

Interesting updates to the flora of the Neretva River delta (south Croatia) with the emphasis on aquatic plants

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Abstract

While working on several projects dealing with the flora of Neretva River delta in south Croatia, interesting floristic discoveries were made. During fieldtrips, freshwater habitats (rivers, channels and lakes) were in the focus of the survey, and were studied in detail both from the boat and from the mainland. Altogether 69 plant taxa were recorded and are presented in the results, out of which 25 taxa associated with aquatic habitats (hydrophytes, helophytes and species of riparian habitats) were discussed in more detail. These taxa are rare, threatened, invasive, newly found or otherwise seen as important for the studied area and their distribution maps are also presented.

Keywords: aquatic plants, endangered plants, flora mapping, invasive plants, new findings, rare plants

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Sažetak

Tijekom rada na nekoliko različitih projekata koji uključuju istraživanje flore u dolini rijeke Neretve na jugu Hrvatske, zabilježeni su neki zanimljivi floristički nalazi. Tijekom terenskih izlazaka, u fokusu su bila slatkovodna staništa (rijeke, kanali i jezera) koja su bila detaljno istražena čamcima i s kopna. Zabilježeno je ukupno 69 biljnih svojti koje su prikazane u rezultatima, dok je 25 svojti prikazano i

diskutirano detaljnije, a radi se o svojstama koje su u određenoj mjeri vezane za vodena staništa (hidrofiti, helofiti i vrste vlažnih staništa). Odabrane svojste su rijetke, ugrožene, invazivne, novo zabilježene ili su njihovi nalazi na drugi način zanimljivi za ovo područje, a prikazane su i njihove karte rasprostranjenosti

Ključne riječi: invazivne biljke, kartiranje flore, novi nalazi, rijetke biljke, ugrožene biljke, vodene biljke

Introduction

The name Neretva River delta commonly refers to the lower reach of the Neretva River, stretching mostly through Croatia and partly through Bosnia and Herzegovina. Croatian part accounts for the 70% of the delta, encompassing the last 22 km of the Neretva River flow, and includes the surrounding waterbodies originating from, or strongly influenced by the river's flow and mouth. The delta is situated in southern Croatia, therefore typically influenced by the Mediterranean climate and consequently belonging to the Mediterranean phytogeographical region. Nevertheless, the floristic composition of the area is strongly influenced by the presence of freshwater habitats, whereas the whole area is originally a mosaic of marshland habitats. A large network of interconnected waterbodies, including rivers, springs, lakes and channels spreads within the area, constituting

what is known as the most valuable wetland on the eastern Adriatic coast and one of only a few wetlands remaining in the Mediterranean region of Europe. Noteworthy, during the last few decades human impact was very severe, accounting for many changes in the landscape due to agriculture-related interventions, mostly melioration, watercourse modification and channelizing.

The diverse nature of the area was the basis for its legal protection on several levels. It is nowadays recognized as a Ramsar (UNESCO 1994) and Natura 2000 site (Anonymous 2019), and includes as many as eight smaller sites protected by Croatian Nature Protection Act in categories of Special Reserves or Significant Landscapes (Fig. 1).

In comparison to terrestrial flora, aquatic flora is less often the main focus of floristic studies. Waterbodies are rarely accessible; most of them are surrounded by thick hygrophilous vegetation, which can be very abundant. Some watercourses are embanked with steep or muddy banks, blocking the approach to the watercourse and the associated aquatic flora, while the presence of water makes it more difficult to observe and assess all present plant taxa, due to reflection and/or dissolved particles. For these reasons, aquatic flora is usually sporadically recorded in regular floristic studies. Most recently, the aquatic flora of Croatia has been studied in a more comprehensive way, within the course of the national monitoring scheme, carried out to meet the requirements of the Water Framework Directive (WFD). Furthermore, aquatic plants stored in the ZA collection were recently analyzed and digitized (Zeko et al. 2020). These research efforts resulted in numerous new data

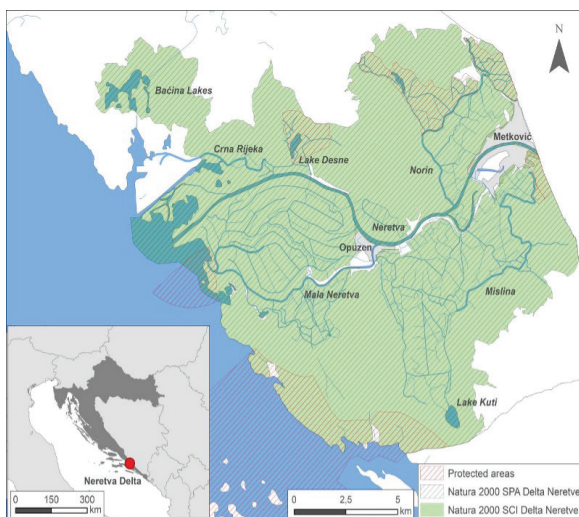


Figure 1. Croatian part of the Neretva River delta (green) encompassing the River Neretva and its tributaries.

on aquatic vascular plants (Koletić et al. 2017b, Vuković et al. 2017, Alegro et al. 2018, Rimac et al. 2018, Šegota et al. 2019, Zeko et al. 2020, Rimac et al. 2021, Vuković et al. 2021), bryophytes (Vuković et al. 2017, Alegro et al. 2019, Rimac et al. 2019, Šegota et al. 2019, Ellis et al. 2020, 2021) and algae (Koletić et al. 2017a, 2018, 2019, 2020, 2021). Neretva River delta was also included into the aforementioned study; although a small number of localities was surveyed for aquatic flora (Rimac et al. 2018), it resulted in significant discoveries and highlighted the need for a more detailed search.

The history of botanical research in the Croatian part of the Neretva River delta is very long, with first botanical notes occurring as early as mid-19th century (Visiani 1842, 1847, Petter 1852). Studies of the area continue through the 20th century (Horvatić 1949, 1954, Jovančević 1972, Topić et al. 1996, Nikolić & Fadljević 1999) until modern times (Jasprica 2007, Jasprica et al. 2014, Glasnović et al. 2015, Jasprica 2016, Jasprica et al. 2017a, b, Rimac et al. 2018), gradually accounting for more than 800 plant taxa in the delta. Nevertheless, no systematic survey of the whole area that would focus on aquatic habitats has ever been performed. Former studies mostly focused on particular species (Horvatić 1949, Topić et al. 1996, Nikolić & Fadljević 1999, Jasprica et al. 2017a, Rimac et al. 2018), associations (Horvatić 1954, Jasprica et al. 2014, Jasprica 2016) or certain localized areas within the delta (Topić 1995, Jasprica et al. 2017b). The most comprehensive study was the one from Glasnović et al. (2015) who investigated ten localities in the area, but also performed an extensive literature search of available data to complement their findings and provide an overview of flora.

