REVUE D'ÉCOLOGIE

LA TERRE ET LA VIE

VOLUME 68 ANNÉE 2013

Edité par la
SOCIÉTÉ NATIONALE DE PROTECTION DE LA NATURE
ET D'ACCLIMATATION DE FRANCE
9, rue Cels - 75014 PARIS

FLIGHT PERIOD, APPARENT SEX RATIO AND HABITAT PREFERENCES OF THE MAGHRIBIAN ENDEMIC *CALOPTERYX EXUL* SELYS, 1853 (ODONATA: ZYGOPTERA)

Rassim KHELIFA[1]

RÉSUMÉ.— *Période de vol, sex-ratio apparent et préférences d'habitat de* Calopteryx exul *Selys, 1853* (Odonata: Zygoptera) *endémique maghrébin.— Calopteryx exul* Selys, 1853 est un Odonate endémique du Maghreb qui se trouve être menacé d'extinction du fait de la dégradation et de la disparition de ses habitats. Son statut de conservation est l'objet de préoccupations croissantes. Une étude concernant sa période de vol, le sex-ratio apparent au niveau de ses populations adultes présentes sur site et les préférences écologiques de l'espèce a été réalisée pendant 2 ans dans le bassin de la Seybouse au nord-est de l'Algérie. La période de vol débute début mai et se termine fin juillet, avec un pic de présence de l'espèce se situant fin mai / début juin. La présence d'un faible nombre d'individus fraîchement émergés ou immatures début septembre doit être reliée soit à l'existence d'un faible bivoltinisme de l'espèce, soit à la survenue d'émergences différées. Une étude approfondie portant sur les générations larvaires sera nécessaire pour répondre à cette question. La période de maturation a été estimée à 11 ou 12 jours. Le sex-ratio quotidien noté au niveau des adultes présents sur site est très généralement biaisé avec 65 à 67 % de femelles. Une étude portant sur le sex-ratio à l'émergence devra être effectuée afin de savoir si ce déséquilibre apparaît dans les populations adultes ou s'il préexiste lors de l'émergence. L'analyse multivariée montre que les adultes préfèrent des eaux peu profondes à écoulement relativement rapide par comparaison à *C. haemorrhoidalis* (Vander Linden, 1825) qui fréquente principalement des eaux plus lentes et plus profondes, très ombragées et portant une végétation riveraine très dense. La population étudiée de *C. exul* est actuellement la plus importante de toutes celles qui ont été signalées au Maghreb du point de vue de ses effectifs. Les données acquises sur la phénologie et les préférences écologiques des adultes seront mises à profit lors de futures études visant à mettre à jour la distribution de l'espèce en Algérie et plus généralement dans l'ensemble du Maghreb.

SUMMARY.— *Calopteryx exul* Selys, 1853 is an endangered endemic Odonata species restricted to the Maghreb that shows an increasing concern about its conservation status, due to substantial habitat loss. A study dealing with its flight period, the apparent sex-ratio of imagoes and adult habitat preferences was carried out in the Seybouse basin, northeastern Algeria, during two years. The flight period of the species begun on early May and ended on late July, showing a peak around late May / early June. Either a small second generation or delayed emergences was responsible of the record of scarce tenerals and immatures in early September. Additional larval investigations are needed to elucidate the origin of such late emergences. The maturation period was estimated to extend over 11-12 days. The apparent daily sex-ratio in the adult population present on site was mostly biased with 65 to 67% of females. Additional work addressing sex-ratio at emergence is needed to understand this disequilibrium. Multivariate analysis showed that adults of *C. exul* prefer relatively fast flowing shallow water when compared to its congeneric *C. haemorrhoidalis* (Vander Linden, 1825), which was mainly observed at deeper, slower and very shaded running waters with dense banks vegetation. The population of *C. exul* dealt with in this study is currently the largest one reported so far in the Maghreb. Data on adult phenology and habitat preferences will allow future investigations about the present distribution of the species in Algeria and the whole Maghreb.

[1] Département d'écologie et du génie de l'environnement, Faculté des Sciences de la Nature et de la Vie et des Sciences de la Terre et de l'Univers, Université 08 Mai 1945, Guelma 24000, Algérie. Tel.: +213 06 69583888; Fax: +213 037 203499; E-mail: rassimkhelifa@gmail.com

Rev. Écol. (Terre Vie), vol. 67, 2012.

