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Touching water by males of *Calopteryx virgo* L. (Insecta: Odonata) in threatening display

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For the first time water dipping behaviour of Calopteryx during threatening flight is reported. Four males of *Calopteryx virgo* in a small rivulet coming from a spring pool in SW France involved in threatening flights near an opponent dipped a wing into the water, producing conspicuous water rings. One male did this twice and additionally hit the water with its legs, splashing water drops forward. Possible interpretations are discussed.

Keywords: dragonfly flight; extra-body signalling; threatening behaviour; beat frequency; territoriality

Introduction

Signalling in flight, or wing clapping when perched, is well known in Calopterygid males. All Calopteryx species show in-phase beating, enlarging the ornamented wing area visible at that moment. This conspicuousness is enhanced by a low beat frequency of 10–18 beats per second, depending on the duration of wing-standstills at the end of upstrokes (Rüppell, 1985). In contrast, high-frequency flight of males is shown when courting. Depending on the position and movement of the female, this can be done at frequencies up to 50 Hz and is species-specific (Anders & Rüppell, 1997). But this high-frequency flight is shown, too, in threatening behaviour. This was shown in *C. splendens* females against other females (Hilfert-Rüppell, 2015) and in male–male contests of *C. virgo* and *C. splendens* and in *C. xanthostoma* females threatening harassing males (unpublished slow motion films 2015–2017). The use of high-frequency flight was seen as an increase in threatening intensity. *Neurobasis* species (Calopterygidae) reduce movements of their metallic ornamented hind wings or even hold them motionless in threatening and courting flight (Günther, 2012). Furthermore, when flying over the surface or settling on the water with still-standing hind wings, the males of *N. chinensis* often produced water ripples by touching the water with the tips of their hind wings. These patterns were interpreted as additional optical stimuli in threatening context (Günther, Hilfert-Rüppell, & Rüppell, 2014). In a population of *Calopteryx virgo* in SW France (Département Gironde) we found touching of water during intense threatening behaviour between males, which we present in this short communication.

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Material and methods

The behaviour was filmed between 24 and 27 June 2018 with a camera capable of slow motion filming (Sony RX 10 III, Tokyo, Japan) at 250 frames per second (fps). *Calopteryx virgo* flew at a small rivulet, entering the river Célé in SW France, Département Gironde (44.35° N; 1.50° E), coming from a spring pool of about 10 m diameter and a depth of 0.6–1 m. The rivulet was 20–40 cm deep, running over rocky ground covered by a thin, light sediment or algae layer, and 60–120 cm wide. Filming was done between 10:00 and 16:00 local time when the ambient temperatures were between 25 and 28°C in sunny conditions. The water temperatures were between 12 and 14°C. The flow velocity ranged between 0.5 and 1 m s^{-1}. The filming was done at a sunny segment of this rivulet (Figure 1) with banks vegetated by lesser water-parsnip (*Berula erecta*), greater spearwort (*Ranunculus lingua*) and some aquatic mint (*Mentha aquatica*). Territories of *C. virgo* – males along each waterside were 1–3 m long. From 23 to 27 June 2018 30 clips of films of threatening behaviour of *C. virgo* were produced with a projection duration of about 10 min. Four times on 25 June water touching of *C. virgo* males, all in a segment of 10 m, was filmed.

The analyses of the films were done by using the program Quick time version 7.7.9 (https://support.apple.com/kb/DL837?locale). For statistical analysis we used SPSS version 25 (https://www.ibm.com/analytics/spss-statistics-software) (*t*-test, at normal distribution).

Results

From about 9:00–11:00 males established territories by threatening flights. Usually two, but also three or four males were involved. They showed frontal threatening, lateral threatening flights and waving flight (= flying up and down). The wing beat pattern showed wing standstills after upstrokes: the duration of wing standstills was, in two normal threatening flights, 25% and 33% of the whole flight duration at beat frequencies of 13 Hz and 11.5 Hz (N = 21; 15 wing beats).

On four occasions males of couples in three intense disputes showed dipping of a hindwing into the water, producing expanding water rings (Figure 2). They dipped to the side where the opponent was flying. To execute this behaviour, the males flew 10–20 cm downward to the water.