In this paper we are presenting interesting findings from several field studies, having different aims but mainly focused on aquatic habitats. The aim of this paper is to merge those findings, focusing on aquatic taxa concerning algae, bryophytes and vascular plants, and elaborate the invasive, rare,

endangered and neglected taxa in more detail.

Material and methods

The fieldwork was conducted within the framework of several projects. Macrophytes were studied within the project of mapping two aquatic invaders *Egeria densa* and *Myriophyllum heterophyllum* in 2018, while some interesting species of riparian habitats were additionally recorded within the project of mapping the terrestrial invasive plants in 2019. In addition, some localities were studied in June 2020, within the project of national monitoring of surface waterbodies. Although these projects had specific aims, during the fieldwork, many interesting rare and threatened species were found in the studied area and those findings were recorded.

The studied area comprised the Croatian part of the Neretva River delta (Fig. 1). Noteworthy, numerous waterbodies were surveyed in detail, including the Neretva River and its tributaries, as well as surrounding lakes, springs and channels. When feasible, the watercourses were searched from the boat, while in fewer cases the fieldwork was performed by approaching the watercourses from the land. In order to collect and identify underwater specimens, in some cases, submerged plant material was sampled using rakes. During fieldwork, localities of interesting plants were recorded with an *etrex 30x* Garmin GPS device, and the coordinates were used to produce distribution maps of the species regarded as the most significant findings (Appendix 1). The coordinates presented on the maps are saved in a form of a shapefile and are available upon request. Collected specimens are stored in the ZA collection (Rešetnik et al. 2020, Thiers 2021).

Nomenclature of vascular plants, as well as the IUCN threat status, are given according to Nikolić (2021), while the legal protection status is derived from Anonymous (2016). Species names of bryophytes are given according to Alegro & Šegota (2021), and of algae according to Guiry & Guiry (2021).

Results and discussion

We have recorded 69 taxa (64 vascular plants, two bryophytes and three algae) in the Neretva River delta within the course of our fieldwork, while in this paper we present the findings of 25 taxa (24 vascular plants and one bryophyte) in more detail (Tab. 1). The selected taxa are either invasive, or

their findings are otherwise significant for the area (newly recorded, endangered, rare and/or strictly protected plants). The selected taxa are grouped into hydrophytes (invasive and native), helophytes, and species of riparian habitats.

Table 1. List of three algal, two bryophyte and 64 vascular plant taxa recorded in the Neretva River delta with IUCN categories and invasive status. Taxa in bold are discussed in more detail.

Family	Taxon	IUCN	Invasive
ALGAE			
Compsopogonaceae	<i>Compsopogon caeruleus</i> (Balbis ex C.Agardh) Montagne		
Rhodolemaceae	<i>Polysiphonia subtilissima</i> Montagne		
Ulvaceae	<i>Ulva flexuosa</i> Wulfen		
BRYOPHYTA			
Fontinalaceae	<i>Fontinalis antipyretica</i> Hedw.		
Ricciaceae	<i>Riccia fluitans</i> L.		
MONYLOPHYTA (PTERIDOPHYTA)			
Equisetaceae	<i>Equisetum ramosissimum</i> Desf.		
Thelypteridaceae	<i>Thelypteris palustris</i> Schott		
SPERMATOPHYTA			
Alismataceae	<i>Alisma lanceolatum</i> With.		
Alismataceae	<i>Alisma plantago-aquatica</i> L.		
Alismataceae	<i>Sagittaria sagittifolia</i> L.		
Apiaceae	<i>Berula erecta</i> (Huds.) Coville		
Apiaceae	<i>Hydrocotyle vulgaris</i> L.	CR	
Apiaceae	<i>Oenanthe aquatica</i> (L.) Poir.		
Apiaceae	<i>Oenanthe fistulosa</i> L.		
Asclepiadaceae	<i>Cynanchum acutum</i> L.	EN	

Family	Taxon	IUCN	Invasive
Asclepiadaceae	<i>Periploca graeca</i> L.	EN	
Brassicaceae	<i>Nasturtium officinale</i> W. T. Aiton		
Butomaceae	<i>Butomus umbellatus</i> L.	NT	
Ceratophyllaceae	<i>Ceratophyllum demersum</i> L.		
Chenopodiaceae	<i>Salsola kali</i> L.	VU	
Chenopodiaceae	<i>Suaeda maritima</i> (L.) Dumort.	VU	
Cucurbitaceae	<i>Ecballium elaterium</i> (L.) A. Rich.	DD	
Cyperaceae	<i>Cladium mariscus</i> (L.) Pohl		
Cyperaceae	<i>Cyperus longus</i> L.	VU	
Cyperaceae	<i>Eleocharis ovata</i> (Roth) Roem. et Schult.	EN	
Cyperaceae	<i>Scirpus lacustris</i> L.		
Fabaceae	<i>Dorycnium rectum</i> (L.) Ser.	CR	
Fabaceae	<i>Glycyrrhiza echinata</i> L.		
Fabaceae	<i>Trifolium fragiferum</i> L.		
Haloragaceae	<i>Myriophyllum heterophyllum</i> Michx.		Inv
Haloragaceae	<i>Myriophyllum spicatum</i> L.		
Haloragaceae	<i>Myriophyllum verticilatum</i> L.		
Hippuridaceae	<i>Hippuris vulgaris</i> L.	EN	
Hydrocharitaceae	<i>Egeria densa</i> Planch.		Inv
Hydrocharitaceae	<i>Hydrocharis morsus-ranae</i> L.		
Iridaceae	<i>Iris pseudacorus</i> L.		
Lamiaceae	<i>Mentha aquatica</i> L.		
Lamiaceae	<i>Lycopus europaeus</i> L.		
Lemnaceae	<i>Lemna minor</i> L.		
Lemnaceae	<i>Lemna trisulca</i> L.		
Lentibulariaceae	<i>Utricularia australis</i> R. Br.		
Lythraceae	<i>Lythrum salicaria</i> L.		

