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DRAGONFLY FAUNA (INSECTA, ODONATA) IN THE TUROPOLJE REGION (CROATIA)

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This study presents the results of dragonfly fauna research in the Turopolje region of Croatia. Faunal analyses were conducted in the period from 1986–2009, with some interruptions, while an ecological analysis (composition of dragonflies according to habitat characteristics such as vegetation structure, air temperature, cloudiness) was conducted in the period 2007–2009. Faunal and ecological analyses were carried out at seventeen and nine localities, respectively. A total of 35 dragonfly species was recorded, indicating high species richness in comparison to the total number of 67 species known in Croatia. Zoogeographic analysis of the recorded dragonfly species showed the domination of the Holo-Mediterranean element which indicates complex glaciation and interglaciation processes during the geological past in Europe, when the Croatian territory served as a refugium. The results show that the distribution and abundance of dragonflies are indicative of habitat characteristics (vegetal structure, cloudiness and air temperature). Dragonflies prefer mosaic habitats (diverse vegetation structure) with average air temperatures ranging from 26–28°C and sunny weather. Since this research was conducted in only a part of the whole Turopolje region, and only adult specimens were sampled, further research should be focused on the life cycles of dragonflies and their distribution throughout the entire Turopolje region.

Keywords: dragonflies, Turopolje, fauna, distribution, habitat characteristics

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U ovom radu je predstavljen prvi sistematski popis faune vretenaca za područje Turopolja sakupljenih u razdoblju 1986.–2009. godine. Također su prikazani rezultati analize sastava faune

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vretenaca i njihove brojnosti u ovisnosti o stanišnim čimbenicima (sastav vegetacije, temperatura i naoblaka) provedene u razdoblju 2007–2009. Utvrđeno je 35 vrsta vretenaca za područje Turopolja, što nam u usporedbi s ukupno 67 vrsta ustanovljenih za Hrvatsku, upućuje na njihovu veliku raznolikost na istraženom području. Zoogeografskom analizom je ustanovljena dominacija Holo-Mediteranskog elementa, ukazujući na kompleksne glacijalne procese u Europi tokom njene geološke prošlosti kada je područje Hrvatske pa tako i Turopolja služilo kao refugij. Naši rezultati ukazuju da su vretenca svojom raznolikošću i brojnošću dobar pokazatelj stanišnih uvjeta (struktura vegetacije, količina naoblake i temperatura zraka). Vretencima pogoduju mozaična staništa (raznolike strukture vegetacije), prosječne temperature zraka između 26 i 28°C te sunčano vrijeme. Kako je ovo istraživanje provedeno samo na dijelu Turopolja i kako su prikupljani samo odrasli stadiji vretenaca, buduća istraživanja se trebaju fokusirati na cijelo područje Turopolja s analizom životnih ciklusa utvrđenih vrsta.

Ključne riječi: vretenca, Turopolje, fauna, rasprostranjenost, uvjeti staništa

INTRODUCTION

Although the first studies on the dragonfly fauna of Croatia began in the second half of the 19th century (CARARA 1846), published data on dragonfly records on Croatian territory are relatively poor. Most research papers contain a small number of localities and/or species. Some of the first data on dragonfly fauna were presented by BRITTINGER (1850), BRAUER (1856; 1876), FRAUENFELD (1856; 1860), HAGEN (1867), KOHAUT (1896), NOVAK (1890) and MOCSARY (1900). In 1900, RÖSSLER published a comprehensive monograph, which was the first scientific publication on dragonflies in the Croatian language. During the last quarter of the 20th century, the number of published data on dragonflies began to increase (see BELANČIĆ *et al*. 2008).

Wetland habitats represent one of the greatest values of biological and landscape diversity in Europe. In Croatia, they provide a habitat for more than 40% of plant and animal species (RADOVIĆ, 2005). Wetland habitats are the most threatened ecosystems due to water drainage, excessive exploitation and pollution, resulting in their disappearance throughout Europe. In biodiversity conservation, dragonflies serve as an umbrella species that represent specific biotic wetland assemblages (SCHINDLER et al., 2003). Conservation of characteristic wetland plant associations helps to support healthy dragonfly fauna; therefore, conservation of the ecological requirements of dragonflies may also conserve wetland plants (BRIED *et al*., 2007). Because of the complex habitat needs of individual species, dragonflies are reliable bioindicators of the stability, health and integrity of wetland ecosystems. Their presence and abundance indicate the wealth and favourable conservation status of the ecosystems they inhabit (BOGDANOVIĆ *et al*., 2008; CORBET, 1999; FRANKOVIĆ, 1999). They have significant potential as bio-indicators as their conspicuousness and sensitivity to small-scale changes in environmental conditions (MOORE, 1997; MORTIMER *et al*., 1998) makes them invaluable for a rapid quality assessment of freshwater ecosystems. The number of dragonflies can provide a quick indication of the health or richness of freshwater ecosystems (HAWKING & NEW, 2002). To maintain high species richness, it is essential to maintain a variety of biotopes (SUH & SAMWAYS, 2005). Therefore, the wetland areas of Turopolje can be an important mosaic of freshwater habitats for biodiversity conservation at both the Croatian and European scales.

The dragonfly fauna of the Turopolje region is poorly known. The first data on the dragonflies of Turopolje were given by ERBEN (1983) and PONGRAC (2000), which

reported the presence of *Calopteryx splendens* and *Coenagrion puella* in the region. No other data have since been published. Therefore, the primary objective of this study was to complete a checklist of the dragonfly species of the Turopolje region and to provide a zoogeographical analysis. A second objective was to estimate the influence of habitat characteristics (e.g. air temperature, cloudiness and vegetation structure) on dragonfly fauna composition and activity.

