

NEW EVIDENCE OF *LINDENIA TETRAPHYLLA* (VANDER LINDEN, 1825) (ODONATA, GOMPHIDAE) REPRODUCTION AT THE NORTH-WESTERN BORDER OF ITS DISTRIBUTION

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A total of 12 dragonfly species were recorded at Vlačine Reservoir in the Dinaric Western Balkan region (ER 5) in Croatia. Habitat conditions, i.e. vegetation structure and physico-chemical water properties of the reservoir, are presented and discussed. Habitat conditions were suitable for life cycle completion of Mediterranean species such as *Lindenia tetraphylla* and *Selysiothemis nigra*. Exuviae of *L. tetraphylla* represent new evidence of the species' reproduction in the north-western border of its distribution

Key words: exuviae, breeding site, emergence, Dinaric Western Balkan region, ER 5, Croatia

Vilenica, M., Alegro, A., Koletić, N. & Mihaljević, Z.: Novi nalaz razmnožavanja vrste *Lindenia tetraphylla* (Vander Linden, 1825) (Odonata, Gomphidae) na sjeverozapadnoj granici njene rasprostranjenosti. *Nat. Croat.*, Vol. 25, No. 2., 287–294, 2016, Zagreb.

Na akumulaciji Vlačine, smještenoj u dinaridskoj ekoregiji (ER 5, Dinaridski zapadni Balkan) u Hrvatskoj, zabilježeno je ukupno 12 vrsta vretenaca. U radu su prikazani i raspravljani okolišni uvjeti na istraživanom staništu, prvenstveno struktura vegetacije i fizikalno-kemijski čimbenici vode. Stanišni uvjeti akumulacije bili su pogodni za uspješno završavanje životnog ciklusa mediteranskih vretenaca poput vrsta *Lindenia tetraphylla* i *Selysiothemis nigra*. Zabilježeni svlakovi vrste *L. tetraphylla* predstavljaju novi nalaz razmnožavanja ove vrste na sjeverozapadnoj granici njene rasprostranjenosti.

Ključne riječi: svlakovi, područje razmnožavanja, emergencija, Dinaridska ekoregija, ER 5, Hrvatska

INTRODUCTION

The Bladetail *Lindenia tetraphylla* (Vander Linden, 1825) is a large and conspicuous gomphid species distributed from Central Asia and Pakistan to parts of the Arabian Peninsula and the Western Mediterranean Basin (BORISOV & HARITONOV, 2008; BOUDOT, 2014; SCHNEIDER, 1986, 1988; SCHORR *et al.*, 1998; SCHRÖTER, 2010a, 2010b; SKVORTSOV & SNEGOVAYA, 2014; STILLE *et al.*, 2014). In Europe, the species has a disjunct distribution, inhabiting mostly large Mediterranean lakes, with relatively few strong permanent po-

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pulations (e.g. BOUDOT *et al.*, 2009; KALKMAN, 2006). The strongest populations worldwide are found at Lakes Kandahar (Afghanistan) and Doiran (Macedonia/Greece) (observations made by Thomas Schneider). The species is listed in Annexes II and IV of the Habitats Directive, in the European Red List (KALKMAN *et al.*, 2010) as vulnerable, in the Croatian Red List (BELANČIĆ *et al.*, 2008) as endangered and as a Natura 2000 species (DZZP, 2016).

Larvae predominantly inhabit lakes, but also other stagnant waterbodies and slow flowing rivers with dense and diverse aquatic and riparian vegetation (BOUDOT, 2014; SCHORR *et al.*, 1998; STILLE *et al.*, 2014). The adults have high migratory potential and usually travel over long distances from their reproductive site (BOUDOT *et al.*, 2013). Consequently, the species records often include only adult observations, while evidence of reproduction is more rarely documented (e.g. DE KNIJF *et al.*, 2013; KULIJER *et al.*, 2013; STILLE *et al.*, 2014).

Although the first studies on the dragonfly fauna of Croatia began in the second half of the 19th century (CARARA, 1846), there is still relatively little published information. Fortunately, our knowledge began to increase during the last quarter of the 20th century (e.g. BOGDANOVIĆ *et al.*, 2008; PEROVIĆ & PEROVIĆ, 2006; ŠTIH *et al.*, 2011; ŠTIH *et al.*, 2015; VILENICA *et al.*, 2011; VILENICA & DIJKSTRA, 2014) and the most comprehensive data about the Croatian dragonfly fauna are presented in the Red Book of Dragonflies (BELANČIĆ *et al.*, 2008). Still, despite the known data, there are still some gaps in our knowledge of Croatian dragonflies, which limits species protection and management of important areas. BELANČIĆ *et al.* (2008) presented several sites with *L. tetraphylla* records, five of which were confirmed as reproduction sites. Additionally, there have been several attempts (FRANKOVIĆ & BOGDANOVIĆ, 2010; MIHOKOVIĆ, 2010; ŠPANIĆ *et al.*, 2014) to determine additional suitable sites where the species can complete its life cycle, but without success. Thus, the aims of this paper were to present new data about the distribution and habitat of *L. tetraphylla* and associated dragonfly species.

