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# Diversity, Status and Phenology of the Dragonflies and Damselflies of Cyprus (Insecta: Odonata)

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**Abstract:** Based on literature data, unpublished material and the results of the year-round monitoring at selected sites island-wide by the Cyprus Dragonfly Study Group since 2013, we acquired an excellent knowledge of the diversity and status of the Odonata of Cyprus. Altogether, 37 species are on the island's checklist. *Ischnura pumilio*, *Aeshna affinis and Brachythemis impartita* were only very rarely recorded in the past but are considered to be no longer present. The single record of *Calopteryx virgo* from 1930 is in our opinion a misidentification and has been removed from the checklist. The island has a rather impoverished odonate fauna compared to neighbouring countries. There are no endemic species, but the island is home to some range of restricted species of which *Ischnura intermedia* is the most important. Flight seasons determined for the 31 species with sufficient data were generally found to be longer than reported for other countries in the Eastern Mediterranean. This may be due to intensive year-round monitoring but could also result from Cyprus' warmer climate. Very wide annual variations were found in the abundance of all species over the seven years and show an almost immediate response to the wide fluctuations in Cyprus' annual rainfall levels.

**Keywords:** odonate; flight period; checklist; Eastern Mediterranean; citizen science; climate



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## 1. Introduction

Biodiversity monitoring is an essential first step in being able to track changes in ecosystems and species distributions and abundances locally and contributes to an important global understanding of trends. Records collected through structured monitoring schemes, as well as opportunistic observations, can assist in developing conservation measures aimed at halting or reversing declines in species and habitat quality. Data collected through citizen science projects are increasingly important for assessing biodiversity at global and regional scales [1]. For dragonflies and damselflies in Europe, such detailed information is only available for northern and central localities, but not in any depth for any country or the area in general in the Eastern Mediterranean [2,3]. Kalkman and van Pelt [4] published data on the distribution and flight season of species in Turkey but acknowledged that their records were not evenly distributed over the year. In the European Atlas of Odonata [5], flight season data for the Maghreb, Turkey and Greece, were included but it was stated that the data were limited since very little recording had been conducted outside the main summer holiday season. The recently published Atlas of the dragonflies and damselflies of West and Central Asia [6] also contains phenology data, which includes all species present on Cyprus. The data, however, need to be interpreted with care since flight seasons for species for which there are few records may be longer than indicated and for widespread species may be longer than that found at any given location.

As a first step towards filling the gap in our knowledge in the Eastern Mediterranean, the Cyprus Dragonfly Study Group (CDSG) was established to carry out year-round monitoring of the island's Odonata, starting at the beginning of 2013. In this paper, we present the results from the first seven years of this monitoring programme. This has

allowed us to determine the status of each species and the flight season of all but the island's rarest species with a high degree of confidence. Although not as thorough as the CDSG programme, an expedition in June 1994 [7] and an intensive survey from June 2003 to September 2004 on the northern side of the island [8] gave us insights into how the status of species has changed and the impact of climate change over this 26-year timeline.

## 2. Study Area

Cyprus, the third-largest Mediterranean island, lying at the eastern extremity of the Mediterranean basin, sits at the intersection of the Middle East (Asia), Europe and Africa. The island (Figure 1) is defined by two mountain ranges, the Troodos massif and the Kyrenia (Pentadaktylos) range, separated by a flat, broad east–west plain, the Mesaoria. The Troodos massif dominates the south, west and central part of the island, rising to 1951 m a.s.l. The Kyrenia range, which rises to a maximum of 1024 m a.s.l., is a narrow, largely unbroken ridge that runs for approximately 160 km along the north coast. A coastal plain up to five km in width separates it from the sea.

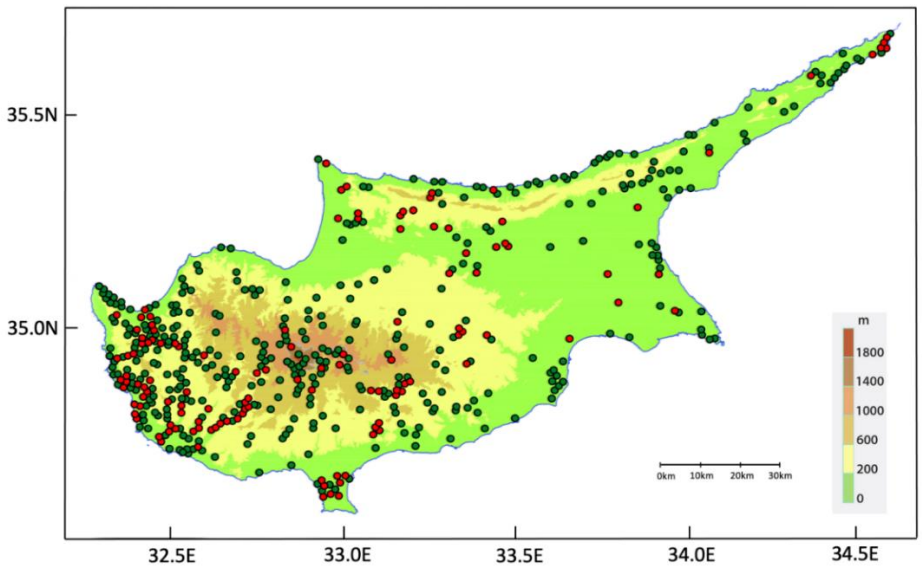


**Figure 1.** Map of localities from which dragonflies and damselflies have been recorded by the CDSG on Cyprus ($n$ = 703). The red dots relate to sites ($n$ = 136) that have been monitored for at least two years, and the green dots to other non-regularly surveyed sites.

Cyprus has an intense Mediterranean climate with hot rainless summers from mid-May to mid-September and generally mild and rainy winters from November to mid-March. Consequently, annual rainfall is measured for hydrometeorological years (1-x to 30-ix). The average annual rainfall is considered to be 503 mm (based on the average for the thirty-year period from 1961/1962 to 1990/1991) [9], but the island has a high regional variation with the wettest area (1100 mm per annum) at the top of the Troodos massif, dropping to a low of 300 to 350 mm per annum on the Mesaoria plain and in the east. Hence, the main rivers arise on the Troodos massif and the lotic Odonata species are restricted to this region. In response to the water stress levels, numerous reservoirs and water storage tanks have been created with 108 listed [10]. All the major rivers are dammed and the resulting reservoirs, along with other water storage tanks, have created new habitats for lentic species, but have had a major impact on the downstream habitats. Annual rainfall levels vary significantly and during the study period varied from 309 mm in the hydrometeorological year 2015/2016 to 795 mm in 2018/2019 [9]. This results in many habitats being highly unstable. Reservoir levels can change very rapidly. Rivers can go from being in flood to having no flow and also becoming overgrown with vegetation.

