CHAPTER- 3

LARVAL BEHAVIOUR PATTERNS

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3.1. INTRODUCTION

Insect behaviour includes various activities such as predation, feeding, migration and courtship. The various behaviour patterns help the organism to survive better in different biotic and abiotic conditions. Both larvae and adults shows different patterns of specific behaviour which may be a strategy to develop its survival rate. Spider, honey bee and antlions are some of the organisms which make a special behaviour or architecture for building their shelter as well as improving predation. The spider makes its web for predation purpose, but honey bee makes its comb for shelter. In the case of antlion, it makes its pit for both shelter and predation.

For the successful survival, organisms exhibit different behaviour patterns which help to live in the present environment. The individuals adapt some behaviour for the smooth survival in that particular environment. The common behaviour patterns of insects include feeding, mating and predation. But in the case of Myrmeleontids, they are the good predators which use a planned strategy for feeding, pit building and predation. They made conical pits in the substrate and wait for the prey to fall down in to it. By making the conical pits, they got its shelter from enemies as well as food. But there are exceptions also. The Mediterranean antlion species *Neuroleon microstenus* do not build pit fall traps, they dug in sand backwards and wait for the prey (Devetak *et al*., 2010a)

Antlion larvae made its pit by using the substrate usually sand or dry soil through a series of backward movements. After making the pit, they wait for the prey and once the larvae encounter a prey, the different predatory behaviour pattern starts followed by feeding. Napotilano (1998) investigated about the predatory behaviour patterns of antlion larvae, from this he made a conclusion that a total of twelve discrete behaviour pattern where listed which is as follows.

1. Attack

   The head is moved rapidly forward while closing the mandibles and is often flicked rapidly back, expelling sand from the pit.

2. Holding

   The prey is gripped securely in the mandibles.

3. Submergence

   Holding prey, the larva moves down and back into the substrate until the entire larva and at least part of the prey are not visible.

4. Emergence

   Holding prey, the larva moves up and forward until the entire prey and at least part of the larva's head /mandible is visible.

5. Prey beating

   Holding prey, the larva rapidly flicks its head up and down (4-5 beats per bout), often drumming the prey on the substrate.

6. Feeding

   While at least one mandible tip is inserted, fluids are extracted from the prey, often alternating with mandibular probing and manipulation of the prey.

7. Pit clearing

   The head is moved laterally, accumulating sediment on the dorsal surface, they flicked rapidly back, expelling sediment.

8. Head roll

   The head is raised and swept in a circular motion along the pit wall, accumulating sediment in the pit center.

9. Prey clearing

   The mandibles are used to position prey on the dorsal head surface, then the head is flicked rapidly back, expelling prey.

10. Grooming

    The tip of one mandible is moved along the groove on the inside edge of the opposing mandible.

11. Quiescence

    Larva remains motionless, without prey, for 7 + seconds

12. Jaw set

    The larva pulls beneath the sand, while fully opening the mandibles. The eyes, antennae and mandible tips remain visible. (Napotilano, 1998)

Predation helps to maintain the balance of animal populations and the predators selectively remove the young, old and diseased or injured individuals from prey populations (Southwick, 1976). The Neuropterans are mainly predators in both larval and adult stages, but in the case of Family Myrmeleontidae, the larval stages are more predatory than adults. Adult antlions survival period is below one month when compared with the lengthy larval period of upto two years.

Both pit building and non pit building antlions were present and the species are given in Table 24. The pit builders have seven stemmata or larval eyes which are situated on eye tubercles. Non pit builders have more prominent eye tubercles as an adaptation to non pit building condition (Delakorda *et al*., 2009). The non pit building antlion species of genus *Brachynemurus* has sit and wait prey capture behaviour and they burrow backwards through the sand leaving a narrow furrow (Cain, 1987).

Table 24. Pit building and non pit building antlion species

Sl No.	**Pit building antlion**	**Non pit building antlion**
1.	*Euroleon nostras*	Neuroleon microstenus
2.	*Myrmeleon pictifrons* (Australian sp.)	Brachynemurus
3.	*Myrmeleon acer*	
4.	*Myrmeleon brasiliensis*	
5.	*Macroleon quinquemaculatus*	
6.	*Morter obscurus*	
7.	*Cueta sp*	
8.	*Hagenomyia sp*	
9.	*Myrmeleon inconspicuus*	

3.2. REVIEW OF LITERATURE

3.2.1. Pit building behaviour

The factors influencing pit building of antlion larvae include starvation or hunger level and density of larvae in that particular area.The spatial distribution of pits are regular and uniform in density 5 larvae per $100cm^2$ in Myrmeleon larvae. If the density increased in an area, *Myrmeleon acer* Walker builds fewer and smaller pits. It is also found that the cannibalism behavior shows above the density of 5 individuals per $100cm^2$ (Day and Zalucki, 2000) and there is no relation between antlion prey abundance and larval pit relocation (Scharf and Ovadia 2006). There are 38% of the pits did not contain antlions in the study area in Florida. The spreading strategy of all pits is random but in the case of live antlion it is clumped in nature (Boake *et al*., 1984).

Myrmeleon immaculatus without food for a month move once in every 10 days and build smaller pits (Heinrich and Heinrich, 1984). Griffiths (1986) studied Pit construction of *Macroleon quinquemaculatus* larvae (First, second and third instar) and concluded that starved, disturbed larvae move their pits from one place to another than well fed ones. Periodically the pits are enlarged and it was mostly during at night. *Myrmeleon bore* larvae never relocates its pits under starvation, whereas *Hagenomyia micans* relocated more frequently than *Myrmeleon formicarius* (Matsura and Murao, 1994). The reason behind the pit aggregation was the antlions reduced relocation tendency, this strategy known to be the evolutionary stable strategy (Tsao and Okuyama, 2012).

In the case of *Myrmeleon pictifrons*, no pits were built by larvae in sand with moisture content greater than 4%. Also no pits were built in substrate of grain size greater than 1mm (Kitching, 1984). Studies were found about the pit character of *Euroleon nostras* in different particle size. They prefer substrate as fine sand (≤ 0.23mm and 0.23-0.54mm). In particle size >1.54mm, the second instar larvae didn’t make any pits (Devetak, 2005). Some experiments were performed for understanding the behaviour of *Myrmeleon formicarius* larvae in forest and non-forest areas of kahramanmaras province, Turkey. They conclude that sand particle size and locality features have an effect on pit size whereas soil temperature, altitude, weather had no effect (Bozdogan *et al*., 2013). Also studies were there about the pit bulding of *Euroleon nostras* and identified the pits lined with small slippery grains to maximise powerful avalanches to capture the prey quickly and they also preferred to eject larger grains from pit (Franks *et al*., 2019).

A computer model was also made to analyse shadow competition (the interception of prey by sit-and-wait predators closest to the source of prey arrival) in antlion larvae and the experiment was conducted in the species *Myrmeleon immaculatus*. The shadowing incorporated treatments had a tendency to make pits in the periphery (Linton, 1991). The experiments results that *Euroleon nostras* larvae of France produce efficient traps for easy predation of preys which direct the prey to the mouth of larvae without any attack. So they make steep sloped pits (Fertin and Casas, 2006). The *Euroleon nostras* larva has the sand tossing angle (the slopes created before and after sand throwing) positively correlated with the prey angle (movements of prey) (Vracko and Devetak, 2007). Maoge (2014) studied about the chetae of antlion larvae and how it helps to make pits in *Hagenomyia tristis* and *Myrmeleon obscures*. The pit construction strategy in thermal conditions, sand depth and soil type were studied, from this study, observed a positive correlation between sand depth and soil type (Alcalay *et al.,* 2014).

When the vibrational signals from the media are close to the antlion (*Myrmeleon crudelis*), they act frequently to get that prey. Also, from this study the larval pit size is highly correlated with larval size (Guillette *et al.*, 2009). Pit diameter is bigger with larval body mass such as they extend its trap by knowing the plenty of prey provided by the habitat. Also depicts that there is a positive correlation between pit depth and pit diameter (Scharf *et al*., 2009a). *Myrmeleon immaculatus* given supplemental heat increased pit size at a faster rate and the larvae fed once every three days build larger pits than fed daily (Niemisto, 2013). In the case of *Myrmeleon bore*, the number of pits and size was influenced by the soil temperature.

3.2.2. Predatory behaviour

The starvation experiments depicts that the *Myrmeleon hyalinus* larvae growing faster during the feeding phase and lost mass during starvation period (Scharf *et al.,* 2009a). The major defensive attack by ants (Fire ants- *Solenopsis invicta*) results in the death of antlion through starvation. The ants bite antlions immediately after they have been caught and sometimes grasps the antlions mandible and dies without releasing the hold causing the the antlion unable to make its pit (Lucas and Brockmann, 1981). Eisner *et al.,* (1993) illustrates the predation of *Myrmeleon carolinus* larvae against the formic acid spraying ants (*Camponotus floridanus*), and the larvae suck the body contents without puncturing the acid sac of ant.

In the case of *Myrmeleon immaculatus*, larger pits trapped larger prey and also the prey observed includes ants, spiders, beetle, midges, red mites and wasps (Heinrich and Heinrich, 1984). *Myrmeleon bore* captured 1.25 prey per day on average during spring to autumn, and in the rainy season the average prey per day decreased to 1.03 due to destruction of pits by rain (Matsura, 1986). Miler *et al.,* (2017) studied the cognitive ability of antlion larvae to differentiate between different sized preys by the help of vibrational cues of the substrate and prefer larger prey and ignore the smaller prey if they came together. Lima (2016) used *Drosophila melenogaster* (fruit fly larvae) as prey. Turza *et al*., (2020) explained as the *Formica cinerea* worker ants are the most found prey item in the pit of *Myrmeleon bore* and *Euroleon nostras*. Bakoidi *et al*., (2019) gave *Tribolium castaneum* (Coleoptera, Tenebrionidae) as prey for *Myrmeleon obscures* in rearing purpose. Cain (1987) studied the prey capture behaviour of *Brachynemurus* larvae of Florida. *Brachynemurus* larvae lying in the pit by exposing only its mandibles above sand. It took 15-50 minutes to feed and throw away the prey in laboratory conditions. If the surface temperature above 55ºC, the larvae burrow deeply. If it began to rain it will remain under the sand surface till the sand become dry. Napotilano (1998) identified twelve descrete behaviour patterns of *Myrmeleon mobilis*, which include attack, holding, submergence, emergence, prey beating, feeding, pit clearing, head roll, prey clearing, grooming, quiescence, and jaw set with description. Lambert *et al*., (2011) examined the feeding kinematics of antlion larvae *Myrmeleon crudelis*. The mean duration of prey capture strike was 17.60±2.82 msec. Kross and Pilgrim (2012) studied the predation rate of *Myrmeleon brasiliensis* larvae were analysed by offering leaf cut ant and the third instar larvae with a predation rate of 96.96%, second instar larvae with 69.7% and first instar larvae with 14.28%.

3.2.3. Intraspecific and interspecific interactions

Griffiths (1993) studied the intraspecific competition of antlion larvae (*Macroleon quinquemaculatus*) in Tanzania. They studied the three instars of larvae regarding food availability, hunger level and competition among *Macroleon* larvae. He inferred that, if the food availability was low, large larvae were not affected too much, but small larvae were found hungry because of interference competition of fed larvae. Prado (1993) investigated the asymmetric competition among *Myrmeleon uniformis* larvae of Southeast Brazil. Under laboratory conditions the larvae didn't move anywhere to make pits in three months food scarcity. Gotelli (1997) studied the competition and coexistence of two species of antlion larvae such as *Myrmeleon crudelis* and *M. immaculatus* in central Oklahoma.From their study it is clear that competition and predation are severe between similar sized larvae. The presence of overlapping generations co exist in the case of antlion larvae. Devetak (2000) studied the competition in two European antlion species *Euroleon nostras* and *Myrmeleon formicarius*. A negative correlation between pit building and larval density was noted. Barkae *et al*., (2014) studied about the factors influencing cannibalism in *Myrmeleon hyalinus*. Lima (2011) depicts that, food availability is the main cause of cannibalism. The study compared the cannibalism of *Myrmeleon brasiliensis* larvae in four different conditions to compare the density and food availability in the context of cannibalism.

3.3. RESEARCH METHODOLOGY

Pit building behaviour, trailing of antlion larvae, predatory/feeding behaviour and intraspecific and interspecific relationship of antlion larvae were carefully analysed in both natural and laboratory conditions. The observations from natural conditions were applied to imitate the natural condition in the laboratory. Before doing each behaviour experiment, standardized substrate, prey species, antlion instars, antlion species, tray size, texture of medium, abiotic factors (atmospheric temperature and humidity), number of antlion larvae in each experiment, and starvation period.

a. Substrate- The sand and dry soil collected from the field in which the presence of larvae were noted and dried in sunlight.

b. Prey species- Mostly ants (Order Hymenoptera) are considered as the common diet of antlions. From the field observation, the most preferred prey of antlion larvae was the ant species *Anoplolepis gracilipes*.

c. Antlion larval instar- Usually three instars (two moulting) are present and the larval instar was analyzed before the experiment from the body size of larvae (Krishnan and kakkssery, 2016).

d. Antlion species- The species of antlion which is used for the experiment was noted by using available literature (Lucas and Stange, 1981). Here, the larva of *Myrmeleon pseudohyalinus* was used as experimental organism.

e. Tray size- The dimension of tray used for the experiment was noted before the start of each experiment with special care to maintain the larval density.

f. Substrate particle texture- Dry soil and sand were used for behaviour experiments. Sand should be dried, the moisture content less than 1%-90% for 4 hours and sieved to get the exact particle fraction or used as such.

g. Abiotic factors- Atmospheric temperature and humidity were noted before the start of each experiment.

h. Number of larvae – The number of larvae must be same in each experiment, it was standardised from previous studies.

i. Starvation period standardization- The fed larvae was fed with 1 prey per day and the starved larvae was fed after 3 days of starvation.

3.3.1. Pit Building Behaviour

3.3.1.1 Pit buiding behavior in different medium, hunger level and instar

Most of the organisms use self secreted silk to form the traps, but larval antlion use materials from environment to make its trap (Franks *et al*., 2019). Pit building behaviour was analyzed in second and third instar antlion larvae of *Myrmeleon pseudohyalinus*. Pit building has two complementary frequently observed steps, the digging of soil and removal of dust from the pit. For this purpose the thick setae present on the IX abdominal segments are used (Ngamo, 2014).

Pit building behaviour of the fed and starved larvae was also noted. Continuous observation was done in the lab condition and natural conditions for studying the pit building nature of antlion larvae *Myrmeleon pseudohyalinus*. The behaviour observations were repeated in order to decrease the bias.

Table 25. Experimental design to analyse the pit building behaviour of *M. pseudohyalinus* larvae

Experiment	Medium (Sand/soil)	Larval Instar (Second/third)	Fed/Starved
1	Sand	Second	Fed
2	Sand	Third	Fed
3	Sand	Second	Starved
4	Sand	Third	Starved
5	Dry soil	Second	Fed
6	Dry soil	Third	Fed
7	Dry soil	Second	Starved
8	Dry soil	Third	Starved

The experiment was done in a plastic tray with a dimension of 23cm X 23 cm, filled with 2 cup (one cup is one litter each) of sand/soil which is collected from antlion inhabited area. The sand or soil depth was maintained as 5 cm (Vracko and Devetak, 2007). The second/third instar larvae fed daily by manually placing one ant (*Anoplolepis gracilipes*) with mean size 0.45±0.05cm (sample size- 137 individuals) as prey. In the case of starved larvae, they were starved for 3 days prior to the experiment. Single larvae were allowed to make its pit in each tray and it was kept in room temperature. The larvae kept 3 days prior to experiment to get acclimatised in that situation. Then the larvae released in the centre of the tray and allow it to make its pit for predation and shelter. From that time, the observations taken in every one hour (pit depth and pit diameter) to identify the progress of pit making process. A total of 12 hour observation was done in the day time, also noted the next morning observation for analysing the progress of pit building after a night.

A total of eight experiments were done for analysing the pit building behaviour of *M. pseudohyalinus* larvae (Table 25) and the experimental set up were given in Fig. 25. Different medium/substrate were given to second and third instar larvae for analysing whether any change in pit building behaviour in each conditions. Also checked whether any influence of hunger level in the pit buiding of *M. pseudoyalinus* larvae.

3.3.1.2. Pit characteristics in different types of substrates

Commonly antlion larvae are seen in dry soil, clay soil, sand and mixture of sand, soil and cement. This study is the comparison of the different soils/media which increase the efficiency of pit building behaviour of the antlions. For this purpose 48 larvae were collected from an abandoned house from which 20 larvae with same body length and body width (body length-1.1cm, body width-3mm) were selected for the experiment. Four trays (28X23cm) were taken and each tray was filled with different type of soils that is, dry soil, brick kiln/claysoil, sand and soil collected from partially completed building (mixture of cement, sand and soil). The soil depth was fixed to 5 cm in each tray. The larvae selected for the experiment was kept 24 hour starvation prior to introduction. Five larvae were introduced into each tray without disturbing them and observed their pit building behaviour. The average soil temperature was 33ºC and the relative humidity was 65 %. The experiment was repeated 6 times in order to decrease the error.