MATERIALS AND METHODS

Study area

Turopolje is geographically situated south of the City of Zagreb in the Posavina area of central Croatia (Fig. 1). It is bordered by the right bank of the Sava River to the northeast and by the Vukomeričke gorice hills to the southwest. Turopolje is a lowland floodplain with a surface area of about 200 km². It is characterized by an altitudinal range between 96 and 110 m and an average annual precipitation of 900 mm. The influence of the continental climate is reflected by the average air temperature in January (–10°C) and July (33°C) and greater cloudiness throughout the Posavina region (BERTOVIĆ, 1975; CRKVENČIĆ *et al.*, 1974). Central Croatia has the highest concentration of surface water and the most widely spread stream network

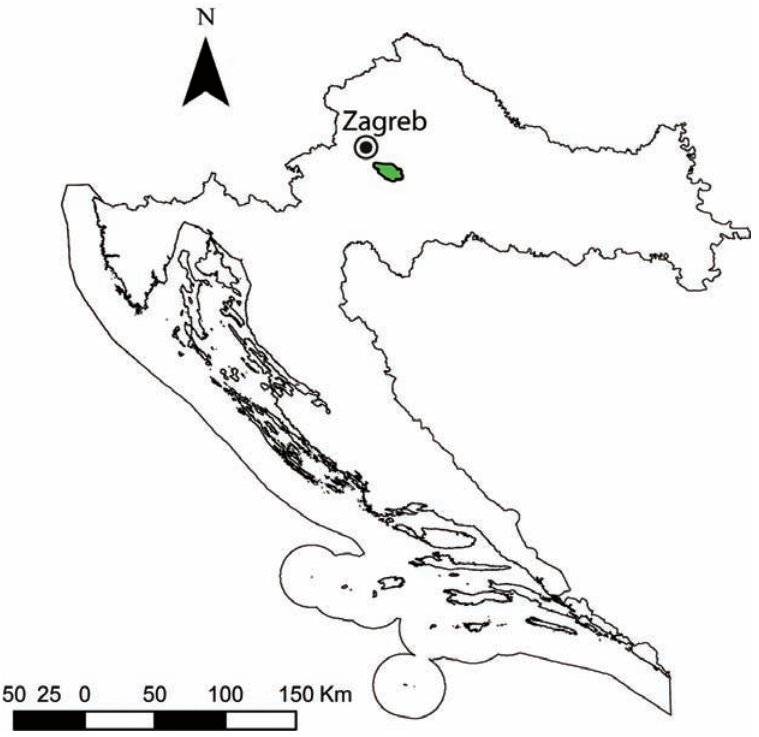

Fig. 1. Position of the Turopolje region in Croatia.

in the country. The hydrogeographical backbone is the Sava River, which connects most of the macro-region. In addition to the Sava, the Odra River and its tributary the Lomnica River also flow through the Turopolje lowland floodplain (DUMBOVIĆ-RUŽIĆ, 2002).

Much of the primary forest vegetation in Turopolje has been transformed into arable land, while land not suitable for arable land due to unfavourable water regimes, has been converted into grasslands, meadows and pastures. Grasslands and forests along the Odra River are the lowest parts of Turopolje. They represent a retention which is periodically filled during high waters of the Sava and Kupa Rivers when water flows into the Odra River. High groundwater and soil compactness also contribute to flooding (DUMBOVIĆ-RUŽIĆ, 2002). Considering the distribution of the different water regimes, forests are not of equal composition in all areas. There are two main forest communities: oak forest with broom (*Genisto elatae-Quercetum roboris* Ht. 1938) and oak forest with hornbeam (*Carpino betuli-Quercetum roboris* Ht. 1938) (ŠEGULJA & TOPIĆ, 2000). At the lowest parts of the depressions with long lasting water, narrow-leaved ash woods with snowflake are developed (*Leucoio-Fraxinetum angustifoliae* Glav. 1959), while in places where the water is almost always present, there are groves of black alder with glossy buckthorn (*Frangulo-Alnetum glutinosae* Raus 1968). This community usually develops in the old riverbeds and on the edges of wetlands and is distributed in fragments over a relatively small area (DUMBOVIĆ-RUŽIĆ, 2002). Meadows in the Turopolje area make an ecological string that includes the lowland swamp (*Caricetum tricostato-vulpinae* H-ić 1930), wet hair grass (*Deschampsietum caespitosae* H-ić 1930) and valley meadow communities (*Bromo-Cynosuretum cristati* H-ić. 1930 and *Arrhenartheretum elatioris* Br.Bl. 1925). Vegetation mainly consists of hairgrass wet meadows. Agriculture and the expansion of arable land on the one hand and the abandonment of agriculture and succession on the other are leading to the disappearance of these grasslands (HULINA, 1975).

Data collection

Data on dragonflies were collected at 17 sites in the period 1986–2009, with interruptions (Tab. 1; Fig. 2). Dragonflies from collections in Croatian Natural History Museum, Zagreb were also analysed.

Research on dragonfly composition and activity in relation to habitat characteristics was conducted from 22 Aug 2007 to 9 May 2009 at nine study sites (Fig. 2; Tab. 1). For ecological analysis, dragonflies were sampled on a transect of surface area 20×2 m (1 m on either side of the water's edge) in a period of 30 min. Researched localities differed in the amount of water and their vegetation alliances. Vegetation alliances were determined according to DOMAC (1994) and ŠEGULJA & TOPIĆ (2000) (Tab. 2). Only adult dragonflies were sampled. Captured specimens were determined, photographed and released. Determination of specimens was conducted according to DIJKSTRA & LEWINGTON (2006) and ASKEW (2004), while taxonomy follows DIJKSTRA & LEWINGTON (2006).

