

Predatory strategies of malacophagus beetle larvae of Lampyridae on *Laevicaulis alte*

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Abstract

Laevicaulis alte is an exotic slug which has expanded its range over most of Kerala. It is pestiferous and poses a threat to the native gastropod fauna. Lampyrid larvae are well-known as predators of gastropods. The present work was conducted from 2019 to 2021 during the monsoon season in the agroecosystems of Elanji in the Ernakulam district of Kerala, India. The Lampyrid larva–gastropod interactions were located in the field by visual search among grasses. The duration of each interaction and photographic records of each stage of attack and defence were made. The interaction can be classified into three stages viz., Initial stage, Subsequent stage and Continuous feeding stage, which lasted for approximately 15, 60 and 240 minutes, respectively. In all instances observed, only a single larva was found to attack one slug. The Lampyrid attack strategies included the secretion of digestive enzymes to paralyse the slug, attacking the anterior end of the slug to reduce mucus secretion and frequently removing mucus from their body using forelegs and pygopodium. The defence strategies of the slug included moving away from the predator, lifting its anterior end to protect it from the Lampyrid bite, and secretion of a white viscous mucus to deter the predator.

Keywords: Fireflies, slug, Tropical leather leaf, exotic slug, mucus defence

Introduction

The terrestrial gastropod fauna falls prey to several organisms in nature, including rodents, aves, reptiles, insects, arachnids and gastropods (Rosin *et al.*, 2011) [15]. Beetles form one of the most diverse and predominant groups of gastropod predators. Lampyridae is a Coleopteran family that includes fireflies known for their bioluminescent properties. Lampyrids are predatory during their larval stages, and they stop feeding once they become adult beetles. Lampyrid larvae include generalist and specialist feeders of snails, slugs and earthworms (Novák, 2018) [11]. Though there have been numerous reports of the predatory behaviour of Lampyrid larvae, detailed studies on the mechanism of the attack have not been done.

Laevicaulis alte is a native of Africa and is commonly known as the Tropical Leather leaf. It is a highly adaptive species which have spread over countries of South Asia, North America and Middle East (CABI, 2020). In Kerala, they are present nearly everywhere in agroecosystems, home gardens, near wetlands and urban and rural ecosystems. Though their pestiferous effect is not as grave as other exotic species, they pose a competitive threat to the native gastropods of Kerala.

The present paper deals with the various stages of predatory interaction of Lampyrid larvae on an exotic slug, the *Laevicaulis alte*. The paper gives a nutshell view of the attack strategies of the Lampyrid larvae as well as the defence strategies of the *Laevicaulis alte*.

Materials and Methods

The study was conducted for a period of three years, from 2019 -2021, in agroecosystems of Elanji in the Ernakulam district of Kerala, India (Fig 1). The study site is an agricultural village in Central Kerala with various ecosystems like wetlands, sacred groves, monoculture and mixed crop agroecosystems.

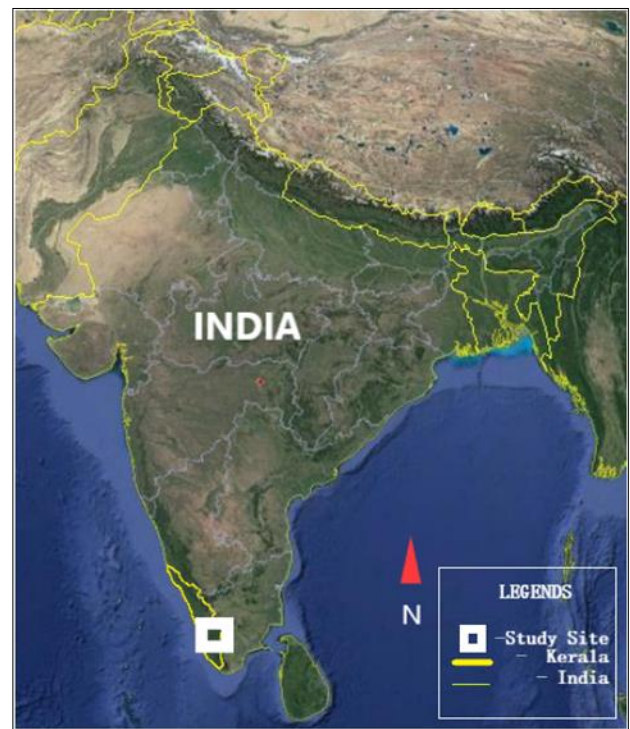


Fig 1: Map showing the location of the study site in Kerala, India

Field visits were conducted during the monsoon season. The Lampyrid larva–gastropod interactions were located in the field by visual search among grasses. Field visits were scheduled during the morning hours. Opportunistic observations were also made whenever possible. The duration of each interaction and photographic records of each stage of attack and defence were made. The gastropod species was identified with the help of standard textbooks (Blanford & Godwin-Austen, 1908; Gude, 1914, 1921; Raheem *et al.*, 2014) [2, 6, 13].

Results and Discussion

General Characteristics of the Attack

The predatory interaction between Lampyrid larvae and *Laevicaulis alte* was observed three times during the study period. The interactions recorded occurred during the daytime, the attack beginning in the morning. Two of the cases were observed from among the leaf litter, and one instance of interaction on the floor of a car porch of a house. The larvae were observed to trace the mucus trail of the slug in several instances, it might have used the slime trail to locate the slug initially. The larva also showed mucus trail tracking in between the attacks if the slug moved away while the larvae took breaks to clean its mouth parts from snail mucus. Studies on mucus trail tracking behaviour of Lampyrid larvae have shown their preference for gastropod mucus trails (Sato, 2019) ^[16]. It was also noted that in all cases, the size of the slug was larger than the larvae and only one larva was found to attack a slug at a time. Though congregating feeding behaviour of Lampyrid larvae are recorded during lab studies, field observations so far have recorded only one larva attacking a gastropod (Riley *et al.*, 2021) ^[14].

