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Reference to use in further citations:

LAMBRET P., 2010. Dynamique d'une population d'adultes de *Lestes macrostigma* (Eversmann, 1836) et implications pour son suivi : l'exemple de la Camargue (Odonata, Zygoptera : Lestidae). *Martinia* 26 (1-2): 19-28.

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Translation: P. Lambret.

Final translation realised on 23 April 2010.

Dynamics of an adult population of *Lestes macrostigma* (Eversmann, 1836) (Odonata: Lestidae) and implications to its monitoring: the example of Camargue (France)

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Keywords: *Lestes macrostigma*, dynamics, survey, monitoring, Camargue.

Summary: The emergence curve, the flight period (phenology) and the number of adults which are detected along the day have been studied in *Lestes macrostigma* (Eversmann, 1836) by the visual transect count method in a temporary pool of Camargue. Results are discussed in the light of other findings across the range of this threatened species. The consequences in term of survey and monitoring are highlighted.

Lestes macrostigma (Eversmann, 1836) is a stenoecic species its larvae mainly develop in stagnant brackish water (e.g. NIELSEN, 1954; ROBERT, 1958; PLATTNER, 1967, AGUESSE, 1968). Its populations are confined to very few sites not only in France but also in the western and the central parts of its distribution area at least (e.g. CHOPARD, 1948; JÖDICKE, 1997; DIJKSTRA, 2007; BOUDOT et al. 2009). *L. macrostigma* is therefore threatened and has a strong conservation status from regional to European scales (see LAMBRET et al., 2009) and is, according to the recent IUCN evaluation, Vulnerable in Europe and even Endangered within the EU27 (J.-P. Boudot, pers. com.). According to the French action plan for priority species of Odonata (DUPONT, 2009), a survey is required to assess whether known populations are

rather declining or stable or increasing. Monitoring is one of the basic recommendations for priority conservation measures (RISERVATO et al., 2009). For species that are under threat across their whole range, long-term coordinated actions are required at regional, national and international level (RISERVATO et al., 2009). Monitoring *L. macrostigma* would also be a tool to assess the conservation status of protected areas in which the species is or has already been present (FERRERAS-ROMERO, 2005). Further on, a survey is important to precise reproduction status for each population and a monitoring can improve the knowledge of its biology and ecological requirements, by increasing both quantity and quality of available information (LAMBRET et al., 2009; RISERVATO et al., 2009).

Within entomological survey and monitoring (here after called SM), it is usually required to collect data within the peaks of activity of the considered taxon. For multi-spp SM, data should be collected during several months and the daily time span should be long, spreading at least from five to eight hours (e.g. Odonata: KETELAAR & PLATE, 2001; SMALLSHIRE & BEYNON, 2009; Rhopalocera: ANONYMOUS, 2009; MANIL & HENRY, 2007), a shorter time span being less common (BROOKS, 1993). But when only one species is concerned, SM frequency and timing are restricted by specific phenology and activity pattern (THOMPSON et al., 2003; DOLNÝ, 2005). It is well known that *L. macrostigma* abundance can greatly vary from one year to another and one can easily miss the species some years when abundance is low (AGUESSE, 1960; PLATTNER, 1967; FERRERAS-ROMERO, 2005; GRAND & BOUDOT, 2006; LAMBRET et al. 2009). To increase the chance to detect its presence during such years, it becomes essential to assess when abundance is the highest during the year (i.e. when the population is the biggest) and when during the day adults are the most likely to be detected (i.e. highest activity). The seasonal pattern of emergence is also required to increase the chance to state whether a population is breeding or not.

The aim of this study was therefore to assess (1) *L. macrostigma* phenology and further on highest abundance of, first, emerging adults and, second, mature adults during flight season and (2) the occurrence of the peak of likelihood to be detected during the day, (1) and (2) allowing the definition for the Camargue of the most favorable period within the day and the year for a long term SM which would be based on the transect method (e.g. POLLARD & YATES, 1993) or the occupancy method (MCKENZIE et al., 2002).

METHODS

The study took place from May, 7th to July, 14th 2009 in Marais du Vigueirat protected area (Camargue, France). One of us (four rangers) at least is always present, insuring a year round ability of detection of the species. The Marais du Vigueirat belongs to the Conservatoire du littoral (French coast conservatory). The coordinates of the centre of the area are 43°32’10’’N / 04°45’15’’E and the area covers 1050 ha which are mainly composed by different marshes. One of these, Baisse des Marcels (BdM), is a temporary brackish pool where dozens of *Lestes macrostigma* have been seen every year since 2005. The vegetation of this pool consists e.g. by *Bolboschoenus maritimus*, *Juncus maritimus* and *J. subulatus*, but also by *Schoenoplectus lacustris* and *Phragmites australis*; borders are colonised by *Tamaris anglica*, *J. acutus* and *Arthrocnemum* spp.

