RAISING DRAGONS:
Managed Care and Breeding of the Dragon-headed katydid (*Lesina intermedia*) at the San Diego Zoo

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INTRODUCTION

Katydids, also known as bush crickets outside of the United States and Australia, comprise a charismatic family of Orthopterans that many people are familiar with due to their large size and melodic, loud mating calls. Though grasshoppers and crickets are more well-known, katydids are particularly interesting because of the huge diversity of taxonomic and behavioral traits within the family. Several species are commonly kept in insect zoos, but the different species can have quite disparate dispositions and care requirements. At the San Diego Zoo's Spineless Marvels, we have worked with: (1) *Neobarrettia spinosa*, a fierce hunter from the arid lands of eastern Texas which has red eyes and a particularly vicious countenance when hungry or threatened, (2) *Neobarrettia victoriae*, a slightly less menacing but equally voracious congener of the greater arid land katydid, (3) *Macrolyristes corporalis*, a large but gentle flower-eater from Malaysia which has a singularly high-pitched, ear-piercing call, and (3) *Lesina intermedia*, the dragon-headed katydid, the thorn-festooned creature with huge mandibles which is the subject of this paper.

NATURAL HISTORY

Tettigoniidae: Katydids belong to the Orthopteran family Tettigoniidae; it is a widespread and diverse family of over 6,000 described species (Naskrecki and Otte, 1999) that is present on every continent except Antarctica. Though people often think of walkingsticks as being masters of camouflage, some katydids are equally as elaborate in the ways that they blend in with their surroundings. Katydids are closely related to but differentiated from crickets by being laterally compressed instead of dorsally flattened. They are differentiated from grasshoppers by their well-developed and specializEd ovipositors. There are many different shapes and sizes of ovipositor within the family which reflect the varied types of oviposition sites used by females. Some ovipositors are scythe-like while others are straight like the blade of a sword, and there are myriad variations somewhere between the two.

The majority of katydids are generalist feeders, eating nearly anything but especially favoring seeds and other protein-rich items; however, there are also species with highly specialized diets. Some species prefer leaves while others only eat flowers, and there are even hunters that thrive

on live prey - some even feeding on small lizards. This variety makes the family interesting, but can also prove problematic for husbandry when little species information is available.

The katydid's most well-known attribute, and likely the inspiration for its common name, is its mating call. Fascinatingly, their nighttime calls can be a means of intra and well as interspecies communication. While used by males to attract mates in most species, there are some species that use their calls as a means to deceive potential predators. The Tettigoniidae also are unique in the insect world when it comes to mating behavior. Males of many species leave their mates with a nuptial gift, a nutrient-packed spermatophylax that the female eats after mating.

***Lesina intermedia*:** Unfortunately, very little is known about the natural history of *L. intermedia*. Though there is abundant general knowledge of katydids, most accessible research has focused on Nearctic, Neotropical, and African species. *L. intermedia*, a Southeast Asian species, has not been extensively studied. A thorough literature search yielded a few results about taxonomy but no information about lifestyle or habitat. We were fortunate to have contact with an expert in Malayan Tettigoniidae to even confirm the ID of this insect (Ingrisch, 2014).

HOUSING AND ENVIRONMENTAL CONDITIONS

When we started displaying this species in 2011, we had minimal knowledge to inform our husbandry. We housed our first group of wild-caught adults in a large glass tank with substrate and many kinds of materials (cocopeat, loamex, rotten wood, bark) for oviposition. These individuals seemed to thrive; however, though we saw mating behavior frequently, we never found eggs or had any surprise hatchlings in the enclosure. Postmortem dissections revealed gravid females, but we had seen no attempts at oviposition..

In February 2013, we decided to try again, with an entirely new batch of katydids from Malaysia. We set up the tank in a similar way as the first time but also added some live plants for perching, a small banana pup and an unknown plant with a large fleshy stem and long, wide leaves. We had had luck in the past with *Macrolyristes corporalis* laying eggs in live plants (mostly bananas and bromeliads), so we decided to try giving the *Lesina* access to live plants too. To our great relief, within two months we found eggs laid in the banana plant!

As a result of this successful oviposition, our adult *Lesina* are now always housed in planted tanks in which they have access to live banana plants. We have tried various other live plants on occasion but have never had oviposition success with anything other than banana. Fortunately, the mild climate of San Diego is ideal for growing bananas and we are able to harvest pups directly on zoo grounds. When the plant inevitably grows too tall for the tank, we simply cut off the top crown of leaves. The plant usually regenerates more leaves a few times before eventually needing replacement.

The set-up we currently use for adults in our containment area is a 89W x 61H x 46D cm ExoTerra tank with front-opening doors, a metal screen top, and room at the bottom for four inches of substrate composed of a wood soil additive such as Loamex and cocopeat fiber to retain humidity (Image 1). The bananas are planted directly in the substrate, allowing the roots to spread out throughout the tank. We also provide ample perching, using branches, palm pieces, and other live plants. Ideally, the larger the enclosure, the better. We have successfully housed about 20 adult individuals together in a tank of this size.