The Mediterranean basin is well known to be a hotspot for biodiversity (Blondel & Aronson, 1999; Myers *et al*., 2000). On its African side, Algeria is the most diversified area in terms of dragonfly richness with 63 species recorded including seven Mediterranean and five North African endemics (Riservato et al., 2009). The biology and ecology of many Mediterranean species remain unknown and *Calopteryx exul* Selys, 1853 is one of them. Together with *C. haemorrhoidalis* (Vander Linden, 1825), a well-known common damselfly showing a large distribution in the West Mediterranean, it represents the second member of the Calopterygid family present in Northeastern Algeria, and the third in the whole Maghreb (Samraoui & Corbet, 2000; Dijkstra & Lewington, 2007; Boudot *et al.*, 2009; Khelifa *et al.*, 2011). *Calopteryx exul* is confined to the Maghreb (Morocco, Algeria, and Tunisia). This endemic is currently listed as "Endangered" in the IUCN global red list (Boudot, 2010), as it suffered from a large degradation of its habitats throughout its range (Riservato *et al.*, 2009; Samraoui *et al.*, 2010). This species has never been studied but only recorded on a few occasions in northern and central Morocco (Dumont, 1973; Lieftinck, 1966; Jacquemin & Boudot, 1999; Boudot, 2008; El Haissoufi *et al.*, 2008), the north of Algeria (Martin, 1910; Khelifa *et al.*, 2011) and northern Tunisia (Dumont, 1977; Jödicke *et al.*, 2000). In Algeria, this species remained unrecorded during nearly a century but was recently rediscovered in June 2007 in the Seybouse basin (North-east Algeria). Six sites were localized (Khelifa *et al.*, 2011). As this population is currently the single one known in Algeria, its monitoring became a priority to increase the knowledge of the species and to establish an effective conservation plan.

In this study, I tried to determine the ecological preferences of *C. exul* and the preferred habitats of the adults compared to those of *C. haemorrhoidalis*, basing on multivariate analysis of some physical parameters collected during two years in the Seybouse basin, one of the largest watershed in Algeria.

SITE, MATERIAL AND METHODS

Study area

The Seybouse watershed is the third largest one in Algeria with an area of 6570 km^2. It is situated in the heart of Numidia (north-eastern Algeria). The Seybouse river results from the confluence of the Cherf and Bouhamdane wadis, which meet at Medjez Amar, west of Guelma (36°26'35" N, 7°18'39" E). It flows into the Mediterranean Sea at Sidi Salem (36°52'3" N, 7°46'25" E) near Annaba. The hydroperiod is similar to that of Numidia (Samraoui & Corbet, 2000), with a wet season extending from October to May and a dry season spanning from June to September. The mean annual rainfall varies from 350 mm upstream to 608 mm downstream (ABHCSM, 2009). The river edges are usually covered by *Typha angustifolia*. *Tamarix gallica*, *Nerium oleander* and *Rubus ulmifolius*. *Calopteryx exul* usually coexisted with *C. haemorrhoidalis*, *Erythromma lindenii* and *Gomphus lucasii*.

Adult and abiotic variables sampling

In a previous study, *C. exul* was recorded at only six sites in the Seybouse watershed (Khelifa *et al.* 2011). Further investigations were undertaken to understand the whole species distribution in the area. I surveyed 17 sites monthly, from April to August, in the Seybouse watershed along an altitudinal gradient (Fig. 1). Geographic coordinates, code, altitude and watercourse type of each site are given in table I. In each site, a stretch of 100 m was sampled in which the number of adults was recorded and some habitat parameters measured (turbidity, water width, water velocity, mean water depth, height and density of bank vegetation, percent of shading). Turbidity was measured by a nephelometric turbidimeter. Water width was measured by a 50 m decameter. Water depth was measured by a graduated stick at 5 random points on the watercourse bed, and all measures were pooled. Current velocity was estimated by timing a floating object over a 10 m stretch of the watercourse with a chronometer. The height of the banks vegetation was measured using a 5 m decameter at 10 different points randomly taken, and its density was estimated by randomly taking 10 quadrats (1 x 1 m) along the watercourse. Since the sample sites were usually crossed by a bridge, the percent of shading area was deduced from pictures taken from the bridge above the watercourse in the morning (11-12 h).

