EAZA Best Practice Guidelines

Dragon-headed katydid *Eumegaladon blanchardi*

Edition 1 (March 2023)

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EAZA Best Practice Guidelines disclaimer

Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country. Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Citation

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Summary

This is the first edition of the Best Practice Guidelines of the Dragon-headed Katydid (*Eumegaladon blanchardi*). These guidelines aim to provide the basic captive requirements for the maintenance of *E. blanchardi*. Due to the lack of information available on the natural history of this species, a majority of the information derived in this guideline was based on similar orthopteran knowledge and first-hand experience from rearing this species in Mandai Wildlife Group (MWG) This document is expected to be continually reviewed as more experience and research is accumulated.

Acknowledgements

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Content

A. Biology

1.1 Taxonomy

Class: Insecta

Order: Orthoptera

Family: Tettigoniidae

Genus: *Eumegalodon*

Species: *Eumegalodon blanchardi*

Common name: Dragon-headed katydid

1.2 Morphology

Body Size/Weight

Table 1. Average growth of moult development, body length and weight of female and male dragon-headed katydids (*E. blanchardi*) (Kaur et al., 2018).

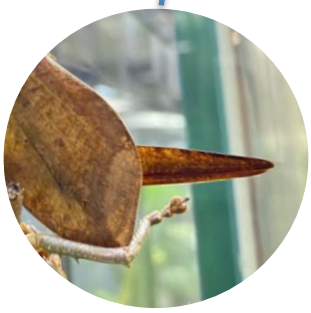
	Female			Male		
Moult	Day	Length (cm)	Weight (g)	Day	Length (cm)	Weight (g)
1st	11.7±2.9	1.3±0.1	0.1±0.0	11.6±1.0	1.3±0.1	0.1±0.0
2nd	24.3±2.3	1.4±0.1	0.2±0.1	23.6±1.3	1.4±0.1	0.2±0.1
3rd	37.7±4.7	1.6±0.1	0.3±0.1	35.4±2.9	1.8±0.4	0.4±0.1
4th	54.0±7.8	1.9±0.2	0.7±0.0	51.6±4.9	2.0±0.2	0.7±0.2
5th	68.3±8.5	2.3±0.1	0.9±0.0	66.1±5.5	2.4±0.3	1.1±0.2
6th	95.0±4.6	3.1±0.3	2.1±0.7	81.9±7.8	3.0±0.3	1.9±0.4
7th	123.7±4.0	3.9±0.4	4.3±0.5	106.7±13.4	3.8±0.3	3.6±0.8
8th	162.7±4.7	5.0±0.2	6.6±0.3	141.9±13.5	4.9±0.7	5.2±0.6

(Note: The above measurements are the average growth of 24 female and 21 male captive bred dragon-headed katydids at MWG.)

Description

Figure 1: Male *Eumegalodon blanchardi.*

Figure 2: Female *Eumegalodon blanchardi.*



Males and females are easily distinguished by the presence of an ovipositor in females, which protrudes out of the abdomen and extends beyond the length of the wings. It is short, thick and curves upwards; adapted to make a slit in the stem of the plant used for oviposition (Kaur et al., 2018).

Katydids belong to the family, Tettigoniidae, and were previously known as “long-horned grasshoppers”. Being part of the order Orthoptera, they are closely related to grasshoppers and crickets. They can easily be distinguished from their cousins with their long antennae, vertically positioned wings and the blade-like protruding ovipositors of the females.

Anatomy

The three main body parts of an insect is the head, thorax and abdomen (Refer to Figure 3). *Eumegaladon blanchardi* goes through incomplete metamorphosis, which is also known as *hemimetabolus* development. For such development, the younger instars (also referred to as nymphs) typically resemble the adults but lack wings.

The exoskeleton is made up of chitin, a naturally occurring biopolymer, which also makes up the human fingernails. This hard exterior provides a structure for the muscles to attach to and thus allowing movement. It also acts as a hard protective armour and forms in varying colours and shapes, making the insect kingdom so diverse. The pronotum, which is part of the thorax of the *E. blanchardi,* is uniquely profound and worthy of combat with its predators.

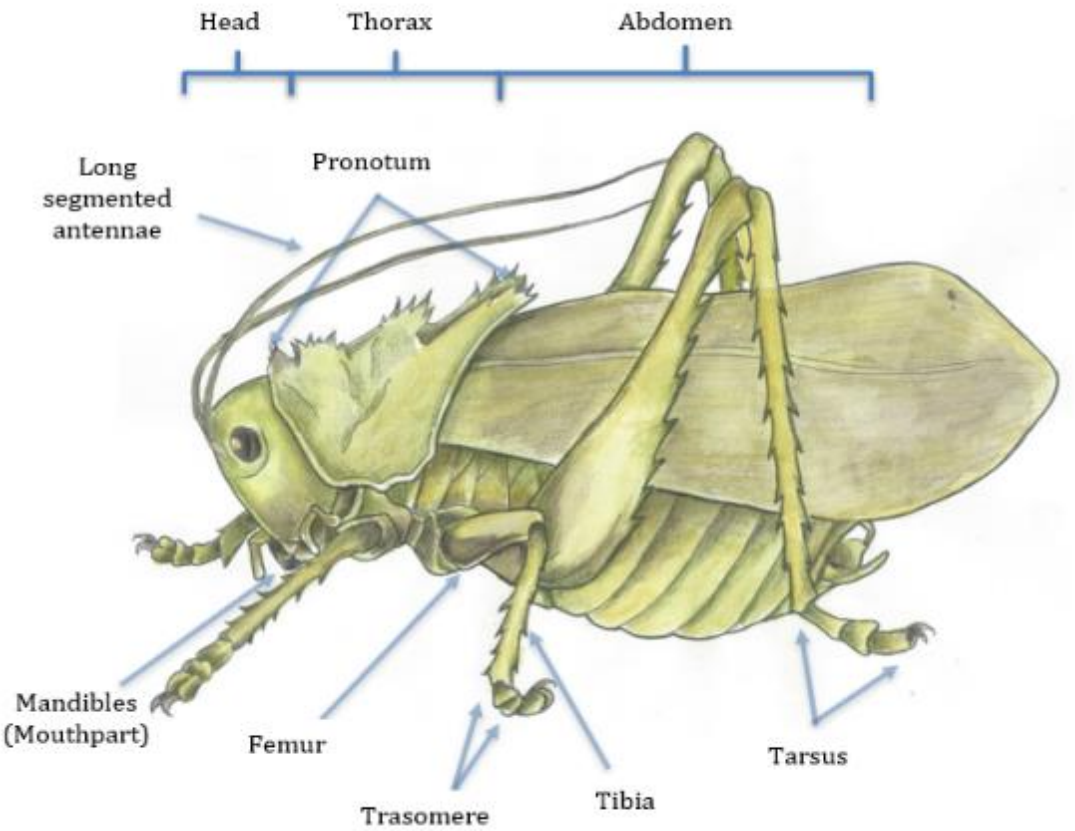


Figure 3: *Eumegaladon blanchardi* basic anatomy (Illustration by Jagan Thanapal,MWG).

