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Telemetry of Anisoptera after emergence – first results (Odonata)

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Abstract

The behaviour of Anisoptera during the period between emergence and the onset of sexual activity is poorly known, mainly because freshly emerged adults are hard to follow. In the present study the system RECCO® Transmitter/Receiver and custom-built tags made from Schottky diodes and copper wire were used to monitor freshly emerged Anisoptera. The system had an average maximum detection distance of ca 85 m. Ten individuals of *Libellula fulva* were successfully tracked for up to five consecutive days. They almost exclusively utilized trees or shrubs as perches at heights ranging from 1.8 to ca 31 m. Open meadows or open river bank vegetation, which were present close to the release site, were never used for perching. Considering that human observers can reasonably detect adult anisopteran up to a height of 3 m, 92.5% of all registered perch sites were "out of reach". The maximum distances covered on the first day averaged 37.7 m and 31.1 m for males and females, respectively. Two individuals, followed for four and five days respectively, remained in relatively small areas of 480 m² - 2,500 m² for three and four consecutive days. Five tagged individuals of *Aeshna mixta* showed a very different behaviour from *L. fulva*. Already in the first hours after release, all flew distances of more than 200 m and were lost. The telemetry system used was not suitable to study this species immediately after emergence.

Introduction

The behaviour of Odonata during the prereproductive period is poorly known (e.g. Parr 1983; Anholt 1990; Jödicke 1997: 179-180; Corbet 1999: 271-273). This is mainly because they are normally out of reach of the human observer and thus largely inaccessible for research. Habitats occupied by immature adults away from the water are often associated with woodland, and include the canopy and crowns of forest trees (Pajunen 1962; Corbet 1999: 271-272; Ha et al. 2002). It is known that teneral Odonata show a negative taxis with respect to water until sexual maturation (e.g. Pajunen 1962; Parr & Parr 1974; Jödicke 1997: 179; Ha et al. 2002).

For the European gomphids, only accidental observations exist about where they live during maturation (Suhling & Müller 1996: 52). Most data available for this critical period originate from mark-recapture studies (e.g. Parr & Parr 1974; Watanabe & Higashi 1989; Ha et al. 2002) and pertain only to habitats accessible to the human observer. For example, a number of individuals of *Nesciothemis nigeriensis* Gambles were only seen again at the water twelve days after having been marked as tenerals without having been observed during the intervening period (Parr & Parr 1974). It is clear that many Odonata species reach maturity in inaccessible habitats, because after the onset of the emergence period, as indicated by the presence of fresh exuviae, adults are often not found for substantial periods (e.g. Suhling & Müller 1996: 51-52; Knaus & Wildermuth 2002; Hardersen 2004). Teneral males of Odonata were shown to stay in forests away from the water before returning to the emergence site (e.g. Pajunen 1962; Watanabe & Higashi 1989; Kirkton & Schultz 2001) and during the teneral phase males of *Calopteryx maculata* (Beauvois) have been predominantly observed feeding (Kirkton & Schultz 2001). The sites where they were maturing were shown to offer a high number of potential prey items (Kirkton & Schultz 2001) and may constitute "hassle-free" refugia where tenerals can feed without interference from territorial males. However, all these observations are to some extent accidental and the dragonflies were not followed continuously.

It is known that behavioural (e.g. Corbet 1999: 271-273) and physiological (Marden 1995) differences exist between tenerals and adults. For example, teneral adults perform better at lower temperatures in comparison with mature dragonflies and optimal thoracic temperature is higher for more mature individuals (Marden 1995). Freshly emerged libellulids spend little time in flight, as they are primarily sit-and-wait predators. In contrast, during territorial defence and mating, mature libellulids are among the most active animals on earth, spending up to 100% of their time in vigorous flight (Marden 1995).