Flight period survey

Daily survey of the flight period of *C. exul* in El Fedjoudj 2 (site 11), a new site recorded for the species, was conducted in the morning (10 h) during two years from early April to early August. I started my daily visits earlier (early April) to record the exact onset of the flight period and stopped them later, when no individual had been observed after seven days of visits. I recorded the number of males and females along a stretch of 100 m. I determined the onset of the

reproductive season when reproductive activities (copulation or oviposition) were observed. The maturation period was considered to be the period between the first adult observed (onset of the flight period) and the first reproductive activity.

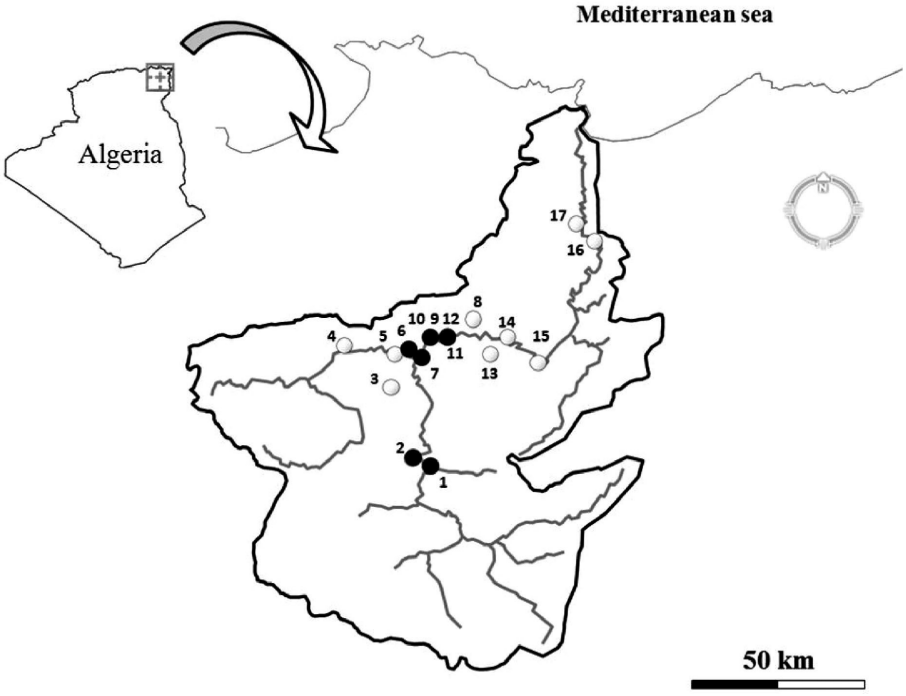

Figure 1.— Sample sites within the Seybouse watershed. Black dots are sites where *C. exul* was observed.

TABLE I

Table of site names, code, geographic coordinates, altitude, and watercourse type. Sites where C. exul *is present are in bold*

Site	Code	Geographic coordinates	Altitude	Watercourse type
Cheniour	S1	36°13’33.44”N 7°19’10.90”E	662	Stream
Ain Makhlouf	S2	36°14’27.71”N 7°18’36.01”E	646	River
Sellaoua	S3	36°23’32.24’’N 7°14’40.07’’E	612	Streamlet
Bouhamdane	S4	36°28’13.67’’N 7°08’36.50’’E	406	River
Hammame Debagh	S5	36°28’01.07”N 7°15’32.56”E	301	River
M. A. Cherf	S6	36°26’33.96”N 7°18’39.20”E	287	River
M. A. Bouhamdane	S7	36°26’30.84”N 7°18’30.91”E	287	River
Bradaa	S8	36°30’48.21”N 7°27’02.16”E	259	Stream
Old Bridge	S9	36°28’16.38”N 7°22’48.57”E	222	Artificial canal
El Fedjoudj	S10	36°28’29.21”N 7°22’26.55”E	221	River
El Fedjoudj 2	S11	36°28’21.43”N 7°22’41.12”E	221	Channel
Salah Salah	S12	36°27’41.00”N 7°20’22.75”E	219	River
Zimba	S13	36°27’48.89”N 7°29’15.10”E	205	Stream
Boumahra	S14	36°27’38.20’’N 7°30’39.42’’E	194	Stream
Halia	S15	36°24’47.65”N 7°36’40.36”E	144	River
Chihani	S16	36°39’12.59”N 7°46’56.61”E	30	River
Drean	S17	36°41’00.23”N 7°45’30.92”E	25	River