The abdomen region constitutes of digestive and reproductive organs (Refer to Figure 4). Spiracles can be found line on the thorax and abdomen. These tiny openings are the method which these insects obtain oxygen. At adult stage, the *E. blanchardi* would possess wings that extends beyond its abdomen. Combined with varying proteins, chitin makes the wings of insects more flexible and adaptable for flight.

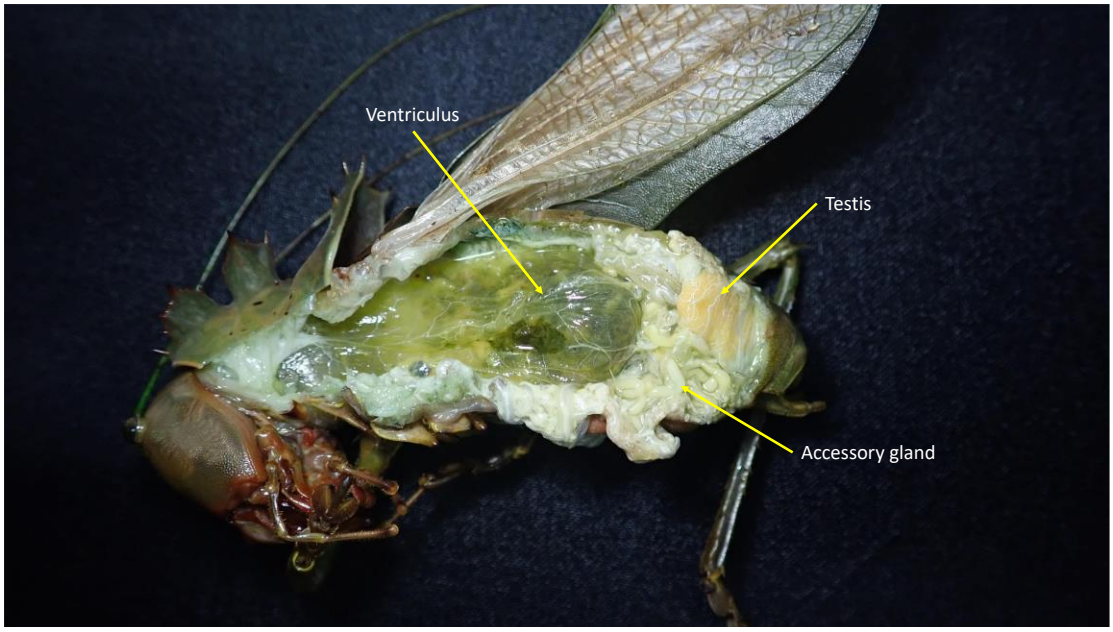


Figure 4: Male *E. blanchardi* internal biology (Photo credits: Dr. Chia-Da Hsu, MWG).

One of the more prominent features of this species is its biting-chewing mouthpart (Refer to Figure 5) which can be identified by long and possess a hook-like feature (Gangwere,1965). Full grown adults have been recorded with mandibles of up to 17mm in length.

Figure 5: Mouthpart of *E. blanchardi* (1: Labrum , 2: Mandibles, 3: Hypopharynx , 4: Maxillae).

1.3 Sound and Vibration

Tettigoniidae possess a tympana, which consist of cuticular folds forming narrow slits (Gwynne, 2001). The tibial tympana is an essential part of the katydid as it contains the crista acustica, which is an auditory structure used to decode waveforms (Montealegre-Z & Robert, 2015). Therefore, each of these slits leads to a membrane, which senses vibration similar to the function of an ear drum (DK, 2019).

Communication is a vital strategy for reproduction. Males create mating calls by stridulating their wings. Females rely on sound detection to locate a suitable mate. Therefore, the role of the tympana is vital to their survival, as it plays a huge role in reproduction of most Tettigoniidae. Calls made are specific to the type of interaction observed (Refer to Figures 7 & 8).

