

Research article

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The EU conservation priority dragonfly *Oxygastra curtisii* in the Italian Lake District: a review and new data (Insecta: Odonata)

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Abstract

Oxygastra curtisii (Dale, 1834) is an Odonate species of EU conservation priority ('Habitat' directive Annex II and IV). In Italy, knowledge about its distribution is fragmentary. We updated and reviewed data on its distribution (geographic and altitudinal) and ecology (habitat preferences and phenology) in the Italian Lake District (an area of >5000 km² in NW Italy) and evaluated the adequacy of the Natura 2000 Network in protecting the species. We found the species to be present and rather widespread at the main pre-Alpine lakes (Lakes Maggiore, Lugano, Orta, Como, and Iseo, with the exclusion of Lake Garda), and several other smaller lakes. Based on current knowledge, a line running roughly north to south from Lake Moro to Lake Iseo is the easternmost limit of the species' range in northern Italy. While the flight period runs from the last decade of May to the second decade of August, it peaks between the second decade of June and the second decade of July. Our study showed the importance of two habitats whose significance for *O. curtisii* had been previously overlooked: lakes, which are an important habitat for reproduction, and grassland on the mountain slopes surrounding the lakes, which serve as an important pre-breeding and foraging habitat for immatures. Only 40% of known breeding localities are included in the Natura 2000 network, highlighting the potential vulnerability of this localized species in the area. In light of this, we believe it is essential to expand the Natura 2000 network to include more sites where this species is present, including foraging and pre-breeding areas, and to begin as soon as possible monitoring efforts to better assess the size of the *O. curtisii* population in the Italian Lake District.

Key words: Grassland, Lombardy, Natura 2000, Prealpine lakes, Piedmont, Synthemistidae.

Introduction

Dragonflies and damselflies (Insecta: Odonata) are widespread and rather easy to detect and identify; for this reason, they are among the best-studied insect taxa (Kalkman et al. 2018). Odonate assemblages respond rapidly to environmental change, making them reliable sentinels of aquatic habitat alterations and indicators of the wider freshwater communities (Assandri & Bazzi 2022; Kietzka et al. 2023). Moreover, as adult odonates need resource-rich terrestrial habitats around waterbodies and watercourses, they are

also sensitive to changes in landscape composition and configuration, such as urbanization and agricultural intensification (Nagy et al. 2019; Smith et al. 2023).

With a history of odonatological research in Italy and a surge of interest in the last 15 years, we now have a rather good knowledge of the Italian odonatofauna (Riservato et al. 2014b; La Porta et al. 2023). However, much remains to be done to uncover the distribution of several scarce or secretive species, including the Orange-spotted Emerald *Oxygastra curtisii* (Dale, 1834), a species of EU conservation priority included in the annexes II and IV of the 'Habitat'

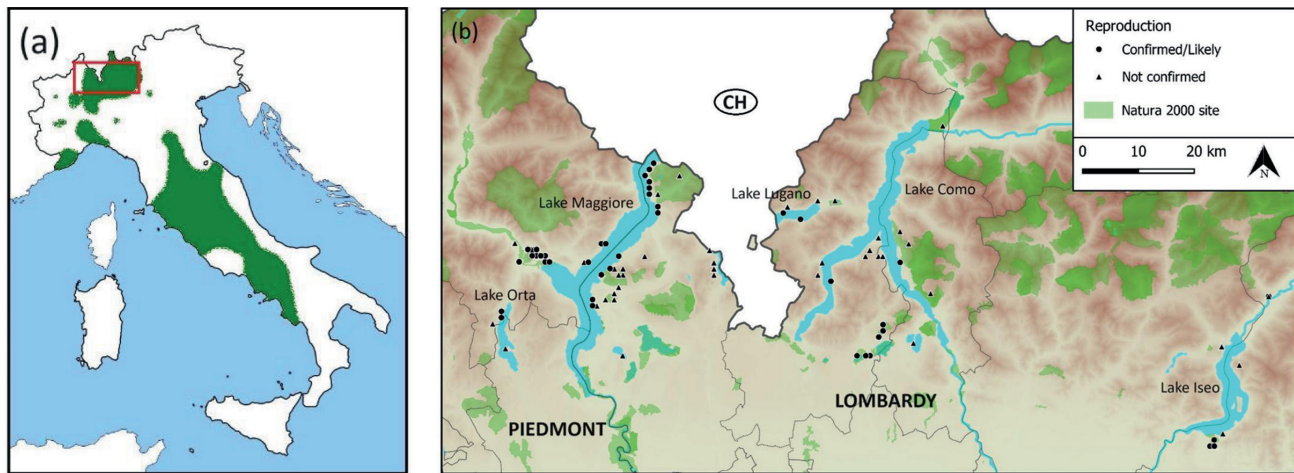


Fig. 1 – a, *Oxygastra curtisii* distribution in Italy. The map was drawn based on Riservato et al. (2014b), Corso et al. (2019) and personal observations of the authors; b, *Oxygastra curtisii* distribution in the Italian Lake District. Localities of occurrence (see text) are presented based on the reproduction status of the species in the area (confirmed or likely VS not confirmed). Natura 2000 sites in the study area are also mapped. Note that the occurrence sites on the rivers draining the lakes were not part of this study and are thus not shown. N=115.