Image 1. Photo by Ken Bohn.

Image 2. Photo by Ken Bohn.

Adults are exhibited in our largest display, a 52W x 45H x 37D cm corner tank (Image 2). Since the katydids spend the vast majority of their time at the top of the tank, we have had success with keeping a coconut crab in the same enclosure. This species seems to thrive at temperatures between 25-30°C and at 60-70% humidity. Our containment area ranges from 24-35°C and the humidity is usually 50-70%; when conditions fluctuate, we occasionally cover the top mesh with plastic strips to retain more humidity or increase misting frequency.

We use full spectrum lighting in the form of power compact fluorescent bulbs on our tanks, which is important for plant growth as well as animal health. The lighting within the exhibit follows the zoo's open hours, but as the display faces the large glass entrance doors, a normal photoperiod is approximated. We have tried giving the katydids incandescent basking lamps, but haven't noticed much difference between those that have heat lamps and those that don't, and we rarely observed active basking.

MATING

Fortunately, we have not had to do much to encourage mating. The males call at night, sometimes starting up as soon as we close and the last visitors are out the door. Since much of the activity happens after hours, we haven't been able to observe the entire courtship behavior. However, once they are coupled, a mating pair will stay connected for hours (Image 3). You can also see the spermatophylax, which looks like a white, gelatinous blob, being passed from the

male to the female (Image 4). Once they have finished mating, the female will begin to eat the nuptial “gift”.

Image 3. Photo by Paige Howorth.

Image 4. Photo by Paige Howorth.

OVIPOSITION AND EGG CARE

Unlike *M. corporalis*, which lays its eggs in crevices on the surface of the plant, *L. intermedia* uses its thin but incredibly strong blade-shaped ovipositor to insert eggs under several layers of stem. The eggs are completely hidden inside the plant. You would never suspect the eggs were there, except for the odd hole the female leaves behind (Images 5, 6).

Image 5. Photo by Paige Howorth.

Image 6. Photo by Paige Howorth.

When beginning the oviposition process, the female first chews a hole in the plant, exposing several layers of stem (Image 7). She then places her ovipositor between the layers (Images 8, 9) and deposits a row of eggs (Images 10, 11). There are often several batches laid in different layers surrounding the hole.

Image 7. Photo by Ester Chang.

Image 8. Photo by Ester Chang.

Image 9. Photo by Ester Chang.

In order to better control the conditions under which the eggs develop we decided to remove the eggs and keep them in an incubator set to a constant 28°C. An open dish of water in the incubator keeps the humidity high.

Image 10. Photo by Paige Howorth.

Image 11. Photo by Ken Bohn.

We used two different methods for housing the eggs. For our first batch we cut down the plant and left the eggs in the stem. We placed the section of stem on top of a bed of vermiculite in a plastic box (Image 12). The box had a solid plastic lid with holes drilled for ventilation. A single layer of tulle was sandwiched between the base and the lid. The vermiculite was kept moist but not wet. For subsequent batches we took the eggs out of the plant and kept them in deli cups. The deli cups also have a layer of moistened vermiculite at the bottom. A piece of windowscreen on top of the vermiculite keeps the eggs from becoming too wet (Image 13). We have had success with both methods, but removing the eggs from the stem eliminates the need to manage rotting plant material during incubation.

As the eggs developed, they began to swell (Image 11). After they had spent about one month in the incubator, we got our first hatchlings! The hatchlings were smaller than expected, highly mobile, and had impressively long antennae (Image 12, 13, 14).

Image 12. Photo by Paige Howorth.

Image 13. Photo by Paige Howorth.

Image 14. Photo by Ken Bohn.

NYMPHS

Initially, we kept the nymphs in one big group in a small front-opening glass tank with substrate and various live plants. However, many of the nymphs died within a few days of hatching. We split them into two groups and moved them into large paper-lined critter keepers with minimal perching in order to be able to better monitor them. They were fed a variety of produce and seeds.

Unfortunately, we still saw high mortality while the nymphs were housed in the critter keepers. There were no catastrophic events, but every few days another nymph would disappear. The containers were secure and the nymphs weren't very strong, so we ruled out escapes. We would occasionally find leftover legs and antennae, so we suspected that there was a good deal of cannibalism occurring, though we didn't know whether the missing nymphs were being attacked while alive or scavenged after death.

As the group number continued to decline, we decided to move the remaining nymphs into individual containers. They went into small critter keepers with paper towel lining and branches for perching. As they grew, they were moved into larger containers. Ultimately, only four individuals survived to adulthood, a disappointing number considering our initial population of 35 nymphs.

When another batch of eggs began to hatch a few months later, we decided to experiment with a few different housing methods. We raised some individually all the way through to adulthood -- they started out in tall deli cups and were transferred to increasingly larger critter keepers as they grew. Others we kept communally in various sizes of glass tank, some with soil and plants and some lined with paper towel on the bottom. Each tank housed about 20 nymphs. All nymphs had access to ample perching, but usually chose to hang from the lids or upper seams of their enclosures.

