TIMINGS OF ADULT EMERGENCE AND FLIGHT PERIODS OF THE ODONATA OF THE GALLECS RURAL AREA PONDS (CATALONIA, NE SPAIN)

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Abstract: This article presents the results of a field study carried out in the Gallecs Rural Area (Barcelona, Catalonia, NE Spain) in 2015 in order to determine the emergence and flight periods of the dragonflies inhabiting a group of four small permanent and temporary man-made ponds set up through an amphibian breeding habitat project. In total fifteen taxa were recorded, most of which are common and well distributed throughout the Iberian territory. Exuviae collection provided valuable information on their life cycle, voltinism and sex ratios at emergence. In general, biotope characteristics influenced the timing of emergence and the composition of larval and adult communities, which differed between ponds, although less markedly in the case of the latter. There were also within-pond differences between larval and adult assemblages. While exuviae collection provided accurate information on the taxa breeding at each pond, records of adults reflected the diversity and composition of species at a broader landscape level due to dispersal movements between ponds.
Key words: Odonata, emergence, flight period, life cycle, ponds, Gallecs, Barcelona, Spain.

Periodos de emergencia y de vuelo de los odonatos de las charcas del Espacio de Interés Natural de Gallecs (Cataluña, NE España)
Resumen: El presente artículo recoge los resultados del trabajo de campo llevado a cabo en el Espacio de Interés Natural de Gallecs (Barcelona, Cataluña, NE España) en 2015 a fin de evaluar los períodos de emergencia y de vuelo de las especies de odonatos que albergan un conjunto de cuatro pequeñas charcas construidas o restauradas para favorecer la reproducción de anfibios. En total se registraron quince taxones, la mayoría de los cuales son comunes y están bien distribuidos por el territorio ibérico. La recogida de exuvias proporcionó información sobre su ciclo de vida, voltinismo y proporciones de sexos en la emergencia. En general, las características de cada biotopo influyeron en los periodos de emergencia y en la composición de las comunidades de larvas y adultos, que presentaron diferencias entre charcas, aunque menos marcadas en estos últimos. También se observaron diferencias dentro en una misma charca entre las asociaciones de exuvias y adultos. Mientras que la recolección de exuvias proporcionó información precisa sobre los taxones que se reproducen en cada charca, el registro de adultos reflejó la diversidad y composición de especies en el área de estudio debido a los movimientos de dispersión entre charcas.
Palabras clave: Odonata, emergencia, periodo de vuelo, ciclo de vida, charcas, Gallecs, Barcelona, España.

Introduction

Lentic water bodies such as ponds, lakes and wetlands are among the most endangered habitats for different reasons, namely pollution, lowering of the water table as a result of overdraft and land reclamation for agricultural, industrial, infrastructure and urban development. As a consequence, there is a growing awareness regarding the conservation of these biotopes that translates into initiatives aimed at their restoration and the creation of new ones. These initiatives, however, are rarely accompanied by studies conducted to identify the local flora and fauna or potential colonizers and the most appropriate way to attract and conserve them. In this regard, the man-made ponds studied in the Gallecs Rural Area (EIN, Area of Natural Interest, Mollet del Vallès, Barcelona), created or recovered in 2009-2010 and managed as amphibian breeding habitats, are an example of the conjunction of research and conservation (Maynou *et al*., 2017).

Odonates, with some notable exceptions, have aquatic larvae. Once metamorphosis is completed, individuals climb on some support, detach themselves from the exoskeleton or cuticle (exuvia) and undertake the adult terrestrial phase of their life cycle.

Information on the emergence and flight periods of the odonata species of a given locality is necessary to determine their temporal patterns of recruitment and reproduction in orden to improve habitat management and conservation. In this respect, exuviae collection provides indications of the effective reproduction of a taxon, its period and pattern of emergence, sex ratio (Hassall *et al*., 2007; Trapero-Quintana & Reyes-Tur, 2010) and other relevant characteristics such as adult size and its seasonal variation, protandry and protogyny and helps assess the viability of local populations (Corbet, 1999).

The present work has as its main goals: (1) to establish the emergence periods of the species reproducing at four managed ponds of the Gallecs Rural Area and to detect possible differences in their timing; (2) to determine the flight periods of all the occurring taxa and (3) to compare the exuviae and adults associations between the four ponds and, in each of them, the similarity in the specific composition of exuviae and adults.

This information, besides its punctual value, can be useful for the study and monitoring of the changes that occur over time in the species life cycles which, in turn, can provide clues on the responses of biota to climate change (Ott, 2010; Hassall *et al*., 2007).