Family	Taxon	IUCN	Invasive
Menyanthaceae	<i>Nymphoides peltata</i> (S. G. Gmel.) Kuntze		
Najadaceae	<i>Najas marina</i> L.		
Nymphaeaceae	<i>Nuphar lutea</i> (L.) Sm.		
Nymphaeaceae	<i>Nymphaea alba</i> L.		
Poaceae	<i>Eleusine indica</i> (L.) Gaertn.		Inv
Poaceae	<i>Paspalum paspalodes</i> (Michx.) Scribn.		Inv
Poaceae	<i>Phalaris arundinacea</i> L.		
Poaceae	<i>Phragmites australis</i> (Cav.) Steud.		
Poaceae	<i>Tragus racemosus</i> (L.) All.		
Polygonaceae	<i>Polygonum amphibium</i> L.		
Polygonaceae	<i>Polygonum mite</i> Schrank		
Potamogetonaceae	<i>Potamogeton berchtoldii</i> Fieber		
Potamogetonaceae	<i>Potamogeton crispus</i> L.		
Potamogetonaceae	<i>Potamogeton lucens</i> L.		
Potamogetonaceae	<i>Potamogeton natans</i> L.		
Potamogetonaceae	<i>Potamogeton nodosus</i> Poir.		
Potamogetonaceae	<i>Potamogeton pectinatus</i> L.		
Potamogetonaceae	<i>Potamogeton perfoliatus</i> L.		
Primulaceae	<i>Hottonia palustris</i> L.	EN	
Primulaceae	<i>Samolus valerandi</i> L.		
Ranunculaceae	<i>Ranunculus lingua</i> L.	EN	
Scrophulariaceae	<i>Gratiola officinalis</i> L.		
Sparganiaceae	<i>Sparganium emersum</i> Rehmman		
Sparganiaceae	<i>Sparganium erectum</i> L.		
Typhaceae	<i>Typha angustifolia</i> L.		
Typhaceae	<i>Typha latifolia</i> L.		
Zygophyllaceae	<i>Tribulus terrestris</i> L.		

Hydrophytes

Invasive

Two invasive species, *Egeria densa* Planch. and *Myriophyllum heterophyllum* Michx., were found in numerous localities, distributed wider than previously recorded. Our detailed search has revealed many previously unregistered sites occupied by these two aliens, significantly improving the knowledge on their occurrence in the delta. Both species were mostly developing large, stable, dense and in some cases almost monodominant populations (especially *E. densa*) (Fig. 2). In smaller watercourses with slower running water, they were forming dense mats sometimes across the whole waterbody. In larger

lakes or deeper, fast-flowing rivers or channels, they mostly develop in side areas with slower water flow. Both species were occasionally found in bloom, while *E. densa* was developing only male flowers (Fig. 2). Interestingly, some years prior to our study, *E. densa* was observed in bloom as late as in December (Mihoci, pers. comm). We have noticed that *E. densa* frequently occurs in springs with significantly lower water temperature than in the rest of the watercourse, which was at the time of our visit generally below 20 °C. The distribution of these species is shown in Appendix 1.



Figure 2. Monodominant stands of *Egeria densa* in bloom (a), male flower of *E. densa* (b), dense stand of *Myriophyllum heterophyllum* with emergent flowering stems (c), emergent flowering stem of *M. heterophyllum* (d).

E. densa was previously recorded in five localities (Rimac et al. 2018), generally developing dense stands, co-dominating with or outcompeting local flora. During our detailed search, the species was confirmed in all known localities while numerous new findings were registered, mainly in rivers Neretva and its tributaries, Norin and Mislina. The Norin River in the north-eastern part of the delta was particularly infested; *E. densa* was present almost continuously and often in large abundance from the spring Prud to the settlement Romići. We cannot say whether the species has spread since the study of Rimac et al. (2018) or our knowledge about its occurrence has simply improved; however, a combination of both scenarios is highly probable. Noteworthy, we have witnessed its tendency to form monodominant stands over large areas (Fig. 2), showing invasive behaviour and aggressive spread. Since it was recorded with significant abundance at the state border in Metković, we believe that the plant is likely also abundant in the neighbouring Bosnia and Herzegovina, probably introduced to Croatia by moving downstream due to its highly efficient vegetative spread.

The only previous record of *M. heterophyllum* in the study area was in Lake Desne in the northern part of the delta (Jasprica et al. 2017a), being the second record in Croatia (Starmühler 2009). We have confirmed the population reported by Jasprica et al. (2017a), and registered new populations within the same lake. Additionally, the species was found in the Desanka River connecting Lake Desne with the Crna Rijeka River, with the most distant site registered approximately 1 km downstream from the lake. We have also found numerous populations of *M. heterophyllum* in the southern part of the delta, in Lake Kuti and the nearby channels. This species is probably more widespread in the studied area; however, the difficulties in the identification related to the great morphological similarity with the native *M. verticillatum* often complicates its detection. Many populations potentially belonging to *M. heterophyllum* were discovered in the studied area but remain unidentified to the species level,

due to the absence of distinctive generative parts.

Overall, the occurrence and spread of these two aquatic invaders is a rather serious problem in the delta. They are obviously well adapted to local conditions, whereas they are forming large and stable populations, sometimes even completely displacing native vegetation. Control measures are highly recommended, in order to prevent further spread and reduce negative impacts of these species on local flora and habitats.

Native

Ceratophyllum demersum L. is one of the most common macrophytes in Croatian freshwaters, frequently recorded in the continental part of the country within the basins of Sava, Drava and Danube rivers but less commonly in Mediterranean Croatia (Nikolić 2021). The species is very common in the Bosnian part of the Neretva River delta (Jasprica & Carić 2002), however there are no known literature records from the Croatian part. Similar to many other submerged macrophytes, this species is frequently unregistered during non-specific floristic studies therefore the data on its distribution are often incomplete. It is a submerged hydrophyte of slow and stagnant eutrophic waterbodies, usually found somewhat deeper than most co-occurring taxa, therefore commonly overlooked in studies not dealing with macrophytes specifically. Noteworthy, we have recorded this species in numerous sites, distributed across the whole area (Appendix 1).

