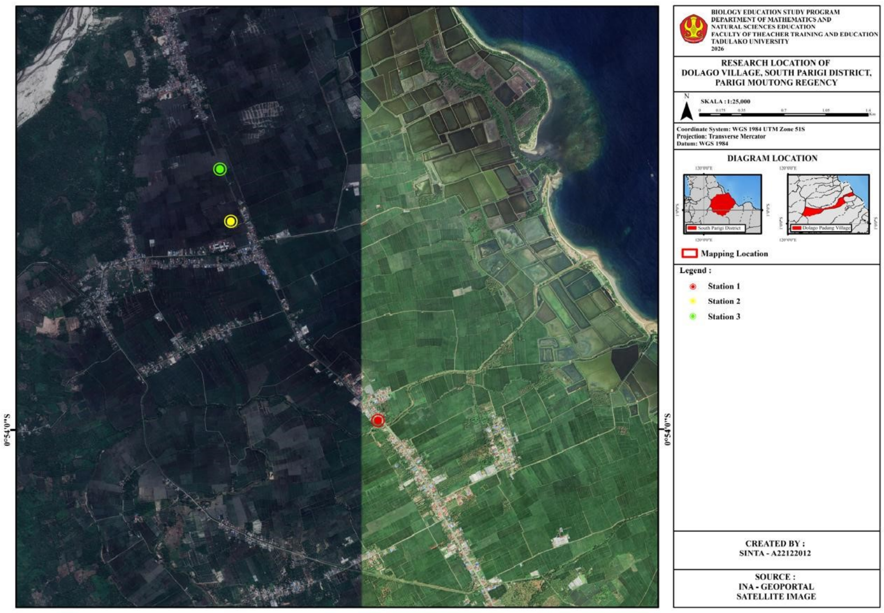

Figure 1. Map of the research location in Dolago Padang Village, Parigi Moutong Regency, Central Sulawesi, Indonesia.

Procedures

The initial stage of the study involved a field survey to determine sampling locations based on the presence of golden apple snails within the rice field ecosystem. Site selection considered environmental conditions favorable for the species, including the presence of standing water, muddy soil substrates, and rice plants that serve as the primary food source. After the study area was established, the rice field was divided into three observation stations. Station 1 was located near residential areas, Station 2 represented a transitional area, and Station 3 was situated farther from residential settlements. This station-based approach was intended to provide a more comprehensive and accurate representation of the golden apple snail population across the study site.

Sampling was conducted using a quadrat method with plot dimensions of 2 × 2 m at each observation station. Quadrats were established systematically while maintaining sufficient distances between plots to prevent overlap among observation areas. An equal number of plots was used at each station to ensure data consistency and facilitate comparative analyses among stations. Each plot was clearly marked to maintain observation consistency throughout the study period. Plot placement was determined based on the predefined sampling locations while taking surrounding environmental conditions into consideration.

Golden apple snails were surveyed through direct counting of all individuals found within each observation plot. Observations were conducted carefully by examining the entire plot area, including the soil surface, standing water, and areas surrounding rice plants, as golden apple snails may occupy various microhabitats within rice fields. The number of individuals recorded in each plot was documented systematically to minimize counting errors. Particular attention was given to ensure that no individuals were overlooked or counted more than once. Data were recorded separately for each plot and observation station to facilitate subsequent data processing and analysis.

During the sampling process, general environmental conditions at the study site were also observed and recorded as supporting data. These observations were used to help explain the relationship between environmental characteristics and the population density and distribution patterns of golden apple snails at each station. All collected data were then organized systematically for further analysis. The data were used to calculate population density based on the number of individuals per unit area and to determine distribution patterns using appropriate ecological analytical methods.

Data Analysis

Data on the population density and distribution pattern of the golden apple snail (*P. canaliculata*) were obtained by calculating the total number of individuals collected during each sampling event. All data were tabulated and analyzed using Microsoft Excel. Supporting environmental data, including water pH and temperature, were measured directly in the field during sample collection.

Individual Density

The population density of golden apple snails in the rice field ecosystem was calculated and expressed as the number of individuals per square meter (individuals/m²) using the following formula (Soegianto, 1994):

$$Di = \frac{N}{A}$$

Where:
Di = population density of species *i*;
N = total number of individuals of species *i*;
A = total area sampled (m²).