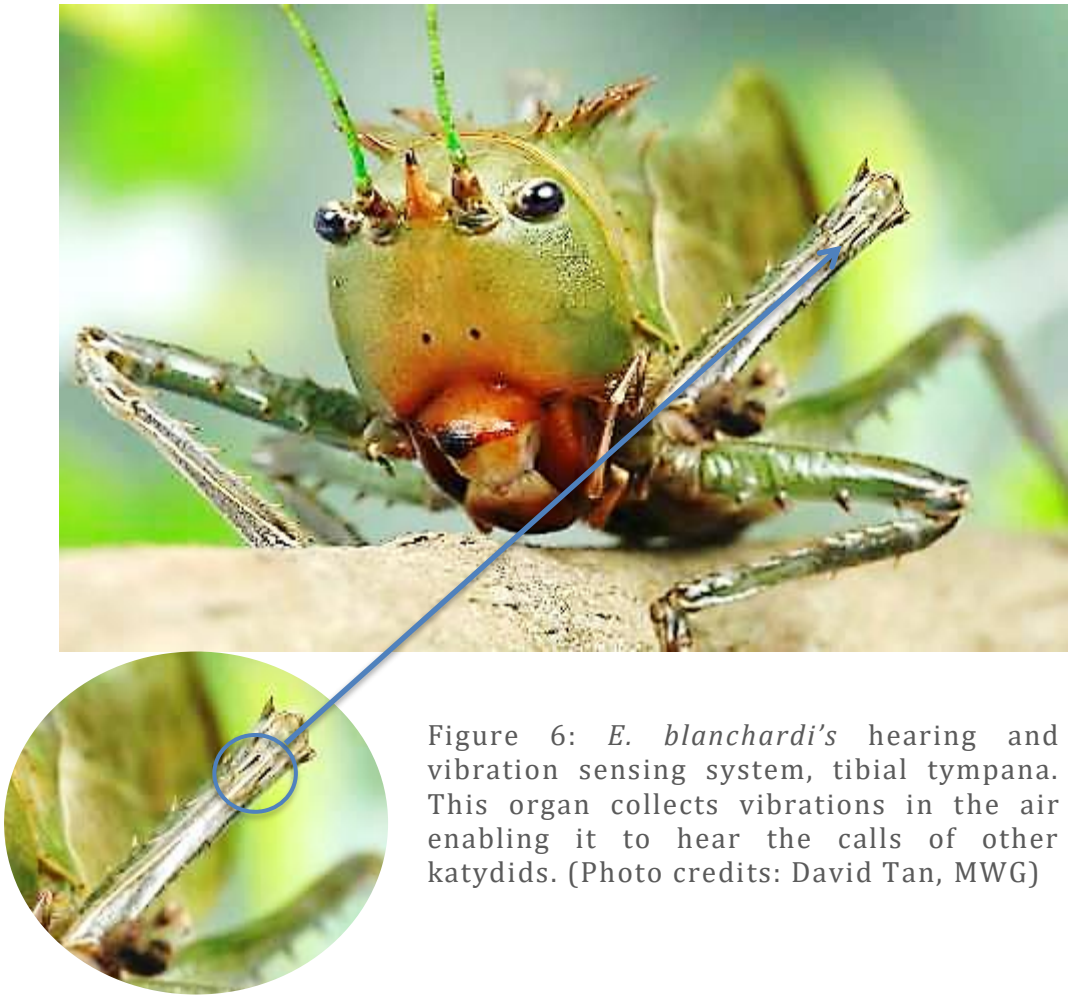


Figure 6: *E. blanchardi's* hearing and vibration sensing system, tibial tympana. This organ collects vibrations in the air enabling it to hear the calls of other katydids. (Photo credits: David Tan, MWG)

Figure 7: Serenading calls produced by males to attract females *(Scan with mobile device to access audio file)*

Figure 8: Aggressive calls produced by males *(Scan with mobile device to access audio file)*

1.4 Longevity

Wild: Unknown

Captivity: 12 –15 months (Based on captive management efforts at MWG)

Field Data

1.5 Zoogeography and Ecology

Distribution: Borneo, Indonesia and Malaysia

Habitat: Primary and secondary forest

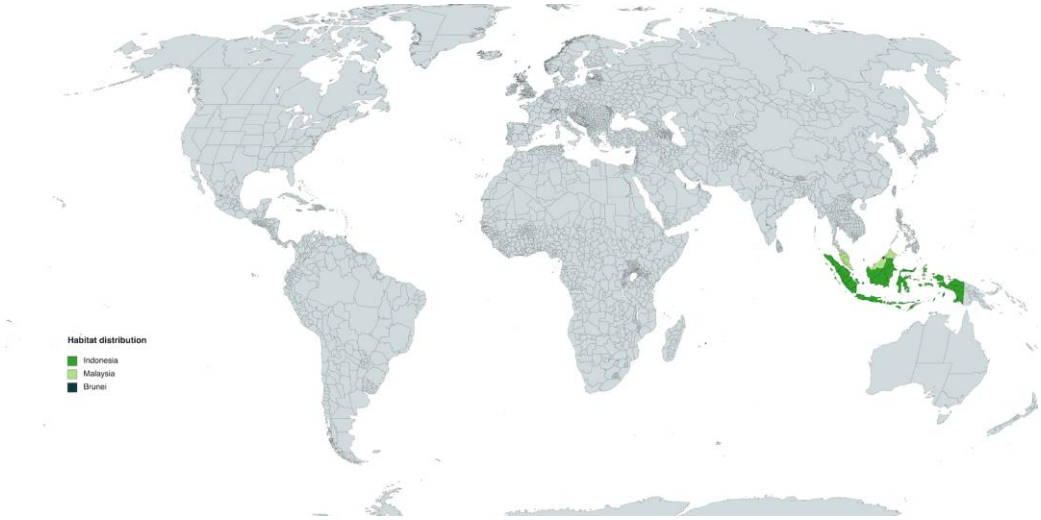


Figure 9: Known distribution of E. blanchardi

Population: Further studies will need to be done to understand population in the wild.

Conservation Status: Unknown

1.6 Diet and Feeding Behaviour

There is little information known on their diet in the wild. However, their mandibular morphology suggests that they have a carnivorous-forbivorous (i.e. broad-leaf plant eaters) diet.

Figure 10: *E. blanchardi* displaying mandibles (Photo credits: David Tan, MWG).

1.7 Reproduction

Information is scarce on the reproductive habits of *E. blanchardi* in the wild. Male and female *E. blanchardi* have been observed engaging in mating behaviour upon reaching their ninth instar stage. Generally for katydids, the mating process involves the transfer of the sperm package containing the spermatophore by the male. An additional nutritional component, spermatophylax, is provided with it which provides as an added nourishment for the female and her developing eggs (Rentz, 2010). While she consumes this nuptial treat, the sperm moves towards her spermatheca, which acts as a fertilisation pod for eggs that pass through it, while the female engages in oviposition.

Katydid species are known to oviposit in/on plant parts (e.g. leaves, stem) and soil substrates. Oviposition patterns can be distinguished between species by looking at the shape of the ovipositor and their eggs (Rentz, 2010; Kaur et al., 2018). Female *E. blanchardi* possess a long narrow ovipositor, which is slightly curved towards the end (Kaur et al., 2018). Katydids with such ovipositor morphology are known to deposit their eggs into plant stems. The number of eggs deposited per transfer in the wild is unknown. In captivity, females are known to deposit up to 100 eggs per transfer and an individual have been to have oviposited up to five time in her lifetime.

1.8 Behaviour

Activity: Mainly arboreal, with the majority of the time spent up in canopy.

Camouflage: The katydids develop full wings at their ninth instar, such as *Tegmina* spp., which are seen in many insects as a predator avoidance mechanism. This may possibly be associated with their dry-leaf cryptic roles which allows the species to be detected but not recognised as a prey or predator (Robinson, 1969; Kaur et al., 2018). When at rest, the adult *E. blanchardi*'s diaphanous cuticular-textured wings resembles a dead leaf, which gives it an advantage to blend into their forest environment. However, there is no literature depicting the strategies used by the immature stages.

Locomotion: They are fast climbers and prefer being at greater heights. This species does not fly but will often display fluttering of wings during leaps. They are also known to jump when in danger.

Sexual behaviour: The male katydids produce mating calls by rubbing their wings against each other, with the assistance of specialised structures found in their forewings (Montealgre, 2009; Kaur et al., 2018), while the females produce a chirping sound. In various publications, the call of the male has been presumed to be a tool to serenade the females. A significant and interesting characteristic of the male dragon-headed katydids would be their mating calls which sound very similar to the rattle of the rattlesnake (Kaur et al., 2018).

Section 2: Management in Captivity

2.1 Enclosure

2.1.1 Boundary

The exhibit is not intended to be accessible by visitors and should have a means of deterring public contact. An enclosed tank will be most suitable for this species. The tank should have no large gaps to prevent katydids from escaping and allow for infestation of pests (e.g. lizards, rats etc.), which could affect the survival rate of katydids. Landscaped tanks with easily available food are usually great refuge for ant colonies. Considerations should be taken seal gaps (e.g. fan outlet etc.) with fine mesh to prevent ants entering exhibit while allowing for necessary air circulation.

