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Behavioral traits of the giant freshwater prawn *Macrobrachium rosenbergii* under laboratory circumstances

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Abstract:
The ethological study of freshwater prawns in India is very alarming, and the behavioral study has significantly contributed towards improvement in animal breeding. *Macrobrachium* is a highly significant commercial species in prawn farming; *Macrobrachium rosenbergii* is economically one of the most important species. To highlight the in-depth analysis of prawn culture, an *ethogram* was prepared in this study to characterize and describe the behavior of *M.rosenbergii* under laboratory conditions. The Focal Animal Method was used to observe and perceive *M.rosenbergii* for 30 days, with one-hour continuous reports from 09:00 to 10:00, 10:30 to 11:30, 12:00 to 13:00, 13:30 to 14:30, 15:00 to 16:00, and 16:30 to 17:30. The experiment commenced with fifty prawns fed with commercial feed three times a day. During our scrutiny we have monitored a handful of behavioral patterns. The observed behaviors were categorized into maintenance, locomotion, feeding, and social behaviors. Molting frequency does not appear to be directly related to growth rate; rather, it is associated with food consumption, irrespective of the molting frequency. From our investigation, the prawns were classified into stages A, B, C0, C1, D0, D1, D2, and D3. This classification was based on visible changes in the exoskeleton, which enabled the determination of molt states. The outcome implies that the multifaceted behavioral activities of *M.rosenbergii* align with existing specialized literature and may be employed in further biological research focused on freshwater prawn cultivation. Additionally, it provides a significant step towards enhancing the management, development, and improvement of animal welfare.

Key words: *M.rosenbergii, ethogram,* Behavioral patterns, Molting frequency, animal welfare.

INTRODUCTION

Aquatic creatures are raised worldwide for human consumption. In particular, Crustaceans have gained attention for their high market value and capacity to adapt to diverse cultural contexts (FAO, 2018). Freshwater prawns have emerged as a vital sector of global aquaculture, notable for both their quantity and value. India is the world's second-largest producer of freshwater prawns (Vagh Sarman *et al.,* 2018). According to FAO, (2014) and Abu Seman, (2020) the prawn aquaculture has contributed significantly to rapid economic growth, generating substantial revenue and fostering sustainability. Notably, the giant freshwater prawn (*M.rosenbergii*) is the sole species from the freshwater sector that enters the export market, while carps and other finfish are mainly cultivated for the domestic market (Dr Gopa Mitra, 2005). *M.rosenbergii* stands out as a key productive species due to its broad temperature tolerance (15–35 °C), stamina persistence, and comparatively quick growth rate, it is the most important cultivable freshwater prawn species (Pontes *et al.,* 2020). It is one of the species specified for shrimp farming because of its expeditious development, easy reproduction, high fertility rates and robust host defense (New *et al.,* 2010). Investigations of animal behaviour have made a substantial contribution towards animal breeding, which is a major concern for scientific communities (Daniels *et al.,* 2016). Laboratory studies are pivotal for genetic selection, disease research and nutritional traits, yet behavioural data under artificial conditions remain fragmented (Karplus *et al.,* 1989). Although *M.rosenbergii* populations exhibit complex social and behavioral patterns, there are little studies on applied ethology. They may be quite beneficial for the development of new management practices. According to Huntingford *et al.,* (2012), a behavioral study applied to commercial breeding is concerned with animal welfare and environmental sufficiency.

The primary goal of applied ethology research is to comprehend and improve animal welfare, which is a genuine concern in modern society and is advised by the International Society for Applied Ethology (Millman *et al.,* 2004). Several studies have addressed the morphology of prawns (Ra'Anan *et al.,* 1991), agonism (Karplus, 2005), zootechnical performance (Lan *et al.,* 2006), and animal behavior in monosex cultures (Santos *et al.,* 2015). An ethogram may provide a complete set of behaviours or a number of distinct behavioural classes (Lehner, 1996). According to Alcock, (2011), the ethogram has significant benefits for grasping and defining the species' history and ecological adaptations because it includes a behavioral profile or a general plan of all the actions the species has produced. (Santos DB, 2016).