For the estimation of habitat characteristics, air temperature and cloudiness were recorded. Air temperature was measured by a handheld thermometer while cloudiness was determined by observing sky clearness. Only partially cloudy and clear skies were considered. The correlation between relative abundance of dragonflies

Tab. 1. Dragonfly species recorded at seventeen localities in the Turopolje region in the period 1986–2009

SPECIES	J	D	VR	S	VI	RI	RII	O	K	SO	VG	TG	TL	SP	P	TP	VII
C. splendens	+			+	+	+	+	+	+	+	+			+			
C. virgo				+				+									
C. puella	+	+			+	+	+	+	+	+					+	+	
E. cyathigerum										+	+						
E. lindenii										+							
E. najas		+			+		+			+							
E. viridulum					+		+			+							
I. elegans		+	+	+	+		+	+	+	+	+						
I. pumilio											+						
P. nymphula								+									
L. barbarus							+										
L. sponsa										+							
L. virens												+					
L. viridis										+							
S. fusca													+				
P. pennipes				+	+			+	+	+	+						
A. affinis					+	+	+	+									+
A. isoceles					+		+		+								
A. imperator					+	+	+	+	+	+	+						
B. pratense								+									
C. aenea											+						
E. bimaculata					+					+							
G. flavipes										+							
G. vulgatissimus								+		+		+					
O. forcipatus				+				+									
C. erythraea		+			+		+			+							
L. depressa	+				+		+	+		+	+					+	
L. fulva										+							
L. quadrimaculata									+								
O. albistylum		+	+		+		+		+	+							
O. brunneum										+							
O. cancellatum					+						+						
O. coerulescens									+								
S. sanguineum	+				+			+				+					
S. striolatum										+	+						

*Abbreviations: J=pond in Jagodno, D=Sava oxbow in Drnek, VR=pond in Vrbovo Posavsko, S=Sava River, VI= Sava oxbow in Veleševec, RI=dead Sava oxbow in Ruča, RII=pond in Ruča, O=Odra River, K= Sava-Odra canal, SO=Selce-Odra, VG=Velika Gorica, TG=Turopoljska greda, TL=Turopoljski lug, SP=Sisak-Pešćenica, P=Pešćenka, TP=Turopolje-Prevlaka, VII=Veleševec

and air temperature and the relationship between relative dragonfly abundance and the number of dragonfly species with cloudiness were analysed. The relative abundance per locality was calculated by the total number of specimens divided by the sampling time.

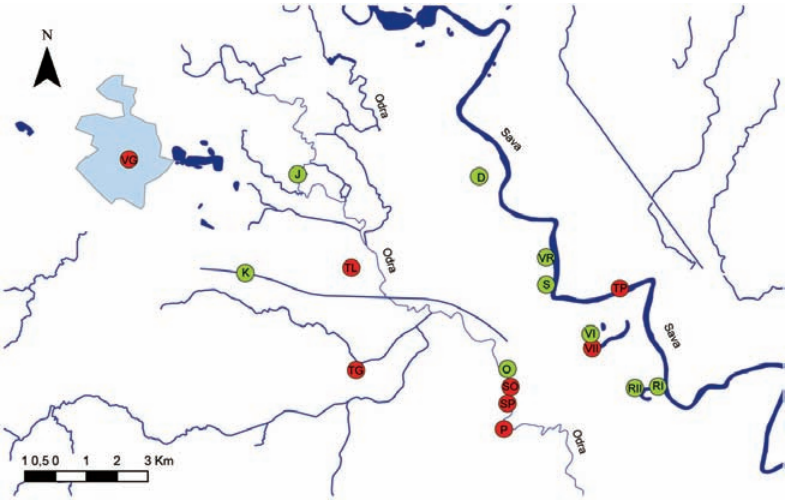

Fig. 2. Map of the Turopolje region with researched localities. Green dots represent localities researched in the period 1986–2000, red dots in the period 2007–2009. Abbreviations of localities are given in Tab.1.

Tab. 2. Vegetation alliances at nine researched localities in Turopolje region in the period 2007–2009

ALLIANCE/LOCATION	J	D	VR	S	VI	RI	RII	O	K
Lemnion minoris de Bolós et Masclans 1955		+			+		+	+	+
right*Hydrocharidion* Rübel 1933		+							
Potamogetonion pectinati (W. Koch) Görs 1977							+		+
Nymphaeion albae Oberd. 1957	+	+		+	+			+	+
Phragmition australis W. Koch 1926.	+	+		+	+			+	+
Magnocaricion elatae W. Koch 1926	+	+		+	+		+	+	
Glycerio-Sparganion Br.-Bl. et Sissingh in Boer 1942					+			+	+
Salicion albae Soó 1930		+		+	+	+	+	+	
NUMBER OF SPECIES	4	5	2	5	15	4	12	13	8

*Abbreviations of localities are given in Tab.1.

Data analysis

Zoogeographical analysis of the determined dragonfly species followed STERNBERG (1998). Research conducted in the period 2007–2009 was statistically analysed using the PRIMER 6 software package (CLARKE & WARWICK, 2001). Species diversity, uniformity of studied sites and similarity between sites with respect to dragonfly composition and abundance were determined by the Shannon-Weaver (SHANNON & WEAVER, 1949) and Simpson indices (SIMPSON, 1949).

For estimation of similarity and differences among the researched sites with respect to dragonfly fauna, cluster and NMDS analysis were used. Similarity among

the researched localities was analyzed by the dragonfly composition determined using the Bray-Curtis similarity index (BRAY & CURTIS, 1957). NMDS analysis was used to estimate the difference in dragonfly composition within the researched sites. Dragonflies were considered as categorical binary variables, with 0 indicating absence of a species and 1 indicating presence of a species at a certain locality.

RESULTS

Faunal analysis

A total of 35 dragonfly species were recorded for the Turopolje region (Tab. 1), 28 dragonfly species of which were recorded in the period 1986–2000 and 22 species (with 307 specimens) in the period 2007–2009. Specimens housed in the collections (*) of the Croatian Natural History Museum and previously published data are included in the list below (ERBEN, 1983**; PONGRAC, 2000***).

