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Behaviour of dragonflies during the 2009 partial solar eclipse in Japan (Odonata: Libellulidae)

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Behaviour of dragonflies was observed during the partial solar eclipse in Saitama, Japan, on 22 July 2009. The solar eclipse started at 09:54 h, reached its maximum magnitude of 74.9% at 11:12 h, and ended at 12:29 h. Light intensity at the peak of the eclipse was 1005 lx, a reduction by 28.2% of that at the start, and the ambient temperature was rather constant because of cloudiness. Dragonflies were active until immediately before the eclipse maximum and thereafter ceased their movements; one *Orthetrum albistylum speciosum* male perched atypically with its body axis nearly parallel to its perch. They resumed activities after a long delay, *c*.40 minutes after the peak. One female of *Pseudothemis zonata* oviposited near a perching male soon after the peak, but the male did not interfere with it. The inactivation of dragonflies in a solar eclipse may be related to the light intensity.

Keywords: Odonata; dragonfly; solar eclipse; inactivity

Introduction

A total solar eclipse occurred in the north of the Nansei Islands in Japan on 22 July 2009, and at other places a partial solar eclipse was seen. At Tokorozawa City in the Kanto region in central Japan a partial solar eclipse of the magnitude of 75% was observed. Several reports on the behaviour of dragonflies in a solar eclipse have been made so far (Mitra, 1996; Dommanget & Williamson, 1999; Kiauta & Kiauta, 1999). However, there are no reports from Japan. The weather was cloudy on the day of the eclipse, providing the opportunity to observe activity of dragonflies under conditions of both the partial solar eclipse and the cloudiness.

Here I report about my observations on the behaviour of dragonflies during the partial solar eclipse in comparison with those on a sunny and hot day in summer in Honshu, the mainland of Japan.

Methods

Observations were made at the bank of a reservoir at B area of Tokorozawa campus of Waseda University (35°47′12″N, 139°23′47″E) at Mikajima, Tokorozawa City, Saitama Prefecture from

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09:50 h till 12:40 h on 22 July 2009, when the partial solar eclipse occurred and, for the comparative data, on 22 July 2010, one year after the eclipse day. The reservoir was 50 m wide and 40 m long and was surrounded with reeds on the south and west sides and roads on the other sides.

Environmental conditions were measured at intervals of 10 min; ambient temperature (Ta) was measured to 0.1°C at a height of 1 m with a digital thermistor thermometer (CT-410WR, CUSTOM Corporation) and the light intensity (Lx) at ground level with a digital illuminometer (Model LX-109, Multi Measuring Instruments Sales Co.).

Chases per 10 min by males of the dragonflies *Orthetrum albistylum speciosum* and *Pseudothemis zonata* were recorded throughout the observation period; *Orthetrum* males chased those of *P. zonata* as well as conspecific males.

Data on the light intensity were analyzed by Mann–Whitney U-test and a chi-square test, and least squares linear regression analyses were applied to the relation among Ta, Lx and the eclipse magnitude.

Results

Environmental conditions

A. Partial solar eclipse

Figure 1 shows the changes of the magnitude of the partial eclipse, the light intensity (Lx), the ambient temperature (Ta) and the frequencies of the intra- and inter-specific chase of *O. albistylum speciosum*, intraspecific chases of *P. zonata* males, and oviposition by females of those species.

The partial solar eclipse at the observation spot started at 09:54 h, reaching the maximum eclipse magnitude (74.9%) at 11:12 h and finished at 12:29 h (Figure 1a), based on the calculation by Ephemeris Computation Office, National Astronomical Observatory Japan. It was cloudy and dark at the beginning of the eclipse; Lx was 1400 lx and Ta was low (22.3°C) at 09:50 h. Lx and Ta at the eclipse maximum were 1005 lx and 22.5°C, respectively, and at the end of the eclipse those were 3875 lx and 25.7°C, respectively. The differences of the two factors between the start and the peak were −395 lx (28.2%) and +0.3°C, respectively. The difference of the former was significant ($p < 0.001$).