Fig. 1. Sampled ponds. Clockwise from top left Can Jornet 1 (CJ1), Can Jornet 2 (CJ2), Torrent dels Oms (TO), Can Veire (CV). / *Charcas muestreadas. De izquierda a derecha y en sentido horario: Can Jornet 1 (CJ1), Can Jornet 2 (CJ2), Torrent dels Oms (TO), Can Veire (CV).*

Table I. Main features of the sampled ponds. / ***Características principales de las charcas muestreadas.***

Features	Can Jornet 1 (CJ1)	Can Jornet 2 (CJ2)	Torrent dels Oms (TO)	Can Veire (CV)
Surface area (m^2)	154	20	300	100
Water depth (cm)	140-170	100	50-100	10-50
Aquatic vegetation	Lilies and bulrushes in floating supports, stonewort, filamentous algae	Lilies, bulrushes, stonewort, filamentous algae	Reeds, bulrushes, stonewort, filamentous algae	Stonewort, filamentous algae
Former use	Irrigation	Irrigation	Newly created	Newly created
Immediate environment	Agricultural	Agricultural	Agricultural	Pine wood
Water permanence	Permanent	Permanent	Permanent	Ephemeral

Material and methods

Study area. The Gallecs Rural Area has an extent of approximately 733 ha belonging to various municipalities in the Vallès Oriental district of Barcelona. The main use of this space is agricultural (75% of the land) and plans are currently being implemented for the development of organic agriculture. The rest are small pine woods, small urban areas, roads and paths. In 2009 it was declared an Area of Natural Interest (EIN) with the aim of protecting one of the most singular landscapes of the Vallès region lowlands. Several streams cross the area although they lack surface water during most of the year. On the other hand, there are a number of man-made ponds scattered throughout the territory, most of them for agricultural use and a few arranged and managed to attract wildlife and especially amphibians. Four of these (Figure 1), created or recovered in 2009-2010, and the main features of which are indicated in Table I, were selected for this study. For more information about them and their surrounding environment and its management see Maynou *et al*. (2017).

Exuviae collection and adults records. To determine the emergence periods 58 visits were made from end of March to mid-November 2015 at irregular intervals but with a maximum of six days between them and always between 10:00 and 14:00 CEST. Corbet (1999) points out that, in order to avoid loss of exuviae due to rain and wind, it is important to carry out daily samplings. In the present study this was not possible. However, the characteristics of the ponds and the structure of the vegetation, which facilitated their detection, together with a favorable weather during practically the entire sampling period, lead to assume that the losses due to meteorological causes were minimal in the case of the species studied. Hence, it can be considered that, in each sampling, the exuviae of the majority of the individuals emerged after the previous sampling could be collected. Exuviae were identified and sexed in the laboratory with the keys of Jödicke (1994), Heidemann & Seidenbusch (2002) and Brochard *et al*. (2012) and stored dry in plastic containers.

Table II. Species recorded at the Gallecs Rural Area ponds and exuviae counts. Ad.: presence of adults; ?: exuviae not sexed. / *Especies registradas en las charcas del EIN de Gallecs y contaje de exuvias. Ad.: presencia de adultos; ?: exuvias no sexadas.*

TAXON	CAN JORNET 1 (CJ1)				CAN JORNET 2 (CJ2)				TORRENT DELS OMS (TO)				CAN VEIRE (CV)			
	Ad.	Exuviae			Ad.	Exuviae			Ad.	Exuviae			Ad.	Exuviae		
		♂	♀	?		♂	♀	?		♂	♀	?		♂	♀	?
Chalcolestes viridis (Vander Linden, 1825)	x	10	8	6	x	-	-	-	x	1	-	-	x	1	1	-
Sympecma fusca (Vander Linden, 1820)	x	2	2	1	x	-	-	-	-	-	-	-	-	-	-	-
Ischnura graellsii (Rambur, 1842)	x	2	5	4	x	2	1	-	x	7	6	2	x	5	6	3
Ischnura pumilio (Charpentier, 1825)	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Aeshna mixta Latreille, 1805	x	-	2	-	x	2	1	-	x	48	41	6	x	-	-	-
Aeshna cyanea (Müller, 1764)	x	-	1	-	x	-	-	-	x	-	-	-	x	-	-	-
Anax imperator Leach, 1815	x	378	383	11	x	68	57	9	x	66	70	-	x	44	64	7
Anax parthenope (Selys, 1839)	x	3	2	-	-	-	-	-	x	1	-	-	x	-	-	-
Libellula depressa Linnaeus, 1758	-	-	-	-	-	-	-	-	x	-	-	-	x	-	-	-
Orthetrum cancellatum (Linnaeus, 1758)	x	1	-	-	-	-	-	-	x	-	-	-	x	-	2	-
Sympetrum fonscolombii (Selys, 1840)	x	1	2	-	x	6	5	-	x	16	14	1	x	168	268	26
Sympetrum sinaiticum Dumont, 1977	x	25	24	1	x	1	-	-	x	1	4	-	x	-	-	-
Sympetrum striolatum (Charpentier, 1840)	x	61	83	9	x	6	4	-	x	2	1	-	x	9	15	4
Crocothemis erythraea (Brullé, 1832)	x	89	114	12	x	223	278	16	x	3	8	-	x	-	1	-
Trithemis annulata (Palisot de Beauvois, 1805)	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