Suborder: ZYGOPTERA
Family: Calopterygidae

Calopteryx splendens (Harris, 1782): Selce-Odra (8.05.1997*, 10.06.1986, 14.07.1990, 4.06.1994), Velika Gorica (2.07.1986), Sisak-Pešćenica (1.01.2000)***, pond in Ruča (15.05.2008, 29.06.2008), Sava oxbow in Veleševec (15.05.2008), Sava-Odra canal (17.06.2008, 22.06.2008), pond in Jagodno (29.06.2008), dead Sava oxbow in Ruča (19.07.2008), Sava River (19.07.2008), Odra River (19.08.2008, 28.08.2008, 9.05.2009)

Calopteryx virgo (Linnaeus, 1758): Sava River (19.07.2008), Odra River (19.08.2008, 28.08.2008)

Family: Coenagrionidae

Coenagrion puella (Linnaeus, 1758): Velika Gorica (9.05.1981)*, Turopolje-Prevlaka (21.05.1986)*, Selce-Odra (10.06.1986, 14.07.1990), Pešćenka (1.01.1999)**, pond in Ruča (14.05.2008, 15.05.2008, 29.06.2008, 9.05.2009), Sava oxbow in Veleševec (2.06.2008), Sava-Odra canal (17.06.2008, 22.06.2008), pond in Jagodno (29.06.2008), dead Sava oxbow in Ruča (19.07.2008), Sava oxbow in Drnek (14.08.2008), Odra River (28.08.2008, 9.05.2009)

Enallagma cyathigerum (Charpentier, 1840): Selce-Odra (10.06.1986), Velika Gorica (2.07.1986)

Erythromma lindenii (Selys, 1840): Selce-Odra (14.07.1990)

Erythromma najas (Hansemann, 1823): Selce-Odra (10.06.1986), Sava oxbow in Veleševec (22.08.2007, 2.06.2008), pond in Ruča (29.06.2008), Sava oxbow in Drnek (14.08.2008)

Erythromma viridulum (Charpentier, 1840): Selce-Odra (14.07.1990), Sava oxbow in Veleševec (22.08.2007, 26.08.2007, 2.06.2008), pond in Ruča (26.08.2007)

Ischnura elegans (Vander Linden, 1820): Selce-Odra (8.05.1977*, 23.09.1985*, 14.07.1990, 17.07.1990), Velika Gorica (16.04.1981*, 2.07.1986), Sava oxbow in Veleševec (22.08.2007, 26.08.2007, 15.05.2008, 2.06.2008), pond in Ruča (26.08.2007, 14.05.2008, 29.06.2008,

9.05.2009), Sava-Odra canal (17.06.2008, 22.06.2008), Sava River (19.07.2008), Sava oxbow in Drnek (14.08.2008), pond in Vrbovo Posavsko (14.08.2008), Odra River (19.08.2008, 28.08.2008)

Ischnura pumilio (Charpentier, 1825): Velika Gorica (2.07.1986)

Pyrrhosoma nymphula (Sulzer, 1776): Odra River (9.05.2009)

Family: Lestidae

Lestes barbarus (Fabricius, 1798): pond in Ruča (15.05.2008)

Lestes sponsa (Hansemann, 1823): Selce-Odra (10.07.1986)*

Lestes virens (Charpentier, 1825): Turopoljska greda (9.07.1986)*

Lestes viridis (Vander Linden, 1825): Selce-Odra (23.09.1985*, 14.07.1990)

Sympecma fusca (Vander Linden, 1820): Turopoljski lug (12.09.1986)

Family: Platycnemididae

Platycnemis pennipes (Pallas, 1771): Selce-Odra (20.05.1986*, 10.07.1986*, 14.07.1990), Velika Gorica (2.07.1986), Sava oxbow in Veleševec (2.06.2008), Sava-Odra canal (17.06.2008, 22.06.2008), Sava River (19.07.2008), Odra River (19.08.2008, 28.08.2008)

Suborder: ANISOPTERA
Family: Aeshnidae

Aeshna affinis Vander Linden, 1820: Veleševec (10.06.1995), Sava oxbow in Veleševec (26.08.2007), pond in Ruča (26.08.2007), dead Sava oxbow in Ruča (19.07.2008), Odra River (19.08.2008), Sava-Odra canal (17.06.2008)

Aeshna isoceles (Müller, 1767): Sava oxbow in Veleševec (2.06.2008), pond in Ruča (15.05.2008), Sava-Odra canal (17.06.2008)

Anax imperator Leach, 1815: Velika Gorica (2.07.1986), Selce-Odra (14.07.1990), Sava oxbow in Veleševec (22.08.2007, 26.08.2007, 2.06.2008), pond in Ruča (15.05.2008, 29.06.2008), Sava-Odra canal (22.06.2008), dead Sava oxbow in Ruča (19.07.2008), Odra River (19.08.2008)

Brachytron pratense (Müller, 1764): river Odra (9.05.2009)

Family: Corduliidae

Cordulia aenea (Linnaeus, 1758): Velika Gorica (22.04.1981)*

Epitheca bimaculata (Charpentier, 1825): Selce-Odra (4.06.1994), Sava oxbow in Veleševec (15.05.2008, 2.06.2008)

Family: Gomphidae

Gomphus flavipes (Charpentier, 1825): Selce-Odra (14.07.1990)

Gomphus vulgatissimus (Linnaeus, 1758): Selce-Odra (8.05.1977*, 10.06.1986, 26.06. 1994), Turopoljska greda (9.07.1986)*, Odra River (9.05.2009)

Onychogomphus forcipatus (Linnaeus, 1758): Sava River (19.07.2008), Odra River (9.05.2009)

Family: Libellulidae

Crocothemis erythraea (Brulle, 1832): Selce-Odra (14.07.1990), Sava oxbow in Veleševec (22.08.2007, 26.08.2007, 2.06.2008), pond in Ruča (26.08.2007, 29.06.2008), Sava oxbow in Drnek (14.08.2008)

Libellula depressa Linnaeus, 1758: Velika Gorica (7.05.1981)*, Turopolje-Prevlaka (11.06.1986)*, Selce-Odra (3.06.1994), pond in Ruča (14.05.2008, 15.05.2008), Sava oxbow in Veleševec (15.05.2008), pond in Jagodno (29.06.2008), river Odra (9.05.2009)

