

## **Breeding of *Trithemis annulata* in quarry lakes in the continental area of Italy (Odonata: Libellulidae)**

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### **Abstract**

In August 2018, an abundant breeding population of *Trithemis annulata* was discovered in some quarry lakes located east of Milan (Lombardy, central Po Plain, northern Italy) and in Poncarale (province of Brescia, Lombardy). The autochthony of the species was confirmed due to the collection of ten exuviae and the observation of several dozens of tenerals and some hundreds of adult individuals. These are the first records of breeding populations of the species in the continental biogeographical zone of Italy. The presence of these populations is discussed from the perspective of the progressive colonization of southern Europe and Italy by this Afrotropical species, which is fostered by ongoing global warming.

### **Riassunto**

**Riproduzione di *Trithemis annulata* in laghi di cava nell'area continentale d'Italia (Odonata: Libellulidae)** – Nell'agosto 2018 un'abbondante popolazione riproduttiva di *Trithemis annulata* è stata scoperta in una serie di laghi di cava situati alla periferia orientale di Milano (Lombardia, Pianura Padana centrale, Italia settentrionale). L'autoctonia della specie è stata confermata grazie al ritrovamento di dieci esuvie e all'osservazione di decine di neosfarfallati e centinaia di adulti. Un'altra popolazione riproduttiva è stata scoperta in un altro lago di cava presso Poncarale (provincia di Brescia, Lombardia). Si tratta delle prime popolazioni riproduttive della specie accertate per la zona biogeografica continentale in Italia. La presenza di queste popolazioni viene discussa nella prospettiva della progressiva colonizzazione dell'Europa meridionale e dell'Italia da parte di questa specie afrotropicale, che è favorita dal riscaldamento globale attualmente in atto.

## Zusammenfassung

**Entwicklung von *Trithemis annulata* in Baggerseen der Po-Ebene, Italien (Odonata: Libellulidae)** – Im August 2018 wurde östlich von Mailand (Lombardei, zentrale Po-Ebene, Norditalien) an mehreren benachbarten Baggerseen eine große bodenständige Population von *Trithemis annulata* entdeckt. Durch die Aufsammlung von zehn Exuvien und die Beobachtung mehrerer Dutzend frisch geschlüpfter und einiger hundert erwachsener Individuen konnte der Bodenständigkeitsnachweis erbracht werden. Eine weitere reproduktive Population wurde an einem Baggersee in Poncarale (Provinz Brescia, Lombardei) nachgewiesen. Dies sind die ersten Bodenständigkeitsnachweise dieser Art in Gewässern der kontinentalen biogeographischen Region auf dem italienischen Festland. Die Entdeckung der Populationen wird im Zusammenhang mit der fortschreitenden Besiedelung Südeuropas und Italiens durch diese afrotropische Libellenart diskutiert, welche anscheinend durch die anhaltende globale Erwärmung begünstigt wird.

## Introduction

Odonata are increasingly recognized as reliable bioindicators of climate change (HASSALL 2015; TERMAAT et al. 2019). The effects of global warming on these insects include direct impacts on physiology, reproductive behaviour, phenology, distribution and dispersal abilities and indirect impacts due to modifications of habitats and trophic relationships (HASSALL et al. 2007; DINGEMANSE & KALKMAN 2008; HASSALL & THOMPSON 2008; GROPPALI 2009). Particularly evident is the double effect that the increase of temperatures due to climate change can have on the distribution of thermophilous odonata: it can foster poleward range expansion or shifts (HASSALL & THOMPSON 2008; GROPPALI 2009; DE KNIJF & ANSELIN 2010; OTT 2010; TERMAAT et al. 2019) and also allow them to colonize waterbodies at higher altitudes than was usual for those species (GROPPALI 2009; OERTLI 2010; OTT 2010).

In Europe, range expansions and/or shifts towards more northern latitudes have been confirmed from continental areas of central Europe (OTT 2007, 2010; BROCKHAUS et al. 2015; TERMAAT et al. 2019), warmer areas of south-western Europe (GRAND 2009) and the British Isles (HICKLING et al. 2005; TERMAAT et al. 2019). Also in the Mediterranean area such a phenomenon has been observed: many Mediterranean species are widening their ranges northwards, due to more favourable temperatures, which now allow their larval development at more northern latitudes and higher elevations (GRAND 2009; GROPPALI 2009). Under this trend, the first records of some African species in southern Italy occurred in recent years (RATTU et al. 2012, 2014; SOINSKI 2015; CONDELLO et al. 2017; CORSO et al. 2012, 2017; VIGANÒ et al. 2017; CILLO & BAZZATO 2018), while in northern Italy the first records of colonization and breeding of Mediterranean dragonflies have been reported recently (ZANDIGIACOMO & BUIAN 2010; SUBRERO 2014; UBONI et al. 2015; ROSSI et al. 2018) and also records of lowland species at higher altitudes are increasing (e.g., FESTI 2018).