3.3.1.3. Trailing Behaviour

Trails are marks made by antlion larvae before deciding the apt place for making its pits and all the pit building antlion larvae make trails in soils before making its pits. The trailing behaviour of larvae was observed under laboratory condition. From this observation a short note was made. For this purpose, a single larva (*M. pseudohyalinus*) was placed on a single tray, and the trailing initiation and progress was analyzed prior to pit making. The dimension of the tray was 23cm X 23cm and soil depth was fixed to 3.2 cm in each experiment.

3.3.2 Predatory/Feeding Behaviour

According to Napotilano (1998), twelve discrete behaviour patterns were exhibited by antlion larva in its due course of time in predation. The various conditions, substrates are same as the above experiments and given in Table 26.

Table 26. The experiments designed for analyzing predatory behaviour of antlion larvae *M. pseudohyalinus*

Experiment	Medium (Sand/soil)	Larval Instar (Second/third)	Feed/Starved
1	Sand	Second	Fed
2	Sand	Third	Fed
3	Dry soil	Second	Fed
4	Dry soil	Third	Fed
5	Sand	Second	Starved
6	Sand	Third	Starved
7	Dry soil	Second	Starved
8	Dry soil	Third	Starved

Here, the plastic trays (23cmX23cm) were filled with sand or soil to a thickness of 5 cm according to the experiment. In the case of starved larvae, they were starved for 3 days prior to the experiment. Single larvae were allowed to make its pit in

each tray and it was kept in room temperature. The larvae kept 3 days prior to experiment to get acclimatised in that situation. The larvae were then released in the centre of the tray and allowed to make its pit for predation and shelter.
The common ant *Anoplolepis gracilipes* (mean size 0.45±0.05 cm) was used as prey for larvae and it was manually placed in the centre of the pit and the behavior patterns were carefully noted in every second by using a hand lens. From the observation data the capture success of the larvae were analysed and the prey escape were calculated.

3.3.3. Types of Interactions- Intraspecific relationships

Intraspecific relationship of *M. pseudohyalinus* larvae were studied by examining cannibalism among the species. The collected *M. pseudohyalinus* larvae were fed eight days and kept in one week starvation (Barkae *et al*., 2014) for standardizing the hunger level. The antlion larvae were separated into two trays according to the instar. Third instar larvae were used for the experiment. The third instar larve were kept in three separate trays for making three hunger levels for cannibalism experiment. The trays filled with sand were labeled as well fed, fed and starved larvae (Table 27). The feeding of *M. pseudohyalinus* larva prior to the experiment was as follows.

Table 27. The hunger level standardization of *M. pseudohyalinus* larvae

1.	Well-fed	2 ants/day
2.	Fed	1 ant/day
3.	Starved	No feeding

After 7 days (one week) of feeding/starvation the larvae were collected and the following experiments were conducted (Table 28).

Table 28. Experiments designed to analyse cannibalistic behavior of *M. pseudohyalinus* larvae

Sl. No.	Experiment
1.	Well-fed vs Well-fed
2.	Well-fed vs Fed
3.	Well-fed vs starved
4.	Fed vs Fed
5.	Fed vs Starved
6.	Starved vs Starved

Six pair wise combination of hunger levels were tested by releasing larvae in to the tray filled with sand. In each tray filled with two cup of sand and the larvae were marked without disturbing them as well fed, fed and starved (Plate 20). Like each experiment two larvae were released in to the tray filled with sand and allow them to make its pits for predation. After five days the soil was sieved and the occurrence of larvae noted as follows.

a. Pupated

b. Dead (With injuries cannibalised) (Devetak, 2000) (Plate 20)

The experiments were repeated 6 times and a total of 36 pairs were tested (Barkae *et al*., 2014)

3.3.4. Types of Interactions- Interspecific relationships

Interspecific relationships were studied by analyzing the predator and prey of antlion larvae Genus *Myrmeleon*. During the field study, observations were done to find out the presence of natural enemies of antlion larvae. For this purpose the natural habitat of antlion larvae like river side habitat, abandoned houses and heap of sand were carefully observed. Similarly observations were also done under laboratory conditions (rearing of antlion larvae) for identifying the natural enemy of this predator.

For understanding the type of prey or diet of antlion larvae Genus *Myrmeleon,* collected prey remnants from the antlion larval pits from study areas. The prey remnants analyzed under binocular microscope and photographs were taken for identification using available literature (Narendra and Kumar, 2006; Imms *et al*., 1977; Nayar *et al*., 1976; Borror *et al*., 1975).

3.3.5. Ethogram

Ethograms are consolidation of each behaviour of an organism and it gives an idea about the life style of that organism easily in a single graph. Here the ethogram of *M. pseudohyalinus* larvae was plotted in different condition, instar and substrate.

Plate 20

Marked Larvae for Cannibalism experiments

Dead antlion- Victim of competition

3.3 RESULTS

3.3.1. Pit Building Behaviour

3.3.1.1. Pit buiding behaviour in different medium, hunger level, and instar

The pit building behaviour of *Myrmeleon pseudohyalinus* larvae were observed under laboratory conditions. The antlion larvae build steep conical funnels which help to fall easily. The diameter and depth of the pit helps the easy falling of prey for this purpose. In each condition (fed and starved), instar (second and third) and medium (sand and soil), the pit building ability of *Myrmeleon pseudohyalinus* larvae was monitored and the interpretation was made according to the results made from Past 4.0 software.

In all the experiments, the diameter and depth were somewhat static up to 9 hours from the starting of pit making. From the 9 th hour onwards the larvae increases its depth and diameter suddenly for creating the steep conical shape. After 11 hours of pit building, the diameter was not increasing in a significant range.

The sample size in each experiment was 30 and the mean and standard deviation were shown in Fig 23 and 24. The progress of depth and diameter were plotted in Fig. 26 and 27 respectively. The mean pit diameter in second instar larvae ranges from 2.5cm to 3.6cm (Appendix 10) and that of third instar larvae was 3.2 to 3.5 cm (Appendix 11). The mean pit depth in second instar larvae ranges from 1.5 cm to 2.2 cm (Appendix 12) and that of third instar larvae was 2cm to 2.2 cm (Appendix 13).

Table 29. One way ANOVA-Test for equal means (Diameter)

	Sum of sqrs	df	Mean square	F	Critical value
Between groups:	20.1913	12	1.68261	15.05	1.86
Within groups:	10.1734	91	0.111796	Permutation p (n=99999)	
Total:	30.3647	103	1E-05		

Since the calculated F value 15.05 is greater than the critical f value 1.86 at 5% (Table 29). It is concluded that there is a significant difference between the pit diameter, size of larvae in different media (sand and soil) and different levels of feeding (fed and starved).

Table 30. One way ANOVA-Test for equal means (Depth)

	Sum of sqrs	df	Mean square	F	Critical value
Between groups:	7.17565	12	0.597971	14.53	1.86
Within groups:	3.74437	91	0.0411469	Permutation p (n=99999)	
Total:	10.92	103	1E-05		

Here, the calculated F value 14.53 is greater than the critical f value 1.86 at 5% (Table 30). It is concluded that there is a significant difference between the pit depth, size of larvae in different media (sand and soil) and different levels of feeding (fed and starved).

In the case of second instar larvae, the average diameters of the pit in the starting hour of pit building were 1.60 cm (sand medium, fed condition), 1.98 cm (sand medium, starved condition), 2.04 cm (soil medium, fed condition), and 2.12 cm (soil medium, starved condition). The final measurements of average diameters were 2.49 cm (sand medium, fed condition), 3.01 cm (sand medium, starved condition), 3.65 cm (soil medium, fed condition), and 3.13 cm (soil medium, starved condition). The fed larvae in soil medium have the highest average pit diameter in the final pit and the lowest value observed in fed larvae in sand medium. In the case of third instar larvae, the average diameters of the pit in the starting hour of pit building were 1.92 cm (sand medium, fed condition), 2.34 cm (sand medium, starved condition), 1.92 cm (soil medium, fed condition), and 2.06 cm (soil medium, starved condition). The final measurements of average diameters were 3.39 cm (sand medium, fed condition), 3.50 cm (sand medium, starved

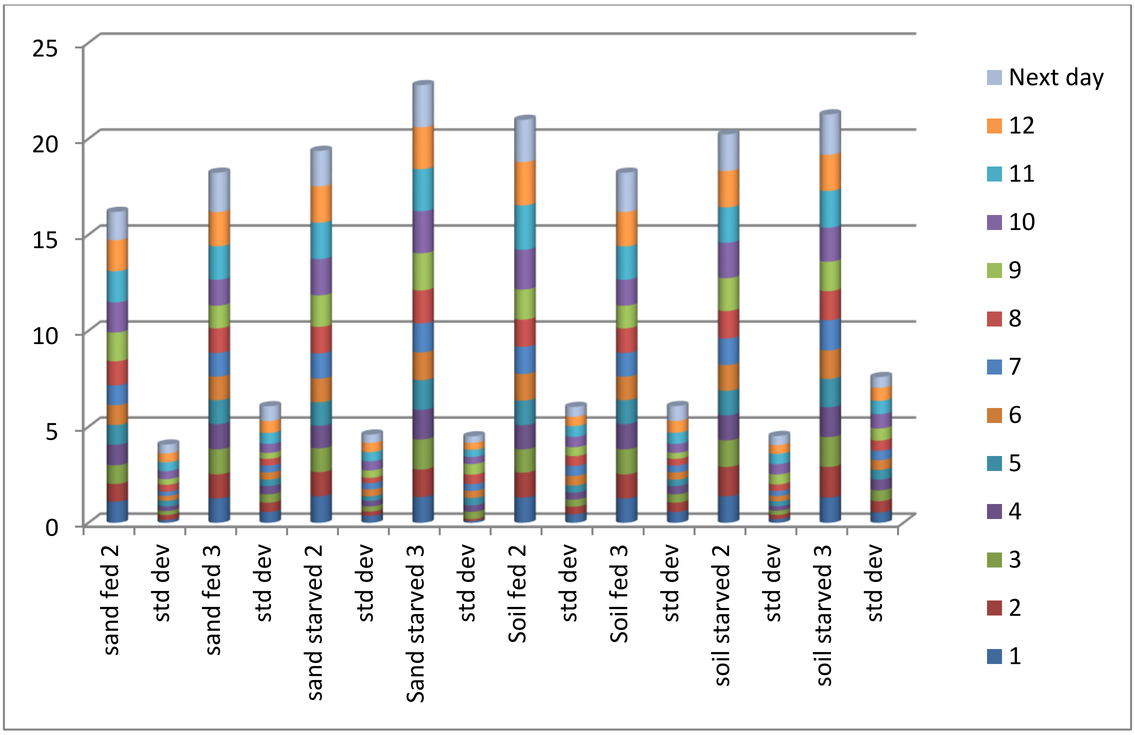


Fig 23. showing the progress of diameter (mean and standard deviation) while pit building of *M.pseudohyalinus* lrvae in different conditions, media and instar

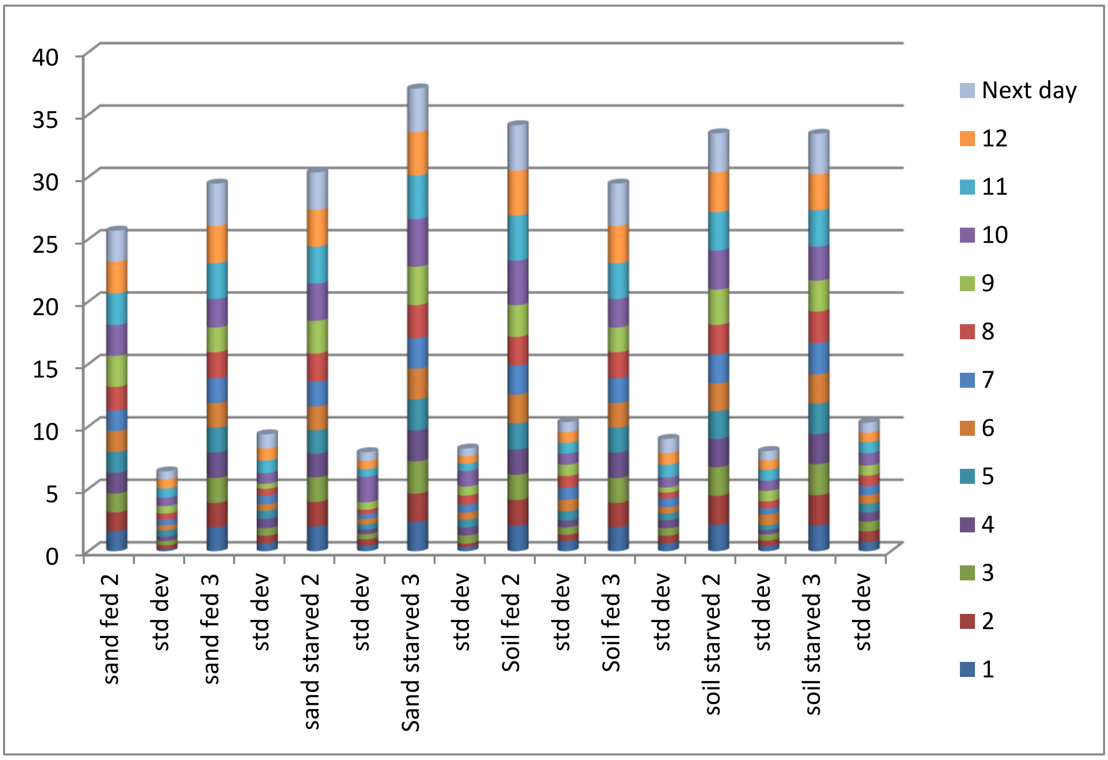


Fig 24. showing the progress of depth (mean and standard deviation) while pit building of *M.pseudohyalinus* lrvae in different conditions, media and instar

Experimental set up

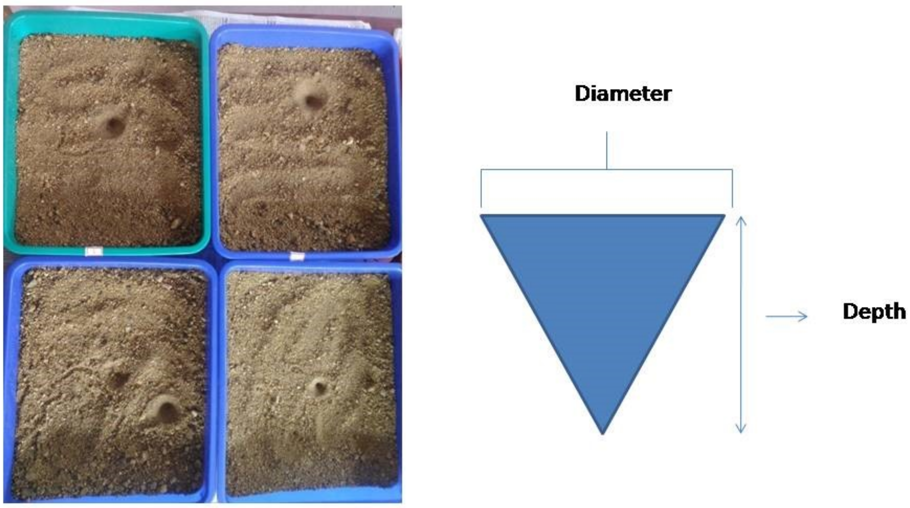


Fig. 25. The experimental set up for analyzing the pit building behaviour

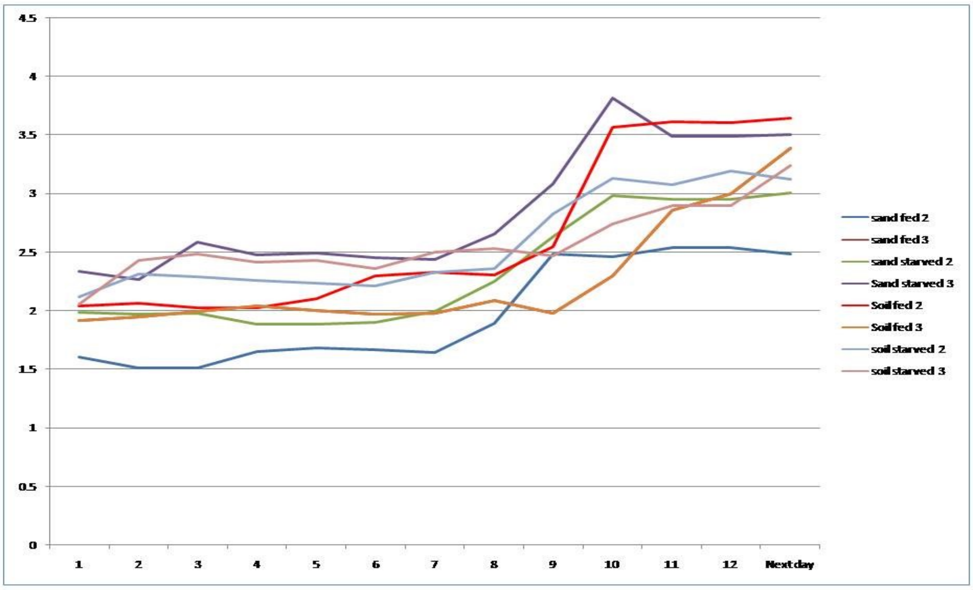


Fig. 26. Shows the progress in diameter while pit building of *M. pseudohyalinus* larvae in different conditions, media & instar