2.1.2 Substrate

Although *E. blanchardi* spend very little of their time at ground-level, substrate should be soft-bedded to break any falls and should take into consideration any other species sharing the exhibit.

2.1.3 Furnishings & Maintenance

Exhibit designs for invertebrates are designed carefully to replicate the natural environment in which they are found. *Eumegaladon blanchardi* is known to be mostly arboreal, spending most of their time on trees and other plants. Katydids are known to spend most of their time on the upper levels of exhibits in captivity. As such, it is essential to utilise the chosen furnishings (e.g. branches, plants etc.) well to showcase the specimens.

Figure 11: Tank set-up for *E. blanchardi* at Singapore Zoo, MWG.

An ample number of plants will visually enhance the exhibit and provide the katydids with hiding locations. Plants that can be used vary from small ferns, which can be attached to the backdrop and even long-leafed plants that will

create better use of the space in the tank. The surface of the tank walls, other than the viewing glass (if applicable to tank), should be rough. Products such as excavator clay or false wood bark can be used to create the needed texture, which will make a good climbing surface for invertebrates.

For zoological collections that aim to breed *E. blanchardi,* it is vital to include suitable egg-laying substrate(s) in the exhibit. To our knowledge, these katydids are known oviposit their eggs into banana pseudostems with a high hatching rate in captivity. Banana pseudostem (*Musa* sp.) should have a minimum diameter of 12cm in thickness to prolong its life span as an egg-laying substrate, which will ensure the degrading process will not affect the development of the eggs. In the event where the exhibit is large enough, it is highly recommended to utilise live banana pseudostems as egg-laying substrate. Under MWG's care, *E. blanchardi* have also been observed to lay their eggs in Fishtail palm pseudostem (*Caryota* spp.). Potentially, there are more species that can be explored to be utilised for egg laying.

Katydids are known to come from high humidity conditions, compared to species like grasshoppers. Therefore, to meet their requirements, exhibits should be misted twice daily. Terrestrial invertebrates could be sensitive to potable water, which contains minute amounts of chlorine. To improve quality of life, it is highly recommended to utilise water that have undergone either ageing for more than a week or reverse-osmosis.

Similar to many other katydids, *E. blanchardi* excrete a liquid, which is known to stain glass. Exhibits which have a viewing glass should be wiped daily with clean water to be kept presentable. Major cleaning should be conducted periodically. This constitutes of the replacement of all furnishings and washing down of the tank. Small amount of dishwashing liquid can be utilised for the cleaning of the emptied tank. It is important to ensure that the tank is thoroughly washed down after utilisation of cleaning products.

2.1.4 Environment

At MWG, the temperature of *E. blanchardi* holding tanks ranges between 25 to 32°C. As a tropical invertebrate, it is highly recommended to ensure the holding area for the *E. blanchardi* has high air humidity. These invertebrates are known to flourish well with an air humidity level of 75 to 85%.

For exhibits, lighting systems were placed on a timed cycle, with at least 12 hours of daylight and 12 hours of darkness. It is recommended to provide ultraviolet light for this species during day hours. Additionally, it is optional to provide a dichroic lamp as a hotspot for two to six hours a day. For hot dichroic lamps, ensure flammable items (e.g. branches, leaves) are at a suitable distance and will not pose as a fire hazard.

No studies have yet concluded the light requirements of this species. Baskir et al. (2021) study which documented nocturnal activity of *Lesina blanchardi* under artificial light concluded more activity observed under night time red LEDs. Further evaluation is required to assess if adopting a reverse light-cycle

will be appropriate to enhance visual experience for visitors while ensuring welfare for insects.

2.1.5 Dimensions

The space in the exhibit is recommended to have an appropriate amount of branching to allow the katydids to move around the exhibit. There should be at least 25cm of branch length for each katydid held in the tank. At MWG, *E. blanchardi* has been communally housed in groups of up to 10 individuals with minimum tank dimensions size 135 cm x 57 cm x 76cm.

It is highly recommended to house nymphs in individual containers with ample climbing space. Nymphs have been observed cannibalising each other in some groups. Refer to 2.4.4 Care of young for more information.

2.2 Feeding

There are no known health problems in *E. blanchardi* that can be directly linked to the diet in captivity. Take necessary precautions to wash food thoroughly to remove any contaminants (e.g. pesticides). Additionally, there is no available list of tools and methods that can be used to evaluate their body condition.

2.2.1 Recommended diet for *E. blanchardi*

Table 2: Diet given in MWG to *E. blanchardi*

Group A	**Group B**	**Group C**	**Group D**
Apple Pear Plum Grapes Orange Papaya Banana Watermelon Honeydew	Cucumber Long bean Lady finger Romaine lettuce Cabbage Corn	Cricket (*Acheta* spp.) Mealworm (*Tenebrio molitor*) larvae/pupa Soldierfly pupa (*Hermetia* spp.)	Fish flakes Calcium powder Insectivore pellet (grounded)
Any 2 of these food items daily	**Corn plus one of the other food items daily**	**At least 2 invertebrate feeder items daily for each individual**	**Sprinkle the above food items on the diet given daily**