*Trithemis annulata* (Palisot de Beauvois, 1805) (Odonata: Libellulidae) is a widespread Afrotropical species, which is expanding its range in southern Europe from the Mediterranean area mainly as a consequence of climate change (BALZAN 2008; BOUDOT et al. 2009; GRAND 2009; GROPPALI 2009). It is a generalist and pioneer species which can develop in waters with low oxygen concentrations (BALZAN 2008) and whose larvae have a fast development (BOUDOT et al. 2017), which also allows it to colonize temporary waterbodies (BOUDOT et al. 2017).

During its ongoing expansion, this species is extending its range along the Italian peninsula northwards. The earliest records in Italy refer to extreme southern and insular regions and date back to the end of the 19<sup>th</sup> century (CONCI & NIELSEN 1956; BOUDOT et al. 2017). Until the late 20<sup>th</sup> century this species was limited to southern regions (Lazio, Campania, Apulia, Basilicata, Calabria, Sicily and Sardinia: CARCHINI et al. 1985), but it has been reported recently in some regions of northern Italy, always in areas with a Mediterranean bioclimate: in 2007, it was recorded for the first time in both Liguria (OTTONELLO & ONETO 2013) and Emilia Romagna (FABBRI 2011). It has recently been recorded also in Veneto (ODONATA.IT 2018) and is currently widespread in southern Italy, Sicily, Sardinia and along the coast in central Italy (ODONATA.IT 2018).

The previous scattered records of *T. annulata* in Lombardy referred to sporadic and probably vagrant individuals (Piglia and Galliani, pers. obs.; cf. ODONATA.IT 2018). The first record for the region was a male observed at the “Parco Le Fologhe” park of Casei Gerola (province of Pavia) on 27. September 2015 by A. Piglia and C. Galliani. The aim of this note is to describe the first breeding populations of this species ascertained for Lombardy and for the continental biogeographical region of Italy, and to discuss this colonization from the perspective of climate change, which is the main driver of the ongoing range expansion of this species (BOUDOT et al. 2009).