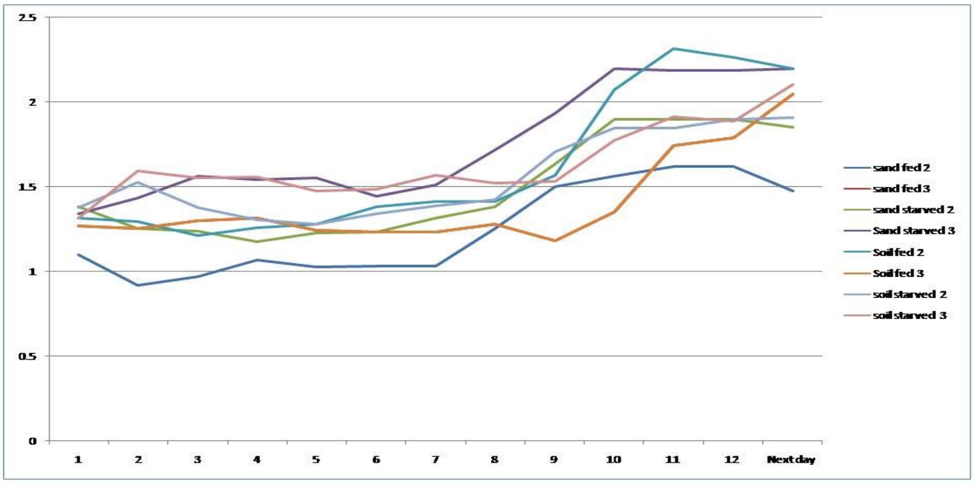


Fig. 27. shows the progress in depth while pit building of *M. pseudohyalinus* larvae in different conditions, media & instar

condition), 3.39 cm (soil medium, fed condition), and 3.24 cm (soil medium, starved condition). The starved larva in sand medium has the highest average pit diameter in the final measurement and the lowest value observed in starved larvae in soil medium.

In the case of second instar larvae, the average depth of the pit in the starting hour of pit building were 1.10 cm (sand medium, fed condition), 1.38 cm (sand medium, starved condition), 1.31 cm (soil medium, fed condition), and 1.38 cm (soil medium, starved condition). The final measurements of average depth were 1.48 cm (sand medium, fed condition), 1.85 cm (sand medium, starved condition), 2.20 cm (soil medium, fed condition), and 1.91 cm (soil medium, starved condition). The fed larvae in soil medium have the highest average pit depth in the final pit and the lowest value observed in fed larvae in sand medium. In the case of third instar larvae, the average depth of the pit in the starting hour of pit building were 1.27 cm (sand medium, fed condition), 1.34 cm (sand medium, starved condition), 1.27 cm (soil medium, fed condition), and 1.31 cm (soil medium, starved condition). The final measurements of average depths were 2.04 cm (sand medium, fed condition), 2.20 cm (sand medium, starved condition), 2.05 cm (soil medium, fed condition), and 2.10 cm (soil medium, starved condition). The starved larva in sand medium has the highest average pit depth in the final measurement and the lowest value observed in starved larvae in sand medium and fed larvae in soil medium.

3.4.1.2. Pit characteristics in different type of substrates

Within 3 hours, the introduced antlion larvae made their pits in the soil. Trailing behaviour was low in sand and the largest pits were built in the sand. The average pit diameter and pit depth was 3.80 cm and 2.85 cm respectively in sand. From this result we can inferred that Genus *Myrmeleon* makes their largest pits in the sand and that was the most preferred soil type. Also the size of the pit indicates the hunger level of the antlion larvae because it was kept 24 hr starvation before doing this experiment. The average depth and diameter in different substrates were given in Fig. 28.

In the case of second preference, the diameter was more in the brick kiln/clay soil than other two, it may be because of the clay soil is very fine and it is very difficult to build more deep pits. In the case of mixture (cement, sand and soil), they form pits with more depth by reducing its diameter. It is inferred that they do prefer the pit depth than diameter for pit building in order to reduce the prey escape. It is also assume that if the soil is more fine, antlion larvae build their pit with increased diameter.Trailing behaviour was low in sand and the largest pits were built in the sand.In the case of second preference, the diameter was more in the brick kiln/clay soil than other two, it may be because of the clay soil is very fine and it is very difficult to build with more deep pits. In the case of mixture (cement, sand and soil), they form pits with more depth by reducing its diameter. The different types of soil with its pit size were shown in Fig. 29.

3.4.1.3. Trailing Behaviour

- The trailing behaviour was observed between 3sec to 50 minutes from the introduction of larvae to the soil.
- In most cases, trailing started within 3seconds.
- From the centre portion of the tray the larvae first moved to the periphery of the tray.
- The larvae make its pits only after the calculation of the boundary of the habitat or environment by moving on to the periphery of the tray.
- Most of the time the trailing started from the centre to north of the tray and they moved near to the centre, which is south.
- After fixing the correct location for its pit building the backward rotation starts with the flipping of soil.

The trailing behaviour of larvae in natural and laboratory conditions were given in Plate 21.

3.4.2. Predatory/Feeding Behaviour

The twelve behaviour patterns were identified and from this data predatory efficiency (Table 31) of *Myrmeleon pseudohyalinus* larvae was explained.

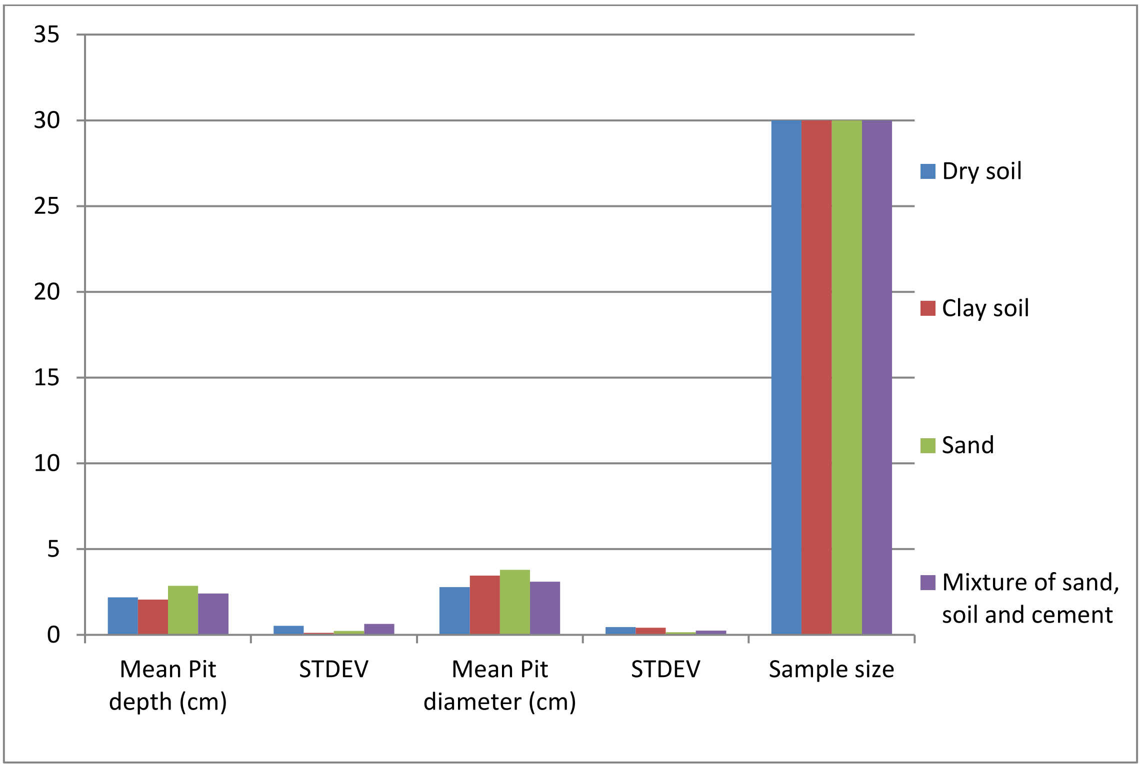


Fig. 28. Average depth and diameter in different substrates

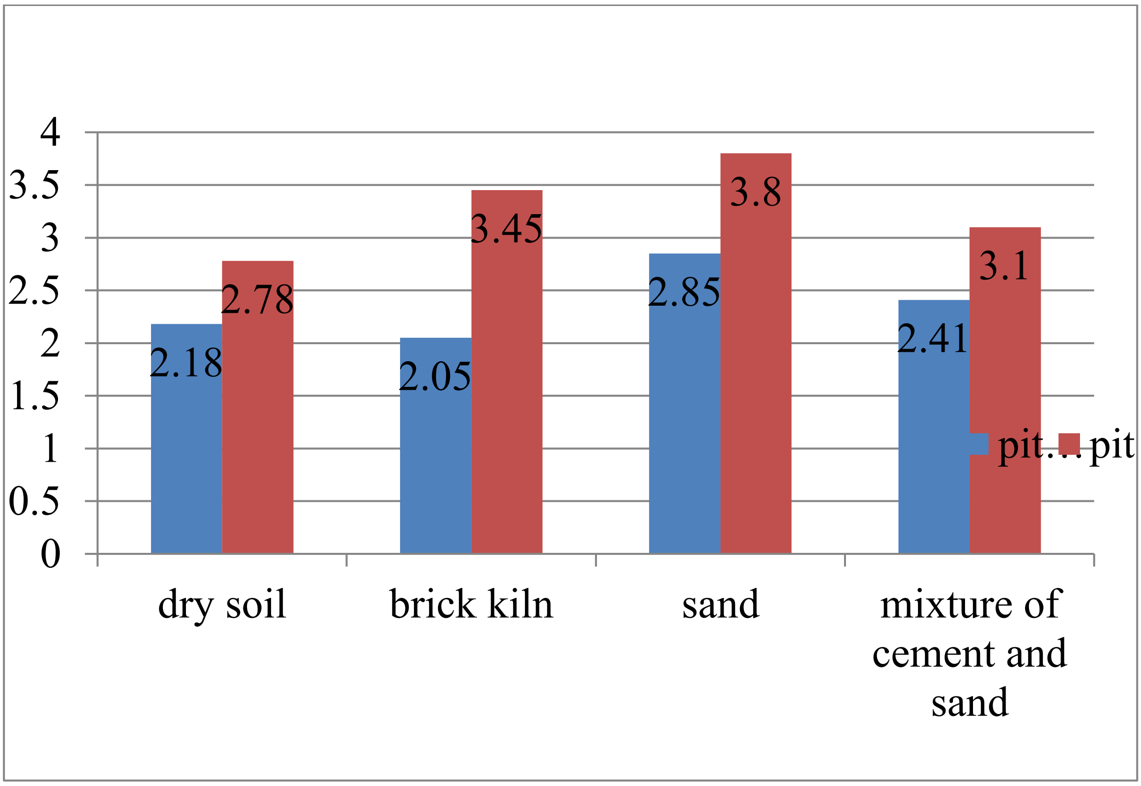
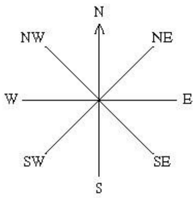


Fig. 29. Showing the different type of soil with its pit size

Plate 21



Turning from N to S is 180 ° clockwise or anticlockwise

Turning from NE to SE is 90 ° clockwise (or 270 ° anti-clockwise)

Turning clockwise from NE to E is 45 ° (or 315 ° anticlockwise)

Trails of antlion larvae both in natural and lab condition

75% of the larvae took 0-35 minutes for the completion of its feeding process (attack to jaw set) and the remaining 25% of the larvae took 0-45 minutes to complete its feeding irrespective of the conditions. Irrespective of the conditions, the second instar (95%) larvae were more successful than third instar (75 %) larvae.

Table 31. Showing the predatory efficiency of *Myrmeleon pseudohyalinus* larvae

Sl No.	Condition	Feeding time (Minutes)	Prey Escape (%)	Capture Success (%)
1	Sand, Fed, Second instar	0-45	20	80
2	Sand, fed, Thirdinstar	0-35	50	50
3	Sand, Starved, Second instar	0-45	0	100
4	Sand, Starved, Third instar	0-35	33	67
5	Soil, Fed, Second instar	0-35	0	100
6	Soil, Fed, Third instar	0-35	0	100
7	Soil, Starved, Second instar	0-35	0	100
8	Soil, Starved, Third instar	0-35	18	82

The Eigen values (Table 32) for Axis1 and 2 added upto 99.99% which indicates that 99% of the variance has been covered. Therefore robustness is very high and can be used for interpretation. The prey beating, emergence and submergence behaviours are influenced by the larval instar (second and third). While the quiescence, pit clearing and jaw set behaviour patterns are influenced by their condition that is whether it was fed or starved. Head roll behaviour is only related to the medium of the substrate in which the larvae inhabiting. Here sand or dry soil are the medium used for the study. The relationship between selected behaviour, instar, medium and condition were plotted in Fig.30.

Table 32. Eigen values

Axis	Eigen value	%
1	0.056716	87.61
2	0.008017	12.38
3	3.91E-06	0.006039

The Eigen values (Table 33) for Axis 1 and 2 added up to 90.8% which indicates that 90% of the variance has been covered. Therefore robustness is high and can be used for interpretation. Medium (sand and soil), condition (fed and starved) or instar (second and third) did not play much of a role in the behaviour but, time period seem to. While the behaviour in the first five and last five minutes of observation seemed very similar (mainly inactivity). Behaviour of 5-10 minutes also showed similarity to this group. Behaviour seemed 10-15 and 15-20 minutes were very unique and therefore lay in different quadrates. Rest of the five minute windows showed similar behaviour. The relationship between selected behaviour, instar, medium, condition and time period were given in Fig.31.

Table 33. The Eigen values

Axis	Eigen value	%
1	0.24361	69.45
2	0.074889	21.35
3	0.032186	9.175
4	0.000101	0.02891

The common ant (*Anoplolepis gracilipes* - worker) was used for the feeding purpose both in rearing and experiments, because it is the most abundant prey item in the antlion larval pit irrespective of species. In all the conditions, the larvae show similar behaviour patterns in first five minutes. Attack, honding, submergence, emergence, prey beating and feeding are the six behaviour patterns. In addition to this, head roll behaviour pattern is present in 5-10 minutes period of feeding except starved second instar larvae in sand medium. Starved second instar larvae in soil medium shows pit clearing behaviour in addition to this head roll.

