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CONTRIBUTION TO THE KNOWLEDGE OF DRAGONFLY FAUNA (INSECTA: ODONATA) OF BJELOVAR AREA, CROATIA – RESULTS OF A FOUR-YEAR PHOTOGRAPHIC STUDY

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This paper gives a list of 10 species from five Odonata families observed in Gornje Plavnice near Bjelovar, Croatia in a period between the 18th of June 2017 and the 11th of August 2020. This photographic research, conducted along the Jarak Pond and on the surrounding meadows, agricultural land and forest edge in Gornje Plavnice, represents a contribution to the knowledge of dragonfly fauna of the Bjelovar-Bilogora area as well as of Croatia as a whole.

Key words: Odonata, fauna, Gornje Plavnice, Bjelovar-Bilogora area

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Rad donosi popis 10 vrsta vretenaca iz 5 porodica zabilježenih u Gornjim Plavnicama blizu grada Bjelovara, Hrvatska, u razdoblju od 18. lipnja 2017. do 11. kolovoza 2020. godine. Ovo istraživanje, temeljeno na fotografijama, provedeno je uz ribnjak "Jarak" te na okolnim livadama, poljoprivrednim površinama i rubnom području šume u Gornjim Plavnicama te predstavlja doprinos poznavanju faune vretenaca bjelovarsko-bilogorskog područja i Hrvatske.

Ključne riječi: Odonata, fauna, Gornje Plavnice, bjelovarsko-bilogorsko područje

INTRODUCTION

Many dragonfly observers avoid collecting and preparation of dragonfly individuals because of personal ethical or legal reasons, which raises the question of a substitute for the collection of voucher specimens to ensure the credibility of species identification (Schmidt, 1982; Day *et al*., 2012). Although in the absence of voucher specimens, the correct identification of any adult dragonfly specimens observed cannot be guaranteed, photography offers some possibilities (Schmidt, 1982). The photographic approach (by taking only decent pictures, without sampling the animal) promises to be of immense help in the inventorying of dragonfly species for its reliability in species identification (Janra, 2018). The ease of digital photography and increasing public interest in research into nature result in a rapidly increasing collection of photographic records of Odonata that provide data useful to science (Day *et al*., 2012). Many different web platforms (e.g. BugGuide, iNaturalist, Croatian checklist of Odonata, etc.) enable such photographic records to become a good basis for further research.

When using "dragonfly watching" as a basis for faunistic records, the great challenge is to filter out the noise of unreliable identification from photographs because photographs are often taken from the wrong angle, or use the wrong plane of focus to show key characteristics such as particular veins or other details. (Schmidt, 1982; Day *et al*., 2012). Knowledge of differential characteristics usable for voucher photos (Schmidt, 1982) as well as guides for the identification of dragonflies by sight and by photographs (Schmidt, 1995; Galliani *et al*., 2017) facilitate species identification from photographs. Reliable photographic records still appear to be biased towards common, photogenic and widespread species (Day *et al*., 2012). However, seven Odonata species were recorded from Thailand for the first time from records mostly based on credible photographs (Sribal *et al*., 2018). Also, Seehausen *et al*. (2018) presented an annotated list of 28 Odonata species from Timor Island based on 464 records via photographs and 56 specimens held in collections at the Museum and Art Gallery of the Northern Territory, Darwin, Australia and the Wiesbaden Museum, Germany. Odonata species are tied to freshwater environments that are degrading because of the changes caused by human impact, so reducing to a minimum or completely the collection of specimens for their identification is nowadays not only possible but even desirable (Galliani *et al*., 2017).