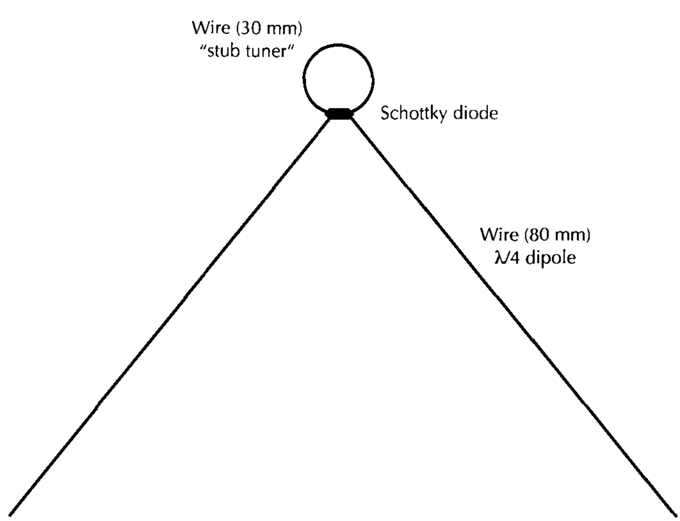


Figure 1: The 'open' configuration of the tags — Schottky diodes with dipole antenna, measuring 80 mm each and with a "stub tuner".

Technological advances (Roland et al. 1996; Naef-Daenzer et al. 2005) now permit the telemetry of insects, thus offering new possibilities to study the behaviour of Odonata in the prereproductive period. Currently, two different techniques exist:

- an active transmitter with a power supply (e.g. Naef-Daenzer et al. 2005; Wikelski et al. 2006) and a minimum weight of 200 mg
- a passive transponder reflecting a signal generated by a harmonic radar (Roland at al. 1996; Capaldi et al. 2000) with a minimum weight of the tag of 0.4 mg

Given the weight of active transmitters of 200 mg (Naef-Daenzer et al. 2005), they can only be used with the largest insect species (e.g. *Anax junius* (Drury), Wikelski et al. 2006). For smaller odonate species the use of passive transponders is thus mandatory. Currently, two forms of harmonic radar are used to study insect behaviour: (1) A ground based scanning radar station in which the tagged insect is tracked automatically (e.g. Riley & Smith 2002) for up to 900 m (Riley et al. 2003) and (2) a more low-cost commercially available transmitter/receiver (RECCO® Rescue System),with a detection range of up to 75 m (O'Neal et al. 2004). One advantage of the RECCO system is that the longer wavelength is not easily blocked by water and therefore also by leaves, twigs and trunks thus being more useful in landscapes with trees. To my knowledge, telemetry using harmonic radar has so far not been applied to Anisoptera and following freshly emerged individuals during the first days of maturation has not been done up to now.

The aim of the present study was (1) to develop a system for the telemetry of teneral anisopteras and (2) to follow freshly emerged individuals in order to monitor movement and habitat preferences prior to maturity.

Material and methods

The study site

This study was carried out in the nature reserve "Bosco della Fontana" (45°12'N, 10°44'E) that is located near Marmirolo, ca 5 km NW of Mantua, Lombardy, Italy. The reserve covers an area of ca 233 ha, 199 of which are occupied by woodland, 33 by meadows and one by an artificial wetland. Many other small freshwater habitats as well as two small streams (Rio Begotta, Roggia Sgarzabella) exist in the reserve; for more details see Mason (2002).

The telemetry system

A RECCO® Transmitter/Receiver (RECCO AB, Lidingö, Sweden <www.recco.com>), an avalanche rescue system, was purchased in April 2005. The tags used consisted of Schottky diodes (Infineon®, BAT62-03WE6327) with a dipole antenna made of two copper wires with 0.1 mm in diameter, each measuring 80 mm in length. Additionally, a piece of the same wire, measuring 30 mm, was used to form a "stub tuner" for impedance matching and, at the same time, a DC loop to preserve the diode from electrostatic charges (Fig. 1). Preliminary tests showed that this configuration maximized the detection range, whilst limiting the length of the wires. It is known that the optimal dipol antenna length is 16 cm (see O'Neal et al. 2004). However, preliminary tests with λ/4 wire dipole tags glued to the abdomen of freshly emerged *Libellula fulva* Müller showed that this configuration was not compatible with the normal flight of the insects, probably because of low mechanical resonance frequency of the long free wires. Therefore a more 'compact' configuration of the tags was developed. The final design of the tags used is presented in Plate Ia, b and with glue has a total weight of 25 mg. All tags were tested prior to application and only tags which gave a clear signal from a distance of 70 m were used.