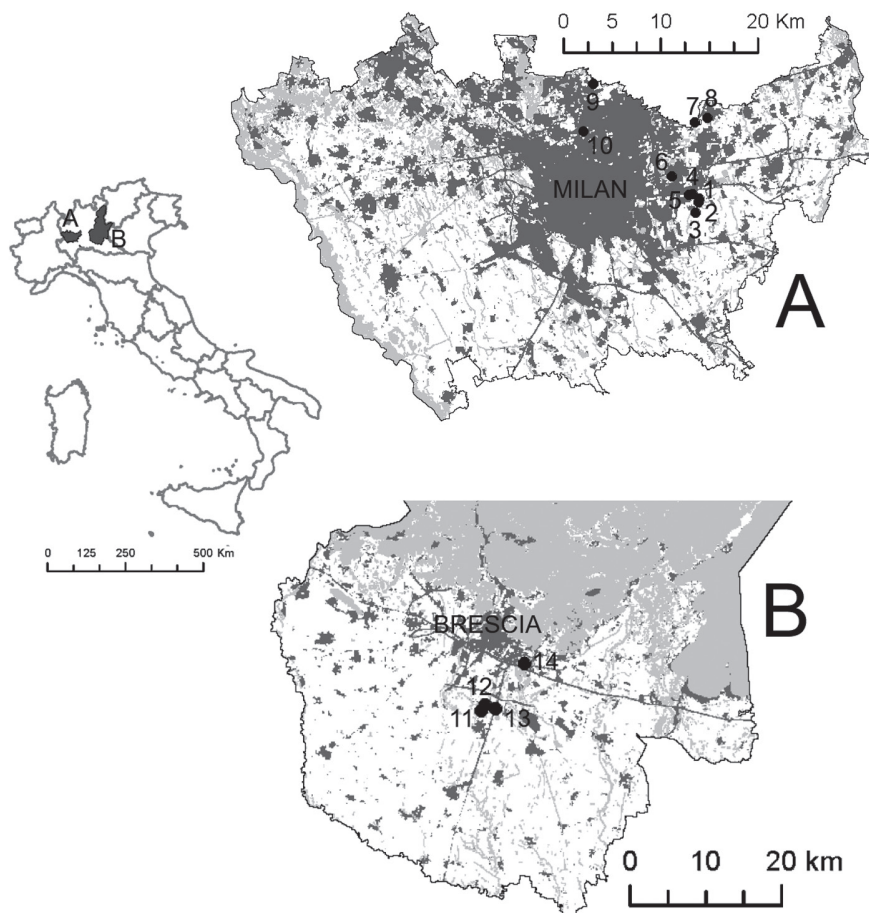
## Study area

The surveyed sites are located in the central Po Plain of Lombardy (northern Italy) (Fig. 1). The climate in the study area is warm temperate, with a mean annual temperature of 12.7°C (23°C of mean temperature in the warmest month, July, and 1.2–1.7°C of mean temperature in the coldest month, January) (CLIMATE-DATA.ORG 2019). The mean annual rainfall is 915 mm (63 mm of mean rainfall in the driest month, February, and 105 mm of mean rainfall in the wettest month, October) (CLIMATE-DATA.ORG 2019).

In Summer 2018, several waterbodies were surveyed in the surroundings of the city of Milan (western Lombardy plain) and in the area south of Brescia (eastern Lombardy plain). Most of them were decommissioned or still active quarry lakes, one is a man-made pond and one is a shallow artificial basin. Quarry lakes have distinctive features which make them different from other generic artificial basins found in the study area: they are deeper, wider, have a different bed and are

usually devoid of vegetation; in contrast, other artificial basins in the same areas (e.g., ponds in private gardens and public parks) are usually shallower, smaller and with aquatic vegetation.

The surveyed sites are briefly described here. Sites 1–10 are located around the city of Milan, in a highly urbanized area, while sites 11–14 are located in the agricultural landscape south of Brescia (Fig. 1). The two groups of sites are located about 80 kilometres apart.



**Figure 1.** Location of the study sites within the Po Plain of Lombardy. Dark grey: urbanized areas; light grey: natural and seminatural areas; white: agricultural areas. – **Abbildung 1:** Lage der Untersuchungsstellen in der Po-Ebene der Lombardei. Dunkelgrau: urbane Flächen, hellgrau: naturnahe Flächen, weiß: landwirtschaftliche Flächen.

1. Stagno della Besozza, Pioltello (45.470556° N, 9.321944° E, 113 m a.s.l.). An artificial pond created by spring water surrounded by a meadow and some shrub vegetation. Some invasive fish and turtle species occur in it.
2. Quarry lake owned by Holcim Aggregati Calcestruzzi s.r.l., Peschiera Borromeo (45.466389° N, 9.320833° E, 110–113 m a.s.l.). This quarry lake is located just south of the Bosco della Besozza. Here, the extraction activity is ongoing in this quarry unlike the other three quarries in the immediate vicinity. The quarry lake investigated here (Fig. 2) is 40 metres deep in the central part, and the extraction activity at the moment is carried out in the eastern part of the lake. The bottom of all the lakes is made of sand and gravel and generally hosts no aquatic vegetation. Only along the banks are there sparse herbs and forbs. The terrestrial vegetation includes mainly ruderal forbs and sparse trees. The lakes are rich in fish, and the invasive *Procambarus clarkii* Girard occurs.
3. Outskirts of San Bovio, Peschiera Borromeo (45.456944° N, 9.316389° E, 117 m a.s.l.). Residential area without waterbodies.
4. Lago Malaspina, Pioltello (45.474722° N, 9.313611° E, 113 m a.s.l.). Private property, only a very small part could be surveyed. Very reduced vegetation along the shores and no floating vegetation.
5. Shallow cement basin in Peschiera Borromeo (45.473611° N, 9.168611° E, 112 m a.s.l.). The basin hosts no vegetation, and is often dredged. It hosts no fish populations.
6. Quarry lake of Segrate (45.491111° N, 9.284444° E, 120 m a.s.l.). A very large lake, a section of which still is subject to extraction activities, the rest being a city park. Most of the shores were not accessible. Also in this case, no floating vegetation and reduced vegetation along the shores.
7. “Parco Increa” park, Brugherio (45.540833° N, 9.317778° E, 130 m a.s.l.). Now part of a city park, it is a large quarry lake. Hardly any floating vegetation, and reduced vegetation on the shores.
8. “Parco Blu degli Aironi” park, Cernusco sul Naviglio (45.544167° N, 9.334167° E, 137 m a.s.l.). Mostly inaccessible. It is a former quarry lake.
9. “Parco Lago Nord” park, Paderno Dugnano (45.577222° N, 9.185278° E, 150 m a.s.l.). Quarry lake turned into a city park. A small section in the middle has reeds, the rest is free of vegetation. A section is run as a fishing lake.
10. Lago Niguarda, Milano (45.524167° N, 9.186944° E, 137–140 m a.s.l.). Quarry lake turned into a city park. Almost all is free of vegetation.
11. “Laghi Mella”, Poncarale (45.447778° N, 10.186389° E, 91–95 m a.s.l.). These waterbodies are former quarry lakes now converted to fishing lakes and are private property. One of the lakes has an area with active extraction activities, and therefore was not accessible except for a very small part. The environmental conditions of the surroundings are very similar to those of the quarry lakes of Peschiera Borromeo. They have extremely reduced floating vegetation and generally a small amount of vegetation along the shores, which is kept clear for the fishermen. Obviously the lakes are rich in fish.