The 10-15 minute period of fed second instar larvae, third instar larvae and starved third instar larvae shows similarity in behaviour patterns and the starved second instar larvae in sand media pit clearing and prey clearing were found in addition to the common behaviour (prey beating, feeding and head roll) in this time period.This indicate that the second instar starved larvae shows more hunger than third instar larvae and clear its pit and throw the prey from pit for making the pit again steep and wait for another prey. In soil media, the second instar fed larvae shows quiescence

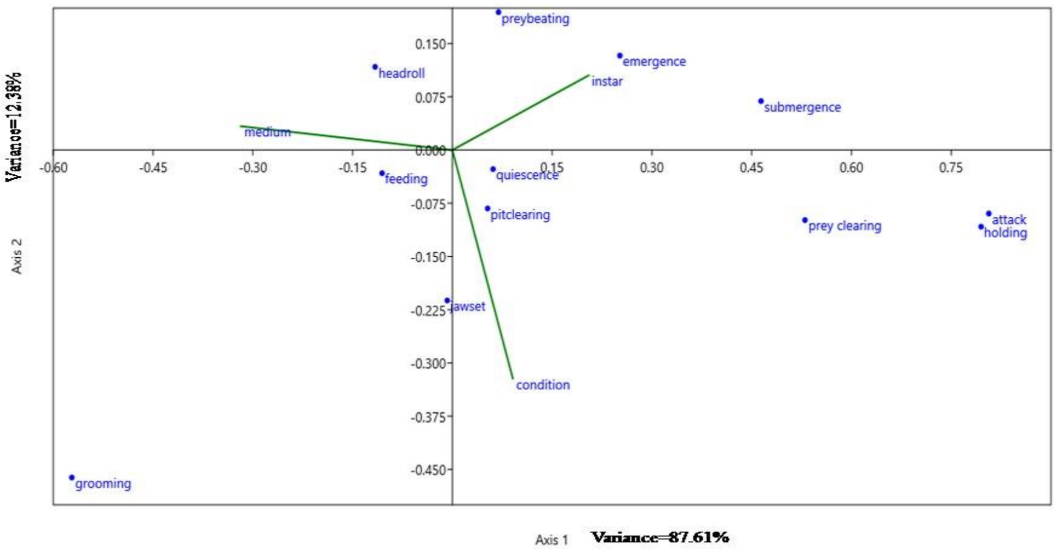


Fig. 30. CCA map showing relationships between selected behaviour and instar, medium and condition

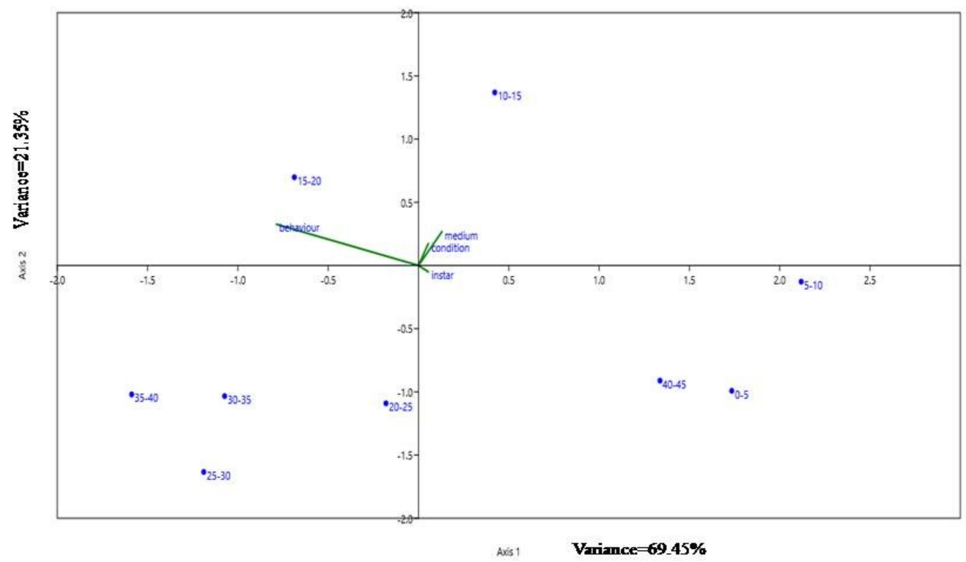


Fig. 31. CCA map showing relationships between selected behaviour and instar, medium and condition & time period

and jaw set behaviour pattern in this period and the third instar fed larvae shows similar behaviour pattern of second and third insat fed larvae in sand media.

15-20, 20-25 and 25-30 minutes are more important in feeding of *M. pseudohyalinus* larvae and the prey beating, feeding, pit clearing, head roll, prey clearing, grooming, quiescence and jaw set avtivities are at its peak. In 30-35 minutes, the jaw set and quiescence are the main patterns and considered as the end point of feeding behaviour.The twelve feeding behaviour patterns of *Myrmeleon pseudohyalinus* larvae in various conditions were plotted in Fig.32 to Fig. 39.

From the feeding behaviour study of *M. pseudohyalinus*, it was understood that the behaviour patterns of fed second instar larvae in sand medium (Fig. 32) and fed third instar larvae in soil medium (Fig. 37) shows a similar pattern with respect to the time period. Here, the maximum feeding activity was present in 15 to 30 minutes. Similarly, the fed third instar larvae in sand medium (Fig. 33) and starved third instar larvae in sand medium (Fig. 35) shows similar pattern with respect to time period. Here, two peaks were present in the activity patterns (0-15 minutes and 15-30 minutes). The remaining experiments such as starved second instar larvae in sand medium (Fig. 34), fed second instar larvae in soil medium (Fig. 36), starved second instar larvae in soil medium (Fig. 38) and starved third instar larvae in soil medium (Fig.39) didn't show a prominent pattern of feeding activity with respect to time period.

3.4.3. Intraspecific relationship-Cannibalism

Well fed vs Well Fed (two larvae in each experiment, six replications, sample size-12): In all the experiment one larva was dead and 50% of mortality was noted. The hunger level was same in each larva so that the competition resulted the mortality of 50% in each replication in both second and third instars.

Well fed vs Fed (two larvae in each experiment, six replications, sample size-12): Here 70% of well fed larvae and 30% of fed larvae were dead due to cannibalism in second instar larvae. No pupation was noted in second instar and the cannibalism noted was high in increased hunger levels in the experiment. In the case of third instar larvae, the mortality rate was same, but 20% of larvae were pupated (all are fed). Also 30% of larvae neither pupated nor dead.

Well fed vs Starved (two larvae in each experiment, six replications, sample size-12): In the case of second instar larvae 70% of starved larvae and 40% of well fed larvae were dead .20 % of larvae neither dead nor pupated. In the case of third instar larvae, only 10% of larvae were pupated. 50% starved larvae and 20% of well fed larvae were dead. Also 40% larvae neither dead nor pupated.

Fed vs Starved (two larvae in each experiment, six replications, sample size-12): 90% of fed larvae were dead in the case of second instar larvae. 10 % of starved larvae were pupated and neither dead nor pupated.70% of third instar fed and starved larvae were dead.

Fed vs Fed (two larvae in each experiment, six replications, sample size-12): 50% of larvae were dead and 10% was pupated. The remaining 40% neither pupated nor dead in second instar larvae. 40% dead 45% pupated and only 15 % has no change through out the period.

Starved vs Starved (two larvae in each experiment, six replications, sample size-12): Here both second and third instar, 50 % were dead, the remaining 50% has no change through out the experiment.

The detailed observed values were given in Appendix 14.

3.4.4. Interspecific relationships-Prey and Predation

Interspecific interactions are the relationship of an organism with other species or between species. Prey and predation are the two major interactions between species and here the interaction of pit building antlion larvae genus *Myrmeleon* with other organisms were illustrated.

The antlion larval pits were carefully observed for understanding the feeding behaviour in natural condition. The prey remnants were collected and observed under Leica Stereozoom research microscope attached with camera. The prey remnants which cleared adjacent to the pits after consuming the body fluid were collected and photographed. Due to predation, only some parts of the prey were available and these specimens were somewhat difficult for identification. The collected specimens included Insects, Arachnids and Millipedes. The prey items were identified using

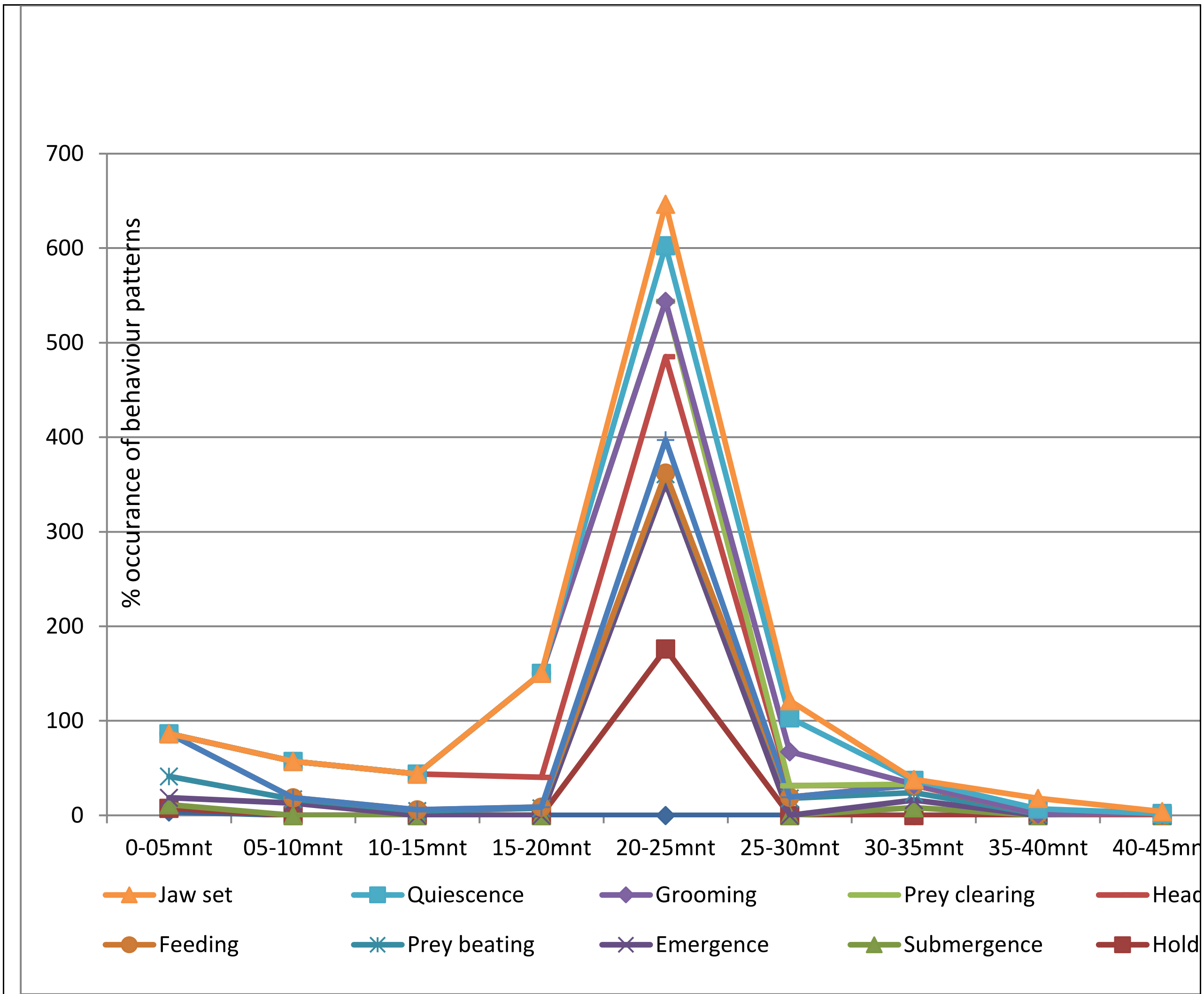


Fig 32. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* fed second instar larvae in each time intervals in sand medium.

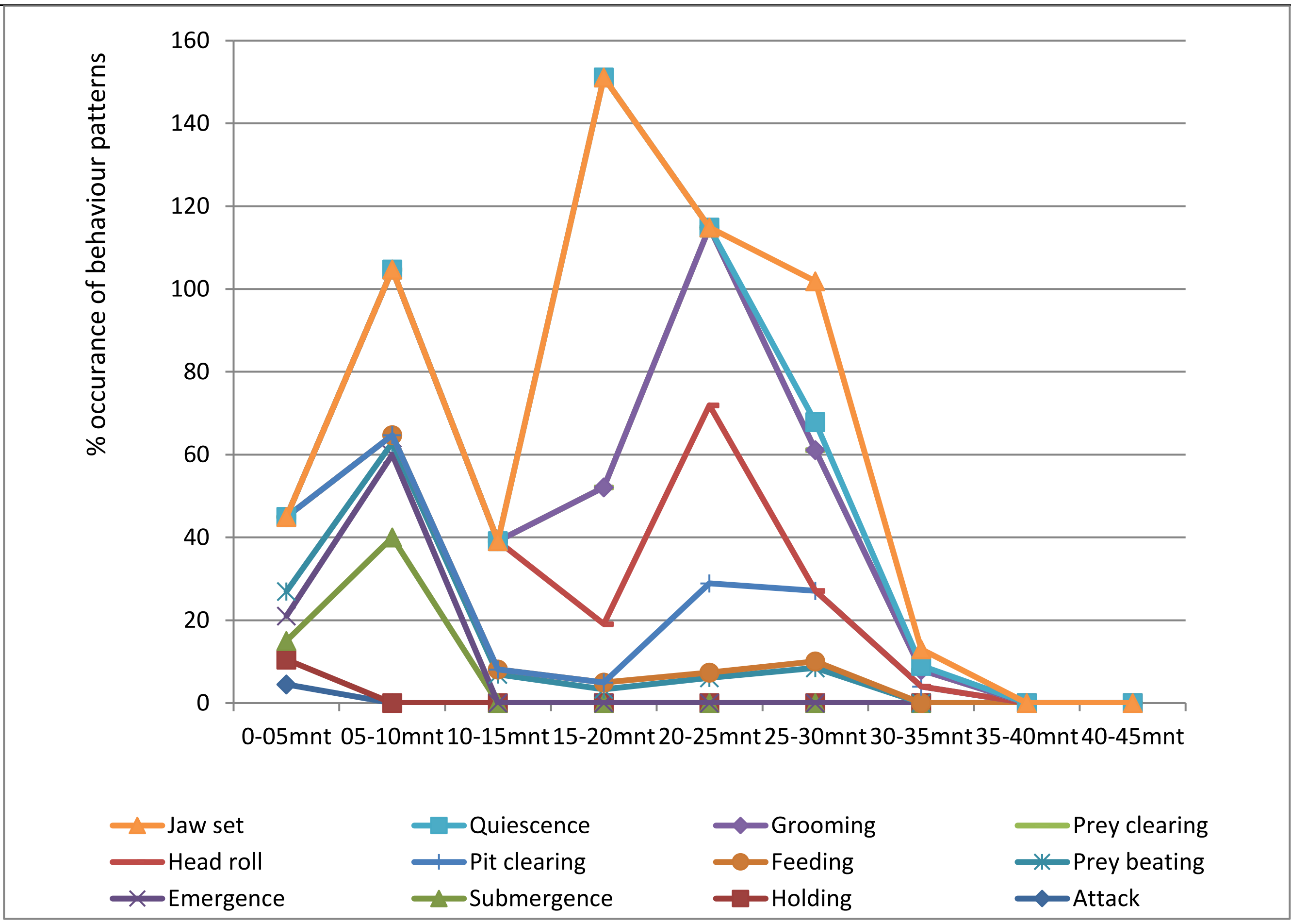


Fig 33. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* fed third instar larvae in each time intervals in sand medium

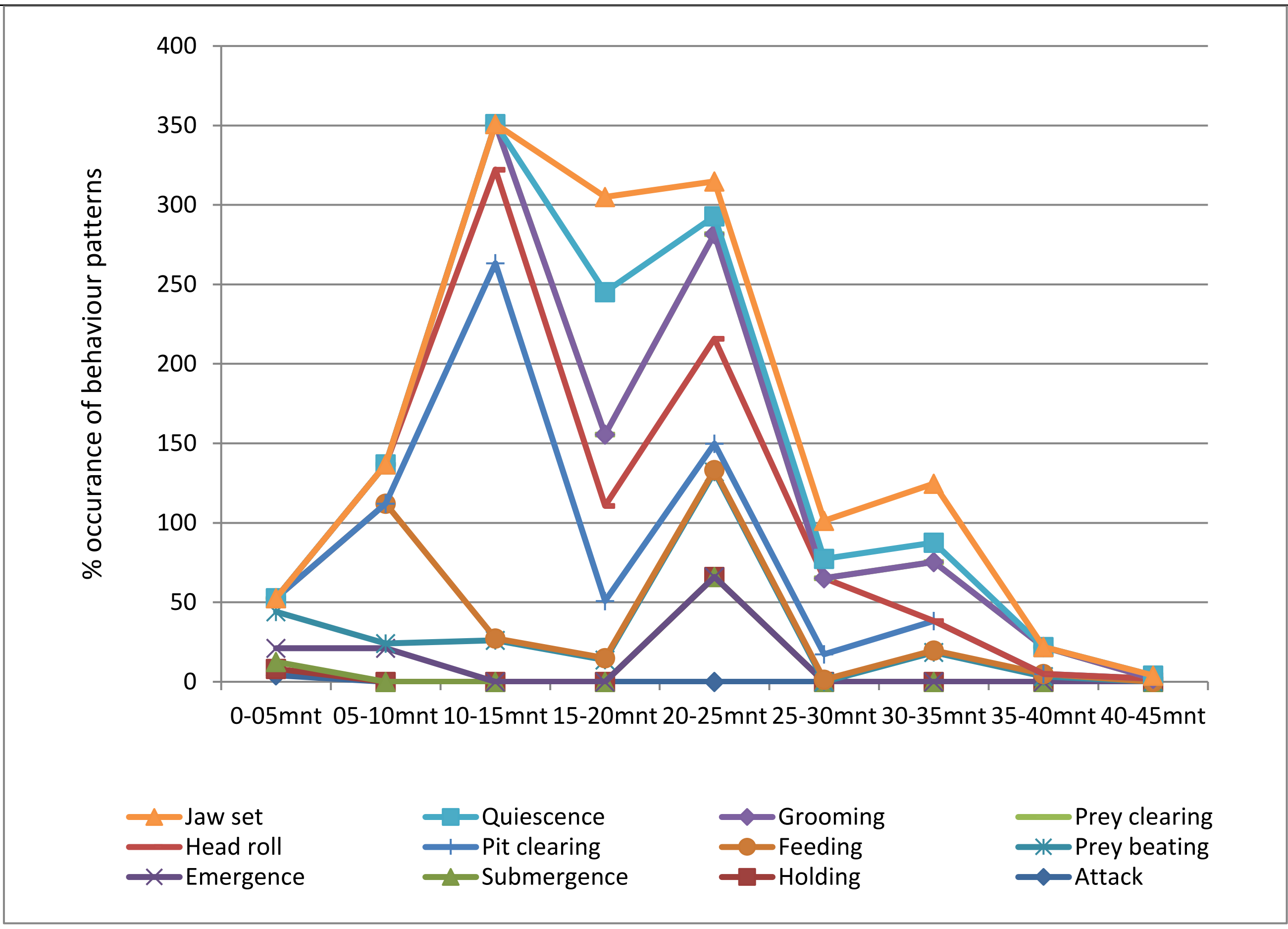


Fig 34. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* starved second instar larvae in each time intervals in sand medium