METHODS

Study area

Vlačine Dam and Reservoir were built in 1969 on Baščica Stream, located in the Dinaric Western Balkan region in Croatia (Ravni Kotari, SW from the Smilčić village; N 44.15679, E 15.42677; Fig. 1). The average annual rainfall is 929 mm and the average air temperature 13-14 °C (PAVLUS *et al.*, 2014; ZANINOVIĆ *et al.*, 2008). Maximal volume of the reservoir is 1 130 000 m³. The average annual water inflow in the reservoir is 2 780 000 m³, and during the dry years between 1 507 000 and 1 800 000 m³. The main purpose of the dam is to provide a water supply for irrigation of the arable land, but also to collect the excessive water inflow during the autumn and winter. The irrigation is managed in a sustainable way by using rainfall water, which least interferes with subterranean water supply (PAVLUS *et al.*, 2014).

Data collection

Data on the dragonfly fauna of Vlačine Reservoir were collected on July 20th 2016, during the period of one hour, until no additional species were found for half an hour. Adult specimens were sampled using an entomological net and the exuviae were collected from the surrounding vegetation and banks by hand. Adult specimens were iden-

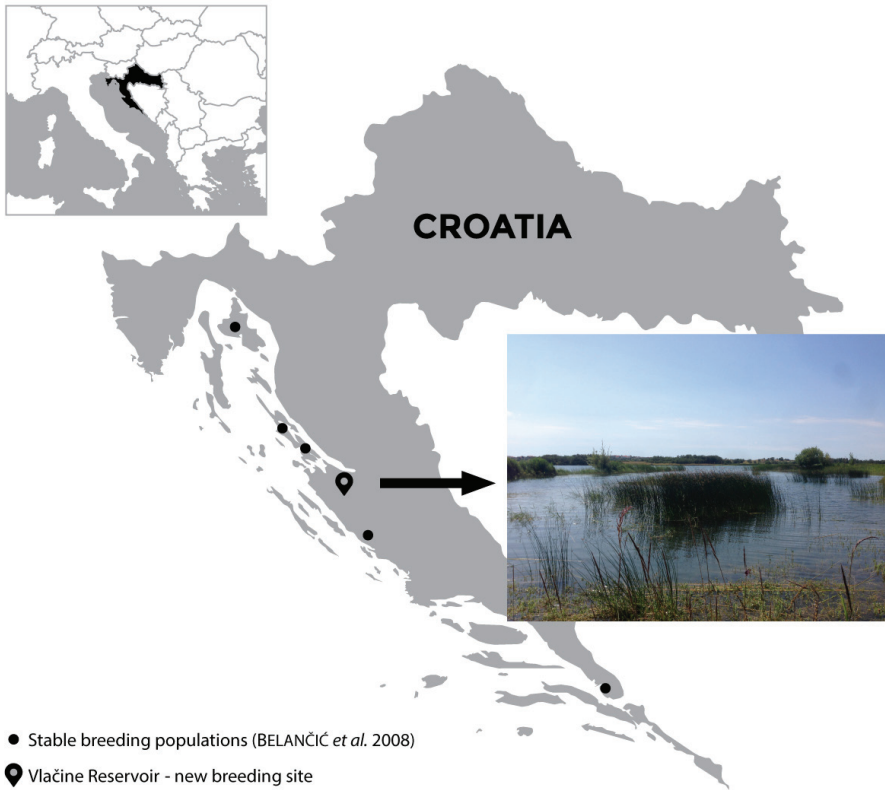


Fig. 1. *Lindenia tetraphylla* reproduction sites in Croatia, at the north-western border of its distribution, with a photograph of Vlačine Reservoir

tified in the field and released, and exuviae were collected. The adult identification and taxonomy follow DIJKSTRA & LEWINGTON (2006). GERKEN & STERNBERG (1999) was used for exuviae determination.

Plant nomenclature follows EURO+MED PLANTBASE (2016).

The physico-chemical water parameters: water temperature, pH, dissolved oxygen concentration, oxygen saturation and conductivity were measured with a multiparameter probe (WTW Multi 3430). Alkalinity (concentration of CaCO_3 (mg/L)) was measured using Standard Analytical Procedure (APHA).