More investigation on freshwater prawn behavioral patterns is recommended. In order to identify strategies to prevent

molting by comprehending the ecological and behavioral implications, the primary objective of this paper is to examine *M.rosenbergii* behavior in controlled circumstances, by creating an ethogram specific to species. As a result, this study provide data for researching the behavior and molting of *M.rosenbergii*. This information can help with species management, behavioral knowledge, physiology and welfare. Ethograms are like lists of all the things that a certain species can do. These lists have countless details about each thing the species can do. People made these lists when they started studying the species. This helps people who want to try ways of managing food, and it gives them some basic information to study what the species does. The ethograms also talk about what happens to the carapace of the species when it gets harder or softer, like when the species sheds its skin, which is called molting. Ethograms are really helpful for understanding the stages of molting. This observational study provides baseline data for the aquaculture of the giant freshwater prawn *M.rosenbergii*.

METHODOLOGY

Ethical Statement : The experiment complied with Indian Council of Agricultural Research guidelines (ICAR, 2018); no IACUC approval was required for invertebrates.

Study species collection and Experimental setup

M.rosenbergii adults were collected from Sri Dhanalakshmi Freshwater Prawn Hatchery (Scamby), Periyakuppam & Post, Kurinjipadi -T.K., Cuddalore DT, Tamil Nadu. The collected post-larvae of *M.rosenbergii* were then taken to the Aquafarming Laboratory of Zoology Department and Research Centre, Sarah Tucker College, located in Tamil Nadu. Prior to initiate the experiment, prawns were stocked in the laboratory, conditioned, and acclimated in experimental units. They were fed live *Artemia nauplii* for two weeks. Abiotic parameters were assessed daily; pH was 8.2 ± 0.2 (pH meter), and temperature was 27.7 °C ± 1, also verified. The ideal oxygen level was maintained with mild aeration, and the prawns were fed three times a day (09:00, 13:00, and 17:00). The leftover feed was siphoned out of the tanks an hour after feeding. Water quality remained throughout the observation period, at the optimal level for the culture of the species (New *et al.,* 2010).

Behavioral Observation

The Focal Animal Method (Martin & Bateson, 2007) was used to conduct observations for each treatment over the course of 30 days. Behavioral activities were observed using visual methods, video recording, and pictures taken with cameras. According to Martin and Bateson (2007); Yamamoto and Volpato (2011), the animals were observed during 30 consecutive days to register the species' behavior with one-hour continuous registers distributed into six periods throughout the day (09:00-10:00; 10:30-11:30; 12:00-13:00; 13:30-14:30; 15:00-16:00; 16:30-17:30) with 30-minute intervals, totaling 180 hours of observation with instantaneous recordings every 60 seconds. Prawns were fed twice a day (08:00 and 16:00 hours). The behavioral repertoire was described and reported based on the ethograms of shrimp species (Silva *et al.,* 2012; Silva & Arruda, 2014; Santos DB, 2016). The following categories were recorded (Table : 1).

Table : 1 - Behavioral categories and associates activities recorded during observation

SI. NO	CATEGORY	BEHAVIOUR	SOURCE
1.	Maintenance	Grooming	Pontes & Arruda 2005a; Pontes & Arruda 2005b; Pontes *et al.,* 2006; Silva *et al.,* 2012; Santos *et al.,* 2013, Daniele Bezerra dos Santos and Cibele Soares Pontes 2016
		Partial immobility	
		Hiding	
		Total Inactivity	
2.	Locomotion	Crawling	
		Swimming	
		Exploring	
3.	Feeding Behavior	Ingestion	
		Cannibalism	
4.	Social Behavior	Aggression	
		Courtship	