The most stable habitats are those fed by springs, which may form small pools, streams or feed village tanks and swimming pools that attract several species.

## 3. Methods

A monitoring programme of the dragonflies and damselflies of Cyprus by the CDSG was set up at the start of 2013. Just over 50 sites were initially selected for either monthly or twice monthly dragonfly recording. Given the limited resources (ca. 10 regular and active volunteers), the selection was made to ensure that all the then-known main species and all habitat types were included and that there was good geographic coverage. A transect was defined for each site, varying in length from a point count to a line transect of 400 m. When counting dragonflies, the recorder walks in one direction, counting individuals observed in front of them, over a section of water and the bank. Any individual that flies in from behind the observer is not counted. Counting dragonflies from a single point was performed where it was not possible to count them on a line transect. In this case, the water and bank vegetation were visually scanned for the presence and abundance of each species of Odonata. Details of all species present along these transects were noted, including evidence of breeding behaviour. With relatively few odonates, all of which can be easily identified in the field, netting is rarely needed. It was, therefore, possible to train inexperienced volunteers in dragonfly recording quite rapidly. Some initial problems were encountered with the pruinose-blue *Orthetrum* species, but when in doubt, the recorders were encouraged to photograph the specimens for later confirmation. We were fortunate in having a team of dedicated volunteers since year-round recording required a high degree of commitment.

The results presented here relate to the years 2013 to 2019 (the study period). During this period, several sites became no longer worthwhile for continued monitoring (see Section 2). However, the CDSG has constantly sought out new localities for monitoring, and once a location became no longer viable, it could be replaced by a new site. This resulted in records from 703 sites island-wide, 136 of which were monitored for a significant time during the study period (Figure 1).

From the data collected, we were able to determine the status of each of the odonate species on Cyprus, based on the number of localities from where it was recorded. Species occurring at more than 150 of the 703 sites are considered to be 'very common'; those above 100 to be 'common'; above 50 are 'rather scarce'; more than 10 sites are 'scarce'; and less than 10 are 'extremely rare'. Species on the checklist for which we have no records since 2013 or the recent study period were considered to be no longer present on the island, given the intensity of monitoring. We then compared these data to the previous studies in June 1994 [7] and June 2003 to September 2004 [8].

Flight season data were derived from the CDGS database and were limited to the period 2013–2019. The data for each species were grouped into 10-day periods (decades) for each month, logging the number of records (one species observed at one site on one day) and abundance (count of adults) into each monthly decade. Data of records of just larvae or exuviae were excluded in this analysis. These results were then graphed out for each species. Species with less than 45 records from the study period were omitted from the phenology calculation. The protocol for determining flight season corresponds with the one used in the European Atlas [5]. The flight season for each species was determined based on the records and since the earliest and latest sightings often refer to unusual events, the flight season was defined as the first and last decade in which one to 99% of the records had been made. The main flight season, when there was a greater chance of observing the species, was also determined, being defined as the first and last decade in which 5% or more of the total number of records occur. We then compared these data with that for Turkey [4] and neighbouring countries presented in the European Atlas [5].

## 4. Results

During the study period, a total of 7877 visits were made to 703 sites resulting in 23,899 records with a count of 343,008 adults. The annual breakdown of these data is shown in Table 1 and Appendix A summarises the number of records and abundance per species per year for the study period and for completion, the earliest and latest annual sightings are given for each species.

**Table 1.** Some general results of the Cyprus Dragonfly monitoring schemes for the period 2013 to 2019.

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2013–2019 |
|---|---|---|---|---|---|---|---|---|
| Number of visits | 865 | 1088 | 1042 | 1049 | 1062 | 1315 | 1456 | 7877 |
| Number of sites | 171 | 126 | 139 | 162 | 214 | 237 | 310 | 703 |
| Number of records | 2937 | 2893 | 3273 | 3233 | 2970 | 4089 | 4504 | 23,899 |
| Count of adults | 67,252 | 41,434 | 53,178 | 36,984 | 35,981 | 42,866 | 65,313 | 343,008 |

### *4.1. Status*

The status of the dragonflies and damselflies on the Cyprus checklist based on the total number of sites from which each was observed during the study period is presented in Table 2. From the total of the 37 species ever observed on Cyprus, 15 can be considered at least as common ('common' and 'very common'), another 16 species are scarce and can be found at a rather reduced number of sites, three species are extremely rare and are limited to a handful of sites and three species were not recently observed. Thus 34 species were observed during the study period, and of these, there were a sufficient number of records to determine with confidence the flight season data for 30 of them, plus good indicative data for one other, *Caliaeschna microstigma*, for which we only have 47 records of adults on the wing.

**Table 2.** Status of the dragonflies and damselflies of Cyprus, based on the total number of sites ($N_{max}$ = 703) where a species was observed during 2013–2019.

| Species | Total | % | Status | Criteria |
|---|---|---|---|---|
| *Sympetrum fonscolombii* | 282 | 40.1 | very common | |
| *Crocothemis erythraea* | 247 | 35.1 | very common | |
| *Trithemis annulata* | 231 | 32.9 | very common | |
| *Ischnura elegans* | 216 | 30.7 | very common | |
| *Sympetrum striolatum* | 202 | 28.7 | very common | |
| *Trithemis arteriosa* | 193 | 27.5 | very common | |
| *Orthetrum chrysostigma* | 178 | 25.3 | very common | |
| *Anax parthenope* | 152 | 21.6 | very common | ≥150 loc |
| *Orthetrum brunneum* | 143 | 20.3 | Common | |
| *Orthetrum coerulescens* | 138 | 19.6 | Common | |
| *Calopteryx splendens* | 134 | 19.1 | Common | |
| *Sympecma fusca* | 124 | 17.6 | Common | |
| *Epallage fatime* | 117 | 16.6 | Common | |
| *Anax ephippiger* | 117 | 16.6 | Common | |
| *Pantala flavescens* | 109 | 15.5 | Common | ≥100 loc |
| *Aeshna mixta* | 95 | 13.5 | Rather scarce | |
| *Onychogomphus forcipatus* | 93 | 13.2 | Rather scarce | |
| *Trithemis festiva* | 90 | 12.8 | Rather scarce | |
| *Chalcolestes parvidens* | 88 | 12.5 | Rather scarce | |
| *Orthetrum taeniolatum* | 76 | 10.8 | Rather scarce | |
| *Orthetrum sabina* | 73 | 10.4 | Rather scarce | |
| *Anax imperator* | 58 | 8.3 | Rather scarce | ≥50 loc |