Hippuris vulgaris L. is a submerged or partially emergent macrophyte with emergent generative parts. Its distribution is nationwide, although the species is generally rare (Nikolić 2021), regarded as endangered and accordingly strictly protected. Its previous records in the studied area are rather scarce and refer to the Norin River and Modro Oko Lake (Schlosser & Vukotinović 1869, Liber et al. 1997, Jasprica 2007, Topić 2011, Glasnović et al. 2015). According to our results, the species is rather common in the area. It was recorded in nine sites

(Appendix 1), mostly in the eastern part of the delta. Its presence was confirmed in the Norin River, and it was also found in River Mislina and Mala Neretva, as well as in Lake Desne and Vreštica spring.

Hottonia palustris L. is a submerged macrophyte with emergent flowers, generally rare in Croatia (Nikolić 2021), therefore endangered and accordingly strictly protected. Interestingly, all previous records of this species refer to the continental part of Croatia, apart from the mention from Jasprica (2007), in the context of the extremely rare occurrence of the community *Hottonietum palustris* in the Neretva River delta. Our records represent the first clear and precise information about the occurrence of this species in the Mediterranean part of Croatia. Nevertheless, in spite of the detailed search, we only found two sites occupied with this species, implying that the species is locally rare. It was found in spring Zloići and the Norin River, both in the north-eastern part of the studied area (Appendix 1).

Hydrocharis morsus-ranae L. is a free-floating aquatic plant, frequently found in Croatian watercourses and backwaters of Podravina, Posavina and Podunavlje regions in continental Croatia (Nikolić 2021). In the Mediterranean part of the country, however, the species is seemingly extremely rare, recorded only in the Neretva River delta in historical times (Visiani 1842, Horvatić 1949) and mentioned by Jasprica (2007) in the context of relatively rare occurrence of the community *Hydrocharietum morsus-ranae*. Our detailed search of the watercourses of the Neretva River catchment shows that *H. morsus-ranae* occupies many sites, and is actually quite widespread in the studied area (Appendix 1). It was often found forming large and stable flowering populations in sites with stagnant or slow-flowing water on the margins of watercourses (Fig. 3).

Hydrocotyle vulgaris L. is a creeping hygrophyte, normally occupying margins of freshwaters where it roots in the water but develops emergent leaves. On the national level, the species is rare, critically endangered and accordingly strictly protected. It

is generally found in the Mediterranean part, with only few old records from the continental Croatia (Nikolić 2021). In the Neretva River delta, however, it was recorded by Horvatić (1963), describing the locality as “the swamp of lower Neretva”, and more recently mentioned by Jasprica (2007). Our records have shown that the species is locally more common. It was recorded in eight sites (Appendix 1), mostly in the northern part of the delta in the Norin River basin, but also in the Neretva River, as well as towards the south in channels Badžula and Pižinovac. The species was regularly found submerged, sometimes in waters more than 1 m deep, but also recorded completely outside the water. The populations in the Norin River were especially well developed.

Lemna trisulca L. is a free-floating aquatic plant of a very small size, normally occurring in stagnant or slow-flowing waters. Unlike other members of the genus, this species does not float on the water surface but rather occurs under the surface, mostly in clusters among other submerged plants or their debris. In Croatia, the species is frequently recorded in the floodplains of Sava, Drava and Danube rivers; however, almost no record is known from the Mediterranean part of the country (Nikolić 2021). The only known notes are from Neretva, including a historical finding from Horvatić (1949), a few field observations in recent times registered online (Liber et al. 1997, Alegro et al. 2001) and a mention by Jasprica (2007). The species was recorded in eight localities during our study (Appendix 1). Most probably it occurs much wider but its distribution is poorly documented, due to its size and microhabitat. The species is not easily detected without careful examination of the site or sampling the plant material from the water.

Najas marina L. is a submerged macrophyte inhabiting bottoms of freshwaters, up to several meters deep. According to the current data, *N. marina* is relatively rarely recorded in Croatia, with most records in Posavina and Podunavlje regions in continental Croatia. Records from the Mediterranean

Croatia are rather scarce (Razlog-Grlica 2003, 2010, Boršić et al. 2011, Alegro et al. 2016, Šegota et al. 2019), while records from the Neretva River delta are not known, apart from a herbarium specimen from 1949 collected by Horvatić (ZA-12236). In spite of scarce past records, we have recorded *N. marina* at numerous sites in the studied area (Appendix 1). Its distribution in Croatia is most probably much wider than currently registered because the species is probably overlooked in studies. It will go undetected in macrophyte non-specific studies, and unlike some other submerged plants with long branches, *N. marina* develops relatively short stems therefore its detection is somewhat more difficult without sampling the material from the bottom.

Nymphoides peltata (S. G. Gmel.) Kuntze is an aquatic plant, rooted in the substrate but developing floating leaves and emergent flowers. In Croatia, the species is relatively rare, with records almost exclusively referring to the continental part, particularly Podunavlje Region (Nikolić 2021). The only historical record from Mediterranean Croatia was provided by Horvatić (1949), referring to the Neretva River delta. Our observations have shown that the species is locally very abundant, recorded in numerous sites (Appendix 1) almost exclusively in the southern part of the delta. Many large, stabile, flowering populations were recorded in stagnant or slow flowering waters (Fig. 3).

Potamogeton berchtoldii Fieber is one of the several narrow-leaved pondweed species naturally occurring in Croatia. Current published data about this species are extremely scarce; apart from few historical findings from the 19th century and the first half of the 20th century, there are almost no records about its presence in Croatia. However, our field observations from the national monitoring of surface waters suggest that this species is actually much more common (unpublished data), but was mostly neglected during botanical studies of Croatia. Prior to our comprehensive study of surface waters, there was only one historical record of this species in the Mediterranean Croatia,

referring to a herbarium specimen from Degen (1913, ZA-12191). The species was never recorded in the Neretva River delta, while our results have registered two sites, in rivers Neretva and Norin (Appendix 1).

Riccia fluitans L. is an aquatic liverwort, developing terrestrial or floating forms. Its rare findings in Croatia currently include only the continental part of the country (Alegro & Šegota 2021), while our results represent the first occurrence of this species in the Mediterranean Croatia. During our fieldwork, *R. fluitans* was found in two localities (Appendix 1): spring Vir (northern bank of Lake Oćuša of Baćina Lakes) and the Mislina River. It was recorded as a floating form in a relatively low cover in both localities.

