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Freshwater Shrimp (*Decapoda*) in Aceh: A Promising Resource for Aquaculture Development

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Abstract

Freshwater shrimp of the genus *Macrobrachium* represent an underutilized resource in Aceh Province, Indonesia, despite the region's rich freshwater ecosystems and the global economic value of shrimp aquaculture. This study presents the first integrative assessment of the aquaculture potential of 13 *Macrobrachium* species collected from 27 freshwater sites across Aceh. Species were evaluated using morphological identification, ecological field surveys, literature reviews, and key biological parameters, including egg size, larval development, salinity tolerance, and local consumption. Most species exhibited r-strategist reproductive traits and prolonged larval stages, requiring brackish or marine environments, which limited their suitability for closed freshwater systems. However, *M. lanchesteri* displayed abbreviated larval development and completed its life cycle in freshwater, making it a strong candidate for sustainable aquaculture. *M. idae* was assessed as moderately suitable due to extensive supporting literature and local use. These findings highlight both the constraints and opportunities for freshwater shrimp cultivation in Aceh, providing a foundation for future research and development in aquaculture diversification and local food security.

1. Introduction

Freshwater shrimp (*Decapoda*) are a significant freshwater commodity, alongside fish, with considerable ecological and economic value [1–4]. In many regions around the world, freshwater shrimp serve as a primary source of protein for local communities, making a significant contribution to the aquaculture industry [5]. Aceh Province is endowed with diverse freshwater ecosystems, rivers, lakes, swamps, and reservoirs that offer promising conditions for aquaculture development. However, freshwater shrimp cultivation remains largely undeveloped in the region, with no production data recorded in provincial aquaculture statistics [6]. This underdevelopment is attributed to several factors, including limited hatchery infrastructure, inadequate technical expertise in larval rearing, and a historical focus on marine shrimp production. As such, there is an urgent

need for a systematic evaluation of local freshwater shrimp species to assess their potential for sustainable aquaculture development.

Several species of freshwater shrimp from the genus *Macrobrachium* have been widely cultivated globally for both consumption and ornamental purposes [7]. Larger-sized species such as *Macrobrachium rosenbergii*, *M. malcolmsonii*, *M. nipponense*, *M. carcinus*, and *M. vollenhovenii* have become important aquaculture commodities for meeting human food demands [4, 7, 8]. Among these, *M. rosenbergii* is the most widely cultured and distributed species across various countries [9, 10], demonstrating high adaptability and economic value in freshwater aquaculture systems.

In Indonesia, the shrimp aquaculture industry is still dominated by marine shrimp commodities, such as Litopenaeus vannamei (Whiteleg shrimp) and Penaeus monodon (giant tiger prawn) [11–16], while the potential of freshwater shrimp, widely distributed in inland and mountainous regions, remains largely underdeveloped. Aceh Province, in particular, harbors a rich diversity of local and endemic freshwater shrimp species, which could serve as a foundation for sustainable aquaculture development to support food security and regional economic growth.

Although several studies have examined the biodiversity and ecological distribution of Aceh's freshwater shrimp, there has been no integrated assessment of their cultivation potential, defined here as their suitability for aquaculture based on documented cultivation feasibility rather than generalized economic or aesthetic descriptors. These biological and economic indicators are critical in evaluating species for sustainable aquaculture development. However, studies on the potential of local Acehnese freshwater fish have been widely reported by researchers [11–13]. Although several studies have documented the biodiversity and ecological distribution of Aceh's freshwater shrimp [2, 14], no previous research has combined species identification with a structured evaluation of their aquaculture potential. This study represents the first integrative assessment in Aceh that links taxonomy with cultivation suitability, defined, documented reproduction or larval rearing in captivity, feed adaptability (acceptance of formulated or natural diets), growth performance, including growth rate or body size at harvest, and Evidence of commercial or experimental cultivation elsewhere. By bridging this gap, the research provides practical insights for developing freshwater shrimp aquaculture that is tailored to local species and conditions, thereby supporting both conservation and livelihood diversification.

