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A survey of Odonata diversity in Zoige wetland, Sichuan Province, China

Xin Yu

College of Life Sciences, Chongqing Normal University, Chongqing, PR China

Email: lannysummer@163.com

Abstract

At Zoige alpine Wetland, a total of 10 species belonging to 4 families and 6 genera were recorded. Obvious melanism in *Coenagrion lunulatum* and feigning death behaviour in *Enallagma cyathigerum* were observed. A preliminary trial on avoiding behaviour of *E. cyathigerum* confirmed that feigning death is one of the major strategies to protect themselves. All these new findings are discussed briefly.

Keywords: Sichuan Ruoergai (Zoige) Wetland National Nature Reserve, death feigning (thanatosis, reflex immobilization, tonic immobility or faking death), *Coenagrion armatum*, *Coenagrion ecornutum*

Introduction

The Zoige alpine Wetland (Sichuan Zoige Wetland National Nature Reserve, geographical coordinates 102°29′-102°59′ E and 33°25′-34°00′ N) has a total area of 166,571 hectares and a wetland area of 112,923.47 hectares (Xu et al., 2015) including rivers, lakes and marshes, which are located in Zoige County of Aba Tibetan and Qiang Autonomous Prefecture (Fig. 1). As a typical high altitude wetland, Zoige's average elevation is above 3,500 meters. Owing to its unique natural conditions, the wetland houses a very special fauna including the globally endangered species black-necked cranes (*Grus nigricollis*). It has been reported that a number of Palaearctic species such as *Coenagrion armatum* occur in Zoige, too (Wasscher & Goudsmits, 2018). However, to date, the species diversity of Odonata in Zoige Wetland is still unknown. Although people can travel there for beautiful scenic spots like Huahu Lake, they cannot access the original areas of this wetland due to both protective policies and the complicated natural conditions. In July of 2019, with the help of the local authority, I had an opportunity to conduct a survey in this huge wetland assisted by some students and reserve staffs. It should be the first exploration to Zoige focusing on odonates.

Through this survey, I got a general knowledge about the species diversity in Zoige wetland. Meanwhile, I also observed some interesting ecological and biological characters of odonates which may inspire future studies.

The area

My survey started at Hongyuan airport, one of the highest airports (altitude more than 3,500 meters) in China. The landscape surrounding the airport immediately looked promising to me: A lot of brooks, pools, and marshes led me to the decision to start the survey right there although there is still quite a distance to the core reserve area. I selected five sites in total: Hongyuan (1), Waqie (2), Tangke (3), Zoige (4), and Huahu (5) (Fig. 1). I believe these sample sites can represent all habitat types of Zoige wetland.

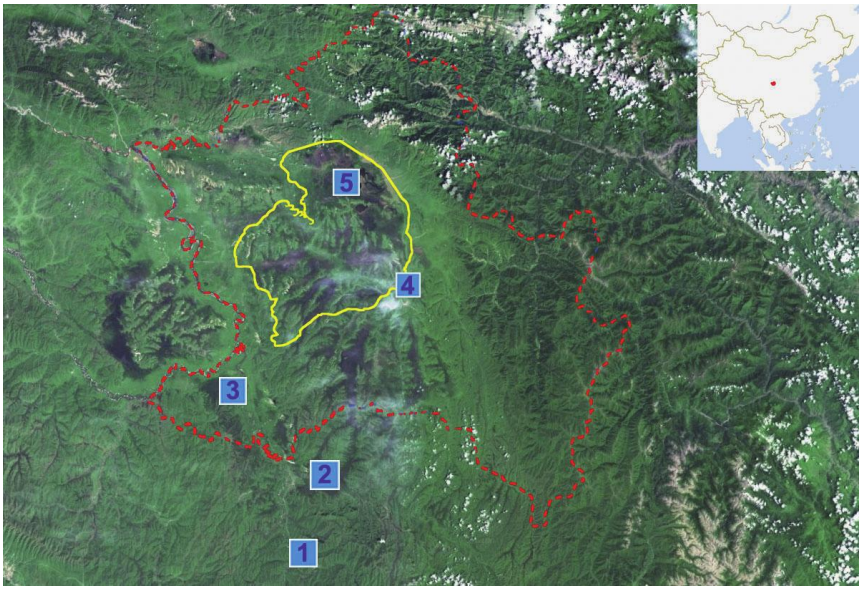

Figure 1. Map of Zoige wetland. Its location in China is shown in the upright corner. The five sample sites are represented by small blue squares. The yellow contour indicates the reserve of Zoige wetland while the red dash line outlines the county of Zoige.