Directive 92/43/EEC. This species is found exclusively in the Western Palearctic, mainly in Europe and locally in Morocco (Boudot et al. 2015). As summarized by Boudot (2020), *O. curtisii* is very rare in Belgium and Switzerland and is uncommon in most of Italy and northeastern and eastern France, while it is fairly common in southwestern and Mediterranean France. It is a local, low-density species in much of the Iberian Peninsula, but is much more widespread in western and southernmost Iberia than previously believed (Heras et al. 2017).

In Italy, the species prevalently occupies the western half of the country and is known from the following regions: Piedmont, Lombardy, Liguria, Emilia-Romagna, Tuscany, Umbria, Marche, Lazio, Abruzzo, Molise and Campania (Corso et al. 2019; La Porta et al. 2023). In northern Italy, most of the records referred to Liguria and southern Piedmont (Riservato et al. 2014b); with only a handful of observations from the left bank of the Po River, in the provinces of Novara, Turin, and Verbano-Cusio-Ossola in Piedmont (Boano et al. 2007; Clemente et al. 2011; Sindaco et al. 2018), and the provinces of Brescia (Balestrazzi & Bucciarelli 1975), Como (Balestrazzi & Pavesi 2008) and Varese (Mermet & Galli 2000) in Lombardy. A recent study elucidated its status in the Lario and Brianza areas, where *Oxygastra curtisii* proved more common and widespread than previously suspected (Bazzi et al. 2023).

Oxygastra curtisii is a thermophilic species that typically breeds along the intermediate course of rivers below an elevation of 500 m, where it generally prefers calmer waters, avoiding areas with strong currents (Mattei-Roesli & Maddalena 2013). Less frequently, it can also be found in standing waters such as abandoned gravel pits and oxbow lakes pools, ponds and large lakes with well-oxygenated waters (Boudot et al. 2015; Boudot 2020). It occupies water bodies characterized by natural shores with scattered

trees partially shading the water surface, combined with areas free from vegetation, particularly shrubs. Also important is the presence of fine sediment on the bottom, a fairly constant water level, and reduced wave activity. The naiads of *O. curtisii* prefer muddy bottoms or those covered by fine organic sediment, often in the tangles of roots of plants growing along the shore, but they also occur in deeper waters (Mattei-Roesli & Maddalena 2013; Boudot et al. 2015).

In Europe, *Oxygastra curtisii* underwent a moderate decline in the second half of the XX century (Boudot et al. 2015), becoming regionally extinct in the United Kingdom (last recorded in 1957), the Netherlands (1982) and recently disappearing from the Germany-Luxembourg border, presumably due to the invasion of the American crayfish *Pacifastacus leniusculus* (Oct 2018). Pollution, climate change, water reduction (use for households and agriculture), structural alteration of streams, and invasive species have contributed to the decline. The species is now considered stable over most of its range, but some of the threats mentioned above still apply and may result in local extinctions in the future, with some populations in parts of the Iberian Peninsula and Italy particularly at risk (Boudot et al. 2015). *O. curtisii* is currently treated as Least Concern in the Red List of globally threatened species (Boudot 2020), while previously it had been listed as Near Threatened in 2006; Vulnerable in 1996, 1994, 1990, and 1988; and Endangered in 1986. Additionally, it is evaluated as Least Concern in the Red List of dragonflies of the Mediterranean basin (Riservato et al. 2009), Near Threatened in the Red List of European dragonflies (De Knijf et al. 2024), and Near Threatened in the IUCN Red List of Italian dragonflies (Riservato et al. 2014a). Together with just 16 other European odonates, it is included in Annex II of Directive 92/43/EEC of the Council of 21 May 1992 (“Habitat Directive”), which comprises