Artificial ponds are an integral feature of an agricultural landscape (Raebel *et al*., 2012), but also to some extent a novel ecosystem and stepping stone habitats across the landscape (Simaika *et al*., 2016). One of the examples is the Bjelovar-Bilogora area with its ponds (mostly fishponds) incorporated into a traditionally agricultural landscape. Ponds contribute considerably to regional diversity in many parts of the world (Harabiš & Dolný, 2011; Raebel *et al*., 2012; Kietzka *et al*., 2014; Simaika *et al*., 2016). Vilenica *et al*. (2020b) found that man-made water bodies with a well-developed riparian zone and aquatic vegetation as well as with low daily and seasonal water level fluctuations, can provide suitable habitats for different Odonata species. Although Simaika *et al*. (2016) found that artificial ponds increase the area of occupancy and population sizes of many generalist dragonfly species but attract no threatened or rare ones, some studies showed that anthropogenic habitats can be suitable habitats for protected species (Renner *et al*., 2016; Holtmann *et al*., 2018; Vilenica *et al*., 2020b). Moreover, man-made water bodies with suitable habitat conditions (favourable physico-chemical water properties and optimal vegetation structure) can even attract threatened species (Vilenica *et al*., 2016, 2020b).

This study aimed to inventory the dragonfly species of an artificial pond and its wider area by using the photographic approach and to provide baseline data for further study in the future.

MATERIAL AND METHODS

Gornje Plavnice is a settlement situated north of Bjelovar town in the continental part of Croatia. Jarak Pond is an artificial lake (fishpond) which was built in the 1980s in Gornje Plavnice; 45°56'26'' N, 16°51'31'' E, 149 m above sea level (see Fig. 2). Depth of the pond is about 1.5 m. Fish species that inhabit this pond are: *Ctenopharyngodon idella* (Valenciennes, 1844), *Carassius gibelio* (Bloch, 1782), *Hypophthalmichthys molitrix* (Valenciennes, 1844), *Abramis brama* (Linnaeus, 1758), *Ameiurus nebulosus* (Lesueur, 1819), *Cyprinus carpio* Linnaeus, 1758, *Hypophthalmichthys nobilis* (Richardson, 1845),

Silurus glanis Linnaeus, 1758, *Esox lucius* Linnaeus, 1758 and *Lepomis gibbosus* (Linnaeus, 1758), (ZŠRDUB, 2020). Data regarding Odonata were collected in a period between the 18th of June 2017 and the 11th of August 2020 along Jarak Pond as well as in the surrounding meadows, agricultural land and forest edge in Gornje Plavnice (see Fig. 1). Total surface area of the study area is approximately 24.030 m^2, of which

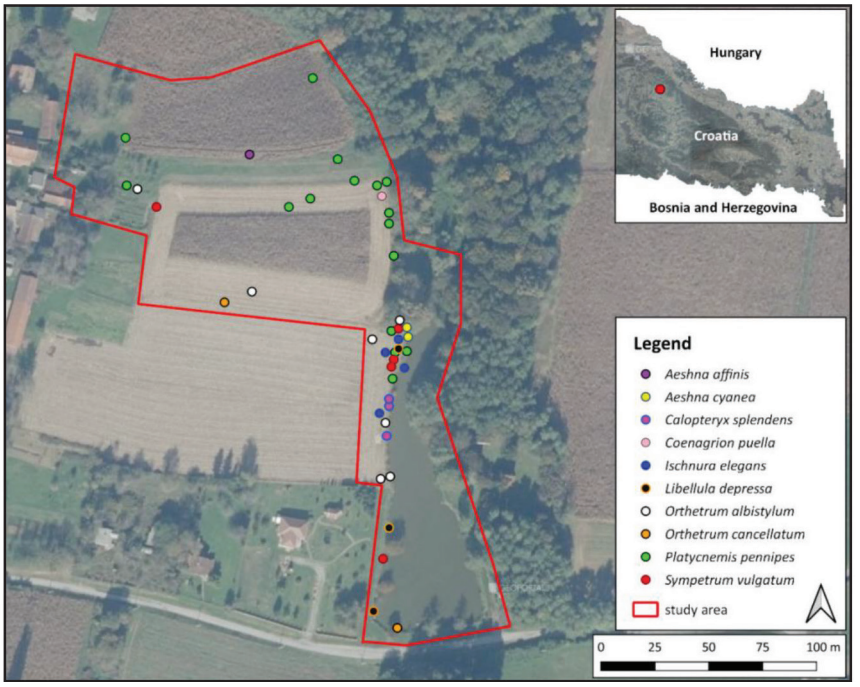

Fig 1. Locations in the study area where dragonfly species were recorded (layer source: GEOPORTAL, 2020).

a) b)