Site 1 (Fig. 2) is located about 50 km north of Hongyuan airport (32.722786 N, 102.395236 E, 3463 m a.s.l.), just beside the highway. There is a temporary river in drought to form several little ponds surrounded by dense vegetation. A chain link fence set up to protect the water area from disturbing by yaks also benefited odonates. The local people are very determined to protect any life-form on their farms. We had hardly started the survey when a local man on a motorcycle approached and tried to stop us. Through mediation of my local assistant we were finally permitted to continue the work. The weather was good except for the relatively strong wind. Around 11:30 am (July 14th, 2019) large numbers of *Enallagma cyathigerum* and *Sympetrum danae* were copulating among weeds. *Lestes sponsa*, *Coenagrion lunulatum*, and *Sympetrum flaveolum* were observed in small numbers. They all showed little flight behaviour and were thus easy to observe and photograph.

Site 2 (Fig. 3) is a swamp next to a transformer substation at the outskirts of Hongyuan country (32.815429 N, 102.556665 E, 3453 m a.s.l.). It seemed that local human activities did not affect odonates too much. Right next to the highway, *C. lunulatum*, *E. cyathigerum*, *L. sponsa*, *L. dryas, S. flaveolum*, and *S. danae* were easily found in large numbers.

Figure 2. Habitat photo of site 1.

Figure 3. Habitat photo of site 2.

Figure 4. Habitat photo of site 3, clean water swamp.

Figure 5. Habitat photo of site 3, little pond.

Figure 6. Habitat photo of site 3, big pond.

Figure 7. Habitat photo of site 3, little river.

Figure 8. *Motacilla citreola* preying on *Sympetrum danae*.

Figure 9. *Sterna hirundo* hovering above the grassland looking for prey.

Site 3 (Figs. 4-7) is about 100 km south of Zoige country (32.535792 N, 102.786969 E, 3399 m a.s.l.). There are many swamps and little rivers embedded in the vast grasslands. Few people are visiting here except for one herdsman family a few kilometres away. The aquatic plants grew very well in the clean water. Large numbers of fish (*Gambusia* sp.) were present in the water. Birds were observed to prey on odonates intensively. I observed several times that *Motacilla citreola* preyed on *Sympetrum danae*, their putative main food in this season (Figure 8). Some *Sterna hirundo* kept hovering just above the grassland looking for prey. I speculate they were searching for dragonflies since in this season the most obvious and abundant food should be odonates (Figure 9).

Site 4 is Kahaerqiao Wetland Park (32.577538 N, 102.957679 E, 3405 m a.s.l.) located in Ruoergai county (Figs. 10-11). Since the human population of this country is small, usually only few people visit this park. Therefore, the park provides well-protected conditions for many local species including odonates. Here, the focus is on protected birds such as *Tringa totanus* (Fig. 12), *Tadorna ferruginea* (Fig. 13), *Phasianus colchicus* (Fig. 14) and further species. However, the park also harbours diverse odonates, including *Coenagrion lunulatum*, *Enallagma cyathigerum*, *Lestes sponsa*, *L. dryas, Aeshna juncea*, *Sympetrum flaveolum* and *S. danae*.

Figure 10. Habitat photo of site 4 in Kahaerqiao Wetland Park.

Figure 11. Habitat photo of site 4 in Kahaerqiao Wetland Park.

Figure 12. ***Tringa totanus*** **in Kahaerqiao Wetland Park.**

Figure 13. ***Tadorna ferruginea*** **in Kahaerqiao Wetland Park.**

Figure 14. ***Phasianus colchicus*** **in Kahaerqiao Wetland Park.**

Site 5 is Huahu (33.919089 N, 102.805790 E, 3431 m a.s.l.), a famous tourist attraction (Figs. 15-16). It is a huge swamp with a lake-like open area in the centre. There is only one long, narrow road connecting highway and lake. All tourists must take shuttle buses to get to the lake edge and then use the observation platform, which is an area without vegetation made of raw soil. Large numbers of birds live here, including the major protected species *Grus nigricollis* (Fig. 17). Thanks to the authority, I was permitted to enter the core zone of the protected area (Figs. 18-19). It was a little dangerous since some bog areas can engulf people. Fortunately, my local assistant was familiar with this area. Nevertheless, it was still a tough trip and my feet were caught by the mud many times.