RESULTS

A total of 12 dragonfly species were recorded (Tab. 1) in adult stages. Additionally, exuviae of three of the recorded species (*L. tetraphylla*, *Selysiothemis nigra* (Vander Linden, 1825), *Sympetrum sanguineum* (Müller, 1764)) were also documented. Exuviae of *L. tetraphylla* (Fig. 2) were collected from the fresh and dry vegetation near the reservoir banks, approximately one meter from the water surface.



Fig. 2. An exuvia of *Lindenia tetrphylla* photographed among vegetation on the banks of Vlačine Reservoir (Photo by Dubravka Čerba)

In the reservoir, three main vegetation belts can be recognized: the belt of reeds, a belt of shallow water dominated by helophytes and belt of submerged vegetation. The belt of reeds is dominated by *Schoenoplectus lacustris* (L.) Palla, which forms an almost continuous ring around the lake. In southern and south-eastern parts of the lake, where banks are less steep and the water shallower, stands of other species occur. The most frequent are *Phragmites australis* (Cav.) Trin. ex Steud., *Arundo donax* L. and *Typha angu-*

Tab. 1. Dragonfly species recorded at Vlačine Reservoir, Croatia. Legend: Relative abundance: 1 – individual record, 3 – several individuals (2-10), 5 – high number of individuals (> 10).

Family	Species	Relative abundance
Coenagrionidae	<i>Coenagrion puella</i> (Linnaeus, 1758)	5 imagoes
	<i>Enallagma cyathigerum</i> (Charpentier, 1840)	3 imagoes
	<i>Ischnura elegans</i> (Vander Linden, 1820)	5 imagoes
Aeshnidae	<i>Anax imperator</i> Leach, 1815	3 imagoes
	<i>Anax parthenope</i> (Selys, 1839)	3 imagoes
Gomphidae	<i>Lindenia tetrphylla</i> (Vander Linden, 1825)	3 imagoes, 3 exuviae
Libellulidae	<i>Crocothemis erythraea</i> (Brullé, 1832)	3 imagoes
	<i>Libellula depressa</i> Linnaeus, 1758	3 imagoes
	<i>Orthetrum cancellatum</i> (Linnaeus, 1758)	3 imagoes
	<i>Orthetrum coerulescens</i> (Fabricius, 1798)	5 imagoes
	<i>Selysiothemis nigra</i> (Vander Linden, 1825)	5 imagoes, 3 exuviae
	<i>Sympetrum sanguineum</i> (Müller, 1764)	3 imagoes, 3 exuviae

Tab. 2. Physico-chemical water parameters at Vlačine Reservoir, Croatia.

Physico-chemical parameters	Measured value
Air temperature (°C)	37.50
Air humidity (%)	34.00
Water temperature (°C)	27.20
Dissolved oxygen (mg/L)	10.16
Oxygen saturation (%)	123.00
Conductivity (µS/cm)	339.00
pH	8.15
Alkalinity (CaCO ₃ mg/L)	270.00

stifolia L. Like the previous one, the belt of helophytes in shallow water is best developed in the southern and south-eastern parts of the lake. The dominant species here is *Gratiola officinalis* L., but *Mentha aquatica* L., *Alisma plantago-aquatica* L., *Baldellia ranunculoides* (L.) Parl., *Agrostis stolonifera* L. and *Lythrum salicaria* L. also occur with high frequencies, as do two stoneworts, *Nitella hyalina* (De Candolle) C. Agardh and *Chara contraria* A. Braun ex Kützing. The most widespread belt is formed of submerged vegetation, and it occupies most of the lake surface except the deepest central parts. The dominant species here, forming dense stands, is *Potamogeton lucens* L. intermixed with the less abundant *P. natans* L., *P. crispus* L., *P. perfoliatus* L. and *Stuckenia pectinata* (L.) Börner. Other macrophytes occurring in this belt are *Myriophyllum spicatum* L., *Najas marina* L., *Veronica anagallis-aquatica* L. and *Nitellopsis obtusa* (N. A. Desvaux) J. Groves, representative of stoneworts.

Physico-chemical water parameters are presented in Tab. 2.