The data were collected along a transect in BdM within the vegetation where most of adults usually stand. This transect was ca 290 m long and five meters wide (2.50m on the left hand side and so on the right) and was walked within 15-20min, at least once a week. As *L. sponsa* was also flying at the same time, I used binoculars to identify some individuals which perched after I spotted them while flying or which were too far for bear eye. Emergence curves (*sensu* CORBET, 2004: 244) were assessed by counting tenerals *sensu lato* (which are

recognizable in *L. macrostigma* by their unhardened cuticule, their dark pattern and bright wings; see CORBET, 2004: 257) – at 12:30 ± 30min (summer time). During the flight season, adults were counted, regardless to their age, between 12:30 and 13:30. To assess the likelihood of one population to be detected during the day, I walked along the transect from 6:30 to 20:30 every two hours (to reduce the bias regarding the disturbance I induced) on June, 9th. I did so on June, 10th but I started one hour latter; this day I also counted ♂♂ and ♀♀ separately. Windy (over 4 Beaufort) and rainy days where avoided.

RESULTS

Very first tenerals were seen on May, 13th. Emergences were synchronized (Fig. 1a): EM_{50} (see CORBET, 2004 : 245) was reached on day four or five, which represents roughly the third of total emergence duration. Only one generation was observed. First tandems were seen on May, 28th, suggesting that maturation period lasts 15 days at least (see CORBET, 2004: 258).

Considering the flight period (Fig. 1b), the population size increased during the first two weeks and reached a peak of abundance between May, 31st and June, 9th, which is 18 to 27 days after the first individuals emerging. Population started then to decrease according to a softer slop than during the increasing phase until July, 12th after which no more individual was seen.

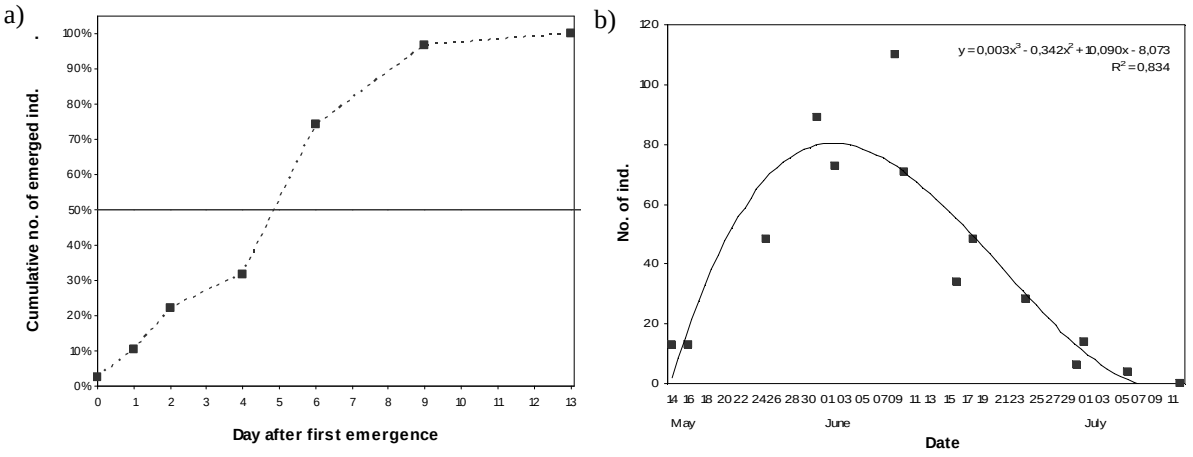

Fig. 1. a) Emergence curves (a) and flight period (b) of *Lestes macrostigma* in BdM pool (Marais du Vigueirat, Camargue, France).

During the breeding period, the no. of adults greatly varied within a day (Fig. 2): max. no. were 2.34 times and 2.07 times the min. no on June, 9th and 10th respectively. Highest no. were counted early in the morning, around noon and in late evening. To the opposite, there was no significant variation of sex-ratio during the day ($p>0.05$, $\chi^2=1.30$, df=7): ♂♂ were on a mean 1.75 times more numerous than ♀♀ (min=1.46, max=2.00, 42<n<88).