Air temperature remained near 23°C and rose only at the end of the eclipse; the change in Ta between the peak and the end of the eclipse was 3.2°C. The change in Lx was relatively greater, from *c*.600 lx to 4000 lx throughout the observation. Averaged throughout the eclipse Ta and Lx were 22.8 ± 0.8°C (range 22.2–25.7°C) and 1693.0 ± 838.4 lx (range 586–3875 lx), respectively. Average Lx during the 40 min before was 1639.4 ± 757.7 lx and during 40 min after the peak was 1076.6 ± 366.4 lx, although the difference was not significant ($z = 0.522$, $p > 0.1$).

The correlation between Ta and Lx was high ($r = 0.721$, $p < 0.001$) but between Ta and eclipse magnitude it was not significant ($r = 0.354$, $p > 0.1$). The magnitude and Lx were negatively related ($r = -0.404$, $p > 0.05$), although the correlation coefficient was not significantly different from that of the magnitude and Ta.

B. Normal hot day

Figure 2 shows the changes of Ta and Lx with the chase frequencies of dragonflies during the same time one year after the solar eclipse day. The weather was fine and very hot. Ambient temperature and light intensity exceeded 33°C and 90,000 Lx, respectively. Mean Ta was 35 ± 1.4°C (33.2–38°C) and Lx was 106, 976.5 ± 5224.6 lx (96,500–110,120 lx), much higher than on the solar