The molt cycle is the most critical and challenging phase in crustacean physiology. Molting leads to the total replacement of the old exoskeleton, including appendages, with a new exoskeleton. Since molting affects the regular behavior of crustaceans, it deserves to be documented. The molting stage of young prawns was observed periodically during the study period (Table: 2). Ecdysis, marked by the presence of exuviae from the animal's body, was observed daily. Tanks were drained daily, and because ecdysis occurs at night, exuviae were counted and recorded on the following morning. To confirm the molting stage, an image was captured using a camera. The external changes in degree of carapace hardness were also observed by gently touching the outer surface of the carapace (Figure 1 & 2).

Table : 2 - Classification of crustacean molting stages used in the study

SI. NO	MOLTING PHASE	STAGE	DESCRIPTION
1.	Post molt	A Early Post molt	Kamaruding, N.A., Ismail, N., and Ikhwanuddin, M. 2018; Juneta-Nor, A.S., Mat Noordin, N. *et al.,* 2020;
		B Late Post molt	
2.	Inter molt	C0 Early Intermolt	
		C1 Late Intermolt	
3.	Pre molt	D0 Early Premolt	
		D1 Early Premolt	
		D2 Late Premolt	
		D3 Late Premolt	



Positioning of animals for observing the external changes of carapace by gently touching the outer surface of the carapace



Placing of animals for observing degree of carapace and rostrum hardness. Arrow indicates the point of examination.

RESULT AND DISCUSSION:

Since *M.rosenbergii* demonstrates an assortment of behavioural activities, developing an ethogram is a vital step before attempting to quantify the species behaviour categories. Researchers who have made ethograms for other shrimp species have only addressed feeding, agonism (struggle), or reproduction (Silva *et al.,* 2012; Silva and Arruda, 2014). Our current assessment comprises 11 behavioral categories grouped under the following classes: maintenance, locomotion, feeding, and agonism.

Behavioural observation

During the observation period, diverse categories of behavioural expressions were noticed in the giant freshwater prawn *M.rosenbergii*. We recorded eleven behavioral actions in this study, which are detailed in Tables 3, 4, 5, 6, and Figure 3. Prawns excavate burrows and spend an inordinate amount of time autogrooming. The astounding behaviors were maintaining cleanliness, interacting one another, locating food and moving around. These actions helped the *M.rosenbergii* prawns stay healthy in their environment. The preparation of an ethogram is a vital stage before any attempts at behavioral quantification for the species.

Table: 3 Maintenance behavior patterns of giant freshwater prawn *M.rosenbergii* observed in the Laboratory

SL. NO	BEHAVIORAL STATE	DESCRIPTION
1	Grooming	The study species rubs and creates frictions on its carapace with its periopods. The animal grooms its dorsal and ventral region using 1-5 pair of pereiopods. To clean its pleopods, antennae, antennules, maxilipedes, and other internal organs, they use 1-3 pairs of pereiopods.
2	Hiding	Once the animal enters the shelter, it spends the most of the day solitary. Within the refuge, the animal may reveal its second pair of antennae or pereiopods, or it may choose to stay completely hidden.
3	Total Inactivity	The study species occasionally displaying locomotory appendage activity it remains immobile on the substrate and does not use its appendages, antennae, antennules and cephalothorax to move.
4	Partial immobility	The studied species is stationary, exhibiting distinct upward and downward motions of the cephalothorax along with very minor alterations in the antennae, antennules, and locomotor appendages.

Table: 4 Locomotion behavior patterns of giant freshwater prawn *M.rosenbergii* observed in the Laboratory

SL. NO	BEHAVIORAL STATE	DESCRIPTION
1	Crawling	Study species are predominantly benthic, they dwell at the bottom of water and walks along the substrate using their legs. This behavior is imperative for evading predators, seeking shelter, and foraging. It can quickly change direction navigate through environment complex to avoid predators.
2	Swimming	Study species moves through the water by using forceful abdominal strokes and continuous, rapid hammering of pleopods in a wavy motion. It moves either horizontally or vertically, or maintains its position in the water column by using its pleopods. It is observed during reproductive activities, migrations, or escaping from predators.
3	Exploring	The study species explores the first pair of pereiopods, the chelae, occasionally to travel along while pinning the substrate or other material on the ground. When investigating, the animal's head and thorax tilt slightly downward; it may move along the substrate or remain immobile.