12. Quarry lake of Cava Gatti, Poncarale (45.465833° N, 10.191667° E, 98 m a.s.l.). Mostly inaccessible, as the extraction activities are still ongoing. Similar to Laghi Mella, it is almost completely devoid of floating vegetation. The shore vegetation is also reduced, including autochthonous as well as allochthonous plants. Part is dedicated to bass fishing.
13. “Parco delle Canoe” park (formerly quarry lake Canali), Montirone (45.469167° N, 10.201667° E, 99 m a.s.l.). Private property, former quarry lake, now a fishing lake with a section for canoeing activities. No floating vegetation and hardly any vegetation along the shore.
14. San Polo quarry lakes, a group of former quarry lakes turned into a large city park. Cava Nuova Beton sud (45.504722° N, 10.263333° E, 122 m a.s.l.); hardly any floating vegetation, extensive vegetation along the shores. It is not a fishing lake, but hosts a variety of fish, both autochthonous and allochthonous. Cava Faustini Nord (45.504167° N, 10.264167° E, 129 m a.s.l.). Unlike the previous former quarry lake, it has a very extensive floating vegetation. It also hosts a variety of fish, both autochthonous and allochthonous.



**Figure 2.** The quarry lake in Peschiera Borromeo in which the most abundant population of *Trithemis annulata* was found near Milan, 28-viii-2018. – **Abbildung 2:** Kiesgrube in Peschiera Borromeo nahe Mailand, in der die Population von *Trithemis annulata* mit der höchsten Abundanz gefunden wurde, 28.08.2018. Photo: AM



## Materials and methods

After the first casual observations of scattered individuals of *T. annulata* in or near Peschiera Borromeo (24.06., 20.07. and 19.08.2018) and in Poncarale (07.08. and 08.08.2018), targeted observations in the field were carried out at these two sites and at waterbodies in the surroundings from late August to November 2018 (see Tables 1 and 2 for the dates). The observations took place starting in the central part of the daytime preferably on warm and sunny days, but also on some days with less favourable conditions.

The finding of exuviae unequivocally indicates odonate autochthony at a water-body (CORBET 1993; OERTLI 2008), and RAEBEL et al. (2010) stated that the sampling of exuviae is the only valid criterion to ascertain the autochthony of odonata. However, BRIED et al. (2012) highlighted that exuvial surveys can underestimate the autochthony of species, and BRIED et al. (2015) proposed adult-based criteria to infer autochthony. Due to the morphology of the lake banks and to access limitations, an exhaustive sampling of exuviae was unachievable at the study sites; therefore, we considered also the criteria suggested by BRIED et al. (2015) as indications of possible autochthony of the species. However, exuviae were looked for whenever possible and where the bank morphology allowed it.

The adults were identified by means of the field guides by DIJKSTRA & LEWINGTON (2006) and GALLIANI et al. (2017) directly in the field and documented by means of good-quality photos taken during the field investigations. The exuviae were collected and identified by means of the keys by CARCHINI (1989) and BROCHARD et al. (2013). Nomenclature and taxonomy used here follow DIJKSTRA & LEWINGTON (2006).

## Results

Overall, this species was recorded in thirteen quarry or former quarry lakes: nine near Milan and four in the area south of Brescia. The largest populations were observed at the quarry lakes of Peschiera Borromeo (Table 1) and at a fishing lake in Poncarale (Table 2). The population of Peschiera Borromeo was first found in June at a pond observed regularly since August and had a gradual decrease until mid October (Table 1), while that of Poncarale, found in August and observed regularly since the beginning of September, decreased abruptly after bad weather occurred at the end of October (Table 2).

Several teneral adults were observed in late August and also in early September (Tables 1 and 2, Fig. 3). Furthermore, respectively two and eight exuviae of *T. annulata* were collected, on 28. and 30. August 2018 in Peschiera Borromeo (Table 1, Fig. 4) and one on 8. September 2018 in Poncarale (Table 2). All exuviae were found between 0 and 5 cm from the water line and between 15 and 30 cm above the ground, on stems of herbs or shrubs of *Salix* sp. Immature individuals were observed until the beginning of September in Peschiera Borromeo and until the second half of October in Poncarale.