Distribution Pattern

The distribution pattern is to take and count all individuals in each plot, then use the Morisita Index formula (Suin, 1989):

$$Id = \frac{\sum ni(ni-1)N}{n(ni-1)}$$

Where:
Id = Morisita Index
ni = Number of individuals in each plot
N = Total number of plots
n = Total number of individuals recorded from all plots

Interpretation of the Morisita Index:
Id = 1 = Random distribution pattern
Id > 1 = Clumped (aggregated) distribution pattern
Id < 1 = Uniform (regular) distribution pattern

RESULTS AND DISCUSSION

Number of Golden Apple Snail Individuals

The number of golden apple snail (*P. canaliculata*) individuals recorded in the rice fields of Dolago Padang Village, South Parigi District, showed considerable variation among the observation stations. A total of 20 individuals were found at Station I, 30 individuals at Station II, and 40 individuals at Station III, which had the highest abundance. Overall, a total of 90 individuals were recorded across all observation stations (Table 1).

The differences in the number of individuals among stations indicate the influence of environmental conditions and the level of human disturbance. Station I, which was located near residential areas, tended to have a lower number of individuals due to anthropogenic activities such as pesticide application and land management practices that may suppress golden apple snail populations (Hasanah et al., 2024). In contrast, Station III, situated farther from residential settlements, supported a higher abundance of individuals because of its more stable habitat conditions and lower levels of disturbance. This finding is consistent with the study of Safitri et al. (2021), which reported that golden apple snail abundance is strongly influenced by habitat environmental conditions. In addition, environmental factors such as water availability and substrate characteristics play important roles in determining population abundance (Tarigan et al., 2017). Favorable environmental conditions can enhance the activity, survival, and reproductive success of golden apple snails, thereby contributing to higher population densities (Savira et al., 2024).

Table 1. Number of golden apple snail individuals.

Station	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Total (N)
I	3	4	5	3	5	20
II	5	6	7	6	6	30
III	7	8	9	8	8	40
Total						90

Population Density

Nilai The population density of the golden apple snail (*P. canaliculata*) in the rice fields of Dolago Padang Village, South Parigi District, Parigi Moutong Regency, varied among the observation stations (Table 2). The density recorded at Station I was 1 individual/m², increasing to 1.5 individuals/m² at Station II and reaching 2 individuals/m² at Station III. Nevertheless, the density values at all three stations were classified within the moderate density category. The variation in population density among stations indicates that environmental conditions at each location influenced the number of individuals found within the same sampling area. In general, the greater the number of individuals recorded within a given area, the higher the population density at that location. The population density of aquatic organisms is strongly influenced by resource availability and habitat quality, as favorable environmental conditions enhance survival and reproductive success (Lodge et al., 2017).

These findings are consistent with the study conducted by Dewi et al. (2022), which reported that the density and distribution patterns of golden apple snails in rice fields are strongly affected by environmental factors such as water depth, food availability, and the degree of habitat disturbance. Furthermore, Horgan et al. (2021) explained that human activities within rice field ecosystems can suppress pest populations, thereby influencing the density values observed in the field. Consequently, differences in environmental quality and anthropogenic disturbance among stations likely contributed to the variation in golden apple snail density recorded during this study.

Tabel 2. Population density of of golden apple snail.

Station	Total of Individual (N)	Area (m²)	Density	Category
I	20	20	1	Currently
II	30	20	1.5	Currently
III	40	20	2	Currently

Distribution Pattern

The calculation of the Morisita Index at each observation station yielded index values (Id) of 0.842105 at Station I, 0.873563 at Station II, and 0.903846 at Station III (Table 3). Since all index values were less than 1 (Id < 1), the distribution pattern of the golden apple snail (*P. canaliculata*) at all three stations was classified as uniform (regular). The uniform distribution pattern observed in this study is likely associated with the relatively homogeneous conditions of the rice field habitat, particularly in terms of water depth, substrate characteristics, and food availability. A uniform distribution pattern commonly occurs in environments where resources are evenly distributed, causing individuals to occupy space more evenly due to competitive interactions in resource utilization. Under such conditions, organisms tend to maintain a relatively regular spacing rather than forming clusters.