**Table 2.** *Cont.*

| Species | Total | % | Status | Criteria |
|---|---|---|---|---|
| *Anax immaculifrons* | 47 | 6.7 | Scarce | |
| *Selysiothemis nigra* | 41 | 5.8 | Scarce | |
| *Diplacodes lefebvrii* | 39 | 5.5 | Scarce | |
| *Orthetrum cancellatum* | 36 | 5.1 | Scarce | |
| *Erythromma lindenii* | 32 | 4.6 | Scarce | |
| *Caliaeschna microstigma* | 28 | 4.0 | Scarce | |
| *Ischnura intermedia* | 24 | 3.4 | Scarce | |
| *Erythromma viridulum* | 19 | 2.7 | Scarce | |
| *Lestes macrostigma* | 10 | 1.4 | Scarce | ≥10 loc |
| *Sympetrum meridionale* | 4 | 0.6 | extremely rare | |
| *Aeshna isoceles* | 2 | 0.3 | extremely rare | |
| *Lestes barbarus* | 1 | 0.1 | extremely rare | <10 loc |
| *Ischnura pumilio* | 0 | 0.0 | no longer present | |
| *Aeshna affinis* | 0 | 0.0 | no longer present | |
| *Brachythemis impartita* | 0 | 0.0 | no longer present | |

### 4.2. Phenology

Dragonflies and damselflies were observed on the wing during every month of the year. The cumulative number of records and the number of species observed in each month during the period 2013–2019 is given in Figure 2. During January and February, the number of records and abundance was low but picked up in March and April, peaking in May and June through to August, followed by a gentle decline to the end of the year. A high percentage of the island's species were recorded from March to November, a consequence of many species having a long flight season.

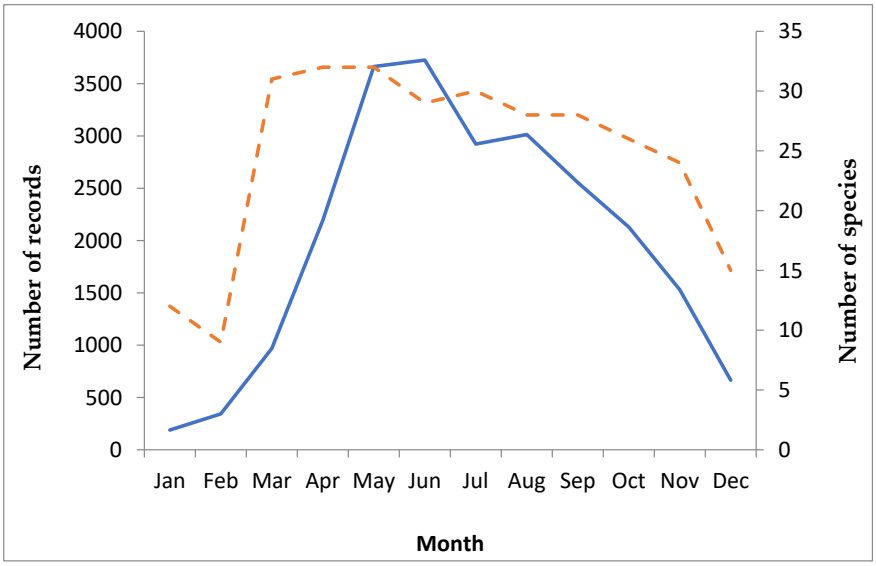


**Figure 2.** The total number of records (continuous blue line) and number of species recorded (dotted red line) for each month for the dragonflies and damselflies of Cyprus for the period 2013–2019.

Flight season per decade (10-day period) of adult Odonata in Cyprus for the period 2013–2019 is presented in Figure 3. Species with fewer than 45 records were not included in this analysis. A distinction was made between the flight season, which contains decades with up to 99% of the records, and the main flight season, being defined as the first and last decade in which 5% or more of the total number of records occurred.