Fig. 2 – Habitats used by *Oxygastra curtisii*: **a**, breeding habitat, Lake d’Orta (Piedmont, Verbania-Ossola province), 03.07.2021 (photo by Lucia Pompilio); **b**, breeding habitat, Lake Maggiore near the Santa Caterina monastery, Leggiuno (Lombardy, Varese province), 21.06.2017 (photo by Michele Viganò); **c**, breeding habitat, Lake Como, Olcio, Mandello del Lario (Lombardy, Lecco province), 03.07.2022 (photo by Gaia Bazzi); **d**, breeding habitat survey by canoe, Lake Mergozzo (Piedmont, Verbania-Ossola province), 08.07.2020 (photo by Lucia Pompilio); **e**, pre-breeding habitat on mountain slopes, open meadows at elevations between 700 and 900 m in Val Buseggia, Cittiglio (Lombardy, Varese province), 28.06.2018 (photo by Michele Viganò); **f**, pre-breeding habitat on mountain slopes, open meadows at elevations between 400 and 550 m above Lake Iseo near Cerrette (Lombardy, Bergamo province), 16.06.2022 (photo by Alessandro Mazzoleni).

plant and animal species of Community interest whose protection requires the designation of special conservation areas, and in Annex IV of the same directive, which comprises plant and animal species of Community interest requiring rigorous protection.

The purpose of our study was to revise and update knowledge on the distribution (geographical and altitudinal) and ecology (habitat preferences and phenology) of this dragonfly in Italy, particularly in the Italian Lake District of NW Italy. We also analysed the degree of overlap between sites where this species occurs and sites included in the Natura 2000 Network, to understand the potential role of this protected area network in the conservation of *Oxygastra curtisii*.

Study area

Our study area extends over the Italian Lake District of Piedmont and Lombardy (Fig. 1), northern Italy, covering more than 5000 km². The study area is located between the southern slopes of the Lepontine and the Bergamasque Alps to the north, where it is largely montane, and the upper Po Plain of Piedmont and Lombardy to the south; in the middle, the area is hilly and pre-Alpine in nature. There is a great diversity of wetland habitats, supported by high levels of annual rainfall ranging between 1400 and over 2000 mm/year (Regione Piemonte 2004, Regione Lombardia 1999). The main subalpine lakes in our study area are, from west to east, Lake Orta, Lake Maggiore, Lake Lugano, Lake Como, and Lake Iseo. These lakes are deep, and nutrient-poor, with relatively cold waters and

steep, rocky shores. In between these larger lakes is the smaller Lake Mergozzo separated from Lake Maggiore by the floodplain of the Toce River. The central part of our study area includes several small and medium-sized lakes, some of which are formed by the rivers that drain the large subalpine lakes. From east to west, these include the lakes of Monate, Comabbio, Varese, Montorfano, Alserio, Pusiano, Segrino, Annone, Sartirana, Garlate, and Olginate (Tab. 1). These are relatively shallow lakes, with water temperatures that are on average warmer than those of the larger lakes. They are mesotrophic, with vegetated and moderately sloping shores, and with a variable degree of floating vegetation. Some of the wetlands located along the main subalpine lakes have been spared from urbanization and are of crucial importance for the conservation of aquatic biodiversity in light of their rarity and uniqueness within a densely populated and urbanized matrix; the most important ones include the reedbeds at Fondotoce and the canal linking Lake Mergozzo and Lake Maggiore (Pompilio et al. 2018), Pian di Spagna, and lakes Alserio and Pusiano (Bazzi et al. 2023). We decided not to include records from the rivers draining the prealpine lakes, since our study focused on the role of lakes and their immediate surrounding habitats for the target species.

Materials and methods

Species occurrence data was obtained through 1) literature reviews; 2) *ad hoc* surveys performed by the authors and their collaborators; and 3) citizen science data. We collected a total of 258 records. Our literature review included