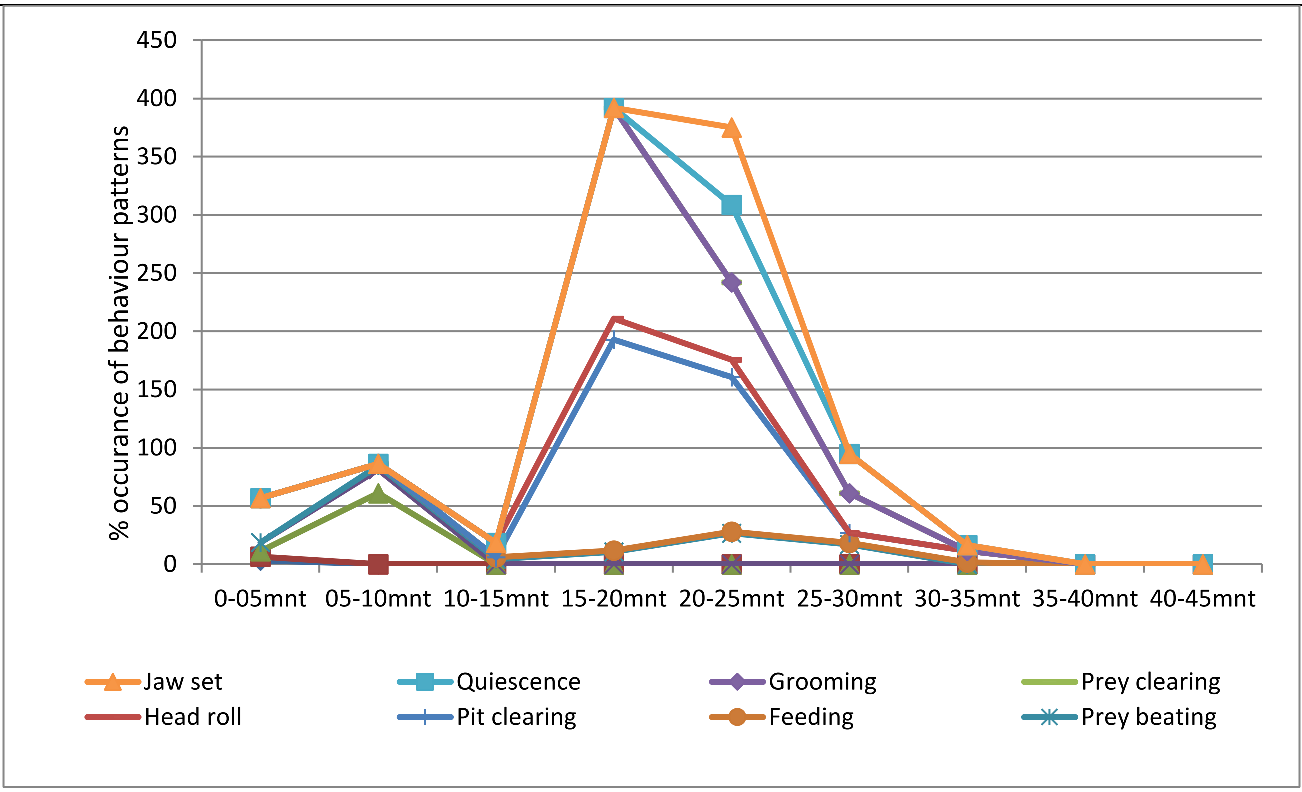


Fig 35. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* starved third instar larvae in each time intervals in sand medium

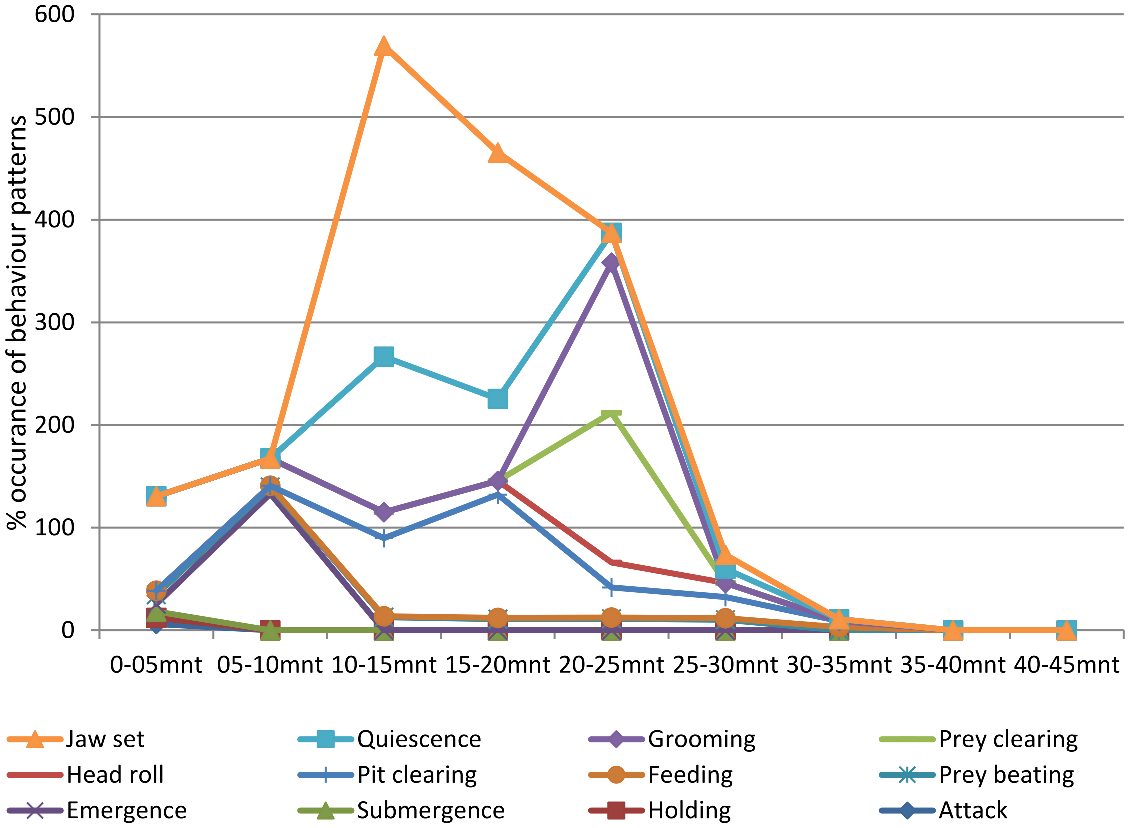


Fig 36. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* fed second instar larvae in each time intervals in soil medium

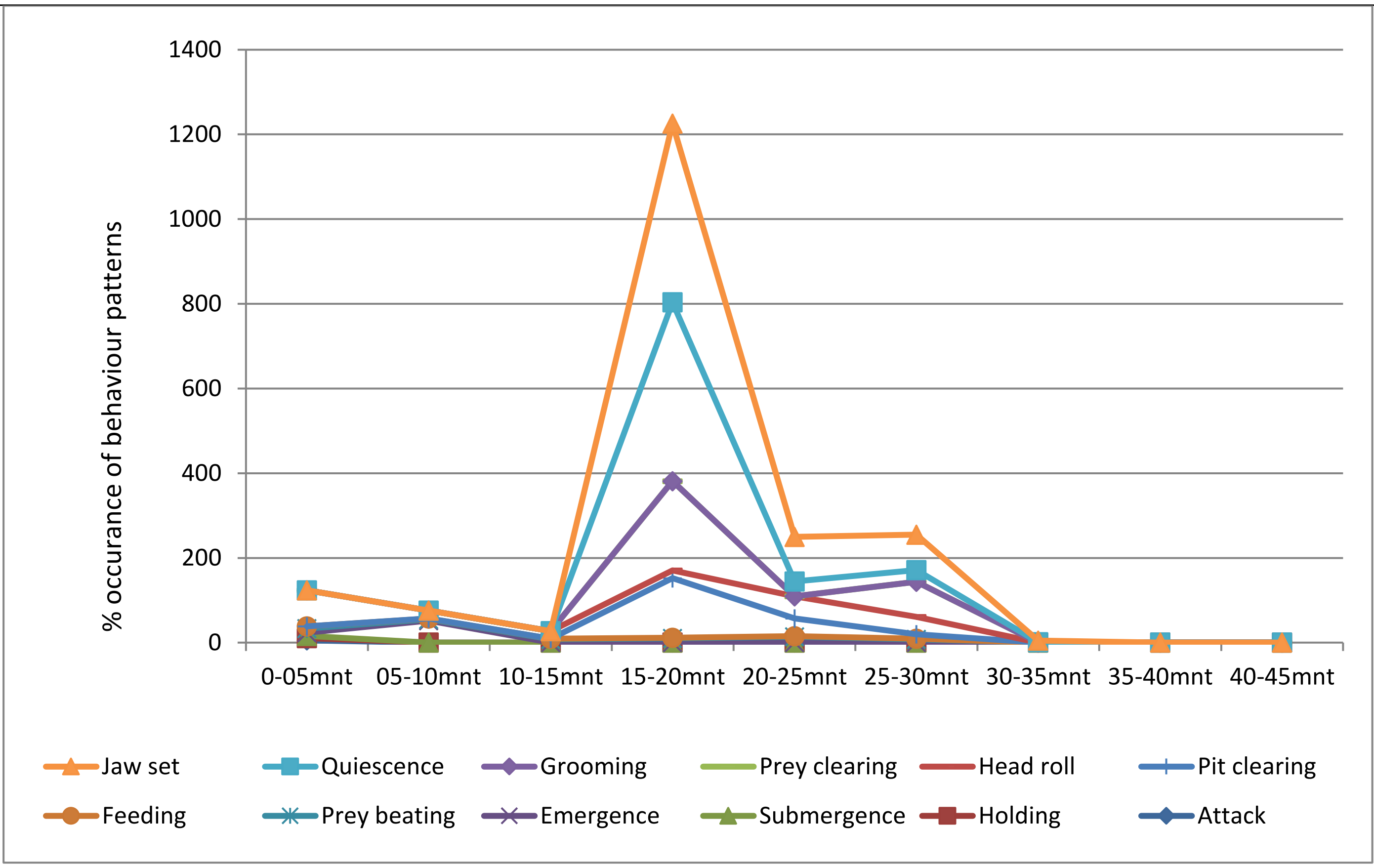


Fig 37. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* fed third instar larvae in each time intervals in soil medium

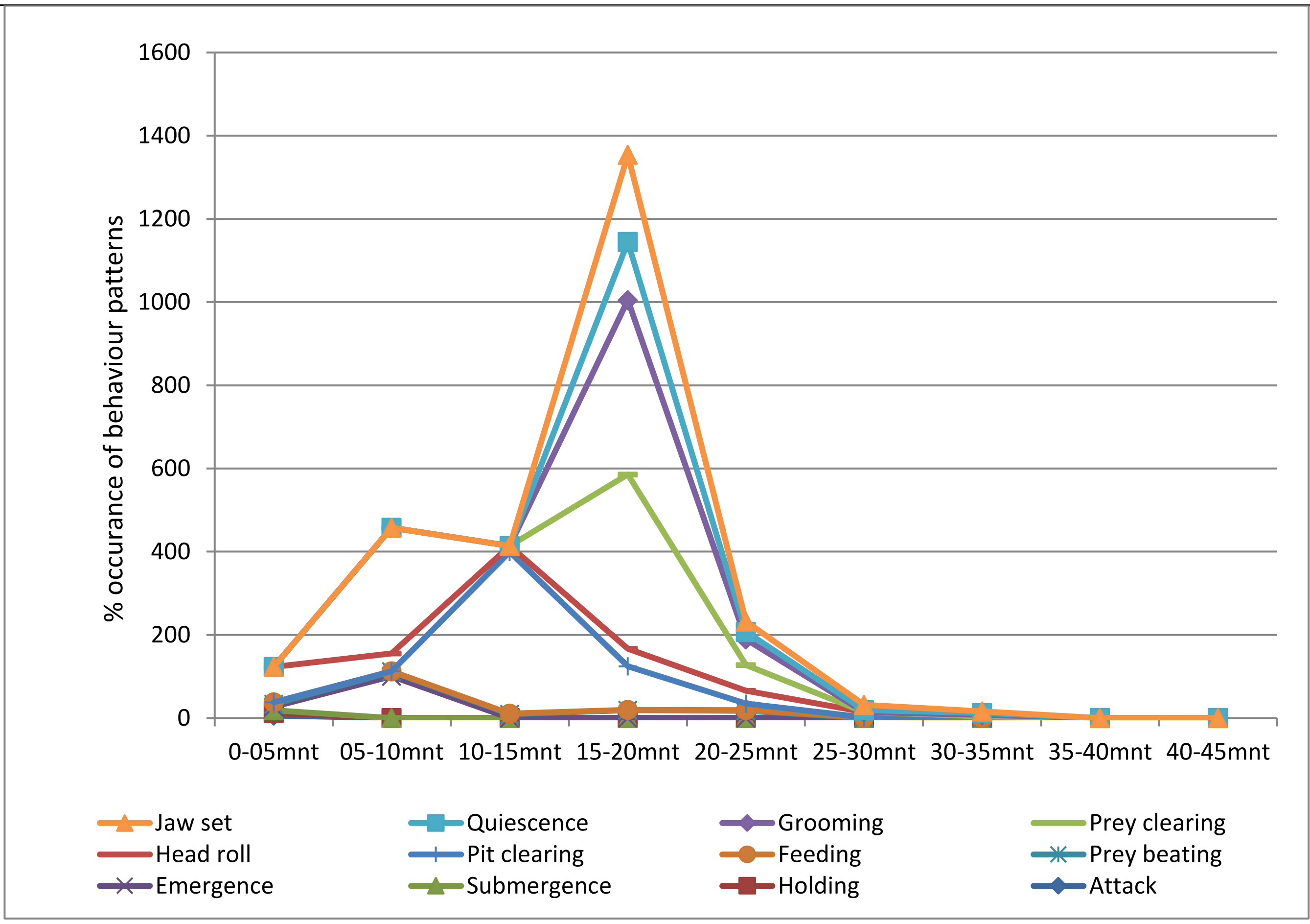


Fig 38. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* starved second instar larvae in each time intervals in soil medium

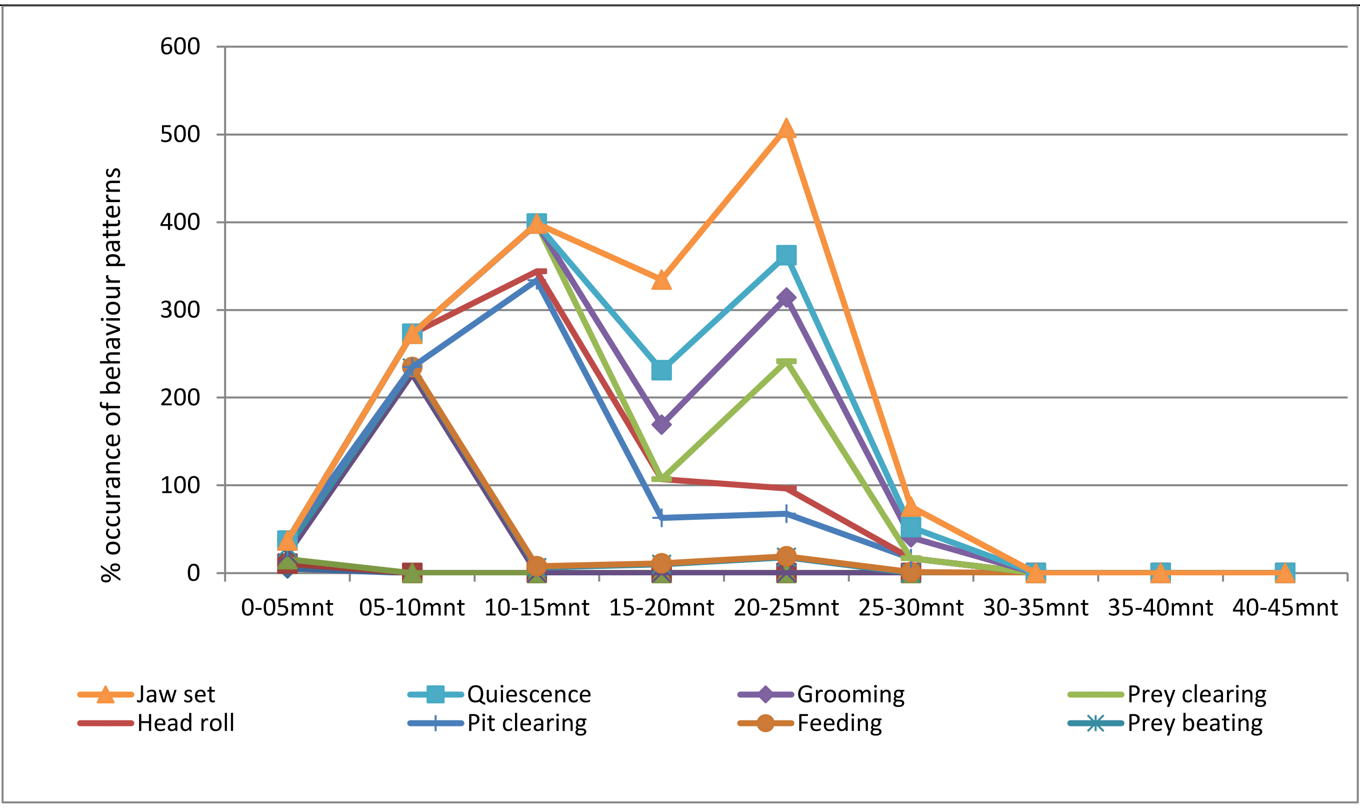


Fig 39. Feeding behaviour pattern of *Myrmeleon pseudohyalinus* starved third instar larvae in each time intervals in soil medium

available literature (Narendra and Kumar, 2006; Sebastian and Peter, 2012; Borror *et al*., 1975) and some specimens were identified by experts.