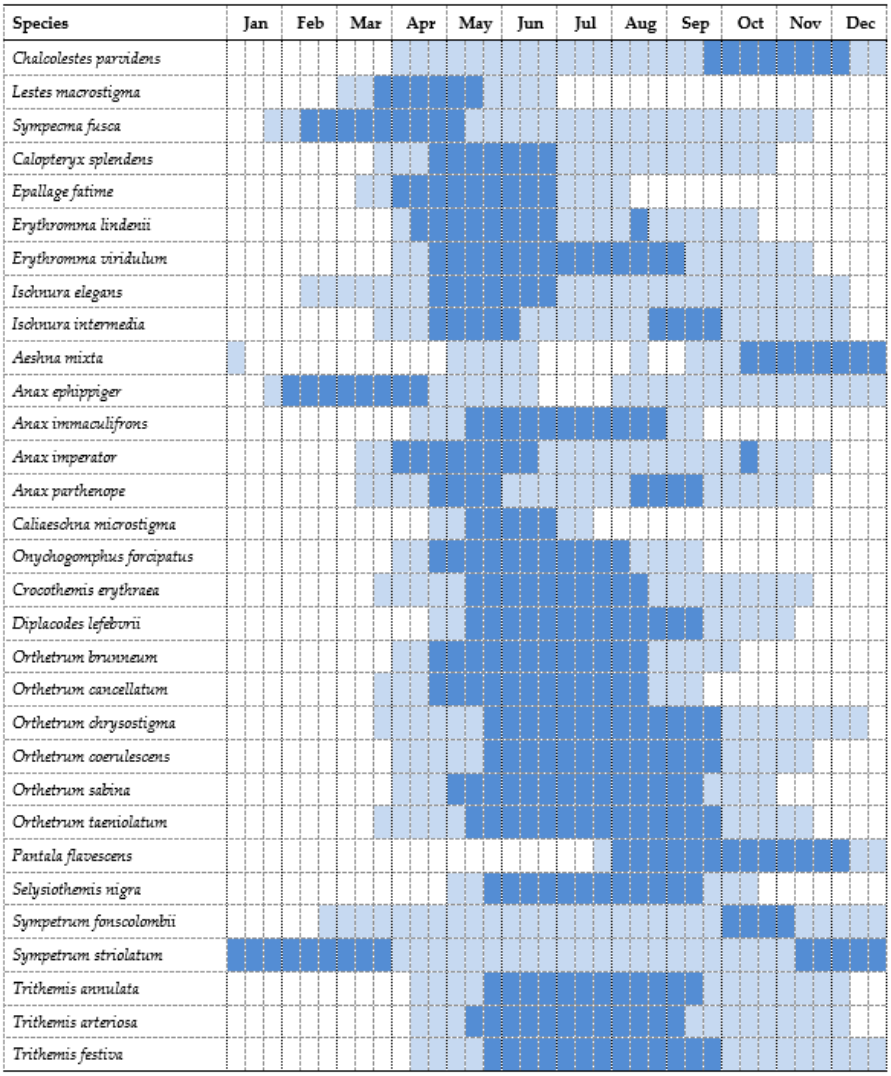


**Figure 3.** The flight season of the Odonata present in Cyprus based on records for the period 2013 to 2019. Flight season (light shading) and main flight season (dark shading).

## 5. Discussion

One of the characteristics of islands is that they often have a low number of species compared to neighbouring countries but a high rate of endemic species [11]. With only 37 species ever observed on Cyprus, the island has a relatively poor dragonfly diversity compared with neighbouring countries such as Turkey with 105 species [6], Syria with 67 species [6], Greece with 76 species [5] but is rather similar to Crete with 35 species [5] and Egypt with 39 species [12]. Although the nearby Mediterranean island of Crete has a similar size, it holds two endemic species [5], while no endemic species are present in Cyprus. The broad separation of Crete from mainland Greece (160 km) compared to the shorter distance from Cyprus to Turkey and Syria (70 km) may be a factor. It may result in a higher probability of migration and gene exchanges with mainland populations compared to Crete. Migration and gene exchanges lower the likelihood of local adaptation and species radiation. However, in some orders, Cyprus has similar or higher levels of endemism than Crete, for instance, six endemic butterflies compared to four in Crete. It has been suggested [8] that the absence of endemism in odonates might be a result of the unstable nature of the habitats and the need for recolonisation preventing the development of insular characteristics. Just a few species present in Cyprus have a rather restricted range, e.g., *Ischnura intermedia* [13], *Epallage fatime* [6], *Caliaeschna microstigma* [14] and occur also in West Asia. Nearly all dragonfly species found in Cyprus are widely dispersed either in

Europe, Asia, or Africa. Several of them are well known migrants such as *Anax ephippiger*, *Pantala flavescens* [15] and *Sympetrum fonscolombii*.

### *5.1. Status*

Six of the eight species in the 'very common' category were recognised as being thus for a long time by comparison with 1994 [7] and 2003/2004 [8] data. The presence of *Orthetrum chrysostigma* and *Trithemis arteriosa* in this category, however, indicates a recent strong expansion on the island. The seven species in the common category include the first two obligate lotic species, *Calopteryx splendens* and *Epallage fatime*, whose distribution is restricted to the streams of the Troodos and western Cyprus, where *Trithemis festiva* is also locally common. Although also in the common category, the two most prominent migrants, *Anax ephippiger* and *Pantala flavescens* show strong yearly fluctuations in numbers (Appendix A). Although very common, and more so than *Anax parthenope* on many Mediterranean islands, *Anax imperator* is ranked as 'rather scarce' on Cyprus. This was already noted by Lopau and Adena [7] who attributed this to its late arrival on the island. However, two decades later it still has only managed to establish a modest presence. We, therefore, presume that the absence of many suitable reproduction habitats, e.g., permanent waters, has a stronger impact. *Orthetrum sabina*, although still rather scarce, has none the less expanded its range significantly since 1994. Earlier population sizes on Cyprus, and even more generally in Europe are small (<10 individuals) [7,8,16] but we have on several occasions observed populations of several hundred individuals. Although *Anax immaculifrons* has been found in less than 10% of the investigated sites, this species is rather widespread in the western part of Cyprus and is a regular visitor to some swimming pools in the Paphos area, where reproductive behaviour, including oviposition has been observed. *Caliaeschna microstigma* is unusual in being active in the late afternoon and early evening when only limited monitoring is carried out by the CDSG and also many of the localities where it occurs are not easily accessible. Consequently, it has almost certainly been under-recorded, which is supported by the large number of exuviae found, indicating that it is much more common than suggested by its scarce ranking. Of the species in the extremely rare category, *Sympetrum meridionale* was found to be the most elusive anisopteran with no established populations or localities where it could regularly be seen: there is just one record from April and two records from November. *Aeshna isoceles* was rediscovered in 2019 and was observed between April and July at two locations in a river valley on the Karpas Peninsula, where populations seemed to be well established [17]. Only a single *Lestes barbarus* individual was observed in August 2019 and this was assumed to be a migrant [17]. Finally, three species, *Ischnura pumilio*, *Aeshna affinis* and *Brachythemis impartita* were not observed during the study period and are assumed to be no longer present on the island. None of these three species ever had a strong presence on Cyprus. For *Brachythemis impartita*, there was only one set of records (1 male and 2 females) in 2006, and these were assumed to be accidental visitors. *Brachythemis impartita* has in recent decades extended its range into Europe and West Asia and to the northeast is found in the Levant and the southernmost part of Turkey [6]. Thus, we can expect that *B. impartita* may be able to colonise Cyprus. For *Ischnura pumilio*, there are only two records from Cyprus: one from 1893 and one from 1947. These also could reasonably be considered to be migrants with no established populations. It is known as a pioneer species with a preference for sparsely vegetated habitats. It seems unlikely that colonisation will occur from Turkey or Syria, where this habitat is also under severe pressure. *Aeshna affinis* was last recorded from Cyprus in 1994. It is a well-known disperser and was until two decades ago a rare observation in most of north-western Europe [5]. As Cyprus is at the south-eastern edge of the range of the species [6], it is not unlikely that the former observations are the result of one or several influxes on the island.