DISCUSSION

In accordance with the characteristics of Lestidae (see CORBET et al., 2006), monovoltism in *Lestes macrostigma* is described implicitly (e.g. NIELSEN, 1954; PICARD & MEURGEY, 2005) and synchronised emergences has already been reported (NIELSEN, 1954) as massive

emergences (DIJKSTRA & KALKMAN, 2001). This is related to the usual biology of the species, as the eggs of the European Lestidae are assumed to routinely undergo a long diapause and to hatch after the winter (see CORBET, 2004: 56). MONTES et al. (1982) reported that last instar larvae and adults were most abundant in March and April but the last could be observed from late February onwards. Then, without more accurate data about eggs hatching time, a bivoltine cycle cannot be excluded in southern Spain (R. Jödicke, pers. com.). A bivoltine cycle implies a more or less permanently flooded environment which is not relevant for a temporary pool system in Southern Spain (J.-P. Boudot, pers. com.). Most probably, MONTES et al. (1982) findings are due to a longer emergence phase in this hotter region than Camargue. Indeed, AGUESSE (1961) reported that the *L. macrostigma* eggs exposure duration to low temperature had an impact on emergence synchronism, a hard winter being source of high synchronism. One could thereby expect that a South Spanish winter would induce a longer emerging phase. Thus, after a particularly cold winter with a further high synchronism in emergences, the latter may be easily be missed if the species is not searched for 2 or 3 times a week. In other words, to state if one population in a given pool is breeding or not, one has to visit this pool every three days from the end of the first decade to the beginning of the last decade of May, at least in Camargue. This makes the number of pools to be monitored directly dependent on the distance between them and on the number of investigators. Obviously one can find exuviae after emergence but these are very light and are likely to be removed rapidly by the wind, which is strong in Camargue (PICON, 1980). In addition, if one wishes to assess the number of emergences and the emergence rate, and to perform comparison, daily visits are absolutely necessary, otherwise the emergence peak (EP) could be missed or overlooked: comparing the no. of emergences on day $D_{(EP)}$ for year Y to that on day $D_{(EP-1)}$ for year Y+1 would most probably bear a strong bias and is not reliable. This makes quantitative SM of emergence very time consuming.

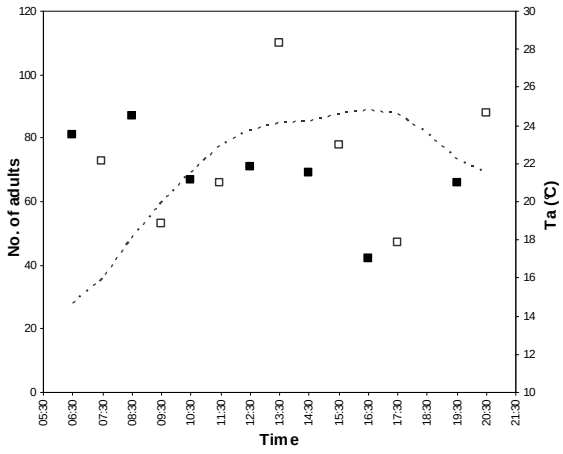

Fig. 2. Variation of ambient temperature Ta (doted line; © Météo France) and of no. of counted adults on June, 9th (□) and 10th (■).

The shape of the flight curve, a Gaussian distribution skewed to the right, is in accordance with previous findings (JOURDE, 2003; MARINOV, 2005; PRECIGOUT et al., 2009). The abundance of adults increased all along the emergence phase (two weeks) and reached a maximum that lasts about ten days. The occurrence of highest abundance two weeks after the first observation of adults is in accordance with the findings of CANO-VILLEGAS & CONESA-GARCÍA (2009). This progressive increase of abundance may indicate an emerging rate higher than mortality and dispersion, resulting in a constant income of new adults. The length of highest abundance could be due to an income of mature adults on reproductive site after their maturation. Then mortality (and/or dispersion) would be higher than those two incoming

rates. One or two visit(s) (depending on available time) during the third week after first emergence should be sufficient to monitor an adult population in Camargue. But Lestids maturation period duration can vary according to latitude, years and also populations within the same year (UTZERI et al., 1988); it is therefore required to assess how consistent is the present maturation period length and its impact on the entire phenology.