Utricularia australis R. Br. is one of the few carnivorous plants naturally occurring in Croatia. This submerged macrophyte develops emergent spikes during summer months bearing bright, yellow flowers. The species is seldom recorded in Croatia, with only few findings in the continental part and several records from Vransko Jezero Lake in Dalmatia (Nikolić 2021). In the studied area, it was previously reported by Horvatić (1949) and Glasnović et al. (2015). *Utricularia australis* is accessed as Data Deficient and is strictly protected. It is important to stress out that *U. australis* is very similar to *U. vulgaris* L. and these two taxa may occupy the same habitats, but the latter was previously recorded in the studied area only in historic times by Visiani (1847). We have identified our specimens as *U. australis* according to the shape of the lower lip, which was evidently straight (Fig. 3). According to our survey, *U. australis* commonly occurs in the Neretva River delta, mostly in the southern and southwestern part (Appendix 1).

Helophytes

Butomus umbellatus L. is a helophyte regularly rooted in the water, developing emergent leaves and inflorescence. Its populations are mainly concentrated in central and eastern Croatia, although

there are records from the Mediterranean but mostly dating to the 19th century (Nikolić 2021). The species was previously recorded in the studied area, but the sources are relatively scarce and rather old (Visiani 1842, Petter 1852, Schlosser & Vukotinović 1869, Beck 1901, Radić 1976). During our study, it was recorded in two localities in the southern part (Appendix 1), in rivers Mislina and Mala Neretva.

Cladium mariscus (L.) Pohl is a species of riparian habitats, often occupying edges of freshwaters. Although not assessed as a threatened species, in Croatia it occurs relatively rarely, with populations mainly in the Mediterranean part and a few findings in Lika and Gorski Kotar regions (Nikolić 2021). There are only few previous records of this species in the Neretva River delta from literature or unpublished observations (Visiani 1842, Liber et al. 1997, Marković et al. 1997, Alegro et al. 2001a, Glasnović et al. 2015) and one historical herbarium sheet (ZA-20301, Horvatić 1949), while our survey recorded this species in several localities (Appendix 1). Large, almost monodominant populations were developed in the area of Baćina Lakes in the north-western part, and between the reserves Orepak and Pod Gredom in the north-eastern part of the delta.

Cyperus longus L. is a species of riparian habitats as well, characteristic for margins of freshwaters. It is relatively rare in Croatia, found mostly in the Mediterranean although some records exist in the continental part (Nikolić 2021). It is a vulnerable species and accordingly strictly protected. Previous literature records referring to the study area are rather old (Visiani 1842, Horvatić 1949, 1963, Radić 1976), and herbarium records include only two sheets from Horvatić from 1947 (ZA-10065, ZA-10085). More recently, the species was recorded by several authors as unpublished observations (Liber et al. 1997, Marković et al. 1999, Alegro et al. 2001b) and was also mentioned by Jasprica (2007). During our study, it was recorded in seven localities, mostly in the eastern part of the area in the Norin River Basin, around Stara Neretva and Mislina River, but also in the area of Baćina Lakes (Appendix 1).

Eleocharis ovata (Roth) Roem. et Schult. is a dwarf annual occurring on low, muddy banks of watercourses or reservoirs, very rarely recorded in Croatia. Most previous records are in the continental part (Baranja, Slavonija, surroundings of Zagreb and Karlovac), and two records are from the Krka River in Northern Dalmatia (Nikolić 2021). The species is typical for amphibian communities of the class *Isoëto-Nanojuncetea*, rare and vulnerable habitats designated for protection on both European (Council of the European Union, 2013) and national (Anonymous 2021) levels. The species is nationally endangered and for this reason strictly protected. In the Neretva River delta, it was found in a single locality, Plitvara (Appendix 1).

Oenanthe aquatica (L.) Poir. is an aquatic plant rooted in the water, with emergent (sometimes submerged) leaves and flowers. It is relatively frequently recorded in the aquatic vegetation of Croatia, mostly in the continental part of the country (Nikolić 2021). On the contrary, records from the Mediterranean part of Croatia are very rare (Marković et al. 1999, Jasprica 2005, Šegota 2010), while the only literature record referring to Neretva is from the mid-19th century (Visiani 1852). During our study, the species was recorded in Lake Modro Oko and the Norin River (Appendix 1), in both localities only submerged leaves were found.

Polygonum amphibium L. is an aquatic plant normally rooted in the water. It often develops submerged stems, floating leaves and emergent flowers (Fig. 3), but it can also grow outside the water. *P. Polygonatum* is mostly recorded in continental Croatia, in the floodplains of large, lowland rivers Sava, Drava and Danube with a few records from the Lika Region (Nikolić 2021). Records from the Mediterranean Croatia are very scarce and include Grobničko polje (Hirc 1907), Lake Ponikve on the island of Krk (Hirc 1909, Starmühler 2003) and the Krka River (Marković et al. 1993), while there are no previous records in our studied area. During our study, altogether six stands of *P. amphibium* were recorded (Appendix 1).

Ranunculus lingua L. is a species of different wet habitat types but often rooting in the water. The species is recorded in different parts of Croatia; however, the number of findings is low and almost half of them originate from the 19th century (Nikolić 2021). In the area of Neretva River delta, the species was recorded only a few times (Visiani 1852, Horvatić 1963, Marković et al. 1999) and the findings are relatively old. *Ranunculus lingua* is nationally endangered and strictly protected. Our study has shown that the species mostly inhabits the area around the Norin River in the north-eastern part of the delta, but it was also recorded in the southern part of the delta, in Mislina River and around Lake Kutu (Appendix 1).

Sagittaria sagittifolia L. is an emergent helophyte, in Croatia mainly found in the floodplains of large, lowland rivers Sava, Drava and Danube and their tributaries (Nikolić 2021). According to the available data, no previous records are known from Dalmatia; therefore, our record is the first. Nevertheless, only one record was found in the Norin River (Appendix 1), meaning that the species is locally rare.

Thelypteris palustris Schott is an aquatic fern generally growing at the margins of waterbodies. This species is quite rare in Croatia and the majority of findings date from the beginning of the 20th century. In the area of Neretva River delta, the species was only recorded once by Visiani (1842), while we found two sites, referring to the southern part of the area, towards lake Kutu and nearby channels (Appendix 1).