**Figure 3.** Teneral female of *Trithemis annulata* observed at the quarry lake of Peschiera Borromeo on 26-viii-2018. – **Abbildung 3:** Frisches Weibchen von *Trithemis annulata*, das an einer Kiesgrube bei Peschiera Borromea am 26.08.2018 beobachtet wurde. Photo: AP



**Figure 4.** Exuvia of *Trithemis annulata* found at the quarry lake of Peschiera Borromeo on 28-viii-2018. – **Abbildung 4:** Exuvie von *Trithemis annulata*, die an einer Kiesgrube bei Peschiera Borromeo am 28.08.2018 gefunden wurde. Photo: GA



Mature males were observed mainly near the waterbodies, while only very few adult females were observed here. Mature males were very territorial not only towards males of the same species, but also against males and females of other dragonflies of the same size (e.g., *Crocothemis erythraea*) and territorial males of bigger species (e.g., *Orthetrum albistylum*, *Anax imperator*). Copulation was observed to take place in flight, as well as oviposition, with the male guarding the female from a short distance. The adults have been observed to be fully active also at relative low temperatures: copulation and oviposition were observed even at 18–19°C during cloudy weather (Table 2).

Other Odonata observed in the investigated quarry lakes are reported in Table 3. *Crocothemis erythraea* in particular occurred in Peschiera Borromeo with a population about five times greater than that of *T. annulata*, whereas in Poncarale *T. annulata* seemed equal in numbers to *C. erythraea* in August and more abundant in September; usually *T. annulata* was more active than *C. erythraea* at low temperatures (18–19°C) with a cloudy sky.

## Discussion

*Trithemis annulata* was observed at 12 sites in the surroundings of Milan and Brescia and certainly reproduces in two of the investigated quarry lakes (Peschiera Borromeo, near Milan, and Poncarale, south of Brescia), since many teneral were observed and also several exuviae were collected at these two sites. The number of observed tenerals and collected exuviae is small compared to the number of mature individuals observed: this is probably due to the delay with which the field investigations began with respect to the beginning of the emergence of the species. The scarcity of collected exuviae is also due to the fact that most of the bank could not be surveyed.

The flight season of *T. annulata* is reported to range from mid April to late December in Malta (GAUCI 2018) and from May to October in southern France (BOUDOT et al. 2017), the second case being compatible with the observations reported here from the Po Plain, where the species was recorded in flight until the end of October. For Liguria, in an area near the sea, OTTONELO & ONETO (2013) indicated the flight period of the species as being between June and August. Our records lack the beginning of the flight period, because the first observations of *T. annulata* at our study sites were made casually on already mature adults. The species is bivoltine in the Mediterranean area (BOUDOT et al. 2017) and its larval development is reported to be of about 7–8 weeks (BOUDOT et al. 2017). However, it is likely that at lower temperatures the larval development takes more time (CORBET 1999). The occurrence of mature individuals in June and of emerging individuals at the end of August gives evidence of bivoltinism, but the origin of the first generation needs to be ascertained with further observations in the coming years.

Quarry lakes are a suitable habitat for Odonata in the outskirts of Milan (FOGLINI 2016) and are reported as one of the main reproductive habitats of

**Table 1.** Observations of *Trithemis annulata* near Milan in the summer of 2018. – **Tabelle 1:** Beobachtungen von *Trithemis annulata* bei Mailand im Sommer 2018.

Date and observer(s)	
<b>1. Stagno della Besozza (Pioltello, MI)</b>	
20.06.2018 CCo	1 mature male.
20.07.2018 CCo	1 mature male.
23.08.2018 AM	6 mature and territorial males, 4 teneral females; territorial behaviour (against conspecific males as well as against <i>C. erythraea</i> and <i>O. albistylum</i> ) observed.
21.09.2018 AP	3 mature males, 4 females.
<b>2. Quarry Lakes of Peschiera Borromeo (Peschiera Borromeo)</b>	
23.08.2018 AM	About 50 adult males, 4 teneral females; mature males not yet territorial, mainly perched not near the water.
26.08.2018 AP, MLS, CG	About 400–500 individuals (immature males and females, mature males, only 1 mature female; a more precise estimation was very difficult), about 20 tenerals; mature males not yet territorial, mainly perched away from the water.
28.08.2018 GA, AM	Many (> 150) individuals (tenerals, immature males and females, mature males; a precise estimation was very difficult), 2 exuviae; mature males not yet territorial, mainly perched away from the water.
30.08.2018 AP, MLS	About 90–100 mature males, 15 tenerals, 8 exuviae; territorial behaviour (against conspecific males as well as against <i>C. erythraea</i> and <i>O. albistylum</i> ) observed for the first time in mature males, which were mostly near the water; no mature females observed on this date.
14.09.2018 AP	About 50 mature males, 1 mature female far from the water; territorial behaviour (against conspecific males as well as against <i>C. erythraea</i> ) observed.
21.09.2018 AP	About 25 mature males, 3 mature females.
12.10.2018 AP, MLS	About 20 mature males, 3 females; territorial behaviour observed, 1 mating and following guarded oviposition.
17.10.2018 AP, MLS	8 mature males, only thermoregulation and foraging behaviour observed.
<b>3. San Bovio (Peschiera Borromeo, MI)</b>	
19.08.2018 CCo	1 mature female.
<b>4. Lago Malaspina (Peschiera Borromeo, MI)</b>	
14.09.2018 AP, MLS	30 males; territorial behaviour (against conspecific males as well as against <i>C. erythraea</i> ) observed.
<b>5. Artificial basin (Peschiera Borromeo, MI)</b>	
09.09.2018 CCo	1 mature male.