In rice field ecosystems, agricultural management practices such as uniform irrigation systems and rice planting at predetermined spacing intervals can create relatively homogeneous environmental conditions. As a result, golden apple snails may be distributed more evenly throughout the cultivated area. This finding is consistent with the study of Dewi et al. (2022), which reported that the distribution patterns of organisms in rice field ecosystems are strongly influenced by environmental uniformity and land management practices. Therefore, the regular distribution pattern recorded in this study suggests that the rice field habitat in Dolago Padang Village provides relatively consistent environmental conditions that support a uniform spatial arrangement of golden apple snail populations.

Table 3. Distribution pattern of golden apple snail.

Station	n	N	Σni(ni-1)	Id	Category
I	5	20	64	0.842105	Regular
II	5	30	152	0.873563	Regular
III	5	40	282	0.903846	Regular

Description: Id = 1 random distribution pattern, Id > 1 clustered distribution pattern, and Id , < 1 regular distribution pattern.

Measurement of Ecological Factors

The physical and chemical environmental parameters measured at the three observation stations in the rice field area included water temperature and pH, which were recorded during both morning and afternoon observations (Table 4). In general, water temperature increased from morning to afternoon at all stations, with values ranging from 27°C to 30°C. Station I exhibited the lowest temperature in the morning (27°C), whereas the highest temperature was recorded at Station III in the afternoon (30°C). This pattern indicates the influence of solar radiation intensity on the increase in water temperature throughout the day. Meanwhile, water pH values ranged from 6.5 to 7.2, indicating conditions that were neutral to slightly acidic. Station II tended to have lower pH values than the other stations, whereas Station III exhibited relatively higher pH values. These temperature and pH conditions remain suitable for aquatic organisms, including the golden apple snail (*P. canaliculata*), as they fall within the optimal tolerance range for growth, survival, and physiological activity (Safitri et al., 2021).

Environmental parameters such as temperature and pH are important factors influencing the distribution, abundance, and biological performance of aquatic organisms. Favorable environmental conditions can enhance metabolic activity, feeding behavior, and reproduction, thereby supporting the persistence and development of golden apple snail populations within rice field ecosystems. Therefore, the ecological conditions observed during this study were considered conducive to the survival and establishment of golden apple snail populations across the three observation stations.

Table 4. Ecological factors measured in Rice Field Area.

No	Parameter	Ecological Factor in Rice Field Area					
		Station I		Station II		Station III	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
1	Temperature (˚C)	27	28	28	29	29	30
2	Water pH	6.8	7.0	6.5	6.7	7.0	7.2

Discussion

The golden apple snail (*P. canaliculata*) is a freshwater mollusk belonging to the family Ampullariidae and is recognized as one of the major pests of rice crops in rice field ecosystems. Native to South America, this species has spread widely throughout many regions of Asia, including Indonesia, primarily through human-mediated introductions. The golden apple snail exhibits a high degree of adaptability to various environmental conditions, thriving in both shallow and stagnant freshwater habitats. In addition, it is a herbivorous organism that actively feeds on young rice plants, causing significant damage, particularly during the early stages of crop growth. Its high reproductive rate and ability to survive under unfavorable environmental conditions have made the golden apple snail a highly successful invasive species that is difficult to control. Therefore, understanding the biological characteristics of this species is essential for the effective management of rice field ecosystems (Horgan et al., 2021).

In relation to these characteristics, the golden apple snail possesses morphological features that support its adaptability to diverse aquatic habitats. Generally, it has a spiral-shaped shell with coloration ranging from golden yellow to greenish-brown, and adult individuals can reach a shell diameter of approximately 5–7 cm. The shell is equipped with an operculum that functions as a protective structure, allowing the snail to seal itself when environmental conditions become unfavorable. Furthermore, the species possesses two respiratory systems, namely gills and a simple lung, enabling it to survive in waters with low dissolved oxygen concentrations. Golden apple snail eggs are bright pink in color and are typically deposited above the water surface or on emergent vegetation to reduce the risk of predation. These characteristics demonstrate the species' strong morphological adaptations that contribute to its survival, dispersal, and establishment in a wide range of freshwater environments (Tarigan et al., 2022).