Statistical analyses

All statistical analyses were computed using the program SPSS 17.0. I used non parametric tests when data were not normally distributed. Mann-Withney test was performed to determine a potential significant difference in the daily sex-ratio between the two years of study. To determine the habitat preferences of *C. exul* in comparison to those of *C. haemorrhoidalis*, a biplot of principal component analysis (PCA) was performed based on all abiotic factors with the maximum adult numbers of both species and all sample sites. The PCA was conducted on the correlation matrix instead of the variance-covariance matrix. I used the Kaiser criterion (Eigenvalue > 1) to determine the number of components to retain (Kaiser, 1960).

RESULTS

Flight period

Figure 2 shows the daily counts of adults during the 2010 and 2011 flight periods. The total flight period lasted approximately three months in both years, beginning on early May (05.V and 01.V, respectively) and ending on late July (21.VII and 24.VII, respectively). In the first year, the population showed two peaks of presence of adults, with the first on mid-May and the second on early June (Fig. 2). The in-between depression corresponded approximately to the period of the temporary presence of a large and noisy water pump used for irrigation at the edge of the channel, and the latter was thought to be a source of disturbance promoting the dispersal of individuals out of the sampled section. In 2011 only one peak was recorded, on mid-May, and the number of adults severely decreased at the beginning of June. Heavy rains recorded at the end of May, accompanied by repetitive discharge of dam water, were thought to have induced an early collapse of the adult population. I was sure that no adult remained at the site studied or at its vicinity at the end of July 2011 (24^{th}-31^{st}) so that the observation of few tenerals and immatures never exceeding 5 individuals from 2 to 16 September 2011 was rather surprising and will be discussed below.

The reproductive season of the species started on 16.V.2010 and 12.V.2011, giving a maturation period of 11-12 days.

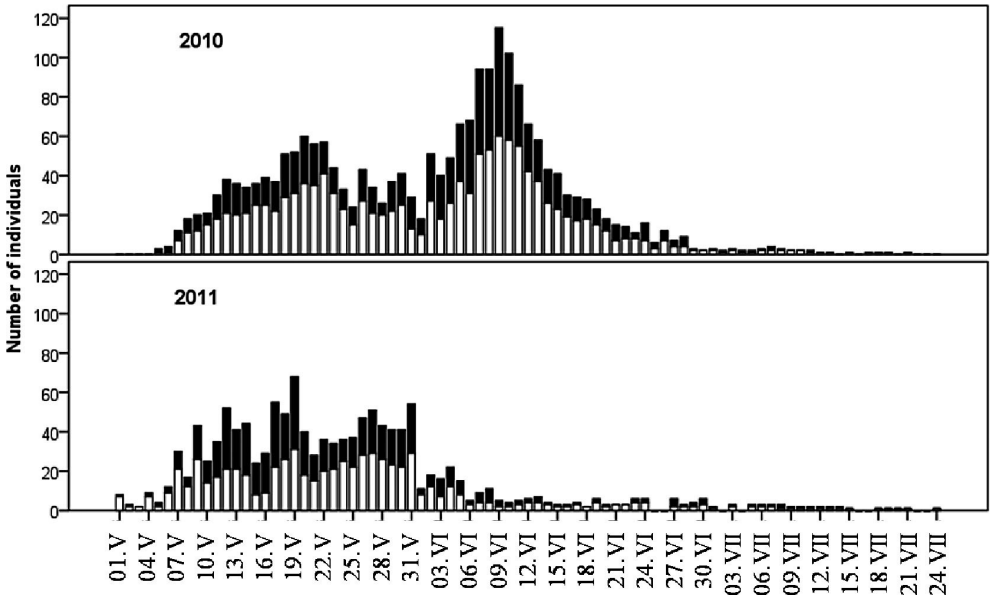

Figure 2.— Daily counts of adult individuals of *Calopteryx exul* in 2010 and 2011. Open bars = females; black bars = males.

Sex-ratio

During the two years of study, the mean daily sex ratio in the adult population was biased with 65% (0.65 ± 0.18) and 67% (0.67 ± 0.21) of females present on site in 2010 and 2011, respectively. There was no significant difference in daily sex ratio between the two years of study (U = 3240, P = 0.80).