Fig. 2. a) Middle and south part of Jarak Pond in Gornje Plavnice, Bjelovar and b) pond edge on the north part of Jarak Pond (photo: M. Veljković)

the pond takes about 4.075 m^2. The visits were under optimal circumstances (sunny, warm days when dragonflies are more active) and lasted until no additional species were found for half an hour. Dragonflies were mostly photographed from late morning (around 10 a.m.) to early afternoon (around 2 p.m.). However, visits were partly conducted during late afternoon because dragonflies are then less active so it is easier to get clearer photographs for species identification (https://www.habitas.org.uk). The focus was on the adult stage while larvae and exuviae were not sampled. Adults were observed and photographed by the author. Identifications were made using Dijkstra & Lewington (2006) and the taxonomy follows the same literature. Reproductive behaviour of adults was also recorded. All collected photographs are stored in the author's private collection. Plant species were identified using Streeter *et al*. (2016).

RESULTS AND DISCUSSION

With this study, 10 dragonfly species were recorded (see Tab. 1). Eight species were identified based on a total number of 1,060 high quality photographs. Two species – *Aeshna affinis* Vander Linden, 1820 and *Aeshna cyanea* (Müller, 1764) were identified by revision of high-quality videos collected during this field research because their great activity hinders the creation of reliable photographs for identification. Species that are documented by means of videos are excluded from the presentation of recorded species (Fig. 3 and Fig. 4). A list of recorded dragonfly species is presented in Tab. 1.

Among the recorded species, only *Sympetrum vulgatum* (Linnaeus, 1758) is listed in the Red Data Book of Dragonflies of Croatia (Belančić *et al*., 2008) as Near Threatened (NT). Although the causes of its endangerment are still insufficiently known, it is NT in Croatia due to the effects of climate change but also because in Croatia, this species reaches the southern border of its distribution (Belančić *et al*., 2008). In this study, the most common dragonfly species were *Platycnemis pennipes* (Pallas, 1771) and *Orthetrum albistylum* (Selys, 1848) while other species were less abundant. At the same time, *P. pennipes* was the most frequent Zygoptera species, while *O. albistylum* was the most frequent Anisoptera species in the study area. *Platycnemis pennipes* inhabits wide range of habitats; from floodplains, oxbows, rivers, open stretches of streams, lakes to man-made habitats like canals, gravel-pits and fishponds (Martens, 1996; Dijkstra & Lewington, 2006). Larvae of this species are well adapted to fish predation (Steiner *et al*., 2000; Dijkstra & Lewington, 2006), which is one of the main factors in structuring the odonate community of freshwater ecosystems (Sih, 1987; Steiner *et al*., 2000). Therefore the adaptation of *P. pennipes* to fish predation could explain its frequent presence in the study area. *Orthetrum albistylum* inhabits lakes and open ponds, usually with very scarce aquatic vegetation (Askew, 2004; Dijkstra & Lewington, 2006; Vilenica & Mihoci, 2018). It also occurs in fishponds (Vilenica & Mihoci, 2018) which it can also use as a breeding habitat (Smallshire & Swash, 2020). As females of this species oviposit directly in water (Askew, 2004) and larvae of *Orthetrum* species lurk for prey from the sediment (Corbet & Brooks, 2008), the presence of aquatic vegetation is not a crucial habitat feature for this species (Vilenica *et al*., 2011, 2020b), so this could explain the records of *O. albistylum* at the pond edge with very little aquatic vegetation. Also, in the study area *O. albistylum* was frequent in the wider fishpond area including agricultural land and its edge where it was recorded

Tab. 1. Systematic list of dragonfly species found in Gornje Plavnice (Bjelovar) with observation dates, sex and habitat where the species were recorded.