In order to compare the detection range of the 'open' (Fig. 1) versus the 'compact' (Plate Ia, b) design, 10 tags of each type were tested in an open field for maximum detection range. The tags were held at a standard 1.55 m above the ground.

The system does not allow differentiation among individuals, but only determination of their position in relation to the observer.

Selection of the species for the study

In order to select the most appropriate anisopteran species for the study, the following factors were considered:

- the population sizes of the species present at Bosco della Fontana (Hardersen 2004)
- the species, i.e. the affiliation to different Odonata families
- the weight of the adults
- the availability of sufficient freshly emerged adults

It was decided to use members of different families and to select species which are common, abundant or very abundant (see Hardersen 2004) at Bosco della Fontana. The chosen species were *Aeshna mixta* (Latreille), *Somatochlora metallica* (Van der Linden), and *Libellula fulva*.

Energetic costs of powered flight increase with extra weight and an anisopteran in flight produces drag which increases with the application of tags. An increase in energy demand is likely to influence behaviour. Moreover, it is known that foraging Anisoptera rely on their exceptional manoeuvrability (e.g. Olberg et al. 2000). Extra weight added by the tags is likely to negatively affect also this aspect of their behaviour. As no guidelines exist for tag loads in insects, a conservative approach was chosen by selecting only species for which the loads were less than 10% of the bodyweight (see Caccamise & Hedin 1985). In order to assure that this weight limit was not exceeded, mature individuals of the selected species were caught on 29 June 2005 and 1 September 2005 and weighed on laboratory scales.

I was not able to find larvae or freshly emerged *S. metallica*, although exuviae were relatively common. Therefore the species selected for the present study were *L. fulva* and *A. mixta*.

Acquisition of freshly emerged adults

Freshly emerged individuals of *L. fulva* were collected at two sites at Bosco della Fontana: (1) in a section of the Rio Begotta enclosed between two brick walls, which was ca 80 m long and 5.5 m wide, in the centre of the reserve and (2) in a stretch of ca 450 m of the Roggia Sgarzabella, which forms the northern outer perimeter of the reserve. Tenerals were collected between 08:40 -14:40 h (all given times of day relate to solar time) on 9 June 2005, 13 June 2005, 15 May 2006 and 23 May 2006 with a standard sweep net or carefully removed by hand from the vegetation. They were placed in small plastic jars with 10.5 cm in diameter and 13.5 cm in height with tissue paper as a support, to allow transportation to a small field cage. In total nine male and seven female freshly emerged individuals were caught.

Adults of *A. mixta* were bred from larvae collected at various sites in and near the reserve between 29 July 2005 and 1 August 2005 and between 31 July 2006 and 2 August 2006 with standard water nets. The larvae were transferred to plastic containers (ca 80 l) with local water and plant material and supplied with food from local sources. The water in the containers was aerated and the containers were placed in field cages so as to retain adult individuals.

Application of tags

The tags were applied to the third abdominal tergite of the anisopterans ca 1-2 h after they had completed emergence (wings completely expanded), using Loctite® "Super Attak Pocket Gel". In order to do so the tenerals were carefully transported from the field cage to a building, ca 20 m away. Here they were placed on a dry twig, which had been placed horizontally on a table in a dark, cool room, where the anisopterans showed a much reduced tendency to take flight. It was sufficient to "tap" the diode in a drop of glue and immediately apply the tag to the third abdominal segment. Another slight tap (with fine tweezers) to the diode assured a temporary fixation. The anisopteran was then, clinging to a twig or a finger, brought to a room without light, where it was placed on a vertically orientated dry twig. Once the individual had settled, the position of the tag was checked and corrected if necessary. Thereafter the individual was left in the dark for one hour to allow for the glue to harden completely.

Releasing and tracking tagged individuals

All tagged insects were released at the same site with a slight difference of ca 10 m in the years 2005 and 2006. Each individual was carefully transferred to a branch (2005) or trunk (2006) at a height of 1.00 - 1.70 m between 13:10 - 15:45 h (*L. fulva*) and 11:25 - 12:30 h (*A. mixta*). Once the insect took flight it was followed with the aid of the RECCO® detector. In cases where the contact was lost, the area where the insect had last been registered was searched intensively. Every time a tagged individual was located, if possible, the following parameters were noted: position on a detailed aerial photograph, time, estimated height, landscape element such as tree species, building, etc., behaviour, cloud cover. In many cases, especially if the insects were perched high in the canopy, behavioural observations were not possible. It was attempted to relocate all individuals at least once every 30 min, but this was not always possible. Individuals tracked for more than one day were left in the evening from ca 19:45 h onward and relocated in the following morning. Hourly averages of temperature data were provided by the Agenzia Regionale per la Protezione dell'Ambiente della Lombardia – Dipartimento di Mantova.