Date and  
observer(s)**6. Quarry lake of Segrate (Segrate, MI)**

14.09.2018 16 males, 8 females, 1 immature individual; territorial behaviour (against AP, MLS conspecific males as well as against *C. erythraea*) observed.

**7. Parco Incea (Brugherio, MI)**

25.09.2018 65 males, 7 females; no territorial behaviour.  
AP, MLS

**8. Parco Blu degli Aironi (Cernusco sul Naviglio, MI)**

25.09.2018 14 mature males, no females observed; territorial behaviour against con-  
AP, MLS specific males as well as those of *C. erythraea*.

**9. Parco Lago Nord (Paderno Dugnano, MI)**

16.09.2018 5 mature males.  
CG

**10. Lago Niguarda (Milano)**

07.09.2018 5 mature males.  
AM

*T. annulata* in southern Europe (BROCHARD et al. 2013), including central northern Italy (FABBRI 2011; OTTONELLO & ONETO 2013). Furthermore, quarry lakes have been demonstrated to be the first colonized habitats by many southern species in central and northern Europe (e.g., BUCZYŃSKI 1999; OLBERG & LØNNVE 2012). However, *T. annulata* is able to colonize a wide variety of still and even slowly running waters (BALZAN 2008; BROCHARD et al. 2013; BOUDOT et al. 2017; GAUCI 2018).

The odonate assemblages observed are similar at the two main study sites (Table 3) and are composed of species which are all widespread in the Po Plain (cf. RISERVATO et al. 2014). The most frequent and abundant species, apart from *T. annulata*, are *I. elegans*, *C. erythraea*, *O. albistylum*, *S. fonscolombii* and *S. striolatum*: they are all species that in the study area typically colonize still waterbodies that have little vegetation and are often ephemeral.

We observed territorial behaviour of *T. annulata* males against *A. imperator*, *O. albistylum* and, most often, *C. erythraea*. Also BALZAN (2008) and CORSO et al. (2012) observed that territorial males are very aggressive not only towards other dragonflies of the same size (e.g., *C. erythraea*), but also towards bigger ones. In Peschiera Borromeo, *T. annulata* was the second most abundant species after *C. erythraea*, while in Poncarale the former was more abundant than the latter. These abundances are in accordance with the observations by BALZAN (2008) and CORSO et al. (2012), who reported that in some cases the colonization by *T. annulata* resulted in a local decline of *C. erythraea* due to the aggressiveness of *T. annulata*.

**Table 2.** Observations of *Trithemis annulata* near Brescia in the summer of 2018. – **Tabelle 2:** Beobachtungen von *Trithemis annulata* bei Brescia im Sommer 2018.