Species	Observation date	Sex	Habitat
Suborder: Zygoptera			
Family: Calopterygidae			
1. *Calopteryx splendens* (Harris, 1782)	30.05.2018	female, male	pond edge
	04.06.2018	male	pond edge
	26.07.2020	male	pond edge
Family: Coenagrionidae			
2. *Ischnura elegans* (Vander Linden, 1820)	28.05.2018	male	pond edge
	30.05.2018	tandem in copulation	pond edge
	24.06.2019	male	pond edge
	11.08.2020	male	pond edge
3. *Coenagrion puella* (Linnaeus, 1758)	11.06.2020	male	forest edge
Family: Platycnemididae			
4. *Platycnemis pennipes* (Pallas, 1771)	18.06.2017	female	edge of agricultural land, agricultural land
	28.07.2017	male	edge of agricultural land
	30.05.2018	male	edge of agricultural land
	30.05.2018	female	edge of agricultural land
	25.05.2019	male	edge of agricultural land
	25.05.2019	teneral female	forest edge
	12.06.2019	teneral female	pond edge
	12.06.2019	male	meadow
	15.06.2019	female	edge of agricultural land
	15.06.2019	male	edge of agricultural land
	24.06.2019	3 males	forest edge
	24.06.2019	teneral female	pond edge
	20.07.2019	tandem in copulation	edge of agricultural land
	21.07.2019	female	meadow
	05.08.2019	female	meadow
	26.07.2020	male	forest edge
Suborder: Anisoptera			
Family: Aeshnidae			
5. *Aeshna affinis* Vander Linden, 1820	04.08.2019	male	edge of agricultural land and meadow
6. *Aeshna cyanea* (Müller, 1764)	06.11.2018	male	pond edge
	26.07.2020	male	pond edge
Family: Libellulidae			
7. *Libellula depressa* Linnaeus, 1758	30.05.2018	male	pond edge
	28.05.2018	male	pond edge
	26.07.2020	male	pond edge
8. *Orthetrum cancellatum* (Linnaeus, 1758)	27.05.2018	female	edge of agricultural land
	04.06.2018	male	pond edge
9. *Orthetrum albistylum* (Selys, 1848)	28.05.2018	male	pond edge
	28.05.2018	female	agricultural land
	02.06.2018	female	edge of agricultural land
	04.06.2018	male	edge of agricultural land
	04.06.2018	female	forest edge
	08.06.2018	female	agricultural land
	11.08.2020	male	pond edge
10. *Sympetrum vulgatum* (Linnaeus, 1758)	01.11.2018	tandem in copulation	agricultural land
	06.11.2018	tandem in copulation	pond edge
	06.11.2018	female	pond edge
	07.11.2018	male	pond edge
	06.11.2018	male	pond edge

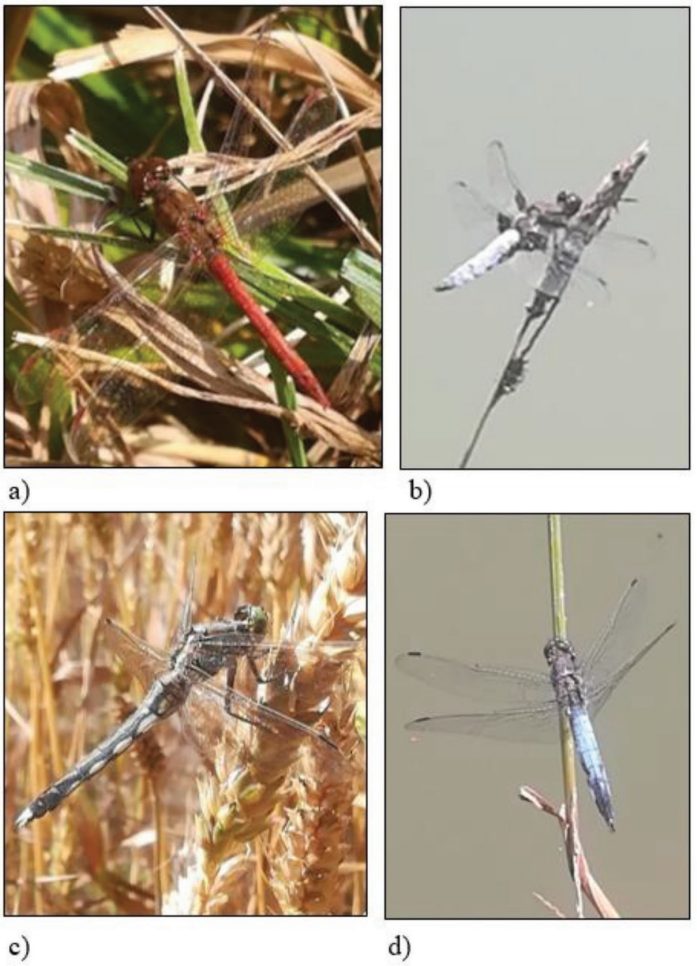

Fig. 3. Dragonfly species (Odonata, Anisoptera) in the study area: a) male of *Sympetrum vulgatum*, b) male of *Libellula depressa*, c) female of *Orthetrum albistylum*, d) male of *Orthetrum cancellatum* (photo: M. Veljković)