There is one published record of *Calopteryx virgo* from Cyprus, reported by Navas [18], who examined material collected by Mavromoustakis, an eminent local hymenopterist, in 1930 at an altitude above 1000 m asl in the Troodos. Since then, this species has appeared

on every published checklist of the island's Odonata. Neither the CDSG nor any other observers have since been able to find a second specimen on the island. Lopau and Adena [7] already considered that this single record was a misidentification of a particularly blue *C. splendens* specimen. The ideal summer water temperatures for *C. virgo* are between 13 and 18 °C [19]. We measured water temperatures in streams in July and August and found that at altitudes above 1200 m, there were waters cool enough to support *C. virgo*. However, these occupy a very small geographic area and are on very precipitous mountain sides that are liable to have severe destructive flash floods during the winter months when rainfall on the Troodos can be torrential. Whereas other species such as *Epallage fatime* could recolonise such mountain streams by spreading upwards from the lower slopes, any species found only in the highest reaches would be particularly vulnerable to local extinction. We, therefore, concur with Lopau and Adena [7] and consider that the species never was found on Cyprus and remove *Calopteryx virgo* from the island's checklist.

### *5.2. Yearly Variation in Abundance*

Monitoring programmes are typically set up to detect trends in the long term, such as the monitoring demanded by the European Union for the species mentioned on the Habitats Directive where a timeline of 24 years is stipulated [20]. It is obvious that our timeframe 2013–2019 is too short to detect statistically sound trends. Nevertheless, some clear differences in the observed number of adults over the years could be detected, which is much more marked than that of the number of records for each species (Appendix A). To correct for sampling effort, we calculated the mean numbers of adults being observed per visit and per year (Figure 4). These numbers correlate very well with the amount of rainfall level during the previous winter (Figure 4). By far, the highest abundance was observed in 2013. Although rainfall during the winter of 2012/2013 was somewhat above normal, this followed four previous winters of well above average rainfall. Reservoirs were full and there was permanent flow along much longer stretches of the rivers than observed in years of low rainfall. In contrast, rainfall during the 2013/2014 winter was well below average and the abundance of the island's odonate populations was immediately reduced. The well above average rainfall during the winter of 2014/2015 resulted in a noticeable rapid recovery of abundance but was reversed by the exceptionally low rainfall during the winters of the next three years (2015/2016, 2016/2017 and 2017/2018). Reservoir levels were low, many stretches of rivers had no flow during the entire period and significant overgrowth with reeds occurred. The winter of 2018/2019 was exceptionally wet, in fact the wettest since record keeping started in 1901. Reservoirs filled, dams overflowed and there was extensive flooding on most of the rivers. Extensive damage resulted; several of the sites that were being monitored were washed away, and, in many locations, the developing larvae may also have been affected. Nonetheless, there was an upswing in the adult abundance during the 2019 season.

This variability is typical of Cyprus' climate, which is characterised by repeating cycles of drought years such as seen 2016 to 2018, resulting in many local extinctions of odonate populations. Consequently, Cyprus' most successful odonate species are those that are habitat generalists and able to rapidly recolonise former habitats or new habitats as they are formed. However, there is also a climatic problem that is equally, if not more worrying than global warming for the flora and fauna of Cyprus, particularly for the odonates. From 1901 onwards, when climate variables started to be recorded, there was a clear decline in rainfall levels (Table 3). The average decline was almost one millimetre per year, a trend that is predicted to continue [9]. Seeing the impact of low rainfall levels, this does not bode well for the future of Cyprus' odonates and we may expect species that are habitat specific and less adept at recolonising to be hit first and hardest. Such clear declines in rainfall have already been observed in Mediterranean-type landscapes in south-western Australia over the last 40 years [21]. Besides climate change, the growing human impact during the past century has also been detrimental to many wetland habitats in Cyprus. The intensified exploitation of water resources and especially dam building, which is well

recognised to have impoverished the valleys below the dams, has certainly affected the population of several species, especially those dependent upon streams and rivers or those species, which only occur in a limited number of sites.

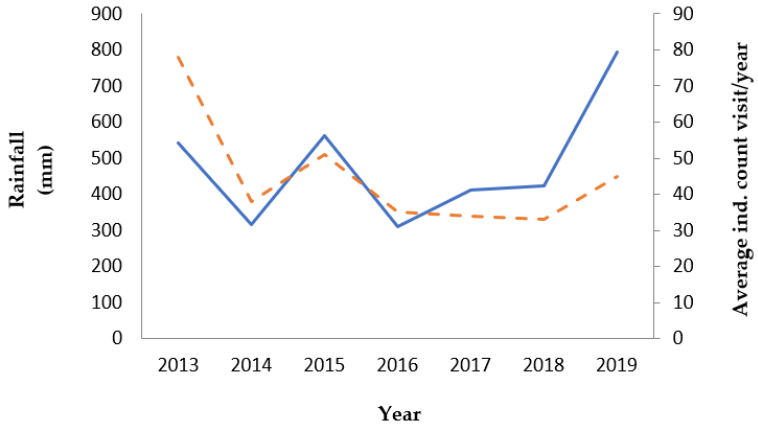


**Figure 4.** Relation between annual rainfall (continuous blue line) and the mean adult count per visit per year (dotted line in red).

**Table 3.** Average annual rainfall levels for the four 30-year periods since 1901.

| 30-Year Period | 1901/02–1930/31 | 1931/32–1960/61 | 1961/62–1990/91 | 1991/92–2020/21 |
|---|---|---|---|---|
| Average annual rainfall mm | 559 | 524 | 503 | 476 |

### *5.3. Phenology*

With seven years of recording experience and a large number of records, we have a good dataset to determine the flight season for 31 of Cyprus' species with a high degree of confidence. Many have long flight seasons (Figure 3) and longer than that reported for their conspecifics in neighbouring countries [4–6].

Just three species, *Lestes macrostigma*, *Epallage fatime* and *Caliaeschna microstigma*, all univoltine, emerge early in the year and have short flight seasons (Figure 4). The duration of the flight season for the first two species is similar to Turkey, Greece and Bulgaria [4,22,23] but the emergence is around one month earlier, which can be explained by the year-round warmer climate in Cyprus. For *C. microstigma*, our flight season is shorter but falls well inside that for Turkey [24] and may be a consequence of our rather low number (47) of records.