Habitat preferences

Calopteryx exul was observed at 7 of the 17 sites (41.2%) surveyed while *C. haemorrhoidalis* was recorded at 12 sites (70.6%). According to their habitat preferences, *C. exul* was clearly isolated from *C. haemorrhoidalis* (Tab. II). When we consider only sites where the two species were abundant (> 20 adults), we found that 4 sites (S2, S10, S11 and S12, called herafter '*C. exul* sites') contained high numbers of *C. exul*, 5 sites (S3, S7, S8, S9 and S14, called hereafter '*C. haemorrhoidalis* sites') contained high numbers of *C. haemorrhoidalis*, and no site supported high densities of both species. In fact, *C. exul* was almost never observed at the *C. haemorrhoidalis* sites (only once when an individual was recorded at S7), although the opposite was not true. Some individuals of *C. haemorrhoidalis* were commonly recorded within the *C. exul* sites, occupying small vegetated parts of the watercourse. Dominant bank vegetation at *C. exul* sites was *Cyperus longus*, *Schoenoplectus maritimus*, *Typha angustifolia*, and *Paspalum distichum*, whereas that at *C. haemorrhoidalis* sites was mainly *Rubus ulmifolius*, *Nerium oleander* and *Typha angustifolia*. Besides, unlike *C. haemorrhoidalis*, *C. exul* was never observed below 220 m a.s.l.

Figure 3 shows a biplot of PCA based on 7 abiotic factors, both *Calopteryx* species maximum abundance and the 17 sampled sites. More than 63% of the total variance was explained by the first 2 principal components. The first component (47.5% of the variance explained; eigenvalue = 4.27) was positively correlated to the percentage of shading, banks vegetation density and abundance of *C. haemorrhoidalis*. This suggests that the latter was abundant where the percentage of shading and the density of the bank vegetation were higher than elsewhere. The second component (15.6% of the variance explained; eigenvalue = 1.40) was positively correlated to water depth and abundance of *C. exul* and negatively related to water velocity. This assumes that *C. exul* tends to avoid very shallow water and very fast flowing water.

Table II

Habitat features of C. exul *and* C. haemorrhoidalis*. Values represent mean and standard deviation of each variable in sites where the species was abundant (>20 individuals)*

	C. exul	*C. haemorrhoidalis*
Turbidity (NTU)	129.79 ± 21.40	49 ± 42.40
Water velocity (m/s)	0.40 ± 0.07	0.34 ± 0.04
Water depth (cm)	36.09 ± 1.43	20.78 ± 7.61
Water width (cm)	13.52 ± 8.55	4.10 ± 6.30
Shading (%)	22.5 ± 7.59	81.20 ± 28.03
Bank vegetation density (%)	37.08 ± 16.28	71.60 ± 25.61
Bank vegetation height (cm)	75.25 ± 39.78	175.67 ± 169.81
Max. number of *C. exul*	60 ± 40.51	0.20 ± 0.45
Max. number of *C. haemorrhoidalis*	4.75 ± 6.90	41.20 ± 21.88

DISCUSSION

This study presents new data regarding the flight period, sex-ratio and habitat preferences of *C. exul*, a threatened species that has never been yet studied. This species had not been reported for a century in Algeria and national extinction caused by habitat degradation as a

main reason was thought to have undergone. However, in order to determine the present species distribution throughout its geographic range, a clear picture of its flight period and habitat preferences is essential.