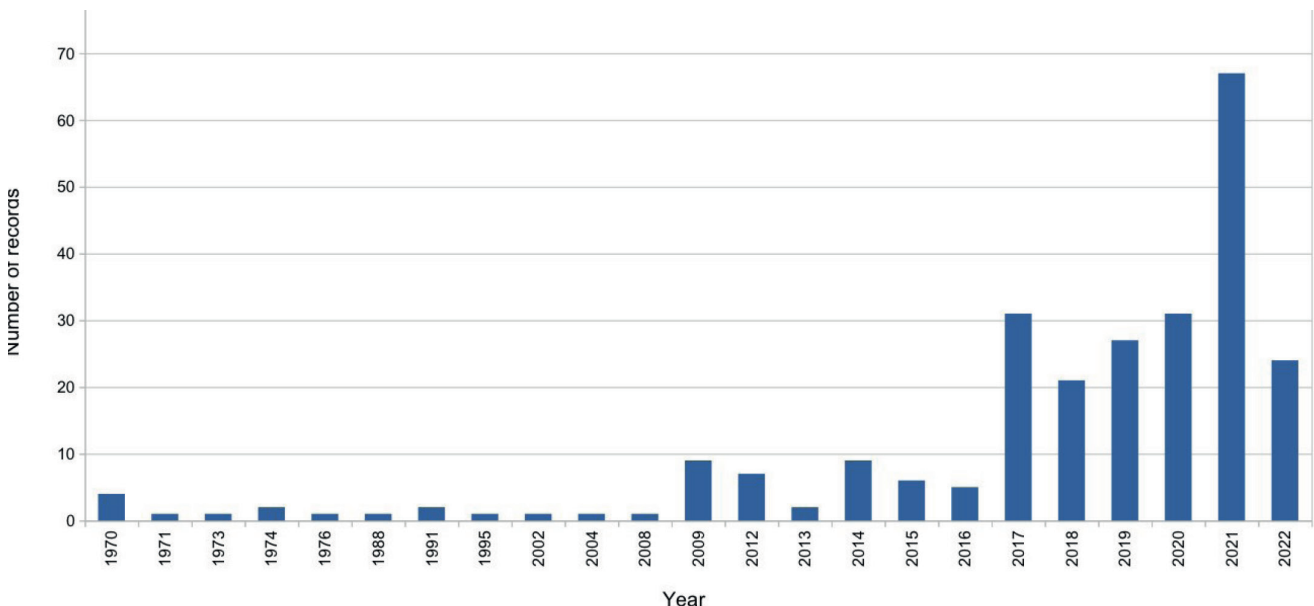


Fig. 3 – Number of records per year. The plot shows the number of records in the study area every year since 1970; the only previous record dates to 1925.

all the publications on the odonatofauna of our study area and resulted in 16 records of *O. curtisii* from 1925-2002 (Morton 1926; Balestrazzi & Bucciarelli 1971; Mermet & Galli 2000; Balestrazzi & Pavesi 2008). The remaining 243 records (94% of the total) concern unpublished data: 136 were collected by the authors during targeted surveys for this species, 12 are from citizen science projects (iNaturalist, observation.org) and the rest were provided by the authors' collaborators.

Targeted surveys were concentrated during the peak of the flight period for *Oxygastra curtisii*, during June and July between 10:00 and 16:00 under ideal weather conditions: air temperature over 17° C, no wind or breeze, and cloud cover under 50%. Adults were monitored by means of visual census, with the aid of 10x40 binoculars, and by entomological net captures. Individuals were counted and identified in the field by observing diagnostic characters following Dijkstra et al. (2020). Whenever possible, we conducted our surveys by canoe or kayak (Fig. 2d), which allowed us to easily explore lakeshore areas with suitable habitats that were not accessible from land. Opportunistic exuviae surveys were also carried out.

All data were scrutinized and validated. Breeding behaviour was evaluated based on Patten et al. (2019). Reproduction at a site was considered confirmed/likely when mating pairs, oviposition, and the occurrence of teneral, larvae, or exuviae were observed; we also included in this category occurrence in sites suitable for reproduction, in which more than one adult, or single individuals in multiple years were observed. Single observations at sites without suitable breeding habitats or for which details were not available were not considered confirmed breeding sites.

Most records were georeferenced in the field and few others through a GIS. Site elevation, when not specifically reported, was obtained based on coordinates from a DTM 20x20 m grid. Additionally, we assessed whether the sites: i) were within the boundaries of the Natura 2000 network based on the most recent Natura 2000 cartography updated to 2021 (<https://sdi.eea.europa.eu/data/dae737fd-7ee1-4b0a-9eb7-1954eec00c65>) and, ii) in which biogeographical area (according to EEA 2024) are located.

Records were merged based on toponyms; when a toponym was not available, we used the geographic coordinates with an approximation of two decimal degrees (approximately 1 km). This was performed to have a comparable number of occurrence localities when multiple records in time or space were available.

Results

We obtained occurrence data for *Oxygastra curtisii* in the study area dating back to 1925. Only 38 records date from earlier than 2014. The remaining 85% of the records in the dataset we report here were collected later, once we actively started exploring subalpine lakes in search of the species (Fig. 3).