At least five species are present year-round on Cyprus. One of these, *Sympecma fusca* overwinters as an adult across its range [25] and mating activity on Cyprus takes place from the beginning of February to the end of April. *Sympetrum striolatum* not only overwinters as an adult on Cyprus as previously mentioned [4,26], but it is the main breeding season. In Europe, the species has normally been observed only until December [27], but it overwinters as an adult in North Africa [28,29] and winter breeding is known to occur in northern Algeria [30]. On Cyprus, after emergence in spring, reproductive activity is delayed until mid-October and continues through to the end of March. For three other species, *Ischnura elegans*, *Sympetrum fonscolombii* and *Trithemis annulata*, the numbers of adults observed in January and February are very low, and most likely these species do not overwinter as adults or only very occasionally. For *I. elegans* and *T. annulate*, numbers start to pick up from March and April, respectively, and mating activity has then been observed right through the remainder of the flight season. However, although not visible on Figure 3, *S. fonscolombii*, shows a typical bivoltine lifecycle with mating occurring from the beginning of April to the end of June and then from mid-September to mid-November, when hundreds of females have been observed ovipositing in tandem over the complete area of many reservoirs and other lentic water bodies. It seems likely that *Anax imperator*

and *A. parthenope* have a bivoltine lifecycle in Cyprus (Figure 3), but a dedicated survey of larvae and exuviae is needed to confirm this.

Apart from *S. striolatum*, two other species delay reproductive activity until autumn/winter. For *Chalcolestes parvidens*, there are a few records from January to April, but numbers start to build up from May. Reproductive activity, however, is delayed until the autumn/winter, starting from mid-September and peaking from mid-October to the end of November, much later than observed elsewhere [31]. This appears to be a response to Cyprus' warmer climate and a need to wait for cooler months to ensure the eggs enter a diapause. *Aeshna mixta* also delays reproductive activity to autumn/winter, emerging from March/April but then moving away from the breeding grounds with mating observed from mid-October to the end of December.

Cyprus' two main migrant species have very different flight seasons. There are records from every month except July for the migratory *Anax ephippiger*, although the main influx occurs from the beginning of February to the end of April when in some years vast swarms have been observed. The few individuals observed from August onwards are thought to be mainly offspring from the spring influx. In contrast, there are no records for *Pantala flavescens* from mid-January to the beginning of July, when it has then been observed to the end of the year. It is also confirmed to breed on Cyprus [15].

*Orthetrum chrysostigma*, *Crocothemis erythraea*, *Trithemis arteriosa* and *Trithemis festiva* also have long flight seasons with records from every month of the year except February or January in the case of *C. erythraea*. The first three species have their main distribution range in Africa where they can be observed year-round [32] just as in many parts of the Arabian Peninsula [6]. *Trithemis festiva* is a mainly Oriental species and its flight season on Cyprus is considerably longer than that reported for Greece and Turkey [33] and somewhat longer than that for West and Central Asia [6]. The range restricted and threatened *Ischnura intermedia* has at least two and possibly even three generations a year and records are only lacking from January and February [13].

The remaining species mostly have flight seasons that are longer, emerging earlier and staying on the wing longer than that reported for Greece and Turkey [4,5]. It is possible that the longer flight season reported for Cyprus may just be a consequence of more intensive year-round monitoring but could also be a result of the warmer climate enabling an earlier emergence and facilitating more generations per year.

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## Appendix A

**Table A1.** Number of records and adult counts (records/counts of adults) of dragonflies and damselflies on Cyprus and earliest and latest annual sighting for each species stored in the CDSG database for the period 2013 to 2019. * Species for which the flight season extends into the early months of the following year.