Table: 5 Feeding behavior patterns of giant freshwater prawn *M.rosenbergii* observed in the Laboratory

SL. NO	BEHAVIORAL STATE	DESCRIPTION
1	Ingestion	The Study creature explores its first pair of pereiopods to hold food, dead animal, or molting exuvia. After pinching some food, the prawn rotates and places it in its mouth, Food intake is also possible with the second, third, and fourth pairs of pereiopods.
2	Cannibalism	Study species uses the first pair of pereiopods, carries the dead animal, and consumes exuvia bit of dead animals. After pinching and rotating the meal, the prawn brings it to its mouth and extracts a few pieces. The second, third and fourth Pereiopod pairs may engage in food taking.

Table: 6 Social behavior patterns of giant freshwater prawn *M.rosenbergii* observed in the Laboratory

SL. NO	BEHAVIORAL STATE	DESCRIPTION
1	Aggression	Study species exposes this behavior, especially during mating phase. Male prawns may compete for access to females, leading to exhibit of aggression and supermacy. They have a keen sense of familiarization which allows them to successfully maneuver their environment during movement.
2	Courtship	The study species exhibits chelae waving for display, embracing and protecting the female. Antennal waving is for sensing, recognizing and vibratory responds to the potential mates. During this period male displays a colorful patterns to attract females. In response to the male, the female shows interest by fanning her tail. Male chase females displaying dominance and courtship intent. Successful males and females form pairs, swims together. Male wraps around females body and releases sperm.

M.rosenbergii exhibits a wide range of behavioural activities, current inquiry comprises eleven Behavioural activities. Similar behavioral activities were observed by Del Claro *et al.,* (2002), according to him behavioural repertoire studies, also known as ethograms, are essential tools for learning more about the biology, ecology, and behavior of animals, especially those kept in captivity. The only topics covered in ethograms created for other prawn species are feeding, agonism (struggle), and reproduction (Silva *et al.,* 2012; Silva and Arruda, 2014). The sea prawns *Litopenaeus vannamei* and *Farfantepenaeus subtilis* have been previously described in terms of their general behavioral categories which include investigating, feeding, grooming, immobility, crawling, and burying (Silva *et al.,* 2012; Santos *et al.,* 2013).