Data analysis

The data concerning the detection range of the tags with the 'open' and the 'compact' designs were compared using the *f*-test and *t*-test – assuming unequal variances – of Excel® 2002.

The positions of all located perches were transferred to a GIS (ArcView® 3.0a). Distances were measured using the appropriate tools of the GIS system. The maximum distances covered by males and females were compared with the Mann-Whitney *U* Test (OS4 Version 1, Revision 7 (© 2006)).

The estimated heights of 21 perch sites were measured using a Hypsometer (Vertex III® with a Transponder T3, Haglöf AB, Långsele, Sweden). The result of a regression analysis of estimated vs. measured heights (using Excel® 2002) was applied to correct all estimated heights of perches. The corrected heights were assigned to height classes for analysis. The height distribution of males and females was compared with the Mann-Whitney *U* Test (OS4 Version 1, Revision 7 (© 2006)).

Results

The average maximum detection distances for the 'open' and the 'compact' design of the tags were similar: 86 m and 84 m, respectively, and did not differ significantly ($p > 0.5$). However, the maximum detection range of the compact tags was much more variable, i.e. the variance was much larger, a highly significant difference ($p < 0.0001$). The weights for the mature individuals selected are given in Table 1. The regression of the estimated heights of 21 perch sites against the measured values gave the following equation to correct the estimated heights: $y = 1.1879x^{1.0595}$, $R^2 = 0.9441$.

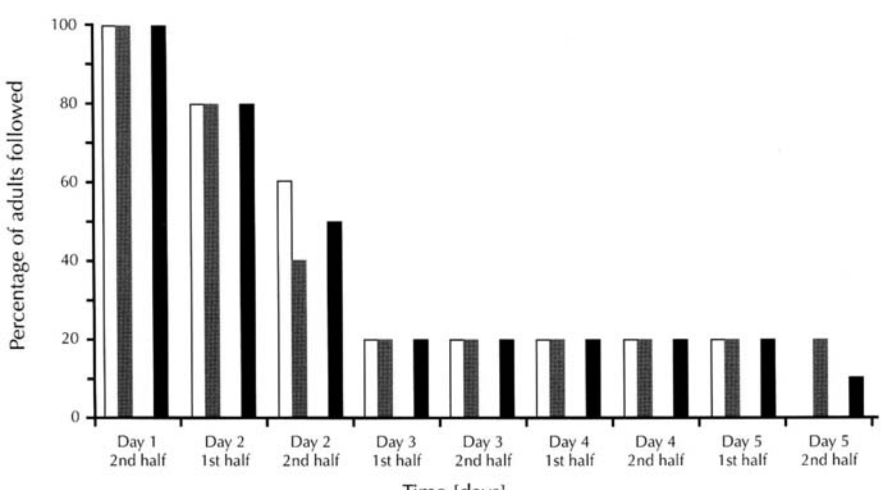


Figure 2: The number of tagged individuals of *Libellula fulva* followed over time. White bars: females; grey bars: males; black bars: all.

Table 1. Average weight [mg] of live, mature adults of selected Odonata species.

Taxon	Males	Females
Aeshna mixta	480 (n = 1)	680 (n = 1)
Libellula fulva	440 (n = 3)	480 (n = 3)

Libellula fulva

Of the 16 tagged individuals, 10 *L. fulva* were successfully followed for up to five consecutive days. Six individuals were either not relocated, the tag fell off or the application of the tag had damaged the individuals. The number of individuals successfully followed over time is presented in Figure 2 and the data-curves for males and females are almost identical. The tracked individuals showed normal behaviour and were seen during perching, flying, hunting, etc. The flight of the tagged animals seemed normal to the observers. The termination of monitoring of the individuals of *L. fulva* occurred for the following reasons: contact loss in eight individuals, tag loss in one individual, tag entangling in one individual.