Figure 1. *Calopteryx virgo* site in SW France. The rivulet comes from a spring pool (near top left). Filming was done at the narrow section at the end of visible water (in the middle, upper background).

Figure 2. Two threatening males of *C. virgo* dipped a hind wing into the water nearly synchronously. Top left: The left male is dipping his right hind wing into water, top right: the other male is dipping his right hind wing; bottom left and right: rings from the dips are expanding (still photos from a film at 250 fps). The beats at dipping and afterward were done without standstills.

The duration of this water contact was 0.004–0.008 s (N = 5, flights). In one case two males involved in a dispute, flying close to each other, dipped nearly at the same time, the second male with a delay of 0.064 s to the dip of the first male.

In another dispute one male dipped twice with the same wing at two successive down strokes. Furthermore, at the second dip he hit the water with the two hind legs, splashing water drops forward (Figure 3). The hitting began 0.004 s before the second dip. The wing beat between first and second dip was very short; its duration was only 0.028 s (= 35.7 Hz) in contrast to durations of another flight with only one dip (0.067 s, = 14.9 Hz); N = 6 wing beats).

The durations of the down strokes (producing most lift) of the water-using male and the male not using water differed clearly ($p = 0.005$, $t = -3.26$, *t*-test, N = 9 and 8 wing beats), being shorter in the dipping male.

During and water splashing the beat frequencies of this male were higher than his own frequencies before, and higher than that of the opponent (dotted bars, $p = 0.033$, $t = 2.35$, *t*-test, N = 10 and 7 wing beats; Figure 4).

Figure 3. A male of *C. virgo* is dipping his left hind wing twice (second and third picture at top, from left to right) and is hitting the water with two legs (probably hind legs, third picture at top and first picture at bottom), generating two imprints and splashing water drops forward (second picture at bottom) (still photos from a film at 250 fps).

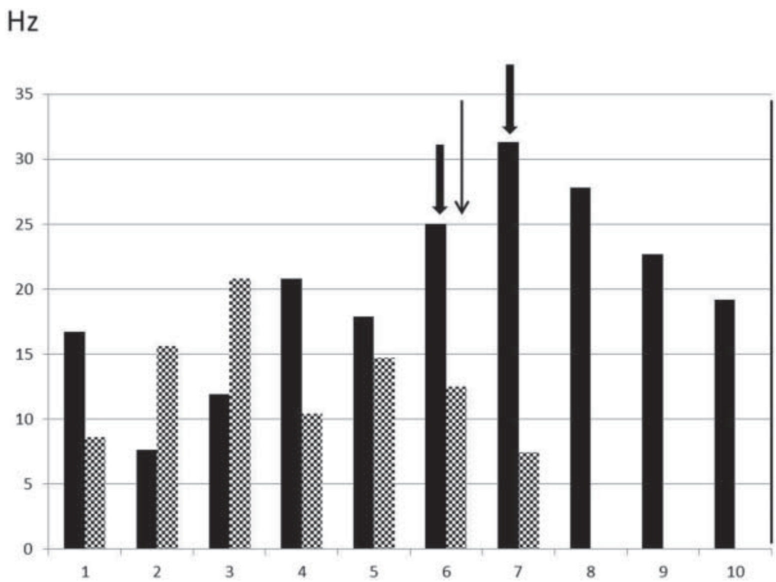

Figure 4. Wingbeat frequencies of two opponents: one male (black bars) was dipping his hind wing into the water twice (solid black arrows) and hitting the water's surface with legs (thin black arrow, same action as in Figure 3). The other male (dotted bars) was threatening only in flight and was out of the screen at beat 8. Numbers in abscissa = successive wing beats.

Discussion

The uniqueness of the reported water-pattern producing behaviour in threatening could be underlined by the fact that we examined more than 10 h of our own slow motion films of threatening flight of *C. splendens* from northern Germany, *C. virgo* from northern and southern Germany, *C. xanthostoma* from southern France and *C. haemorrhoidalis* from southern France, without any signs of a similar behaviour.