while sitting on plants such as bread wheat (*Triticum aestivum* L.) (Fig. 3.c), perennial rye grass (*Lolium perenne* L.) or prickly sow-thistle (*Sonchus asper* (L.) Hill).

Most Odonata species were found at the pond edge (eight species), followed by the edge of agricultural land (four species). More species were observed on the vegetated pond edge (especially where *Carex acuta* L. is present) than on the less vegetated pond edge which confirms the importance of vegetation preference and structure for Odonata (Corbet & Brooks, 2008; Vilenica *et al*., 2020b). Also, most of the recorded species were found on the shallower, northern part of the pond which is more remote from human impact and overgrown with riparian and aquatic vegetation. On the other hand, the southern part of the pond is under higher anthropogenic influence through occasional mowing of pond edge vegetation. Consequently, fewer species were recorded on this part of the pond. The more an area is affected by human activ-

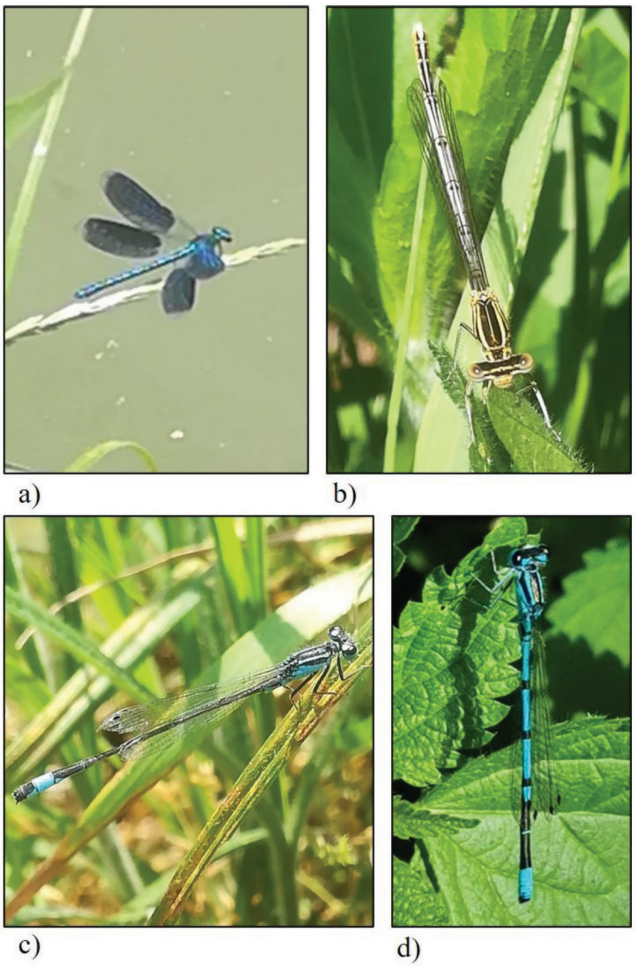

Fig. 4. Damselfly species (Odonata, Zygoptera) in the study area: a) male of *Calopteryx splendens*, b) teneral female of *Platycnemis pennipes*, c) male of *Ischnura elegans*, d) male of *Coenagrion puella* (photo: M. Veljković)

ity, the fewer dragonfly species can be found there (Jomoc *et al*., 2013), and Zygoptera species are considered to be more vulnerable than Anisoptera (Janra, 2018) as they remain in the vicinity of the site from which they have emerged. On the other hand, Anisoptera have much more advanced flying abilities which is why they can easily find new habitats (Janra, 2018). In this study species were mostly observed between late morning (around 10 a.m.) and early afternoon (around 2 p.m.) while only specimens of *P. pennipes*, *Ischnura elegans* (Vander Linden, 1820) and *O. cancellatum* were also recorded in late afternoon (until around 7 p.m.). Although further research should be conducted, these results show that more dragonfly species can be photographed during the time of day when they are more active, even though getting quality photographs of individuals during this period is more demanding.