The prey species includes Order Hymenoptera, Coleoptera and Lepidoptera and very few numbers of spider and millipede. Given below the detailed prey species of antlion larvae (*Genus Myrmeleon*) collected from antlion larval pits.

The prey item was collected from Palakkad, Thrissur, Wayanad, Thiruvananthapuram, Pathanamthitta, Kannur, and Malappuram Districts of Kerala. The most preferred prey was Hymenopterans and it includes *Anoplolepis gracilipes* – worker, *Camponotus compressus*- worker, *Oecophylla smaragdina*- male, *Tetramorium smithi* and Genus *Crematogaster*. The small sized coleopterans like mupli beetle, cerambicids also collected from antlion pits. A spider species coming under Family: Gnaphosidae, *Scotopheu*s species was also collected.The members of the Family Gnaphosidae are commonly called mouse spiders and a total of ten species reported from India so far. The percentage occurrence of prey items were given in Fig. 40 to Fig. 46 and the photographs were given in Plate 22 and Plate 23.

During the study, the main predators in the laboratory rearing are spiders and lizards. One species of spider and one species of lizard were observed and the description is given below.

(1) *Heteropoda venatoria* (Family: Sparassidae)

H. venatoria (Plate 24) coming under family Sparassidae belongs to class Arachnida, are predators of the nature. The members of this family commonly called Giant crab spiders. They are the common house spiders and also seen in tree trunks in gardens. These are nocturnal spider and mainly a cockroach hunter. (Sebastian and Peter, 2012).

(2)Hemidactylus frenatus

These are lizard species coming under subfamily Gekkoninae with 607species and 63 genera (Plate 24). *Hemidactylus* is a large genus with well developed toe pads. Apart from houses, it is present in rocks, dry stone walls and trees (Maltison, 1992).

In the field condition some birds are also found to be eating antlion larvae.

3.4.5. Ethogram

The highest activity present in the predatory/feeding behaviour of the larvae was feeding followed by prey beating except the experiment with starved third instar larvae in sand medium. In this condition attack and holding behaviour patterns were observed more next to feeding pattern. In all the conditions the feeding pattern ranges from 47.8 to 77.8 % and that of prey beating 9.2 to 21 %. The detailed activity budgets of behaviours were given in Table 34.

Table 34. Feeding / predatory activity budget for each behaviour patterns in different conditions

Activity ↓ %→	1	2	3	4	5	6	7	8
A	1.8	5	2.4	12.4	1.5	1.3	1.2	1.4
H	1.9	4.3	2.4	12.4	1.5	1.3	1.2	1.4
S	1.9	5.3	2.2	3.9	1.5	1.3	1.2	1.4
E	1.9	5	2.1	1.1	1.5	1.3	1.2	1.4
PB	16	21	10.4	9.2	11.6	15.2	9.4	12.1
F	70	47.8	71.4	54.1	73.9	71.9	77.8	71
PC	1	1.7	2.1	1.1	1.4	1.2	1.1	1.4
HR	1.8	4.8	2.2	3.7	4.7	4.4	4.1	6.3
PR	1.2	2.3	1.5	0.6	0.1	0.3	0.4	0.9
G	0.1	0	0	0	0.1	0	0.5	0.8
Q	1.4	2.4	2.2	1	1.6	1.3	1.2	1.4
JS	1	0.4	1.1	0.5	0.6	0.5	0.7	0.5
Total	100	100	100	100	100	100	100	100

1-Fed second instar larvae in sand medium, 2- Fed third instar larvae in sand medium, 3- Starved second instar larvae in sand medium, 4- Starved third instar larvae in sand medium, 5- Fed second instar larvae in soil medium, 6- Fed third instar larvae in soil medium, 7- Starved second instar larvae in soil medium, 8- Starved third instar larvae in soil medium.

The ethogram (feeding behaviour) of *M. pseudohyalinus* larvae were plotted as bar diagrams from Fig. 47 to Fig. 54.

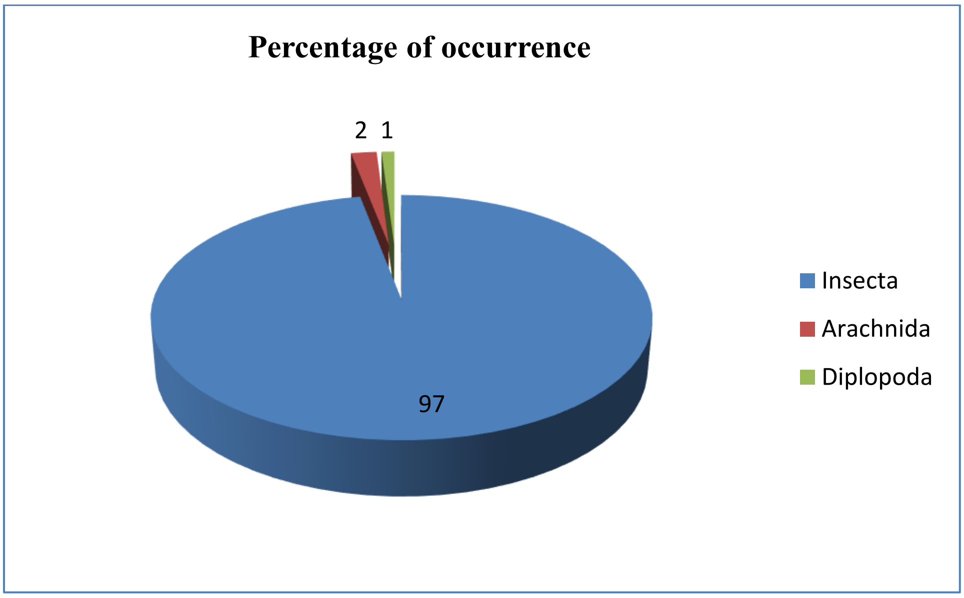


Fig. 40. Percentage occurrence of prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2016

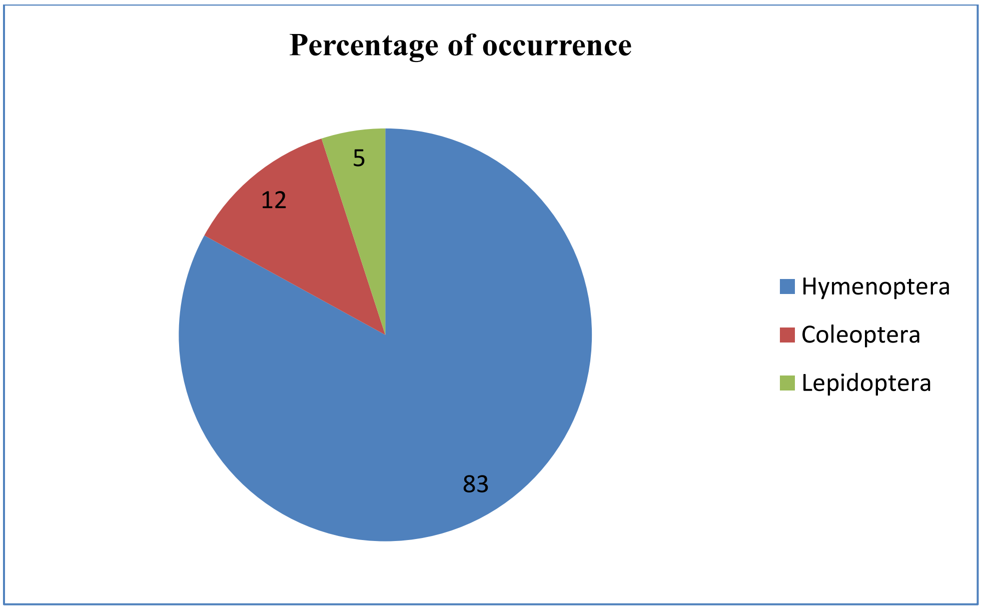


Fig. 41. Percentage occurrence of insect prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2016

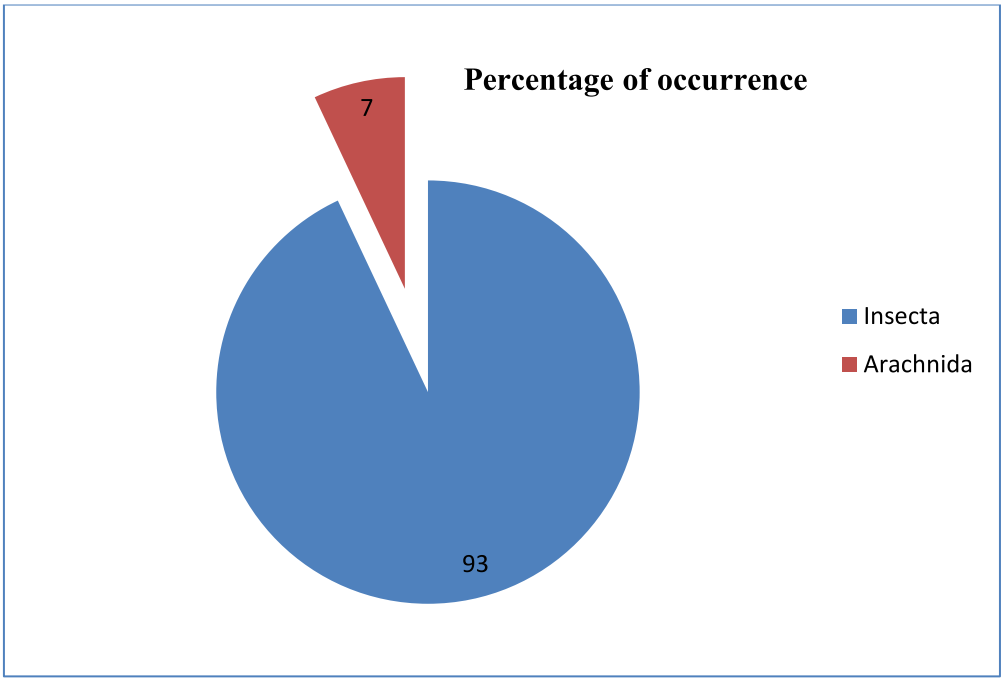


Fig. 42. Percentage occurrence of prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2017

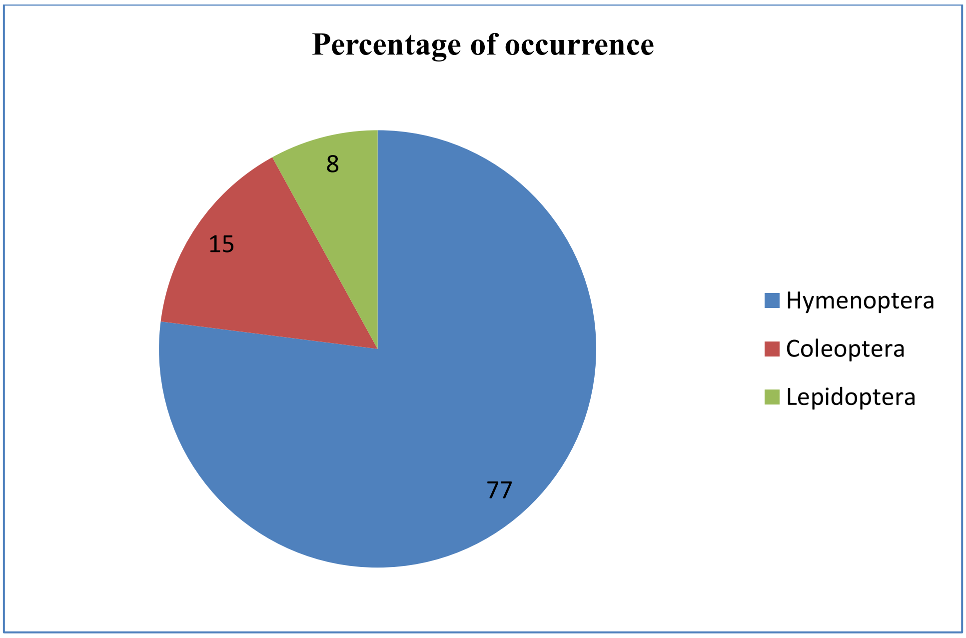


Fig. 43. Percentage occurrence of insect prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2017

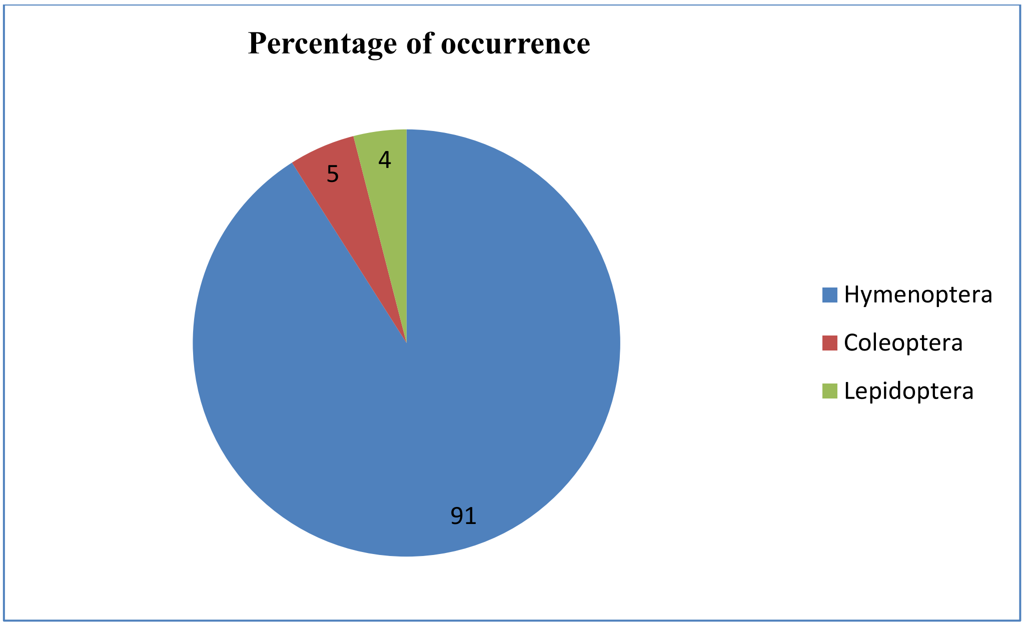


Fig. 44. Percentage occurrence of prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2018