The 50th percentile or EM_{50} indicates the number of days elapsed from the beginning of emergence until half of the individuals have emerged and allows to categorize a dragonfly as a spring species, that is, whose larvae spend the winter in the last stages of development and have a synchronized emergence, often in early spring, or as a summer species, which spends the winter as a larva in previous stages and emerges over a more extended period of time. Examples of these different patterns are found in a study by Corbet (1962) which showed an EM_{50} of three days for *Anax imperator* and one of 25 days for *Aeshna cyanea*. However, it is possible for a species to behave differently depending on the environmental conditions (Corbet, 1999).

Less than daily sampling does not allow identifying the day of the first emergences and makes it difficult to establish the EM_{50} value. On the other hand, this value depends on the size of the population because it is more likely to find the first exuviae in large populations (Hardersen, 2008). For these reasons, it has been decided to establish the characteristics of the emergence time interval according to Westermann's criteria (Westermann, 2002): the ***peak of emergence*** corresponds to the period between the first and third quartiles of all the emerged imagoes and the ***main period of emergence*** to that between the 10th and 90th percentiles. Hence, these periods do not depend on the first or last exuvia collected.

For the elaboration of the emergence graphs, field data have been grouped by weeks and only those species for which more than 49 exuviae were collected in the same pond have been considered. The nonparametric Mann-Whitney U and Kruskal-Wallis tests, using the median value, have been applied to compare emergence periods between ponds for a given species. These tests have the advantage of not being influenced by extreme values and of not depending on population size (Westerman, 2002; Hardersen, 2008). The pairwise Wilcoxon rank sum test, with Bonferroni correction, has been used to compare the timing of emergence among ponds.

The sex ratio has been calculated for the species for which more than 99 exuviae were sexed (Corbet & Hoess, 1998) and expressed as a percentage of males with respect to the total number of emerged individuals. The Pearson Chi-square test has been performed to determine the statistical significance of the proportions obtained. Additionally, the percentage of males at different times of the emergence period has been calculated: from the beginning until reaching P_{25} and P_{35}, as well as between P_{75} and P_{100} and between P_{90} and P_{100} (Farkas *et al.*, 2013). These values represent the sex distribution during the first and last dates of emergence respectively.

All these statistical tests were provided by R software (R Development Core Team, 2015).

To estimate the similarity between the associations of exuviae and adults between ponds and the within-pond similarity between the assemblages of exuviae and adults, presence-absence data were used to obtain the Jaccard index with EstimateS 9.10 (http:// viceroy.eeb.uconn.edu/estimates/).

According to Corbet (1999), the flight period is defined as the time interval when adults are mature and active. This period is influenced by factors such as the seasonal emergence pattern, adult longevity, immigration, local climate and weather and taxonomic affinity. During each visit, identified adult individuals were recorded and the flight period of each species was stablished as the time between the first and the last observations for the combined set of ponds.

Results

Emergences

Adult individuals of 15 species (4 Zygoptera and 11 Anisoptera) were recorded at the Gallecs ponds although one of them, *Ischnura pumilio*, represented by a single male, has been considered accidental. In addition, a total of 2843 exuviae belonging to 12 taxa were collected (Table II).

Aeshna mixta, *Anax imperator*; *Sympetrum fonscolombii*, *Sympetrum sinaiticum*, *Sympetrum striolatum* and *Crocothemis erythraea* were the taxa for which a sufficient number of exuviae were obtained to calculate the emergence parameters. At TO it was only possible to collect the *A. imperator* exuviae detected in the perimeter zone and consequently data obtained for this species at this pond have been excluded from the statistical analysis and calculations. Figure 2 shows the weekly percentages of exuviae collected during the emergence period and Table III the calculations of the descriptive parameters of the emergence pattern followed by each species and the pond from which the information was obtained.