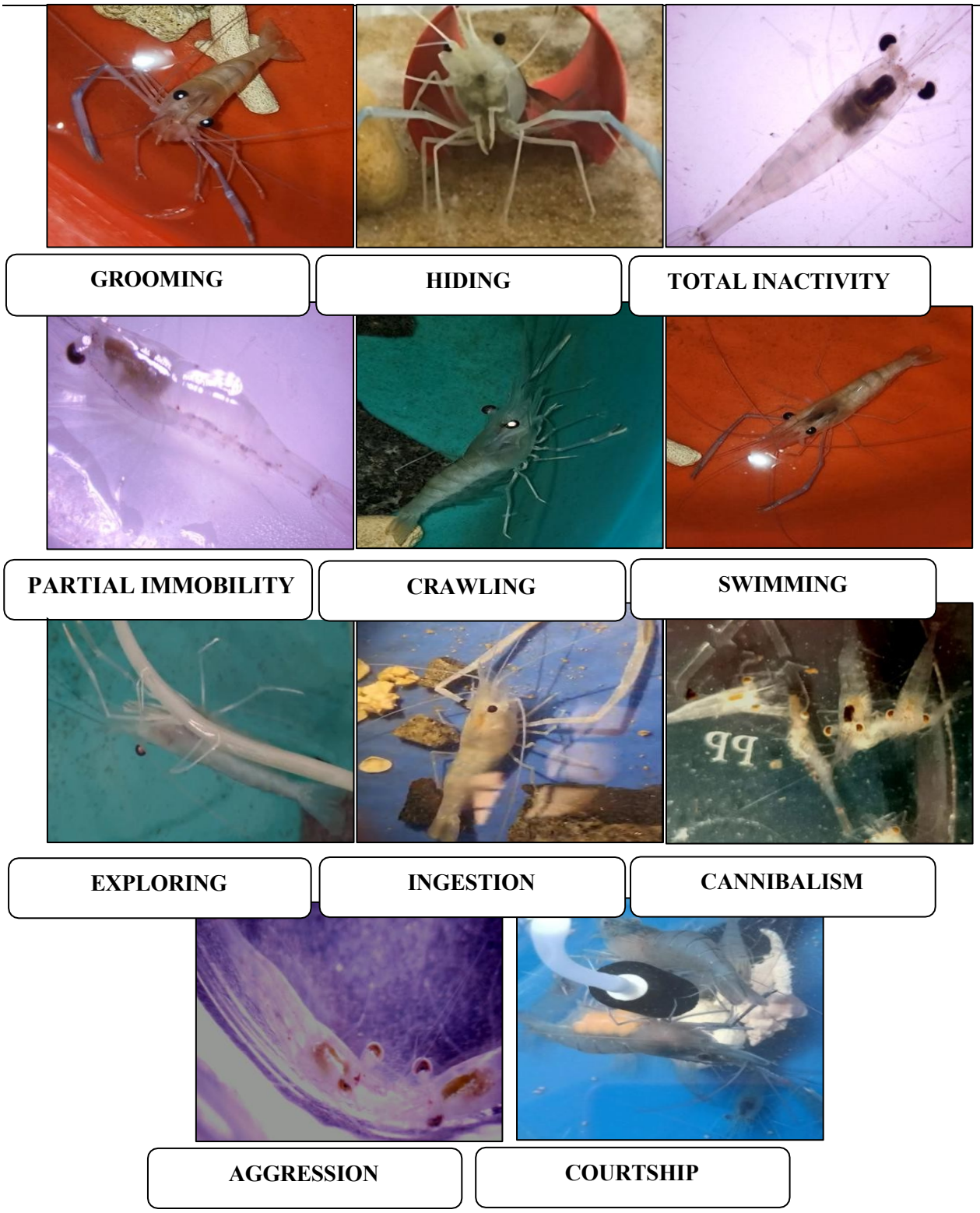


Figure 3- Behavior patterns of giant freshwater prawn *M.rosenbergii*

The experiment showed that pereiopods are extremely relevant for *M. rosenbergii's* daily activities, based on the various behavioral expressions like exploring, hiding, feeding, grooming. Pereiopods serve as the main structures when animals of the same species engage in agonistic behavior (Santos DB, 2016). In captivity, hiding is typically documented for the species *Macrobrachium* because it provides protection from predators in addition to improving access to food and mates (Soderback, 1994). According to Santos *et al.,* 2025, noted that prawns tends to select their hiding place during depending on colour. The social interaction of male *M.rosenbergii* was analyzed by Karplus, (2005), who hypothesized that the experiment's restricted location and high grooming rates were the cause of the animal's behavior. Through our investigation, we observed that prawns groom themselves. According to Barr *et al.,* (2008) and many types of decapod crustaceans spend a lot of time and energy doing this. Locomotion activities that involve moving forward; locomotion

activities that involve a position that is not forward or an increase in distance; behavioral activities that involve the position and movement of the chelae without touching another animal; and behavioral activities that involve the position, movement, and contact with another animal through the chelae. According to Mariappanand & Balasundaram, (1999), the primary defence and attack structures of *M.rosenbergii* are the second pereiopods. the second pereiopod pair in the acquisition and defense of territory by the species *Macrobrachium lamarrei*, *Macrobrachium nobilii*, and *Macrobrachium malcolmsonii*. AS Juneta-Nor *et al.,* 2020 assert that *M.rosenbergii* shares two types of chemosensory organs with other crustaceans: sensilla dense arrays on the mouthparts and walking legs.