| Species | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Total Records | Total Ind. | Earliest Sighting | Latest Sighting |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chalcolestes parvidens* | 86/2189 | 71/354 | 122/1626 | 76/685 | 120/1780 | 111/2799 | 144/2716 | 730 | 12,149 | 20-iii-2014 | 02-ii-2015 * |
| *Lestes barbarus* | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 3/3 | 3 | 3 | 14-viii-2019 | 31-viii-2019 |
| *Lestes macrostigma* | 6/964 | 8/263 | 4/121 | 5/145 | 6/20 | 13/577 | 15/903 | 57 | 2993 | 04-iv-2019 | 16-vi-2017 |
| *Sympecma fusca* | 55/1937 | 86/3089 | 59/349 | 165/4121 | 35/175 | 101/2882 | 77/1414 | 578 | 13,967 | year-round | year-round |
| *Calopteryx splendens* | 178/4809 | 118/2140 | 173/3948 | 135/1653 | 121/2173 | 202/2548 | 227/2817 | 1154 | 20,088 | 07-iii-2014 | 21-xi-2019 |
| *Epallage fatime* | 110/2084 | 83/1387 | 87/2128 | 84/434 | 54/710 | 94/738 | 144/717 | 656 | 8198 | 07-iii-2013 | 20-viii-2013 |
| *Erythromma lindenii* | 13/53 | 19/361 | 14/216 | 17/197 | 19/197 | 23/133 | 13/45 | 118 | 1202 | 05-iv-2019 | 11-xi-2016 |
| *Erythromma viridulum* | 5/9 | 2/12 | 6/23 | 17/2205 | 9/907 | 19/284 | 16/276 | 74 | 3716 | 03-iv-2018 | 12-xi-2015 |
| *Ischnura elegans* | 299/10,197 | 379/5232 | 425/9197 | 436/5815 | 348/7653 | 467/6841 | 439/11,234 | 2793 | 56,169 | year-round | year-round |
| *Ischnura intermedia* | 49/364 | 35/242 | 78/1069 | 93/798 | 77/780 | 84/926 | 64/404 | 480 | 4583 | 05-iii-2017 | 05-xii-2019 |
| *Ischnura pumilio* | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0 | 0 | | |
| *Aeshna affinis* | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0 | 0 | | |
| *Aeshna isoceles* | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 15/58 | 15 | 58 | 13-iv-2019 | 08-vii-2019 |
| *Aeshna mixta* | 46/212 | 63/207 | 85/315 | 35/66 | 82/163 | 79/194 | 75/240 | 465 | 1397 | 06-iii-2013 | 16-i-2016 |
| *Anax ephippiger* | 51/2508 | 20/294 | 10/37 | 15/104 | 34/142 | 26/268 | 54/1928 | 210 | 5281 | 26-i-2017 | 21-xii-2019 |
| *Anax immaculifrons* | 12/20 | 27/54 | 34/71 | 55/96 | 26/36 | 45/74 | 29/33 | 228 | 384 | 13-iv-2016 | 27-ix-2015 |
| *Anax imperator* | 37/78 | 10/21 | 7/12 | 12/17 | 16/18 | 16/21 | 11/13 | 109 | 180 | 06-iii-2013 | 28-xi-2014 |
| *Anax parthenope* | 133/482 | 154/771 | 131/454 | 139/375 | 141/551 | 182/444 | 149/581 | 1029 | 3658 | 04-ii-2014 | 21-xii-2018 |
| *Caliaeschna microstigma* | 9/14 | 9/10 | 2/2 | 8/20 | 8/11 | 14/77 | 11/10 | 61 | 144 | 24-iv-2014 | 13-vii-2013 |
| *Onychogomphus forcipatus* | 93/667 | 34/60 | 76/330 | 19/35 | 31/71 | 56/114 | 113/155 | 422 | 1432 | 20-iii-2013 | 16-x-2013 |
| *Brachythemis impartita* | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0/0 | 0 | 0 | | |
| *Crocothemis erythraea* | 283/2393 | 296/2747 | 302/2389 | 301/1301 | 261/1326 | 391/2122 | 420/2230 | 2254 | 14,508 | 20-ii-2014 | 15-xiii-2014 |
| *Diplacodes lefebvrii* | 29/822 | 34/197 | 25/437 | 17/94 | 14/169 | 23/140 | 20/153 | 162 | 2012 | 21-iv-2016 | 17-xi-2018 |
| *Orthetrum brunneum* | 112/1122 | 105/404 | 107/540 | 95/265 | 118/465 | 148/524 | 120/302 | 805 | 3622 | 20-iii-2014 | 28-x-2017 |
| *Orthetrum cancellatum* | 21/234 | 18/133 | 19/814 | 24/663 | 28/380 | 32/366 | 31/197 | 173 | 2787 | 29-iii-2013 | 14-ix-2013 |
| *Orthetrum chrysostigma* | 193/2071 | 177/1599 | 248/3470 | 220/2062 | 196/1022 | 291/1341 | 355/2265 | 1680 | 13,830 | 02-iii-2018 | 15-i-2018 * |
| *Orthetrum coerulescens* | 92/1186 | 130/1854 | 180/1706 | 182/1417 | 226/2171 | 279/2176 | 266/2434 | 1355 | 12,944 | 21-iii-2018 | 24-xi-2013 |
| *Orthetrum sabina* | 89/398 | 85/650 | 54/708 | 72/1299 | 78/749 | 74/955 | 89/793 | 541 | 5552 | 15-iii-2018 | 24-xi-2013 |
| *Orthetrum taeniolatum* | 38/506 | 31/94 | 47/163 | 32/71 | 13/21 | 31/76 | 48/333 | 240 | 1264 | 23-iii-2014 | 27-xi-2013 |
| *Pantala flavescens* | 1/1 | 13/24 | 2/5 | 9/13 | 13/17 | 45/74 | 146/233 | 229 | 367 | 09-vi-2018 | 11-i-2015 * |
| *Selysiothemis nigra* | 23/1069 | 34/1006 | 31/2299 | 42/1269 | 35/828 | 32/300 | 34/547 | 231 | 7318 | 20-iv-2018 | 19-x-2018 |
| *Sympetrum fonscolombii* | 173/10,088 | 206/7825 | 254/11,290 | 185/4329 | 249/7306 | 238/7283 | 299/17,861 | 1604 | 65,982 | year-round | year-round |
| *Sympetrum meridionale* | 1/11 | 2/2 | 0/0 | 0/0 | 0/0 | 0/0 | 1/0 | 4 | 13 | - | - |
| *Sympetrum striolatum* | 162/4536 | 172/1536 | 129/590 | 196/1756 | 136/1204 | 258/1766 | 226/4009 | 1279 | 15,397 | year-round | year-round |
| *Trithemis annulata* | 294/12,382 | 275/6533 | 279/6213 | 286/4089 | 252/3839 | 321/5223 | 343/7248 | 2050 | 45,527 | year-round | year-round |
| *Trithemis arteriosa* | 72/716 | 60/137 | 68/224 | 124/331 | 103/343 | 176/639 | 268/1397 | 871 | 3787 | 23-iii-2018 | 06-i-2018 * |
| *Trithemis festiva* | 172/3130 | 215/2196 | 137/2432 | 121/1259 | 218/754 | 239/961 | 1239/1764 | 1239 | 12,496 | 26-iii-2018 | 09-i-2016 * |
| Number of records | 2937 | 2893 | 3273 | 3233 | 2970 | 4089 | 4504 | 23,899 | - | | |
| Total adult count | 67,252 | 41,434 | 53,178 | 36,984 | 35,981 | 42,866 | 65,313 | - | 343,008 | | |