The higher the latitude the latter the flight season of *L. macrostigma*, as it has been described for *L. barbarus* (UTZERI et al., 1988). Indeed, when Camargue flight season corresponds to Ukraine's (MARTYNOV & MARTYNOV, 2008), Bulgaria's (MARINOV, 2005) and Italy's (NIELSEN, 1954), flight period starts earlier in the southern part of its distribution area and finishes later in the northern part: respectively, from [February]-March in Turkey, Greece, Spain... to August in Romania, Austria, French Atlantic coast... (PLATTNER, 1967; MONTES et al., 1982; GONZALES DEL ROSARIO, 1994; KALKMAN & VAN PELT, 2006; CANO-VILLEGAS & CONESA-GARCÍA, 2009; PRECIGOUT et al., 2009; T. Benken, pers. com.; W. Lopau pers. com. to J.-P. Boudot; J.-G. Robin, pers. com.). But beside the influence of latitude could be the influence of temperature and rainfalls (i.e. water regime). The temperature has an impact on emergence (see above). Water is obviously required for larval development but can also activate post-diapause egg development (SAWCHYN & GILLOT, 1974) and hatching in Lestids even in sp which oviposit well above water surface such as *Chalocolestes viridis* (PIERRE, 1904; GAMBLES, 1960; F.-S. Schiel, pers. com.) although this stimulus is not required in some spp of the family (BICK & BICK, 1970); one may therefore expect that water activate hatching in *L. macrostigma*, a typical sp. of temporary pools. Flight period can start earlier or latter within a same latitude or even a same region from year to year: J.-P. Boudot (pers. com) found emergences of *L. macrostigma* in Sardinia, at Isola de Asinara, on July 29th of 2008 and adults have already been recorded in Camargue in September (AGUESSE, 1968, pers. com.) (see also CANO-VILLEGAS & CONESA-GARCÍA, 2009). Thus, the flying period would be flexible according the temperatures and the water regime of a particular year. Once again, only a monitoring will allow us to assess the variability of flying period regarding those factors.

The fact that during the breeding period, the total no. of adults varied greatly during the day (Fig. 2) should be related to the reproductive behaviour, as it is well known that the ♂♂ are more present at the rendezvous than the ♀♀ (CORBET, 2004: 538). This is supposed by UTZERI et al. (1988) to explain why the sex ratio was ♂ biased after maturation although it was roughly 1:1 at emergence. But the consistency of the sex ratio along the day in the present study suggests that ♀♀ were always present at the reproductive site and did not move, at the macro-habitat scale at least. Variations in counted no. of adults could rather be related to variations in activity. It is well known that Odonata activity depends on ambient temperature (T_a) and ability to regulate their body temperature (T_b) (e.g. MAY, 1980; HILFERT-RÜPPEL, 1998; DE MARCO & RESENDE, 2002; SFORMO & DOAK, 2006; MCKAY & HERMAN, 2008). According to the flyer/percher classification of Odonata (CORBET, 1962; CORBET & MAY, 2008), Lestids are perchers that regulate T_b by behavioural and postural adaptations (ROBERT, 1958; MCKAY & HERMAN, 2008). Activity includes different behaviours as reproduction, foraging and dispersal at least. CORBET & MAY (2008) emphasized that the likelihood to fly at a time rather define whether an individual is ‘active’ or ‘inactive’. Thus, the variation of the no. of adults that I counted could reflect different phases in the day with the highest number of counted adults corresponding to the maximum of their daily activity period. This could be, from the morning to the evening: (1) searching for a partner and setting of tandem [flight phase fp], (2) heating [perching phase pp], (3) mating and ovipositing [fp], (4) avoiding hottest part of the day [pp] and (5) feeding [fp]. Although it is recommended to avoid counting when the temperature is more than 30°C (PONT et al., 1999; KETELAAR & PLATE, 2001), this could be difficult in some countries of the

Mediterranean as this occurs often only in the morning or in late evening during part of spring and summer. The amplitude of these variations makes present data insufficient to state about the occurrence of the peak of likelihood to be detected during the day and further research is required to confirm or infirm the present activity hypothesis and thereby determine the time of the day that is the most suitable for SM.

EPILOGUE

During the symposium 'Monitoring Dragonflies in Europe' (June, 13th & 14th, 2008, Wageningen, the Netherlands), V. Kalkman emphasized the interest of a European coordination between odonatologists, especially regarding monitoring dragonflies. Some biology traits, such as permanence of water where *Lestes macrostigma* breeds or salinity, seem to differ across its distribution range, so that a SM leaded to a European scale would certainly allow a better understanding of the ecological requirements of this species (see LAMBRET et al., 2009). In France, a highly standardised SM should be set and tested during 2010 in several sites of the Mediterranean and Atlantic coasts. Further steps are needed to develop this first network at the European scale, and this should be done during the first European congress on odonatology in Porto, July 2010.

ACKNOWLEDGEMENTS

I am grateful to N. Sadoul for his valuable comments during the study and the analysis of data. I warmly thank not only P. Aguesse, T. Benken, F.J. Cano Villegas, M. De Block, K.-D.B. Dijkstra, R. Jödicke, V.J. Kalkman and J.-G. Robin for fruitful discussions about present topic, but also J.-P. Boudot and J. Ott for reviewing the manuscript.

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