Date and observer(s)	
<b>11. Laghi Mella (Poncarale, BS)</b>	
07.08.2018 CCh	1 male and 1 female.
08.08.2018 CCh	2 males.
02.09.2018 AP, MLS	About 200 mature males, 1 mature female, 1 teneral male; about 10 matings and following guarded ovipositions, plus 1 unguarded oviposition. Territorial behaviour observed against conspecific, <i>C. erythraea</i> and <i>Anax imperator</i> . In spite of the bad weather, the maiden flight of one teneral male was observed in the morning (18°C); several mature adults showed breeding behaviour (copulation, oviposition) and were observed in the afternoon under a cloudy sky (19°C).
08.09.2018 AP, MLS	About 200 mature males, 6 mature females observed far from the water, 1 exuvia; territorial behaviours of males observed, also against <i>C. erythraea</i> males.
12.09.2018 CCh	38 mature males, 1 mature female; territorial behaviour of males observed, also against <i>C. erythraea</i> males.
15.09.2018 AP, MLS	About 150 mature males, 4 mature females, 3 immature males; territorial behaviour observed, but not reproductive activities.
22.09.2018 AP, MLS	About 350 mature males, 5 females, 3 immature males, 1 teneral male; territorial behaviour, foraging and thermoregulation; several matings and guarded ovipositions.
29.09.2018 AP, MLS, FS	About 300 mature males, 21 females, 7 immature males.
07.10.2018 AP, MLS, FS, CCh	About 130 males, 9 females, 6 immature males; about 40 matings and following guarded ovipositions plus 2 unguarded ovipositions.
14.10.2018 AP, MLS, FS	About 310 mature males, 7 females including old ones, 4 immature males.
20.10.2018 AP, MLS, FS, CCh	About 386 males, 5 females, 1 immature male; territorial behaviour against conspecific as well as against <i>C. erythraea</i> ; about 41 matings and following guarded ovipositions.
04.11.2018 AP, MLS, FS, CCh	4 males, 1 female; 1 mating and following guarded oviposition.
<b>12. Quarry lake Cava Gatti (Poncarale, BS)</b>	
12.09.2018 CCh	2 mature males.

Date and  
observer(s)**13. Parco delle Canoe (Montirone, BS)**

15.09.2018 28 mature males, 5 mature females, 2 immature males.

AP, MLS

14.10.2018 10 mature males.

CCh

**14. Cave di San Polo – Cava Nuova Beton Sud (Brescia)**

28.09.2018 3 mature males.

CCh

02.10.2018 8 mature males, 2 females.

CCh

12.10.2018 1 mature male.

CCh

Climate change is considered the main driver fostering the expansion of mediterranean odonata northwards (HICKLING et al. 2005; GRAND 2009; GROPPALI 2009; OTT 2010; TERMAAT et al. 2019) and this is surely true in the case of *T. annulata* (BALZAN 2008; BOUDOT et al. 2009; GRAND 2009; GROPPALI 2009). The sites reported here represent the northernmost breeding populations of *T. annulata* in Italy. In Europe, the species has reached such northern latitudes so far only in western France (BOUDOT et al. 2009). The northernmost record of the species in Europe however occurred near to Fadd, in Hungary (BIRDLIFE HUNGARY 2019). Furthermore, as a lentic species, *T. annulata* can be expected to have a wider northward shift, together with other lentic odonates, than lotic species (GREWE et al. 2013). This tendency seems to be related to the persistence of reproductive habitats, since lentic habitats are often less stable than lotic ones, and therefore lentic odonata disperse better than lotic ones (GREWE et al. 2013).

In recent years, other odonate species with similar ecology and/or dispersal abilities shifted their range northwards along Italy. Some of them crossed the Mediterranean occasionally or even began breeding in southern peninsular Italy or in the main islands. *Brachythemis impartita* (Karsch, 1890) was recorded in 2015 in peninsular Italy (Calabria and Apulia: CONDELLO et al. 2017), *Diplacodes lefebvrei* (Rambur, 1842) in 2013 in Sardinia (RATTU et al. 2014), *Tramea basilaris* (Palisot de Beauvois, 1805) in 2016 in the Sicilian Channel (VIGANÒ et al. 2017), *T. kirbyi* Selys-Longchamps, 1819 in 2003 in Sardinia and in 2012 in the Sicilian Channel (HOLUŠA 2008; CORSO et al. 2012, 2017), *Zygonyx torridus* (Kirby, 1889) in 2014 in Sicily (SOINSKI 2015). In northern Italy, *Calopteryx haemorrhoidalis* (Vander Linden, 1825) and *Selysiothemis nigra* (Vander Linden, 1825) began breeding in the Po Plain, outside areas with mediterranean climate (ZANDIGIACOMO & BUIAN 2010; SUBRERO 2014; UBONI et al. 2015; ROSSI et al. 2018).



**Table 3.** Odonata surveyed at the main and most investigated waterbodies (Stagno della Besozza, quarry lakes of Peschiera Borromeo and quarry lakes of Laghi Mella, Poncarale), with the dates on which they were observed. \* Occasional species; \*\* regular species, whose autochthony was not proved; \*\*\* likely autochthonous species. – **Tabelle 3:** Libellenarten der hauptsächlich untersuchten Gewässer (Stagno della Besozza, Kiesgruben bei Peschiera Borromeo and Kiesgruben bei Laghi Mella, Poncarale), mit Beobachtungsdatum. \* Nur gelegentlich beobachtete Arten; \*\* regelmäßig auftretende Arten ohne Bodenständigkeitsnachweis; \*\*\* sicher bodenständige Arten.