## References


1. Theobald, E.; Ettinger, A.; Burgess, H.; De Bey, L.; Schmidt, N.; Froehlich, H.; Wagner, C.; HilleRisLambers, J.; Tewksbury, J.; Harsch, M.A.; et al. Global change and local solutions. Tapping the unrealized potential of citizen science for biodiversity research. *Biol. Conserv.* **2015**, *181*, 236–244. [CrossRef]
2. Termaat, T.; van Strien, A.J.; van Grunsven, R.H.A.; De Knijf, G.; Bjelke, U.; Burbach, K.; Conze, K.-J.; Goffart, P.; Hepper, D.; Kalkman, V.J.; et al. Distribution trends of European dragonflies under climate change. *Divers. Distrib.* **2019**, *25*, 936–950. [CrossRef]
3. Bried, J.T.; Ries, L.; Smith, B.; Patten, M.; Abbott, J.; Ball-Damerow, J.; Cannings, R.; Cordero-Rivera, A.; Cordoba-Aguilar, A.; De Marco, P., Jr.; et al. Towards global volunteer monitoring of Odonate abundance. *BioScience* **2020**, *70*, 914–923. [CrossRef]
4. Kalkman, V.J.; van Pelt, G.J. The distribution and flight period of the dragonflies of Turkey. *Brachytron* **2006**, *10*, 83–153.
5. Boudot, J.-P.; Kalkman, V.J. (Eds.) *Atlas of the European Dragonflies and Damselflies*; KNNV Publishing: Zeist, The Netherlands, 2015; p. 381.
6. Boudot, J.-P.; Borisov, S.N.; De Knijf, G.; van Grunsven, R.; Schröter, A.; Kalkman, V.J. Atlas of the dragonflies and damselflies of West and Central Asia. *Brachytron* **2021**, 3–248.
7. Lopau, W.; Adena, J. *Die Libellenfauna von Cypern Naturkundliche Reiseberichte. Heft 19*; Private Publikation: Gnarrenburg, Germany, 2002; p. 73.
8. Flint, P. Observations of dragonflies (Odonata) from northern Cyprus. *Libellula* **2019**, *38*, 1–28.
9. Ministry of Agriculture, Rural Development and the Environment. Previously. Available online: https://www.cyprus.gov.cy/moa (accessed on 3 January 2020).
10. Water Development Department. Dams of Cyprus. Ministry of Agriculture, Natural Resources and Environment. 2009. Available online: https://www.cyprus.gov.cy/moa/wdd (accessed on 2 July 2020).
11. Kier, G.; Kreft, H.; Ming Lee, T.; Jetz, W.; Ibisch, P.L.; Nowick, C.; Mutke, J.; Barthlott, W. A global assessment of endemism and species richness across island and mainland regions. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 9322–9327. [CrossRef] [PubMed]
12. Boudot, J.-P.; Kalkman, V.J.; Azpilicueta Amorín, M.; Bogdanovic, T.; Cordero Rivera, A.; Degabriele, G.; Dommanget, J.-L.; Ferreira, S.; Garrigos, B.; Jovic, M.; et al. Atlas of the Odonata of the Mediterranean and North Africa. *Libellula* **2009**, *1* (Suppl. 9), 1–256.
13. De Knijf, G.; Sparrow, D.J.; Dimitriou, A.C.; Kent, R.; Kent, H.; Siedle, K.; Lewis, J.; Crossley, L. Distribution, ecology and status of a threatened species *Ischnura intermedia* (Insecta: Odonata), new for Europe. *Int. J. Odonatol.* **2016**, *19*, 257–274. [CrossRef]
14. Vilenica, M.; Kulijer, D.; Gligorovic, B.; Gligorovic, A.; De Knijf, G. Distribution, habitat requirements and vulnerability of *Caliaeschna microstigma* (Odonata: Aeshnidae) at the north-western edge of the species' range. *Odonatologica* **2021**, in press.
15. Sparrow, D.J.; De Knijf, G.; Smith, M.S.; Sparrow, R.; Michaelides, M.; Konis, D.; Siedle, K. The circumtropical *Pantala flavescens* is a regular visitor to Cyprus and reproducing on the island (Odonata: Libellulidae). *Odonatologica* **2020**, *49*, 289–311.
16. Kalkman, V.J. Orthetrum sabina (Schneider, 1845). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 283–285.
17. Sparrow, D.J.; Makris, C.; Sparrow, R.; Michaelides, M.; Konis, D.; De Knijf, G. First records of *Aeshna isoceles* and the rediscovery of *Lestes barbarus* on Cyprus (Odonata: Lestidae, Aeshnidae). *Not. Odonatol.* **2020**, *9*, 185–195.
18. Navas, R.P.L. Insect Orientalia. Serie 9. *Mem. Accad. Pontif. Nuovi Lincei* **1932**, *2*, 913–919.
19. Boudot, J.-P.; Prentice, S. Calopteryx virgo (Linnaeus, 1758). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 73–74.
20. DG Environment. *Reporting under Article 17 of the Habitats Directive: Explanatory Notes and Guidelines for the Period 2013–2018*; DG Environment: Brussels, Belgium, 2017; p. 188.
21. Care, N.; Chester, E.T.; Robson, B.J. Flow regime change alters shredder identity but not leaf litter decomposition in headwater streams affected by severe, permanent drying. *Freshw. Biol.* **2021**, *66*, 1813–1830. [CrossRef]
22. Boudot, J.-P.; Raab, R. Lestes macrostigma (Eversmann, 1836). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 58–60.
23. Kalkman, V.J.; Marinov, M.; Kutsarov, Y. Epallage fatime (Charpentier, 1840). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 78–79.
24. Kalkman, V.J.; Jovic, M. Caliaeschna microstigma (Schneider, 1845). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 184–185.
25. Jödicke, R. *Die Binsenjungfern und Winterlibellen Europas/Lestidae*; Westarp Wissenschaften/Die Neue Brehm-Bücherei (Bd. 631): Magdeburg, Germany, 1997; p. 277.
26. De Knijf, G.; Demolder, H. Early spring observations of Odonata from Cyprus. *Libellula* **2013**, *32*, 59–74.
27. Kalkman, V.J.; Sacha, D.; David, S. Sympetrum striolatum (Charpentier, 1840). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 309–311.
28. Samraoui, B.; Bouzid, R.; Boulahbal, R.; Corbet, P.S. Postponed reproductive maturation in upland refuges maintains life-cycle continuity during the hot, dry season in Algerian dragonflies (Anisoptera). *Int. J. Odonatol.* **1998**, *1*, 118–135. [CrossRef]
29. Samraoui, B.; Corbet, P.S. The Odonata of Numidia, Northeastern Algeria. Part II. Seasonal ecology. *Int. J. Odonatol.* **2000**, *3*, 27–39. [CrossRef]

30. Dijkstra, K.-D.B.; Schröter, A.; Lewington, R. *Field Guide to the Dragonflies of Britain and Europe*, 2nd ed.; Bloomsbury Nature Guides: London, UK, 2020; p. 336.
31. Boudot, J.-P.; Dyatlova, E. Chalcolestes parvidens (Artobolevskij, 1929). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 52–53.
32. Tarboton, W.; Tarboton, M. *A Guide to the Dragonflies & Damselflies of South Africa*; Struik Nature: Cape Town, South Africa, 2015; p. 224.
33. Boudot, J.-P. Trithemis festiva (Rambur, 1842). In *Atlas of European Dragonflies and Damselflies*; Boudot, J.-P., Kalkman, V.J., Eds.; KNNV Publishing: Zeist, The Netherlands, 2015; pp. 317–318.