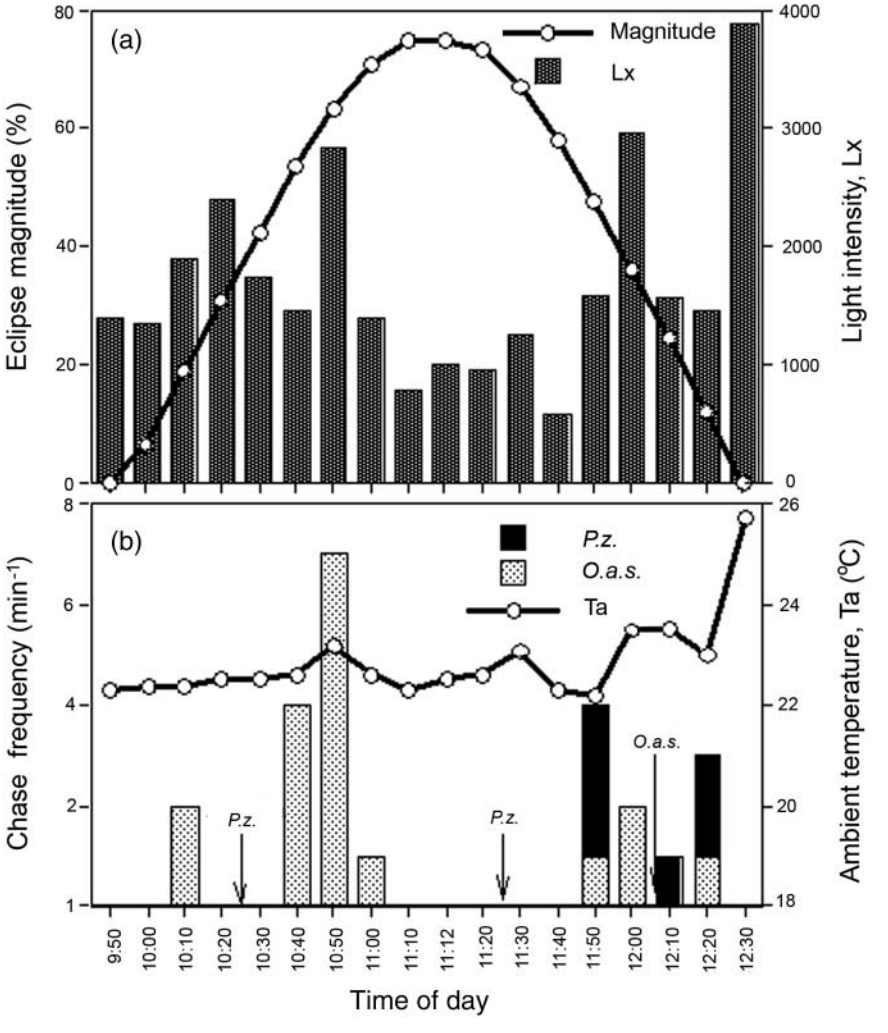

Figure 1. Changes of environmental conditions during the partial solar eclipse at Tokorozawa City, Saitama Prefecture, Japan, on 22 July 2009. (a) Light intensity (Lx) and the magnitude (%) of the partial solar eclipse. The event started at 09:54 h and finished at 12:29 h. (b) Chase frequencies of males of *Orthetrum albistylum speciosum* (*O.a.s.*) and *Pseudothemis zonata* (*P.z.*) and the ambient temperature (Ta). In *O.a.s.* the chase frequency includes interspecific chase to *P.z.*, which did not interefere with *O.a.s.*, as well as the intraspecific ones; downwards arrows show times of appearance of a male of *P.z.* at the first half of the eclipse and oviposition by females of the indicated species at the latter half. Data were collected at the edge of a reservoir at B area of Tokorozawa campus of Waseda University at Mikajima, Tokorozawa City, Saitama Prefecture.

eclipse day. The correlation coefficient between Ta and Lx was 0.748 ($p < 0.001$), almost the same as that of the solar eclipse day.

Behaviours of dragonflies at the observation site

A. During the eclipse

In dragonflies, males of *O. albistylum speciosum* were present at the observation spot from the start of the eclipse, and males of *P. zonata* appeared later. *Orthetrum* males were chasing each other until shortly before the peak magnitude (Figure 1b). However, at the peak they disappeared