This study aims to provide up-to-date information on native freshwater shrimp species in Aceh Province, highlighting their promising potential for aquaculture development, particularly for consumption purposes. By generating baseline data, the study seeks to inform policymakers, researchers, and aquaculture practitioners, ultimately supporting the development of sustainable freshwater shrimp farming that contributes to environmental conservation and promotes local economic growth. The research focuses on the genus *Macrobrachium* due to its ecological abundance in Southeast Asian inland waters and its established or emerging importance in global freshwater aquaculture. This genus encompasses species with diverse ecological characteristics, body sizes, and local consumption preferences, making it a suitable candidate for assessing its cultivation potential. To ensure comprehensive spatial coverage and ecological representation, 27 sampling sites were strategically selected across multiple districts in Aceh, encompassing various freshwater habitat types (lotic and lentic systems). This approach enables a robust evaluation of species distribution, ecological suitability, and aquaculture prospects within the region.

2. Materials and Methods

2.1. Sampling and Aquaculture Potential Evaluation

This study employed a descriptive-exploratory approach to assess the aquaculture potential of various *Macrobrachium* species inhabiting freshwater ecosystems in Aceh Province, Indonesia. The evaluation was based on a synthesis of primary species identification, literature review, and analysis of key biological and ecological parameters relevant to successful cultivation in closed freshwater systems. Primary data were obtained through extensive field surveys across diverse freshwater habitats, including rivers, lakes, swamps, and reservoirs. Collected specimens were identified morphologically using taxonomic keys specific to the genus *Macrobrachium*, which feature diagnostic characteristics such as rostrum shape, pereiopod structure, and body proportions [15–18].

Secondary data were compiled from both national and international scientific literature focusing on aquaculture-related aspects of each species. Particular emphasis was placed on publications detailing life cycle characteristics, salinity requirements, egg size and fecundity, and the number of larval stages. Each species was evaluated and classified according to the following parameters:

- Origin status (native vs. introduced): to infer species dispersal history in Aceh;

- Local consumption level: based on community interviews to assess market preference and socio-cultural value;
- Availability of aquaculture literature: quantified as the number of relevant peer-reviewed publications;
- Egg size and fecundity: serving as indicators of reproductive strategy and larval development type;
- Larval stage number and salinity requirement: to determine compatibility with closed freshwater culture systems;
- Aquaculture potential: qualitatively categorized as high, moderate, low, or very low based on the integrated analysis of all above parameters.

The final classification of aquaculture potential was primarily determined by biological suitability for freshwater culture systems, particularly the ability to complete the life cycle under freshwater conditions, abbreviated larval development duration, and support from both local market demand and technical literature. Species exhibiting abbreviated or direct larval development with minimal salinity requirements were identified as high-priority candidates for sustainable aquaculture development in Aceh's inland waters.

2.2. Data Analysis

Data analysis was conducted by integrating both qualitative and quantitative variables into a multi-criteria assessment matrix. Scores were assigned to each parameter per species based on thresholds derived from literature benchmarks and field observations. For categorical parameters such as origin status and local consumption, ordinal scales were applied to standardize values across species. Numerical data, including egg size, fecundity, and larval stage counts, were normalized and ranked to enable cross-species comparison. The combined scores were used to generate a composite aquaculture suitability index, allowing for classification into potential categories (high, moderate, low, very low). Descriptive statistics and comparative tables were used to highlight species-specific strengths and limitations, facilitating the prioritization of species for future aquaculture development.

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3. Results and Discussion

3.1. Results

A total of thirteen *Macrobrachium* species were identified from diverse freshwater habitats across Aceh Province, Indonesia. All species were classified as native, except for *M. lanchesteri*, which is considered an introduced species. Several species, such as *M. australe*, *M. equidens*, *M. idae*, *M. lanchesteri*, *M. lar*, *M. mammillodactylus*, *M. pilimanus*, *M. placidum*, and *M. scabriculum*, are utilized locally as sources of animal protein (Table 1). However, scientific investigations into the aquaculture potential of these taxa remain limited. Only a few species have been documented in aquaculture-related literature, with *M. idae* and *M. lanchesteri* receiving the greatest attention, supported by 10 and 9 relevant publications, respectively (Table 2). The majority of species lack sufficient technical or biological documentation to inform cultivation strategies.