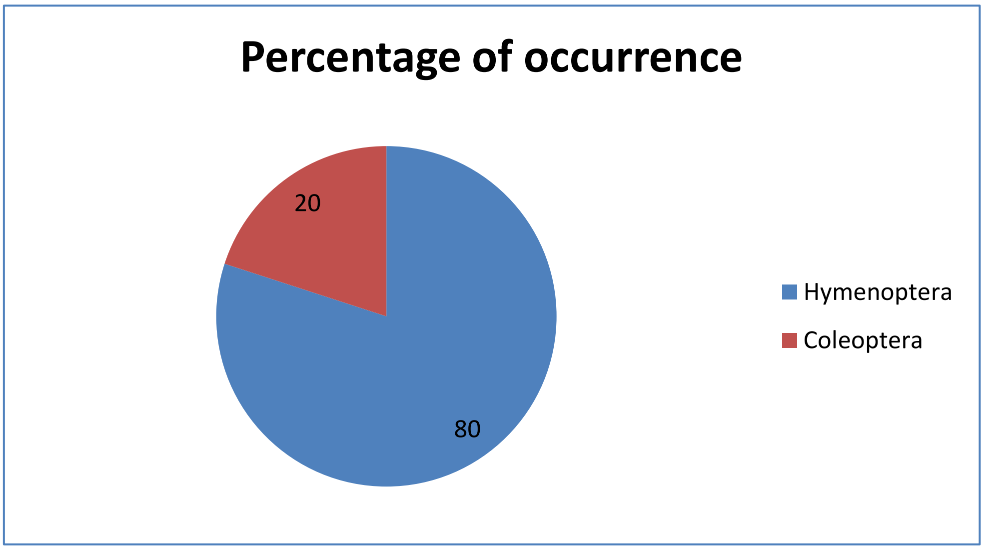


Fig. 45. Percentage occurrence of prey items collected from antlion larval pits (Genus *Myrmeleon)* in 2019

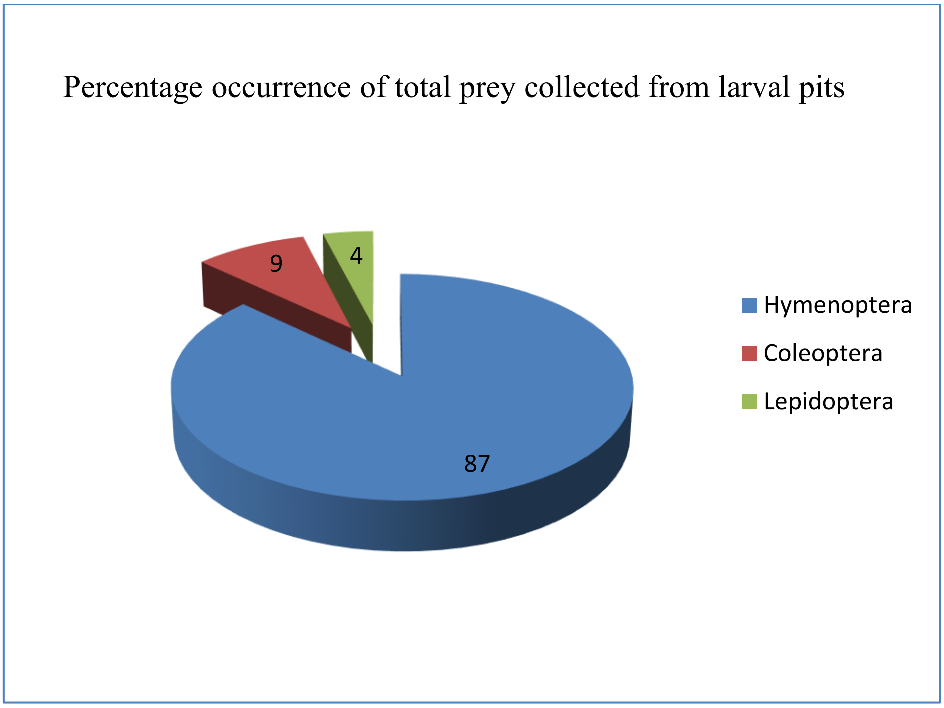


Fig 46. Consolidated data of prey preferred by antlion larvae Genus *Myrmelon*

Plate 22

Order Hymenoptera

Camponotus compressus- worker

Oecophylla smaragdina- male

Genus *Crematogaster*

Tetramorium smithi

Anoplolepis gracilipes

Plate 23

Order Coleoptera

Scotopheus Sp.

Diplopoda

Plate 24

Hetropoda venatoria

Hemidactylus frenatus

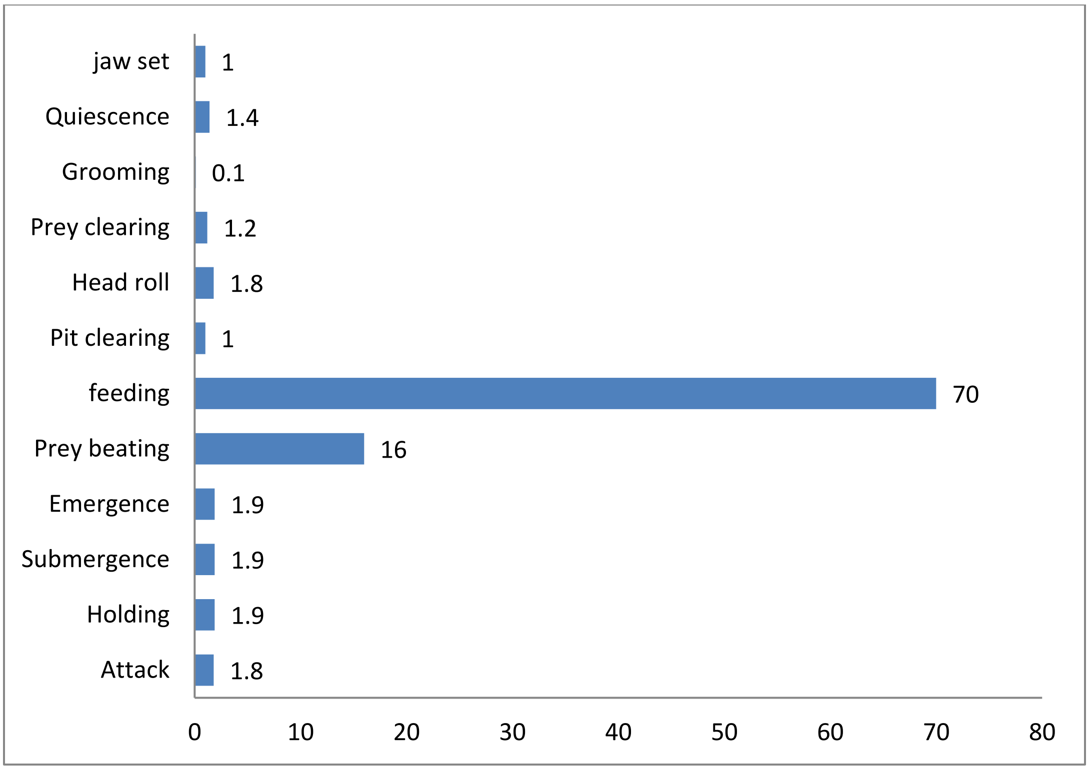


Fig. 47. Feeding / predatory activity budget for each behaviour patterns in sand medium, fed second instar larvae

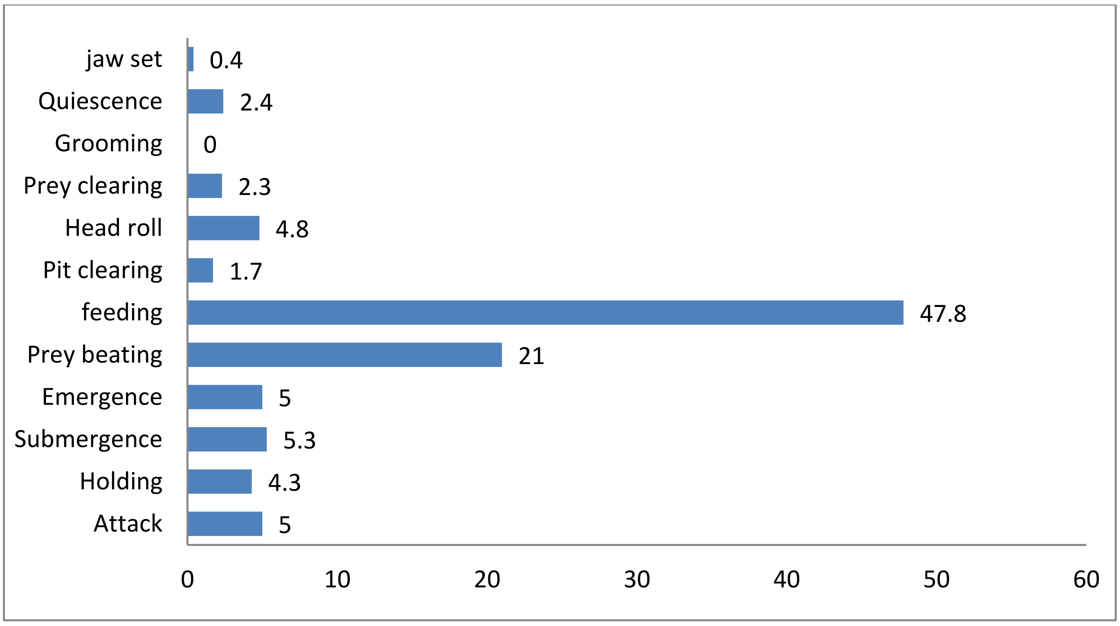


Fig. 48. Feeding / predatory activity budget for each behaviour patterns in sand medium, fed third instar larvae

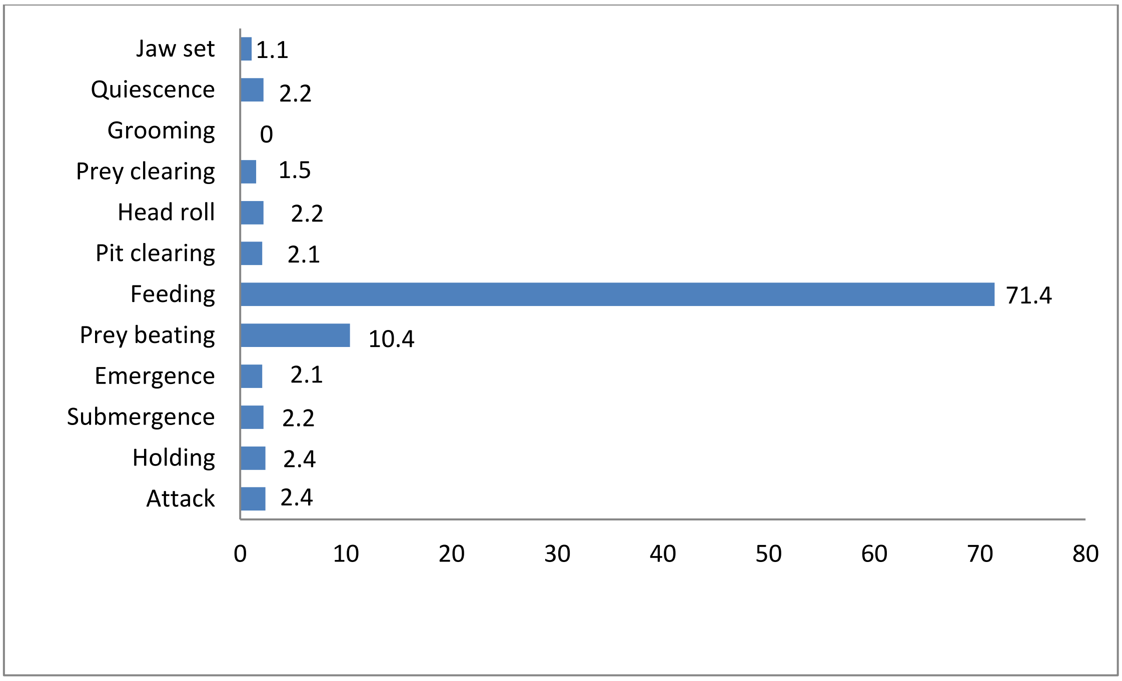


Fig. 49. Feeding / predatory activity budget for each behaviour patterns in sand medium, starved second instar larvae

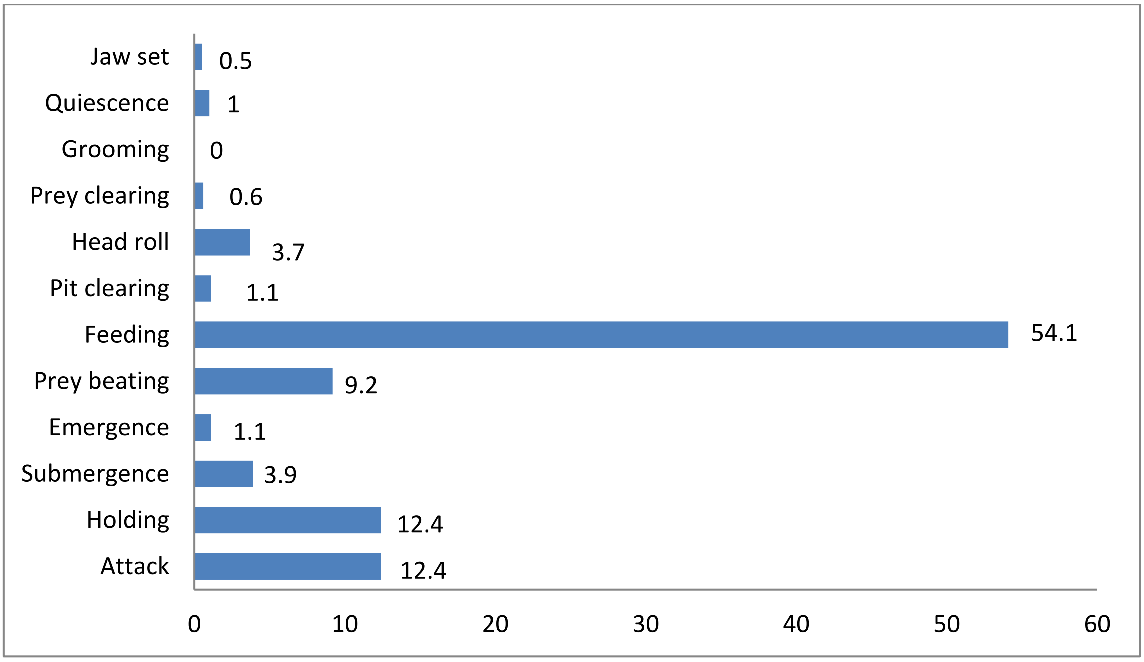


Fig. 50. Feeding / predatory activity budget for each behaviour patterns in sand medium, starved third instar larvae

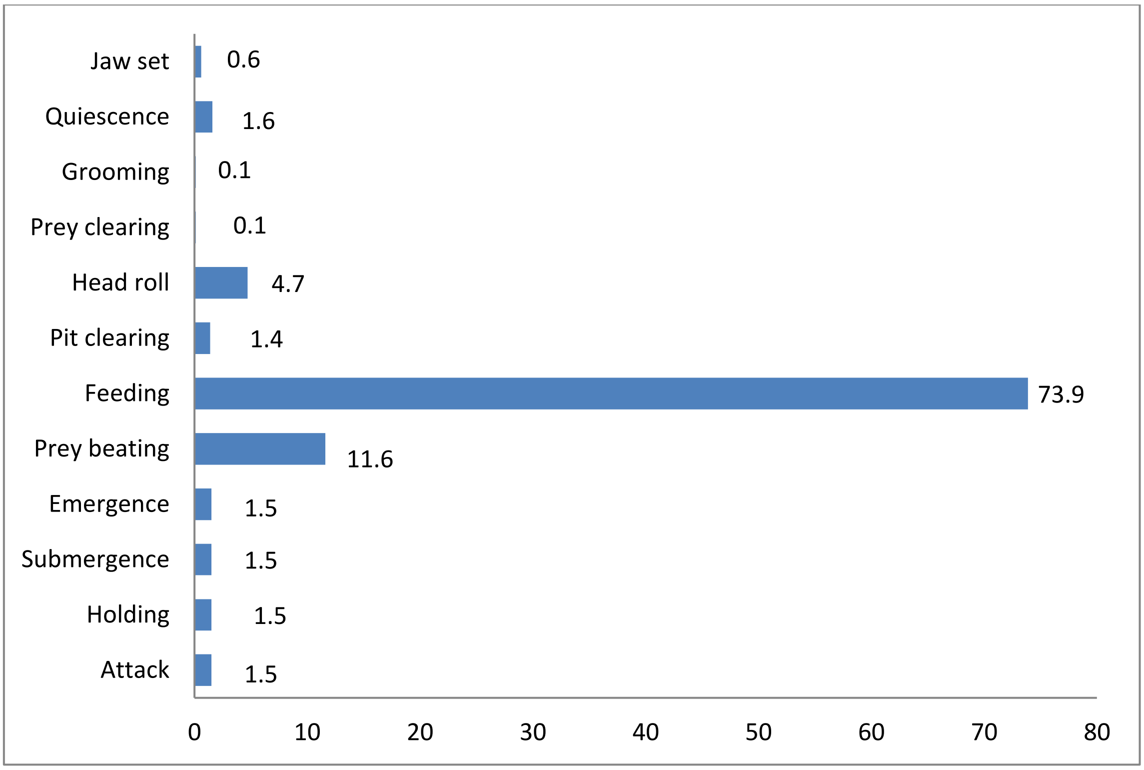


Fig. 51. Feeding / predatory activity budget for each behaviour patterns in soil medium, fed second instar larvae