Overall, we gathered 115 occurrence localities of *O. curtisii*. In 59 of these breeding was confirmed or suspected, while in 56 it was not confirmed, or the sites were not suitable for breeding (Fig. 1b). All the larger prealpine lakes in the study area harbour reproductive populations of the species, although most records are concentrated in the Lake Maggiore and Lake Como basins,

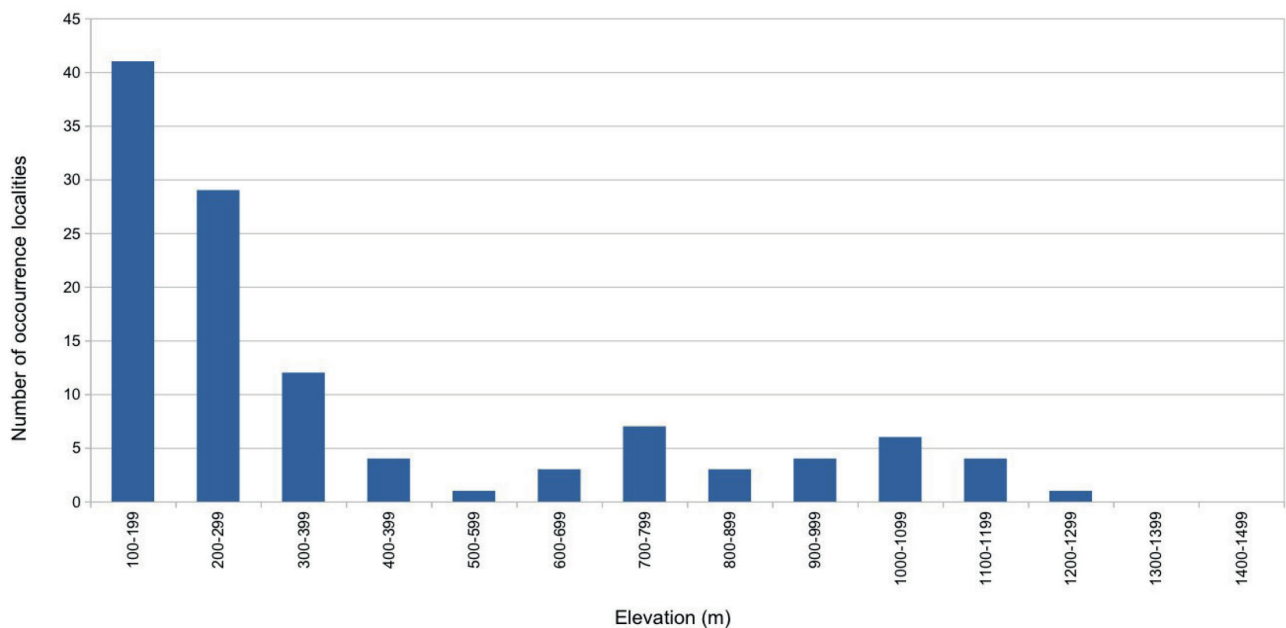


Fig. 4 – Number of occurrence localities per elevation belt.