2.2.2 Special Diet Requirement

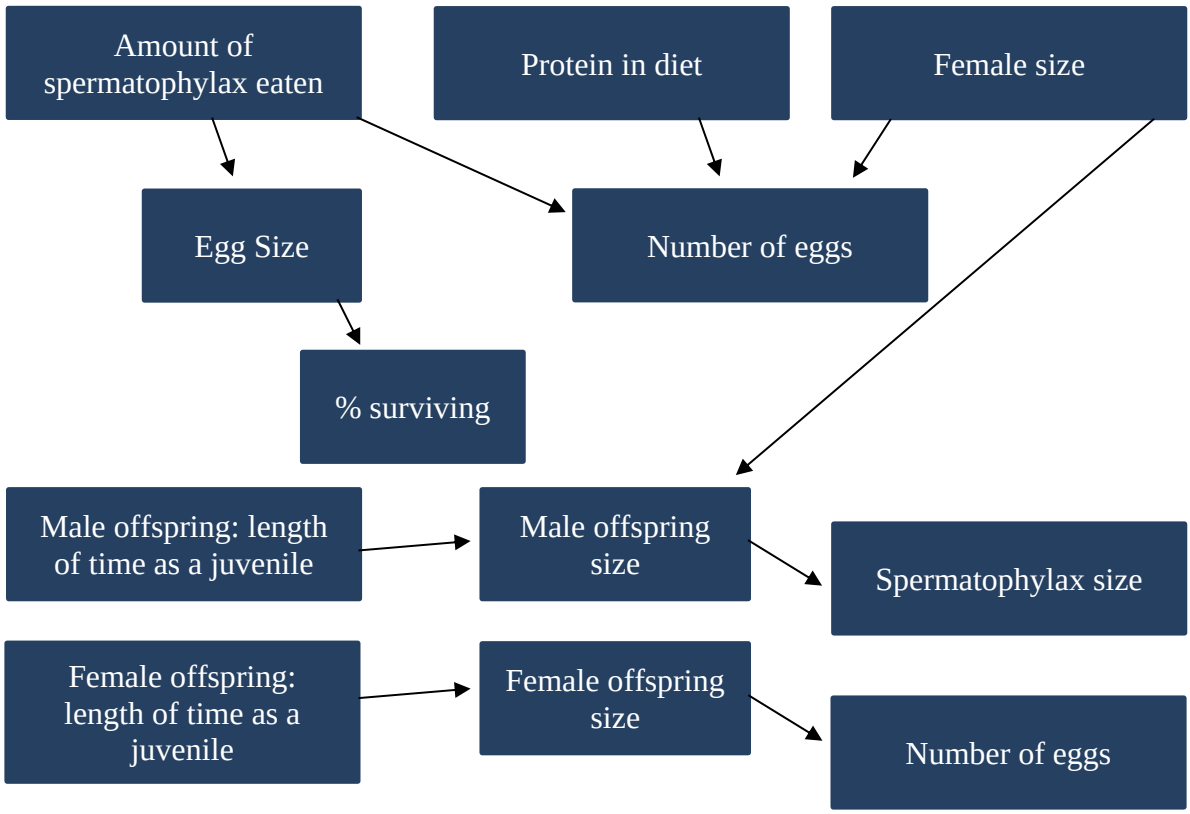


Figure 12: Gwynne's Model (Gwynne, 1988)

In most katydids, the remains of the spermatophore are left attached to the external areas of the female genitalia, allowing her to consume it. This is thought to be vital to fertilization (Resh, 2003). The above chart illustrates the impact of the consumption of spermatophore on the katydids's life cycle (Gwynne, 1988). As *E. blanchardi* is a carnivorous-forbivorous (broad-leaf plant eater) species, it is vital that they receive a variety of food of both plant and animal origin. It has been discerned that the protein received in the form of invertebrate feeders is vital to the reproduction and development needs of katydids, which can be seen in Gwynne's model.

Similarly, during the upkeep of *E. blanchardi*, younger instars were presented with food with fleshy bits exposed (e.g. corn kernels were sliced open) for easy consumption. This is attributed to the size of their mandibles. The mandibles of the first instar accounted for only approximately 4% the size of adult mandibles (Kaur et al., 2018).

Invertebrate feeders (e.g. crickets, mealworms, etc.) are recommended to be given daily to katydids (Refer to Figure 12). Gut-loading live feed will ensure optimum nutritional benefits as it recreates the nutrients found in insects eaten by animals in the wild. For younger katydids, it would be better to immobilise the feeder before feeding. For example, you can gently crush the head of the cricket before presenting it. This is to prevent the feeders from running around the tank and opportunistically predating on weaker katydids. For nymphs, the

first recording of full consumption of a pinhead (young cricket) was recorded on Day 16 of development, after having undergone its first moult.

Figure 13: Nymph consuming a Mealworm (*Tenebrio* molitor) pupa

2.2.3 Method of Feeding

For groups placed in exhibits meant for visitor viewing, it is highly recommended that food be distributed evenly around the tank, which is accessible to the species and within the viewing area. This will create excellent viewing opportunities for the guest while ensuring that the katydids have easy access to food. As this is an arboreal species, food should always be should always be presented at an elevated level. One of the methods of placing food at higher levels is to attach skewer-like structures on branches which food can be attached to.

For younger nymphs kept in smaller containers, food is presented similarly placed on an elevated position. Small structures like small cups or more natural substances such as chopped plant stems like banana pseudostems can be utilised when presenting food for consumption. It is still unknown if the banana pseudostem (*Musa* sp.) has nutritional benefits for *E. blanchardi*. At MWG, different instars have been observed consuming the banana pseudostem (*Musa* sp.) on multiple occasions.

Figure 14: Diet presentation for *E. blanchardi* nymphs.

2.2.4 Water

Katydids are known to come from more moist conditions as compared to grasshoppers. Therefore, to meet their requirements, exhibits should be misted twice daily. Terrestrial invertebrates could be sensitive to potable water, which contains minute amounts of chlorine. To improve quality of life, it is highly recommended that water administered should have been left to sit out for more than a week to allow for natural de-chlorination or preferably undergone reverse-osmosis.

2.3 Social Structure

2.3.1 Basic Social Structure

Eumegaladon blanchardi are known to inflict extremely painful bites and have also been observed to encounter conflict amongst each other. It is highly recommended that this species be kept separated according to their different instar stages.

For social group structures aimed to attain breeding activity, there should be more males than females in the tank to ensure there is healthy competition. The recommended sex ratio of males to females is 3:1.

2.3.2 Changing Group Structure

When groups are being mixed, one would have to ensure there is enough space for katydids to move around and hide. It is also recommended that nymphs and adults are not to be kept in the same holding tank together, due to cannibalism.

2.3.3 Sharing Enclosure With Other Species

For mixed-species groups, it is recommended to use candidates such as millipedes and frugivorous beetles.

2.4 Breeding

2.4.1 Mating

Mating calls by the males are often heard in the morning and evenings, and mating was observed as early as an hour later. Mating is often observed to last for more than an hour. Male katydids ejects spermatophore to the attached female and produces an additional sperm-free package called the spermatophylax (Gwynne, 1988). Notably, it has been observed that as the male excretes the spermatophylax, it glows fluorescent green before turning milky white (Refer to Figure 13). It is left attached to the external areas of the cloaca, allowing the female to consume it. This nuptial gift is vital for improving fitness of females and development of offsprings (Refer to 2.2.2, Special Diet Requirements).

Figure 15: Male *E. blanchardi* excreting spermatophylax during mating process.

2.4.2 Egg-laying/Oviposition

The females will bite a hole in the banana pseudostem, exposing several layers of collenchyma. It was noted that the females were not the only ones biting a hole in the banana pseudostem; males also participated in this activity. Within three to five days after mating process, females may start depositing eggs into the pseudostem by inserting her strong blade-like ovipositor, into the holes created. Egg laying is accompanied by a rhythmic wave-like motion along the ovipositor. Mating behaviour was observed as early as 48h after oviposition (Kaur et al., 2018). Female katydids can produce hundreds of eggs (Gwynne, 2013). The eggs vary between 1.0 to 1.2 cm in length.