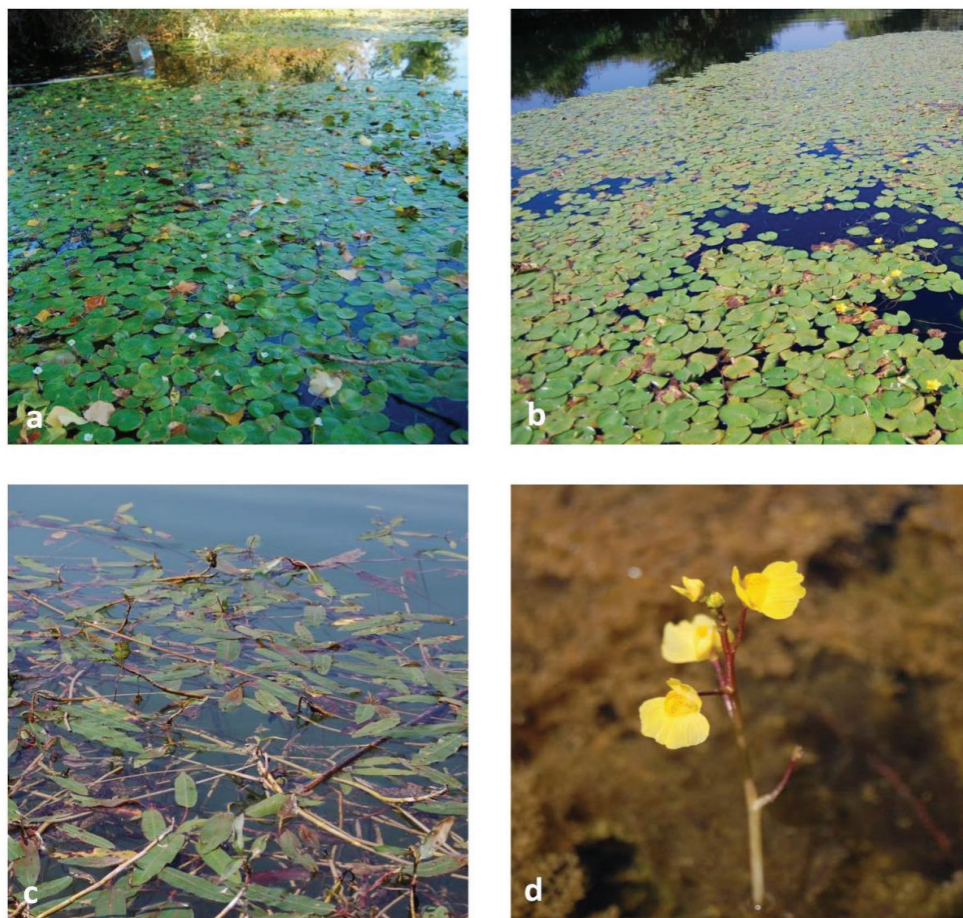


Figure 3. Dense stand of *Hydrocharis morsus-ranae* in river Mislina (a), dense stand of *Nymphoides peltata* in river Mislina (b), floating leaves of *Polygonum amphibium* in Baćina Lakes (c), flowering spike of *Utricularia australis* (d).

Species of riparian habitats

The data on the distribution of three rare and threatened terrestrial plants, *Cynanchum acutum* L., *Dorycnium rectum* (L.) Ser. and *Periploca graeca* L. were significantly updated by our field study. All of these taxa are rare in Croatia and their populations are generally concentrated in the Neretva River delta. Due to the low number of findings, different levels of threat are assigned to these taxa, and they are accordingly strictly protected. Croatian distribution of these taxa is a reflection of their European distribution, whereas they are thermophilous species of generally southern-European distributions. *Cynanchum acutum* is generally found across the Balkan Peninsula (Tutin et al. 2010b), *D. rectum* occurs within the Mediterranean Region (Topić et al. 1996, Tutin et al. 2010a) and *P. graeca* extends through Southern Europe (Tutin et al. 2010b).

Cynanchum acutum is very rare in Croatia, with documented distribution in the Mediterranean part extending from Istria to Mljet (Nikolić 2021). Due to the thermophilous character of the species, records from Moslavina in Central Croatia (Hruškadel'Uomo 1975, 1977) and Plitvice Lakes in the Lika Region (Šegulja 2005) are highly dubious. The species is however common in the studied area, with findings mostly concentrated in the western part of the delta, towards the confluence of the Neretva River into the Adriatic Sea (Appendix 1).

Dorycnium rectum has a very limited distribution in Croatia. Until very recently, it was recorded only in the Neretva River delta (Topić et al. 1996, Marković et al. 1999, Jasprica 2007, Jasprica 2011, Jasprica et al. 2017b, Bogdanović 2021-ZAGR-62697) with one isolated record from the island of Rab in northern Adriatic (Nikolić 2001). The record from Rab is however doubtful as the source of this data is unclear. Most recently, the species was indeed recorded outside of the Neretva River delta by Bogdanović, who collected this species in July 2021 in the settlement of Slano (ZAGR-62696). Because of its limited distribution, the species is regarded as Critically Endangered in Croatia. We

have recorded seven populations in the western part of the Neretva River delta, mostly associated with the Neretva River (Appendix 1).

Periploca graeca is a perennial, deciduous climber usually climbing on other vascular plants, particularly reed. Its populations in Croatia are mostly concentrated in southern Dalmatia (Nikolić 2001), with several historical findings scattered through the northern Adriatic (Neilreich 1868, Hirc 1909, Rossi 1930, Degen 1937) and one recent finding from Split (Ruščić 2003). The species was also documented in Central Croatia in historical times (Schlosser & Vukotinović 1857, 1869, Neilreich 1868); however, these records refer to ornamental use of *P. graeca* which was historically used as an ornamental and planted in gardens around castles and monasteries. We registered numerous sites occupied with *P. graeca* in the studied area (Appendix 1). The species is very common in the delta due to its association with reed, which forms long belts along the watercourses or sometimes occurs in large reed beds.