Observation on Molting

According to Corteel *et al.,* 2012, assert that molting or ecdysis, is one of the most significant physiological processes in crustacean. It is an inherent habit of crustaceans, in which the old exoskeleton is cast off and a new one is formed periodically. Information regarding the frequency of molting in *M.rosenbergii* is limited. To obtain such information, it is necessary to monitor individual animals during their molting cycles. Prawns must molt, or lose, its stiff exoskeleton to grow larger. They undergo changes in hormone levels, biological substances, physiological processes, and prawn behaviors throughout this period (AS Juneta-Nor *et al.,* 2020). The fascinating natural phenomenon known as ecdysis was witnessed during study period. In giant freshwater prawns, molting generally takes place at night. In addition to growth, molting also leads to varied changes in the general behavior of the prawn. There are no issues while the creatures are alone, but when they are in groups, they need to be able to recognized individually. Identification of the pre-molting changes might be feasible around 3 days prior to molt. Based on the observation, animals were categorised into four general stages such as Post molt, Inter molt, Pre molt, and Ecdysis were record (Table – 7). It is important to distinguish between small, young animals and small aged creatures. Although every young animal is small, certain old animals are also small. Although all of our experimental animals were the same age, some of them were larger than others.

Table : 7 Molting stages observed in giant freshwater prawn *M.rosenbergii* observed in the Laboratory

SI. NO	MOLTING STAGES	DESCRIPTION
1.	Post Molt	The time after the animal sheds its skin, which is called the -molt stage or metecdysis happens a few days after it has finished molting. The species under study becomes larger at this point by absorbing water quickly. Although the exoskeleton is highly porous, flexible, and semi-calcified, it provides hydrostatic pressure to the limbs to allow animals to move. At last, the texture of the exoskeleton became hardened, although it retained some rigidity. As per Abu Seman Juneta *et al.,* 2020, the post-molt stage had the lowest levels of protein, fat, and total glucose.
2.	Inter molt	The statement highlights that the process of intermolt happens when the development of new integument and muscle tissue is completed.
3.	Pre molt	Pre-molt is the stage occurs prior to molting and is also referred to as Pro ecdysis or Peeler stage, it prepares for molting. Highest total glucose, lipid and protein levels were detected during the pre-molt stage, (Abu Seman Juneta *et al.,* 2020).
4.	Ecdysis	At this point, study species struggle to emerge after shedding their exoskeleton on the dorsal surface. They are motionless (unable to move) and do not consume feed after the molting. An ecdysis, is an instar or intermolt, is the phase that occurs in between successive molts. After the exoskeleton structural development, the texture of the exoskeleton turns completely rigid, and it has a firm feel. It is evident that, when the old integument sheds its skin during a molt, the appendages will also regenerate. To grow larger and heavier, a new exoskeleton needs to grow below the old one.

Over this duration, prawns that refused food were documented. As soon as they had finished molting, you would observe them lying on their sides approximately 5 to 30 minutes as they got used to their new exoskeleton. Among clustered animals, the bigger prawns ate the discarded exoskeleton within a day. Ecdysis events were tracked daily through the gathering of exuviae and video monitoring. Digital photographs were taken in order to verify the molting stage (Figure 4 & 5). Giant river prawns eat all sorts of things—plants, animals, anything living, dead, or even decaying. But in captivity, they turn aggressive and start cannibalizing each other, which makes things tough for producers (Malcolm L. McCallum *et al.,* 2019). It is an essential feed source to satisfy prawns' high appetites and nutritional needs during the pre- and inter-molting stages (Carter and Mente, 2014). During the initial 20 minutes after a molt, an animal is most vulnerable to cannibalism. Cannibalism is one big reason their productivity drops (Azra *et al.,* 2019; AS Juneta-Nor *et al.,* 2020). Even though it is capable of swimming, it cannot walk; they can only react by escaping or hiding.