The first flight of males and females covered 23.2 m and 21.1 m respectively, a non-significant difference (Mann-Whitney *U* Test, $Z = 0.8356$, $p > 0.2$). The maximum distances covered by males and females on the first day were 33.8 m and 31.1 m, a non-significant difference (Mann-Whitney *U* Test, $Z = 0.6267$, $p > 0.2$). On the second day the average distance covered from the point of release increased to 52.6 m for males and 90.6 m for females on average, that is 71.6 m with sexes combined, to a maximum of 178 m for a female.

The height distribution of all perch sites located is given in Figure 3. Average height of located perches for males and females was 10.6 m and 11.7 m respectively, a non-significant difference (Mann-Whitney *U* Test, $Z = 0.075$; $p > 0.4$). The range of located perch heights was 2.2 - 25.4 m for males and 1.2 - 31.4 m for females.

Of the 107 located perch sites, 103 were on trees or shrubs. Two were on a building and two were on sedges on a river bank under dense forest cover. Open meadows or open river bank vegetation, which were present close to the release site, were never used as perches and only rarely crossed during flight. One individual of *L. fulva* flew from the release site in the direction of the meadows, but after only a few metres made a turn and headed for the forest.

The two individuals which were followed for four and five days, respectively, did occupy small areas for a number of consecutive days (see Fig. 4). A female of *L. fulva* utilized an area of only 24 m x 20 m for three consecutive days with registered perch heights ranging from 1.2 to 31.4 m. A male stayed in an area of 96 m x 26 m for four consecutive days with registered perch heights ranging from 2.2 m to 25.4 m. This male remained on the same tree for ca 47 h where it was observed while hunting. In both cases the areas utilized coincided with visually clearly identifiable landscape structures: in the first case a stretch of the stream Rio Begotta and in the second case a park road with trees on either side.

During the intensive monitoring of the tagged individuals some behavioural observations were made:

— On 17 May 2006 from 10:44 to 11:44 h, a male on its second day as adult, while perched on a twig at a height of ca 8 m was observed repeatedly to make short flights, duration ca 2-4 s, and subsequently returned to the same twig.

A total of 24 such flights were recorded during the observation period.
— On 23 May 2006 a female which had been released at 14:24 h was perched at 18:04 h on a shrub at a height of 2.2 m when heavy rain set in. The individual was found in the same position but hiding under a leaf at 19:06 h. It stayed in this position until 09:14 h the next morning. At 09:44 h the female had climbed on to the leaf where it stayed at least until 10:14 h before flying away.
— Another female was observed during its second day on 24 May 2006 when at 15:44 h a thunderstorm arrived. The female had previously been seen perched at a height of 4.5 m under dense forest cover while repositioning itself, climbing on a twig. After the rain had stopped, the individual was found on the same twig but in a 'rain position', hanging down backwards with its wings drooping. Shortly afterwards the wings were reopened and held in the usual fashion. The individual remained in the same hanging position until the next morning at 09:09 h when it slowly started to climb higher. The animal remained on the same plant, now and then climbing a little higher for 4 h before flying away at 13:14 h.
— The same female was observed on its third day on 25 May 2006, perching at 1.5 m on *Phalaris arundinacea* on the banks of the Rio Begotta under dense forest cover from where it flew down and touched the water surface, obviously drinking. While flying away from the water a territorial male attempted to grasp the female, unsuccessfully.

Aeshna mixta

Five tracked individuals of *A. mixta*, one female and four males, showed a very different behaviour from *L. fulva*. Already in the first hours after release all flew distances of more than 200 m and subsequently were lost. Three individuals were lost within 1 min after taking off. The first flight of two *A. mixta*, one female and one male, covered ca 15-20 m, after which they perched on a tree at a height of 6 m and 15 m respectively. The male took off after only 1 min and was subsequently lost. The female, on the other hand, stayed in the same position for 1 h before flying to another tree ca 10 m away. Here she stayed for ca 45 min before the signal was lost.

Discussion

The results of the present pilot study with tagged individuals of *Libellula fulva* showed that telemetry by harmonic radar with the technology presently available proved a successful method for tracking freshly emerged anisopterans. Both the method and the first results will be discussed and critically evaluated hereunder.