Libellula fulva Müller, 1764: Selce-Odra (10.06.1986)

Libellula quadrimaculata Linnaeus, 1758: Selce-Odra (14.07.1990)

Orthetrum albistylum (Selys, 1848): Selce-Odra (14.07.1990), Sava oxbow in Veleševec (22.08.2007, 26.08.2007, 2.06.2008), Sava-Odra canal (22.06.2008), pond in Ruča (29.06. 2008), Sava oxbow in Drnek (14.08.2008), pond in Vrbovo Posavsko (14.08.2008)

Orthetrum brunneum (Fonscolombe, 1837): Selce-Odra (14.07.1990)

Orthetrum cancellatum (Linnaeus, 1758): Velika Gorica (2.07.1986), Sava oxbow in Veleševec (22.08.2007, 2.06.2008)

Orthetrum coerulescens (Fabricius, 1798): Sava-Odra canal (22.06.2008)

Sympetrum sanguineum (Müller, 1764): Turopoljska greda (9.07.1986)*, Sava oxbow in Veleševec (26.08.2007), pond in Jagodno (29.06.2008), Odra River (19.08.2008, 28.08.2008)

Sympetrum striolatum (Charpentier, 1840): Selce-Odra (23.09.1985)*, Velika Gorica (9.11.1986)

Tab. 3. Zoogeographical analysis of recorded dragonfly species in the Turopolje region in the period 1986–2009

SPECIES	ZOOGEOGRAPHICAL ELEMENT
Calopteryx splendens	Ponto-Mediterranean
Calopteryx virgo	Euroasian
Coenagrion puella	Ponto-Mediterranean
Enallagma cyathigerum	Euroasian
Erythromma lindenii	Atlantic-Mediterranean
Erythroma najas	Euroasian
Erythroma viridulum	Atlantic-Mediterranean
Ischnura elegans	Euroasian
Ischnura pumilio	Ponto-Mediterranean
Pyrrhosoma nymphula	Euroasian
Lestes barbarus	Holomediterranean
Lestes sponsa	Euroasian
Lestes virens	Ponto-Caspian
Lestes viridis	Atlantic-Mediterranean
Sympecma fusca	Holomediterranean
Platycnemis pennipes	Ponto-Caspian
Aeshna affinis	Holomediterranean
Aeshna isoceles	Atlantic-Mediterranean
Anax imperator	Holomediterranean
Brachytron pratense	Holomediterranean
Cordulia aenea	Euroasian
Epitheca bimaculata	Euroasian
Gomphus flavipes	Ponto-Caspian
Gomphus vulgatissimus	Ponto-Caspian
Onychogomphus forcipatus	Ponto-Caspian
Crocothemis erythraea	Holomediterranean
Libellula depressa	Ponto-Mediterranean
Libellula fulva	Ponto-Caspian
Libellula quadrimaculata	Euroasian
Orthetrum albistylum	Ponto-Mediterranean
Orthetrum brunneum	Holomediterranean
Orthetrum cancellatum	Holomediterranean
Orthetrum coerulescens	Atlantic-Mediterranean
Sympetrum sanguineum	Holomediterranean
Sympetrum striolatum	Holomediterranean

The highest number of recorded species belonged to the family Libellulidae. The most abundant species were: *C. splendens*, *C. puella* and *I. elegans* recorded at nine, ten and eleven researched localities, respectively. The species *E. lidenii*, *I. pumilio*, *P. nymphula*, *L. barbarus*, *L. sponsa*, *L.viridis*, *S. fusca*, *B. pratense*, *C. aenea*, *G. flavipes*, *L. fulva*, *L. quadrimaculata*, *O. brunneum* and *O. coerulescens* were each recorded at only one locality.

Zoogeographical analysis of the determined dragonflies showed the domination of the Holo-Mediterranean zoogeographical element (28.6%), while the smallest presence (14.3%) was established for the Atlantic-Mediterranean and Ponto-Mediterranean elements (Tab. 3).

Ecological analysis

The highest number of dragonfly species (15) with the highest Shannon-Weaver and Simpson indices (2.708; 0.933) was determined at the locality Sava oxbow in Veleševec. The locality pond in Vrbovo Posavsko had the lowest number of dragonfly species (2) and the lowest diversity and similarity indices (0.693; 0.500) (Tab. 4). The highest dragonfly abundance was recorded for the localities Sava oxbow in Veleševec (96) and Odra River (72), and the lowest (6) for localities pond in Vrbovo Posavsko and dead Sava oxbow in Ruča. Cluster analysis showed the highest similarity in dragonfly composition between the localities Sava oxbow in Veleševec and pond in Ruča (82%). The localities Sava oxbow in Drnek and pond in Vrbovo Posavsko (with a mutual similarity of 58%) had the highest difference from all other localities. The smallest similarity due to dragonfly composition was recorded for the localities pond in Jagodno and dead Sava oxbow in Ruča (Fig. 3). In the NMDS analysis, the localities Sava oxbow in Veleševec and pond in Ruča grouped together. The locality Odra was distinctive from all other localities (Fig. 4).

In the analysis of dragonfly activity in correlation to air temperature, average temperatures were recorded (Fig. 5). The highest relative dragonfly abundance was recorded for the locality Odra River (26°C) and the Sava oxbow in Veleševec (26.5°C).

Tab. 4. Diversity and similarity indices for nine researched localities in the Turopolje region in the period 2007–2009

Location	Number of species	Shannon-Weaver Index	Simpson Index
J	4	1.386	0.750
D	5	1.609	0.800
VR	2	0.693	0.500
S	5	1.609	0.800
V	15	2.708	0.933
RI	4	1.386	0.750
RII	12	2.485	0.917
O	13	2.565	0.923
K	8	2.079	0.875

*Abbreviations of localities are given in Tab.1.