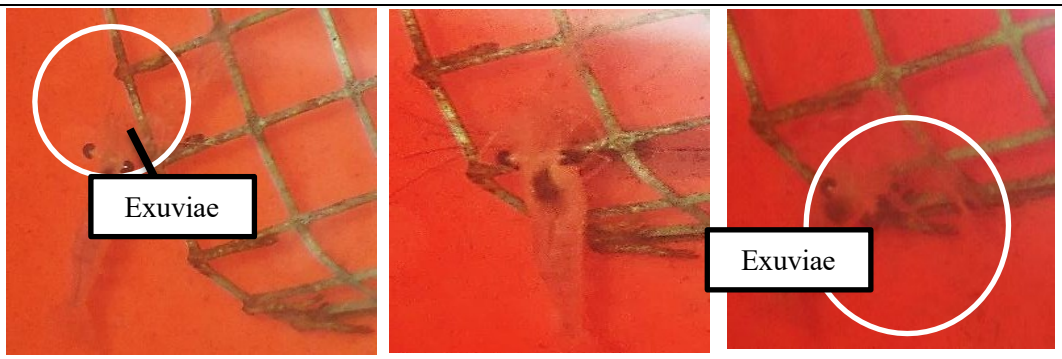


Figure 4 : Molting observed during study period



Figure 5: Exuvium of *M.rosenbergii*

Throughout the experimental duration, the molt cycle varies based on the animal's age, sex and size. Our findings strongly suggest that the frequency of molting is not a factor in growth, though it may not preclude it. According to Saravanan, S, (2008) it has a characteristics of lengthy inter-molt periods (approximately 30 to 80 days), short pre-molt periods (10 to 12 days), and extremely short post-molt periods (2–6 days). Based on our observations, we believe that it is more accurate to state that individuals provided with a greater quality and higher quality of food grow more rapidly, irrespective of the molting frequency. Then the characteristics of molting stages and approximation of during after ecdysis in laboratory condition were record (Table – 8).

Table : 8 Characteristics of molting stages and approximation of duration after ecdysis in laboratory condition

Molting Stage	Approximation of duration after ecdysis	Exoskeleton texture	Activity	Feeding
A Early Postmolt	24 hours	Soft	Slight	Low
B Late Postmolt	1- 3 days	Soft	Considerable	None
C0 Early Intermolt	4-9 days	Hard	Full	Yes
C1 Late Intermolt	10-16 days	Hard	Full	Yes
D0 Early Premolt	17-20 days	Hard	Full	Yes
D1 Early Premolt	21-23 days	Hard	Full	Yes
D2 Late Premolt	24- 27 days	Hard	Full	Reduced
D3 Late Premolt	28- 29 days	Soft	Reduced	None

Stage A is the initial phase right after the prawn flicks the old exuvia. In this phase, the whole body and exoskeleton appears to be soft and feel slippery to touch. Because of these traits, the prawn remain motionless concealing itself to escape being eaten by other intermolt prawns. It has a light color, resembling flesh and its lifespan is brief; it lasted just a few hours under 24 hours post-ecdycis. Stage B typically occurred 1 to 3 days post – ecdysis. The exoskeleton became quite rigid yet remains somewhat unflexible. It doesn't consume any feed, yet it was easily depressed. The level of activity during this phase will be substantial. The most notable finding of Stage C0 was completely functional with rigid exoskeleton. It is transparent and minimal pigment retraction. This phase occurred roughly 4 to 9 days after ecdysis. In stage C1fully engaged with a hard exoskeleton. This is the last intermolt with satisfactory feed intake. This particular phase took place 10 – 16 days following ecdysis. Stage D0 is an initial premolt phase that takes place 17 to 20 days after ecdysis.