The Mann-Whitney U test for *C. erythraea* (p-value< 0.001) indicates statistically significant differences in the emergence periods between ponds CJ1 and CJ2. For *A. imperator*, the Kruskal-Wallis test (p<0.001) points out significant differences between ponds CJ1, CJ2 and CV and the paired Wilcoxon rank sum test, with the Bonferroni correction, reveals that the differences were between CJ1 and the other two

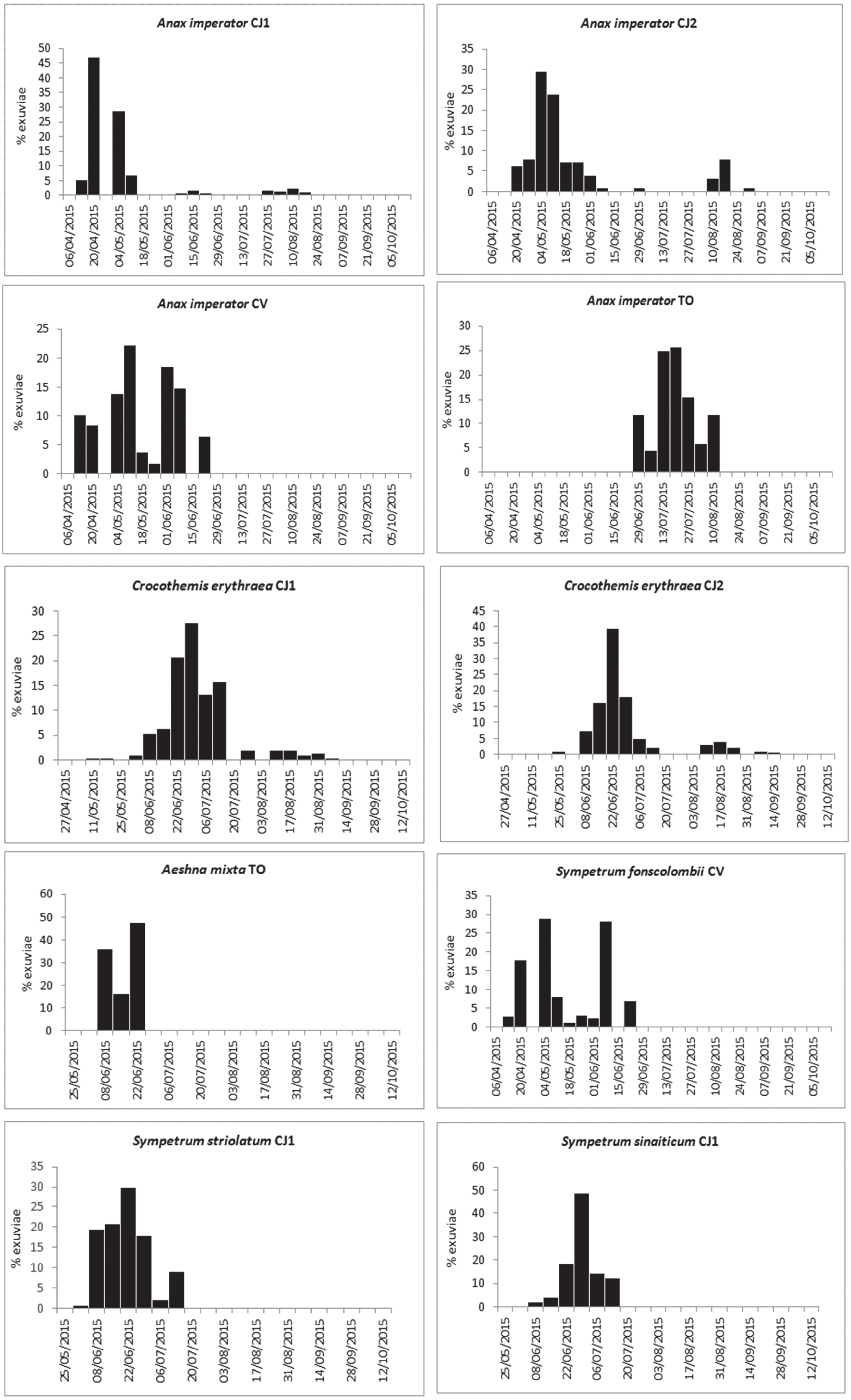

Fig. 2. Emergence periods. Data aggregated to weekly level. */ Periodos de emergencia. Datos agrupados semanalmente.*