One of the largest females raised was one that was raised individually; however, the individuals reared in this manner did tend to have shorter antennae. The major drawback of this method is that it requires much more space and is labor-intensive in terms of feeding and cleaning. Unfortunately, we did see quite a bit of aggression and cannibalism in the nymphs raised communally. In the end, however, the survival rate between the two methods was about the same, at about 25%.

As the nymphs grew, we measured them weekly. We had planned to measure them after molting, but because of their ability to contract or lengthen their abdomens and tendency to eat their entire exuviae, it proved difficult to tell when they had actually molted for the first few instars. Measuring weekly also provided more uniform data. Here are the measurements from one male and one female, both individually raised (measurements taken in mm):

Group 1b - Individual #1 (DOH 9/13/13), Male

Date	Body Length	Antennae
11/7/2013	21.15	59.41
11/14/2013	22.24	79.65
11/21/2013	21.64	77.21
12/5/2013	26.9	83.3
12/12/2013	29.37	81.92
12/19/2013	31.84	83.2
12/26/2013	28.46	58.49
1/2/2014	32.65	66.23
1/9/2014	35.35	78.73
1/16/2014	39.87	69.84
1/23/2014	43.88	79.26
1/30/2014	40.59	60.54
2/3/2014	63.77	98.18

Group 1b - Individual #2 (DOH 9/13/13), Female

Date	Body Length	Antennae
11/14/2013	21.05	86.78
11/21/2013	23.27	85.42
11/28/2013	23.69	67
12/5/2013	25.56	86.5
12/12/2013	27.27	85.76
12/19/2013	27.48	82.79
1/2/2014	32.13	93.58
1/9/2014	31.94	91.95
1/16/2014	39.04	78.61
1/23/2014	38.98	59.57
1/30/2014	38.39	89.32
2/6/2014	44.24	99.64
2/13/2014	43.83	96.64
2/19/2014	46.47	91.96
2/27/2014	47.53	68.31
3/6/2014	84.09	114.5

Development times varied from individual to individual, but males tended to mature more quickly than females. It took a male about 3 months to reach adulthood whereas it took a female about four. When we import this species next, we will compare the the measurements to wild specimens.

DIET

Since we didn't have much information about what *L. intermedia* eats in the wild, we used a kitchen-sink approach and offered a wide variety of food items. All of the nymphs received the same basic diet of produce and seeds, but some groups were also offered fresh animal protein (in

the form of frozen or freshly killed crickets, mealworms, or housefly larvae). For produce they were offered various combinations of cucumber, zucchini, romaine lettuce, red and green grapes, apple, yam, orange, corn, kale, cabbage, dandelion greens, watermelon, avocado, jicama, carrot, and green beans. All of the produce was sprinkled with bee pollen, fish flake, and chitin powder. Preferred produce items were romaine lettuce, cucumber, zucchini, apple, and grape.

Image 15. Photo by Ken Bohn

Because the katydids spent nearly all of their time at the tops of their enclosures, all of the produce was placed on bamboo skewers that could then be propped up on their perching (Image 15). These skewers, while somewhat time-consuming to make, did speed up the time needed for changing out food.

In addition to the produce, we also offered a mix of seeds and grains consisting of: oatmeal, rye seed, buckwheat, flaxseed, amaranth seed, white rice, pearl barley, sunflower seed, pumpkin seed, and red and white millet. At first the seed mix was glued onto popsicle sticks with honey, but these sticks took a long time to make, molded quickly, and caused a lot of seed to be wasted. So, we switched to using small dishes made of a plastic bottle caps mounted to bamboo skewers. We later started offering an orthopteran diet adapted from the *Bugs Alive* husbandry guide published by Museum Victoria in Australia (Henderson and Sinclair, 2008). This diet was made up of various crushed seeds with the addition of fish food and sea salt. While the katydids did not consume great quantities of orthopteran diet, they were seen eating sunflower seed, rye seed, pumpkin seed, buckwheat, and barley. We also offered supplemental sodium by giving them gelatin, and then agar, made with a 25% salt solution, but we never observed evidence of consumption.

Though the katydids did not show any interest in hunting live prey at any life stage, those that were receiving animal protein did voraciously consume freshly killed crickets, mealworms, and housefly larvae. We started out hand-feeding these items to the adults, but this method proved too time-consuming for the nymphs. Instead, we placed the items on a lettuce leaf on the produce skewers. Nymphs that did not receive fresh animal protein tended to grow more slowly. We also saw cannibalism and exuvia consumption decrease as consumption of animal protein/chitin increased.

CONCLUSION

We have learned a lot about what is essential to raising *L. intermedia* in these beginning stages of establishing a sustained captive colony of the species. The most crucial discoveries were the necessity for fleshy, soft-stemmed live plants (banana, in our case) for oviposition and the need for dead animal protein in the diet. We did notice that while our first generation of captive-bred adults are comparable in size to their wild counterparts, their coloring is different. While our founding group was made up of some individuals that were

green and some that were brown, all of their offspring have been brown. We are now experimenting with adding supplements to their diet that may correct a possible nutritional deficiency. Fortunately, we also currently have a second generation of eggs in our incubator and many more questions to explore.

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