Key biological parameters, such as egg size and fecundity, the number of larval stages, and salinity tolerance, were used to evaluate aquaculture potential. Most species exhibit small-sized eggs produced in high numbers, consistent with an r-strategist reproductive mode. For instance, *M. equidens* produces 1,000–6,000 eggs per clutch, while *M. lar* may produce up to 40,000 eggs. These species generally undergo prolonged larval development and require brackish to marine conditions to complete their life cycles, rendering them poorly suited for closed freshwater aquaculture systems. This is particularly evident for *M. equidens*, *M. latidactylus*, *M. lanatum*, *M. australe*, and *M. lar*, all of which were categorized as having low to very low aquaculture potential.

In contrast, *M. lanchesteri* displayed traits favorable for closed freshwater aquaculture. The species produces a relatively small number of medium-sized eggs and undergoes abbreviated larval development, with only two or more larval stages, all of which can be completed in freshwater without the need for salinity input. Based on these characteristics, *M. lanchesteri* was classified as having high aquaculture potential and is considered a promising candidate for the development of freshwater aquaculture based on local species resources.

M. pilimanus also exhibited large egg size and abbreviated larval development (two stages), and is physiologically adapted to freshwater environments. However, due to the limited availability of technical literature, particularly concerning larval rearing protocols, the species was provisionally categorized as having low aquaculture potential. *M. idae*, although still requiring low salinity conditions during early development, was assigned a moderate aquaculture

Table 1. Freshwater shrimp species and consumption preferences in Aceh waters.

No.	Species	Author and Year	Native/Introduced	Local Consumption
1	*M. australe*	Guérin-Méneville, 1838	Native	Yes
2	*M. equidens*	Dana, 1852	Native	Yes
3	*M. escelentum*	Thallwitz, 1891	Native	No Data
4	*M. idae*	Heller, 1862	Native	Yes
5	*M. latidactylus*	Thallwitz, 1891	Native	No Data
6	*M. lanatum*	Cai & Ng, 2002	Native	No Data
7	*M. lanchesteri*	De Man, 1911	Introduced	Yes
8	*M. lar*	Fabricius, 1798	Native	Yes
9	*M. mammillodactylus*	Thallwitz, 1892	Native	Yes
10	*M. neglectum*	De Man, 1905	Native	No Data
11	*M. pilimanus*	De Man, 1879	Native	Yes
12	*M. placidum*	De Man, 1892	Native	Yes
13	*M. scabriculum*	Heller, 1862	Native	Yes

Table 2. Evaluation of aquaculture potential based on reproductive traits and existing literature.

No.	Species	Egg Size and Fecundity [4]	Number of Larval Stages and Salinity Requirement [4]	Aquaculture-Related Literature	Aquaculture Potential
1	*M. australe*	Small (?)	13+? (Marine water)	1	Low
2	*M. equidens*	Small (1,000–6,000)	10 (Brackish water)	2	Low
3	*M. escelentum*	Small (?)	(Brackish water)	-	-
4	*M. idae*	Small (210–5,600)	10 (Brackish water)	10	Moderate
5	*M. latidactylus*	Small (503–1,605)	8+? (Brackish water)	-	Low
6	*M. lanatum*	Small (?)	(Brackish water)	-	Low
7	*M. lanchesteri*	Medium (59–393)	2+? (Freshwater)	9	High
8	*M. lar*	Small (up to 40,000)	11+? (Marine water)	3	Very Low
9	*M. mammillodactylus*	Small	(Brackish water)	-	Low
10	*M. neglectum*	?	?	-	-
11	*M. pilimanus*	Large	2 (Freshwater)	1	Low
12	*M. placidum*	Small	(Brackish water)	-	Low
13	*M. scabriculum*	Small (?)	(Brackish water)	1	Low

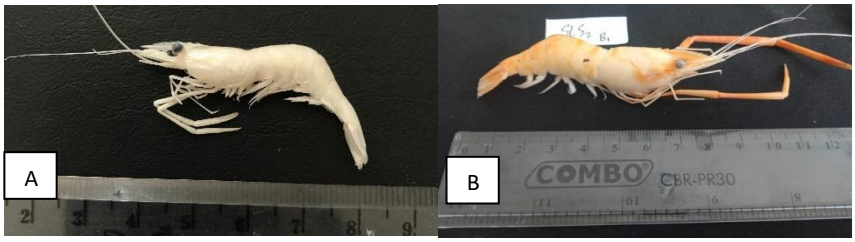

Figure 1. the high potential shrimp culture *M. lanchesteri* (A) and moderate potential culture shrimp *M. idae* (B).

potential due to its relatively well-documented life history and consistent local utilization. Visual representations of M. lanchesteri and M. idae, highlighting their suitability for aquaculture, are provided in Figure 1. Several other species, such as *M. escelentum*, *M. mammillodactylus*, and *M. neglectum*, remain poorly studied both biologically and technically. As a result, their aquaculture potential could not yet be confidently assessed. Further research is needed to explore the domestication prospects of these lesser-known species, particularly concerning their physiological adaptability and responses to controlled culture environments.