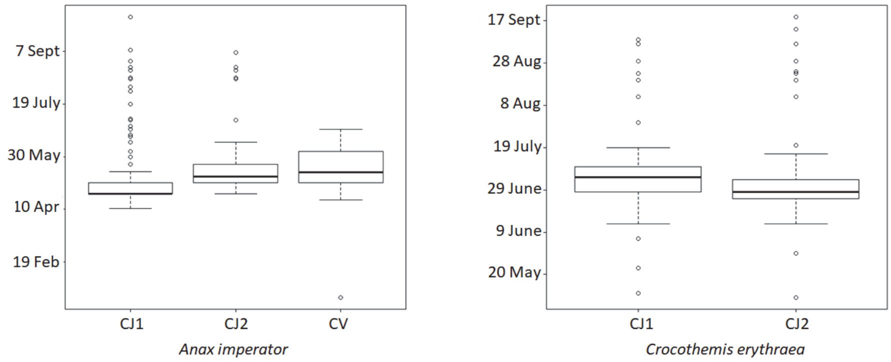

Fig. 3. Box-and-Whisker plots showing the timing of emergence of *Anax imperator* at ponds CJ1, CJ2 and CV and of *Crocothemis erythraea* at CJ1 and CJ2. / *Diagramas de caja de los periodos de emergencia de* Anax imperator *en las charcas CJ1, CJ2 y CV y de* Crocothemis erythraea *en CJ1 y CJ2.*

Table III. Main descriptive parameters of the emergence patterns followed by the species for which sufficient information could be obtained. N: total number of exuviae collected. The percentage values associated with the percentiles indicate the proportion of males that emerged at the beginning (P_{25}, P_{35}) and at the end (P_{75} - P_{100}, P_{90} - P_{100}) of the emergence period. *: Pearson Chi-squared test. / *Periodos de emergencia y principales parámetros descriptivos de los patrones seguidos por las especies de las que se pudo obtener suficiente información. N: número total de exuvias recogidas. Los valores porcentuales asociados a los percentiles indican la proporción de machos que emergieron al principio (P_{25}, P_{35}) y al final (P_{75} - P_{100}, P_{90} - P_{100}) del periodo de emergencia. *: prueba Chi-cuadrado de Pearson.*

	Anax imperator				*Aeshna mixta*	*Crocothemis erythraea*		*Sympetrum fonscolombii*	*Sympetrum striolatum*	*Sympetrum sinaiticum*
	CJ1	CJ2	CV	TO	TO	CJ1	CJ2	CV	CJ1	CJ1
N	761	125	108	136	89	203	490	436	144	49
First recorded emergence	11.IV	25.IV	11.IV	4.VII	13.VI	11.V	9.V	19.IV	6.VI	13.VI
Last recorded emergence	10.X	6.IX	10.X	-	28.VI	8.IX	19.IX	28.VI	19.VII	19.VII
Main period of emergence	25.IV–18.VI	30.IV-12.VIII	25.IV-18.VI	-	13.VI-25.VI	18.VI-19.VII	18.VI-12.VIII	25.IV-14.VI	13.VI-10.VII	25.VI-13.VII
Peak of emergence	25.IV–5.V	5.V-12.VIII	25.IV-5.V	-	13.VI-25.VI	28.VI-10.VII	25.VI-4.VII	5.V-14.VI[a]	18.VI-5.VII	4.VII-8.VII
Median	25.IV	11.V	25.IV	-	20.VI	5.VII	28.VI	11.V	25.VI	5.VII
% males (* = p-value<0.05)	49.67%	54.4%	40.7%	-	-	43.84%	45.30% *	38.5% *	42.4%	-
P_{25}	52.8%	70.7%	31.4%	-	-	38.57%	44.21%	37.3%	49.0%	-
P_{35}	52.8%	65.5%	38.2%	-	-	38.96%	44.1%	37.2%	49.0%	-
P_{75}-P_{100}	46.3%	45%	48.8%	-	-	50%	49.4%	41.1%	41.0%	-
P_{90}-P_{100}	46.2%	53.3%	61.1%	-	-	44%	32.7%	41.1%	33.3%	-

[a] (two maxima)

(p<0.001), while there were no significant differences between CJ2 and CV (see Figure 3).

The Jaccard index shows a lower similarity between the association of exuviae at CV and the rest of ponds and also between CJ1 and CJ2 (Table IV, a). For adults, the lowest similarity was recorded between CJ2 and CV and the highest between TO and CV (Table IV, b). The within-pond similarity between the assemblages of exuviae and adults was highest at CJ1 and lowest at CV (Table IV, c).

Flight periods

Regarding the flight periods of adult individuals, a large enough number of records could only be obtained for eleven species: *Chalcolestes viridis*, *Ischnura graellsii*, *Aeshna mixta*, *Anax imperator*, *Anax parthenope*, *Libellula depressa*, *Orthetrum cancellatum*, *Sympetrum fonscolombii*, *Sympetrum sinaiticum*, *Sympetrum striolatum* and *Crocothemis erythraea*. Figure 4 shows the time intervals corresponding to the flight periods of each species for the combined set of ponds.