Figure 15. Habitat photo of site 5, Huahu in summer.

Figure 16. Habitat photo of site 5, Huahu in early spring.

Figure 17. *Grus nigricollis* at Huahu, very close to the tourism line.

Figure 18. Protected area in Huahu. I (in blue) was working with two local assistants.

Figure 19. Looking for larvae in Huahu.

Figure 20. Mosquitoes on my leg during a short sunny time.

The two major difficulties encountered when surveying odonates in Zoige were high altitude sickness and unpredictable weather. During the first two days, one of my students from east China suffered from serious high altitude sickness so that he could not work anymore but had to go to a pharmacy to take oxygen. Almost all of us were suffering from a headache at the beginning. The weather of Zoige is so enigmatic that no-one, not even the local people, knows what it would be like in the next 10 minutes. Rain and sunshine always occur alternatively, sometimes accompanied by hail. The worst thing was that there was never a way to escape bad weather conditions. As soon as the sun came out, the very strong solar radiation dried our wet clothes within a short period. Then, legions of mosquitoes ascended and attacked any living creature they encountered (Fig. 20). I suppose that these huge quantities of mosquitoes serving as prey allow for the huge population densities reached by some odonate species in this area.

List of odonate species

1. *Coenagrion armatum* (Charpentier, 1840) (Figures 21, 22)

Site 3: 1♀ collected, 1♂ observed in dense inundated grass. **Site 5:** 1♂, 1♀ collected, several ♂♂, ♀♀ and 1 copula seen. (2 localities).

Observations. Not abundant, always in dense grass in water or swamps, rarely in copula.

Remarks. Before, the distribution of *C. armatum* in China was doubtful (Yu & Bu, 2011). Wasscher & Goudsmits (2018) first reported the occurrence of this species in Zoige. Putatively, this species should have more localities in China, therefore, further exploration is necessary. This species seems to strongly prefer *Juncus*-swamps and can occur with *Enallagma cyathigerum* synchronously (Fig. 21).

2. *Coenagrion ecornutum* (Selys, 1872) (Figure 23)

Site 3: 1♂, 1♀ collected, 1 more copula observed in dense inundated grass vegetation. **Site 5:** 1♂ collected, some ♂♂, ♀♀ seen. (2 localities).

Observations. Not abundant, always in dense grass in water or swamps.

3. *Coenagrion lunulatum* (Charpentier, 1840) (Figures 24-26)

Site 3: 1♂, 1♀ collected, many copulae observed in dense weeds. **Sites 2-5:** large number of ♂♂, ♀♀ seen. (5 localities).

Observations. Usually abundant, can be seen in grass almost anywhere.

Remarks. Compared with Northern China populations of this species (Figure 25), individuals in Zoige show obvious melanism. Usually, this species co-occurs with *Enallagma cyathigerum* (Fig. 26).

4. *Enallagma cyathigerum* (Charpentier, 1840) (Figures 27-29)

Sites 1-5: large number of ♂♂,♀♀ as well as many copulae observed. (5 localities).

Observations. Usually abundant, in dense grass beside water or swamps or just near the highway.

Remarks. This is definitely the dominant species with an enormous population density. Here, I observed very interesting avoiding behaviours of this species when people were approaching including flying away, sidling (see discussion), and feigning death. One female feigning death even let itself fall down and remained motionless underwater for about 2 minutes. Sometimes feigning death seemed to be the major strategy to escape from threats posed by other animals including approaching men. As I supposed that this is no common behaviour in odonates, I decided to conduct a simple behavioural experiment (see below). Another observation was that, in cool mornings, individuals changed their bodies into dull colours (Fig. 29), an example of the so-called RTCC (reversible temperature-induced colour change; Corbet, 1999).

Figure 21. Habitat of *Coenagrion armatum*.

Figure 22. *Coenagrion armatum*, male.

Figure 23. *Coenagrion ecornutum*, in tandem.

Figure 24. ***Coenagrion lunulatum*** **from Zoige, male.**

Figure 25. ***Coenagrion lunulatum*** **from Chifeng, Inner Mongolia, male.**

Figure 26. *Coenagrion lunulatum* roosting with *Enallagma cyathigerum*.