Stages of Attack

The interaction can be studied in three stages *viz.*, Initial stage, Subsequent stage and Continuous Feeding Stage (Table 1). The initial stage involves time from locating the prey to the first attack of the larvae on the slug. The subsequent stage includes all interactions like consequent attacks and corresponding defence strategies till the death of the slug. The Continuous feeding stage is demarcated by the death of the slug.

Table 1: Duration and progression of events during each stage of Lampyrid – slug interaction

Sl. No.	Stages of attack	Average Duration (Mins.)	Defence strategies of <i>Laevicaulis alte</i>
1	Initial attack	15	Moves away, Hides its anterior end, Retracts its tentacles
2	Subsequent attack	60	Thick sticky mucus secretion, Raising its upper body
3	Feeding after the death of the slug	240	-----

Attack Strategies Adopted by Lampyrid Larvae

In all three instances, once the Lampyrid larvae locates the prey, they walk around the prey to locate and position itself to attack the anterior end of the slug which bears antennae. The attack begins with the larvae pricking the slug on its anterior end using its mouthparts. The mandibles of snail feeder Lampyrids are sickle shaped (Novák, 2018) ^[11]. The slug instantaneously withdrew its antennae and showed a twirling motion (Fig 2B). The larvae might be injecting some secretions that cause paralysis in the snails. Because the snails stopped moving or moved slowly after the attack. In many Lampyrid-snail interaction, the larval injection of digestive enzymes have shown to paralyze the snail (Hess, 1920; Sato, 2019) ^[9, 16]. The larvae use its pygopodium to hold on to position for attack and use it to clean their legs and mouthparts from the slug mucus.

The larvae preferred to attack the slug on its ends, especially the anterior end with tentacles (Fig 2A). Such behaviour is also seen in many slug predator carabid beetles which help them to paralyze slugs faster with lesser mucus secretion (Pakarinen, 1994) ^[12]. The larvae never attacked the leathery dorsal side or the slimy foot of the slug. In a single case, the larva was found to attack the central region of the body once in between the attack.

The attack on the slug was not continuous, the larvae took breaks in between the attacks. It cleaned its jaws and mandibles during this time but never left the vicinity of the slowly moving slug. The larvae cleaned their mouth parts at an average interval of two minutes. Though the mouthparts are cleaned mainly with the help of pygopodium, they also use their forelegs to rub off the sticky mucus (Fig 2C, 2D).

The interaction might take two to five hours before the slug completely dies. Once the slug is dead, the larvae feeds on the snail continuously. It was observed to use its jaws to tear the slug's flesh and ingests it into its mouth. Previous studies have also reported such behaviour of ingesting partially digested flesh of gastropods by Lampyrid larvae (Hess, 1920) ^[9]. The part of the body of the slug on which the larva fed was observed to be covered in a dark coloured liquid (Fig 2F). This might be the mid gut digestive fluid secreted by the larva to predigest the slug flesh (Hess, 1920) ^[9]. During this time, it does not take any break as in case of their interaction with a live gastropod where they took breaks to clean their mouth parts from the sticky mucus secretions.



Fig 2: [A] *Laevicaulis ite* raising its anterior end and Lamproyrid larva attacking the slug at the posterior side. [B]. *Laevicaulis alte* curling its anterior side. [C]. Larva cleans its mouthparts with pygopodium. [D]. Larva cleans its mouthparts using forelegs. [E]. Thick white mucus secreted by the slug as a defense strategy. [F]. Lamproyrid larva feeding on its kill.

Defensive strategies of *Laevicaulis alte*

Laevicaulis alte tried to escape the predator by moving away throughout the various stages of attack. The primary defense strategy common to most slugs is to avoid predators by recognizing environmental cues and to move away quickly from the surrounding (Armsworth *et al.*, 2005; Hanlon *et al.*, 2018)^[1, 8].

The slug raised its body upward in a twisting and twirling motion after the larval bite. The slug sometimes tried to move away with its anterior end raised for short distances. Such behaviour of lifting up anterior part of the body during a predator attack is recorded in the family Limacidae (Foltan, 2004)^[4]. This could also be an act to protect its antennae from attack.

The slug produced thick mucus for defence which is very sticky and different from the colourless slippery less viscous mucus produced for locomotion. The mucus was observed to become whitish and viscous as the attack progresses (Fig 2E). The sticky mucus production is a major secondary defense technique employed by most slugs (Hanlon *et al.*, 2018; Mair & Port, 2002)^[8, 10]. The mucus interrupts the attack process and makes it difficult for the predator to consume slugs (Gould *et al.*, 2019)^[5].

Conclusions

Lamproyrid larva are a major predator of land gastropods. The study above presents the sequence of events involved in a predatory interaction between Lamproyrid larva and *Laevicaulis ite*. More research needs to be done to throw light on to the biochemical processes taking place in this interaction. Identification and conservation of native Lamproyrid larva can help in biocontrol of exotic gastropod species. Lamproyrid fauna of Kerala need to be studied extensively to throw light on their ecosystem services.

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