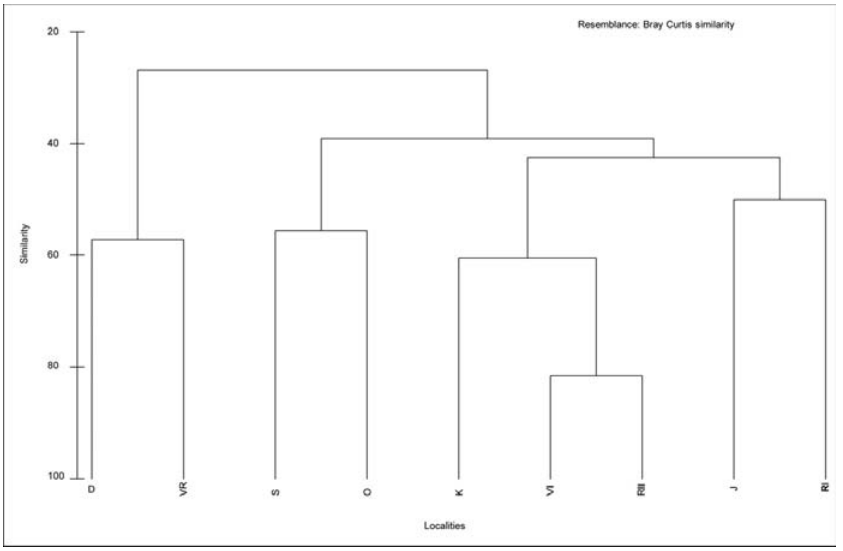

Fig. 3. Cluster analysis of dragonfly composition at nine researched localities in the Turopolje region in the period 2007–2009. Abbreviations of localities are given in Tab.1.

Fig. 4. NMDS analysis of dragonfly composition at nine researched localities in the Turopolje region in the period 2007–2009. Abbreviations of localities are given in Tab.1.

The localities pond in Jagodno and the Sava-Odra canal, and localities pond in Vrbovo Posavsko and Sava oxbow in Drnek, differed in dragonfly abundance despite having similar average air temperatures (28°C; 30°C) during the sampling period.

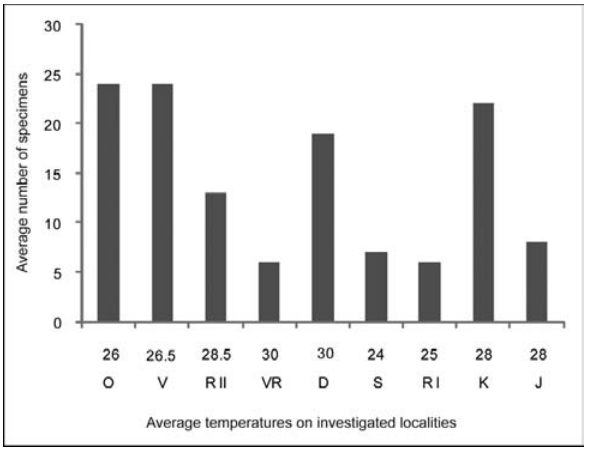

Fig. 5. Average number of dragonfly specimens recorded in relation to air temperature in the Turopolje region in the period 2007–2009. Abbreviations of localities are given in Tab.1. Average air temperatures are given in the degree Celsius (°C).

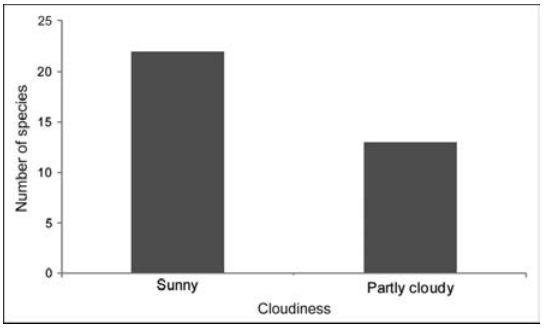

Fig. 6. Diversity of dragonflies in relation to estimated cloudiness at nine localities in the Turopolje region in the period 2007–2009.

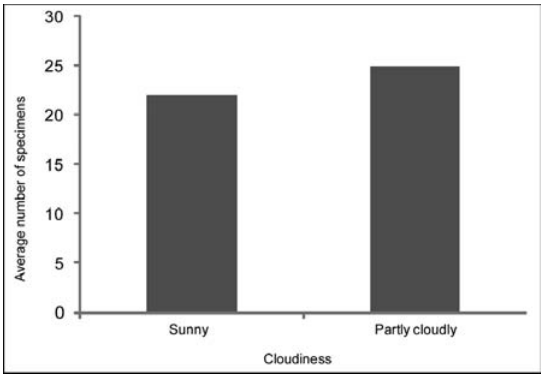

Fig. 7. Relative abundance of dragonflies in relation to estimated cloudiness at nine localities in the Turopolje region in the period 2007–2009.

Dragonfly diversity was higher (22) during clear skies, and lower (13) during partly cloudy skies (Fig. 6). With regard to relative abundance, a higher average number of specimens (25) was recorded during partly cloudy than during sunny (22) weather (Fig. 7).

DISCUSSION

This study recorded a total of 35 species for the Turopolje region, which represents 52.2% of the total number of 67 dragonfly species previously estimated for Croatia. The family Libellulidae, determined to be the dominant European dragonfly family by ASKEW (2004) was also the dominant dragonfly family in this study. Only one species of the family Platycnemididae (*P. pennipes*) was found, thereby confirming the report that this is the only species from this genus and family in Croatia (BELANČIĆ *et al*., 2008). According to DIJKSTRA & LEWINGTON (2006), the most abundant species recorded in this study, *I. elegans*, *C. splendens* and *C. puella*, are amongst the most common and numerous dragonfly species in Europe. In addition, they inhabit a wide range of habitat types, and the flight season is quite long, from late April until mid or late September. Fifteen species were recorded at only one locality, where *L. barbarus* was recorded with the smallest number of specimens during the period 2007–2009. The reason for this can be due a mismatch in their activity and sampling time or their correspondence to specific habitat conditions. The species *L. barbarus* was recorded only at the locality pond Ruča, which differed from other localities due to the presence of stagnant water that dries out during summer, which was reported as a typical habitat for that species in Croatia (BELANČIĆ *et al*., 2008).