Croatian part of Neretva River delta was previously studied on several different occasions; however, no study was focused particularly on freshwater habitats. In the same time, aquatic plants (especially submerged ones) are frequently under recorded in regular floristic studies. For this reason, the existing data about aquatic plants in the lower reach of Neretva River and its tributaries were very much deficient in comparison with the results of our survey. Some taxa recorded in our study were poorly documented in previous studies, although they are quite common in the area, while other had no previous records. In the same time, taxa like *Ceratophyllum demersum*, *Hippuris vulgaris*, *Hottonia palustris*, *Hydrocharis morsus-ranae*, *Hydrocotyle vulgaris*, *Lemna trisulca*, *Najas marina* and *Nymphoides peltata* are present upstream in Hutovo Blato Nature Park in Bosnia and Herzegovina (Jasprica & Carić 2002), and would be expected in the Croatian part of the river as well. Finding these aquatic taxa previously unrecorded or rarely recorded in the studied area is therefore not surprising, as most of them are likely under

recorded due to the lack of specialized studies. The same goes for taxa reported in our studied area but seemingly absent from upper reaches of Neretva. Most importantly, invasive taxa *Egeria densa* and *Myriophyllum heterophyllum* are most probably also present in upper reaches, although to our knowledge not yet reported from Bosnia and Herzegovina.

Some aquatic taxa typically found in lowland areas of continental Croatia are also found in the Neretva River delta, although they are not recorded in other areas of Mediterranean Croatia. This is not surprising, given that some of these species typically inhabit true lowland marshlands, usually found along the valleys of large lowland rivers (Sava, Drava, Dunav etc.) in continental Croatia. Contrary to these continental rivers, watercourses from the Adriatic Basin are predominantly fast-flowing karst rivers passing through the Dinaric Mountains, usually forming canyons instead of marshlands. Neretva River is rather an exception, forming a large delta as it flows into the Adriatic Sea, therefore representing a true marshland along the eastern Adriatic coast and a “resort” for true marshland flora.

It should be emphasized that the Neretva River delta is a fragile ecosystem largely influenced by humans (Glamuzina & Glamuzina 2001, Jasprica 2007). Namely, the hydrological regime of the river is greatly changed due to the several hydroelectric stations built in the upper reach, accounting for changes in the water flow. Direct consequences of these changes are decreased water levels during summer months, decreased inflow of sediment into the lower reach of Neretva and increased inflow of sea water. In the same time, intense agriculture additionally changes the water regime through melioration, and impacts the system by changing the chemistry, adding nutrients and pesticides. These human interventions inevitably cause gradual changes in the vegetation structure and may shift the “border” between aquatic and terrestrial system towards the latter (Jasprica et al. 2002). These impacts should be taken seriously when making management plans and control measures

should be implemented into future management of this important area. Otherwise, habitat destruction and species loss may be the final result of human practices in the Neretva River delta.

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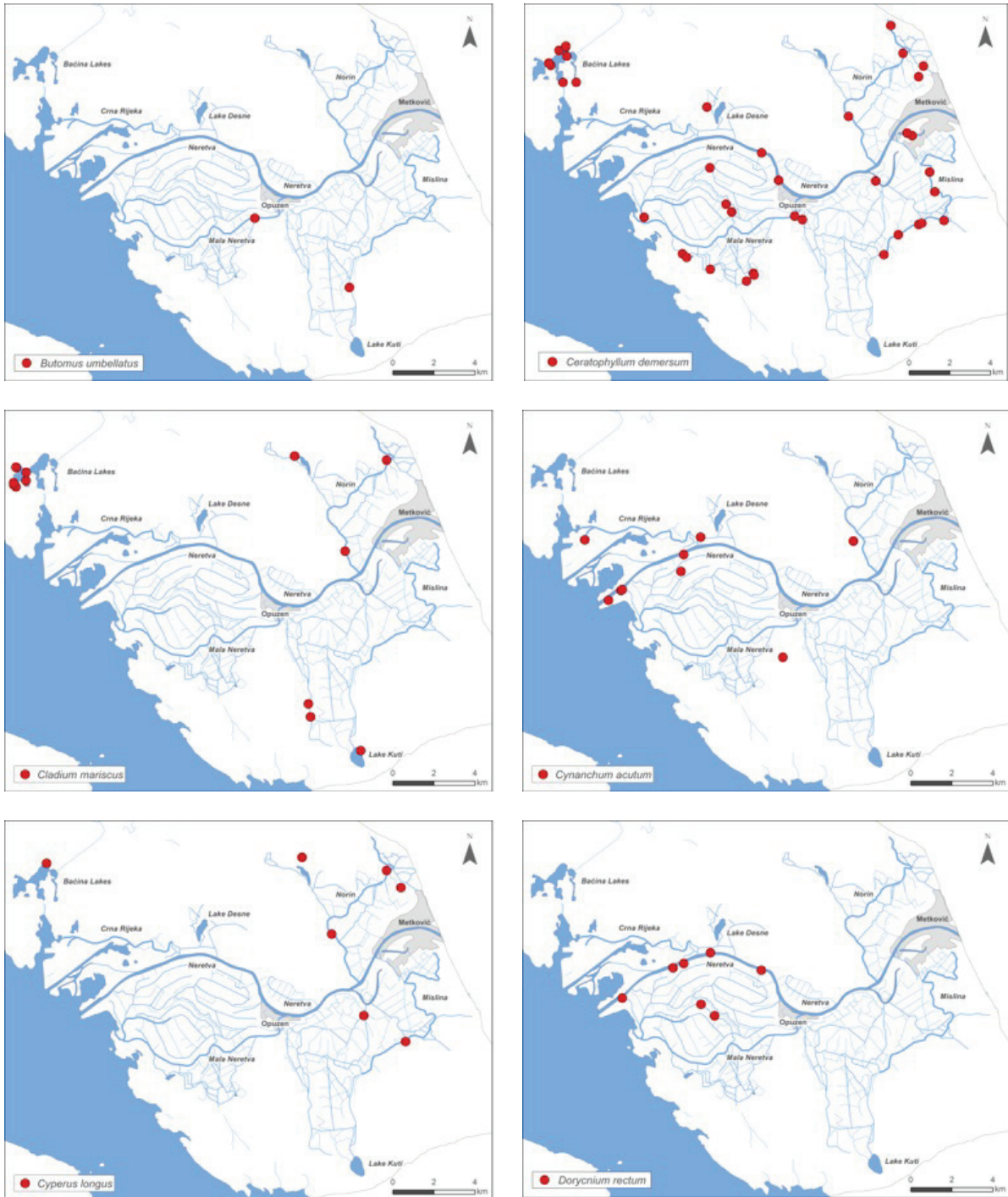
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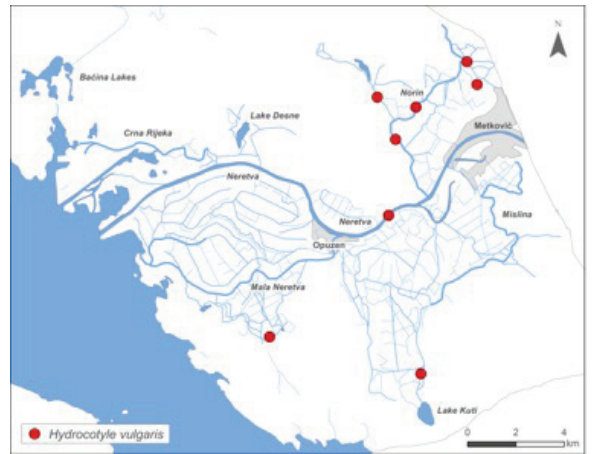
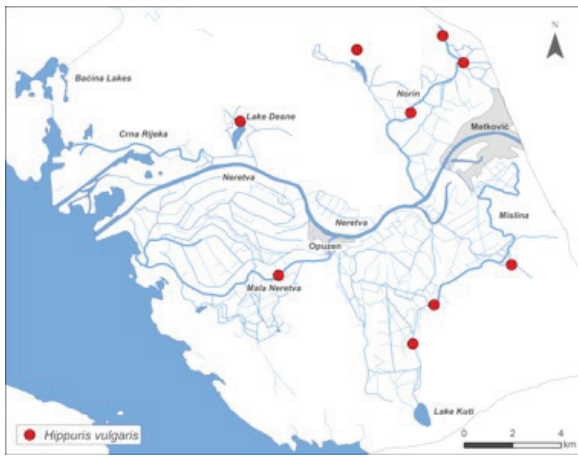
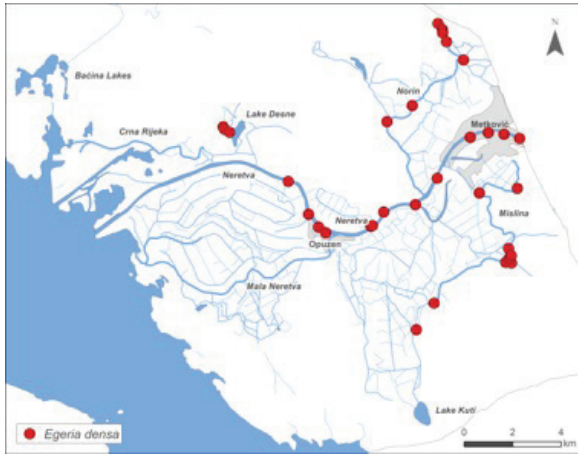
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Interesting updates to the flora of the Neretva River delta (south Croatia) with the emphasis on aquatic plants