One of the problem areas recognised for the reproductive cycle is the egg-laying segment. For some breeding groups, mating was observed but the katydids were not seen biting a hole in the pseudostem. It has been proven

successful to mitigate this issue by making a hole in the pseudostem (maximum depth: 5cm, width: 2.5cm). Based on several case studies at MWG, female katydids were seen ovipositing for their first time into the hole made by animal care staff and observed to bore similar openings in the pseudostem after.

Figure 16: Female ovipositing eggs and egg display in banana pseudostem .

Based on the experience of animal care staff at MWG, it has been noted that female *E. blanchardi* have also oviposited into Fishtail palm pseudostem (*Caryota* spp.). More studies will have to be conducted to evaluate the effectiveness of the specified pseudostem as a suitable medium for egg incubation.

2.4.3 Incubation

Method A

Eggs are to be removed from the pseudostem and transferred to a small plastic container with moist vermiculite (vermiculite-to-water weight ratio of 1:1) in the base. Eggs are to be placed on a window screen elevated in the container to prevent them from getting too wet (Figure 15). The incubator is to be ideally kept at 28°C and at 70% relative air humidity. There is no recommended period for when the eggs are to be removed from the pseudostem. Egg incubation is generally more successful in the banana pseudostem and Method A can be utilised when the substrate medium is heavily degraded, not making it suitable for egg incubation.

Figure 17: Egg-incubation (Method A).

Method B

Eggs are to be left to incubate and hatch in the original banana pseudostem. The room temperature recorded was 30°C and at 89 to 99% relative air humidity. This method is recommended over Method A. Based on previous studies, Method B has been assessed to have a higher hatchability rate as compared to Method A. The hatchability rate varied by 58.5%.

Banana pseudostems can be left in the exhibit for a recommended period of 16 to 21 days, depending on the rate of deterioration of the stem. The banana pseudostems should be at least 12 cm in thickness to ensure sufficient lifespan for egg development before deterioration of the pseudostem. Pre-soaked superabsorbent polymers in bags can be attached to the ends of the stem to also increase longevity. However, in situations where the banana substrate ceases to be a feasible medium for incubation, the eggs can be removed and incubated according to Method C. Banana substrate may be deemed to be unsuitable as an incubation medium when there is extreme degradation of plantfibres, resulting in the stem losing its structure and/or when its infiltrated with other organisms (e.g., insects, fungi).

Figure 18: Banana pseudostem substrate after nymphs hatched.

Based on studies done with Orthoptera species, a trend appears to be apparent in substrate selection based on a preference of higher moisture levels, which is suspected to play a vital role in the development of eggs (de Farias-Matins et al., 2017; Hertl et al., 2001; Kaur et al., 2018). Tettigoniidae eggs are known to absorb water through contact with water and the absence of moisture could lead to dormancy (Ingrisch, 1984; Kaur et al., 2018).

Method C

Eggs are removed from pseudostem and transferred to a small plastic container with adequate ventilation which is lined with paper towel, kept at 24 to 28°C. Mist contents of the container to ensure that paper towel is damp. It is recommended to mist the container twice daily, allowing the base paper to dry completely before misting. Similar incubation methods are applicable to other insects (e.g. Phasmid species).

Figure 19: Egg-incubation (Method C).

2.4.4 Care of young

Katydid nymphs are highly sensitive and require intensive care. Based on nymphs raised at MWG, the first 8 days are the most crucial. Nymphs have also shown cannibalistic behaviour when placed in groups; therefore, it is highly recommended that they be housed individually for optimal survival rates. For younger instars, small plastic containers can be used to house them (Refer to Figure 18). It is advisable to utilise containers with a minimum height of 14cm as these nymphs are arboreal. Small holes (1cm diameter) should be made at the top of the mentioned container and the internal surface can be lined with a filter paper which creates a suitable humid environment. In the event where they are to be housed in groups, nymphs should be placed in a large holding facility with sufficient height for arboreal species and ample hiding locations (e.g. furniture such as plants and tubes).

Figure 20: Nymph holding containers

2.4.5 Development

Instars

The below table presents the different stage of the life cycle of *Eumegaladon blanchardi.*

 Figure 21: 1st instar *E. blanchardi.*	<u>1ST INSTAR (BEFORE 1ST MOULT)</u> Nymphs measure an average of 1 cm in length. Due to its minute size, it is not uncommon to find that the nymphs easily damage their antennae.
 Figure 22: 2nd instar *E. blanchardi.*	<u>2ND INSTAR (AFTER 1ST MOULT)</u> The first moult occurred between the 12th and 16th day of the nymph's development. Nymphs would develop a darker colouration after going through its first moult. Development of two white markings on its thorax. Further development of the pronotum occurs, resembling its adult counterpart. The exoskeleton is hard and spiny. The prothoracic (front) and mesothoracic (middle) legs have grown longer.

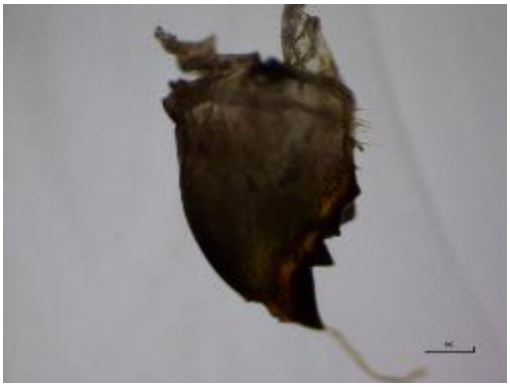
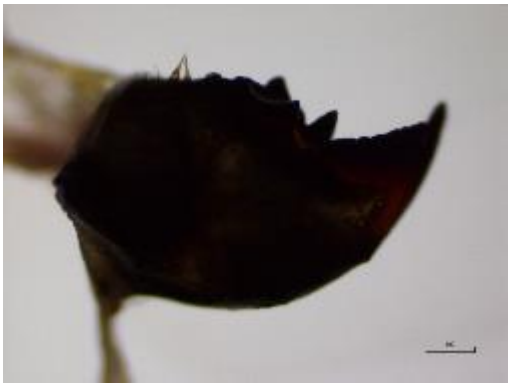
 Figure 23: 3rd instar *E. blanchardi.*	<u>3RD INSTAR (AFTER 2ND MOULT)</u> The second moult occurred between the 23rd and 27th day of the nymph's development. The nymphs have developed a much darker coloration compared to their previous instar. White markings on its thorax are now more noticeable. There is a drastic development in the mandibles of the nymphs, as they are now able to eat more easily. The metathoracic (hind) legs have grown significantly longer due to the development of their tarsus, allowing them to jump significantly further compared to previous instar.
 Figure 24: 4th instar *E. blanchardi.*	<u>4TH INSTAR (AFTER 3RD MOULT)</u> The third moult took place within the 34th and 43rd day. There has been further improvement on the mandibles of the nymphs. After going through this moulting process, they can now bite through the corn kernel. Keepers are no longer required to feed them with sliced corn kernels. Further development of the exoskeleton observed on the thorax.
 Figure 25: 5th instar *E. blanchardi.*	<u>5TH INSTAR (AFTER 4TH MOULT)</u> The fourth moult took place within the 46th and 52nd day. First stage of ovipositor for females. (0.2 cm in length)