According to the *Ordinance on the proclamation of protected and strictly protected wild taxa* (OFFICIAL GAZETTE 99/09), 33 of the recorded dragonfly species are protected as a strictly protected or protected species. In line with the Red List of endangered dragonfly species (FRANKOVIĆ, 2006), species recorded for the Turopolje region are classified into four categories: *E. bimaculata* is classified as endangered (EN), *L. virens* as vulnerable (VU), *L. barbarus*, *L. sponsa*, *E. najas*, *A. isosceles* as near threatened (NT) and *O. coerulescens* as data deficient (DD).

Zoogeographical analysis indicates the dominant impact of the Holo-Mediterranean zoogeographical element on the dragonfly fauna of Turopolje. This is explained by the past glaciation processes in Europe, during which time this complex of dragonfly fauna found refuge in this part of Europe. Research conducted by JELENKOVIĆ (1983) in the Lonjsko polje wetland, situated near Turopolje, showed a dominance of the Eurasian zoogeographical element. The presence of the Mediterranean zoogeographical element can be aligned with the occurrence of small areas with Mediterranean floristic/vegetal elements in the Pannonian plain (MATVEJEV, 1961), to which the Turopolje region belongs.

In the analysis of dragonfly composition and activity in correlation to habitat characteristics, the diversity index was highest for the locality Sava oxbow in Velešević where conditions for the development of dragonflies were favourable due to the presence of swamps, reeds, and hydrophilic and floating vegetation. According to SUH & SAMWAYS (2005), these conditions may be suitable for mating, oviposition, foraging, shelter from predators and other behavioural patterns for most dragonfly species. The use of different types of vegetation and perching spots may allow species to co-exist. The results presented here indicate that a lack of hydrophilic and

hygrophyilic vegetation may result in a low diversity of dragonfly species. For example, only two species, *O. albistylum* (abundant) and *I. elegans* (a single specimen) were recorded at the locality pond Vrbovo Posavsko. According to ASKEW (2004), *O. albistylum* lays its eggs directly in water and therefore the presence of vegetation is not a necessary habitat feature. *I. elegans* is a common species that tolerates different habitat conditions. In this study, only one specimen was recorded, and was likely sampled as it was passing through the sampling site.

Cluster analysis showed that the most similar localities were Sava oxbow in Veleševec and pond in Ruča, probably due to their vicinity. Therefore the flight activity of some species corresponded to sampling period. In addition, these two localities had a similar vegetation structure. The smallest number of common species was recorded for the localities pond in Jagodno and dead Sava oxbow in Ruča, which differed greatly in terms of habitat characteristics. The locality pond in Jagodno was a sunny and shallow site with dense wetland vegetation and surrounding trees, while the dead Sava oxbow in Ruča was mostly an obscured locality with little water and related vegetation. The localities pond in Vrbovo Posavsko and Sava oxbow in Drnek grouped separately from other localities. This could be the result of the determination of two common dragonfly species, estimated as the only two for the pond in Vrbovo Posavsko.

In the NMDS analysis, the locality Odra River was separate from the rest of the localities due to the three species found only at that location. Furthermore, the Odra River is a mosaic habitat with sunny and shady areas, dryer and wetter parts of the river banks and different vegetation, which makes it favourable for many dragonfly species. The localities Sava oxbow in Veleševec and pond in Ruča grouped together, like the rest of the localities due to their habitat characteristics. This analysis suggested that vegetation is one of the main factors affecting the composition of dragonfly communities. Some dragonfly species prefer a particular plant species composition for laying eggs and shelter (DIJKSTRA & LEWINGTON, 2006), so the heterogeneous composition of swamp, reed, hydrophytic and floating vegetation provides opportunities for various dragonfly species.

Important ecological factors in the dragonfly life cycle are air temperature and insolation. The daily fluctuation of air temperature is the single most important factor that determines the pattern of adult activity (CORBET, 1962). In this study, the largest number of dragonfly species was recorded in the air temperature range from 26–28°C and during sunny weather. The estimated range among recorded average air temperatures was the result of difference in vegetation structure among localities, with varying amounts of shaded and unshaded areas (e.g. localities pond in Jagodno and canal Sava-Odra and pond in Vrbovo Posavsko and Sava oxbow in Drnek; both with the same average temperatures but different dragonfly abundances). The locality pond in Jagodno was a small, shallow and partly shaded pond, different from the locality canal Sava-Odra, which is completely unshaded and open. In addition, the locality canal Sava-Odra was under the strong influence of a regular regime of mowing and cutting of the riparian vegetation, which results in the creation of microhabitat patches with pool-like sections and diverse vegetation. At these microhabitat patches, a high number of dragonfly species was recorded, unlike the rest of the canal where fewer species were recorded but with higher abundance. Also, the locality pond in Vrbovo Posavsko was a site without favourable vegetation for the resting of adults and emerging of dragonfly larvae,

while the locality Sava oxbow in Drnek had diverse and dense vegetation. High dragonfly abundance was recorded at the latter locality, primarily of damselfly species caught during rest on the surrounding vegetation. It is known that high air temperatures may result in overheating, which causes dragonflies to seek out shade and rest until the air temperature drops (ASKEW, 2004). The time of flight of adults and their behaviour are largely determined by their need to maintain a body temperature within the range at which spontaneous activity is possible. Also, the selection of sites for resting or feeding seems to be dictated by the protection the habitat structure offers from cold and wind (CORBET, 1962). Future research should avoid sampling during the very hot (25–30°C shade air temperatures) mid-day periods when territorial males are less active (see SUH & SAMWAYS, 2005).