Figure 27. *Enallagma cyathigerum*, male.

Figure 28. *Enallagma cyathigerum*, melanized male in tandem.

Figure 29. *Enallagma cyathigerum*, changing body colour in the early morning.

5. *Lestes dryas* Kirby, 1890 (Figure 30)

Site 2: 2♂,1♀ collected. **Site 4:** large number of♂♂, ♀♀ seen, many copulae observed in dense weeds. **Site 5:** some ♂♂, ♀♀ seen. (3 localities).

Observations. Usually abundant, in dense grass around water or swamps.

Remarks. This is another dominant species with high population densities. Individuals here are distinctly smaller in body size than those in North China and relatively more hairy.

6. *Lestes sponsa* (Hansemann, 1823) (Figure 31)

Site 1: 1♂, 1♀ collected, many observed in dense weeds. **Site 2:** 1♂, 1♀collected, many copulae observed in dense weeds next to the highway. **Site 4:** some♂♂,♀♀ seen. (3 localities).

Observations. Usually abundant, in dense grass around water or swamps.

Remarkss. This is also a dominant species with high population densities. Individuals here are distinctly smaller in body size than those in North China and relatively hairy. Unlike *L. dryas*, most of the specimens were in the teneral stage. Copulae seldomly were observed.

7. *Aeshna juncea* (Linnaeus, 1758) (Figure 32)

Site 3: 1♂, collected, not so often observed at open water of pools and ponds. **Site 4:** several♂♂,♀♀ seen. **Site 5:** only a few individuals seen. (3 localities).

Observations. Usually not abundant, most of them just emerged, so no copulae observed.

Figure 30. *Lestes* dryas, in tandem.

Figure 31: *Lestes sponsa*, male.

Remarks. This should be also a dominant species here in the later season. I found many teneral individuals floating on the water surface. Some of them were still struggling to take off from the water. They may have been blown down into the water by strong winds, or been pushed down by sudden heavy rains (Fig. 32). They probably served as food for birds or other big animals.

Figure 32. *Aeshna juncea*, male.

Figure 33. *Sympetrum flaveolum*, male.

8. *Sympetrum flaveolum* (Linnaeus, 1758) (Figures 33-34)

Site 1, 2, 4: 2♂♂, 2♀♀ collected, and larger numbers of ♂♂, ♀♀ observed in dense weeds, including many copulae. **Site 3** and **5:** several ♂♂, ♀♀ seen. (5 localities).

Observations. Usually abundant, in dense grass on the land but not so often flying over water or laying eggs. Due to strong winds, they rested in the vegetation or on the ground most of the time.

Remarks. This is one of the dominant dragonfly species and possibly the main food of local birds (Fig. 8).

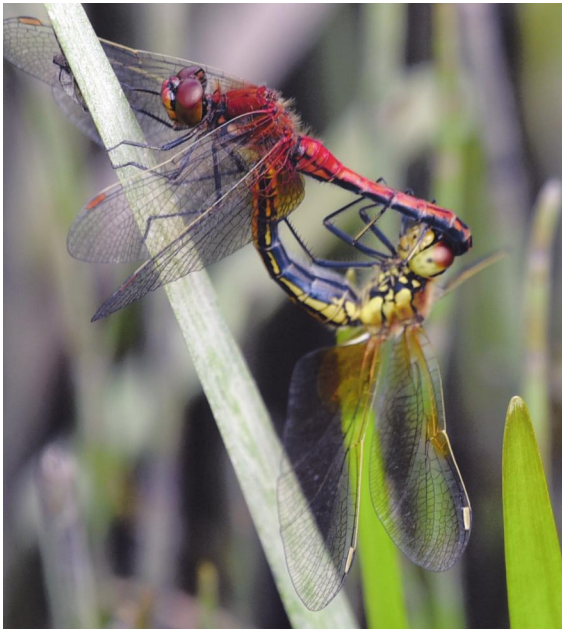

Figure 34. *Sympetrum flaveolum*, in tandem.

Figure 35. *Sympetrum danae*, male.

9. *Sympetrum danae* (Sulzer, 1776) (Figure 35)

Site 1, 2, 4: 2 ♂♂, 2 ♀♀ collected, and larger numbers of ♂♂, ♀♀ observed in dense weeds, including many copulae. **Site 3** and **5:** several of ♂♂, ♀♀ seen. (5 localities).