Method

An average maximum detection distance of 84 m for the tags is greater than that reported for similar designs without the additional "stub tuner" (e.g. Lövei et al. 1997; O'Neal et al. 2004; Williams et al. 2004). The application of the "stub tuner" increased the maximum detection rate, an important factor in the present study, as 80% of the individuals were not tracked further because the signal was lost. A telemetry system with a greater detection range would clearly have allowed me to collect more data. The disadvantage of having the "stub tuner" is an increase in weight of the tags and an increase in the risk of entanglement.

The fact that the maximum detection range of the compact tags was much more variable can be explained by the observation that normally complex antenna designs tend to have an extreme variability of parameters, i.e. impedance at working frequency, caused by slight differences of the geometry due to the hand-made construction. A simple design like a dipole (Fig. 1) is not critical and its impedance remains stable even when slightly changing the geometry of the wires. Therefore, the reflecting characteristics and thus the detection range of the tags of the compact design can easily be influenced by the anisopteran touching obstacles and by doing so slightly deforming the wires.

The 'compact' tags were suitable to be attached to freshly emerged Anisoptera and allowed to follow freshly emerged individuals of *L. fulva* for a number of consecutive days. The technique used for the application and the release resulted in 62.5% of *L. fulva* being successfully monitored for some time. This value is lower than that reported by Wikelski et al. (2006) for the radio telemetry of *Anax junius*. However, during the present study it was attempted to apply the tags to freshly emerged individuals, ca 1-2 h after they had completed emergence, with the exoskeleton of the insects still soft and delicate. In contrast, most of the aeshnids used by Wikelski et al. (2006) appeared sexually mature and were therefore much more robust.

When tagged individuals were perched on forest margins the maximum detection range was comparable to the data reported above, i.e. ca 85 m. In the closed forest the maximum detection distance decreased considerably, presumably due to the presence of trunks, branches and leaves. The maximum distance from where an odonate was located in the forest was 45 m, measured with Vertex III® with a Transponder T3 (see Methods). When tagged adults were perched on the highest trees ca 30 m up in the forest it was very difficult to locate them. It is assumed that most of the individuals lost had flown into the canopy of the closed forest where they were very hard to find with the telemetry system used.