3.2. Discussion

Of the 13 *Macrobrachium* species identified from freshwater ecosystems in Aceh Province, approximately 69.23% are both edible and potentially cultivable, categorized as high, moderate, and low in value. This high proportion is attributed to their relatively large body size and widespread utilization by local communities as a protein source. Among these, at least seven species have been previously studied about aquaculture feasibility, particularly concerning larval development and early life-stage management under controlled conditions.

For instance, research on *M. lanchesteri* has provided insights into breeding, larval culture, reproductive biology, and nutrition management [19–22]. Studies on *M. idae* have explored embryonic development, hatchery seed production, dietary experimentation, and growth performance [23–26]. The larval development of *M. australe* has been successfully reared in laboratory

settings [27], while *M. equidens* has been investigated in terms of larval biology and feeding protocols [28, 29]. Similarly, larval culture techniques for *M. lar* have also been explored through experimental trials [30–32].

The development of freshwater shrimp aquaculture in Aceh is critical as a prospective contributor to regional food security and economic diversification. The province is endowed with abundant native shrimp resources that have yet to be fully utilized for cultivation [2, 14]. This situation parallels the early development of *M. rosenbergii* aquaculture, a species that now plays a major role in the global economy [1, 3, 33]. *M. rosenbergii* has experienced a steady increase in global production, reaching 313,756 metric tons in 2021, with an estimated value exceeding USD 2.45 billion. China remains the leading producer, accounting for 54.4% of global output, followed by Bangladesh, Thailand, Myanmar, and India [34]. In contrast, Indonesia contributed only 54,998.8 tons in 2022, equivalent to just 5% of the total national shrimp production (1,099,976 tons) [35]. These figures underscore the urgent need to enhance the cultivation of alternative freshwater shrimp species as a viable economic option for Indonesian communities.

Beyond *M. rosenbergii*, several other large-bodied freshwater *Macrobrachium* species have been identified as potential candidates for aquaculture, including *M. nipponense* (De Haan, 1849), *M. carcinus* (Linnaeus, 1758), *M. acanthurus* (Wiegmann, 1836), *M. tenellum* (Smith, 1871), *M. vollenhovenii* (Herklots, 1857), *M. americanum* (Bate, 1868), and *M. gangeticum* (Bate, 1868) [8, 36–38]. Cultivation efforts typically begin with broodstock management and larval rearing, which involve precise control of water quality, feeding strategies, and specific hatchery techniques [38–40]. Although larval rearing remains a key challenge in the domestication of several native freshwater shrimp species [38], ongoing scientific efforts continue to address these bottlenecks, to develop scalable aquaculture systems that both rural communities and commercial producers can adopt.

4. Conclusions

An evaluation of the 13 *Macrobrachium* species identified in Aceh Province indicates that the majority exhibit biological traits that are suboptimal for freshwater aquaculture development. This limitation is primarily associated with reproductive strategies characterized by high fecundity of small eggs and the requirement for elevated salinity during extended larval development phases (prolonged larval development). Species such as *M. australe*, *M. equidens*, *M. lar*, and *M. latidactylus* fall into this category and were accordingly classified as having low to very low aquaculture potential. In contrast, *M. lanchesteri* demonstrated traits favorable for cultivation, including the ability to complete its life cycle entirely in freshwater, abbreviated larval stages, and strong local market demand. Based on these combined factors, *M. lanchesteri* was classified as having high aquaculture potential. *M. idae* was assessed as having moderate potential, supported by a relatively extensive body of technical literature and widespread local consumption, despite requiring brackish water during larval development. Several other species lack sufficient biological and technical data for a definitive assessment. This highlights the need for additional research on reproductive biology and salinity tolerance to support the sustainable development of aquaculture systems that utilize local biodiversity.

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