Observations. Usually abundant, in dense grass on land but not so often flying over water or laying eggs. Due to strong wind, they rested in the vegetation most of the time.

Remarks. This is another dominant dragonfly species and it often occurs together with *Sympetrum flaveolum*, with almost the same abundance.

10. *Libellula quadrimaculata* Linnaeus, 1758 (Figure 36)

Site 3: a large number of ♂♂, ♀♀ seen in dense weeds. **Site 5:** a few individuals observed flying over the wetland (2 localities).

Observations. Moderately abundant, in dense grassland near mountains usually far from human habitations.

Remarks. This is the best flyer of all species here in Zoige wetland. However, no copulae were observed although all individuals were mature.

Figure 36. *Libellula quadrimaculata*, male.

Feigning death of *Enallagma cyathigerum*

Avoiding behaviours of odonates have been mentioned in Corbet (1999) especially of damselflies, including flying away, sidling (moving "around a stem so as to present the least outline in the direction of the intruder"), and feigning death. Among them, feigning death is the last one which has been reported as the first response strategy. True records of feigning death in odonates were only reported by Moore (1983) and Khelifa (2017), but both were single observations. During the survey in Huahu (site 5), feigning death was observed sometimes as the first strategy employed by *Enallagma cyathigerum* to avoid enemies including conspecifics, birds, cattle or humans. This inspired me to conduct a short field experiment to see how often and why they adopted this strategy. Other species, like *Lestes sponsa*, also showed a similar behaviour. I chose *E. cyathigerum* as the focal species because it had the largest population density. Within an area of 60 m * 50 m in site 5, six people were divided into 3 groups (20 m distant from each other) and moved forward 50 m simultaneously to observe and record the avoiding behaviour of each encountered individual. Damselflies dropping into the vegetation directly when disturbed were treated as feigning death ones. Individuals that sidled first and then dropped following continuous disturbing were not treated as feigning death but as sidling ones. In total, we repeated this field experiment three times during different periods of two continuous days.

We did the first two tests at 14:35 and 16:50 on the first day, and at 11:00 on the second day of our study. There is a meteorological station nearby providing diverse weather data during the testing period. The results of the tests are shown in Figure 37.

I found that individuals of *E. cyathigerum* use different strategies depending on meteorological conditions. Feigning death is one of the major avoiding behaviour strategies for the Zoige population (Fig. 37). In general, when temperature and wind speed decline and the relative humidity increases, *E. cyathigerum* individuals tend to increasingly use the feigning death method to protect themselves (Fig. 38).

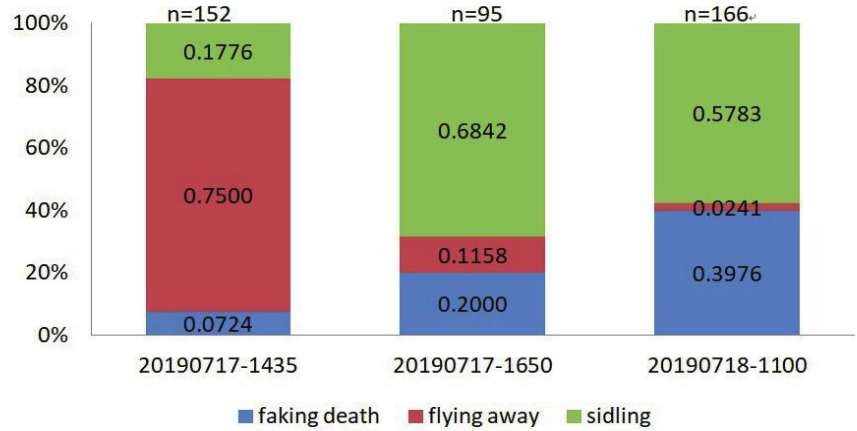

Figure 37. Percentage of the three escaping strategies employed by *E. cyathigerum* in the 3 field experiments. The beginning time of each experiment is indicated below the column.