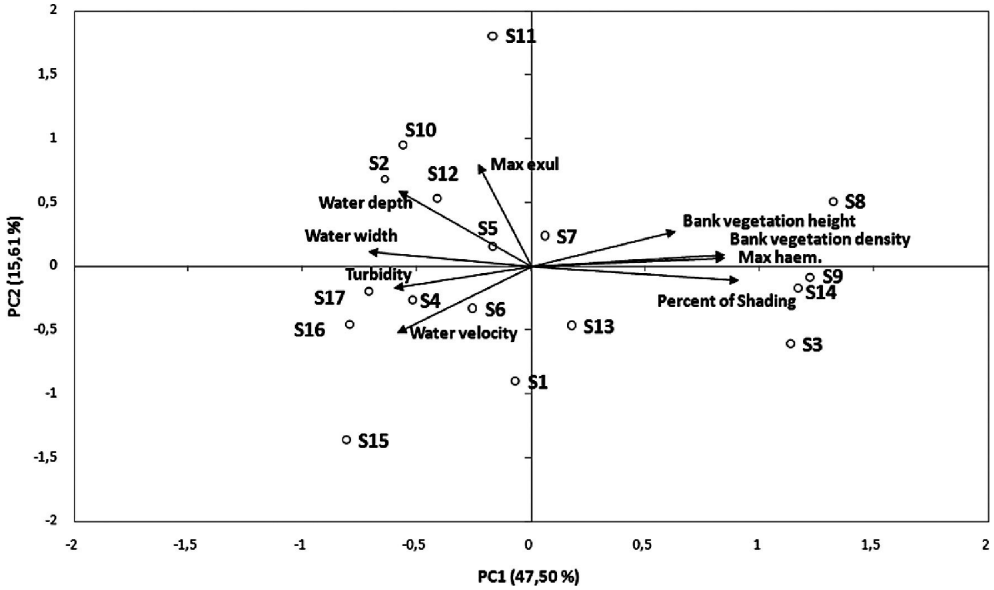

Figure 3.— Biplot of Principal Component Analysis performed for habitat features, species abundance and sample sites. Site codes are presented in table I."Max exul" and "max haem." refer to the maximum number of adult individuals recorded for *Calopteryx exul* and *C. haemorrhoidalis* respectively.

TABLE III

Principal component analysis of habitat features with C. exul *and* C. haemorrhoidalis *abundance. Values greater than 0.4 are in bold*

	PC1	PC2
Turbidity (NTU)	-0.29	-0.14
Water velocity (m/s)	-0.28	**-0.44**
Water depth (cm)	-0.28	**0.49**
Water width (cm)	-0.34	0.09
Shading (%)	**0.43**	-0.09
Bank vegetation density (%)	**0.41**	0.08
Bank vegetation height (cm)	0.30	0.22
Max. number of *C. exul*	-0.11	**0.67**
Max. number of *C. haemorrhoidalis*	**0.41**	0.05
Eigenvalue	4.27	1.40
Variability (%)	47.49	15.61
Cumulative (%)	47.49	63.11

We found that the species started to emerge on early May and that the main flight period could last three months, that is shorter than what is found in the literature. Published flight periods [May to August according to Jacquemin & Boudot (1999) and Boudot (2008)] were based on extreme records (earliest and latest) instead of regular monitoring. During the present study, it became clear that the last reported dates corresponded to sparse individuals pertaining to late emergences and did not pertain to the main flight period of the species, which is determined by the spring/early summer generation.

Two hypotheses may account for such late individuals, namely either the occurrence of a partial bivoltinism in the species or the occurrence of delayed emergences. A larval study allowing for the identification of larval generations and cohorts would be needed to elucidate the question, but such study would be destructive so that it was not done. Referring to the literature, a perfect larval study is available in the case of *C. haemorrhoidalis* (Rüppell *et al*., 2005, Fig. 8 p. 28). In this species, last instar larvae (F0 larvae) appear in May for a final exuviation in June, peaked in June and July for delayed emergences, decreased in August and did not reach September due to progressive August emergences. There was no trace of a second annual generation originating from egg-deposition by the spring individuals, which would result in the occurrence of a rapid succession of F-12 to F0 larvae from May/June to August and the lack of F0 larvae in part of the summer. In this case, the late August / September adults resulted from delayed emergences in an univoltine species showing non-synchronized emergences ("summer species" sensu Corbet, 1957). There is a strong probability that the same is true in the case of *C. exul* reported in this paper, as the "*C. splendens* group" pertains also to "summer species". However, as north-eastern Algeria has a warmer climate than southern France, a partial bivoltinism with a full development from eggs to adults of only three months cannot be eliminated a priori, as envisaged by Rüppell *et al.* (2005). This is not documented in Calopterygidae, however (see Córdoba-Aguilar & Cordero-Rivera, 2005; Corbet *et al.*, 2006).

The maturation period estimated for *C. exul* was around 11-12 days and was similar to that reported for *C. japonica* (11 days) (Miyakawa, 1982), *C. maculata* (11 days) (Waage, 1972, 1973), *Mnais pruinosa* (10.7 ± 0.73 days) (Higashi, 1982) and *Hetarina cruentata* (12 days) (Córdoba-Aguilar, 1994).