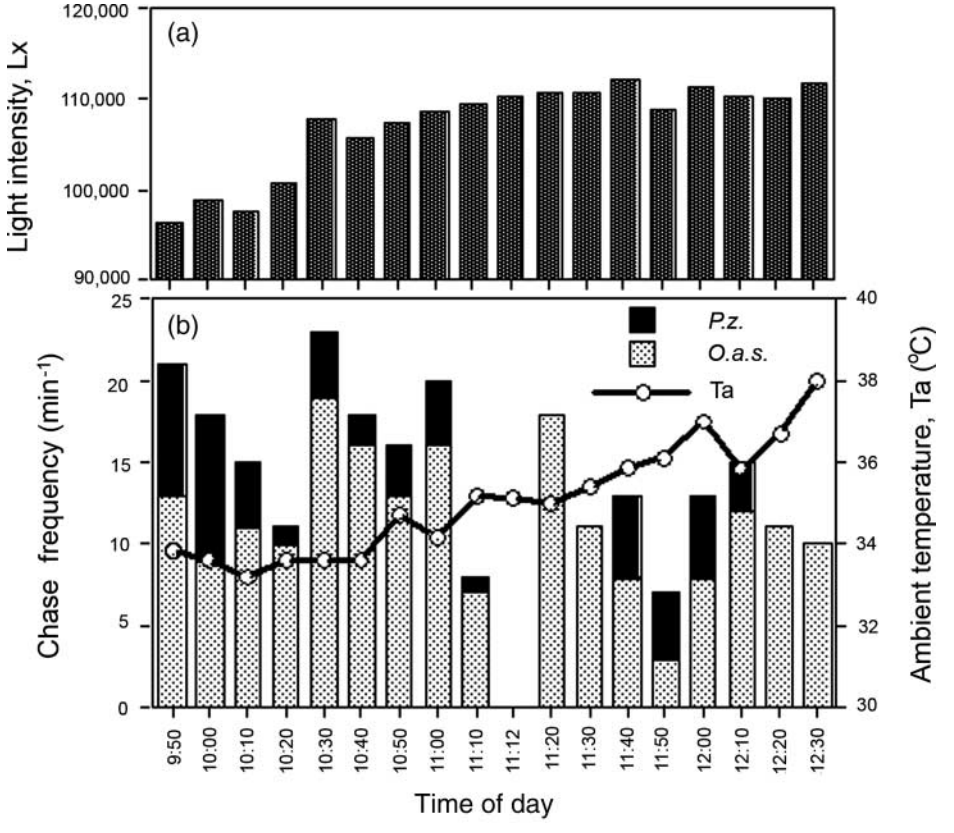

Figure 2. Changes of environmental conditions at Tokorozawa City, Saitama Prefecture, Japan, on 22 July 2010, just one year after the solar eclipse day. (a) Light intensity (Lx). (b) Chase frequencies of males of *Orthetrum albistylum speciosum* and *Pseudothemis zonata* and the ambient temperature (°C).

except for resident males; these continued to perch for more than 40 minutes after the peak, but with their body axis more parallel than usual to the perch (Figure 3b). At other times, both species perched nearly horizontally (Figure 3a, c). In other species *Pantala flavescens* appeared during the eclipse and disappeared just before the peak, and a *Deielia phaon* male appeared just before the end of the eclipse.

Oviposition by females of *O. a. speciosum* and *P. zonata* was seen. The latter started oviposition *c*.13 minutes after peak magnitude. Although the female appeared from in front of the male, the latter never responded, and the female was able to oviposit without interference of the male for more than two minutes.

At this time of year Lx normally exceeds 100,000 lx as shown in Figure 2a; however, it was cloudy and dark, and the average Lx was less than 2000 lx. Dragonflies were active and conducted intraspecific chases until just before the maximum of the eclipse, and they started activities after a rather long lapse of time, *c*.40 min from the peak; in *P. zonata* after 39 min (1975 lx), and in *O. a. speciosum* after 43 min (2657 lx).

B. During a fine, hot day 1 year after the eclipse

On the normal but hot day males of dragonflies were active throughout the observation hours (Figure 2b). The chase frequencies of the dragonflies on that day were significantly greater

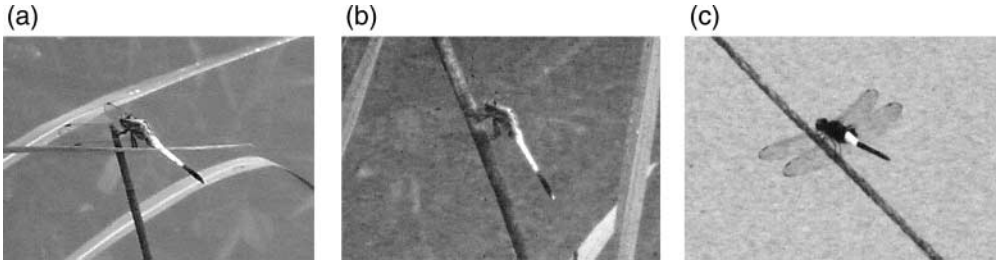

Figure 3. Perching postures of dragonfly males during the partial solar eclipse in 2009 in Japan. (a) Resident male of *Orthetrum albistylum speciosum* with the normal posture; (b) same male with its body nearly parallel to its perch; (c) male of *Pseudothemis zonata* with the normal posture.

Table 1. Relationships of chase frequencies of male *Orthetrum albistylum speciosum* and *Pseudothemis zonata* to ambient temperature (Ta) and the light intensity (Lx) at the observation spot, using multiple regression analysis. Data were collected on 22 July of the two years, 2009 and 2010 at Mikajima, Tokorozawa City, Saitama Prefecture, as described in the text.