The described wing-dipping or water-hitting with legs was only observed during intense threatening flight (at in-phase beating) in the presence of an opponent who was threat-flying nearby. It is not clear how many individuals at this dipping flight were involved, because the damselflies were not marked; however, at least two males must have been touching water, as in one event both opponents did it. At this dipping there are differences to normal threatening flight patterns. After wing-dipping and hitting the water's surface with legs, there are no wing standstills at the end of upstrokes. Furthermore, the beat frequency in the water-using male was increased and the durations of down strokes were shorter than in males threatening only by flying.

The result of water-pattern producing behaviour of *C. virgo* are short optical stimuli: expanding rings on the water's surface and reflections on the ground and, as an enhancement, two dips shortly one after the other together with the legs splashing water drops forwards.

Possible interpretations of this behaviour include signal enhancement as part of threatening flight. All five wing-dips and the water-splashing by legs were performed during intense male–male threatening at very close distances. Females were not involved. The wing dipping was done only by the hind wings, which is economical, because the hind wings are beaten nearer to the water's surface on a lower path than the forewings.

Other interpretations of water contact could be: (1) by chance during flight; (2) by accident during fights; and (3) during drinking or bathing. In drinking, the water contact is done with the head and mouth or body, never only with wings or legs. The head then is dipped into the water, as shown in Figure 5 and in slow motion films on *C. splendens* and *C. virgo* (our films, unpublished). The wings in drinking touch the water, too, but then propel the body for take-off afterwards.

Accidental water contact is not a plausible explanation either, because to dip a wing or splash water, the damselflies changed their flight path and flew downwards for water contact. The repeat of two dips accompanied by water hitting by legs of one male is another argument against the by-chance hypothesis.

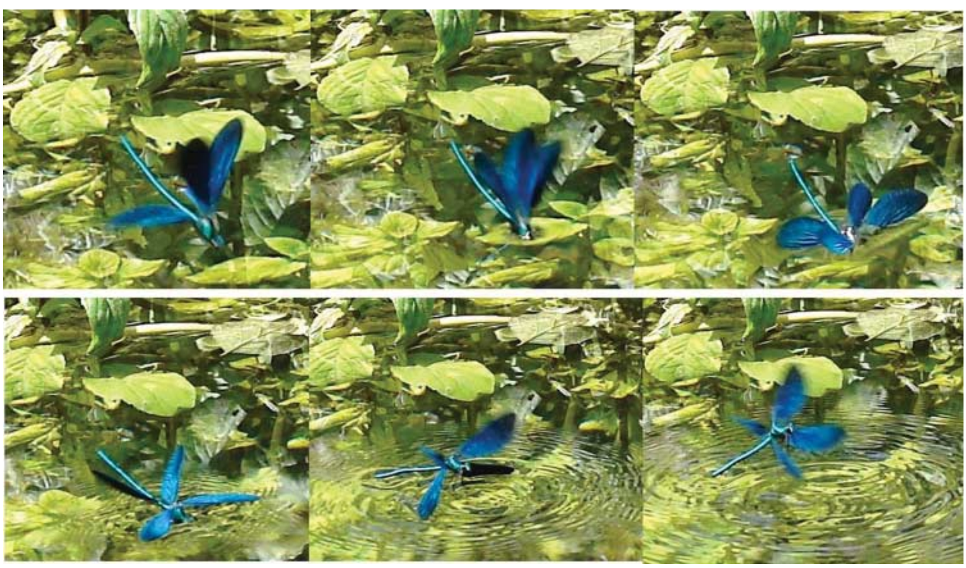

Figure 5. When this male was drinking he landed on the water with outstretched wings, putting his head under water (third picture on top – from left to right). At take-off the wings were flapping on the water's surface (still photos from a film at 250 fps).

Water contact by accident during fight can also be ruled out, too: the damselflies were not fighting with body contact, but flying narrow and in a steady path, without any tumbling or disharmonic wing movements.

The described display only was found in threatening males, not in females or other flying males. So an explanation of this behaviour as a result of parasites or diseases can also be excluded.

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Supplementary data

Supplemental data for this article can be accessed here https://doi.org/10.1080/13887890.2018.1563917

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