These adaptive characteristics are reflected in the results of the study on the abundance of golden apple snails at each observation station. As shown in Table 1, the number of golden apple snail (*Pomacea canaliculata*) individuals varied considerably among stations, with the lowest abundance recorded at Station I (20 individuals) and the highest at Station III (40 individuals). This variation indicates that environmental conditions and human activities influence the abundance of golden apple snails. Habitats with more stable environmental conditions and lower levels of disturbance generally support larger populations (Wibowo & Rahayu, 2021). In addition, the availability of organic matter within the aquatic substrate contributes to increased abundance, as golden apple snails utilize it as a food resource (Kurniawati & Sari, 2021). Station I, located near residential areas, was likely subjected to greater environmental pressure due to anthropogenic activities such as pesticide application and land management practices. In contrast, Station III, situated farther from human settlements, provided a more stable habitat with fewer disturbances. Therefore, the variation in the number of individuals observed among stations reflects differences in habitat quality across the study area (Safitri et al., 2021).

Consistent with the variation in abundance, population density also differed among observation stations. As presented in Table 2, the lowest density was recorded at Station I, with 1 individual/m², whereas the highest density occurred at Station III, reaching 2 individuals/m², although all stations remained within the moderate density category. These differences suggest that environmental conditions influence the number of individuals occupying a given area. The higher density observed at Station III indicates that habitat conditions at this location were more favorable, particularly regarding water availability, food resources, and the relatively low level of environmental disturbance. Environmental factors such as water depth, food availability, and substrate quality are recognized as major determinants of golden apple snail population density (Sari & Utami, 2022). Conversely, anthropogenic activities, including pesticide use at Station I, may suppress population size and reduce density. Furthermore, the species' ability to efficiently exploit available resources contributes to increased population density in habitats that provide suitable environmental conditions (Dewi et al., 2022).

In addition to population density, the distribution pattern of golden apple snails is an important indicator for understanding the spatial arrangement of populations within a habitat. Based on the Morisita Index calculations presented in Table 3, all observation stations exhibited index values lower than 1, indicating a uniform distribution pattern. This pattern suggests that individuals were distributed relatively evenly across the sampling plots. Such a distribution indicates that environmental conditions at the study site were relatively homogeneous, allowing resources to be distributed evenly throughout the habitat (Yuliana & Fitriani, 2022). Furthermore, agricultural management practices, such as irrigation systems and planting arrangements, may create uniform environmental conditions that influence the spatial distribution of organisms within rice field ecosystems (Horgan et al., 2021). Therefore, the observed uniform distribution pattern reflects a habitat that is relatively stable and homogeneous (Rahmawati et al., 2023). A uniform distribution pattern is commonly associated with habitats characterized by low environmental variability, where resources are evenly available and organisms are distributed more regularly across space (Isabwe et al., 2022).

The observed population density and distribution patterns are closely related to the environmental factors measured at the study site. As shown in Table 4, water temperature ranged from 27–30°C, while pH values ranged from 6.5 to 7.2, indicating environmental conditions that remain within the optimal range for the survival of golden apple snails. These temperature and pH conditions support metabolic activity and reproduction, thereby influencing population abundance. Physicochemical parameters such as temperature and pH are among the primary factors affecting the growth and reproduction of freshwater mollusks, with optimal conditions generally occurring at temperatures of 25–30°C and pH values that are neutral to slightly acidic (Zhang et al., 2018). In addition, stable environmental conditions help maintain the physiological balance of aquatic organisms (Effendi, 2003). Consequently, the environmental parameters recorded during this study can be considered favorable for the survival, growth, and reproductive success of golden apple snails, thereby supporting the persistence of their populations within the rice field ecosystem (Horgan et al., 2018).

CONCLUSION

In rice field ecosystem of Dolago Padang Village, South Parigi District, consisted of 90 individuals distributed across three observation stations. Population density ranged from 1–2 individuals/m² and was categorized as moderate, with the highest density recorded at the station characterized by more stable habitat conditions and minimal anthropogenic disturbance. The Morisita Index analysis indicated that the distribution pattern at all stations was uniform ($Id < 1$), suggesting a relatively even spatial distribution of individuals, likely influenced by the homogeneous environmental conditions and the uniform management practices of the rice fields. Furthermore, environmental parameters, including water temperature (27–30°C) and pH (6.5–7.2), were within the optimal range for the survival, growth, and reproduction of golden apple snails. These findings provide baseline information on the population dynamics and distribution patterns of *Pomacea canaliculata*, which may serve as a scientific basis for the management and control of this pest species in rice field ecosystems.

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