DISCUSSION

Our observations of *Lindenia tetraphylla* exuviae represent new evidence of the reproduction of the species at the north-western border of its distribution, which could be important for species and habitat protection and management. According to BELANČIĆ *et al.* (2008), the species was recorded as reproducing and forming five stable populations in Croatia: the population in Ponikve and Njivice Lakes on Krk Island, the population in Velo Blato Lake on Pag Island, the population in Vransko Lake near Zadar and the population in the delta of the Neretva River. Even though the species has been studied several times (see in BELANČIĆ *et al.*, 2008), and there have been several relatively recent attempts to detect additional reproduction sites (MIHOKOVIĆ, 2010; ŠPANIĆ *et al.*, 2014), so far none of the studies recorded new sites. MIHOKOVIĆ (2010) and ŠPANIĆ *et al.* (2014) visited a number of potentially suitable sites that corresponded to habitat descriptions in the literature (DIJKSTRA & LEWINGTON, 2006) or were similar to the species reproductive habitats in Croatia (BELANČIĆ *et al.*, 2008). However, some of them were too small in size or did not have the vegetation coverage required by the species. Thus, the species was documented to emerge only at the previously known sites (BELANČIĆ *et al.*, 2008; MIHOKOVIĆ, 2010; ŠPANIĆ *et al.*, 2014).

BELANČIĆ *et al.* (2008) described species habitats in Croatia as predominantly natural Mediterranean lakes, yet a number of studies conducted in southern Europe and the Middle East have reported the species' occurrence in the man-made reservoirs with concrete or stony banks lacking aquatic vegetation (e.g. KALKMAN & VAN PELT, 2006; STILLE *et al.*, 2014; SCHNEIDER & DUMONT, 2015; SCHNEIDER & IKEMEYER, 2016), which could be a substitute for the former habitats. Still, none of them have reported successful life cycle completion in such habitats. For completing the life cycle at some habitat type, *L. tetrphylla* requires dense riparian vegetation, often with wide stands of *Phragmites australis* (Cav.) Trin. ex Steud. essential for larval emergence. However, open shore sections without dense vegetation and with sandy substrate have shown to be a very important habitat component of larval ecology (SCHORR *et al.*, 1998; MIHOKOVIĆ, 2010). Thus, even though it is man-made, Vlačine Reservoir has most of the species' requirements, such as Mediterranean climate, high water temperature, mesotrophic water quality, good oxygen saturation, rich and diverse riparian and aquatic vegetation, shore sections without vegetation and sandy substrate.

Within this study, *Selysiothemis nigra*, another interesting Mediterranean species was recorded. *Lindenia tetrphylla* and *S. nigra* both represent an Iranoeremian faunal element. Consequently, they share similar biogeographical histories, distribution patterns (e.g. LOHMANN, 1981), habitat requirements and can usually be found syntopically (e.g. SCHORR *et al.*, 1998; SKVORTSOV & KUVAEV, 2010; UBONI *et al.*, 2015). Consequently, during the recent years, both species showed positive population trends in Europe due to the increasing number of suitable man-made habitats (e.g. UTZERI *et al.*, 2006; BOUDOT, 2014; STILLE *et al.*, 2014; UBONI *et al.*, 2015).

The dragonfly species richness recorded at Vlačine Reservoir could be considered relatively high, as some species with disjunct (Mediterranean) (e.g. *L. tetrphylla*, *S. nigra*), together with some species with wide European distribution (e.g. *C. puella*, *I. elegans*, *C. erythraea*) were recorded. Since the study was conducted in the midsummer period, the number of species recorded is probably not final. It is expected that more extensive study will record several additional spring species (e.g. *Brachytron pratense* (Müller, 1764), *Pyrrhosoma nymphula* (Sulzer, 1776)) and some other species preferring stagnant larger waterbodies with abundant riparian vegetation (e.g. *Aeshna mixta* Latreille, 1805, *Erythro-*mma lindenii* (Sélys-Longchamps, 1840)).*

Future activities should include detailed monitoring of *L. tetrphylla* population size at Vlačine Reservoir in order to determine the population's character, i.e. if it is only temporary or long-term, numerous and stable.

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SUMMARY

New evidence of *Lindenia tetraphylla* (Vander Linden, 1825) (Odonata, Gomphidae) reproduction at the north-western border of its distribution

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Lindenia tetraphylla is a large, highly migratory dragonfly species representing an Iranoe-remian faunal element. In Europe, the species has a disjunct distribution, mainly inhabiting large Mediterranean lakes, with relatively few strong permanent populations. In Croatia, the species was previously recorded as reproducing and forming five stable populations, mainly at large Mediterranean lakes. Additional reproducing sites have not previously been documented. Even though it is man-made, Vlačine Reservoir has suitable habitat conditions for species' life cycle completion, i.e., a Mediterranean climate, high water temperature, mesotrophic water quality, good oxygen saturation, rich and diverse riparian and aquatic vegetation, shore sections without vegetation and a sandy substrate. Within this study, life cycle completion was recorded for another interesting Mediterranean species, *Selysiothemis nigra*.