Table IV. a) Similarity in the composition of species between ponds based on the collection of exuviae. b) Idem based on adult individuals. c) Comparison between associations of exuviae and adults within each pond. In all cases, presence-absence data were used to calculate the Jaccard index. / *a) Similitud en la composición de especies entre charcas a partir de la recolección de exuvias. b) Ídem a partir de individuos adultos. c) Comparación entre las asociaciones de exuvias y adultos en cada una de las charcas. En todos los casos se utilizaron datos de presencia para calcular el índice de Jaccard.*

		CJ1	CJ2	TO
Table IVa	CJ1			
	CJ2	0.583		
	TO	0.750	0.777	
	CV	0.583	0.555	0.600

		CJ1	CJ2	TO
Table IVb	CJ1			
	CJ2	0.769		
	TO	0.857	0.769	
	CV	0.785	0.692	0.923

	Pond	Jaccard similarity index
Table IVc	CJ1	0.923
	CJ2	0.700
	TO	0.692
	CV	0.583

Discussion

Three species, *Ischnura graellsii*, *Anax imperator* and *Sympetrum fonscolombii*, had very long flight periods in Gallecs, from mid-April to early or mid-November.

In the case of *I. graellsii*, the recorded period was longer than those reported for Tarragona (S Catalonia) (Jödicke, 1996), Catalonia in general (Martín *et al*., 2016) and Asturias (N Spain) (Ocharan Larrondo, 1987), all ending in late October, but shorter than in Andalusia (S Spain), where it extends from early March until end of November (Ferreras-Romero & Puchol Caballero, 1984). It was not possible to collect a sufficient number of exuviae to establish an emergence pattern with which to determine the number of peaks (generations). Nevertheless, such a long flight period points to a multivoltine life-cycle, probably with two or three generations per year as reported for Tarragona (Jödicke, 1996) but perhaps less than four as indicated for Morocco (Ben Azzouz & Aguesse, 1990).

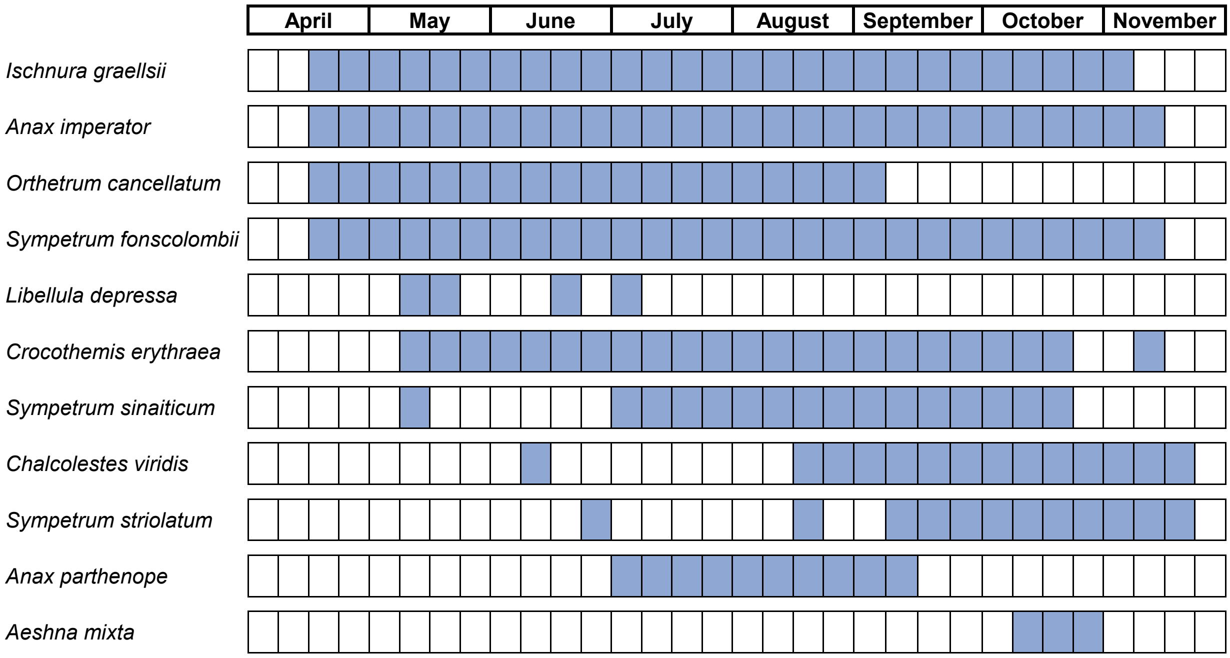

Fig. 4. Flight periods of the Odonata taxa occurring at the Gallecs Rural Area ponds recorded in 2015. / *Periodos de vuelo de los taxones de odonatos de las charcas del EIN de Gallecs registrados en 2015.*