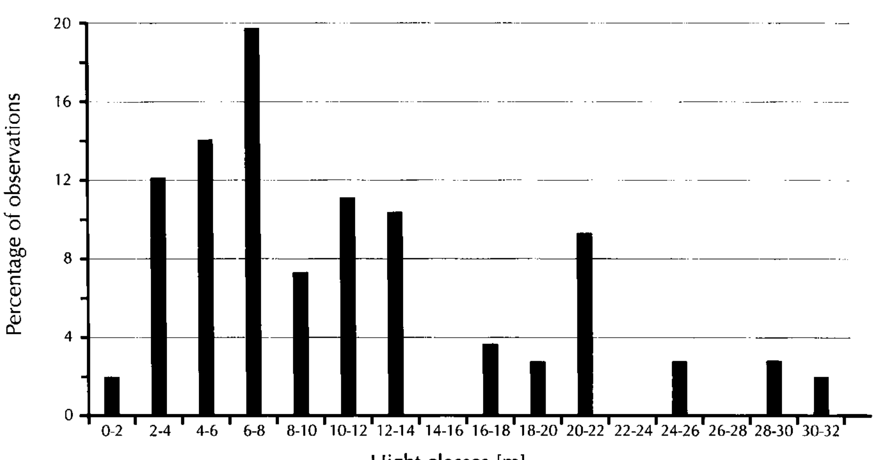
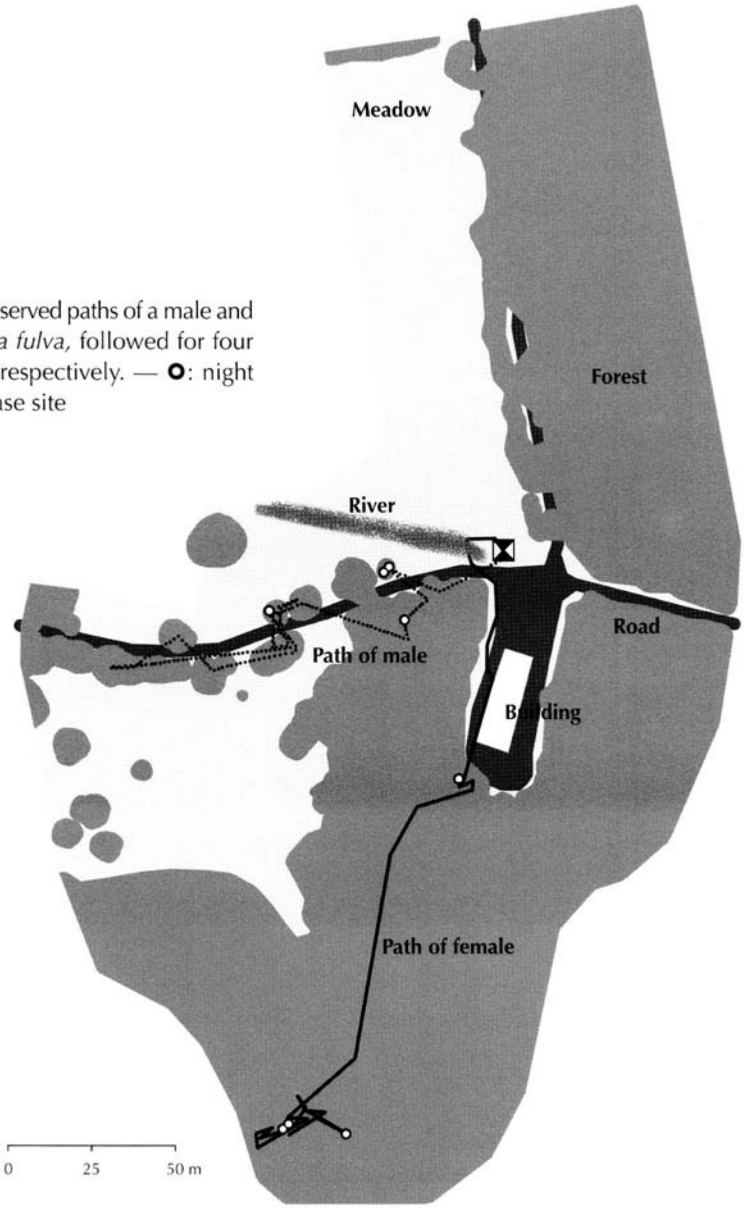


Figure 3: The height distribution of all located perch sites of tagged individuals of *Libellula fulva*. Heights are corrected estimates.

The fact that the tags did not allow differentiation between different antennae was of minor importance in the present study as most tracked individuals of *L. fulva* remained localized. It was therefore possible to follow the movements of each insect separately with a high level of probability, due to the fact that neighbouring individuals were commonly far apart.

Figure 4: The observed paths of a male and female *Libellula fulva,* followed for four and five days, respectively. — **O**: night perch; **⧗**: release site



Results

Tenerals of *L. fulva* moved on average 71.6 m in the first two days with a maximum of 178 m. This seems to be a small distance considering that individuals were observed to cover more than 100 m in a short space of time (see further below). However, Macagno (2005) reports for the Parco Fluviale del Po in northern Italy that marked males and females of *L. fulva* moved on average ca 160 m and 110 m in two days, respectively, with maximum distances of 400 m. It is thus evident that most tenerals, as well as adults, of *L. fulva* generally remain localized and do not wander far, an observation supported by the high level of resightings (67%) during a mark-recapture study by Szállassy et al. (2003) in Hungary.

The maximum time an individual of *L. fulva* could be followed was five days. Considering that the maturation time in northern Italy is estimated to last 10-16 days (Hardersen 2004; Macagno 2005), between 50% and 31% of the maturation period was covered during the present study and the data should reflect the general behaviour of *L. fulva* during the prereproductive period.