	Stagno della Besozza (pond)	Peschiera Borromeo (quarry lakes)	Laghi Mella (quarry lakes)
<i>Calopteryx splendens</i>	—	—	* 08.09, 29.09.2019
<i>Calopteryx virgo</i>	—	—	* 29.09.2019
<i>Enallagma cyathigerum</i>	—	* 28.08.2018	—
<i>Ischnura elegans</i>	* 24.06.2018	** 26.08, 28.08, 30.08.2018	** 02.09, 15.09, 29.09, 7.10, 20.10.2018
<i>Platycnemis pennipes</i>	—	—	* 02.09, 15.09.2018
<i>Aeshna cyanea</i>	—	* 23.08.2018	—
<i>Anax imperator</i>	* 24.06.2018	* 26.08.2018	* 02.09.2018
<i>Anax parthenope</i>	—	*** 26.08, 28.08, 30.08, 14.09.2018	—
<i>Crocothemis erythraea</i>	* 24.06, 23.08.2018	*** 26.08, 28.08, 30.08, 09.09, 14.09, 12.10, 17.10.2018	*** 07.08, 02.09, 12.09, 15.09, 22.09, 29.09, 07.10, 14.10, 20.10.2018
<i>Orthetrum cancellatum</i>	—	—	** 08.09, 12.09, 15.09, 22.09.2018
<i>Orthetrum coerulescens</i>	* 24.06.2018	—	** 08.09, 15.09.2018
<i>Sympetrum depressiusculum</i>	* 23.08.2018	—	* 22.09.2018
<i>Sympetrum fonscolombii</i>	—	*** 26.08, 28.08.2018	* 07.08, 15.09.2018
<i>Sympetrum pedemontanum</i>	—	** 26.08, 30.08, 21.09.2018	—

	Stagno della Besozza (pond)	Peschiera Borromeo (quarry lakes)	Laghi Mella (quarry lakes)
<i>Sympetrum striolatum</i>	—	*** 14.09, 21.09, 12.10, 17.10.2018	** 08.09, 15.09, 22.09, 29.09, 7.10, 14.10, 20.10.2018
<i>Trithemis annulata</i>	* See Table 1	*** See Table 1	*** See Table 2
Number of species	7	11	13

## Conclusions

The breeding of *T. annulata* has been reported to occur at some quarry lakes of the central Po Plain of Lombardy in the summer of 2018. However, the autochthony of the species is demonstrated only for that period, and could be due to the breeding of a few vagrant individuals which oviposited in the spring. A great number of emerged individuals and the good dispersal abilities of the species could even have been sufficient to determine the colonization of several waterbodies in a single flight season. On the other hand, single observations of vagrant individuals near Milan have also been made in recent years before 2018 (Piglia and Galliani, pers. obs.; cf. ODONATA.IT 2018). In any case, it is yet to be demonstrated whether the species is able to survive the winter season at such a northern latitude: further observations in a geographic situation such as the currently reported sites in future years will be necessary to clarify this issue, together with the phenology and voltinism of this species.

If, due to the now milder winters, *T. annulata* is able to survive the cold season, it could be expected to further expand its range in the Po Plain. The ecological characteristics of this species – the ability to colonize pioneer waterbodies, the fast larval development, the good dispersal capacity, and strong territoriality of adult males – make it a good candidate to quickly colonize the lowlands of northern Italy. Quarry lakes are a candidate to be the most suitable habitat in the area: in fact, quarry lakes have been reported as colonization waterbodies for Mediterranean odonata in central and northern Europe (BUCZYŃSKI 1999; OLBERG & LØNNVE 2012), and they are certainly a suitable habitat mainly for early colonizers such as *T. annulata*.

The further expansion of this species in quarry lakes and similar habitats of the Po Plain should be carefully monitored in the coming years, in order to better understand its colonization dynamics, voltinism and phenology at such a northern latitude.

## Acknowledgements

We thank the company, Holcim Aggregati Calcestruzzi s.r.l., and in particular its Production Manager and Quarry Manager, Massimiliano Volpones, as well as Luigi Lamperti, president of the Fishing Club Laghi Mella, and finally Mr. Giancarlo Tognassi and Mr. Roberto Pietroboni of the association Lago Canali Liberaventura who assisted us with information and authorizations to access the areas at the quarry lakes we investigated. We also gratefully acknowledge Maurizio Pavesi for his useful comments, Christian Dreifert, Mathias Lohr and Andreas Martens for the translation of abstract and captions into German and Matteo Barcella for his help in the realization of the map.

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*Manuskripteingang: 25. Juni 2019*