Anax imperator showed a spring emergence pattern (*sensu* Corbet, 1962), i.e., emergence largely took place during a few weeks in spring. At two of the permanent ponds (CJ1 and CJ2) there was a second episode in summer although the number of exuviae collected was much smaller. This second episode could correspond to those larvae that spent the winter in stages prior to the last larval instars and were therefore not ready to emerge in spring. They were probably the offspring of individuals that also emerged and reproduced late in the previous year and consequently did not have enough time to reach more advanced development stages due to the onset of winter. At CV the pattern was similar although this second emergence event was not observed as the pond dried up in July. In the case of TO, the impossibility of accessing all the exuviae does not allow to determine the pattern with certainty but there was definitely a considerable delay in the beginning of emergence and it was also found that the exuviae were of smaller size in comparison with the rest of ponds (pers. obs). These findings may be attributed to several causes, including the absence of surface water for several weeks between July and August of the previous year (2014), the lower water temperatures recorded in the second half of 2014 in relation to CJ1 and CJ2 (between 2 and 5ºC less) and the disruption that suffered in January 2015 due to enlargement works. These works involved the addition of a large amount of relatively cold water extracted from a nearby well that could probably have diluted the available food or change saline proportions, affecting the larvae. Faced with this food shortage, it is likely that *A. imperator* larvae slowed their growth and even reduced the number of larval stages. This would explain the delay in its emergence and the smaller size of the exuviae in comparison with the rest of ponds (see Nijhout, 2008).

The flight period of *A. imperator* in Gallecs was long, ranging from mid-April to mid-November. The second emergence group (observed at CJ1 and CJ2), although much smaller than the first in number of individuals, would have extended the presence of adults at the breeding sites well into autumn, since it is not likely that individuals belonging to the first emergence group could be so long-lived.

Evidence obtained from the Gallecs ponds, located relatively close to each other, indicates that biotope characteristics affect the timing of emergence of *A. imperator* but it also points to a reasonably synchronized univoltine life-cycle for this species, as suggested by the examination of larval instar composition right before the onset of spring (pers. obs.). In contrast, Jödicke (1996) found a bivoltine pattern for this species in the province of Tarragona with a continuous emergence in May and June and without evidence of synchronization. Sánchez *et al.* (2009) point out that in Extremadura (SW Spain) the species can be uni or bivoltine depending on the temperature and D'Aguilar *et al.* (1986) sustain that larval development is completed in 3 or 4 months in the Mediterranean area. Lamelas-López *et al.* (2017) suggest a univoltine life cycle in the Azores archipelago.

At CV, in 2015, *S. fonscolombii* exhibited an emergence pattern corresponding to a bivoltine species. Observations made in 2014 (pers. obs.), a year during which the pond did not dry up, point even to trivoltinism, with a first generation occurring in spring, a second in early summer and a third in autumn, as also suggested by Jödicke (1996) for Tarragona. In Gallecs, its long flight period –from mid-April to mid-November–, similar to that reported by Jödicke (1996) for the Ebre river delta (S Catalonia), may be determined by this multivoltinism as well as by immigration of individuals from other areas (see Maynou *et al.*, 2017).

Chalcolestes viridis, *A. mixta*, *S. sinaiticum* and *S. striolatum* showed a similar emergence pattern, clearly unimodal, occurring in June in the first two cases and in June and the first half of July in the last two. Their flight periods occurred late in the season –except in the case of *S. sinaiticum*– from mid-August to end of November for *C. viridis* and *S. striolatum* and in October in the case of *A. mixta*. These periods are typical of estivating species that in the Mediterranean region undergo a process of slow maturation far from the reproductive habitats probably as an adaptation to their seasonality or to avoid competition with other species. The same phenology has been observed in populations of *S. sinaiticum* and *S. striolatum* in Tarragona (Jödicke, 1996). Cordero (1988) describes a similar life cycle pattern for *C. viridis* in Galicia. Agüero-Pelegrin *et al*. (1999) report a similar pattern in the Sierra Morena mountains, Andalusia, but with a more protracted estivation period (up to three months) and a flight period extending until early December, which seems to confirm a latitudinal cline in the phenology of this species. On the other hand, Muñoz-Pozo & Ferreras-Romero (1996) report a phenology for *A. mixta*, also in Sierra Morena, almost identical to that found in Gallecs, with a period of aestivation lasting about four months.