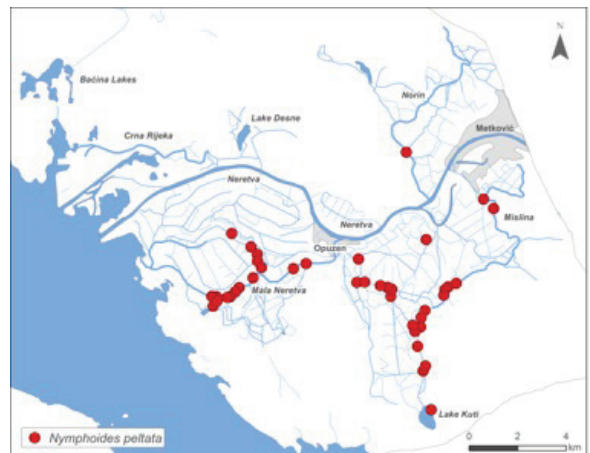
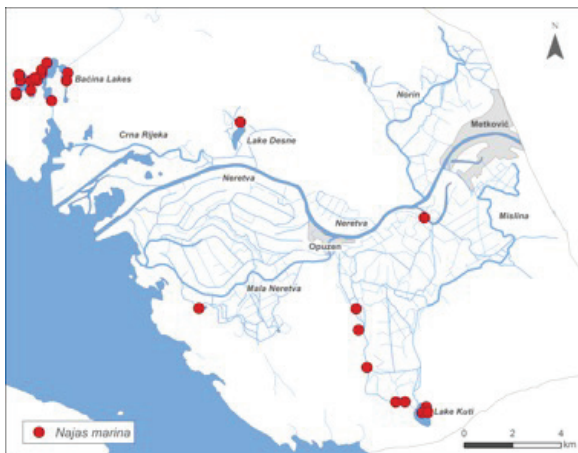
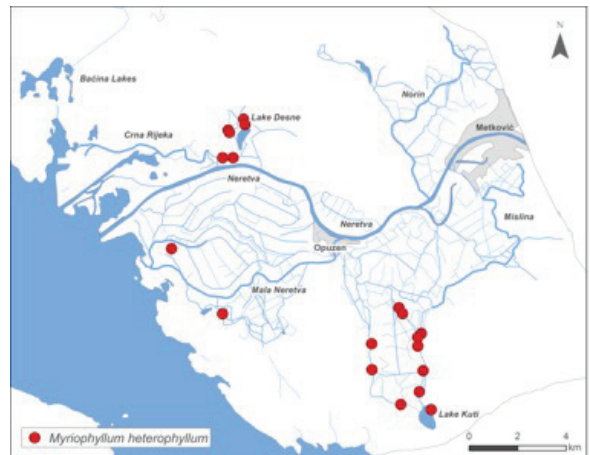
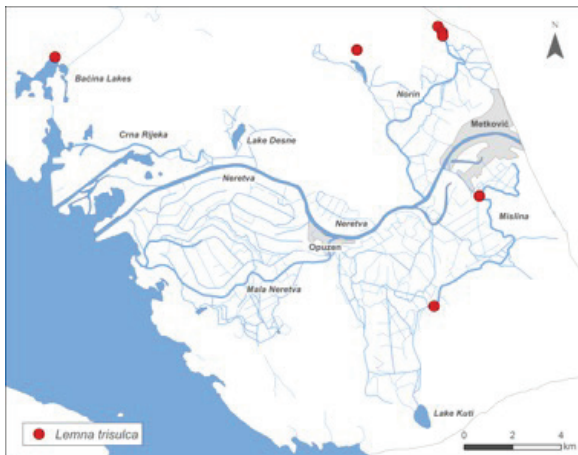
Appendix 1. Distribution maps of some selected taxa in the Neretva River delta.



Interesting updates to the flora of the Neretva River delta (south Croatia) with the emphasis on aquatic plants



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