Trees and forests seem to be a highly important requisite during the maturation period of *L. fulva*, as the followed individuals almost exclusively used trees and shrubs as perches. This close relation might explain why Höppner (1994) found that at least 10% of the habitat surrounding the breeding water had trees and for large populations 20% - 55% of the banks were shaded by trees in southern Germany. Similarly, the analysis of habitat requirements carried out by Riservato (2006) showed that the absence of forests explained 94.6% of the absence of *L. fulva* from habitats in the Ticino Valley Park in northern Italy. The maps of the habitat use by adults of *L. fulva* provided by Macagno (2005) also show a clear preference for forest habitats when away from the water in northern Italy. Dolný et al. (2003) write about the habitats of *L. fulva* in the Czech Republic that "the surrounding country should be forested". Certainly, trees are important for a great number of other odonate species (e.g. Pither & Taylor 1998; Cordero 2006). In North America it has been shown that aquatic habitats surrounded by forests show greater species richness and diversity for Odonata, increasing with forest age (Rith-Najarian 1998).

The data presented show that the distances of the first flight and the distances covered in the first day are very similar for males and females of *L. fulva* and did not differ significantly. Also Ha et al. (2002) found no difference between males and females of *Cordulia aenea* (Linnaeus) in the direction of their first flight. Corbet (1999:271) states that it is usual for both sexes to behave similarly during the prereproductive period and differently afterwards (but see Jödicke 1997: 182-184).

The finding that individuals of *L. fulva* remained in a relatively narrow space of forest, visually clearly identifiable landscape structures, for many consecutive days was unexpected. However, Parr & Parr (1974) marked 82 tenerals of *Nesciothemis nigeriensis* Gambles in Nigeria and one individual was recognized in the same place for 11 consecutive days during maturation. Thereafter it was seen occupying a territorial area at the water. The fact that this specific behaviour, observed in the present study in tagged teneral individuals, had already been observed in another libellulid, suggests that it is not an artefact induced by the tags. The work by Wikelski et al. (2006) suggests that even a transmitter load higher than in the present study does not restrict the flight ability of Odonata, as they could not detect flight differences between tagged and untagged individuals in *A. junius*. A number of observations of the tagged *L. fulva* also suggest that the restriction to a small area by the teneral was not caused by their inability to fly well:

- The female that stayed in an area of only 24 m x 20 m for three consecutive days flew to this place covering ca 115 m in 2½ h with three registered perch sites on the way.
- The female changed perches from 3.8 m to 25.4 m in less than 30 min, using at least three intermediate perches.
- On 17 May 2006 a male was observed while perched on a twig ca 8 m above ground from where it made 24 short hunting flights in 1 h (see results, observation no. 1).
- A female was observed crossing 104 m of open meadows in a few minutes with one intermediate perch.

Considering that a human observer can reasonably detect adult anisopterans up to a height of ca 3 m, 92.5% of all registered perch sites were "out of reach". However, this value is clearly a conservative estimate as the data on height distribution of all perch sites located as given in Figure 3 are likely to underrepresent the higher perch sites, as it was difficult to locate tagged individuals perched high up. The behavioural observations reported above were only possible because these individuals were perched relatively low or in particularly open environments. The telemetry system allowed me, for example, to verify that anisopterans did not change tree between 19:44 and 08:44 h. However, often when a *L. fulva* remained on the same tree for many hours during the day and was not visible, it was obvious from fluctuations in the signal strength that the animal was moving.

The tagged individuals of *Aeshna mixta* were lost already in the first hours after release, because all flew more than 200 m. Therefore, the harmonic radar telemetry system proved unsuitable for this species, which is known to fly for long distances (Corbet 1999:392-393, 423).

Conclusions

The technology offered by the RECCO® Transmitter/Receiver permits investigation of parts of the life cycle of certain Anisoptera which would be impossible to observe without this aid. However, the system also poses severe limitations:

— The weight of the tags is 25 mg and thus the system is not suitable for small species as e.g. *Sympetrum* spp.

— Maximum detection range is ca 85 m and is thus suitable only for species, which do not migrate/wander after emergence.

— The tags can get entangled.

— The technology does not allow to differentiate among tagged individuals.

— Forest cover limits the detection range of the system.

In order to facilitate further investigations of the habitat use of Anisoptera with the RECCO® Transmitter/Receiver, I recommend choosing landscapes with open spaces and small woods and/or hedges in order to make it easier to detect the tagged individuals.

The technology offered by the A RECCO® Transmitter/Receiver could also be useful in following mature adults between sites of reproduction, feeding areas and roosting locations. It might, e.g., permit studies of time partitioning among reproductive activity, feeding, and resting.

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