It primarily defined the formation of the new exoskeleton with active movement through proper nutritious feeding. Stage D1 is also termed as an early premolt. The prawns typically entered this stage 21 – 23 days after ecdysis. Stage D2 is a late premolt; during this phase, the formation of new cuticle beneath old exoskeleton were observed. This phase typically occurred 24 – 27 days after ecdysis. Morphological observations at the D3 phase showed that old seta organs had vanished and the new seta beginning to fold, marked by full apolysis. The carapace turned pliable and spongy. The activity decreased without consuming any feed. This phase typically occurred 28 – 29 days after ecdysis.

Romano and Zeng's (2017) findings are consistent with the findings of and Luvizotto-Santos *et al.,* (2003) that the chemical cues glucose, protein, and lipid play significant roles in the molting process (AS Juneta-Nor *et al.,* 2020). During and after molting, a variety of chemical cues are released into the water, causing changes in hormone levels, biochemical substances, physiological processes, and prawn behavior (Barki *et al.,* 2011). The release of amino acids (proteins), which initiates cannibalism and easily enters an encounter with a resident or non-resident, is generated during the molting process (AS Juneta-Nor *et al.,* 2020). This process results in the release of high concentrations of FAA chemicals, particularly tryptophan, which has made non-molting prawns more likely to attack freshly molted prawns (Carter and Mente, 2014). During molting, the organism may give off signals about itself using its olfactory sense. They produce a chemical cue or signal that increases chemoreceptor activity and, in turn, indirectly encourages cannibalism (Carter and Mente, 2014), it indirectly encourages the chemical cues that enhance feeding behavior and increase chemoreceptor activation (Barki *et al.,* 2011).

According to the data we have to cultivate *M.rosenbergii* effectively, it is advisable to offer them shelters. There exist targeted approaches we can take to lower the count of prawns dying from fighting and stress due to molting in farming. We need to inspect the water daily it ensdure a habitat suitable for *M.rosenbergii*. This means checking the temperature how acidic the water is and how much oxygen is, in it. If we carry out all these steps, by understanding *M.rosenbergii* behavior we can establish a habitat suitable for *M.rosenbergii*. This will help minimize the issues that arise when prawns fight and become stressed in the water where they are farmed. This will ensure that *M.rosenbergii* remains healthy and strong.

CONCLUSION :

Research on the behaviour of *M.rosenbergii* is quite significant. It gives perspective in terms of how we can make aquaculture more sustainable. Growing *M.rosenbergii* generates ample revenue for farmers and people who lives in rural areas because it promotes their economy with better lives. *M.rosenbergii* exhibits a rich behavioural pattern under laboratory conditions categorized into Maintenance, Locomotion, Feeding behavior, Social behavior. If we know how *M.rosenbergii* live together, what they prefer to live, we can develop plans to cultivate more of them at a lower cost. Four distinct molting stages Post molt, Inter molt, Pre molt and ecdysis were identified. Optimizing conditions and adoption of molting stage is recommended to enhance success in prawn yield and hatchery development. Understanding molting biology reduces the molting related mortality and supporting future studies on *M.rosenbergii* integrated physiological markers with behavioral data for deeper insights. These finding supports, detailed ethograms provide a foundation for evidence- based husbandry improvments, enhancing welfare, reducing losses from cannibalism. By applying our knowledge of *M.rosenbergii* behavior to aquaculture management, we can cultivate more of them globally. This study could be a guideline for more scientific improvement in *M.rosenbergii*. Continued study of *M.rosenbergii* could ensure that cultivating it remains both sustainable and profitable.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare that they have no conflict of interest.

Credit authorship contribution statement

Kishwar Fathima: Writing –Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Conceptualization. Selva Ponmalar: Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

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