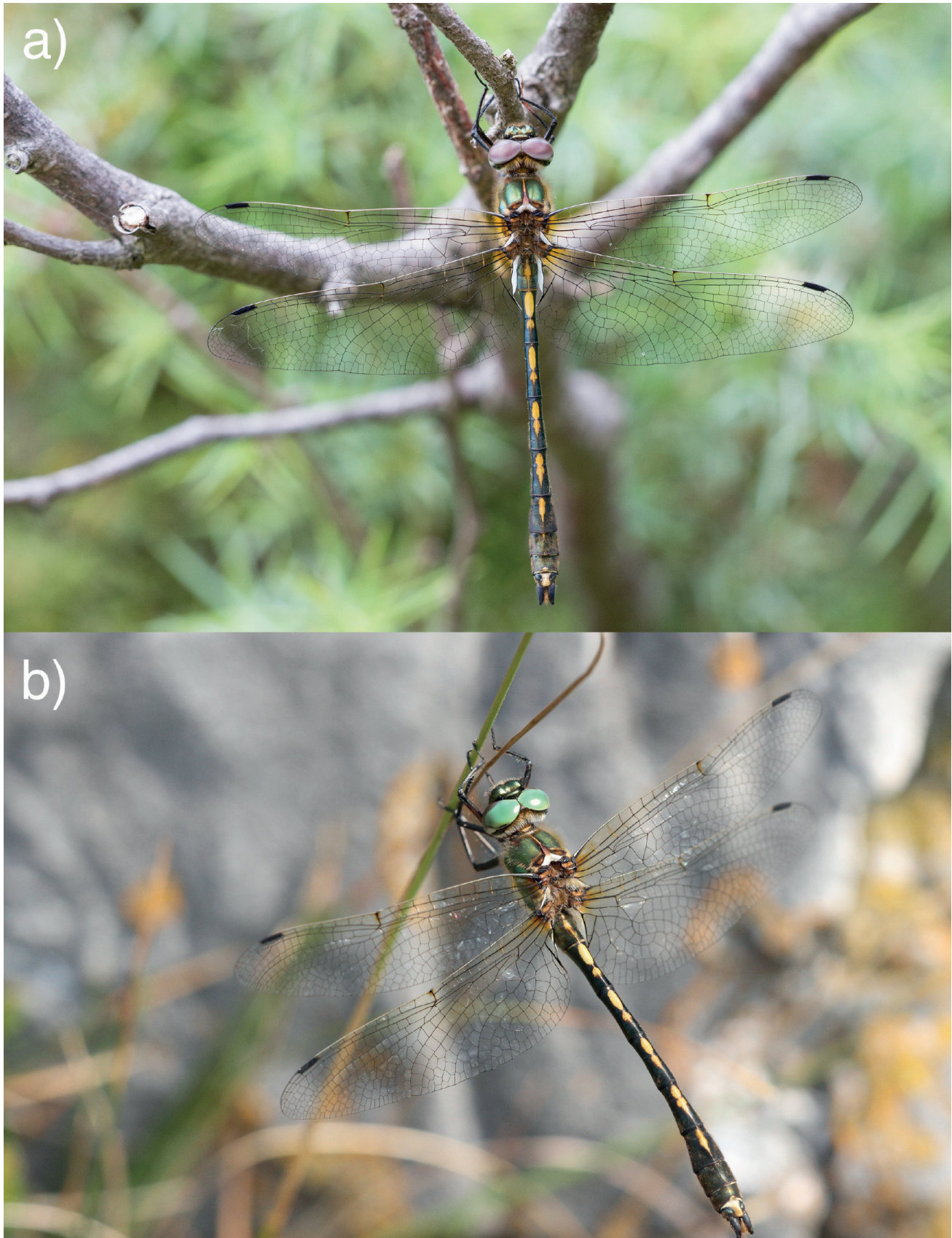


Fig. 5 – Males of *Oxygastra curtisii* in their pre-breeding habitat, open grassland in Val Buseggia, Cittiglio (Lombardy, Varese province): **a**, immature individual, 21.06.2018 (photo by Michele Viganò); **b**, fully mature individual, 03.07.2014 (photo by Michele Viganò).



Fig. 6 – Exuviae of *Oxygastra curtisii*: **a**, on a trunk, Lake Maggiore near the Santa Caterina monastery, Leggiuno (Lombardy, Varese province), 21.06.2017 (photo by Michele Viganò); **b**, on a rock, Como Lake, Olcio, Mandello del Lario (Lombardy, Lecco province), 03.07.2022 (photo by Gaia Bazzi).

while the species is apparently rarer in the Lake Iseo basin. On the contrary, only 7 out of 13 smaller lakes host populations of the species. The easternmost record in our study area concerns a population occurring at Lake Moro (Darfo Boario Terme, Brescia province), a small, natural lake (Fig. 1b; Tab. 1).

Our records span an elevational range from 185 m to 1291 m (Fig. 4). 71% of our occurrence localities (82), including all breeding localities, are comprised in an elevation belt between 185 and 399 m, covering the main pre-alpine lakes and the smaller lakes located in the study area (Fig. 2a-c). There are few occurrence localities between 400 and 599 m, but we find a second, lower peak between 600 and 1299 m, with 28 occurrence localities. These high-elevation records can be referred to individuals using grassland and open scrubland on mountain slopes in the vicinity of the main lakes (Fig. 1b; Fig. 2e-f). Specifically, these habitats are used from the second decade of June to the first decade of August by immature individuals, which can be recognized by pinkish eyes and variably translucent wings (Fig. 5a), to mature; later in the period adults can be seen as well (Fig. 5b). Some of these areas, such as Val Buseggia (Cittiglio, Varese), regularly host significant concentrations of *O. curtisii*, up to 40 individuals at a time.

The flight period in the study area spans from the third decade of May to the second decade of August. Emergence, as indicated by the presence of exuviae along lakeshores (Fig. 6) and freshly emerged individuals (Fig. 7), takes place in late May/June. The peak of occurrence is in the third decade of June (67 records) and the first decade of July (85 records), gradually diminishing thereafter (Fig. 8).

The species occurs in 13 Natura 2000 sites in our study area (10 SACs or SACs and SPAs and 3 SPAs) for a total of 46 occurrence localities, though breeding has been confirmed/is likely in only 6 of these sites (4 SACs or SACs and SPAs, and 2 SPAs) for a total of 24 occurrence localities. The near-totality of Natura 2000 sites in which the species is present are in the Alpine biogeographical region, except for site IT2020005-Lago di Alserio, which is in the Continental region. To date, a significant number of breeding sites are not included in the Natura 2000 network (Tab. 2).