	Regression coefficient				
Species	Ta	Lx	Intercept	r	Probability
O. albistylum speciosum	−2.635	0.00040	60.607	0.861	$p < 0.0001$
P. zonata	−0.396	0.00007	9.351	0.566	$p < 0.01$

than during the eclipse (in *O. albistylum speciosum*, $10.9 \pm 5.0 : 1.4 \pm 2.0$, $p < 0.0001$; in *Pseudothemis zonata*, $3.1 \pm 2.7 : 0.4 \pm 0.9$, $p < 0.0001$; t-test).

In regression analysis of the chase frequencies and the environmental factors (Figure 1a, 1b), chase frequency of *O. albistylum speciosum* was rather highly correlated with Lx ($r = 0.590$, $p < 0.05$), but not significantly so with other factors, and in *P. zonata* data were insufficient for comparison with the partial solar eclipse.

However, in the multiple regression analyses on the combined data of both days, chase frequency of both species was related with both Ta and Lx ($r = 0.861$, $p < 0.0001$ in *O. albistylum speciosum* and $r = 0.566$, $p < 0.01$ in *P. zonata*, respectively; Table 1). Furthermore, in the simple regression analyses, chase frequency was rather more influenced by Lx than by Ta in both species; $r = 0.773$ *vs.* 0.710 (both $p < 0.00001$) in *O. albistylum speciosum* and $r = 0.547 (p < 0.01)$ *vs.* 0.520 ($p < 0.001$) in *P. zonata*, respectively. The regression coefficients of the relationship between chase frequency and Ta in both species were negative, −2.635 in *O. albistylum speciosum* and −0.396 in *P. zonata*.

Discussion

Usually as an eclipse progresses, the light intensity and the ambient temperature decrease until the peak magnitude and thereafter increase again. However, the weather of the day was cloudy and the eclipse was partial, so Ta was rather constant and change between the start and the maximum of the eclipse was +0.3°C, clearly less than previous observations of 4.8°C (Kiauta & Kiauta, 1999), 4.0°C (Mitra, 1996), 2.0°C (Dommanget & Williamson, 1999) and 1.8°C (Grand, 2000). Also, Lx varied by less than twice its average magnitude (1693 lx) during the eclipse. In spite of the small differences, the peculiar posture of a dragonfly (in this case an *O. albistylum speciosum* male) with its body axis more parallel to the perch (Figure 3b) in the solar eclipse, as reported by other authors (Kiauta & Kiauta, 1999; Mitra, 1996; Dommanget & Williamson, 1999;

Grand, 2000) was observed. This typical posture agreed with the observation by Katatani (2010) in Nara Prefecture at the same time of the same day: *O. albistylum speciosum*, *O. triangulare melania* (Selys) and *Sympetrum darwinianum* (Selys) adopted the same posture as that when seemingly sleeping.

The prolonged duration of rest and inactivity by both species after the maximum of the eclipse is similar to the cases noted by Kiauta and Kiauta (1999), Dommanget and Williamson (1999) and Grand (2000), in which the lethargic state of odonates continued more or less for total 40–50 minutes before and after the peak. This is different from the report of Mitra (1996), who noted that dragonflies were active *c*.7 min after the maximum of the eclipse. That might have been due to a rapid increase of the air temperature, while in my case the light intensity declined after the peak. However, on a more typical (albeit abnormally hot) day, at the same time of day exactly one year later, when Lx exceeded 90000 lx, dragonflies were active without the lethargic state as seen during the eclipse. Dragonflies seem to be influenced by Lx more than Ta as argued above. In this connection, however, the negative regression coefficients of Ta may be an artifact of the lack of data between the low and the abnormally high Ta. The curves of the relationship between chase frequency and Ta may have a maximum at intermediate Ta.