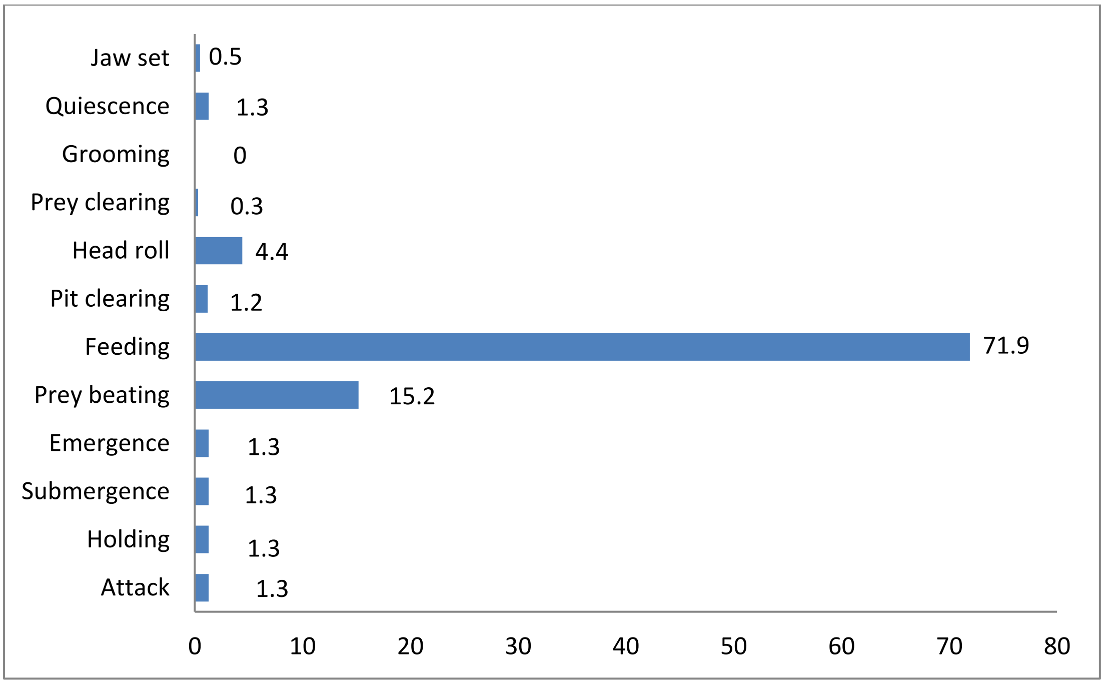


Fig. 52. Feeding / predatory activity budget for each behaviour patterns in soil medium, fed third instar larvae

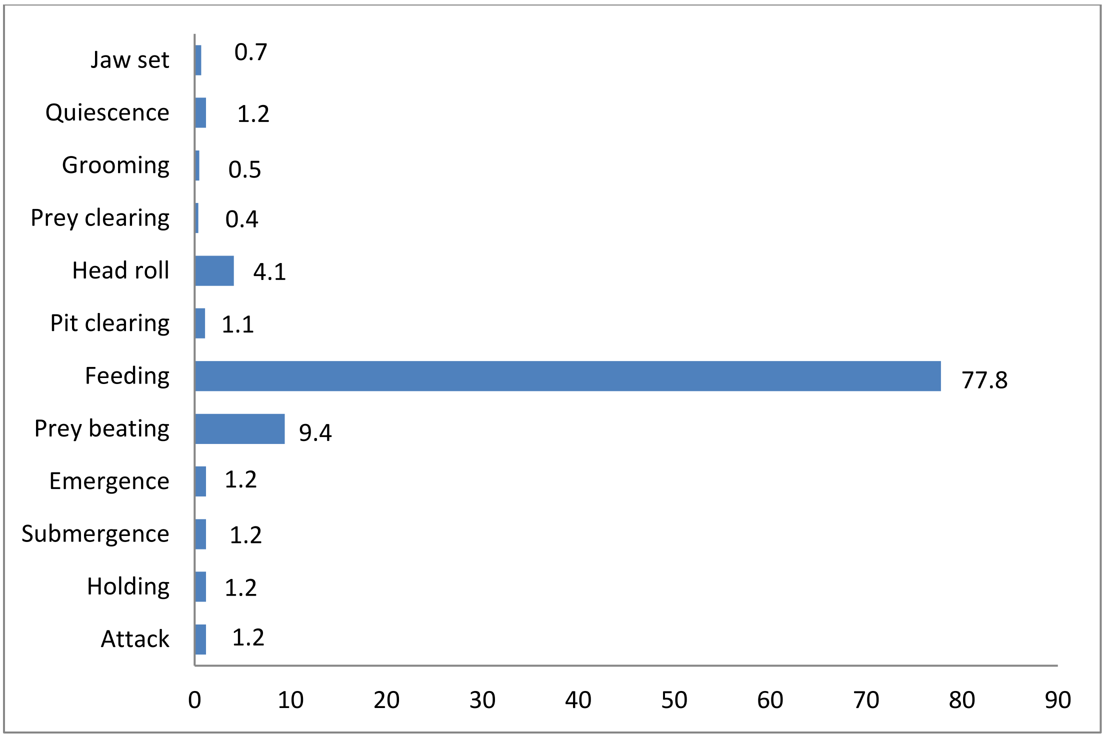


Fig. 53. Feeding / predatory activity budget for each behaviour patterns in soil medium, starved second instar larvae

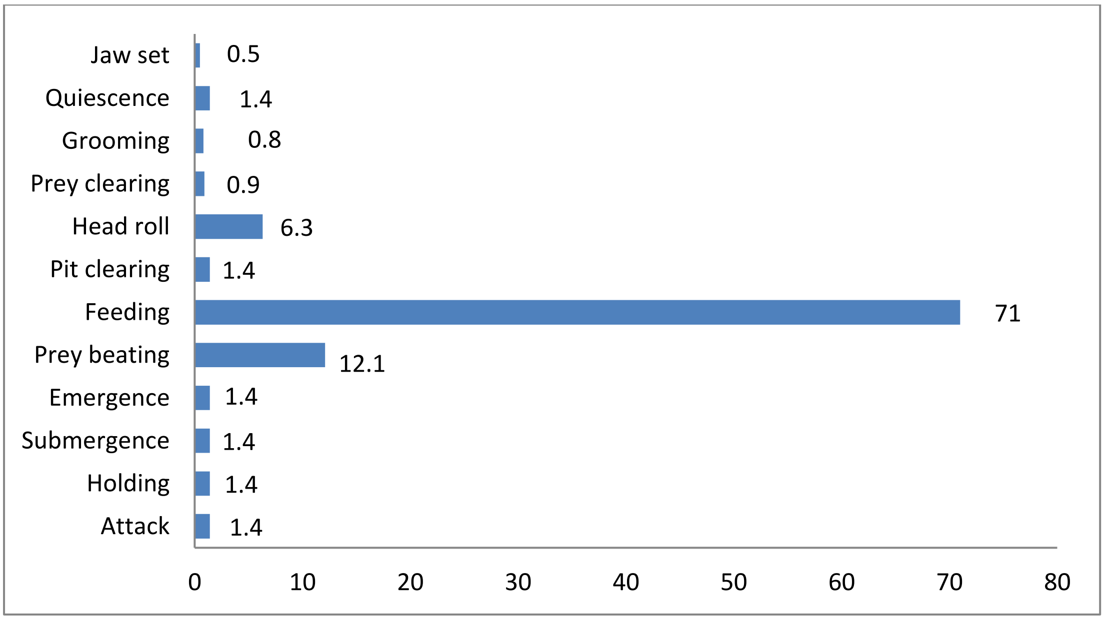


Fig. 54. Feeding / predatory activity budget for each behaviour patterns in soil medium, starved third instar larvae

3.4. DISCUSSION

Pit building antlion larvae made its conical pit by performing a series of concentric backward movements followed by flipping of sand or soil. The depth and diameter of pit increases with the spiral movement up to the mark when maximum prey capture success is reached. Pit building is seen in different species of antlions which are coming under family Myrmeleontidae. Here, *M. pseudohyalinus* larvae made its steep conical shaped pits for predation, it is very similar to the pit building of *M. hyalinus* which also make simple inverted cones (Pit diameter 30±0.5mm, min 25mm, max 34mm), but in *Cueta lineosa* they make two inverted truncated cones inserted on one another (Devetak *et al.*, 2020).

The pit building behaviour of *Myrmeleon pseudohyalinus* larvae in different media (sand and soil), hunger level (fed and starved) and instars (second and third) were studied. The diameter and depth are the two characteristics of funnel shaped pits. The increase in the diameter and depth helps the larvae to build its conical shaped pit. The depth and diameter remain similar up to 9^{th} hour of pit building and a sudden progress occurs in the next 3 hours. In second instar larvae, the fed larvae in soil medium has the highest pit size and fed larvae in sand medium has the lowest pit size in pit building experiments. But in the case of third instar larvae, the starved larvae in sand medium has the highest pit size and the lowest pit diameter observed in starved larvae in soil medium and that of depth in starved larvae in sand medium and fed larvae in soil medium.

The pit building behaviour shows similar in both laboratory and field conditions (Liang, 2010), so that the pit building antlion species can easily be studied under captivity. There are many factors which influence the pit building of antlion larvae, and it was compared in previous studies by using different species of *Myrmeleon*, *Cueta* and *Euroleon*. From the field observation data, it is reported that the maximum pit diameter of *M. formicarius* was 4 cm in non forested areas and 2.5cm in forest areas (Bozdogan *et al.*, 2013). But from the laboratory study, the maximum diameter is 3.65 cm in *M. pseudohyalinus* larvae.

The pit characters were studied in four different types of substrates which were collected from natural habitat of pit building antlion larvae. Dry soil, clay soil, sand and a mixture of sand, soil and cement collected from partially built house. The mean pit depth and diameter observed was high in sand medium (depth-2.85 cm and diameter- 3.80 cm). The mixture of sand, soil and cement has the second highest pit size with a depth of 2.41 cm and diameter 3.1 cm. Larvae made it pits in dry soil and clay soil with moderate size.

Antlion larvae build its pit for predation and shelter and the predatory efficiency was described by examining the predatory behaviour patterns. From this experiments, the prey escape and capture success were calculated and found 67-100% capture success of prey irrespective of different conditions, hunger level and instars. Prey escape was noticed in fed second instar larvae in sand medium, fed third instar larvae in sand medium, starved third instar larvae in sand medium and starved third instar larvae in soil medium (Table 31). From the result, it was understood that the prey escape was highest in sand medium and the highest capture success was observed in soil medium.

All the pit building antlion larvae has a similar pattern of feeding the prey and the behaviour patterns were influenced by the softness or hardness of the body of prey. The predatory behavior was analysed by Napotilano (1998) using termite (*Reticulitermes flavipes*), ant (*Prenolepis impairs*) and beetle (*Alphitobius diaperinus*) and all preys followed a core pattern of behaviours. The only difference was occurred in prey beating behaviour, 90% of beetles, 20% of ants and 10% of termite trials were shows this behaviour and it may be an adaptation to enhance the penetration of mandibles in beetles . The present study shows, *Myrmeleon pseudohyalinus* larvae took 35 to 45 minuts to feed its prey in laboratory conditions. The capture success noted from the study was 50-100% and the second instar larvae have the more capture success (95%) than third instar larvae (75%). But the previous study of Nonato and Lima (2011) differ from the present study in that, they noted that the third instar (96.96%) larvae are more successful than second instar larvae (69.70%).

The intraspecific interaction or cannibalism in *M. pseudohyalinus* larvae in different hunger levels were studied by conducting six experiments. The experiments were Well fed vs Well fed, Well fed vs Fed, Well fed vs Starved, Fed vs Starved, Fed vs Fed and Starved vs Starved (in second and third instar larvae). In the case of second instar larvae, the highest mortality was observed in the experiment Fed vs Starved (90% of fed larvae were dead), the starved larvae (higher hunger level) cannibalized the fed larvae. 70% of the mortality was observed in the experiments Well fed vs Fed and Well fed vs Starved. In the case of third instar larvae, 80% of mortality was observed in experiment with Fed vs Fed followed by Well fed vs Fed and Fed vs Starved.

The factors influencing cannibalism include developmental stage, sand depth, and conspecific density and hunger level. The cannibalism in antlion species studied by Lima (2016) and the food availability influences the antlion larvae *Myrmeleon brasiliensis* to do cannibalistic behavior, the lesser the food availability, the higher the cannibalism. The evaluation of both food availability and density were analysed and came to the conclusion that absence of food causes cannibalism in both high and low density of antlion larvae. Also records were present that the cannibalism occurs only at densities greater than 5 antlion larvae per 100 cm^2 in *Myrmeleon acer* larvae (Day and Zalucki, 2000). Cannibalism frequency was higher in the case of both individuals was in starved condition. 38 % of cannibalism occurred in *M. hyalinus* larvae (Barkae *et al*., 2014). But the present study disagree with the result, here a 50% of mortality was noticed both larvae in starved condition. Cannibalistic behaviour of *Myrmeleon brasiliensis* larve were studied by Lima (2016) in four treatments, low density/without food, low density with food, high density without food, high density with food. *Drosophila melanogaster* was used as prey and high density without food treatment found to be higher cannibalistic behaviour than other three treatments.

As a part of interspecific relationship study, analysed the prey items and observed the prey of antlion larvae which includes 87% of Hymenoptera, 9% of Coleoptera, and 4% of Lepidopterans. Mainly ants are the most preferred prey of antlion larvae according to this study in natural condition. There are many studies which quantified the prey of antlion larvae in different countries and this result shows the predatory capacity of antlion larvae in an ecosystem. Also the ecosystem services were found as a predator which influences the foodweb and controlling lots of small insect populations. The detailed prey items which is controlled by pit building antlion species helps to understand how diverse the predatory behaviour. The prey eaten by non pit building antlion species Brachynemurus includes worker ants, alate male ants, pygmy mole cricket, and beetles (Staphylinidae and Elateridae) and also there is a correlation between prey weight and feeding time (Cain, 1987). Out of 228 prey items 79 are ants , 36 spiders, 32 beetles, 27 midges, 21 red mites, 19 small wasps, 2 caterpillars, leaf hoppers, millipedes and hemipteran bugs were observed and 6 other miscellaneous winged insects (Heinrich & Heinrich, 1984). The prey experienced by

Szentkiralyi and Kazinczy (2002) from antlion larval pits are Formicoidea, Hymenoptera, Collembola, Coleoptera, Diptera, Homoptera, Heteroptea, Araneidea, Aphidina, Acariformes and Staphylinidae . Ngamo *et al*., (2015) observed the prey of antlion larvae includes Hymenoptera (Family- Formicidae and Pompilidae), Diptera (Drosophilidae, muscidae), Orthoptera (Gryllidae), Isoptera (Termitidae), Coleoptera (Carabidae), and Araneae (Araneidae). Ant species *Myrmicaria opaciventris* (Family Formicidae) comprises 40% of the total prey trapped. *Myrmeleon quinqemaculatus* prey consists of arachnids, crustaceans, insects and myriapods, 85.97 % include hymenopterans (Djibo *et al*., 2020).

Ants are the common prey of pit building antlion larvae and the minimum distance of antlion pit and ant nest were noted as 9 cm and maximum distance was 44 cm. Also shows that a minimum distance of 27 meter from the pit building antlion larvae and water body. There are not many studies on the predators of antlion larvae in the world. In Israel, hyper desrt area, antlion larvae predated by 4 species of scorpions (*Orthochirus scrobiculosus*, *Buthus Israelis, Buthacus yotvatensis, Buthacus* sp) (Segev *et al.*, 2019). Here the predators in the laboratory rearing are *Heteropoda venatoria* and *Hemidactylus frenatus*.

The study has given some insights on the ecology and behavior of antlion fauna in India with a new report. Provided data about habitat and its abiotic characters, morphometry of larvae, cocoon and adult, physical and chemical nature of soil, seasonal adaptation and habitat choice of antlion larvae in detail as a part of ecology. Observations in the study area are explained in the ecology part and it was validated by doing some experiments in the laboratory as a part of behavior study. The prey, predator, pit building behavior, feeding behavior and cannibalism were explained in the behaviour part and this is the first study of antlions in this region. Hopefully further study can take off from the data given in thi study. It may consider as a comprehensive study of pit building antlion especially *M. pseudohyalinus* species in this region.