Within the study, a rheophile *Calopteryx splendens* (Harris, 1782) was also observed. This species inhabits most open running waters but wandering males could often be recorded far from a suitable habitat (Dijkstra & Lewington, 2006). In the study area, males (Fig 4.a) and female were mostly recorded while resting on the pond edge vegetation. These individuals probably came from the small open stream which flows into Jarak Pond from its northern side. Individuals of *P. pennipes* were recorded at the fishpond edge but also on agricultural land (teneral female on the leaf of the *Solanum tuberosum* L.), edge of agricultural land (e.g. tandem in copulation), forest edge (e.g. males on the leaves of the *Solidago canadensis* L.) and on meadows in the study area. In earlier studies, individuals of *P. pennipes* were recorded on meadows at distances of up to 750 meters from waterbodies (Wild, 2017), so the observation of numerous individuals of *P. pennipes* on meadows and agricultural land in distances of up to 160 meters from Jarak Pond was not surprising. The flight season of this species is from the beginning of May to the end of September in central Europe, and it is especially busy in June and July (Dijkstra & Lewington, 2006). In this study, most specimens were recorded in June while only one specimen was observed in August.

In this study, suborder Anisoptera was represented with two families: Aeshnidae and Libellulidae. Both families are mostly associated with standing or slow-flowing, often well-vegetated, water habitats, (Dijkstra & Lewington, 2006) which is probably the reason for their occurrence near the studied fishpond. Furthermore, Libellulidae is the most speciose Anisoptera family in Europe but also the largest family of European dragonflies (Kalkman *et al*., 2010). In the study area Aeshnidae are represented by only two species: *A. affinis* and *A. cyanea*. *Aeshna affinis* prefers standing waterbodies which dry up during summer and are overgrown with bulrushes, low rushes and reeds (Dijkstra & Lewington, 2006). The species (a male) was recorded only once, during a patrol of the edge of agricultural land and a meadow in August 2019. *Aeshna cyanea* breeds in a wide variety of waterbodies but prefers small, stagnant and shaded waterbodies like garden ponds or forest pools and is a common species in heavily forested and urban areas (Dijkstra & Lewington, 2006). It was a more frequent species in the study area than *A. affinis.* Only males were observed while patrolling along the pond edge. As vagile Anisoptera are much better fliers than the sedentary Zygoptera, they can often search for and use additional habitats away from their emergence sites (Samways & Niba, 2010; Simaika *et al*., 2016). So, it is possible that the males of *A. affinis* and *A. cyanea* observed in the study area, had migrated from other local populations but for more conclusions further research should be conducted.

Orthetrum albistylum and *S. vulgatum* were the most frequently found species from the family Libellulidae in the study area. Some photographs ere unreliable in that they could not show the key characteristics for identification, and accordingly some species from the family Libellulidae were excluded from the species list. Therefore, the number of species in the study area could be higher, which should be examined with further research. *Sympetrum vulgatum* is one of the most common dragonflies in eastern and northern Europe, while its distribution also spreads deep into northern Asia (Dijkstra & Lewington, 2006). The species' flight season is between June and November, but most records were reported from July to September. *Sympetrum vulgatum* inhabits all kinds of standing water habitats (Dijkstra & Lewington, 2006). During this study, it was recorded only in November 2018, mostly on the pond edge (see Fig. 3.a). Two records showed a copulation tandem near the pond edge and on

the agricultural land, while other individuals were recorded on the pond edge. Also, a teneral female and a male of *S. vulgatum* were recorded in the vicinity of the study area during July and September 2017 (see Veljković, 2018). It is possible that observed individuals of *S. vulgatum* represent vagrant individuals that originate from elsewhere in the wider region, but for correct conclusions more targeted research should be conducted.