The presence of mature adults of *S. sinaiticum* in mid-May and of *S. striolatum* at the end of June, as shown in the graph in Figure 4, corresponds to one single male in each case. Consequently, these dates have not been considered within the main flight periods characteristic of these species in Gallecs.

At CJ1 and CJ2, *C. erythraea* showed an emergence period beginning in May but occurring mostly in June, with a second smaller peak in August (Figure 2) that could correspond to a second generation. This species had also a long flight period extending from mid-May to mid-November, suggesting a possible bivoltinism in Gallecs. This idea was further reinforced by a mark-and-recapture study carried out in parallel (Maynou *et al*., 2017) that showed a high level of natal phylopatry in this species (see also Ott, 2007). Besides, the fact that the maximum longevity detected in this study was 28 days, in agreement with the 29-32 days observed by Ott (1988), also points to a second generation flying until late in the season. Bivoltinism in *C. erythraea* in the Mediterranean region is also supported by the observations of Aguesse (1968), Montes *et al*. (1982) and Sánchez *et al*. (2009).

Little can be said about the emergence period of *O. cancellatum* in Gallecs from the field data obtained since only two exuviae were collected, one at CV on April 19 and another at CJ1 on June 4. The flight period ranged from beginning of May to mid-September, which seems to indicate that emergence starts early and extends over time, a typical feature of summer species (Hadjoudj *et al*., 2014).

Adults of *A. parthenope* were recorded between July and mid-September, a very short period of time compared to that reported for Catalonia (Martín *et al*., 2016), which ranges from mid-April to beginning of November. In addition, very few exuviae (N = 6) were found, suggesting that in Gallecs this species may only be an occasional breeder. This is possibly due to the strong competition of *A. imperator*, as was confirmed by the observation of frequent clashes between individuals that usually led to the expulsion of *A. parthenope*.

No exuviae of *L. depressa* were found and only a few adults were observed at TO and CV during May and June and consequently reproduction of this species at these ponds cannot be confirmed. It is possible that these individuals were incoming colonizers from nearby sites, a fact that agrees with the pioneer character of this species (Di Giovanni *et al*., 2000). The aspect of CV, a temporary pond, and of TO, recently reconditioned and almost devoid of aquatic vegetation during the above mentioned period, reinforces this hypothesis.

In Gallecs there were differences in the timing of emergence from pond to pond for the species for which comparisons could be made i.e. *A. imperator* and *C. erythraea*. Emergence is a critical step for dragonflies and they can adjust its timing depending on environmental conditions. Hence, life-history plasticity may lead to patterns differing considerably for a given taxon in nearby habitats. Many authors point to temperature as the main reason for this variation (Westermann, 2002; Suhling & Müller, 1996) but others report effects of food availability, predation risk (Brodin & Johansson, 2002), habitat temporality (De Block & Stoks, 2004), time of hatching (De Block & Stoks, 2005) and larval density (Farkas *et al*., 2012). At the investigated ponds, any of these causes or a combination thereof could have been responsible for the differing emergence patterns recorded for both species.

Differences were also found between the associations of exuviae at the four ponds (Table IV. a), which might be due to their different characteristics of size, degree of naturalness and seasonality and the conditions of their immediate surroundings, despite their proximity to one another. The temporality of CV may be the cause of the lower similarity that it showed, both in its association of exuviae with respect to the rest of the ponds and between its own associations of exuviae and adults. Within-pond differences were also found between the associations of exuviae and adults at CJ2, TO and CV (Table IV. c), which can be attributed to the instability of the water levels during 2014 and 2015. CJ1 showed a higher degree of similarity in this respect, perhaps explained by its larger size and much more stable water level. In any case, sampling methods for exuviae and adults are often not comparable and result in different associations, as some studies have shown (Hardersen, 2008; Raebel *et al*., 2010). Some exuviae are not detected during samplings, and therefore some species can be undersampled when studied as exuviae, while sampling of adults usually reflects the diversity and composition of species on a broader scale due to dispersal movements between nearby habitats (Giuliano *et al*., 2012) as reflected by the Jaccard test results for adults (Table IV. b), which confirm a greater similarity in species composition between the ponds studied.

More studies are needed to corroborate all these similarities and differences and to infer their causal associations at the Gallecs ponds.

Acknowledgements

To Manuel Ferreras-Romero, Roger Vila, David Martín and the anonymous reviewers for their valuable comments and suggestions; to Dani Aranda, for his collaboration in the field work; to Gemma Safont, technical manager of the Consortium of Gallecs, for allowing us to sample the ponds, and to the 'Departament de Territori i Sostenibilitat de la Generalitat de Catalunya' for the capture permits kindly granted. The authors would like to extend their gratitude to Jürgen Ott for kindly providing some of the works cited.

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