Discussion

Until a few years ago, data on the distribution of *Oxygastra curtisii* in Italy was fragmentary. This is true for the Italian Lake District as well; indeed, when the Italian odonate atlas (Riservato et al. 2014b) was published, there were only



Fig. 7 – Freshly emerged individuals of *Oxygastra curtisii* in their pre-breeding habitat, Rocca di Caldé, Castelveccana (Lombardy, Varese province): **a**, female, 20.06.2012 (photo by Michele Viganò); **b**, male, 20.06.2012 (photo by Michele Viganò).

38 records of the species in our study area. From then on, advances in odonatological research spurred by the activities of the Italian Odonatological Society (Odonata.it) and the launch of the present study added a substantial amount of data that allowed us to elucidate the distribution of *O. curtisii* in this part of northern Italy and to better understand certain aspects of its biology.

More specifically, our surveys showed that the species is rather widespread in the study area, occurring in all of the main subalpine lakes (Lakes Maggiore, Orta, Lugano, Como, and Iseo) and at several smaller lakes. As far as is known, in northern Italy, the species does not occur east of Lake Iseo and Lake Moro; in fact, there are no records for the Lake Garda basin. While not included in our study area, this lake was the subject of other recent research which did not confirm the presence of the species (Riservato et al., 2014b; Assandri 2019); nevertheless, targeted surveys along the more natural stretches of the Lake Garda shoreline may be worthwhile to confirm (or not) the true absence of the species.

The known distribution of *Oxygastra curtisii* in our study area reflects our targeted research and suggests that the species may be more widespread in Italy than currently believed, as it has recently emerged in southern France (Krieg-Jacquier et al. 2014) and in Spain (Heras et al. 2017). Nevertheless, certain behavioural and ecological characteristics of *O. curtisii* make it elusive and difficult to survey. It prefers rivers and, as shown in this study, lakes, while most odonatological surveys take place in other types of wetlands such as ponds, marshes, and bogs. As shown in this study, while the flight period starts in the last decade of May and ends in the second decade of August,

it is highly concentrated in a single 30-day span: 85% of records are from the second decade of June to the second decade of July. Additionally, it is hard to see *O. curtisii* perched unless freshly emerged; the vast majority of sightings are of individuals in flight, either foraging over open meadows or patrolling territories. Finally, their preference for lake and river shores with a good amount of tree cover makes them hard to find from easily accessible waterside locations: the use of a canoe or kayak can greatly increase the chances of finding them.

Our study highlighted the importance for *Oxygastra curtisii* of two habitats whose significance had been underestimated in Italy. The first, from which most records derive, is lakes, an important breeding habitat (Fig. 2a-c). Before our study, there were only a handful of records from Italian lakes, and they were scattered over a lengthy period of time. The second important habitat is grassland and open scrublands on the mountain slopes surrounding the main subalpine lakes. Similar situations exist in nearby Canton Ticino (Switzerland), where stable populations on Lake Lugano and Lake Origgio use nearby mountain slopes during the pre-breeding period (Robert 1959; De Marmels & Schiess 1978; Wildermuth et al. 2005; Mattei-Roesli & Maddalena 2013).

In light of the decline of its European populations, especially during the second half of the XX century (Boudot et al. 2015), *Oxygastra curtisii* was included in Annex II of the “Habitat” Directive, meaning that EU Member states must designate Special Areas of Conservation for its protection. Although our study reports the discovery of significant, nationally and internationally relevant populations of the species in our study area, it also showed that only