 Figure 26: 6th instar *E. blanchardi.* (Photo credits: David Tan, MWG)	<u>6TH INSTAR (AFTER 5TH MOULT)</u> The fifth moult took place within the 52nd and 78th day. First stage of wing development. Second stage of ovipositor for females. (0.5 cm in length)
 Figure 27: 8th instar *E. blanchardi.* (Photo credits: David Tan, MWG)	<u>7TH INSTAR (AFTER 6TH MOULT)</u> The sixth moult occurred between the 80th and 96th day. Second stage of wing development. Third stage of ovipositor for females. (1.3 cm in length)
 Figure 28: 9th instar *E. blanchardi.* (Photo credits: David Tan, MWG)	<u>8TH INSTAR (AFTER 7TH MOULT)</u> The seventh moult occurred within the 104th and 123rd day. Third stage of wing development. Fourth stage of ovipositors for females. (3.8 cm)

 Figure 29: 10th instar *E. blanchardi.* (Photo credits: David Tan, MWG)	<u>9TH INSTAR (AFTER 8TH MOULT)</u> Adult stage - The eighth moult took place within the 131st and 168th day. Fourth stage of wing development. Fifth stage of ovipositors for females. (6.5 cm in length)

Mandibles

The table below presents the development of mandible growth for *E. blanchardi*. Mandibles were removed from dead specimens and recorded according to instar. Although the size of the mandibles might not be identical in measurement across all instar specimens, the table below provides some reference to possible development characteristics which may affect consumption habits.

 Figure 30: 1st instar *E. blanchardi* mandible. (Photo credits: Dr Chia-Da Hsu)	1ST INSTAR (BEFORE 1ST MOULT) MEASUREMENT: 0.7 mm
 Figure 31: 2nd instar *E. blanchardi* mandible. (Photo credits: Dr Chia-Da Hsu)	2ND INSTAR (AFTER 1ST MOULT) MEASUREMENT: 1.2 mm

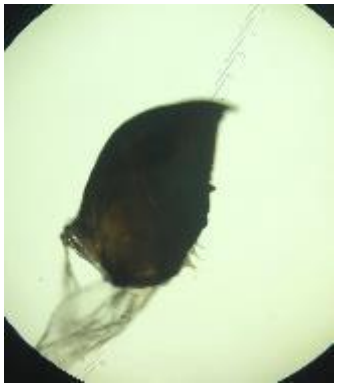
 Figure 32: 3rd instar *E. blanchardi* mandible. (Photo credits: Dr Chia-Da Hsu)	3RD INSTAR (AFTER 2ND MOULT) MEASUREMENT: 1.8 mm
 Figure 33: 4th instar *E. blanchardi* mandible. (Photo credits: Dr Chia-Da Hsu)	4TH INSTAR (AFTER 3RD MOULT) MEASUREMENT: 2.8 mm
 Figure 34: 5th instar *E. blanchardi* mandible.	5TH INSTAR (AFTER 4TH MOULT) MEASUREMENT: 3.5 mm

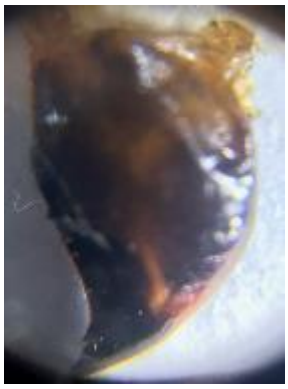
 Figure 35: 6th instar *E. blanchardi* mandible.	6TH INSTAR (AFTER 5TH MOULT) MEASUREMENT: 4.0 mm
 Figure 36: 7th instar *E. blanchardi* mandible.	7TH INSTAR (AFTER 6TH MOULT) MEASUREMENT: 5.5 mm
 Figure 37: 8th instar *E. blanchardi* mandible.	8TH INSTAR (AFTER 7TH MOULT) MEASUREMENT: 6.8 mm

 Figure 38: 9th instar *E. blanchardi* mandible.	9TH INSTAR (AFTER 8TH MOULT) MEASUREMENT: 17 mm

Ovipositor

The table below presents the development of the ovipositor for female *E. blanchardi*.

 Figure 39: 5th instar *E. blanchardi* ovipositor.	<u>5TH INSTAR (AFTER 4TH MOULT)</u> First stage of development of ovipositor for females. Length of the ovipositor is approximately 2 mm.
 Figure 40: 6th instar *E. blanchardi* ovipositor.	<u>6TH INSTAR (AFTER 5TH MOULT)</u> Second stage of development of ovipositor for females. Length of the ovipositor is approximately 5 mm.
 Figure 41: 7th instar *E. blanchardi* ovipositor.	<u>7TH INSTAR (AFTER 6TH MOULT)</u> Third stage of development of ovipositor for females. Length of the ovipositor is approximately 13 mm.

 Figure 42: 8th instar *E. blanchardi* ovipositor. (Photo credits: David Tan, MWG)	<u>8TH INSTAR (AFTER 7TH MOULT)</u> Fourth stage of development of ovipositor for females. Length of the ovipositor is approximately 38 mm.
 Figure 43: 9th instar *E. blanchardi* ovipositor.	<u>9TH INSTAR (AFTER 8TH MOULT)</u> Fifth stage of development of ovipositor for females. Length of the ovipositor is approximately 45 mm.

Wings

The table below presents the development for wings for *E. blanchardi.*

 Figure 44: 6th instar *E. blanchardi* wings. (Photo credits: David Tan, MWG)	6TH INSTAR (AFTER 5TH MOULT) First stage of development of wings for both males and females.
 Figure 45: 7th instar *E. blanchardi* wings. (Photo credits: David Tan, MWG)	7TH INSTAR (AFTER 6TH MOULT) Second stage of development of wings.
 Figure 46: 8th instar *E. blanchardi* wings. (Photo credits: David Tan, MWG)	8TH INSTAR (AFTER 7TH MOULT) Third stage of development of wings.