There are some additional cases cited by Corbet (1999, p. 311) on the influence of the reduction of light intensity on the activities of dragonflies: *Epiophlebia superstes* (Selys) left the water, all odonates abruptly left the water after a sudden drop of the light intensity in North Carolina, and *Ictinogomphus ferox* (Rambur) left the water when the sun was obscured for more than a few minutes. The dragonflies at the present site started activity at Lx near 1500 lx, but they seemed to be lethargic when Lx fell to *c*.1000 lx. Considering the Ta did not change markedly from the start to the peak, and rose just before the end of it, Ta did not seem to affect odonate activities. Kiauta and Kiauta (1999) also noted that the rapid reduction of light intensity rather than a minor drop in the ambient temperature seemingly triggered the behavioural response during a solar eclipse.

Dragonflies can see and discriminate a fairly wide range of wavelengths within the (human) visible spectrum as well as in UV (Armett-Kibel & Meinertzhagen, 1983; Meinertzhagen et al., 1983; Corbet, 1999). The spectral quality of sunlight is affected in different ways by clouds, solar declination, and the occurrence of a solar eclipse, during which intensity decreases more at shorter wavelengths (Kazadzis et al., 2007). It is possible that reduced activity of dragonflies during an eclipse and during normal dusk and dawn are responses, in whole or in part, to changes in spectral quality, especially UV. Given the large changes in overall light intensity, however, it appears more plausible to assume that intensity *per se* controls their response. It might, nevertheless, be informative to examine the effects of spectral variation on activity by using a spectroradiometer sensitive to the full solar spectrum.

As to the fact that a male of *P. zonata* did not interfere with a congeneric female that oviposited nearby it, the male might have been lethargic and unable to recognize or to respond to the female. As it oviposited in lower Lx at the latter half of the maximum eclipse, females, especially in libellulids, seem to have the ability to be active at a low light intensity in which males cannot be active. In Japan *Anotogaster sieboldii* females were seen often ovipositing around midnight when no males are active (K. Makita, personal communication, October 9, 2009); however, males of some crepuscular dragonflies, which were not seen during my observations, also fly late in the evening. It would be interesting to see how they behave in such a solar eclipse.

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References

Armett-Kibel, C., & Meinertzhagen, I.A. (1983). Structural organization of the ommatidium in the ventral compound eye of the dragonfly Sympetrum. *Journal of Comparative Physiology (A)*, *151*, 285–294.

Corbet, P.S. (1999). *Dragonflies: behavior and ecology of Odonata*. Ithaca: Cornell University Press.

Dommanget, J.-L., & Williamson, T. (1999). Réactions de querques odonates en forêt de Rambouillet lors de l'éclipse de soleil du 11 août 1999 (Département des Yevelines). *Martinia*, *15(3)*, 79–82.

Grand, D. (2000). Influence d'une éclipse de soleil sur une population d'Odonates. *Bulletin Romand d'Entomologie*, *18*, 84–91.

Katatani, N. (2010). Observation of the behavior of dragonflies during a solar eclipse in Nara Prefecture. *Aeschna*, *46*, 9–16.

Kazadzis, S., Bais, A., Blumthaler, M., Webb, A., Kouremeti, N., ... & Kazantzidis, A. (2007). Effects of total solar eclipse of 29 March 2006 on surface radiation. *Atmospheric Chemistry and Physics*, *7*, 5775–5783.

Kiauta, B., & Kiauta, M. (1999). A note on dragonfly response during the 93.8% solar eclipse of 11 August 1999 in the Netherlands (Odonata). *Opuscula Zoologica Fluminensia*, *172*, 1–6.

Meinertzhagen, I.A., Menzel, R., & Kahle, G. (1983). The identification of spectral receptor types in the retina and lamina of the dragonfly *Sympetrum rubicundulum*. *Journal of Comparative Physiology*, *151*, 295–310.

Mitra, T.R. (1996). A note on dragonfly behaviour during the 1995 total solar eclipse near Calcutta, India. *Notulae Odonatologicae*, *4*, 133–134.