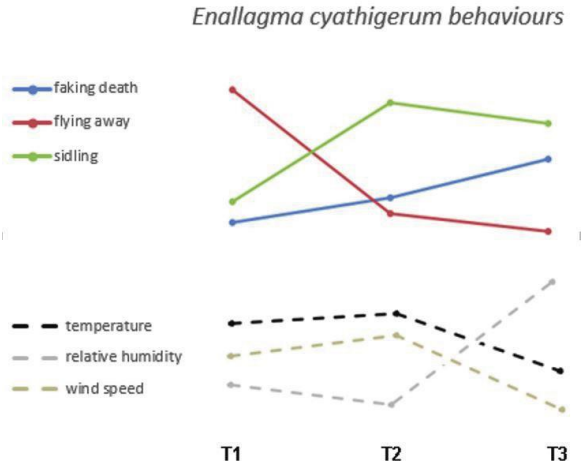

Figure 38. General relationship between escaping strategies and main meteorological conditions.

Discussion

Due to the tough living conditions, odonate diversity in Zoige wetland is not very high. I discovered, however, that each species here is to some degree special. Besides a very southward distribution of some species, such as *Coenagrion* spp and *Lestes* spp, I observed also some interesting biological, ecological and behavioural features. Furthermore, since the food web in Zoige is relatively simple, I suppose that, at least in the summertime, odonates can be the major supporters of higher-level predators like birds since not many large insects can have such high population densities.

Coenagrion lunulatum showed obvious melanism compared with other populations in Northern China (Figs 24-25). Other species, like *C. ecornutum* and *E. cyathigerum*, were also more or less melanic although not as conspicuously as *C. lunulatum*. Both Barnard et al. (2015) and Sanmartín-Villar & Cordero-Rivera (2016) reported melanism of damselflies under lab-rearing conditions. Barnard et al. (2015) supposed that the incomplete UV radiation in the lab caused the melanism. They also believed that melanism will seldom occur under natural conditions. My observation is not consistent with their opinions. The UV radiation in Zoige is very strong with an annual average sunshine of 12 hours (Wu & Yang, 2011) but I never found “normally coloured” *C. lunulatum*. The limiting environmental factor in Zoige is the low temperature with an average annual temperature of 0.7°C (Wu & Yang, 2011). I suppose the melanism is related to high altitude (strong solar radiation) and low temperatures in Zoige. A higher amount of black body colour can gather more solar radiation to keep the insects warm. The observed RTCC in *E. cyathigerum* (Fig. 29) is another good example of thermoregulation (Sternberg, 1996).

Feigning death as a major strategy of avoiding disturbance or threats, although quite common in other insects like true bugs and beetles, is not very common in Odonata. After all, in most places in the world plunging into dense vegetation is dangerous for odonates. That means they cannot fly away quickly, may wet their wings and bodies, and risk being caught by predators on the ground. Therefore, except to avoid very special predators like larger congeners (Moore, 1983) or intensive sexual conflict (Khelifa, 2017), odonates are considered to rarely feign death. The field experiment we conducted, however, showed that feigning death is one of the major strategies (Fig. 38, $F = 6.754$, $p = 0.014$) for *E. cyathigerum* in Zoige. Especially in the morning, when the temperature is quite low (the damselfly cannot fly), the wind is not so strong (it will not affect the position to fall down), and the relative humidity is high (the body is wet so no more troubles to fall into the water), the damselflies often adopt feigning death to protect themselves.

My observations and behavioural experiment are preliminary and the conclusions need further studies to be confirmed. However, all these findings are inspirational and may provide good topics for further research. Cordero-Rivera (2017) put it this way: “Ethodiversity [i. e. behavioural diversity] is important at the intraspecific, inter-population, and species level and has practical relevance in several fields, like captive breeding, eco-novelty, and popular science. Finally, I expect ethodiversity to show a latitudinal cline, with more diverse and elaborate behaviors per species in the tropical regions, given the increase in interactions near the equator“.

To follow these ideas, the feigning death behaviour of *E. cyathigerum* in Zoige is a good example of species-related or geographic effects. Moore (1983) gives information on phylogenetic differences in feigning death behaviour. In Hawai'i he observed this behaviour in most members of the endemic genus *Megalagrion*, but not in the invasive resp. introduced species *Enallagma civile* and *Ischnura ramburi*. Moore (1983) also studied populations of *Enallagma cyathigerum* and *Lestes sponsa* in the UK, but reported no observations of death feigning behaviour; we can not exclude, however, that Moore did not include enough specimens in his study.

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