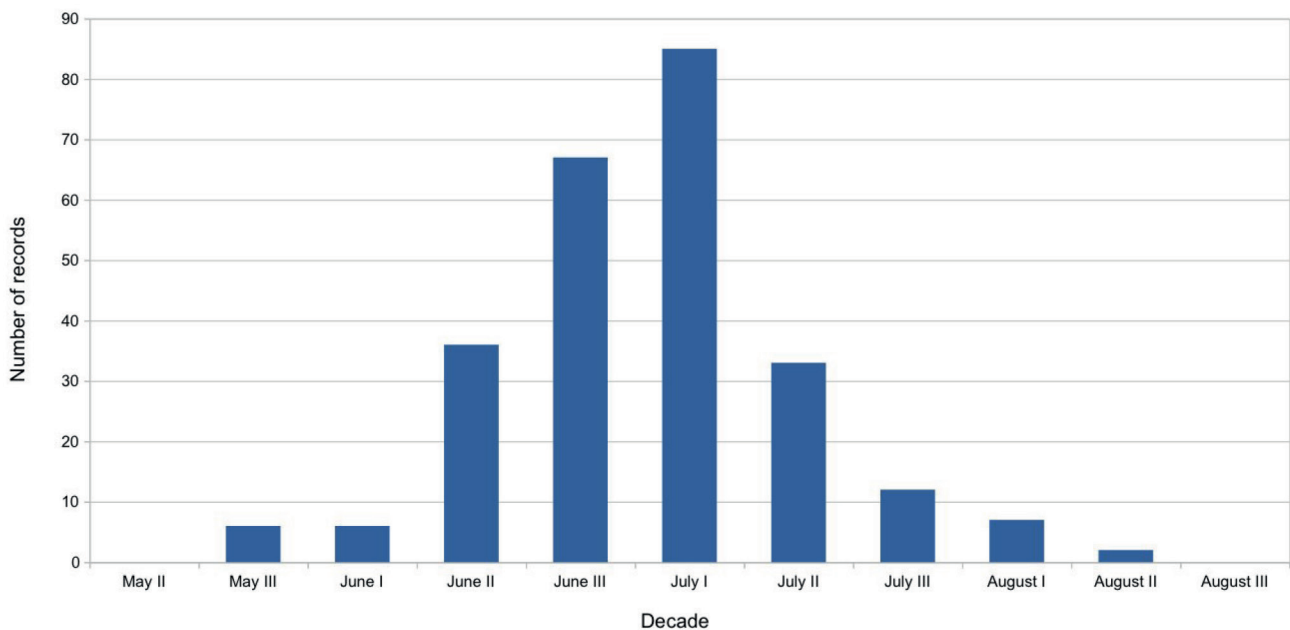


Fig. 8 – *Oxygastra curtisii* flight period in the study area. The number of records within each 10-day period is shown.

Table 1 – Main lakes surveyed during this study, with their surface area, elevation, and indications on the occurrence and reproduction of *Oxygastra curtisii*.

Lakes	Area (km ²)	Elevation (m a.s.l.)	Occurrence/reproduction
Orta	18.2	290	Reproduction confirmed/likely
Maggiore	213	193	Reproduction confirmed/likely
Lugano	48.7 (18 in Italy)	270	Reproduction confirmed/likely
Como	146	198	Reproduction confirmed/likely
Iseo	62	186	Reproduction confirmed/likely
Mergozzo	1.8	194	Reproduction confirmed/likely
Monate	2.5	266	Reproduction not confirmed
Comabbio	3.4	243	Never recorded so far
Varese	14.5	238	Never recorded so far
Montorfano	0.46	397	Never recorded so far
Alserio	1.2	260	Reproduction confirmed/likely
Pusiano	5.2	257	Never recorded so far
Segrino	0.3	374	Reproduction confirmed/likely
Annone	5.7	224	Reproduction not confirmed
Sartirana	0.1	319	Reproduction not confirmed
Garlate	4.5	198	Never recorded so far
Olginate	0.6	198	Never recorded so far
Moro	0.2	381	Reproduction confirmed/likely

40% of breeding localities and 38% of foraging localities or areas where breeding has not been proven fall within the Natura 2000 network, highlighting the potential vulnerability of the local populations of this uncommon species. Keeping in mind that the breeding sites for *O. curtisii* are under the constant threat of urbanization and tourism infrastructure (Bazzi et al. 2023), and that montane grassland hosting pre-breeding habitats are also diminishing because of the abandonment of traditional agricultural practices (MacDonald et al. 2000; Assandri et al. 2019), we

believe it is essential to expand the Natura 2000 network to include more sites where the species occurs, including those used by immature individuals to mature, and to rapidly strengthen monitoring efforts to better quantify the extent of the species population in the Italian Lake District.

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Table 2 – Presence of *Oxygastra curtisii* in the Natura 2000 network in the Italian Lake District. For each type of site in the Natura 2000 network, we indicate the occurrence localities for the species and its reproduction status (confirmed/likely vs not confirmed), along with the number of sites occupied. SPA: Special Protection Area (according to the Birds Directive); SAC: Special Area of Conservation (according to the Habitat Directive); SCI: Site of Conservation Interest.

		Reproduction			
		Confirmed/Likely		Not Confirmed	
		Occurrence localities	Number of Natura 2000 sites	Occurrence localities	Number of Natura 2000 sites
Site type	SPA – Type A	10	2 (2 Alpine)	3	3 (3 Alpine)
	SAC (or SCI) and SPA/SAC -Type B and C	14	4 (3 Alpine; 1 Continental)	19	7 (7 Alpine)
	Outside Natura 2000	35		34	

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