The apparent daily sex-ratio was almost always biased in favour of females, which reached 65-67% of the adults present on site. Whether this appeared only in the adult population after emergence or already at emergence is still unknown and needs further studies during the emergence period. The present data don't fit those published by Cordero-Rivera (1989) on *C. haemorrhoidalis*, *C. virgo* and *C. xanthostoma* in Spain, where the sex-ratio was biased in favour of males. In these species, the deficit in females is due to the fact that the latter left the watercourse during the reproductive season and returned only for mating and ovipositing, whereas the males guard territories within the watercourse. Although a biased apparent sex-ratio in favour of females in adult populations along the watercourse is rare among Odonata (Stoks, 2001), both mortality and behaviour of males may produce such a trend, even when the sex-ratio at emergence was equilibrated. With their attractive colour and reflects, males are more conspicuous than females and exhibit often a more striking behaviour favouring predation (e.g. birds and frogs). Many studies on Calopterygids showed that the survival rate was usually lower among males than females (Cordoba-Aguilar & Cordero-Rivera, 2005). Additionally, a strong territoriality develops in males Calopterygidae (Cordoba-Aguilar & Cordero-Rivera, 2005; Rueppel *et al.*, 2005), so that the latter exclude other males from large areas during the reproductive season.

In this study, the sites where *C. exul* was abundant showed relatively fast flowing shallow water (but not very shallow) with some turbidity, sparse vegetation, and low shading. Similar water velocity preferences were observed on Moroccan populations (Boudot, 2008; El Haissoufi *et al.,* 2008). El Haissoufi *et al.* (2008) briefly described a site where the species was recorded stating that the watercourse had a dense bank vegetation; however, their description was based only on one observation of one male and was not representative. In the present study, I found that the species has never been recorded below 220 m a.s.l., which is consistent with earlier observations in which elevation ranged between 200 and 2000 m (Lieftinck, 1966; Jacquemin & Boudot, 1999; El Haissoufi *et al.,* 2008; Boudot, 2008; Khelifa *et al.*, 2011).

Cordero (1989) studied three species of *Calopteryx* (*C. haemorrhoidalis*, *C. xanthostoma* and *C. virgo*) in Spain and found that the former was abundant in coastal streams, the second in slow and sunny water and the latter in rapid water far from the coast. According to the present results, *C. exul* belongs to an intermediate category between the two latter species and is found in fast and sunny waters far from the coasts. In contrast, the habitat of *C. haemorrhoidalis* was different from that recorded for *C. exul*. *Calopteryx haemorrhoidalis* is mostly abundant

at very shallow water with very low turbidity, moderate flow rate, high vegetation density and high shading, searching for cool habitats. High numbers of this species were also observed at coastal streams (Khelifa personal observation), that fit Cordero's (1989) observations.

Data regarding the dispersal, demographic parameters and population estimation [based on marked adult individuals] which are essential to understand the population dynamics of the species are not included in the current paper and will be published in the near future.

The present status of *C. exul* in the Seybouse watershed is, on one hand, satisfying, and on the other hand, worrying. The best news is that this population is currently the largest one known in the Maghreb and in the world, reaching more than one hundred individuals in some localities. The worst one is that serious threats, already noted earlier (Khelifa *et al.*, 2011), continue to affect the population in some places. Extensive water pumping, water pollution, river damming and road construction are definitely not compatible with the conservation of a so strong population. Such reckless actions must be stopped and locations where the species is known to be abundant should be a priority for protection to ensure the conservation of this promising population and to avoid a second eclipse of the species in Algeria, which this time would be irreversible.

ACKNOWLEDGMENTS

I sincerely thank Pr. Henri Dumont and Dr. Jean-Pierre Boudot for their comments and suggestions. I am also indebted to Dr. Jean-Pierre Boudot, Dr. Adolfo Cordero-Rivera and Sónia Ferreira for helping me with the documentation. Data collection efforts were assisted by Youcefi Djalil, Kahalerras Amine, Zebsa Rabah, Sekrane Nani, Bouchahdan Issam, Ben Souilah Sofyane, Khaled Hamza, Amari Hichem and Mellal Khalil.

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