The studied habitats could be suitable for some other dragonfly species that were not recorded during this study. The fishpond in the study area is partly surrounded by forest, so Zygoptera species like *Lestes viridis* (Vander Linden, 1825) and *Lestes parvidens* Artobolevskii, 1929 that inhabit almost any type of slow-flowing or standing water with bordering trees and bushes (Dijkstra & Lewington, 2006) could occur there. Furthermore, *Sympecma fusca* (Vander Linden, 1820),which inhabits all kinds of well-vegetated standing waters (Dijkstra & Lewington, 2006), could also occur here. Adults of this species can be seen throughout the year but are most reproductively active in April and May. A peak of their activity is in August and September (Dijkstra & Lewington, 2006). This study was not conducted during April and during most of May so it is possible the species was missed in this period, while it might have been overlooked in the second part of its flight activity. Anisoptera species such as *Aeshna grandis* (Linnaeus, 1758), which usually occur in forested areas and breed in a wide range of calm waters (like oxbows, abandoned canals, fenlands, etc.) with rich bankside or submerged vegetation (Dijkstra & Lewington, 2006; Belančić *et al*., 2008) and *Anax imperator* Leach, 1815, which inhabits standing, well-vegetated waters (Dijkstra & Lewington, 2006), could also be expected in the study area. Furthermore, *Aeshna mixta* Latreille, 1805, which breeds in a wide range of still and slow-flowing waters with riparian vegetation, but may be found anywhere when hunting or migrating, *Libellula quadrimaculata* Linnaeus, 1758, which inhabits most still waters, especially with well-developed vegetation and *Sympetrum sanguineum* (Müller, 1764), which inhabits most waters with lush marshy vegetation (Dijkstra & Lewington, 2006) could also be expected in the study area. The studied habitats could also be suitable for *Aeshna isoceles* (Müller, 1767), which inhabits ponds, ditches, marshes and lakes with rich vegetation as well as for *Cordulia aenea* (Linnaeus, 1758) and *Epitheca bimaculata* (Charpentier, 1825), which inhabit standing waters, including fishponds (Dijkstra & Lewington, 2006).

The main threats to freshwater biota are habitat loss, diverse anthropogenic habitat alterations and pollution (Thomas *et al*., 2004; Vilenica *et al*., 2020b). One of the major threats to the dragonfly species in the study area is agricultural intensification because nowadays agricultural land that stretches along to the pond has expanded and now reaches the pond edge. Consequently, the width of the pond edge is at some parts reduced to less than 0.5 m. Furthermore, periodical mowing of pond edge vegetation (including *Carex acuta*) as well as treating crops with herbicides and pesticides on agricultural land along the pond edge where the most dragonfly species were found, could affect the occurrence and survival of dragonflies that breed and/or feed there. Globally, extensive urbanization, agriculture and industry, large quantities of pesticides, industrial and domestic waste as well as pharmaceuticals that are discharged daily into freshwater habitats negatively influence populations of many aquatic organisms, including Odonata (Zhang *et al*., 2004; Arimoro *et al*., 2008; Vilenica *et al*., 2020a). Also, a high level inflow of nutrients from agricultural land into the pond supports excessive growth of aquatic macrophytes and algae, resulting in low

oxygen concentrations in the waterbody which consequently limits Odonata presence in influenced habitats (Rose & Crumpton, 1996; Boeykens *et al*., 2017; Vilenica *et al*. 2020a).

This research provides additional knowledge about the possibilities of photographic research into dragonflies, obviating the need for the collection of dragonfly specimens. However, the results of this photographic research have a preliminary character so they should be a starting point for further research. Although further research into the importance of Jarak Pond and its wider area for Odonata species is needed, results of this research show that this pond is one more example of how man-made water bodies, with well-developed riparian and aquatic vegetation as well as with low daily and seasonal water level fluctuations, can provide suitable habitats for different species of Odonata (Vilenica *et al*., 2020b), especially in an agriculturally fragmented landscape. Although mostly generalist species were recorded in the study area, the conservation of the total assemblage is also important as in the future some may become rare (Simaika *et al*., 2016). In conclusion, more recent knowledge about dragonfly fauna in the Bjelovar-Bilogora area (including artificial ponds) is needed, in order to manage conservation methods to sustain the biodiversity and stability of dragonfly populations under different threats such as agricultural intensification, abandonment of traditional agriculture, global climate crisis, etc.

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