 Figure 47: 9th instar *E. blanchardi* wings. (Photo credits: David Tan, MWG)	<u>9TH INSTAR (AFTER 8TH MOULT)</u> Final stage of development of wings. Once the wing has extended further than the abdominal length of the katydid, it is classified as an adult.

2.5 Handling

2.5.1 General Handling

Fully developed *E. blanchardi* are known to have mandibles exceeding 1 cm in length (refer to 2.4.5 Development). Thorny spines are also found on their legs. Therefore, it is not recommended to handle this species with bare hands as they can cause injuries to the handler.

2.5.2 Catching/restraining

When catching/restraining *E. blanchardi,* use a small net or forceps.

2.5.3 Transportation

For short journeys (i.e. in-house moves), a suitable sized plastic container will be appropriate, e.g. a small plastic aquarium tank (20 x 15 x 15cm, 2.5L).

However, for long journeys, ensure the katydids are transported in a container which is small enough to ensure movement is limited. This will ensure the insect will not injure itself by sudden movements. The container should have its inner surface area lined with window screen (Figure 45) to allow the specimen to have a good grip on the surface to prevent any injury during locomotion and movement of the parcel during transport. Wet sponges can be included in the packaging for long journeys to ensure controlled humidity in the container.

Figure 48: Packaging for transportation of *E. blanchardi* (Packaged by Entopia, Penang)

2.5.4 Safety

If the species is to be handled, ensure cut-resistant gloves are worn.

2.6 Medical Euthanasia

The use of carbon dioxide is popularly used for anaesthesia of insects (Lewbart & Mosley, 2012; Pellett et al., 2017). It is noted that the literature does highlight that this agent can result in convulsions, excitation and even mortality (Nicolas & Sillans, 1989; Walcourt & Ide, 1998; Bennie et al., 2012). Sedation via isoflurane will be a more suitable method. Based on the recommendations of Bennie et al. (2012), euthanasia can be carried out by injecting potassium chloride (10% v/w 300mg/ml KCl) between the first pair of the legs.

For preservation in alcohol, the specimen can be injected with at least 90% ethanol and stored in a suitable sized container of ethanol. Otherwise, the euthanised specimen should be disposed of in an appropriate manner.

2.7 Specific Problems

Compared to other Orthoptera, the maintenance of *E. blanchardi* is challenging. The mortality rate of this species is relatively high compared to other species.

One of the main challenges encountered while maintaining nymphs was due to dysecdysis (failure to moult properly). The below case study was explored at MWG to find the most suitable environmental condition for the best development of growing nymphs.

CASE STUDY - To determine which would be the best conditions for nymph development and survival; at MWG the nymphs were housed in two different environments, varying in temperature and humidity. The nymphs from method A were placed in the air-conditioned office where the temperature was kept at 25°C with a relative humidity of 50 to 60%. The nymphs from method B were placed in one of the breeding rooms, where the temperature ranged from 27 to 30°C with a relative humidity of 70 to 95 %. A difference in moulting success (ecdysis) was noted, with method B nymphs moulting more successfully. Often the nymphs would also consume their moulted skins. We also noted that in most cases, dysecdysis invariably led to death. The drier conditions related to the air-conditioned environment were deemed the main contributor to the higher proportion of dysecdysis encountered in method A.

We observed a nymph stuck to its exoskeleton, hindering its movements (see Figure 12). This nymph was part of Group A, which was situated in the air-conditioned office.

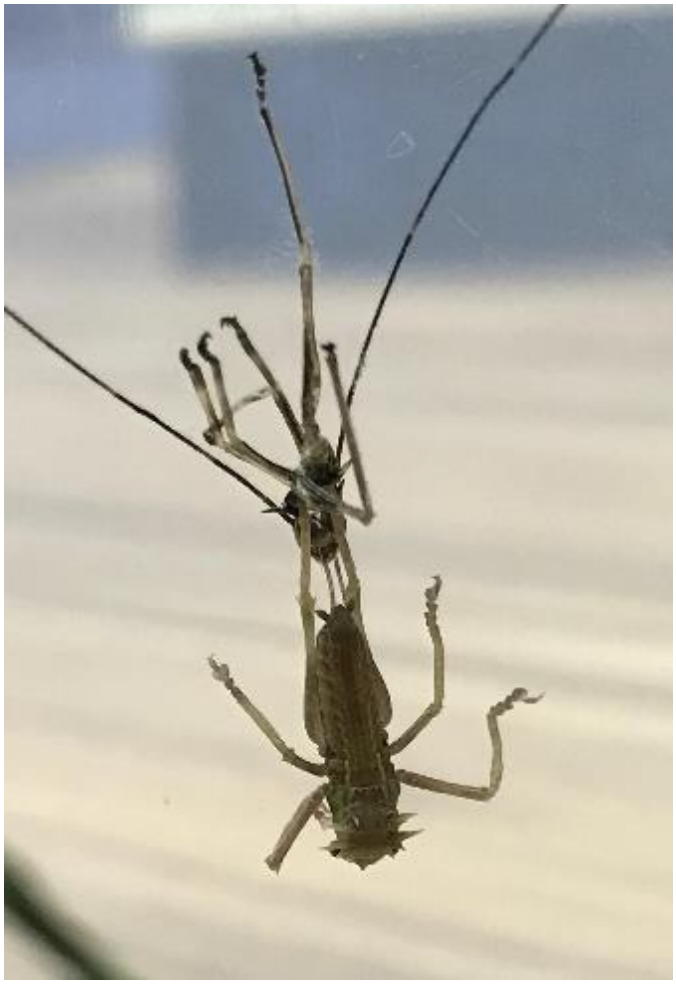


Figure 49: *E. blanchardi* nymph affected by dysecdysis.

2.8 Recommended Research

Substrate	Research on more suitable substrate mediums and a better understanding of the plant-egg relationship. • Currently, MWG is in the process of accessing the effectiveness of the Fishtail palm pseudostem (Caryota spp.) as a substrate medium.
Environment	• Model for displaying nocturnal Tettigoniidae: Further evaluation is required to assess if adopting a reverse light-cycle will be appropriate to enhance visual experience for visitors while ensuring welfare for insects.
Behaviour	• What are the contributing factors which attract females to males besides their mating calls? By understanding the requirements, social groups can be planned more effectively in captivity to attain optimal breeding. • Monitoring of individuals through the day and night to log significant difference in activities and behaviour observed.
Nutrition	More research required on the nutritional requirements of *E. blanchardi* at different instars. • Is the plant-part chewing behaviour significant to the species? • Both adult and nymphs have been observed participating in this behaviour. If the noted behaviour displayed is driven to attain nutritional content, can it be replaced with a supplement in captivity?
Population	More field research is required to understand the natural history and population status of *E. blanchardi.*

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