This study indicated that more dragonfly species, though with a smaller number of specimens, were active during completely clear skies as opposed to during partly cloudy skies. More dragonfly specimens were recorded during partly cloudy weather as they were mostly caught while resting on surrounding vegetation. According to DIJKSTRA & LEWINGTON (2006), the majority of species are most active in direct sunshine. Nonetheless, there are many species, especially in the suborder Zygoptera, that are also active during overcast weather when it is sufficiently warm. Some studies suggest that many Odonata species avoid shaded areas, likely because orientation is almost entirely based on visual cues, so lighting can play an important role in habitat selection (REMSBURG *et al*., 2008; CORBET, 1962). An experiment carried out by REMSBURG *et al*. (2008) provided strong evidence for shade avoidance behaviour by the two most abundant dragonflies found at the study sites. It still remains to be tested whether shade limits prey availability, hunting effectiveness, mate attraction or thermoregulation.

The number of recorded dragonfly species compared to the total number in Croatia indicates the favourable ecological state of the study areas. These results clearly indicate that the distribution and abundance of dragonflies are indicative of the characteristics of the habitats they inhabit. Vegetation structure and composition are among the main characteristics limiting their abundance, which makes them vulnerable in the face of disappearing habitats such as wetlands. Since this study was conducted in only part of the Turopolje region, it can be expected that the number of species recorded will be higher in the future. However, it is important to note that only adult specimens were included in the statistical analysis; dragonfly larvae and exuviae should be included in further work. Future research from early spring to late autumn will reveal the more detailed composition of the dragonfly fauna and their distribution in the Turopolje region. Due to the age of some of the data presented in here, further research is necessary to obtain a more accurate picture of the overall state of the dragonfly fauna in this region.

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SAŽETAK

Fauna vretenaca (Insecta, Odonata) područja Turopolja

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Vretenca se koriste kao bio-indikatori kvalitete slatkovodnih ekosustava, jer njihova prisutnost ukazuje na bogatstvo i očuvanost područja u kojem žive. Područje istočnog dijela Turopolja evidentirano je u kategoriji kulturnog krajolika-krajobrazne cjeline regionalnog značaja. Literaturni podaci o vretencima Hrvatske su slabo zastupljeni, a sistematsko istraživanje faune vretenaca Turopolja do sada nije provedeno. Osnovni cilj ovog istraživanja bio je dati cjeloviti popis vretenaca za područje Turopolja sa zoogeografskom analizom utvrđenih vrsta. Dodatni cilj je bio odrediti njihove ekološke karakteristike, u vidu njihove ovisnosti o sastavu vegetacije na lokaciji, temperaturi i naoblaci. U vremenskom razdoblju od 1986. do 2009. godine periodički je provedeno faunističko istraživanje na 12 lokacija. Analizirane su i zbirke Hrvatskog prirodoslovnog muzeja u Zagrebu te je učinjena zoogeografska analiza zabilježenih vrsta vretenaca. Također, od kolovoza 2007. do svibnja 2009. godine provedeno je i faunističko-ekološko istraživanje na 9 lokacija koje nisu bile obuhvaćene prethodnim istraživanjima, prilikom kojeg su uzorkovane samo odrasle jedinke. Utvrđene su 22 vrste vretenaca s 307 jedinki te su ti podaci korišteni u

statističkim analizama. Od fizikalnih parametara staništa mjerena je temperatura zraka, naoblaka te bilježen sastav vegetacije. Za statističku obradu podataka korišteni su Shannon-Weaverov i Simpsonov indeks raznolikosti te klaster i NMDS analiza. Za područje Turopolja ukupno je zabilježeno 35 vrsta vretenaca što čini 52,2% faune vretenaca Hrvatske, čime možemo zaključiti da je područje Turopolja još uvijek dobro očuvano močvarno stanište. Od 8 zabilježenih porodica, najveći broj vrsta zabilježen je za dominantnu europsku porodicu Libellulidae. Vrste *Calopteryx splendens*, *Coenagrion puella* i *Ischnura elegans* nađene su na najvećem broju lokacija (7), dok su vrste *Erythromma lidenii*, *I. pumilio*, *Pyrrhosoma nymphula*, *Lestes barbarus*, *L. sponsa*, *L. viridis*, *Sympecma fusca*, *Brachytron pratense*, *Cordulia aenea*, *Gomphus flavipes*, *Libellula fulva*, *L. quadrimaculata*, *Orthetrum brunneum* i *O. coerulescens* nađene samo na po 1 lokaciji. Zabilježene su neke od zaštićenih vrsta kao što su *L. barbarus*, *L. virens*, *L. sponsa*, *E. najas* (Zygoptera) te *Epitheca bimaculata*, *Otrhetrum coerulescens* i *Aeshna isoceles* (Anisoptera). Zoogeografska analiza je pokazala najveći utjecaj holomediteranskog zoogeografskog elementa vjerojatno uzrokovano utjecajem oledbenih i međuoledbenih procesa tijekom geološke prošlosti.

Najveći broj vrsta i broj jedinki vretenaca su zabilježeni na lokacijama s razvijenom močvarnom i okolnom vegetacijom dok je na lokacijama bez takove vegetacije zabilježen najmanji broj vrsta i njihova brojnost. Utvrđeno je da vretenca na staništima koja su pod antropogenim utjecajem koriste mikrostaništa gdje se održavaju kao stabilne populacije. Najveći broj jedinki na istraživanim lokacijama je zabilježen pri srednjoj temperaturi zraka od 26°C, a ustanovljeno je da povećanjem temperature zraka dolazi do smanjenja njihove brojnosti zbog smanjene aktivnosti. Na visokim temperaturama vretenca miruju na okolnoj vegetaciji zbog čega je na pojedinim lokacijama unatoč visokoj temperaturi ulovljen veći broj jedinki. Pri analizi utjecaja naoblake na brojnost vretenaca utvrđeno je da se njihova aktivnost smanjuje pri njenom povećanju. Kako je ovo istraživanje provedeno samo na dijelu Turopolja i kako su prikupljani samo odrasli stadiji vretenaca, buduća istraživanja se trebaju fokusirati na cijelo područje Turopolja s analizom životnih ciklusa utvrđenih vrsta.